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ESTABLISHMENT OF FORESTS AFTER LOGGING IN NORTH CENTRAL BRITISH COLUMBIA

A BIBLIOGRAPHY WITH ABSTRACTS

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ESTABLISHMENT OF FORESTS AFTER LOGGING IN NORTH CENTRAL BRITISH COLUMBIA

by

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INTRODUCTION

There is a significant regeneration problem in the Prince George Forest District. As a result of improving technology of felling, extraction and transportation combined with a steadily increasing demand for wood and wood products the problem will probably intensify in the future. Therefore the forest manager must develop new techniques of regeneration or improve old ones to ensure that forest lands cleared by logging or other means will be promptly and thoroughly restocked.

This bibliography facilitates retrieval of information by managers and researchers on the impact of harvesting methods, site treatment, and artificial regeneration upon the re-establishment of forests in the spruce-alpine fir region of northern British Columbia, particularly the subalpine and Montane areas of the Prince George Forest District[1]. As such it would provide a useful basis for prescribing guidelines for regeneration of managed forest lands in north central British Columbia. While the bibliography specifically seeks to serve those concerned with regeneration in the Prince George region, it should also serve those concerned with regeneration in other parts of the northern hemisphere where Picea-Abies or Picea forests are similar.

The bibliography was compiled following intensive searches through government and university libraries (Appendix I). It includes all available published and unpublished literature up to September, 1973. Relevant articles are included from British Columbia, from adjacent areas in Canada, and from ecologically similar areas in other parts of the world including Montane regions of the U.S.A., north central and north eastern North America,

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[1] Rowe, J.S. 1972. Forest Regions of Canada, Canada, Forestry Service. Publ. 1300.

and Northern Europe. Much literature from outside British Columbia related to species not growing naturally in the province but whose regeneration and growth habits are sufficiently similar to the indigenous species to be considered relevant. One such species is Picea abies (Norway spruce). Where doubt existed as to a publication's relevance to the Prince George area, it was usually included. The researchers using the bibliography can best decide such article's utility.

Titles occur only once in the bibliography and are grouped under those headings which must closely indicate their major information content. An explanatory note introduces each section. Key wording and the subject index ensure that minor information components of each article are also easily retrieved by users of the bibliography. Most articles are abstracted. However some, usually those of a more general nature or which included extensive tables of survival or growth data, are only annotated. No annotations or abstracts are given where the publication or an abstract thereof could not be obtained, or where the title provides sufficient information by itself. In the case of unpublished materials, interested users might obtain information directly from the researcher involved. Some articles, especially from foreign sources, were seen only in abstract. These are indicated by the abbreviation ABSTR, where appropriate, followed by a citation to the title, volume, and page number of the abstracting service's publication as well as the original journal in which the article appeared. In most cases, pertinent parts of abstracts are quoted verbatim. Each reference is keyworded for its major and minor information content.

The information in this bibliography is made more accessible to the user by cross referenced indexes to subjects, species and authors. The keywords provide the basis for the subject index and cover the range of forest harvesting, site preparation, and regeneration practices, and environmental influences. Judicious use of the Table of Contents and the indexes allows rapid access to information on specific topics.

The terms of reference for this study and the sources of information, including a list of journals searched, are given in the Appendices.

II NATURAL REGENERATION

Natural regeneration is taken to mean the re-establishment of forest cover without the intervention of man, essentially by natural re-seeding.

a) INFLUENCES OF HARVESTING PROCEDURES

This section includes papers dealing principally with the influences of cutting patterns and of logging procedures such as skidding upon the natural regeneration of spruce and spruce-fir forests. Cutting patterns are shown to influence seed dispersal and amount and species composition of natural regeneration. Logging procedures such as skidding influence the seedbed left after logging and thus play a determining role in distribution and amount of natural regeneration.

1. Ackerman, R.F. 1959. The effect of seed crop periodicity on the reproduction of subalpine spruce after clear cutting and scarifying. Canada, Forestry Branch, Forest Research Division, Unpubl. M.S. (ABSTR.).

   Scarification to produce mineral seedbed is highly beneficial to spruce-fir regeneration in the subalpine forest. However, spruce seed production is highly unpredictable, good seed years occurring relatively infrequently. It is estimated that scarified seedbeds have an effective lifespan of about 5 years before they become totally unacceptive to seedfall.

   K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), germination, scarification, seedbed, seedfall, vegetation.

2. Addison, J. 1966. Regeneration of spruce. B.C. Lumberman 50(6): 42, 44, 46, 48.

   Essay concerned with regeneration of white spruce in the Prince George Region. Gives a history of logging in this area and describes various types of stand treatments used to gain adequate natural regeneration of white spruce. Artificial regeneration, both seeding and planting, their advantages and disadvantages are also discussed.

   K.W. Picea glauca (white spruce), artificial regeneration, economics, forest management, logging, regeneration, site treatment.

3. Alexander, R.R. 1956. A comparison of growth and mortality following cutting in old-growth mountain spruce-fir stands. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note 20. 4 pp.

   Alternate clear strip cutting, group selection cutting and single tree selection cutting were carried out in spruce-fir forests in Colorado. There was no evidence that growth of residual stand was stimulated by cutting. Alternate clear strip cutting produced greatest ingrowth. Growth selection produced significantly less mortality than the other cutting forms or uncut control.

   K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), decay, fungi, logging growth, mortality, regeneration, residual stand, windthrow.

4. Alexander, R.R. 1957. Damage to advanced reproduction in clear-cutting spruce-fir. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note 27. 3 pp.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

Clear strip felling was carried out in Colorado in 1954. Before logging, strips contained an average of 20,570 seedlings and saplings (under 4" d.b.h.) per acre, 88% of which were subalpine fir. Horse logging destroyed or damaged about 2/3 of the advanced growth, leaving an average of 6,560 seedlings and saplings per acre. Proportionately less spruce than fir was destroyed. Total stocking was reduced 16%. Logging damage was most serious where advanced reproduction was scarce. These are sites where reproduction is difficult to establish, so that special care is needed when cutting them. Recommendations are made.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), advance growth, clear felling, horse logging, logging damage, regeneration, seedbed.

5. Alexander, R.R. 1957. Preliminary guide to stand improvement in cutover stands of spruce-fir. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note 26. 6 pp.

Two methods of stand improvement were applied to old growth spruce-fir stands in Colorado after 60% of merchantable volume was removed by logging. Average basal area was practically unchanged after 11 years regardless of treatment. Both spruce and fir showed a small increase in increment. Pine showed a reduction in average basal area. A stand improvement guide is given.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), decay, fungi, growth increment, stand improvement, thinning.

6. Alexander, R.R. 1963. Harvest cutting old growth mountain spruce-fir in Colorado. J. For. 61(2):115-119.

Analysis of the effect of 3 cutting methods: alternate strip clear cutting, circular patch clear cutting, and single tree selection cutting, on natural reproduction, growth, and mortality of Engelmann spruce and subalpine fir indicate that alternate strip clear cutting is the best harvest method as it produces more abundant and better distributed reproduction, better windthrow reduction, and an improvement in net increment.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), clear strip cutting, growth increment, patch cutting, regeneration, residual stand, selection cutting, windthrow.

7. Alexander, R.R. 1966. Stocking of reproduction on spruce-fir clear cutting in Colorado. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note RM-72. 8 pp.

Stocking on 200-400 ft. wide clearcut strips was determined on 99 cutting units on 8 National forests. Stocking to reproduction and residual understory trees of good quality will insure an adequate replacement stand on all cutting units examined. Stocking to new reproduction was related to seedbed condition, aspect, slope, amount of slash, vegetative abundance, soil texture, width and direction of cut strip and number of years since cutting.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), clear felling, ecology, regeneration, seedbed, seedfall, slash, soil, vegetation.

8. Alexander, R.R. 1967. Windfall after clear cutting on Fool Creek - Fraser Experiment Forest, Colorado. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note RM-92. 11 pp.

Summarizes results of 10 years of observation on the relative effects of various factors on blowdown after clear felling of stands of Picea engelmannii, Abies lasiocarpa, and Pinus contorta.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), clear felling, windthrow.

9. Alexander, R.R. 1968. Natural reproduction of spruce-fir after clear cutting in strips, Fraser Experiment Forest, Colorado, U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note RM-101. 4 pp.

Numbers and stocking of seedling and sapling on 1, 2, 3, and 6 chain-wide clear cut strips were determined in 1956 and 1966. Reproduction in 1966 was adequate but was largely advance growth which had survived logging. Most of the advance growth and regeneration is subalpine fir, but regeneration of Engelmann spruce is adequate.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), advance growth, clear strip cutting, regeneration, seedling survival, stocking.

10. Alexander, R.R. 1969. Seedfall and establishment of Engelmann spruce in clear cut openings: a case history. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Pap. RM-53. 8 pp.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

Spruce seedfall and the establishment of new seedlings were observed on two 3-5 acre clear cut openings on the Fraser Experimental Forest, Colorado, 1956-65. Numbers of sound seed caught in traps placed beneath the uncut stands along the margins of the openings were always greater on the windward side of the openings. Seedlings became established in significant numbers only on scarified seedbeds along the margins of the openings.

K.W. Picea engelmannii (Engelmann spruce), clear felling, regeneration, scarification, seedfall.

11. Armit, D. 1966. Silvics and silviculture of lodgepole pine in the North Central Interior of British Columbia. B.C. Forest Service, Res. Note 40.

Deals briefly with the history of lodgepole pine utilization, management and silviculture in north central British Columbia, in which the author predicts that within the next decade radical changes in utilization and harvesting techniques will necessitate intensive silviculture practices to ensure adequate regeneration. He refers to the knowledge of the ecology of the region and reviews literature on silvics, ecology and silviculture likely to be applicable to the local environmental conditions. Needs stressed for investigation of all aspects which are critical to regeneration. Includes brief section on past and present forest management practices for lodgepole pine.

K.W. Pinus contorta (lodgepole pine), ecology, forest management, regeneration, silviculture.

12. Armit, D. 1969. E.P. 653 - Seed dispersal study, Verdun Mt., B.C. Forest Research Review. pp. 33-34.

Seed dispersal of white spruce and lodgepole pine into a clear cut area in the Prince Rupert Forest District was measured. 1968 produced a good seed crop. Dispersal of combined spruce and pine seed was considered sufficient for adequate stocking of 50% of a 60 acre clear cut with another 30% partially restocked. In 1969, most germinants that were detected were on seed spots within 2 chains of clear cut margins. Also reported 1967 - pp. 36-37, 1968 - pp. 32-33.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), clear felling, regeneration, seed crop, seed dispersal, stocking.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

13. Arnott, J.T. 1968. Tree-length wheeled-skidder logging and its effect in certain black spruce forest types in Quebec. Pulp and Paper Magazine of Canada 66(10):103-109.

Results of a survey carried out to assess the effects of tree-length wheeled-skidder logging on black spruce forest types show that such a system greatly reduces the amount of advance growth which was present before the logging operation. Little scarification of the soil occurred. The problems of restocking in these areas is discussed.

K.W. advance growth, regeneration, scarification, seedbed, tree-length skidding, [Picea mariana].

14. Arnott, J.T. 1969. Regeneration two years following mechanized logging. Canada, Forestry Service, Laurentide Forest Research Centre, Quebec, Info. Rept. Q-X-10. 8 pp.

This paper provides interim results of the second postcut survey of 11 cutover areas in Quebec for a study on the effects of mechanized logging on silvicultural aspects of advance growth, soil scarification, and quality and quantity of residual regeneration.

K.W. advance growth, clear felling, mechanized logging, regeneration, residual stand, scarification, [Abies balsamea, Picea mariana].

15. Barnes, G.H. 1937. The development of uneven-aged stands of Engelmann spruce and probable development of residual stands after logging. Forestry Chronicle 13(3):417-457.

Deals with experiments at Aleza Lake, Prince George Forest Region, on 17 plots, 4 cutover and 13 uncut. These were examined over the period 1926-1934. Data recorded on 17 permanent plots included d.b.h. height and age of every tree over 4" d.b.h. in the uncut stands and 1" d.b.h. in the cut stands. Growth increment, number of trees per sub-plot, and later, mortality were also measured. Development and growth of mature stands, and probable development and expected yield of cutover stands, are tabulated in detail. Recommendations are made for future study.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), growth increment, mortality, regeneration, residual stand.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

16. Barr, P.M. 1933. Ecological aspects of spruce regeneration. 5th Pacific Science Congress 5:4001-4007.

Applies to all spruce species in general, but deals specifically with research done in British Columbia. Points out similarity of spruce forests here to those in eastern Canada, Northern Europe and Japan. Outlines silvicultural research carried on in B.C. and describes in detail ecological factors affecting seed germination and seedling growth and survival. Concludes that natural regeneration of cutover spruce forests is highly unlikely and outlines 3 solutions. 1) creation of a complete underwood of coniferous seedlings beneath the mature forest, followed by a series of release cuttings. 2) remove vegetation and humus soil on cutover areas by broadcast burning to allow regeneration. 3) burn cutover areas and plant, at the earliest suitable season, a satisfactory new crop of trees.

K.W. Picea glauca (white spruce), Abies lasiocarpa (subalpine fir), artificial regeneration, burning, logging, planting, release cutting, seedbed, site preparation, soil.

17. Bedell, G.H.D. 1948. White spruce reproduction in Manitoba. Canada, Forest Service, Silvic. Res. Note 87. 16 pp.

A regeneration survey was carried out to determine the relative value of shelterwood and seed tree systems in securing reproduction after logging mixed stands of spruce and hardwoods. Stocking, including all species, was satisfactory under both systems. Spruce regeneration, however, was sparse or lacking over much of the area, possibly a result of a lack of moisture or excessive depth of litter and humus. Of the two systems, shelterwood felling was by far the more productive for spruce regeneration.

K.W. Picea glauca (white spruce), hardwoods, humus, regeneration, scarification, seed tree cutting, seedbed, shelterwood felling, silviculture, soil moisture.

18. Belyea, H.C. 1924. A study of mortality and recovery after logging. J. For. 22:768-779.

Analysis of data from four permanent sample plots in New York indicates that a high mortality in trees surviving the logging operation is influenced directly by the intensity of the operation, it begins shortly after cutting and lasts 12-14 years. Recovery of the site is centered on saplings and seedlings rather than an increased growth of the survivors. Mortality is less and recovery quicker in the mixed hardwood type than in either the spruce flat or spruce swamp types.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Picea sp. (spruce), advance growth, cutting intensity, mortality, partial cutting, regeneration, residual stand.

19. Blyth, A.W. 1952. Growth and yield of residual stands of white spruce in logged areas of the Boreal Forest Region of Alberta. Canada, Forestry Branch, Forest Research Division, Unpubl. M.S. (ABSTR.).

Analysis of data from permanent sample plots cut 1920-1950 indicate that there is a great acceleration in growth of the residual trees following logging. Regeneration, however, is far from sufficient.

K.W. Picea glauca (white spruce), logging, partial cutting, regeneration, residual stand, growth.

20. Bowman, A.B. 1944. Growth and occurrence of spruce and fir on pulpwood lands in Northern Michigan. Michigan State College, Agricultural Experiment Station, Tech. Bull. 188. 82 pp.

In spruce-fir forests, the most important factors affecting the kind and quantity of reproduction following cutting are: fire, proximity of seed trees, seedbed conditions, degree of cutting, vegetative cover, logging damage and slash. Reproduction on cutovers is adequate if fire is kept out. Seeding from side cannot be depended upon if seed trees are more than 500 ft. distant. Spruce and fir prefer a mineral seedbed for regeneration, however they have a better change where a duff layer exists and there is a light or moderate amount of shade. Cutting and leaving slash destroys much advance reproduction. Slash must be disposed of.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), Picea mariana (black spruce), regeneration, seedbed, slash disposal, vegetative competition.

21. Boyd, R.J. 1952. Effect of harvesting methods on reproduction in the mountain Engelmann spruce-alpine fir type. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note 11. 2 pp.

Single tree selection, group selection and clear strip felling were carried out in spruce-fir forests. Survey made 5 years later showed that with any of the harvesting methods, advance growth surviving logging was sufficient to provide a well-stocked stand, consisting mostly of sub-alpine fir. Natural regeneration is rapid and stocking nearby complete 5 years after logging, being highest under group selection and lowest in clear felling. With all methods of harvesting, subsequent reproduction tends toward Engelmann spruce and lodgepole pine.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), advance growth, clear strip cutting, regeneration, selective cutting, succession.

22. B.C. Forest Service. 1944. Report of the Forest Branch for the year ended Dec. 31, 1943. B.C. Forest Service. 71 pp.

An experiment in selective logging of Engelmann spruce was made to determine the effect on windthrow and reproduction of the removal of different proportions of the stand, three degrees of cutting being used. Two years after logging, conditions with regard to windthrow, slash, and drying out of the forest floor were more favourable on the selectively cut than on the clear cut areas.

K.W. Picea engelmannii (Engelmann spruce), clear cutting, diameter limit cutting, regeneration, selective cutting, slash, windthrow.

23. Burton, D.H. 1948. Regeneration of cutover pulpwood stands near Iroquois Falls, Ontario, 1925-1947. Ontario Dept. Lands and Forests, Res. Rept. 16. 36 pp.

Survey of vegetation and regeneration in spruce-fir forests in clay belt area. Spruce swamps were moderately stocked to spruce regeneration. Elsewhere balsam fir regeneration dominates all other species.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), Picea mariana (black spruce), cutting, regeneration.

24. Candy, R.H. 1951. Reproduction on cutover and burned-over land in Canada. Canada, Forestry Branch, Forest Research Division, Silv. Res. Note 92. 224 pp.

A major survey of the extent of regeneration on various cutover and/or burned-over areas in Canada (except British Columbia). Gives case histories for various areas.

K.W. advance growth, logging, prescribed burning, regeneration, residual stand.

25. Chapman, H.H. 1944. Is selective cutting a panacea for forest regeneration? J. For. 42:345-347.

Summarizes the objects of forest regulation and redefines "selective cutting". Recommends use of clear cutting in certain instances, and recommends clarification of aims and methods of selective cutting.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. clear felling, economics, forest regulation, improvement cutting, selective cutting, thinning.

26. Clark, M.B. 1956. E.P. 468 - Seed dispersal in the spruce-alpine fir type. B.C. Forest Service Research Review. p. 16.

Studies amounts of seedfall under various cutting methods, and the distance of seed dispersal on clear cut and burned areas.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), clear felling, cutting patterns, seed dispersal, seedfall, slash burning.

27. Clark, M.B. 1959. E.P. 286 - Cutting methods in overmature spruce-alpine fir (Bear Creek, Kelowna). B.C. Forest Research Review. pp. 9-15.

Growth increment, regeneration and residual stand growth are tabulated completely after various partial cutting regimes were carried out in an overmature spruce-alpine fir stand. Also reported 1956 - p. 20.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), diameter limit cutting, growth increment, mortality, regeneration, selection cutting.

28. Clark, M.B. 1959. E.P. 286 - Growth and development of a cutover spruce-alpine fir stand in the Southern Interior. B.C. Forest Research Review. pp. 9-15.

Engelmann spruce-alpine fir near Kelowna was clear cut and partially cut using horses in 1940-41. Development of stands on these logged areas are tabulated, but the project was abandoned because of lack of experimental objectives or control.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), clear felling, partial cutting, regeneration.

29. Clark, M.B. 1961. E.P. 467 - Regeneration studies in interior spruce types. B.C. Forest Research Review. p. 39.

Studies a series of case histories of logging involving some features which may influence subsequent regeneration in the Kamloops Forest District in spruce-alpine fir and spruce-alpine fir - Douglas fir. Regeneration found after logging and/or burning was unsatisfactory. Advance growth was primarily alpine fir, in large quantity but of poor form, and with much incipient butt rot. Those slots well regenerated have disturbed seedbeds with exposed mineral soil or rotten

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

wood. Such seedbeds are produced by skidding, road construction, or intentional scarification. Controlled burning was ineffective in producing seedbeds. All seedbeds became quickly overgrown with moss and weeds. Also reported 1956 - pp. 23-24, 1957 - pp. 24-25, 1959 - pp. 7-9, 31-32.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), advance growth, logging, regeneration, scarification, seedbed, site treatment, skidding, slash burning, [Pseudotsuga menziesii].

30. Clark, M.B. 1963. E.P. 371 - Cutting methods in overmature spruce-alpine fir (Bolean Lake). B.C. Forest Research Review. pp. 34-35.

Seven cutting treatments were measured for influence on growth increment of residual stand and regeneration. These results were tabulated over a ten-year period since cutting. 1) Any growth of residual stand was more than offset by mortality (mainly windthrow). 2) Alpine fir regeneration outnumbers spruce by 2.3:1. 3) Alpine fir advance growth outnumbers spruce by 3.9:1. 4) Total regeneration provides adequate stocking on all areas. Advance growth is of poor quality. 5) Clear cut areas are progressing better than uncut or partially cut areas. Also reported 1956 - p. 20, 1957 - p. 22, 1958 - pp. 23-24.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), advance growth, clear felling, growth increment, logging, partial cutting, regeneration, salvage logging, selection cutting, silviculture, slash burning, strip cutting.

31. Croome, G.C.R. 1968. Conversion of a mature fir-spruce-birch forest to the periodic selection system of management. Canada, Forestry Branch, Forest Research Lab, Fredericton, Internal Rept. M-26. 27 pp.

Outlines requirements of selection forestry in New Brunswick. Recommendations are made for more efficient regeneration cutting.

K.W. Abies sp. (fir), Picea sp. (spruce), regeneration, selection cutting.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

32. Croome, G.C.R. 1970. A trial of selection management in a mature fir-spruce-birch forest. Forestry Chronicle 46(4):317-321.

Outlines trial of selection logging in New Brunswick to convert forests to uneven-aged structure. Aim of increasing spruce has been unsuccessful, volume declining from 24% to 13% in 20 years as a result of fir competition. At the present time there is no indication that such a system will increase volume production compared to clear felling.

K.W. Picea glauca (white spruce), Picea mariana (black spruce), Abies balsamea (balsam fir), selection cutting, silviculture.

33. Day, M.W. 1942. Selective cutting well adapted to spruce-fir forests. Michigan Agricultural Experiment Station, Quart. Bull. 24:238-240. (Abstr. F.A. 4:99).

Results from experimental cuttings of different intensities in second growth spruce/fir forests indicate that the selection method of cutting is well suited to this type. The degree of cutting to be applied to a particular stand will vary with volume and composition of original stand amount and suitability of young grown present, and site exposure.

K.W. Abies sp. (fir), Picea sp. (spruce), advance growth, selective cutting.

34. Day, M.W. 1945. Spruce-fir silviculture. Michigan Agricultural Experiment Station, Quart. Bull. 28:59-65.

Essential points in management of spruce-fir forests are: to cut early, often and lightly; to protect young growth; and to remove overtapping hardwoods. Short cutting cycles and marking should be used. Only a minimum number of young trees should be cut to facilitate felling and skidding. These should be mostly fir to increase the proportion of spruce in the residual stand.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), advance growth, hardwoods, horse logging, logging damage, silviculture, skidding.

35. Day, R.J. 1961. Spruce and fir seedling survival in relation to habitat factors in the Crowsnest Forest. Canada, Dept. Forestry, Forest Research Branch, Unpubl. MS.

Summer heating and drying of the soil surface was seen to be a principle cause of severe seedling mortality in cutovers on the Crowsnest Forest. Spruce and fir regeneration both apparently require moist shaded environments. Various methods of shading were tested to reduce mortality.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), Picea engelmannii (Engelmann spruce), climate, regeneration, seedling mortality, shade, soil moisture, soil temperature.

36. Day, R.J. 1962. The micro-environments occupied by spruce and fir regeneration in the Rocky Mountains. Canada, Dept. Forestry, Forest Research Branch, Mimeo, Alberta 62-5. 24 pp.

In the Crowsnest Forest, a study was made of micro-environments occupied by spruce-fir regeneration. Results are given: spruce growth is slightly better than that of fir, but both are slow; most spruce and fir regeneration occurred in moist, shaded sites; shaded decayed wood, mineral soil with incorporated humus, and F. and H. humus were the best seedbeds; regeneration was prolific on thick organic matter; soil moisture is critical in regeneration; fir can establish in hotter, drier conditions than spruce. About 30% of the seedlings of both species occurred in micro-environments with heavy shade for 50%-100% of the day. Spruce and fir regeneration increases considerably in abundance with increasing residual stand density up to 50%.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii X Picea glauca (hybrid spruce), climate, drought, germination, humus, regeneration, residual stand, seedbed, seedling mortality, seedlings, soil.

37. Day, R.J. 1962. Spruce seedling mortality caused by adverse summer micro-climate in the Rocky Mountains. Canada, Dept. Forestry, Forest Research Branch, Mimeo, Alberta 62-14. 47 pp.

Reports an experiment conducted to demonstrate that summer heating and drying of the soil surface can be a cause of severe seedling mortality on logged-over land in subalpine fir-spruce forests of Alberta. Severe mortality of hybrid spruce seedlings was found in seedbeds exposed to full sunlight. A 40% shade significantly reduced mortality on all seedbed types. Seedling mortality increased in severity over time after cessation of watering. Different seedbed types showed different mortality rates after a given time. In shade, seedling mortality was correlated with the soil moisture retention of the seedbed. In the open, mortality was correlated with surface temperature and moisture retention.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

Surface temperatures of above 50° cause severe mortality despite soil moisture. The length of the growing period before drought reduced mortality. The suggestion is made that shelterwood cutting should replace clear cutting.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca X engelmannii (hybrid spruce), artificial regeneration, clear felling, girdling, logging, planting, regeneration, seedbed, seedling mortality, shelterwood cutting, soil moisture, soil temperature.

38. Day, R.J. 1963. Spruce seedling mortality caused by adverse summer micro-climate in the Rocky Mountains. Canada, Dept. Forestry, Forest Research Branch, Publ. 1003. 36 pp.

Summer heating and drying of soil surface can be a cause of severe seedling mortality on logged-over land in the subalpine forests of Alberta. When in a greenhouse, drought was artificially maintained for fifty days over spruce seedlings. Full isolation caused more severe mortality than 40% shade. Seedling mortality in the shade was best correlated with the soil moisture retention of the seedbeds. In the open, mortality was correlated with both moisture retention and surface temperature. Surface temperatures of 45°-50°C can cause stem girdle depending upon soil moisture. Above 50°C, severe mortality is caused even when the soil is moist at one-inch depth. The length of growing period before the onset of drought appears to reduce susceptibility to mortality. The results suggest that harvesting methods and seedbed treatments, that will provide shelter to the seedlings, will result in better regeneration than clear cutting.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca X engelmannii (hybrid spruce), artificial regeneration, girdling, logging, planting, seedbed, seedlings, seedling mortality, site treatment, soil, soil moisture.

39. Day, R.J. 1964. The micro-environments occupied by spruce and fir regeneration in the Rocky Mountains. Canada, Dept. Forestry, Forest Research Branch, Publ. 1037. 25 pp.

A study of spruce and fir regeneration in cutovers in the subalpine forest of Alberta showed that seedling growth is very slow, and abundant regeneration becomes established very infrequently. Since most seedlings are found in cool, moist and shaded micro-environments, it is suggested that regeneration methods which provide shelter and conserve soil moisture be tested.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii X glauca (hybrid spruce), logging, regeneration, seed production, seedbed, site preparation, soil moisture.

40. Day, R.J. 1970. Shelterwood felling in late successional stands in Alberta's Rocky Mountain subalpine forest. Forestry Chronicle 46(5):380-386.

Shelterwood felling, removing 30% of a spruce-alpine fir-lodgepole pine stand did not markedly increase advance growth over level before cutting, but the number of seedlings after shelterwood felling was about twice as great on non-scarified areas and about 4 times as great on scarified areas as before shelterwood felling. Established seedlings showed a fourfold increase on non-scarified areas and a tenfold increase on scarified areas. Height growth of seedlings was slightly greater on non-scarified soils, but height growth throughout shelterwood felled area compared favourably with that of seedlings on clear felled areas. Shelterwood felling, is however, not likely to be used for economic reasons.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca X engelmannii (hybrid spruce), Pinus contorta (lodgepole pine), advance growth, scarification, seedling growth, shelterwood felling, silviculture.

41. Day, R.J. and P.J.B. Duffy. 1961. Regeneration after logging in the Crowsnest Forest. Canada, Dept. Forestry, Forest Research Branch, Unpubl. MS.

See Canada, Dept. Forestry, Publ. 1007

42. Day, R.J. and P.J.B. Duffy. 1963. Regeneration after logging in the Crowsnest Forest. Canada, Dept. Forestry, Forest Research Branch, Publ. 1007. 32 pp.

In 1958, a study was made of the reproduction in a number of logged-over areas in the Crowsnest Forest of southwest Alberta. This paper describes the study area, outlines the site classification and the method of survey and gives an analysis of: 1) reproduction; 2) effect of site on the establishment of seedlings; 3) effect of within-site moisture variation; 4) influence of logging methods and time elapsed since logging; 5) seed source; 6) influence of vegetation upon stocking; 7) degree of stocking to seedlings on various seedbed types. The implications of the result are discussed briefly in relation to regeneration silviculture.

K.W. logging, regeneration, seedbed, soil, soil moisture, vegetation.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

43. de Grace, L.A. 1949. The effect of tree length skidding in relation stands. B.C. Forest Service, Unpubl. Rept.

44. de Grace, L.A. 1950. Management of spruce on the east slope of the Canadian Rockies. Canada, Forestry Branch, Forest Research Division, Silv. Res. Note 97. 55 pp.

Eighty cutover plots in Alberta were examined to determine growth in the residual stand. All trees were tallied into vigour classes, and reproduction and mortality assessed on each plot. Results indicate that cutting must not reduce stand volume per acre below 3000 f.b.m. if further cuts within 40 years are desireable. Reproduction will provide an adequate supply of stand recruits wherever residual stands exceed 1000 f.b.m. in volume. Vigour of residual stand trees was found to be a matter of spacing. Mortality averaged 13.5%. Recommendations are made for future cutting.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), growth increment, logging, mortality, regeneration, residual stand, selective cutting, spacing.

45. de Grace, L.A. 1950. Selective logging of spruce in subalpine Alberta. Canada, Forestry Branch, Forest Research Division, Silv. Res. Note 96. 15 pp.

Clear cutting in spruce-fir stands in Alberta tends to destroy advance growth so that even with an available seed source, regeneration period is at least 30 years. Selective logging preserves most of the advance growth as well as leaving a residual stand capable of increased growth.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), advance growth, clear felling, logging, regeneration, regeneration period, residual stand, seeding, selective cutting.

46. de Grace, L.A., E.W. Robinson and J.H.G. Smith. 1952. Marking of spruce in the Fort George Forest District. B.C. Forest Service, Res. Note 20. 13 pp.

Reproduction of spruce after logging is extremely slow. Preproduction of spruce on burned or otherwise devastated forest land shows little evidence of providing early restocking. Advance growth, however shows good growth increment. Marking to leave trees of good vigour characteristics is considered beneficial.

K.W. Picea sp. (spruce), advance growth, fire, growth increment, logging, regeneration.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

47. Dekatoff, N.E. 1932. The natural regeneration of spruce, at Ssiverskaja Experimental Forest near Leningrad, Russia. For. Chron. Vol. 8. pp. 152-153.

Reports the following conclusions from an investigation of the natural regeneration of spruce: 1) self-regeneration of spruce under parent crown canopy is successful where density is average or inferior, but requires a gradual opening up of the canopy; 2) clear cutting does not allow successful spruce regeneration on very productive sites; 3) on moderately productive sites, spruce regeneration can occur after clear cutting; 4) regeneration of spruce occurs in the first ten years after cutting; 5) lighter crown-canopy allows more spruce to grow. Recommendations for cutting undertaken in 40-year-old stands as being most favourable are made.

K.W. Picea sp. (spruce), clear cutting, crown canopy, crown density, regeneration.

48. Dobbs, R.C. 1970. White spruce (Picea glauca (Moench) Voss) regeneration. A problem analysis with special reference to the subalpine region of the British Columbia Interior. Canada, Forestry Service, Forest Research Lab, Victoria, Unpubl. MS. 56 pp.

Problem analysis initiated in spring of 1970 with express purpose of formulating objectives and shaping of strategy to fulfill them, with respect to reducing problems of seedling mortality and slow initial growth in logged-over spruce-alpine fir areas in the Prince George Forest District.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), artificial regeneration, containers, logging, planting, regeneration, seeding, seedling growth, seedling mortality.

49. Dobbs, R.C. and R.G. McMinn. 1970. Improved regeneration in white spruce-alpine fir forest types in the North Central Interior of British Columbia. A proposal of research. Canada, Forestry Service, Forest Research Lab, Victoria, Unpubl. MS. 27 pp.

See also Internal Rept. BC-X-24 and Project Proposal Statement BC-914. Introduces and outlines problems involved in regeneration of cutover spruce-alpine fir forests in the Prince George area. Includes a description of the ecology of the area, the history and development of forestry practices, and a detailed description of the proposed research programmes.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), artificial regeneration, logging, planting, regeneration, seeding, site treatment, vegetative competition.

50. Dobbs, R.C. and R.G. McMinn. 1971. Regeneration of spruce/alpine fir types in British Columbia. Canada, Forest Service, Forest Research Lab, Victoria, Internal Rept., BC-24. 26 pp.

Reviews cutting and regeneration practices used in the Prince George Forest area, and points out the present disparity between areas logged and regenerated. Present systems of logging and site preparation are not adequate to meet the demands for regeneration in this area. The problem is basically one of economics, but has biological and ecological aspects. Planting is probably the best way of regenerating spruce in this area, but even this system is not trouble-free. Outlines proposed research into the problem of obtaining adequate regeneration.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), artificial regeneration, forest management, logging, planting, prescribed burning, regeneration, scarification, seedbed, seeding, silviculture.

51. Dobbs, R.C. and R.G. McMinn. 1972. The status of regeneration in the Prince George Forest District of British Columbia: an analysis. Canada, Forestry Service, Pacific Forest Research Service, Pacific Forest Research Centre. 36 pp.

Describes ecology of Prince George Forest District and present picture of timber resources in this area. Status of both artificial and natural regeneration and various means of site preparation are described. Concludes that there is a significant regeneration problem in the Prince George District and in B.C. as a whole. Various recommendations are made.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, burning, clear felling, economics, logging, planting, regeneration, seeding, seedling growth, seedling survival, site preparation.

52. Dračkov, V.N. 1970. [Effect of diseases and injuries on spruce natural regeneration.] Lesn. Hoz. 1970(8):57-59. (Abstr. F.A. 32:290).

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

When felling is done in years with a good seed crop, adequate natural regeneration will be obtained; in other years, additional measures will have to be undertaken.

K.W. Picea sp. (spruce), clear felling, regeneration disease, seed production, seedling mortality.

53. Drinkwater, M.H. 1960. Regeneration after shelterwood felling in field spruce in Nova Scotia. Canada, Dept. Forestry, Forest Research Division, Mimeo Rept. 60-5. 15 pp.

3 systems of shelterwood felling tested and the experiment all fulfilled their promise of adequate growth were best on the open sections of the strip and group systems rather than under uniform shelterwood cutting.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), regeneration, seedling growth, shelterwood cutting, windthrow.

54. Eichel, G.H. 1957. Management of spruce-balsam stands towards natural regeneration. Forestry Chronicle 33(3):233-237.

Suggests various methods of forest management, both cutting patterns and post harvest treatment, to ensure adequate natural regeneration of the spruce-fir stands of the Cariboo region.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), forest management, regeneration, silviculture.

55. Eis, S. 1963. Preliminary study of white spruce and alpine fir seedling characteristics in relation to environmental conditions on clear cut strips in the Prince George area. Canada, Dept. Forestry, Forest Research Lab, Victoria, Mimeo 63-BC-11. 23 pp.

A study of germination, first year growth and survival of white spruce and alpine fir seedlings on clear cut strips was carried out near Prince George. Mortality of seedlings was 45% on mineral soil and 100% on raw humus. Mortality on mineral soil occurred only in severe drought. Main cause of mortality on both types of seedbed was moisture deficiency in the root zone.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), clear strip logging, humus, regeneration, seedbed, seedling mortality, soil, soil moisture, soil temperature.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

56. Eis, S. 1965. Development of white spruce and alpine fir seedlings on cutover areas in the central interior of British Columbia. Forestry Chronicle 41(4):419-431.

Germination of white spruce and alpine fir was similar on mineral soil at all forest sites studied, averaging 33% for spruce and 6% for alpine fir. Mortality of seedlings in mineral soil was confined to periods of summer drought. On undisturbed seedbeds, germination of both species was very low. Shoot growth of both species ceased well before root growth. The main cause of seedling mortality on both types of seedbed appears to be the water deficit in the root zone. Increased mortality on fully exposed plots can be attributed to the direct heating of the living tissue under water stress.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), germination, regeneration, seedbed, seedlings, seedling mortality, soil.

57. Endean, F. 1972. Soil temperature, seedling growth and white spruce regeneration. In: White spruce, the ecology of a northern resource. Canada, Forestry Service, Northern Forest Research Centre, Alberta. pp. 15-20.

Deep organic layers in overmature spruce stands are considered a serious impediment to the establishment of regeneration followinc clear cutting. Low soil temperature below this organic layer is thought to be a major factor limiting regeneration success. Soil temperatures are evaluated for a few years following reduction of organic layers by prescribed burning.

K.W. Picea glauca (white spruce), clear felling, humus, prescribed burning, regeneration, seedbed, soil temperature.

58. Endean, F., H.J. Johnson and J.C. Lees. 1971. Silvicultural implications of large block clear cutting in Alberta. In: Some implications of large scale clear cutting in Alberta - a literature review. Canada, Forest Service, Northern Forest Research Centre, Alberta, Info. Rept. NOR-X-6. pp. 19-43.

Reviews literature on clear felling and regeneration, particularly that of spruce and pine. Conclusions are: 1) clear cut area, being hotter and drier than the stand margin area, has probably less competing vegetation to impare seedling growth; and 2) natural regeneration of spruce in clear cuts is poor, and should be augmented.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, clear felling, planting, regeneration, seedbed, seedling survival, temperature, vegetation.

59. Farrar, J.L. 1960. The response of spruce seedlings to release from shade at different ages. Univ. Toronto Forest Research Review. p. 5.

Experiment simulates exposure suffered by forest grown seedlings after clear cutting the overstory. Also reported in other reviews.

K.W. Picea sp. (spruce), clear felling, exposure, vegetative competition.

60. Frank, R.M. and E.L. Putnam. 1972. Seedling survival in spruce-fir after mechanical tree harvesting in strips. U.S. Dept. Agric., Northeastern Forest Experiment Station Res. Pap. NE-224. 16 pp.

The stocking of seedlings survived on strips logged during winter conditions with a Beloit Tree Harvester and a rubber tired skidder, is apparently adequate under most conditions at the end of two years. A sample of plots measured 1 and 2 growing seasons after harvest indicated that heavy slash accumulations contributed most to seedling mortality. Survival was greater off skidroads than on skidroads.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), advance growth, Beloit Harvester, logging damage, mortality, regeneration, seedling mortality, skidding, slash, [Picea rubens].

61. Franklin, J.F. and K.W. Krueger. 1968. Germination of true fir and mountain hemlock seed on snow. J. For. 66(5):416-417.

Seed germination of true firs, including Abies lasiocarpa, in or on snowbanks in Oregon was observed. Subalpine fir was observed much later than other fir species. It was thought that few germinants of any species would become established. Thus too early broadcast seeding or clear cutting to gain snowpack might retard regeneration of firs.

K.W. Abies lasiocarpa (subalpine fir), germination, logging, regeneration, seeding, snowbanks, [Abies sp., Tsuga sp.].

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

62. Fraser, A.R. 1948. Logging damage to advanced growth in the spruce-balsam type. B.C. Forest Service, Unpubl. Rept.

63. Fraser, A.R. 1949. Tree length logging as a silvicultural problem in the uneven-aged spruce-balsam type of the Prince George District. B.C. Forest Service, Unpubl. Rept.

64. Fraser, A.R. and J.L. Alexander. 1949. The development of the spruce-balsam type in the Aleza Lake Experimental Forest. B.C. Forest Service, Tech. Publ. T.32. 41 pp.

A Picea glauca - Abies lasiocarpa stand, cut to a diameter limit of 12 in. using horses for skidding, showed a greatly increased growth increment of the residual stand. Advance growth provided 87% of the stand volume 29 years after logging.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), advance growth, diameter limit cutting, growth increment, residual stand.

65. Haig, R.A. 1962. Regeneration in Manitoba. Forestry Chronicle 38:74-78.

After logging in Manitoba, regeneration is not sufficient to provide future well-stocked stands. Two important factors are seed supply and seedbed condition. Experimentally modifying these two factors has produced excellent regeneration at moderate expense. Operational trials are urged.

K.W. Picea glauca (white spruce), logging, regeneration, seed, seedbed, stocking, supply.

66. Haig, R.A. 1964. Silvicultural operations in white spruce-aspen stands on the Riding Mountain Forest Experimental area, 1960-1963. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 64-MS-4. 18 pp.

Outlines silvicultural experations, particularly partial cutting in overmature stands, coupled with measures to obtain adequate regeneration of spruce. Planting and seedbed preparation are both considered from an economic standpoint.

K.W. Picea glauca (white spruce), artificial regeneration, economics, partial cutting, planting, regeneration, scarification, seeding, silviculture, [Populus tremuloides].

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

67. Harris, A.S. 1967. Natural reforestation on a mile square clear cut in southeast Alaska. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Pap. PNW-52. 16 pp.

Natural reforestation on a 700 acre logging unit of the Maybeso Experimental Forest, Prince of Wales Island, Alaska, was studied during 9 years beginning with clear cutting of the old growth western hemlock-Sitka spruce stand. Production and dissemination of seed and establishment, development, and species composition of tree reproduction are discussed.

K.W. Chamaecyparis nootkatensis (yellow cedar), Picea sitchensis (Sitka spruce), Thuja plicata (western red cedar), Tsuga heterophylla (western hemlock), clear felling, regeneration, seedfall.

68. Harrison, J.D.B. 1929. Silviculture in the Prairie Provinces. Forestry Chronicle 5(1):10-16.

Makes recommendations for logging to gain maximum regeneration. States problems of obtaining adequate natural regeneration. Points out that artificial regeneration will be necessary in the future.

K.W. Picea glauca (white spruce), artificial regeneration, fire, logging, regeneration, silviculture.

69. Hart, A.C. 1964. Spruce-fir silviculture in northern New England. Proc. Soc. Amer. Foresters Meeting, 1963. pp. 107-110.

The former practice of clear felling these mixed spruce-balsam fir forests resulted in even-aged stands with a high percentage of balsam fir. The present practice of selective felling is resulting in uneven-aged stands with a higher percent of spruce.

K.W. Abies sp. (fir), Picea sp. (spruce), clear felling, regeneration, selective felling, silviculture.

70. Holt, L. 1949. Restocking of spruce. Practical departures from our present cutting methods, when required. Canadian Pulp and Paper Assoc., Woodlands Research Index 53(F-2). 15 pp. (Abstr. F.A. 11:42).

Literature on regeneration of red, white, and black spruce is reviewed. White spruce presents greatest problem. In eastern Canada, fir, not spruce, is climax and cutting practices presently in use are working against spruce reproduction. To obtain spruce regeneration, some form of mechanical soil disturbance is necessary.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), logging, regeneration, soil disturbance, succession, [Abies sp., Picea mariana, Picea rubens].

71. Horton, K.W. 1965. Mechanical pulpwood logging and regeneration. Pulp and Paper Magazine of Canada, Nov:494-498. Also Woodlands Review, Index 2346 (F-1). 6 pp.

The effects of mechanical logging on silvicultural methods, based on field observations of black spruce and jack pine logging in the Lakehead region of Ontario, are discussed.

K.W. mechanized logging, regeneration, [Picea mariana, Pinus banksiana].

72. Hosie, R.C. 1947. Report on regeneration studies on the limits of Spruce Falls Power and Paper Company, Ltd., Kapuskasing, Ontario and Pulpwood Supply Company, Ltd., Longlac, Ontario. Ontario, Dept. Lands and Forests, Res. Rept. 10. 56 pp.

Typical uncut stands and cutover areas in a white spruce-black spruce-balsam fir forest were examined in 1945 to determine whether under present cutting methods, areas are being adequately restocked to spruce, and if not, what steps should be taken to assure a future spruce cut on these lands. Conditions of regeneration in uncut mature forest were much better than on cutover areas. Forest fires are discussed. Slash burning destroys the seedbed for conifers but does not kill shrubby vegetation. Consequently, seedlings germinated after slash burning quickly die. The effect of cutting is much the same. It destroys up to half of the future potential conifer crops and what is left faces stiff competition from vegetation and hardwoods. Selective cutting, seedbed preparation, and planting are all encouraged.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), Picea mariana (black spruce), advance growth, artificial regeneration, cutting, planting, regeneration, scarification, seedbed, seedling, seedling mortality, slash burning, soil.

73. Hosie, R.C. 1953. Forest regeneration in Ontario. University of Toronto, Forestry Bull. 2. 134 pp.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

Contains abstracts of reports made by private companies and government agencies, 1919-1951 concerning forest regeneration studies as well as an initial report concerning procedure in carrying out and reporting regeneration surveys. For all studies made, area studies, method of studying, observations and conclusions are reported. Much of the work applies to spruce-balsam forest.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), Picea mariana (black spruce), advance growth, artificial regeneration, cutting, planting, regenerating, seedling growth, seedling survival, site treatment, slash burning, soil, [Betula sp., Populus sp.].

74. Jablanczy, A. 1967. A generalized scheme for the natural regeneration of old-field spruce. Canada, Forestry Branch, Forest Research Lab, Fredericton, Info. Rept. M-X-11. 4 pp.

Makes recommendations for regeneration oriented cutting in white spruce-balsam fir stands. A strip shelterwood system is considered best for regeneration when economics are also considered. Details of the system are given. Scarification is also considered desirable.

K.W. Picea glauca (white spruce), advance growth, regeneration, scarification, shelterwood cutting, [Abies balsamea].

75. Jablanczy, A. 1969. Establishment of white spruce and balsam fir in shelterwood felling of field spruce in Nova Scotia. Canada, Forestry Service, Forest Research Lab, Fredericton, Internal Rept. M-48. 29 pp.

Of group, strip and uniform shelterwood cuttings, each applied in two places, only one uniform cut resulted in satisfactory stocking to white spruce 5 years after preparatory fellings. Balsam fir had adequate regeneration where seed was plentiful. Neither strip nor group cut methods resulted in satisfactory regeneration of white spruce because of logging damage to advance growth, dry and hot conditions developing after cutting, and accelerated invasion of weeds. Only the edge of cuts was favourable to establishment of white spruce seedlings. Heavy mortality of advance growth was probably a result of desiccation of the organic rhizosphere. Categorizes regeneration behaviour of both white spruce and balsam fir.

K.W. Picea glauca (white spruce), advance growth, regeneration, seedbed, seedling mortality, shelterwood cutting, strip cutting, weed growth, [Abies balsamea].

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

76. Jablanczy, A. 1969. Natural reproduction after clear felling of old-field spruce stands in the Maritime Provinces. Canada, Forestry Branch, Forest Research Lab, Fredericton, Internal Rept. M-44. 27 pp.

New regeneration after logging in undisturbed spruce-fir stands usually does not compensate for the loss of advance growth caused by logging damage and subsequent drying of the forest floor. If the felling is timed to coincide with a good seed year, however, fairly good regeneration can be expected. Old field white spruce stands will frequently be followed by mixed wood stands after clear felling.

K.W. Picea glauca (white spruce), advance growth, clear felling, regeneration seedbed, [Abies balsamea].

77. Jones, J.R. 1971. Mixed conifer seedling growth in eastern Arizona. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Pap. RM-77. 19 pp.

Seedling height growth of several species including Englemann spruce, subalpine fir and Douglas fir was reconstructed from case studies. In small openings receiving no direct sunlight, height growth was slow, Engelmann spruce and subalpine fir seemed healthy after 6 growing seasons; Douglas fir did not. In an abandoned roadway receiving light at midday, growth was moderately faster and all species seemed healthy. Seedlings grew faster in a clear cutting. Growth of Engelmann spruce and subalpine fir understory seedlings released by partial cutting increased markedly. Douglas fir did not. On a burn, growth of Engelmann spruce seemed reduced by intense overstocking.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Pseudotsuga menziesii (Douglas fir), clear felling, partial cutting, regeneration, root growth, seedbed, seedling growth, seedlings, slash burning.

78. Kagis, I. 1952. Some problems of mixedwood stands. Forestry Chronicle 28(2):6-18.

Describes several areas of mixedwood stands of different age classes. Sample plots were taken at random in stands of 50-60 years of age. Data presented provided the basis for discussion of problems that may arise in the management of mixedwood stands, some caused by man, others such as fire, or flooding, by natural causes. The economics of management are discussed. Recommends further studies in the costs of release cuttings and the influence of such cuttings on regeneration.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), economics, forest management, regeneration, [Abies balsamea, Populus tremuloides].

79. Kirby, C.L. 1962. The growth and yield of white spruce-aspen stands in Saskatchewan. Saskatchewan, Forestry Branch, Tech. Bull. 4. 58 pp.

Describes silviculture of spruce-aspen stands, including cutting, thinning, and all aspects of artificial regeneration. Contains yield tables and makes recommendations for cutting regimes.

K.W. Picea glauca (white spruce), Populus tremuloides (trembling aspen), artificial regeneration, cutting, economics, nurseries, planting, regeneration, thinning.

80. Konishi, J. 1969. Silviculture annual report. Prince George Forest District. B.C. Forest Service, Unpubl. Rept. 28 pp.

K.W. artificial regeneration, silviculture.

81. Koroleff, A. 1944. The need for adequate basis for control of forest regeneration. Forestry Chronicle 20:188-191.

Natural regeneration of felled areas depends on conditions brought about by logging and the inherent characteristics of the tree species concerned. A table showing requirements of various species, including white spruce is presented.

K.W. Picea glauca (white spruce), ecology, logging, regeneration, silviculture.

82. Larsen, J.A. 1924. Some factors affecting reproduction after logging in northern Idaho. Jour. Agric. Res. 28:1149-1157.

Large openings made in the forest cover by clear cutting increase air and soil temperature, evaporation and moisture deficit, which present unfavourable conditions for re-establishment of moisture-loving species. Further, changed surface conditions resulting from large openings, and vegetation on areas completely cleared, may defeat natural regeneration altogether. A method of cutting which would provide smaller openings and partial shade on shelter would produce better silvicultural results.

K.W. air temperature, canopy, clear felling, evaporation, regeneration, soil temperature, vegetation.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

83. Larsson, H.C. and N.F. Lyon. 1949. Regeneration studies on spruce-fir, spruce, pine, and poplar lands in the mid-western region. Ontario, Dept. Lands and Forests, Res. Rept. 19. pp. 1-39.

Regeneration in cutover stands is generally similar in composition but not in numbers to what occurred prior to cutting. Often there is a large increase in poplar. Logging appears to destroy considerable numbers of balsam fir and spruce advance growth. Mechanical logging reduces fire hazard by breaking up and scattering slash.

K.W. Picea glauca (white spruce), cutting, regeneration, slash burning, [Abies balsamea, Picea mariana, Populus sp.].

84. Larsson, H.C. and G.C. Wilkes. 1947. Forest regeneration survey on cutover spruce and pine lands in the Thunder Bay and western regions. Ontario Dept. Lands and Forests, Res. Rept. 14. 45 pp. and 6 pp.

Two papers under one cover and title. Stand histories and ecologies of various site and cover types are described. Regeneration after cutting is described.

K.W. Picea glauca (white spruce), regeneration, vegetative competition, [Picea mariana, Pinus banksiana, Abies balsamea].

85. Le Barron, R.K. 1945. Mineral soil is favourable seedbed for spruce and fir. U.S. Dept. Agric., Lake States Forest Experiment Station, Tech. Note 237. 1 p.

On a clear cut area after 5 years 26.8% of seeds of white spruce sown had established themselves on mineral soil, compared to 0.2% on duff, and 0.5% on slash. Under a 40% tree cover, figures were 42.5%, 0% respectively. Fir did much better on duff than did spruce.

K.W. Picea glauca (white spruce), clear felling, duff, germination, regeneration, seedbed, seeding, seedling survival, slash, soil.

86. Lees, J.C. 1970. A test of silvicultural practices designed to secure spruce reproduction in partially cut mixedwood stands in Alberta. Canada, Forestry Service, Forest Research Lab, Edmonton, Internal Rept. A-31. 10 pp.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

A 2-cut shelterwood system with seedbed scarification and seeding between cuttings was designed for trial in a range of sites in the spruce-aspen mixedwood. In 1969, two to three years after second logging, regeneration was assessed comparing performance on three sites, and between logged over and control blocks. Re-logged plots show lower rates of regeneration quality than control areas, but the quality of the seedlings is much higher on such sites.

K.W. Picea glauca (white spruce), artificial regeneration, regeneration, scarification, seeding, seedling quality, seedling survival, shelterwood felling, [Populus sp.].

87. Linn, E.R. 1918. Silvical systems in spruce in northern New Hampshire. J. For. 16:897-908.

Describes results of cutting to a diameter limit of 12 to 14 inches for softwoods in the hardwood type, and to a diameter limit of 12 to 14 inches in the spruce types. Also gives a summary of clean cutting, which results indicate, will give better reproduction than previously supposed.

K.W. Abies sp. (fir), Picea sp. (spruce), clean cutting, diameter limit cutting, hardwoods, regeneration, seedling growth, slope type.

88. Ljvov, P., P. Pastuhova and A. Višnjakova. 1952. [Leaving seed trees in groups during mechanized skidding] Lesn. Prom. 12(11):16-17. (Abstr. F.A. 15:163).

Instead of single scattered trees, recommends concentrating the seed trees in the corners of square felling areas, the groups so retained present the form of four pointed stars whose rays extend along the site boundaries; the areas under seed trees forms 9% of the total area and the group occupy 70% of the site perimeter.

K.W. seed tree cutting, seed trees, seedfall.

89. Long, H.D. 1945. Spruce reproduction. Canadian Pulp and Paper Association, Woodlands Section Index 774(F-2). 3 pp. (Abstr. F.A. 8:232).

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

Spruce reproduction in Canada can be encouraged by two general methods: 1) exposing the mineral soil, which would involve some expense and probably necessitate artificial sowing; 2) maintaining the deep moist humus seedbed of mature spruce stands by selective cutting methods. The rotting logs and mossy floor of a mature stand provide an excellent seedbed for spruce and enable it to compete successfully with balsam fir, which on cutover sites, usually replaces spruce.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), cutting methods, regeneration, seedbed, seeding, soil.

90. Long, H.D. 1946. Investigations of the factors affecting the regeneration of spruce. Pulp & Paper Assoc., Montreal, Canada, Woodlands Section Index No. 875 (F-2). 14 pp.

Spruce regeneration often fails for the following reasons: 1) lack of seed source; 2) clear cutting in poor seed years; 3) destruction of seed by birds, rodents, etc; 4) competition from ground vegetation; 5) destruction by insects and mice; 6) destruction of seedlings by fungi; and 7) mineral nutrient deficiency owing to presence of deep moss and humus.

K.W. Picea sp. (spruce), drought, fungi, regeneration, seed destruction, seed production, seed source, seedbed, seedling mortality.

91. Long, H.D. 1946. Observations on spruce regeneration. Pulp and Paper Magazine of Canada 47(4):67-68.

Mature spruce in Quebec may be clear cut and will regenerate to spruce. Clear cutting of immature stands will result in growth of fir and hardwoods. Cutting on a short rotation, and skidding timber to scratch up the raw humus, and expose the moist humus and mineral soil should help regeneration of spruce.

K.W. Abies balsamea (balsam fir), Picea sp. (spruce), clear felling, hardwoods, humus, regeneration, seedbed, skidding, soil.

92. Lowdermilk, W.C. 1925. Factors affecting reproduction of Engelmann spruce. Jour. Agric. Res. 30(11):995-1009.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

Establishment of Engelmann spruce seedlings requires conservation of surface soil moisture throughout the dry period. Reproduction of spruce from seed deposited on the duff cannot be depended upon under any conditions. Mineral soil surfaces and lightly burned surfaces decisively favour the quick stocking of Engelmann spruce under favourable moisture conditions, but a plentiful seed supply is necessary. Therefore seed trees must be reserved, despite the possibility of windthrow. Selective cutting on southerly exposures, breaking up of duff, litter and vegetation and more general burning is advised. Dense vegetative cover will render soil as critically dry for spruce reproduction as exposure.

K.W. Picea engelmannii (Engelmann spruce), burning, regeneration, scarification, seedbed, seedfall, selective cutting, soil moisture, vegetative competition.

93. Lull, H.W. 1959. Soil compaction on forest and range lands. U.S. Dept. Agric., Misc. Publ. 768. 38 pp.

Describes the process of compaction by logging, analyses the site factors that affect compaction and discusses the effects of compaction on infiltration, percolation, and vegetation.

K.W. Infiltration, logging, soil, soil compaction.

94. MacBean, A.P. 1949. Silviculture and cutting methods in British Columbia. Forestry Chronicle 25(3):164-169.

Gives history of logging in British Columbia and deals with silviculture of coastal and interior regions. Reports on the status of regeneration after logging white spruce-fir stands and makes recommendations for increased production of new stands.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), forest management, regeneration, scarification, silviculture.

95. McMinn, R.G. 1970. Regeneration of spruce-alpine fir types in British Columbia - a problem analysis for the North Central Interior. Canada, Forestry Service, Forest Research Lab, Victoria, Unpubl. MS.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

Discusses a problem analysis directed to regeneration research in spruce-alpine fir forests. Gives a brief resumé of forestry practices and deals with the problem of resource management. Describes two proposed complimentary five-year projects: 1) artificial regeneration of interior spruce-alpine fir types; 2) ecology of site preparation in interior spruce-alpine fir types.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), regeneration, resource management.

96. Miller, J.B. 1940. Spruce regeneration in Canada. III. Ontario Forestry Chronicle 16(1):21-29.

Findings show regeneration of spruce after fire and wind is good. However, after clear cutting, it is only satisfactory in swamps and flats, there being too much fir regeneration on slopes. Recommends that more studies of cutting systems be made.

K.W. Picea sp. (spruce), clear felling, fire, logging, regeneration, windthrow.

97. Minore, D., C.E. Smith and R.F. Woollard. 1969. Effects of high soil density on seedling root growth of seven northwestern tree species. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Note PNW-112. 6 pp.

Seedlings of various species including lodgepole pine and Douglas fir were grown over soil columns compacted to bulk densities of 1.32, 1.45, and 1.59 grams/cm^3. In two years, roots of both Douglas fir and lodgepole pine penetrated 1.32 and 1.45 gm/cm^2 columns. No seedlings penetrated the 1.59 gm/cm^3 column.

K.W. Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, root growth, soil density.

98. Mjakotina, Č.V. 1963. [Spruce seed trees on clear fellings.] Lesn. Ž., Arhangel'sk 6(4):44-46. (Abstr. F.A. 25:383).

In Russian spruce forests, it is perfectly sound practice to leave spruce of small diameter as seed trees on felled areas. Wind resistance and seed production of these trees are both good.

K.W. Picea abies (Norway spruce), clear felling, regeneration, seed production, seed trees, windthrow.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

99. Pearce, W.J. 1939. Growth in cutover stands in the Engelmann spruce type. J. For. 37:977.

A mortality of 62% of gross volume increment may be expected within the first 13 years after cutting.

K.W. Picea engelmannii (Engelmann spruce), growth, mortality, partial cutting, residual stand.

100. Phelps, V.H. 1938. Growth and reproduction of white spruce on cutover areas of The Pas Lumber Company in northern Saskatchewan. Canada, Forest Service, Unpubl. MS. 96 pp.

101. Phelps, V.H. 1941. Mortality and increment of white spruce on cutover lands. Canada, Forest Service, Unpubl. MS.

102. Phelps, V.H. 1948. White spruce reproduction in Manitoba and Saskatchewan. Canada, Forest Service, Silv. Res. Note 86. 32 pp.

After logging and fire in white spruce stands, there is insufficient natural regeneration to provide for properly stocked future stands. Many seedlings become established, but most fail to survive more than two or three years. Factors influencing germination and survival are being studied. It is suggested that some form of silvicultural treatment will be necessary to induce adequate regeneration.

K.W. Picea glauca (white spruce), artificial regeneration, fire, forest management, litter, logging, scalping, seedbed, seedling mortality, seedling survival, seedlings, silviculture.

103. Phelps, V.H. 1948. White spruce stands cut to different diameter limits in northern Saskatchewan. Canada, Forest Service, Silv. Res. Note 85. 20 pp.

A survey was made of logged-over white spruce stands to determine which cutting policy was best with respect to future spruce regeneration. Recommendations are that a policy of cutting to a minimum diameter limit of fourteen inches on a twelve-inch stump be adhered to, that the minimum diameter limit be judged according to each individual stand, and that immature stands growing at a good rate should be left.

K.W. Picea glauca (white spruce), diameter limit cutting, economics, forest management, regeneration, residual stand, silviculture, [Populus sp.].

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

104. Pogue, H.M. 1946. Regeneration and growth of white spruce after logging. B.C. Forest Service, Tech. Publ. T.29. 26 pp.

Studies on areas logged in 1923 and 1926 using horse skidding were measured at 5 year intervals. A satisfactory crop resulted from residual stand. A strict diameter limit should be maintained in order to retain maximum forest yield.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), diameter limit logging, growth increment, residual stand.

105. Prochnau, A.E. 1960. E.P. 458 - Seed production and dissemination under various stand conditions in the spruce-alpine fir types. B.C. Forest Research Review. p. 13.

Measures seed production of various species in the spruce-alpine fir stand in, a) natural stand and b) selectively logged stand. In all cases, paper birch releases by far the most seed, with seed production of spruce and alpine fir very low. Normal heavy spruce seedfall proves itself to be adequate for dispersal over 10-chain clear cut strips or blocks. Also reported 1956 - pp. 15-16, 1957 - p. 17, 1958 - pp. 16-17.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), regeneration, seed dispersal, selective cutting, [Betula papyrifera].

106. Quaite, J. 1957. Results of partial cutting in an overmature even-aged stand of subalpine white spruce in Alberta. Canada, Forestry Branch, Forest Research Division, Mimeo 57-7.

Partial cutting in a typical overmature spruce-alpine fir stand is silviculturally unsound. Residual spruce did not release, regeneration was a failure and mortality was greater than growth in the residual stand. Clear felling and artificial regeneration are advocated.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), advance growth, bark beetles, growth increment, logging, mortality, partial cutting, regeneration, release, residual stand, windthrow.

107. Revel, J. n.d. E.P. 639 - Silviculture in spruce-alpine fir types in the north central interior of British Columbia: problem analysis. B.C. Forest Service, E.P. 639, Unpubl. Rept. 49 pp.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

Attempts to outline major silvicultural problems in the spruce-alpine fir types, but ignores administrative problems. Includes a description of the subalpine forest, its geology, soil, climate and forests; a review of harvesting and silvicultural practices carried out currently or in the past, the major problems of regeneration in this area, and research proposals for this area.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), artificial regeneration, ecology, forest harvesting, land use, planting, regeneration, seeding, silviculture, site preparation, slash disposal, soil.

108. Richardson, J. and J.P. Hall. 1973. Natural regeneration after disturbance in the forests of central Newfoundland. Canada, Forestry Service, Newfoundland Forest Research Centre, St. Johns, Info. Rept. N-X-86. 63 pp.

Stands of balsam fir and black spruce in central Newfoundland regenerate satisfactorily after cutting or fire. After cutting problems may arise in some black spruce stands due to unfavourable seedbed conditions which delay the establishment of a fully stocked stand of regeneration. Balsam fir stands do not as a rule regenerate after burning but black spruce stands regenerate well unless a seed source is lacking or seedbeds are unfavourable.

K.W. germination, logging, prescribed burning, regeneration, seedbed, [Abies balsamea, Picea mariana].

109. Robertson, W.M. 1927. Cutting for reproduction in spruce stands. Forestry Chronicle 3(3):n.p.

Evaluates various methods of cutting spruce stands for their efficiency in promoting natural regeneration.

K.W. Picea glauca (white spruce), clear felling, diameter limit cutting, regeneration, seedbed, selection cutting, shelterwood cutting.

110. Robertson, W.M. 1945. Some observations on silvicultural cutting methods. Canada, Forest Service, Res. Note 75. 18 pp.

Standard silvicultural cutting methods are reviewed and condensed to serve as a guide in selecting methods adapted to management of Canadian pulpwood forests. The methods are classified; each method is described; the advantages, disadvantages, and application of each are stated.

K.W. clear felling, cutting methods, diameter limit cutting, logging, regeneration, selection cutting silviculture.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

111. Robinson, A.J. 1970. Logging by the seed tree system and prescribed burning to encourage black spruce regeneration. Canada, Forestry Service, Forest Research Lab, St. Johns, Info. Rept. N-X-42. 16 pp.

Seed tree logging resulted in extensive blowdown. Burning does not appreciably reduce the thickness of the organic mantle, although slash was reduced considerably. Burned seedbeds were no more favourable for natural spruce regeneration than those on unburned areas.

K.W. germination, regeneration, seedbed, seed tree cutting, slash burning, [Abies balsamea, Picea mariana].

112. Robinson, A.J. 1970. Spruce regeneration resulting from seed tree cutting and clear cutting in Newfoundland. Canada, Forestry Service, Forest Research Lab, St. Johns, Info. Rept. N-X-43. 9 pp.

Most areas were reasonably stocked to spruce five years after logging. Stocking to spruce was similar in clear cut and seed tree cut areas. Regeneration of black spruce was favourable on sphagnum moss, decayed wood, mineral soil, Polytrichum moss and shallow humus. Seedlings were most abundant on fresh to moist sites where there was light vegetative competition.

K.W. clear felling, regeneration, seed tree cutting, seedbed, vegetative competition, [Picea mariana].

113. Robinson, E.W. 1949. The practice and some problems of partial cuttings in the yellow pine and spruce types of the interior of B.C. Proc. Vancouver Section, Canadian Society of Forest Engineers.

114. Roe, A.L. 1967. Seed dispersal in a bumper spruce seed year. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Res. Pap. INTO-39. 10 pp.

Sound seed is dispersed in considerable quantities (0.5 to 4.6% of seed released in timber) to a distance of 10 chains from the timber edge. Pattern of seed dispersal was quite similar in all areas. However this was a good seed year, and might account for as much seed produçtion as the sum of 3-5 poor years. Additional data is necessary.

K.W. Picea engelmannii (Engelmann spruce), clear felling, regeneration, seed dispersal, seed production, seedbed.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

115. Roe, A.L. and G.M. DeJarnette. 1965. Results of regeneration cutting in a spruce-subalpine fir stand. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Res. Pap. INT-17. 14 pp.

Old growth Engelmann spruce/subalpine fir was logged in Idaho between 1916 and 1925. Partial cutting, clear felling, seed tree felling, strip cutting, and block cutting, were all carried out. In all cases growth and mortality of residual stand is reported over the period 1925-1954. In addition, the status and progress of natural regeneration in 1954 is reported in detail. Results indicate that seedfall was significantly greater within 10 chains of the forest edge than beyond that district. Mineral soil (13.3% of the area logged) was by far the best seedbed for both spruce and fir, followed by burned surface. In all cases, except in the partially cut area, fir regeneration outnumbers that of spruce by as much as 4:1. In the partially cut area, spruce outnumbers fir by 1 1/2:1. Best growth of seedlings occurs on clear cut areas. Recommendations are made.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), advance growth, clear felling, cutting regimes, partial cutting, planting, regeneration, scarification, seedbed, seeding, seedling mortality, seed tree cutting, slash burning, windthrow.

116. Roe, A.L. and W.C. Schmidt. 1964. Factors affecting natural regeneration of spruce in the Intermountain region. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Mimeo Rept. 68 pp.

117. Roe, A.L., R.R. Alexander and M.D. Andrews. 1970. Engelmann spruce regeneration practices in the Rocky Mountains. U.S. Dept. Agric., Production Research Report 115. 32 pp.

Attempts to bring together pertinent information, based on experience and research on spruce regeneration requirements and limitations and to provide some preliminary guides to aid the land manager in developing regeneration practices for restocking spruce stands. Greater emphasis is put on natural regeneration rather than artificial regeneration. Extensive literature review.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), artificial regeneration, clear felling, planting, regeneration, seeding, silviculture, site preparation, soil.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

118. Ronco, F. 1970. Engelmann spruce seed dispersal and seedling establishment in clear cut forest openings in Colorado - a progress report. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note RM-168. 7 pp.

Good crops of 100,000 or more seeds/acre were produced only once in 4 or 5 years on 3 areas. On other areas, seed crops were good in 3 of 6 years. Seedfall into clear cut openings decreased rapidly beyond about 1.5 chains from standing timber, but considerable sound seed was still dispersed across openings in years of good seed production. In general, openings were stocked with less than 300 well distributed seedlings per acre; seedling establishment appeared to be limited more by environmental factors that affect germination and survival than by seed supply.

K.W. Picea engelmannii (Engelmann spruce), clean felling, germination, regeneration, seed dispersal, seed production.

119. Ronco, F. and D.L. Noble. 1971. Engelmann spruce regeneration in clear cut openings not insured by record seed crop. J. For. 69(9):578-579.

Natural regeneration on some clear cut openings does not depend upon the amount of seed produced, but upon favourable seedbed and micro-environment for germination and seedling survival.

K.W. Picea engelmannii (Engelmann spruce), clear felling, climate, regeneration, seedbed, seedfall, soil.

120. Rowe, J.S. 1955. Factors influencing white spruce reproduction in Manitoba and Saskatchewan. Canada, Forestry Branch, Forest Research Division, Tech. Note 3. 27 pp.

A study of Picea glauca reproduction was made during the summers of 1949, 1950, and 1951 on cutover and burned-over areas and in undisturbed forest stands. The most favourable seedbed in undisturbed forest is decayed wood. In disturbed stands where the humus layer has been burned or scraped away, conditions are also suitable for establishment since competition is temporarily eliminated and the mineral soil is exposed. Logging rarely counteracts the conditions of the forest floor unfavourable to the reproduction of spruce; the humus is not much disturbed (particularly in winter logging) and trees that would produce a rotted wood seedbed are removed.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), humus, logging, regeneration, slash burning, soil.

121. Silburn, G. 1960. Reforestation problems in western spruce forests. Forestry Chronicle 36(2):150-152, 155.

Brief resumé of reforestation practices and problems within the Prince George region with respect to spruce regeneration both natural and artificial.

K.W. Picea glauca (white spruce), artificial regeneration, planting, regeneration, seeding.

122. Siskov, I.I. 1950. [Spruce seed bearers on clear felled areas.] Lesn. Hoz. 3(7):61-62. (Abstr. F.A. 13:272).

It is possible to leave spruce seed trees without serious risk of windthrow on certain site types, provided that attention is paid to the type of tree selected for this purpose. Recommendations concerning type of trees to be left are made. Spruce is windfirm on all soils but peat podzol clay-loams to clays with poor drainage. For successful regeneration, it is essential either to burn the ground cover or to scarify the soil mechanically.

K.W. Picea sp. (spruce), burning, clear felling, regeneration, scarification, seed trees, soils.

123. Skoklefald, S. 1967. [Release of natural regeneration of Norway spruce.] Medd. Norske Skogforsøksv. 23(85):381-409. (Abstr. F.A. 29:434).

Mortality of regeneration under a shelterwood felling after release was greatest in small seedlings ($\leq$ 10 cm high), survival was much higher for seedlings of 25-30 cm, especially if slash was dispersed. The depth of slash cover influenced mortality considerably, > 50% of seedlings up to 50 cm high were killed on areas covered with slash depths of 30-50 cm. No conclusions are drawn concerning most favourable season for felling to favour seedling survival. Plants $\geq$ 2 m high showed a slight reduction in growth for a short time after felling. There was a considerable increase in height growth 3-4 years after felling. Increased height growth after removal of stand followed more rapidly with increasing plant size.

K.W. Picea abies (Norway spruce), logging, logging damage, regeneration, residual stand, seedling mortality, shelterwood felling, skidding, slash.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

124. Smerlis, E. 1962. Reproduction on clear cut and partial cut areas in southern Labrador. Canada, Dept. Forestry, Forest Research Lab, St. Johns, Mimeo 62-8. 15 pp. (ABSTR.).

On clear cuts and partial cuts, reproduction consisted mainly of black spruce and balsam fir with little white spruce. In some areas, vegetation dominated cutovers.

K.W. Picea glauca (white spruce), advance growth, clear felling, partial cutting, regeneration, vegetation, [Abies balsamea, Picea mariana].

125. Smith, J.H.G. 1950. Silviculture and management of Engelmann spruce in B.C. Yale University, School of Forestry, M.F. Thesis. 198 pp.

Field data on wind damage, reproduction, and sample plots were gathered in 1949. Results show blowdown and breakage are reduced considerably by light cuttings, but alpine fir losses are greater than spruce. Larger trees suffer most, with worst damage in swamped and overmature stands. Windfall losses may be reduced by light selection, salvage-group-selection, or alternate strip clear cutting methods. Reproduction was surveyed and observed to be best in moist mineral soil. Alpine fir may tend to be favoured, but this can be reduced by light selection or salvage-group-selection systems. The economic feasibility of logging in both Engelmann spruce and alpine fir is still to be considered, but may be considered optimistically. Recommendations are made for further study on permanent sample plots to determine growth, yield, mortality, and reproduction changes due to partial cutting, as in systems mentioned.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), cutting methods, economics, forest management, logging, regeneration, soil, windthrow.

126. Smith, J.H.G. 1954. A cooperative study of Engelmann spruce-alpine fir. Silviculture and management. Northwest Science 28(4):157-165.

Summarizes briefly results of a study investigating silvicultural requirements of spruce and alpine fir and comparing them with cutting methods to determine which system of logging could provide conditions necessary for adequate reproduction. Results indicate the effect of site on early development was less than that of seedbeds and light. Germination was usually high on mineral soil, burns, and rotted-wood seedbeds, but lower on moss and litter seedbeds. Mortality was highest on burns and rotted wood seedbeds, survival highest on mineral soil. Greater amounts of shade increased germination, but seedlings grew best in full sunlight.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), burning, decay, insect damage, germination, planting, regeneration, seedbed, seedling growth, seedling mortality.

127. Smith, J.H.G. 1956. Some factors affecting reproduction of Engelmann spruce and alpine fir. B.C. Forest Service, Tech. Publ. T.43. 43 pp.

After logging, less than one third of advance growth was spruce, and that was poorly distributed because of its growth in clumps on rotten wood and mineral soil seedbeds. Spruce advance growth was more abundant in the wetter sites. Alpine fir was able to establish itself on litter and moss as well as those seedbeds favourable to spruce. Amount of germination decreased and mortality increased directly with increased light. Germination was high on mineral, burn, and rotten wood seed beds, and on these was significantly higher than on litter. Increased temperature, caused by exposure to light, increased rate of germination significantly. Mortality was highest on burned surfaces, high on moss, moderate on litter and rotten wood and lowest on mineral soil. Drought and rodents were the most important causes of seedling and seed losses. Survival of spruce was high on mineral soil, burned areas, and rotten wood, and was significantly low on moss and litter. Moss was a much poorer seedbed for spruce than for fir. Over winter leaching and shade were essential for germination and survival on burned surfaces. Survival was best in moderate shade. Moisture was the factor most limiting to both species. Growth of spruce and fir was best on burned and mineral seedbeds that received 70% of full sunlight. Relative proportions of spruce and alpine fir regeneration can be controlled best by adjusting seed supply. Bulldozer scarification resulted in excellent seedbeds at low cost.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), germination, regeneration, scarification, seed supply, seedbed, seedling mortality, shade, slash burning, soil moisture.

128. Smith, R.B. and H.M. Craig. 1968. Decay in advanced alpine fir regeneration in the Prince George District of British Columbia. Forest Chronicle 44(3):37-44.

Incidence, extent and causal fungi of decay was investigated in Abies lasiocarpa advanced growth up to 7" d.b.h. and 7-264 years of age from logged and unlogged white spruce-alpine fir stands in the Prince George District. Management recommendations are given and variation in recommended stand improvement procedure are discussed.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. *Abies lasiocarpa* (subalpine fir), advance growth, decay, logging, regeneration, residual stand.

129. Smith, R.B. and H.M. Craig. 1970. Decay in advanced alpine fir regeneration in the Kamloops District of British Columbia. Forestry Chronicle 46(3):217-220.

After clear felling, advanced regeneration of *Abies lasiocarpa* was essentially decay-free. Where *Picea engelmannii* - *Abies lasiocarpa* stands are not cleanly logged, decay in residual alpine fir may be considerable. Makes recommendations to reduce decay of advance regeneration.

K.W. *Abies lasiocarpa* (subalpine fir), *Picea engelmannii* (Engelmann spruce), advance growth, clear felling, decay, fungi, regeneration, residual stand.

130. Smithers, L.A. 1964. The impact of mechanical logging on silviculture in Canada. Canada, Dept. Forestry, Forest Research Branch, Contribution 648. 10 pp.

Theoretical discussion of the problem of the effects of fully mechanized logging methods on the forest. The characteristics of efficient mechanical logging which will influence silvicultural methods include: the year-round nature of operations, the change from steel track to wheeled equipment, the tendency toward larger clear cut areas, and the possibility of using larger quantities of low grade material from hardwood stands. Includes brief sections on advance regeneration, slash disposal, natural regeneration artificial regeneration, planting, and high yield silviculture.

K.W. advance growth, artificial regeneration, clear felling, mechanized logging, regeneration, season of logging, silviculture, slash disposal.

131. Spencer, J.W. 1915. Management of Engelmann spruce - alpine fir stands. Proc. Soc. Amer. Forester 10:192-198.

Silviculturally ideal system, not practical at the time of writing is clear cutting in strips, preparing artificial seedbeds and allowing them to seed from residual stand.

K.W. *Abies lasiocarpa* (subalpine fir), *Picea engelmannii* (Engelmann spruce), logging, regeneration, silviculture, site preparation, slash burning, strip cutting.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

132. Squillace, A.E. 1954. Engelmann spruce seed dispersal into a clear cut area. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Res. Note 11. 4 pp.

Fall of sound Engelmann spruce seed into a clear cut in Montana averaged 953,000/acre within cut timber, dropping sharply to ca 70,000/acre 7 chains from the cut edge and levelling off at about 60,000/acre at 9-11 chains from timber. Dispersal patterns obtained indicate that 20 chains should be a maximum clear cut width.

K.W. Picea engelmannii (Engelmann spruce), clear felling, regeneration, seedfall, soil, stocking.

133. Stettler, R.F. 1957. E.P. 504 - A problem analysis on silvicultural conditions in the spruce-alpine fir type of the Kamloops Forest District. B.C. Forest Research Review. pp. 22-23.

Various cutting methods and logging practices in spruce-alpine fir were examined with respect to stand response. Results indicate that spruce regeneration is sparse, partially because of bush and herbaceous growth. Studies of artificial regeneration and inducing natural regeneration should be made for this forest type.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), artificial regeneration, logging, methods, regeneration, vegetative competition.

134. Stettler, R.F. 1958. Development of a residual stand of interior spruce-alpine fir during the first twenty-eight years following cutting to a 12 inch diameter limit. B.C. Forest Service, Res. Note 34. 15 pp.

In Similkimeen Land District, a spruce-alpine fir stand was cut to a 12 inch diameter limit in 1928. 87% of the stand was spruce, the rest alpine fir and lodgepole pine. Slash piling and burning created a pattern of 30-40 well distributed patches of exposed mineral soil per acre. Residual stand by 1957 was much reduced by windthrow, especially of spruce (one stand showed 100% mortality). On a total stand basis, accelerated rate of growth of individuals did not compensate for the reduction suffered due to mortality. Regeneration, however thrived as a result of favourable seedbed and species ratio, alpine fir; spruce, changed from 6:1 to 3:1.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), diameter limit cutting, growth increment, mortality, regeneration, residual stand, seedbed, slash burning, slash piling, windthrow.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

135. Stettler, R.F. 1958. E.P. 160 - Conditions in a residual stand of interior spruce-alpine fir. B.C. Forest Research Review. pp. 24-25.

Measures survival and growth of stems after partial cutting in alpine fir and the subsequent rate of seedling establishment in White Mountain, Kelowna. The area was logged, with slash burned and piled. Greatest mortality of the residual stand, especially spruce, was by windthrow. Advance growth suffered a considerable reduction. Subsequent establishment of regeneration was faciliated by seedbed preparation of slash piling and burning. Spruce showed a definite preference for spots of exposed mineral soil. Alpine fir: spruce ratio changed from 6:1 in 1929 to 3:1 in 1957.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), advance growth, mortality, partial cutting, regeneration, residual stand, slash burning, windthrow.

136. Stettler, R.F. 1958. E.P. 503 - Some factors affecting radial release growth of a residual stand in interior spruce-alpine fir. B.C. Forest Research Review. p. 25.

A residual stand of a partially cut spruce-alpine fir stand showed a marked increase in radial growth.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), growth increment, partial cutting, residual stand.

137. Stettler, R.F. 1958. E.P. 514 - Cutting methods in immature and thrifty mature spruce types. B.C. Forest Research Review. p. 27.

Cutting by diameter limit in spruce-alpine fir stands results in poor residual stands. Advance reproduction contains few future crop trees. Species ratio favours undesirables such as alpine fir, aspen, etc. Bush growth is favoured by cutting and competes successfully with coniferous regeneration. Extensive thickets are found in cutovers. Seedbed preparation amounts to at most 25% of area logged, and mush of this is covered by slash. Studies concerning scarification and seeding are recommended. Prince Rupert Forest District (Babine Lake, Bulkley Valley, etc).

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), advance growth, diameter limit cutting, regeneration, residual stand, seedbed, slash, vegetative competition.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

138. Tiren, L. 1951. [Spruce cull trees and their importance in the regeneration of felled spruce areas in northern Sweden.] Medd. Skogsforskn. Inst., Stockholm 39(8):1-28. (Abstr. F.A. 13:272).

Seed viability of cull trees is about the same as that of normal trees. At levels higher than 300 m above sea level, scarifying or burning over areas near seed trees will be necessary as well as leaving a minimum of 50 trees/ha of large diameter.

K.W. Picea sp. (spruce), burning, logging, regeneration, seed trees, seed viability.

139. U.S. Dept. Agric. 1943. Silviculture of the spruce-fir types. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept., 1943. pp. 37-43.

Outlines problems in spruce-fir silviculture in the Rocky Mountains and reviews various cutting methods. Problem in regeneration is slash accumulation and seedbed problems. Burning of slash is recommended as a solution for this problem.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), burning, cutting method, logging, regeneration, silviculture, slash.

140. U.S. Dept. Agric. 1961. Spruce and fir reproduce abundantly following three methods of cutting. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept., 1960. pp. 19-21.

Clear cutting in alternate strips, clear cutting in small groups and single tree selection were carried out in old growth spruce-fir forest in Colorado. Advance growth, dominated by fir was abundant and well distributed at time of logging. Logging by horses destroyed 44% of advance growth on group clear felled plot, 56% on selection plot, and 60% on strip cut plot. More fir than spruce was destroyed. After 15 years, total reproduction and number of spruce were most abundant on clear strip cut plots and least on selection plots. More spruces than firs came in after cutting by all three methods. Stocking was good (89-92%) regardless of cutting methods. From 61 to 69% of all milacres were stocked with spruce.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), advance growth, clear felling, horse logging, regeneration, selection cutting, stocking, strip cutting.

141. U.S. Dept. Agric. 1967. Pattern of mixed conifer seedfall on a clear cutting in Arizona. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept., 1966. p. 7.

On a 10 acre clear cutting, seedfall averaged more than 400,000 seeds/acre within only 1-1.5 chains of the upwind timber margin and much less along other margins. Within a 1.6 acre central area, seedfall averaged only about 10,000 acres.

K.W. Picea engelmannii (Engelmann spruce), clear felling, seedfall.

142. U.S. Dept. Agric. 1967. Reproduction good on small clear cuttings in spruce-fir in Colorado. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept. 1966. pp. 8-9.

83% of sample plots were found to be stocked on strip clear cuts 200-400 ft. wide. 67% were stocked with fir and more than 50% stocked with spruce. Advance growth stocked 61% of plots and regeneration stocked 54%. Advance growth was mostly fir, but subsequent regeneration was evenly distributed between spruce and fir.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), advance growth, regeneration, strip cutting.

143. U.S. Dept. Agric. 1969. Reproduction good after clear cutting spruce-fir in strips. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept., 1968. p. 19.

Where timber was harvested to a 4.0 inch diameter limit in alternate strips 1, 2, 3 and 6 chains wide in Colorado, enough trees survived to restock all strips. Composition of surviving advanced growth was predominantly subalpine fir. New regeneration added considerably to stocking. There was no direct relationship between number of seedlings and width of opening. By 1966, 78-88% of milacres sampled were stocked and spruce was present on 46-64% of milacres.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), advance growth, diameter limit cutting, regeneration, stocking, strip cutting.

144. U.S. Dept. Agric. 1970. Good spruce seed crops occur infrequently. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept., 1969. p. 24.

One good seed crop (100,000 + seeds/acre) and two moderate crops (50,000 - 100,000 seeds/acre) were recorded under uncut Engelmann spruce along margins of a clear cut between 1956 and 1965. Seed production was poor or nearly non-existent in the other 7 years. Seedfall into clear cut openings was not uniformly distributed, but decreased as distance from source increased. 50% of seed in a moderate year fell within 65-100 ft. of timber edge, but 10% was dispersed across 400 ft. wide opening.

K.W. Picea engelmannii (Engelmann spruce), clear felling, regeneration, seed dispersal, seedfall.

145. U.S. Dept. Agric. 1971. Engelmann spruce seed production is irregular. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept., 1970. p. 4.

See U.S. Dept. Agric. 1970. Good spruce seed crop occurs infrequently.

K.W. Picea engelmannii (Engelmann spruce), clear felling, seed dispersal, seed production.

146. Vincent, A.B. 1951. Experimental cutting in mixedwood stands, Green River, New Brunswick. Canada, Forestry Branch, Silv. Leaflet 58. 4 pp.

Outlines a project established in 1937 to develop for mixedwood stands, a cutting method which would ensure satisfactory future representation of white spruce and balsam fir. Four cutting methods were applied. In general, 1) spring cutting did not result in a better stand of softwoods than summer cuttings; 2) leaving two spruce seed trees per acre did not result in increased regeneration; 3) girdling of defective, overmature hardwoods at the time of cutting softwood pulpwood apparently favoured establishment of softwood advance growth and regeneration; 4) skidding and yarding by tractor resulted in more softwood and hardwood regeneration than when the seedbed was disturbed more lightly by horse-yarding or stump cutting.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), cutting method, girdling, horse skidding, logging, regeneration, seedbed, skidding, [Abies sp., Populus sp.].

147. Vincent, A.B. 1952. Logging damage to spruce and fir advance growth. Canada, Forestry Branch, Forest Research Division, Silv. Leafl. 69. 4 pp.

A heavy cut (60%) and a light cut (30%) in spruce-fir forest in New Brunswick were tested for damage to advance growth. Reduction of stocking (tabulated) is small in both cuts, the percentage of quadrats being reduced from 98% to 94% on the light cut, and from 99% to 93% on the heavy cut. There was no significant difference either between the number of seedlings destroyed per tree cut or per acre on the two intensities of cutting.

K.W. Picea glauca (white spruce), advance growth, logging damage, mortality, partial cutting, seedlings, stocking, [Abies sp.].

148. Vincent, A.B. 1956. Balsam fir and white spruce reproduction on the Green River watershed. Canada, Dept. Forestry, Forest Research Branch, Tech. Note 40. 26 pp.

The most important factors affecting the condition of reproduction of Abies balsamea and Picea glauca include: 1) density, age, and composition of the original stand; 2) suppression by maple in cutover mixed woods; 3) discouragement of regeneration and smothering of advance reproduction by slash piles; 4) destruction of advance growth during logging; 5) site factors; 6) effects of sun and frost in preventing establishment of spruce and fir. Recommendations for encouraging spruce and fir regeneration include release of shrubs, care to avoid unnecessary logging damage, and lopping and scattering of slash. If planting is done on logging roads it should be done not later than one growing season after logging, using planting stock at least 8 in. high.

K.W. Picea glauca (white spruce), advance growth, artificial regeneration, light, logging damage, logging roads, regeneration, slash disposal, vegetation, [Abies, sp., Acer sp.].

149. Vjalyh, N.I. 1969. [Survival and growth of Norway spruce advance growth on extensive clear felled areas in the Archangel region.] Lesn. Ž., Arhangel'sk 12(3):16-19. (Abstr. F.A. 31:507).

Much of advance growth can survive. Survival was best on areas logged by a system of narrow cuts (1 1/2 times standard height), the trees being felled towards the skidding trail and skidded top first down the trail.

K.W. Picea abies (Norway spruce), advance growth, logging, logging damage, skidding.

150. Wagg, J.W.B. 1962. White spruce regeneration on the Peace and Slave rivers. Canada, Dept. Forestry, Forest Research Branch, Mimeo Alberta 62-8. 61 pp.

Describes forests, geography, climate, soils and rivers of the Peace and Slave river lowlands. The importance of fire, logging, floods and small mammals in regeneration of forests, is discussed. Regeneration was inadequate on clear cut areas eight years after logging, most seedlings being on mineral soil seedbeds. Small mammals consume much seed on cutovers. Regeneration silviculture is recommended for white spruce.

K.W. Picea glauca (white spruce), clear felling, ecology, floods, logging, mammals, regeneration, seedbed, seedling mortality, silviculture, soil.

151. Wagg, J.W.B. 1964. White spruce regeneration on the Peace and Slave river lowlands. Canada, Dept. Forestry, Forest Research Branch Publ. 1069. 35 pp.

Reports observations made in 1959 on white spruce regeneration in alluvial soils of the lower Peace and Slave river forests. Most white spruce seedlings on cutover and burned-over areas were found on mineral soil seedbeds. Regeneration silviculture is recommeded for white spruce. Discussed are ecology of white spruce, nature of seed source and seedbeds, influence of flooding and alluvial deposition, influence of small mammals on regeneration, and development of white spruce, forests.

K.W. Picea glauca (white spruce), forest management, logging, mammals, regeneration, seedbed, seeding, silviculture, slash burning.

152. Wahlenberg, W.G. 1948. Development of reforestation methods in the subalpine region. Project A-6. Applied silviculture seeding and planting. Canada, Dominion Forest Service, Unpubl. Rept.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

153. Waldron, R.M. 1959. Experimental cutting in a mixedwood stand in Saskatchewan, 1924. Canada, Forestry Branch, Forest Research Division, Tech. Note 74. 13 pp.

Diameter limit, seed tree, and strip cuttings were carried out in a mixedwood stand. The white spruce component of the new stands thus created will probably equal or surpass that of the original stands, due to a heavy white spruce seed year in 1924. There was a relationship between amount of white spruce replaced in stands by 1956 and residual basal area of all species. The optimum was about 75 ft.^{2}/acre.

K.W. Picea glauca (white spruce), diameter limit cutting, logging, regeneration, residual stand, seed production, seedling growth, strip cutting.

154. Waldron, R.M. 1960. Cutting methods for management of white spruce, Riding Mountain Forest Experimental Area. Canada, Forestry Branch, Forest Research Division, Mimeo Rept. 64-MS-13. 5 pp.

Various cutting methods in spruce-aspen stands are evaluated. Best survival of regeneration was obtained when 15% of spruce and all hardwoods were left. Regeneration was vastly aided by bulldozer scarification.

K.W. Picea glauca (white spruce), Populus tremuloides (trembling aspen), cutting methods, regeneration, scarification, seedling mortality.

155. Webber, B., J.T. Arnott, G.F. Weetman and G.C.R. Croome. 1969. Advance growth destruction, slash coverage, and ground conditions in logging operations in eastern Canada. Pulp and Paper Research Institute of Canada, Woodlands Paper 8. 109 pp.

On 34 different mature pulpwood stands in eastern Canada, 4110 acre study areas were established in which quantity and distribution of seedlings was measured. While many areas after logging had 1000 or more seedlings per acre, they were poorly distributed, and it is estimated that many would not survive. There is indication that tractor logging creates enough soil disturbance to ensure germination and survival of coniferous trees. Case histories of all areas are given.

K.W. advance growth, regeneration, scarification, slash, soil disturbance, tractor logging.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

156. Weetman, G.F. 1965. The need to study silvicultural effects of mechanized logging systems in eastern Canada. Forestry Chronicle 41:252-256.

Biological problems which may result from the use of heavy logging equipment are discussed. Scarification from logging rarely produces enough seedbed favourable to natural regeneration. Full tree logging may cause nutrition problems by removing tree crowns from poor sites. Further study of logging systems to assess effects on stands soils and future regeneration are necessary.

K.W. logging, regeneration, scarification, seedbed, soil nutrients.

157. Wellburn, G.V. and L. Adamovich. 1973. Trends in logging in central British Columbia. Seventh World Forestry Congress Commission IV. The Loggers (Reprint). 10 pp.

Reviews timber cutting and regeneration techniques practised in the central B.C. area. Future trends in all aspects of forest utilization are predicated.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), Pinus contorta (lodgepole pine), forest management, logging, silviculture.

158. Westveld, M. 1926. Logging damage to advance spruce and fir reproduction. J. For. 24:579-582.

On permanent sample plots in the White Mountain National Forest, it was found that, after removal of the mature stand of spruce-hardwood forest by horse logging, hardwood reproduction was twice as profuse as that of spruce and fir, but the conifers had adequate regeneration to compete successfully.

K.W. Abies sp. (fir), Picea sp. (spruce), advance growth, hardwoods, horse skidding, logging damage, regeneration.

159. Westveld, M. 1930. Suggestions for the management of spruce stands in the northeast. U.S. Dept. Agric., Circular 134. 24 pp.

Introduces spruce-fir forests of the northeast and describes the effects of past and present treatments on spruce stands. Silvicultural recommendations are made for cutting, protection of young growth, and slash disposal.

a) INFLUENCES OF HARVESTING PROCEDURES, cont'd.

K.W. Abies balsamea (balsam fir), Picea sp. (spruce), cutting, regeneration, silviculture, slash disposal.

160. Westveld, M. 1938. Silvicultural treatment of spruce stands in northeastern United States. J. For. 36:944-950.

Describes a scheme of silviculture designed to maintain the productivity of spruce forests. Management should aim at securing proper reproduction before heavy cuttings, at freeing spruce and fir regeneration from hardwood competition and reducing logging damage. Such efforts are expected to be repaid by increased yields.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), advance growth, logging, logging damage, regeneration, silviculture, vegetative competition.

161. Westveld, M. and A.G. Snow. 1940. Reproduction conditions on cutover old-field spruce stands in New England. U.S. Dept. Agric., Northeastern Forest Experiment Station, Tech. Note 32. 2 pp. (ABSTR.).

Cutover area show satisfactory amount of coniferous reproduction although more than 85% was balsam fir and only 11% spruce. Hardwoods are rapidly becoming established on these areas and are represented by nearly as many seedlings/acre as are the conifers. These relatively fast growing hardwoods are overtopping the conifers and hindering their normal growth. Reproduction is sparse or absent on areas occupied by dense conifers slash.

K.W. Abies balsamea (balsam fir), Picea sp. (spruce), hardwoods, regeneration, vegetative competition.

b) INFLUENCES OF SITE PREPARATION PROCEDURES

Site preparation procedures, such as slash burning, scarification, cultivation, and the use of herbicides exert a profound influence upon natural regeneration occurring both under uncut stands and in areas cleared by logging, fire, or other activities. The papers in this section deal with the influences of such site preparation procedures upon the natural regeneration of spruce and spruce-fir forests.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

162. Ackerman, R.F. 1957. The effect of various seedbed treatments on the germination and survival of white spruce and lodgepole pine seedlings. Canada, Forestry Branch, Forest Research Division, Tech. Note 63. 23 pp.

Removing one or more of the sources of competition for available moisture improves germination and survival. This improvement varies with species and the condition of the site. Trenching appeared to have no influence on spruce germination. Removing vegetation and dry, unincorporated vegetable matter significantly improved germination and survival, but removal of organic matter by burning had an adverse effect on germination and survival. Results for pine are also given.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), burning, germination, humus, regeneration, scarification, seedbed, seedling survival, site treatment, slash, soil moisture, trenching, vegetation.

163. Anderson, E.F. and C.A. McCormack. 1965. Anchor chain scarifiers in Ontario. Ontario, Dept. Lands and Forests, Silvic. Note 2. 16 pp.

Anchor chains have some potential as a scarifying tool. Costs are low and the technique is adaptable to various circumstances. They should not, however, be used in all circumstances.

K.W. anchor-chain scarifiers, cutting, planting, scarifying.

164. Arlidge, J.W.C. 1967. The durability of scarified seedbeds for spruce regeneration. B.C. Forest Service, Res. Note 42. 20 pp.

Effective life of machine-scarified seedbeds was investigated on 17 acres in the Prince George Forest District. Seedbeds were seeded 0-4 years after scarification in such a manner as to imitate natural seedfall, thus essentially testing natural reproduction into scarified areas. Survival of spruce was greatest on large scarified areas and on those areas seeded immediately after scarification. Stocking was unsatisfactory if seeding took place more than 1 year after scarification. Balsam and birch survival varied with seedbed size, but not seeding year. Possibly, on sites tested, preparation and planting would be better than scarifying and seeding.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

K.W. Abies lasiocarpa (subalpine fir), Betula papyrifera (paper birch), Picea glauca (white spruce), artificial regeneration, scarification, seedbed, seedfall, seeding, vegetation.

165. Arlidge, J.W.C. 1967. E.P. 528 - Influences of time on effectiveness of scarified seedbeds. B.C. Forest Research Review. p. 35.

Experiments with various scarification times were carried out in the Prince George Forest District to determine how long scarified seedbeds remain effective as a medium for germination, survival, and growth of spruce regeneration. It was found that large tractors were most effective scarifying agents. After four years, areas scarified and seeded in the same year produced a stocking of 50.5%, and areas seeded one year after scarification produced a stocking of 32.8%. Any greater delay caused unsatisfactory stocking. Scarified spots larger than 4.5' in diameter were more tolerant of late seeding. Deterioration occurred mainly as a result of competition and leaf fall following regrowth of vegetation. Also reported 1959 - p. 29, 1960 - pp. 20-21, 1962 - pp. 21-22, 1963 - p. 23.

K.W. Picea glauca (white spruce), artificial regeneration, competition, scarification, seedbed, seeding, vegetation.

166. Armit, D. 1962. E.P. 558 - Scarification in spruce-alpine fir. B.C. Forest Research Review. p. 17.

Two scarification trials of various intensities were tested at Babine Lake on areas clear felled in strips and cut to an 11 inch diameter limit. About 36% of the soil was disturbed by 60 min./acre scarification. A larger machine than that used could have distributed disturbance more effectively over the whole area. Also reported 1961 - pp. 22-23.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), economics, scarification, scarification time, seedbed.

167. Barr, P.M. 1927. Spruce investigations in central British Columbia. Forestry Chronicle 3(3):n.p.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

Gives a history of logging in the Prince George area, and a history of the Aleza Lake Experiment Station. Outlines the nature of spruce-balsam stands and describes seedbed treatments attempting to improve spruce regeneration, as well as giving the preliminary results of these investigations concerning favourable seedbeds.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), fire, logging, regeneration, scarification, seedbed, slash burning, soil.

168. Baskerville, G.L. 1959. Softwoods respond to weeding. Pulp and Paper Magazine of Canada, Woodlands, Review 60(8):WR140, WR144.

Spruce-fir young growth overtopped by shrubs responded immediately to release with a steadily increasing rate of height growth over 3 years. By the end of this time, shrubs had enclosed stand again and growth levelled off at a rate 4.5 times that before weeding. By 1958, the increased growth had continued for 9 years with no sign of ceasing. Spruce responded less rapidly than fir, but height growth continued to increase even after shrubs closed in.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), height growth, vegetative competition, weeding.

169. Baskerville, G.L. 1961. Response to young fir and spruce to release from shrub competition. Canada, Dept. Forestry, Forest Research Branch, Tech. Note 98. 14 pp.

In 1949, white spruce and balsam fir regeneration in N.B. was released by removing all shrubs within 3 ft. of each stem. Both spruce and fir responded. In 9 years, height growth increased up to 6 times that of control stems of the same size. Although shrubs reoccupied the openings in 4 years, the softwoods continued to grow at increased rates throughout the study period.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), height growth, vegetative competition, weeding.

170. Bjorkbom, J.C. and R.M. Frank. 1968. Slash burning and whole tree skidding fail to provide mineral soil seedbeds for spruce-fir. Northern Logger 16(7):20, 45.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

A 75 year old spruce stand was logged between November 1964 and April 1965 on snow cover. Slash burning was carried out in Aug. 1965. Burning consumed foliage, twigs, and small branches in about half the piles. Some slash piles were untouched. These results were not influenced by strip width. As carried out here, slash burning was almost totally ineffective in exposing mineral soil. Skidding during winter logging exposed 3% mineral soil-totally inadequate for spruce regeneration. 88% of the area was undisturbed.

K.W. Abies sp. (fir), Picea sp. (spruce), logging, mineral soil, regeneration, seedbed, slash burning, soil exposure.

171. Boyd, R.J. and G.H. Deitschmann. 1969. Site preparation aids natural regeneration in western larch-Engelmann spruce. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Res. Pap. INT-64. 10 pp.

In northern Idaho, site preparation methods following strip clear cutting in western larch-Engelmann spruce had important effects on the character and amount of natural regeneration. While percentage of stocked quadrats was not particularly affected, the entry of new seedlings and increased representation of intolerant species were promoted by prescribed broadcast burning and by scarification of the seedbed.

K.W. Abies lasiocarpa (subalpine fir), Larix occidentalis (western larch), Picea engelmannii (Engelmann spruce), regeneration, scarification, seedbed, site preparation, slash burning, strip cutting.

172. Brown, G. 1966. A modified barrel scarifier. Ontario Dept. Lands and Forests, Silvic. Note 6. 8 pp.

The shark-finned scarifier provides a continuous strip for planting that is free of competition without totally destroying ground cover between rows. The prepared strip affords the planted seedlings some protection from frost and drought during the establishment period. The method is economically sound.

K.W. economics, planting, scarification, shark-fin scarifier.

173. Canada, Forest Service. 1941. Cleaning young spruce and balsam fir. Canada, Forest Service, Silv. Leaflet 7. 1 p.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

Two stands of spruce-balsam fir were cleaned at different intensities. Diameter growth in the heavily-cleaned plot (1200 stems) increased from 0.10 to 0.15 in./year in both species. Height growth of balsam fir increased considerably, but that of spruce increased only a small amount. The volume growth rate per year of 200 dominant trees was 21, 29, and 34 $ft.^3$ on the control plot, lightly-cleaned, and heavily-cleaned plots, respectively.

K.W. Abies sp. (fir), Picea sp. (spruce), cleaning, growth increment, height growth, thinning.

174. Carlquist, C-G. 1950. [Soil scarification on high ground.] Svenska SkogsvFören. Tidskr. 48(4):426-429. (Abstr. F.A. 13:272).

Regeneration on an area in North Sweden, scarified without burning over, was surveyed. Essentials for successful regeneration include: at least 25 or preferably 50 seed trees per ha.; sufficient ripening of humus after felling; a good seed year after scarification; careful siting of scarified patches and a method of scarification suited to the climate and other local conditions.

K.W. climate, humus, regeneration, scarification, seedbed, seedfall, seed trees.

175. Clark, J.D., L.W.W. Lehrie and J.H.G. Smith. 1954. Scarification in Engelmann spruce - alpine fir forests. B.C. Forest Service, Res. Note 25. 7 pp.

Single tree selection and diameter limit cutting are the most common harvest practices in spruce-alpine fir forests. However, logging damages residual stand and advance growth and reproduction becomes established slowly. Scarification by tractor in spruce-alpine fir stands costs relatively little. Results of trials indicate that scarification was highly effective in inducing regeneration. (188,500 spruce and 5,000 alpine fir seedlings per acre versus 682 spruce and 86 alpine fir seedlings per acre on an unscarified area).

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), advance growth, diameter limit cutting, economics, logging damage, regeneration, residual stand, scarification, single tree selection.

176. Clark, M.B. 1960. E.P. 533 - Scarification trials in spruce-alpine fir. B.C. Forest Research Review. pp. 24-25.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

Average cost of scarification in the spruce-alpine fir types was $10.80/acre. The type of equipment necessary to achieve satisfactory scarification depends on slope, density of vegetation, amount of windfall and/or slash, and soil moisture conditions. One hour per acre with suitable equipment should produce a minimum of satisfactory seedbeds. Also reported 1959 - p. 35.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), economics, scarification, time study.

177. Clark, M.B. 1964. Regeneration methods in the interior of B.C. In: Western Reforestation, Western Forestry and Conservation Assoc., Proc. Western Reforestation Co-ordinating Committee, Annual Rept. 1964. pp. 7-9.

Outlines methods used in various forest types in the Kamloops area, including spruce-alpine fir. Emphasis is upon natural regeneration and consequently upon scarification and/or prescribed burning.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), artificial regeneration, planting, scarification, seeding, slash burning.

178. Crossley, D.I. 1947. Mechanical seedbed treatment. Canada, Dominion Forest Service, Unpubl. MS.

179. Crossley, D.I. 1949. Reproduction of white spruce in a mixedwood stand following mechanical disturbance of the forest floor. Canada, Forest Service, Silv. Res. Note 90. 25 pp.

In 1946, on the Kananaskis Forest Experiment Station, the influence of bulldozer scarification was tested on the conversion of a mixedwood stand to white spruce. At the end of the second growing season, scarified plots showed a much greater rate of survival and size of germinants than did controls, which were, however, adequately stocked. There is a possibility that the scarified plots might stagnate.

K.W. Picea glauca (white spruce), germination, regeneration, scarification, seedbed, seedling mortality, seedling survival, soil, [Populus sp.].

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

180. Crossley, D.I. 1952. The survival of white spruce reproduction originating from mechanical disturbance of the forest floor. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 63. 4 pp.

Reports interim conclusions of a project initiated to investigate the problem of obtaining coniferous regeneration under a mixedwood standy by scarification with a bulldozer blade. At the time of writing, even the control area has a better than adequate seedling survival. No conclusions can be drawn, but the possibility of ultimate stagnation of stands on treated areas exists.

K.W. Picea glauca (white spruce), growth increment, mounding, regeneration, scarification, seedbed, seedling survival, site treatment, soil, [Populus sp.].

181. Crossley, D.I. 1952. White spruce reproduction resulting from various methods of forest soil scarification. Canada, Forestry Branch, Forest Research Division, Silv. Res. Note 102. 18 pp.

Reports results of a study undertaken to investigate the use of fire and of various mechanical methods of forest floor scarification as a means of inducing regeneration of white spruce on inadequately restocked cutover areas. Two years after initiation, the control plot had no regeneration, while three scarified plots were fully stocked, seven were well stocked, and one was understocked.

K.W. Picea glauca (white spruce), germination, prescribed burning, regeneration, scarification, seedbed, seedling mortality.

182. Crossley, D.I. 1955. Mechanical scarification to induce white spruce regeneration in old cutover spruce stands. Canada, Forestry Branch, Forest Research Division, Tech. Note 24. 13 pp.

During the summer of 1950, light mechanical equipment was used to scarify the forest floor under an inadequately regenerating residual stand of Picea glauca, Populus balsamifera, and P. tremuloides, in Alberta. The results, 4 years later, indicated that scarification had improved the quantity of spruce regeneration, but was relatively expensive (6 tractor-man hours/acre) and also stimulated the growth of competing vegetation. There was little poplar regeneration after scarification.

K.W. Picea glauca (white spruce), competition, economics, regeneration, scarification, vegetation, [Populus sp.].

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

183. Crossley, D.I. 1955. Survival of white spruce reproduction resulting from various methods of forest soil scarification. Canada, Forestry, Branch, Forest Research Division, Tech. Note 10. 9 pp.

Three years additional data on a study on the Kananaskis Forest Experimental Station to investigate the effect of fire and of certain mechanical equipment in the preparation of seedbeds receptive to white spruce reproduction on inadequately restocked cutover areas. Results indicate that all methods of scarification under study have proven more effective than the untouched control.

K.W. Picea glauca (white spruce), regeneration, scarification, seedbed, slash burning.

184. Curtis, J.D. 1964. What do you mean, "site preparation"? U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Res. Note INT-15. 8 pp.

Successful regeneration of many forest tree species requires planned treatment of the site, commonly called site preparation. Such treatment can be accomplished by mechanical means, by use of chemicals or by burning. The amount and kind of site treatment needed depend on local conditions, silvical requirements, and costs. An attempt is made to set forth and describe the methods frequently used by foresters in the course of preparing ground for regeneration.

K.W. artificial regeneration, economics, herbicides, regeneration, silviculture, site treatment, soil, soil moisture, slash burning, vegetation.

185. Davis, G. and A.C. Hart. 1961. Effect of seedbed preparation on natural reproduction of spruce and hemlock under dense shade. U.S. Dept. Agric., Northeastern Forest Experiment Station, Sta. Pap. 160. 12 pp.

Study undertaken in Maine to investigate the effects of several seedbed treatments on spruce and hemlock reproduction in a dense softwood stand that had been logged using a selection cutting system. Removal of the humus layer to expose mineral soil or mixing humus with mineral soil resulted in more favourable conditions than either burning or leaving humus undisturbed. Cutting when soil is not frozen or covered with snow ensures the breakup and mixture of humus in mineral soil and reduces root competition to some degree. Also recommends logging during good seed years when practical and removing hardwoods to minimize accumulation of hardwood litter on newly germinated softwood seedlings.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea sp. (spruce), hardwoods, humus, litter, regeneration, season of felling, seedbed, seedfall, selective cutting, slash burning.

186. Day, R.J. 1963. Additional watering to improve spruce germination in the Crowsnest Forest. Canada, Dept. Forestry, Forest Research Lab, Calgary, Mimeo 63-A-13. 15 pp.

Four watering regimes were tested during the 1962 growing season to assess the levels of precipitation necessary for spruce germination on exposed seedbed types not receiving seepage. Germination in all cases was low, even the best treatment (35%) being less than half the normal for that seed stock. In all watering regimes, the percent germination was higher on decayed wood than sandy loam. Generally germination increased with an increase in the volume of water added per week, except where flooding occurred. About eight inches of water were required for abundant germination and temperatures above 60-65°F appeared desirable.

K.W. Picea engelmannii X Picea glauca (hybrid spruce), air temperature, artificial regeneration, germination, irrigation, seeding, soil, soil moisture.

187. Day, R.J. 1963. Regeneration in old cutover spruce stands eleven years after scarification. Canada, Dept. Forestry, Forest Research Lab, Calgary, Mimeo 63-A-14. 10 pp.

Bulldozer scarification to induce white spruce regeneration was carried out in 1950. By 1961, regeneration was judged poor. Since 1954, mortality had reduced stocking of spruce to 37% on scarified areas and 32% on unscarified areas. Lack of adequate soil moisture may have been the cause of the poor response and growth of spruce regeneration on scarified soil.

K.W. Picea glauca (white spruce), regeneration, scarification, seedbed, seedling growth, seedling mortality, soil, soil moisture.

188. Day, R.J. 1963. Scarification before felling in high yield spruce-fir stands in the Crowsnest Forest. Canada, Dept. Forestry, Forest Research Lab, Calgary, Mimeo. 63-A-8. 10 pp.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

Blocks adjacent to clear cut scarified areas were pre-scarified. Subsequently soil moisture and temperature, rainfall and air temperature, were monitored and regeneration tallied. Percent stocking of spruce is tabulated. After one year, the average stocking on clearcut scarified areas was about 27% and that on pre-scarified uncut areas was about 58% despite the fact that there was less area disturbed on the pre-scarified site. Mortality of spruce seedlings over summer was 35% on the clear cut and 21% on the pre-scarified area. Reasons for the mortality are examined.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), climate, pre-scarification, regeneration, scarification, seedling mortality, seedling survival, soil moisture, soil temperature.

189. Decie, T.P. 1957. E.P. 501 - Soil scarification trials. B.C. Forest Research Review. pp. 25-26.

Various types of scarification were tested in the Prince George Forest District. Seedbed quality and regeneration are measured. Also reported in B.C. Forest Service Res. Note 36.

K.W. regeneration, scarification, seedbed.

190. Decie, T.P. 1959. E.P. 524 - Regeneration on scarified areas. B.C. Forest Research Review. p. 33.

In all cases, the percentage of stocked quadrats decreased in the second year after scarification.

K.W. regeneration, scarification, seedbed, stocking.

191. Decie, T.P. and A.R. Fraser. 1960. Miscellaneous notes on scarification trials, Prince George Forest District, 1956 to 1959. B.C. Forest Service, Res. Note 36. 22 pp.

Reports results of scarification trials on 2000 acres in the Prince George Forest District. Evaluates pre- and post-logging scarification according to cost and type of seedbed left, the emphasis being upon the leaving of mineral soil.

K.W. economics, pre-scarification, scarification, seedbed.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

192. Dobbs, R.C. 1972. Artificial regeneration of interior spruce-alpine fir types. Canada, Forestry Service, Study Review Statement, Pacific Region. pp. 415-419.

Reports progress to date on study initiated in 1970. At this point, a growth chamber experiment has shown that growth of spruce and pine on scalped soils is inferior to growth on other seedbeds. Inferior growth is probably due to nutrient deficiency. A seed dispersal study showed quantities of sound seed exceeding 1 lb/acre dispersed into a clear cut as far as 15 chains from stand edge. Planting studies indicated a growth retardation for some years after planting. Another such study indicated that initial fresh weight of seedlings affect outplant establishment, particularly on plots where stresses due to low soil temperatures and/or vegetative competition are evident.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, planting, scalping, seed dissemination, seedbed, seedling growth, seedling mortality, seedling size, soil moisture, vegetative competition.

193. Dobbs, R.C. and R.G. McMinn. 1973. The effects of site preparation on summer soil temperatures in spruce-fir cutovers in the British Columbia interior. Canada, Forestry Service, Bi-Monthly Res. Notes 29(1):6-7.

Increased soil temperatures within the rooting zone for forest regeneration follow mechanical site preparation and persist at least through the subsequent summer. Such changes, probably a result of duff removal, are probably biologically significant and will perhaps last over a period of several years.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), regeneration, site preparation, soil, soil organic matter, soil temperature.

194. Dyrness, C.T. and C.T. Youngberg. 1957. The effect of logging and slash burning on soil structure. Proc. Soil Sci. Soc. Amer. 21(4):444-447.

Soil surface conditions after logging and slash burning in western Oregon were: lightly burned 44.7%, severely burned 8%, unburned 30.1% and undisturbed 17.2%. Severe burning was the only treatment that had a significant

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

effect on soil structure, particle size or soil organic matter content. Severely burned soils had a significantly lower amount of clay than did unburned soils as well as a 20.6% decrease in degree of aggregation an a 61.1% decrease in organic matter.

K.W. logging, slash burning, soil, soil organic matter, soil structure.

195. Erusalimskij, V.I. 1962. [The change in micro-environment with different methods of soil preparation in felled areas still carrying stumps.] Naučnaja Informacija, Lesnoe Hozjajstvo, VNIILM Puskino 2:12-16. (Abstr. F.A. 25:235).

Compares N content, temperatures and moisture of the soil, and weed invasion on ploughed slices, furrows, scarified strips, and a control area, on a clear felling.

K.W. clear felling, nitrogen ploughing, scarification, soil moisture, soil temperature, vegetation.

196. Flowers, J.F. 1968. The cone and barrel-ring scarifiers. Ontario, Dept. Lands and Forests, Silvic Note 11. 6 pp.

Barrel-ring scarifiers are evaluated. Further field trials are necessary.

K.W. artificial regeneration, barrel-ring scarifier, planting, scarification.

197. Germeten, F. 1947. [Investigations of the vegetation and soil of screefed areas.] Medd. Norske. Skogforsoksv. 9(4):(No. 34):393-458. (Abstr. F.A. 10:44).

Describes studies undertaken in Norway to determine the composition of vegetation invading screefed patches, the time elapsed between screefing and invasion, the likelihood of such vegetation interfering with natural regeneration of Scots pine and Norway spruce and difference that might exist between screefed and intact areas in soil pH, humus content, nitrate content, and NH_4Cl-soluble Ca. Results are given in detail.

K.W. humus, regeneration, screefing, site preparation, soil nutrients, soil pH, succession.

198. Gilmour, J.R. 1966. Winter scarification and white spruce regeneration, Saskatchewan. Forestry Chronicle 42(2):167-174.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

Tests the effectiveness of winter seedbed disturbance on a 2-chain cut strip in Saskatchewan. Adequate natural regeneration of white spruce was observed the following summer in unsown areas. The results from areas artificially sown were obscured by natural regeneration from the residual stand. The results do indicate, however, that spring sowing produces more seedlings than winter seeding.

K.W. Picea glauca (white spruce), artificial regeneration, regeneration, residual stand, scarification, seeding, time of sowing.

199. Gilmour, J.R. 1970. Methods and treatments used to secure natural regeneration in British Columbia. Forestry Chronicle 46(6): 451-452.

Gives statistics for the amount of natural regeneration in British Columbia. Describes methods used in all Forest Regions to ensure adequate natural regeneration.

K.W. clear felling, economics, felling regimes, regeneration, scarification.

200. Gilmour, J.R. and J. Konishi. 1965. Scarification in the spruce-alpine fir type of the Prince George Forest District. B.C. Forest Service, Forest Management Note 4. 21 pp.

Cutover areas in the Prince George region were scarified in 1956 to obtain spruce regeneration. Results have been encouraging. This report describes scarification procedures and methods with a summary of costs. Regeneration following scarification is evaluated. An average stocking of 49% in all species has been attained on 6,549 scarified acres sampled in the study. This does not include a measurement of supplementary advance growth. It is concluded that in the Prince George District, seeding, planting, burning or some other treatment should augment scarification.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), advance growth, artificial regeneration, economics, planting, regeneration, scarification, seeding.

201. Glew, D.R. 1963. The results of stand treatment in the white spruce-alpine fir types of the the northern interior of British Columbia. B.C. Forest Service, Forest Management Note 1. 27 pp.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

Reviews single tree selection and alternate strip clear-cutting as silvicultural tools to obtain spruce regeneration. Alternate strip cutting appears to have promise, especially on scarified areas. However there are problems with this system. Pre-scarifying the leave strips may solve some of these. Shelterwood cutting might be of use in the Prince George area, as might artificial regeneration. Scarification should be increased.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), alternate strip clear felling, artificial regeneration, pre-scarification, regeneration, scarification, shelterwood felling, single tree selection.

202. Hermann, R.K. 1963. Temperatures beneath various seedbeds on a clear cut forest area in the Oregon coast range. Northwest Science 37(3):93-103.

Studies a clear cut in Douglas fir. Temperatures were recorded at a depth of 2" below unburned mineral soil, hard-burned mineral soil, a 1" layer of litter, and a 1" layer of charcoal. Even a thin layer of organic matter acted as an effective insulator, litter being more effective than charcoal. Large diurnal fluctuations occurred only to 3" depth; below this, the effect of cover was small. The top layer of soil covered with organic matter was cooler by day and warmer by night than mineral soil. Mineral seedbeds lost moisture faster than did organic ones.

K.W. burning, clear felling, scarification, seedbed, soil, soil moisture, soil temperature, [Douglas fir].

203. Holman, H.L. 1927. Natural regeneration of spruce in Alberta. Forestry Chronicle 3(3):n.p.

Spruce reproduction was found to be very inadequate except where mineral soil had been laid bare. Seeding experiments showed that spruce seedlings did not survive on a thickness of duff or moss 72 in. deep. From field experiments, several recommendations for removal of duff and litter, including by fire, are made.

K.W. Picea glauca (white spruce), artificial regeneration, regeneration, seedbed, seeding, slash burning.

204. Horton, K.W. 1964. Scarifying and screefing for regeneration. Canada Lumberman, Jan. 4 pp.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

Discusses choice of method, selection of equipment, timing and costs, all with relation to Canadian conditions.

K.W. economics, regeneration, scarifying screefing.

205. Hughes, E.L. 1967. Studies in stand and seedbed treatment to obtain spruce and fir reproduction on the mixedwood slope type of Northwestern Ontario. Canada, Forestry Branch, Publ. 1189. 138 pp.

Summarizes a series of experiments involving various methods of scarification, spraying, cutting, planting, and seeding, alone and in combination, to obtain adequate regeneration, especially of spruce. It was found that regeneration of spruce and fir can be obtained by scarification in clear cut strips up to 6 chains wide, better results being achieved on fresh than on moist sites. No control over damaging agents was deemed necessary. If failure occurs, a new stand can be established by planting the scarified area within 3 years of the treatment.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), Picea mariana (black spruce), artificial regeneration, clear felling, herbicides, planting, regeneration, scarification, seeding site preparation, soil, vegetative competition, wildlife.

206. Isaac, L.A. 1929. Seedling survival on burned and unburned surfaces. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Note 3:3-4.

K.W. regeneration, slash burning.

207. Jarvis, J.M. 1960. Growth of white spruce following release from aspen, Manitoba and Saskatchewan. Canada, Forestry Branch, Forest Research Division, Unpubl. MS.

Describes a study designed to determine the effects of partial and complete removal of the trembling aspen overstory on the development of the white spruce understory. Two stands were chosen for the study, in which six square 1/10 acre plots were established. 50% of the overstory was removed from two plots, 100% from two others, and none from the remaining two. Results show diameter and volume growth of white spruce to be best on plots with all the aspen overstory removed and poorest on the controls where none was removed. Further studies are recommended.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), Populus balsamifera (balsam poplar), Populus tremuloides (trembling aspen), overstory, partial release, seedling growth.

208. Jarvis, J.M. 1962. Uniform shelterwood cutting and mechanical seedbed treatment in white spruce-trembling aspen stands to induce white spruce regeneration, Manitoba and Saskatchewan. Canada, Dept. Forestry, Forest Research Division, Manitoba, Mimeo Man.-Sask. 62-18. 7 pp.

Project plan for proposed experiment and brief literature review of pertinent article.

K.W. Picea glauca (white spruce), artificial regeneration, scarification, seedbed, seeding, shelterwood felling, soil, [Populus sp.].

209. Jarvis, J.M. 1963. Clear cutting alternate strips and scarifying in pure white spruce stands to induce white spruce regeneration, Saskatchewan. Canada, Dept. Forestry, Forest Research Division, Mimeo 63-MS-2. 18 pp.

Records work done during 1962 and summarizes data already collected in two areas. In one area, one year after planting, 80% of the seedlings survived on a cutover scarified site, 60% on a cutover unscarified site, and 50% on an uncut area. Average height growths were 2.0, 1.8, and 0.7 inches, respectively. Almost all the survivors in the uncut area were heavily browsed. In the other area, survival on the cutover scarified site after one year was 69%, that on the unscarified cutover was 29%, and on the uncut area, 61%. Average height growths were 2.4, 1.7, and 1.0 inches, respectively. Healthy specimens in each plot numbered 96%, 90% and 77%, respectively. The generally favoured conclusion is that scarification and clearing are useful for seedling growth. Site moisture is also correlated with seedling mortality, there being very high mortality on wet sites.

K.W. Picea glauca (white spruce), artificial regeneration, cultivation, planting, scarification, seedbed, seedling mortality, soil moisture, strip felling.

210. Jarvis, J.M. 1963. Creating seedbeds by burning slash piles and scorching with a torch, Riding Mountain Experimental Area. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 63-MS-24. 10 pp.

Introduces a future experiment. Observations in the introduction state that while light surface fires do not favour conifer regeneration, severe fires make successful establishment possible because mineral soil is exposed and competition from plants and animals eliminated. Fire creates other sets of conditions also, all of which will be investigated.

K.W. humus, regeneration, seedbed, slash burning, soil, vegetative competition, wildlife.

211. Jarvis, J.M. 1963. The effect of scalping and cultivating (prior to planting) on the survival and growth of white spruce, mesic clay loams, Riding Mountain Forest Experiment Areas. Canada, Dept. Forestry, Forest Research Branch, Mimeo 63-MS-4. 4 pp.

Introduces an experiment to test the influence of four soil treatments, 1) scalping to B horizon, 2) scalping - then cultivation of B horizon, 3) litter, humus, and A_2 horizons dug into and mixed with B horizon, and 4) control.

K.W. Picea glauca (white spruce), artificial regeneration, cultivation, planting, scalping, seedbed, seeding.

212. Jarvis, J.M. 1963. Uniform shelterwood cutting and mechanical seedbed treatment in white spruce-trembling aspen stands to induce with spruce regeneration, Manitoba and Saskatchewan. Canada, Dept. Forestry, Forest Research Branch, Mimeo 63-MS-3. 3 pp.

Initial report on an experiment attempting to induce adequate white spruce natural regeneration.

K.W. Picea glauca (white spruce), regeneration, scarification, seedbed, shelterwood felling.

213. Jarvis, J.M. 1964. Creating seedbed by burning slash piles and scorching with a torch, Riding Mountain Forest Experiment Area. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 64-MS-1. 10 pp.

Introduction and progress reports giving rationale for the experiment and treatments carried out.

K.W. Picea glauca (white spruce), germination, seedbed, seedling survival, slash burning, [Abies balsamea, Picea mariana, Pinus banksiana].

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

214. Jarvis, J.M. 1964. The effect of scalping and cultivating (prior to planting) on the survival and growth of white spruce, mesic clay loams, Riding Mountain Forest Experimental Area, Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 64-MS-2. 6 pp.

Progress report outlining work done in 1963 and that which is to be done in 1964. None of the treatments differed significantly from the others, but all were significantly better than the control plots.

K.W. Picea glauca (white spruce), cultivation, growth increment, scalping, scarification, seedbed, seedling survival, soil.

215. Jarvis, J.M. 1965. Initial development of white spruce and competing vegetation on mineral soil and humus seedbeds, west central Canada. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 65-MS-19. 12 pp.

Experiment tests the hypothesis that deep scalping to expose the B horizon is necessary in order to obtain good white spruce reproduction on fresh clay loam soils following logging. In this study, humus seedbeds provided a better medium for initial white spruce establishment than mineral soil. Although results were not significant, second year survival may have been better on mineral soil. There is an indication that on humus seedbeds, severe competition will soon impede the development of white spruce.

K.W. Picea glauca (white spruce), germination, logging, regeneration, scalping, seedbed, seedling survival, vegetative competition.

216. Jarvis, J.M. 1965. Uniform shelterwood cutting and mechanical seedbed treatment in white spruce-trembling aspen stands to induce white spruce regeneration, Manitoba and Saskatchewan. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 65-MS-22. 4 pp.

Progress report giving information concerning work done on the project to date. No results are given here.

K.W. Picea glauca (white spruce), logging, regeneration, scarification, seedbed treatment, shelterwood cutting, [Populus sp.].

217. Jarvis, J.M. and G.A. Steneker. 1962. Growth of white spruce following release from aspen. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo Man.-Sask. 62-13. 26 pp.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

Diameter and volume growth of white spruce were found to be best in plots where all trembling aspen were removed, and poorest on plots where no trembling aspen was removed. However, results obtained may not necessarily be significant. Reasons and recommendations for an improved study are given.

K.W. Picea glauca (white spruce), growth increment, thinning, weeding, [Populus tremuloides].

218. Jarvis, J.M. and R.E. Tucker. 1968. Prescribed burning after barrel scarifying on a white spruce-trembling aspen cutover. Pulp and Paper Magazine of Canada 69(21):70-72.

Burning on a cutover spruce-aspen stand was preceded by scarification by shark-finned barrels. In an area burned twice in August, organic layer was reduced by 50%, pulverized decayed wood by 35% and piled debris by 45%. Results are still insufficient but further development of this technique should be done.

K.W. Picea glauca (white spruce), burning, regeneration, scarification, seedbed, [Populus tremuloides].

219. Kolabinski, V.S. 1963. Clear cutting alternate strips and scarifying in white spruce-aspen stands to induce white spruce regeneration, Manitoba and Saskatchewan. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 63-MS-16. 11 pp.

Progress report summarizing work completed in 1962. At this time scarified plots were well stocked with white spruce regeneration while unscarified and uncut plots had virtually none.

K.W. Picea glauca (white spruce), regeneration, scarification, strip cutting, [Populus tremuloides].

220. Kolabinski, V.S. 1964. Clear cutting alternate strips and scarifying in white spruce-aspen stands to induce white spruce regeneration. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 64-MS-15. 14 pp.

Progress report outling work done in 1963 and to be done in 1964. In sites studied, white spruce regeneration was greatest in cut and scarified strips. Advance growth of white spruce was virtually the same in cut and scarified, cut and unscarified, and uncut areas. Survival of 1962 germinants to the end of the 1963 growing season was best on fresh and moderately moist sites, (67% and 64% respectively). On moist sites, survival was 41%. Detailed stocking figures by seedbed types are tabulated and discussed.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), germination, growth increment, regeneration, scarification, seedbed, seedling mortality.

221. Kolabinski, V.S. 1964. Clear cutting alternate strips and scarifying in pure white spruce stands to induce white spruce regeneration, Saskatchewan. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 64-MS-22. 20 pp.

Gives a progress report for 1963 and a preview of work to be done in 1964. Of all the areas studied, growth and survival of spruce seedlings was much greater on cut, scarified strips than on uncut areas. Unscarified cut areas were intermediate in growth and survival of the seedlings, in all cases. Results of the work are tabulated.

K.W. Picea glauca (white spruce), growth increment, regeneration, scarification, seedling survival, strip cutting.

222. Kolabinski, V.S. 1964. Uniform shelterwood cutting and mechanical seedbed treatment in white spruce-trembling aspen stands to induce white spruce regeneration, Manitoba and Saskatchewan. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 64-MS-8. 7 pp.

Outlines work for 1964 and summarizes data collected. The degrees of stocking for different seedbed treatments are tabulated.

K.W. Picea glauca (white spruce), fungicide, regeneration, scarification, seedbed treatment, shelterwood cutting, [Populus tremuloides].

223. Kolabinski, V.S. 1965. Clear cutting alternate strips and scarifying in pure white spruce stands to induce white spruce regeneration, Saskatchewan. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Internal Rept. MS-6. 4 pp.

Introduces experiment begun in 1959 and outlines progress to 1964. 2-2 white spruce stock was planted on scarified, unscarified, and uncut strips in one area. In another, natural regeneration on scarified and uncut areas was observed with needlefall. In another area, spots were sown. All areas will be analyzed in the future.

K.W. Picea glauca (white spruce), artificial regeneration, germination, planting, scarification, seeding, seedling survival, strip cutting.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

224. Kolabinski, V.S. 1965. Clear cutting alternate strips and scarifying in white spruce-aspen stands to induce white spruce regeneration, Manitoba and Saskatchewan. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Internal Rept. MS-5. 4 pp.

Introduces a study to determine whether clear cutting in strips and mechanical seedbed preparation in white spruce-trembling aspen stands will induce enough spruce to regenerate to form potentially mechantable stands.

K.W. Picea glauca (white spruce), artificial regeneration, planting, regeneration, scarification, seeding, strip cutting, [Populus tremuloides].

225. Kolabinski, V.S. 1965. The effect of scalping and cultivating (prior to planting) on the survival and growth of white spruce, mesic clay loams - Riding Mountain Forest Experimental Area. Canada, Dept. Forestry, Forest Research Lab, Internal Rept. MS-4. 7 pp.

A description of the experiment and an outline of work done during 1964.

K.W. Picea glauca (white spruce), artificial regeneration, cultivation, herbicides, planting, scalping, seedling survival, soil, [Populus tremuloides].

226. Kolabinski, V.S. 1967. Clear cutting alternate strips and scarifying in pure white spruce stands to induce white spruce regeneration, Saskatchewan. Canada, Forestry Branch, Forest Research Lab, Internal Rept. MS-60. 33 pp.

Continuing report. Includes treatment information for work done in 1966 and complete tabulation of germination and survival percentages of all experimental plots to 1966.

K.W. Picea glauca (white spruce), artificial regeneration, germination, planting, scarifying, seedling mortality, strip cutting.

227. Kolabinski, V.S. 1967. Uniform shelterwood cutting and mechanical seedbed treatment in white spruce-trembling aspen stands to induce white spruce regeneration. Manitoba and Saskatchewan. Canada, Forestry Branch, Forestry Research Lab, Manitoba, Internal Rept. MS-52. 8 pp.

Introduction of an experiment initiated in 1962. Report summarizes work done in 1966.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), regeneration, scarification, shelterwood cutting, [Populus tremuloides].

228. Kolabinski, V.S. and J.M. Jarvis. 1970. Clear cutting alternate strips and scarifying in white spruce-trembling aspen stands to induce white spruce regeneration, Manitoba and Saskatchewan. Canada, Forestry Service, Forest Research Lab, Manitoba, Internal Rept. MS-115. 40 pp.

Attempts to determine whether mechanical scarification in conjunction with logging (strip clear cutting) would result in adequate spruce regeneration. Article reports results in the form of case histories. Results are tabulated. Generally, it was found that site treatment, when properly carried out, provides favourable habitats for white spruce regeneration. Recommendations for site type and scarification equipment are made.

K.W. Picea glauca (white spruce), artificial regeneration, planting, regeneration, scarification, seedbed, [Populus tremuloides].

229. Kuraev, V.N. and V.A. Šestakova. 1970. [Changes in the properties of soils with different methods of preparation for planting.] Lesoved., Moskva 1970(1):75-81. (Abstr. F.A. 31:513).

Studies on strongly podzolic soils prepared by various Soviet ploughs or a root rake indicated that the physical and chemical soil properties and survival of spruce seedlings were best on the furrow slice produced by a heavy forest plough.

K.W. Picea sp. (spruce), cultivation, furrowing, seedbed, seedling survival, soil.

230. Lees, J.C. 1963. Partial cutting with scarification in Alberta spruce-aspen stands. Canada, Dept. Forestry, Forest Research Branch, Publ. 1001. 18 pp.

Three seedbed types, scarified, mounded and undisturbed were investigated for regeneration of white spruce after partial cutting to four residual stand densities. Only scarified seedbeds permitted satisfactory establishment of spruce regeneration and remained receptive for five years. Regeneration establishment was not affected significantly by residual stand density or time of scarification. Spruce residual stands grew well with little windthrow. Aspen residual growth was poor.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), mounding, partial cutting, regeneration, residual growth, residual stand, scarification, seedbed, [Populus sp.].

231. Lees, J.C. 1964. Release of white spruce from aspen competition in Alberta's spruce-aspen forest. Canada, Dept. Forestry, Forest Research Lab, Calgary, Mimeo 64-A-19. 22 pp.

Removing aspen competition within twice the crown width of spruce crop trees in spruce-aspen stands produced a considerable increase in both height and diameter growth of spruce. Ammonium sulphamate poisoning of aspen stumps prevented suckering and sprouting of aspen for several years. Release was effective on all sites and in all ages and diameters sampled. Release of spruce should be carried out before spruce and aspen become co-dominant.

K.W. Picea glauca (white spruce), competition, growth increment, herbicides, release, silviculture, [Populus sp.].

232. Lees, J.C. 1964. A test of harvest cutting methods in Alberta's spruce-aspen forest. Canada, Dept. Forestry, Forest Research Branch, Publ. 1042. 19 pp.

A bare mineral soil prepared by scarification provided a receptive medium for spruce seedling establishment under all harvest cutting. Seedling survival did not vary between treatments. Individual tree growth rates improved following cutting and mortality and windthrow after logging were slight. Further research into different felling regimes is advised.

K.W. Picea glauca (white spruce), cutting, logging, logging wounds, mortality, partial cutting, regeneration, residual stand, scarification, seedling survival, selection cutting, shelterwood cutting, [Populus sp.].

233. Lees, J.C. 1964. A test of silvicultural practices designed to secure reproduction in partially cut mixedwood stands in the B-18a section of Alberta. Canada, Dept. Forestry, Forest Research Lab, Calgary, Mimeo 64-A-18. 12 pp.

After scarification with a toothed tractor blade under residual spruce-aspen stands, germination and survival of white spruce seedlings were tallied. Regeneration stocking of white spruce four years later was satisfactory, being 84% on scarified seedbeds and 30% on unscarified beds. Scarified areas remained receptive to seed for four years. Stocking and seedling growth were greatest on moist sites. Vegetative competition was heaviest on wet sites.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), flooding, germination, regeneration, scarification, seedbed, seedling survival, soil moisture, vegetative competition, [Populus sp.].

234. Lees, J.C. 1964. Vegetative competition following scarification. Canada, Dept. Forestry, Forest Research Lab, Calgary, Mimeo 64-A-1. 8 pp.

Scarified seedbed receptivity to white spruce seedfall lasted only two seasons as a result of vegetative competition on low, moist, grassy areas. Competition from grasses was associated with a dense underlying mat of mosses and liverworts. Recommendations are made for further study on scarified seedbed size and selective weed killers for eradication of grasses.

K.W. Picea glauca (white spruce), regeneration, scarification, seedbed, seedfall, vegetative competition.

235. Lees, J.C. 1965. Assessment of operational scarification in the spruce-aspen forest of Alberta. Canada, Dept. Forestry, Forest Research Lab, Alberta, Internal Rept. A-2. 14 pp.

Under a variety of stand conditions, adequate mineral soil exposure can be achieved by scarification. Germination of spruce seed and initial seedling survival on mineral soil seedbed are good. However, vegetative growth is rapid and affects subsequent seedling growth and survival. Describes conditions under which alternate treatments may be necessary.

K.W. Picea glauca (white spruce), growth increment, regeneration, scarification, seedbed, seedling growth, soil, vegetative competition, [Populus sp.].

236. Lees, J.C. 1966. Release of white spruce from aspen competition in Alberta's spruce-aspen forest. Canada, Dept. Forestry, Publ. 1163. 16 pp.

Measurement of stems ten years after release from aspen competition indicate that over a wide diameter and age range, growth of spruce increased significantly after treatment. Trees above a five-inch breast height diameter limit increased in mean merchantable cubic foot volume by 20% - 40%.

K.W. Picea glauca (white spruce), growth increment, release growth, silviculture, thinning, weeding, [Populus sp.].

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

237. Lees, J.C. 1970. Natural regeneration of white spruce under spruce-aspen shelterwood, B-18a forest section, Alberta. Canada, Forest Service, Publ. 1274. 14 pp.

Scarification under a spruce-aspen shelterwood felling produced a receptive seedbed and the residual stand provided an adequate natural seed supply. White spruce regeneration averaged 43%, with 44% stocking on dry, 47% on moist, and 38% on wet sites. Failure of regeneration because of seedbed flooding was common on wet sites. Initial seedling mortality was high. Mineral soil was the most productive seedbed in scarified areas, while rotten wood was best on undisturbed areas.

K.W. Picea glauca (white spruce), germination, mortality, regeneration, scarification, seed source, seedbed, shelterwood felling, soil moisture, vegetative competition, [Populus sp.].

238. Leibundgut, H. 1960. [The effect of charcoal on the germination and development of spruce, pine and larch.] Schweiz. Z. Forstw. 111(3):172-178. (ABSTR.).

Adding charcoal in 2 concentrations to a seedbed of litter compost had no effect on germination or early seedling growth of the three species. It is concluded that the beneficial effect of burning on regeneration is not related to enrichment of soil, but to sterilization of soil and reduction of plant competition.

K.W. Picea sp. (spruce), Pinus sp. (pine), burning, germination, seedling growth, vegetative competition, [Larix sp.].

239. Lesko, G.L. 1971. Early effects of a prescribed fire in spruce-fir slash on some soil properties. Canada, Forest Service, Forest Research Lab, Edmonton, Internal Rept. A-44. 12 pp.

A prescribed burn was carried out in an overmature spruce-fir stand in Alberta. 27 tons of organic matter/acre were consumed out of a total of 45.6 tons of logging slash/acre left by clear cutting. Maximum intensity of the fire was 800 BTU/sec/ft. Chemical analyses of soil samples taken and tabulated before and after burn indicate among other things, that soil pH increased in surface organic layer. Water-soluble Ca and K increased in conc. Mg conc. decreased. A 20% N loss was recoverable due to improved soil temperatures in the burned area. Little is known about temperature requirements of white spruce and alpine fir. However, water and mineral uptake and seedling growth

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

showed significant increases. It is felt that improved soil temperature caused by burning accelerated physiological processes and therefore seedling growth with faster growth, seedlings reach mineral soil more quickly and are less susceptible to drought.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), humus, regeneration, seedling growth, slash burning, soil moisture, soil nutrients, soil temperature.

240. McCulloch, W.F. 1944. Slash burning. Forestry Chronicle 29(2): 111-118.

Gives a complete resumé of status of slash burning. Continues by describing influences upon forest soil, on the environment and upon forest regeneration, both natural and artificial.

K.W. artificial regeneration, economics, regeneration, slash burning, soils.

241. McKinnon, F.S. 1940. Spruce regeneration in Canada. V: British Columbia. Forestry Chronicle 16(1):37-45.

Discusses three areas of spruce, including the north-central spruce-fir stands. Recommendations are made to increase regeneration and decrease fir hazards in these stands. It seems necessary to have the soil for adequate regeneration after logging first generation stands.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), diameter limit cutting, fire hazard, regeneration, scarification, windthrow.

242. MacLean, D.W. 1959. Five year progress report on Project RC-17. Pulp and Paper Research Institute of Canada, Woodlands Research Index 112. 142 pp. (ABSTR.).

Conclusions to date are that: scarification of the seedbed with a root rake is an effective method of encouraging softwood regeneration, particularly that of spruce; spraying with herbicides has not helped seedbed condtions, and should be limited to release of established seedlings; the maximum width of clear felled strip still allowing satisfactory seeding from adjacent uncut areas would appear to be 3 chains.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea sp. (spruce), herbicides, regeneration, scarification, seedbed, seeding, strip felling, vegetative competition.

243. McMinn, R.G. 1972. Ecology of site preparation in interior spruce-alpine fir types. Canada, Forestry Service, Study Review Statement, Pacific Region. pp. 421-425.

Objectives of study are; to determine conditions and site treatments required for the establishment and optimal early growth of tree species suitable for reforestation; and to test and recommend procedures for site preparation which meet the requirements for establishment and early growth to acceptable standards of tree species suitable for reforestation. Reports establishment of a series of experiments to be reported in the future.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), Pinus contorta (lodgepole pine), germination, herbicides, regeneration, seedbed, seedling growth, site preparation, vegetative competition.

244. Morawski, J.R. 1966. Site preparation methods and recommendations for equipment usage. Ontario Dept. Lands and Forests, Timber Branch, Silvic Note 8. 25 pp.

Presents extensive description of types and combinations of site preparation, including scarification and prescribed burning. Recommends treatments for several species, including spruce. Treatments are classified by types of site and species of tree and equipment is recommended.

K.W. Picea spp. (spruce), prescribed burning, scarification, seed, seedbed, seeding.

245. Muri, G. 1955. The effect of simulated slash burning on germination, primary survival and top-root ratios of Engelmann spruce and alpine fir. U.B.C. Forest Club Res. Note 14. 7 pp.

Evaluates the effect of degree of burning (amount of ash) and degree of leaching (amount of "rainfall" after burning) on germination, primary survival and top-root ratios. Ashes had little effect on germination if seeds were well stratified, and carefully sown and watered. Survival on ash-covered seedbeds was about half that on unburned seedbeds. Relatively more Engelmann spruce than alpine fir survived on burnt areas. After three months, top-root ratios showed no significant effects, but top-root ratios of spruce and alpine fir were quite different at that time, 1.2 and 2.2, respectively. General conclusions were that Engelmann spruce had a slight survival advantage over alpine fir on burned seedbeds in the greenhouse. The advantage was neither consistent nor large enough to suggest controlled burning in order to favour spruce over fir.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), burning, germination, leaching, seedbed, seedling survival, slash burning, top-root ratios.

246. Olson, D.S. and G.R. Fahnestock. 1955. Logging slash: a study of the problem in Inland Empire Forests. Univ. Idaho, Forest, Wildlife and Range Experiment Station, Bull. 1. 52 pp.

Reviews progress in the research programme on logging slash and its disposal in Montana, Idaho, and parts of Washington.

K.W. slash, slash disposal.

247. Ontkean, G. and L.A. Smithers. 1959. Growth of Alberta white spruce after release from aspen competition. Canada, Forestry Branch, Forest Research Division, Mimeo 59-1. 8 pp.

The removal of competing aspen from young spruce-aspen stands in northern Alberta has produced a definite increase in diameter and height growth of spruce. It is considered that treatment in all diameter classes would be less successful.

K.W. Picea glauca (white spruce), release growth, seedling growth, seedling mortality, silviculture, vegetative competition, weeding, [Populus sp.].

248. Packer, P.E. 1971. Site preparation in relation to environmental quality. In: Western Reforestation, Western Forestry and Conservation Assoc., Proc. Western Reforestation Co-ordinating Committee, Ann. Rept., 1971. pp. 23-28.

Details are given concerning objectives of site preparation, disposal of logging residue, reducing or eliminating plant competition, preparing mineral soil seedbeds, and providing a favourable micro-environment. Site preparation methods are discussed in relation to environmental quality as well as their efficiency in favouring regeneration. New and needed developments are discussed.

K.W. artificial regeneration, herbicides, planting, scarification, seeding, site preparation, slash disposal, terracing, vegetative competition.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

249. Parker, H.A. 1944. Effect of site and density on lodgepole pine seedling growth. Canada, Dominion Forest Service, Silv. Leaflet 20. 1 p.

Cleaning of a dense 7 year old lodgepole pine stand in Saskatchewan to 3 and 6 ft. intervals stimulated height growth, light cleaning being more beneficial than heavy cleaning on a good site. Regeneration of lodgepole pine was prolific on exposed mineral soil. Dry, exposed sites favoured germination but a moist site favoured growth.

K.W. Pinus contorta (lodgepole pine), cleaning, germination, height growth, seedbed, seedling growth, site type.

250. Parker, H.A. 1952. Spruce regeneration on deep moss after logging. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 62. 2 pp.

Reports a test of the value of artificial seeding and several types of seedbed treatment in Alberta. Treatments were light burning, heavy burning and stripping. Ten years after treatment, all treated plots, regardless of site, types of treatment, or method of seeding, were adequately stocked. Fifteen years after logging, only regeneration on deep, untreated moss was inadequate. Artificial seeding had insufficient advantage over natural seeding to warrant carrying out. The most satisfactory treatments were heavy burning and stripping the moss to mineral soil, although in wet sites, such a treatment caused seedling loss due to washing and frost heaving.

K.W. Picea glauca (white spruce), artificial regeneration, frost-heaving, prescribed burning, scalping, seedbed, seedling, seedling mortality.

251. Phelps, V.H. 1949. Scarification to induce white spruce regeneration. Canada, Forest Service, Silv. Leaflet 29. 2 pp.

A comparison is made of unscarified seedbeds and those scarified by an Athens plough, in Riding Mountain Forest. One year after treatment, 43% of the scarified plots showed white spruce seedlings, while only 14% of the untreated plots contained white spruce regeneration. The number of seedlings per acre for the scarified and untreated plots was 3124 and 569, respectively. There was little competition at this time, but considerable mortality was expected at the end of the first year.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), Athens plough, germination, scarification, seedbed, seedling mortality, soil, vegetative competition, [Populus sp.].

252. Phelps, V.H. 1951. Survival of white spruce seedlings. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 56. 2 pp.

Scarification of the litter and humus with an Athens plough was carried out in an attempt to improve establishment and survival of white spruce seedlings under a white spruce stand. Exposed mineral soil was shown to be a more favourable seedbed medium than undisturbed litter for both the establishment and subsequent survival of seedlings.

K.W. Picea glauca (white spruce), germination, regeneration, scarification, seedbed, seedfall, seedling mortality, seedling survival.

253. Quaite, J. 1953. Poisoning with "ammate" to eliminate aspen. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 94. 2 pp.

Stump and notch methods of poisoning with ammate are quite effective in killing aspen and preventing sprouting in all but very young stands. This is used in order to release white spruce growth. The poison not only kills treated trees, but also, underground connections and untreated stems. Aspen less than one inch in diameter is harder to kill. The poison is more effective if applied in late summer or autumn.

K.W. Picea glauca (white spruce), ammate, herbicides, release growth, vegetative competition, [Populus sp.].

254. Revel, J. 1972. Silviculture in spruce-alpine fir types in the north central interior of British Columbia: problem analysis. B.C. Forest Service, E.P. 639. 49 pp.

Natural regeneration of white spruce is difficult to obtain, due to problems of wind and insect damage to reserved seed sources and the inhibiting influences of clear cut seedbeds. Some form of site preparation is generally prerequisite to either natural or artificial regeneration, and reduction of slash hazard is often necessary. Gives recommendations of areas to be favoured for regeneration and reports on progress of nurseries. Natural regeneration should remain the major treatment for low and medium spruce sites.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), artificial regeneration, clear felling, insect damage, nurseries, regeneration, seed source, silviculture, slash hazard, wind damage.

255. Rieche, K.W. 1961. A preliminary study of the economic use of crawler tractor equipment for scarification. B.C. Forest Service, Engineering Services Division. Unpubl. Rept. 29 pp.

256. Rowe, J.S. 1952. Influences of litter and humus on spruce regeneration in cutover mixed wood stands, Riding Mountain, Manitoba. Canada, Forestry Branch, Forest Research Division, Unpubl. MS.

Best germination was on mineral soil, then on lightly scarified humus, then on control and burned plots. Fewer seedlings appeared on controls dominated by Calamagrostis canadensis than on those dominated by Corylus cornuta. Delayed germination was evident on burned ground.

K.W. Picea glauca (white spruce), Populus tremuloides (trembling aspen), burning, germination, scarification, seedbed, vegetative competition.

257. Rowe, J.S. 1953. Delayed germination of white spruce seed on burned ground. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 84. 3 pp.

The normal pattern of white spruce germination is at its peak in early summer but may be drastically altered by seedbed conditions. Burning the seedbed caused a great portion of the seed to remain ungerminated until late last summer. Such unhardened late germinants are likely to succumb to winter conditions.

K.W. Picea glauca (white spruce), artificial regeneration, germination, scarification, seed, seedbed, seedling survival, slash burning, soil moisture.

258. Smithers, L.A. 1959. Some aspects of regeneration silviculture in spruce-aspen stands in Alberta. Canada, Forestry Branch, Forest Research Division, Mimeo 59-5. 15 pp.

In each of 4 residual stand densities left after cutting a 110 year-old spruce-aspen stand, mechanical scarification was carried creating 3 seedbed types, a) scarified, b) mounded, and c) undisturbed. Germination and survival of spruce seedlings was studied in 1956-1957. 1) Time of scarification did not significantly affect regeneration; 2) scarified seedbeds remained receptive to regeneration over 5 year study period; 3) residual stand density did

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

not significantly affect germination and survival of spruce; 4) scarified seedbed was the only one allowing satisfactory establishment of spruce regeneration.

K.W. Picea glauca (white spruce), germination, mounding, partial cutting, regeneration, residual stand, scarification, seedling mortality, [Populus sp.].

259. Steneker, G.A. 1966. The effect of scarification upon the development of residual spruce trees in a partially cut white spruce-trembling aspen stand. Canada, Dept. Forestry, Forest Research Lab, Manitoba Internal Rept. MS-16. 8 pp.

Indicates the effect of different degrees of scarification upon subsequent increment, mortality, windthrow, and fungal infection among the residual spruce stand.

K.W. Picea glauca (white spruce), fungi, growth increment, infection, injury, mortality, partial cutting, residual stand, scarification, [Populus sp.].

260. Steneker, G.A. 1969. The effect of scarification upon the development of residual spruce trees in a partially cut white spruce/trembling aspen stand. Canada, Forestry Branch, Forest Research Lab, Manitoba, Info. Rept. MS-X-14. 5 pp.

Scarification can injure the roots of residual spruce trees if carried too close to all sides of the tree. Any wounds will allow disease organisms to enter. In tests, no mortality due to scarification was observed.

K.W. Picea glauca (white spruce), disease, partial cutting, residual stand, scarification, wounds, [Populus sp.].

261. Sutton, R.F. 1964. Rehabitation of overmature mixedwood with white spruce after Dybar treatment. Canada, Dept. Forestry, Forest Research Lab, Mimeo 64-0-6. 18 pp.

Pelleted fenuron was broadcast at 0, 8, 16, 32 and 48 lbs. per acre in plots 3, 6, 9, 12 and 15 yards diameter in all combinations. Dybar at 48 lbs/acre in plots 6+ yards diameter and at 32+ lbs. acre in plots 12+ yards diameter, was highly effective in killing mountain maple and speckled alder. Balsam fir and white spruce advance growth was more susceptable than mountain maple. Fourth year height growth of white spruce planted 1 year after herbicide treatment was significantly increased in the 48 lbs/acre Dybar treatment.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, Dybar, Lenuron, herbicides, planting, seedling growth, vegetative competition.

262. Tucker, R.E. and J.M. Jarvis. 1967. Prescribed burning in a white spruce-trembling aspen stand in Manitoba. Pulp and Paper Magazine of Canada, Woodlands Review 68(7):333-335.

Briefly reports successful slash burning trials in felled Picea glauca - Populus tremuloides stands and tabulates data on air temperature, wind speed, moisture content of slash and litter, etc.

K.W. Picea glauca (white spruce), slash burning, [Populus tremuloides].

263. U.S. Dept. Agric. 1960. Engelmann spruce regeneration. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Annual Rept. pp. 5-6.

Site preparation treatments were applied to clear cut strips in an attempt to determine seedbed requirements for Engelmann spruce regeneration. Treatments were: a) three degrees of dozer scarification (25%, 50% and 75% of area covered); b) prescribed broadcast burning; and c) untreated control. Each was replicated twice. Results showed burning increased stocking, and stocking varied directly with the degree of scarification. Dozer scarification of at least 50% of the area seems most promising, while burning is not as good, but better than no treatment.

K.W. Picea engelmannii (Engelmann spruce), Pseudotsuga menziesii (Douglas fir), prescribed burning, regeneration, scarification, site preparation, stocking, [Abies grandis, Larix occidentalis].

264. U.S. Dept. Agric. 1963. Silviculture of lodgepole pine: seedbed preparation for regeneration. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Annual Rept. 1962. pp. 6-7.

Presents first year results in terms of germination and survival % in seedbeds prepared by 9 different methods. Those that included cross trenching generally gave best results, but those including scalping were nearly as effective. Discing or burning gave poor results.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

K.W. Pinus contorta (lodgepole pine), artificial regeneration, burning, discing, germination, scalping, seedbed, seeding, seedling survival, trenching.

265. Vincent, A.B. 1954. Release of balsam fir and white spruce reproduction from shrub competition. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 100. 3 pp.

An experiment was performed in New Brunswick concerning the influence of release from shrub competition on the growth of spruce and balsam fir reproduction. Conclusions made were: 1) removal of shrubs from a circle 3 ft. in radius about spruce and fir reproduction results in a distinct and rapid increase in height growth for stems below 6 ft. at the time of release; 2) axe clearing has only limited use, but a cheaper method of release (such as spraying) would shorten the establishment period for a new stand and be a valuable silvicultural test.

K.W. Picea glauca (white spruce), herbicides, release, release growth, vegetative competition, [Abies sp.].

266. Vogl, R.J. and C. Ryder. 1969. Effects of slash burning on conifer reproduction in Montana's Mission Range. Northwest Science 43(3):135-147.

Density counts of regeneration of subalpine fir, western larch, Engelmann spruce, lodgepole pine and Dougla fir differed between burned and adjacent unburned sites; there was 80% less regeneration on severely burned sites. Burned sites also carried less shrub cover. Detrimental physical soil changes due to high temperatures and addition of ash and charcoal persisted for at least 15 years on burned sites, and number of years since burning affected conifer density. Conifers growing on burned sites produced 20% of the growth of those on unburned sites.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), regeneration, seedling growth, slash burning, soils, vegetation, [Larix occidentalis].

267. Waldron, R.M. 1959. Hazel foliage treatments to reduce suppression of white spruce reproduction. Canada, Forestry Branch, Forest Research Division, Tech. Note 75. 17 pp.

2, 4-D, 2, 4, 5-T, ammate, or a 50-50 mixture of 2, 4-D and 2, 4, 5-T, were applied to plots of dense hazel under scattered white spruce and aspen to study the use of herbicides for the release of white spruce reproduction.

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

All chemicals and concentrations produced a fairly complete kill of the above ground portions of hazel, although subsequent sprouting was high. The treatment resulted in an increased growth rate of natural white spruce reproduction under hazel. A planting experiment of 3-2 white spruce in dense hazel, sprayed later, resulted in better survival and a higher rate of growth than in similar unsprayed plots.

K.W. Picea glauca (white spruce), hazel, herbicides, seedling growth, vegetation, weed control.

268. Waldron, R.M. 1961. Seedbed preparation for white spruce regeneration in the white spruce-aspen stands of Manitoba. Canada, Dept. Forestry, Forest Branch, Mimeo 61-19. 15 pp.

Discing with an Athens plough and scalping with a bulldozer blade were tested as possible means of preparing mineral soil seedbeds suitable for the establishment of white spruce seedlings in undisturbed and cutover white spruce-aspen stands in Manitoba. Prepared seedbeds were superior to undisturbed forest floor for the germination and survival of white spruce seedlings. Stocking was higher in the cutover, in disced areas, and on scalped seedbeds. Only scalping produced moderate to full white spruce regeneration. No treatment had any significant effect on seedling height growth.

K.W. Picea glauca (white spruce), discing, germination, logging, scalping, seedbed, seedling survival, soil, soil moisture, [Populus sp.].

269. Waldron, R.M. 1963. Factors affecting natural white spruce regeneration on artificially prepared seedbeds at the Riding Mountain Forest Experimental Area. Canada, Dept. Forestry, Forest Research Lab, Manitoba Mimeo 63-MS-30. 36 pp.

Trials and studies of the factors affecting germination, early seedling survival, and growth of natural white spruce regeneration on artificially prepared seedbeds in mature white spruce-trembling aspen stands on fresh to moist clay loam soils were carried out at Riding Mountain. Results indicate that shelterwood cutting with preparation of mineral soil seedbeds provides conditions ideally suited for the establishment of natural white spruce regeneration.

K.W. Picea glauca (white spruce), germination, regeneration, scarification, seedfall, seedling survival, shelterwood cutting, soil, [Populus tremuloides].

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

270. Waldron, R.M. 1965. Converting aspen stands to white spruce by planting and seeding on scalped strips, Manitoba. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Internal Rept. MS-1. 15 pp.

Attempts to test hypothesis that aspen stands can be converted to mixed coniferous-deciduous stands by planting or seeding Picea glauca on scalped strips spaced at regular intervals. Article describes treatments.

K.W. Picea glauca (white spruce), artificial regeneration, planting, scalping, seeding, strip cutting, [Populus tremuloides].

271. Waldron, R.M. 1965. Early survival and growth of planted and seeded white spruce as affected by seedbed types occurring in scalped strips prepared in aspen stands, Manitoba. Canada, Dept. Forestry, Forestry Research Lab, Manitoba, Internal Rept. MS-2. 12 pp.

Early survival and growth of seeded and planted Picea glauca were studied on three seedbed types, mineral soil, mixed soil and humus and humus on scaled strips in aspen stands. Results are tabulated.

K.W. Picea glauca (white spruce), artificial regeneration, growth increment, planting, scarification, seeding, seedling survival, strip cutting, [Pinus sp., Populus tremuloides].

272. Waldron, R.M. 1966. Factors affecting natural white spruce regeneration on prepared seedbeds at the Riding Mountain Forest Experimental Area, Manitoba. Canada, Forestry Branch, Publ. 1169. 41 pp.

Weather, seedbed, litter, crown cover, site, lesser vegetation and animals played important roles in the germination, early survival, and growth of white spruce on artificially prepared seedbeds on clay loam soils in mature white spruce-trembling aspen stands. Results of experiments show that shelterwood cutting accompanied by preparation of mineral soil seedbeds using a bulldozer creates conditions suitable for the establishment of natural white spruce regeneration.

K.W. Picea glauca (white spruce), climate, germination, mammals, regeneration, scarification, seedbed, seedling survival, shelterwood felling, site treatment, soil moisture, vegetation, [Populus tremuloides].

b) INFLUENCES OF SITE PREPARATION PROCEDURES, cont'd.

273. Wile, B.C. 1957. Effect of controlled fire on the composition of reproduction in a spruce-fir stand. Canada, Forestry Branch, Forest Research Division, Mimeo 57-10. 4 pp.

Reports an attempt to determine whether controlled burning could be used to increase the proportion of spruce in a regenerating spruce-fir stand in New Brunswick. Burning and the resulting environment destroyed 90% of the advance growth. However, regeneration, is good and the proportion of spruce in the regenerating stand is increased. Recommendations are made for burning regimes.

K.W. Abies sp. (fir), Picea sp. (spruce), advance growth, logging, mortality, prescribed burning, regeneration, seed trees, stocking.

274. Wilkins, R.A. 1969. Influence of seedbed type on water stress in white spruce (Picea glauca (Moench) Voss) seedlings. Canada, Forestry Branch, Forest Research Lab, Manitoba Internal Rept. MS-89. 6 pp.

Project examines relationships between seedbed type and water available to seedlings. Four seedbeds were studied: mineral soil, cultivated mineral soil, burned seedbed and undisturbed seedbed. Survival of seedlings on all plots is tabulated.

K.W. Picea glauca (white spruce), artificial regeneration, planting, scarification, seedbed, soil moisture, water stress, [Populus sp.].

275. Wilton, W.C. and E.C. Salter. 1969. Scarification trials in Newfoundland. Canada, Forestry Branch, Forest Research Lab, St. Johns, Info. Rept. N-X-32. 14 pp.

Evaluates quality of two scarifying machines used in Newfoundland. Neither works well in slash or on thick humus seedbeds.

K.W. scarification, scarification tools.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT

Natural regeneration of forests in natural or man-made openings is ultimately determined by an interaction of all the environmental factors of the site. The papers in this section explore the influences of factors in the natural environment, both singly and in interaction, upon the natural regeneration of forests. Because of the nature of such factors, precise field study is sometimes difficult. Consequently a portion of the papers in this section deal with greenhouse or laboratory simulations of the natural environment.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

276. Abbott, H.G. and A.C. Hart. 1960. Mice and voles prefer spruce seeds. U.S. Dept. Agric., Northeastern Forest Experiment Station, Sta. Pap. 153. 12 pp.

White spruce and balsam fir seeds exposed over a 5-week period in feeders designed to keep larger animals and birds out. Small mammals showed a marked preference for spruce seed, taking fir seed only when spruce seed was exhausted. This may account for the greater amount of fir regeneration.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), mice, regeneration, seed consumption, voles, wildlife.

277. Ahlgren, C.E. and H.L. Hansen. 1957. Some effects of temporary flooding on coniferous trees. J. For. 55(9):647-650.

Observations were carried out on trees flooded for periods from a few days in length, up to most of the growing season. Data was collected on the effect of flooding on growth rate, foliage endurance, and tree mortality. Balsam fir and black spruce appeared to be most flood resistant of the conifers in submergence periods up to 48 days. White spruce was next most flood resistant. Submergence for longer periods resulted in mortality of all species.

K.W. Abies balsamea (balsam fir), Picea mariana (black spruce), Picea glauca (white spruce), flooding, growth rate, mortality, survival.

278. Allen, G.S. 1941. A basis for forecasting seed crops of some coniferous trees. J. For. 39:1014-1016.

Discusses a method of forecasting seed crops of Douglas fir, based upon an estimate of the number of ovulate buds made the year previous to maturation of cones and seeds. This gives a potential cone crop, which can then be modified to account for adverse factors such as insect damage. The success of the method depends on the ability of the forester to evaluate all possible modifying factors. Seven references are cited.

K.W. Pseudotsuga menziesii (Douglas fir), cone crop, insects, ovulate buds, physiological abortions, seed, seed crops, weather.

279. Arlidge, J.W.C. 1955. A preliminary classification and evaluation of Engelmann spruce-alpine fir forest at Bolean Lake, B.C. University of B.C., Faculty of Forestry, M.F. Thesis. 72 pp.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

The thesis is divided into two parts: first a classification of Engelmann spruce-alpine fir forests at Bolean Lake, B.C., and second an evaluation of two forest associations in these forests. The first part includes discussion of some ecological concepts, with the forest association referred to as an ecological unit, including factors such as climate, flora, and fauna. The area studied is described and two forest associations: Engelmann spruce-alpine fir, black huckleberry-trailing oak fern association, are designated. The second part involves comparison and analysis of data from these associations. Results indicate that the latter association has better site quality and will probably give different responses to silvicultural treatment.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), classification, ecology, forest associations, growth, silviculture.

280. Arlidge, J.W.C. 1957. E.P. 489 - Stand condition classification for spruce-alpine fir stands. B.C. Forest Research Review. p. 23.

Attempts to develop classification of spruce-alpine fir stands in all relevant B.C. Forest Districts on the basis of habitat and stand history.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), ecology, stand classification.

281. Arlidge, J.W.C. 1959. E.P. 373 - Ecological investigations in the spruce-alpine fir type. B.C. Forest Research Review. p. 30.

Describes association of the spruce-alpine fir forest and determines the characteristics of the stands in these forest associations. Also reported 1956 - p. 17, 1957 - p. 21.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), ecology.

282. Arlidge, J.W.C. 1959. Forest site types of spruce-alpine fir forests at Prince George, B.C. B.C. Forest Service, Unpubl. Rept.

283. Arlidge, J.W.C. 1972. E.P. 553 - Ecological classifications in the interior forest regions. B.C. Forest Research Review. pp. 11-13.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

Attempts to develop on an ecological basis, a classification of forest site types in the Interior Forest Regions, and to determine the characteristics of forest stands on these site types. Data are divided into groupings by means of various methods of computer analysis. Also reported 1967 - p. 27, 1969 - p. 23, 1970 - pp. 19-21, 1971 - p. 21.

K.W. ecology, plant sociology.

284. Arlidge, J.W.C. and K. Illingworth. 1960. Interim report on some forest site types in lodgepole pine and spruce-alpine fir stands. B.C. Forest Service, Res. Note 35. 44 pp.

Describes five principle site types identified in the spruce-alpine fir stands of Prince George. Relationships between site types and stand data are shown. The application of site types and their relation to silviculture and forest management are indicated briefly. In addition five major and four minor sites of lodgepole pine in the southern interior of British Columbia are described.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), Pinus contorta (lodgepole pine), cutting, ecology, regeneration, silviculture, site type.

285. Armson, K.A. 1964. Growth measurement of white spruce seedlings. Univ. Toronto, Forest Research Review. p. 7.

Measurements were made of white spruce seedlings in their first two years of growth. During second growing season, three distinct patterns of height growth were shown: 1) height growth was complete by first week of June; 2) initial flush was completed by first of June, followed by 2-4 weeks of little or no growth. After this, growth continued for 5-10 weeks; 3) greatest rate of height growth occurred in late May, but growth continued at a reduced rate until the end of July. These growth patterns also occurred in first year.

K.W. Picea glauca (white spruce), flushing, height growth, seedlings.

286. Armson, K.A. 1969. Growth characteristics of white spruce seedlings. Univ. Toronto, Forest Research Review. p. 3.

Picea glauca seedlings in their first and second years were sampled every 14 days during the 1968 growing season. Various measurements were taken and growth curves constructed.

K.W. Picea glauca (white spruce), growth, growth curves, root growth.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

287\. Baker, F.S. 1929. The effect of excessively high temperatures on coniferous reproduction. J. For. 27(8):949-975.

Reports on investigation into the problem of heat relations of seedlings to determine the importance of this factor, particularly in coniferous stands of the Pacific Coast. Six separate sections are discussed: nature of direct heat injury in the open; reaction of protoplasm of different species to high temperatures; reaction of protoplasm of seedlings of different ages; relation to internal temperatures to external air and soil temperatures; protective devices in conifers; and effect of morphology and age on extent of injury. Thirteen species of conifers were studied in detail, with results tabulated. Results show seedling tissues are killed when a temperature of 54°C (130°F) is reached, but that they can withstand temperatures just slightly lower for some time. Heat injury ranges from mere discoloration to complete killing of a whole ring of tissue, and is difficult to distinguish from "damping off", although the edges of the lesion are more sharply defined in heat injury. The degree of heat injury varies with ages, as "hardening" of the stem tissues hinders the entrance of pathological organisms and reduces the tendency to top over. Thirty-four references are included.

K.W. conifers, damping off, heat injury, regeneration, seedling growth, seedling mortality, soil temperature, temperature.

288\. Balch, R.E. 1942. A note on squirrel damage to conifers. Forestry Chronicle 19(1):42.

Reports damage done by red squirrels, nipping off shoots of spruce and fir trees. Usually large buds on the leaders and year old laterals are favoured, as are new shoots at the base of the last year's growth. It should be noted, damage of this kind is not generally very serious.

K.W. Picea spp. (spruce), Abies spp. (fir), damage, squirrels.

289\. Barr, P.M. 1928. The Aleza Lake Forest Experiment Station: Its development and purpose. Forestry Chronicle 4(3):n.p.

Outlines the history of the Aleza Lake Station and the various problems that led to its establishment, and reviews current research projects. The principal investigation at the time of writing was a study of the factors controlling the natural establishment of spruce seedlings in a mature stand. Interim results are given.

K.W. Picea glauca (white spruce), nursery, regeneration, seedbed.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

290. Barr, P.M. 1930. The effect of soil moisture on the establishment of spruce reproduction in British Columbia. Yale University, School of Forestry, Bull. 26. 77 pp.

291. Bates, C.G. 1917. The role of light in natural and artificial reforestation. J. For. 15:233-239.

Five species of trees in the Rocky Mountains are discussed, in order of their apparent light requirements: yellow pine, lodgepole pine, Douglas fir, Engelmann spruce and alpine fir. Describes relationships of light intensity to soil moisture and temperature and hence to germination and growth of the conifers. Both nursery and forest conditions are considered. Emphasizes two points: 1) radiant energy becomes inseparable from heat which may be obtained by conduction from the air, and 2) the effectiveness of rays for heating purposes is proportionate to their intensity only in a vacuum or in still air.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), conifers, germination, growth, light intensity, reforestation, soil temperature.

292. Bates, C.G. 1923. The physiological requirements of Rocky Mountain trees. Journal of Agricultural Research 24:97-164.

Complete cataloguing of physiological requirements of species including Engelmann spruce, lodgepole pine and Douglas fir. May be of great use in silvicultural decisions.

K.W. Picea engelmannii (Englemann spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), climate, ecology, silviculture, soil.

293. Bates, C.G. 1925. The relative light requirements of some coniferous seedlings. J. For. 23:869:879.

Eight species of conifer seedlings were grown under artificial light comparatively rich in longer wave-lengths, varying in intensity from 53.5% to 1.2% in the first 6 months, and from 16.6% to 0.4% in the last five months of exposure. It was found that Engelmann spruce required 1.0% or less light intensity, and lodgepole pine ranged from 1.20% to 1.90%. Norway spruce was most tolerant, with light of an intensity of 2.3%. Larger-seeded species grew less vigorously than smaller-seeded ones in the weakest light in which each survived. It appeared that the height of seedlings was not affected by light intensities. Results indicate that light is not likely to be the limiting factor in seedling survival.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

K.W. Picea abies (Norway spruce), Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), conifers, light intensity, light requirements, seedling growth, seedling mortality, seedling survival.

294. Bates, C.G. and J. Roeser Jr. 1924. The relative resistance of tree seedlings to excessive heat. U.S. Dept. Agric., Bull. 1263:1-16.

295. Bates, C.G. and J. Roeser Jr. 1928. Light intensities required for growth of coniferous seedlings. American Journal of Botany 15:185-194.

A soil-covered circular table, 7 ft. in diameter, was constructed, over which seeds of several coniferous trees were broadcast. A single light was suspended at the center of the table as the only source of light, after germination had occurred. Light intensity ranged from about 1/8 (13.08%) as great as sunlight in the center, to about 1/160 (0.71%) at the outer edges. Results indicate great variation in the ability of different species to use weak light. Engelmann spruce required about twice as much as redwood, which only needed 3/4 of 1% for growth. Most of the pines tested appear to require three to four times as much light as redwood. Geographic forms or variations of the same species exhibited different individual physiological characteristics.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), germination, light intensity, light requirements, seed, seedling growth.

296. Bloomberg, W.J. 1950. Fire and spruce. Forestry Chronicle 26: 157-161.

Examines observations made in a 90 square mile are centering around a minor tributary of the Oldman River in Alberta. The mature timber is a spruce-balsam fir association, generally well-stocked. Observations show spruce regeneration to be healthy under a pine nurse crop, but decadent or non-existent under a canopy of its own species, and in this area, age-class distribution is attributable to fire. Fire has a positive and causative effect on the establishment of spruce as a climax species, as is evident in many areas. The question of whether fires have been detrimental or if they have actually been necessary and useful is raised.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), fire, regeneration.

297. Blumer, T.C. 1906. Rocky Mountain seedling growth. Forestry Quarterly 4:98-105.

Describes a study of seedling growth carried out in the Pike's Peak Forest Reserve. Habitat of numerous coniferous species is described, with particular attention given to Engelmann spruce. This requires shaded, moist areas, preferably in mineral soil. Seedling appear to grow singly, with a shallow root system. In the area covered, reproduction was practically even-aged. It seems Engelmann spruce takes 27 years to reach breast height and first bears cones at 25 years. Once seeding is established, humus in large quantities aids growth. No reproduction occurs in heavy grass sod. The density for natural pruning in Engelmann spruce was found to be very great.

K.W. Picea engelmannii (Engelmann spruce), logging, mortality, natural pruning, regeneration, seedling growth, seedlings, snow damage.

298. Brink, C.H. and F.C. Dean. 1966. Spruce seed as a food of red squirrels and flying squirrels in interior Alaska. Jour. Wildlife Management 30:503-512.

Feeding trials in Alaska revealed that red squirrels can live on nothing but white spruce seeds for at least 3 weeks. Under such conditions they consume about 144 cones/day/squirrel. Flying squirrels do poorly and probably eat few seeds in the wild. Red squirrels scatter about 1 filled seed for every two cones they strip, but it is unlikely that many of these scattered seeds successfully germinate.

K.W. Picea glauca (white spruce), germination, regeneration, seed, seed consumption, seed scattering, squirrels.

299. Brix, H. 1972. Growth response of Sitka spruce and white spruce seedlings to temperature and light intensity. Canada, Forest Service, Pacific Forest Research Centre, Victoria, Info. Rept. BC-X-74. 17 pp.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

With constant day-night temperatures, dry matter production increased greatly within the temperature range 8-18°C. With an increase from 18-24°C, the growth response varied with seed source and light intensity, but in most cases, there were no changes in growth. A further increase to 28°C decreased growth considerably except for white spruce at low light intensity (450 ft - c). Most beneficial regime for dry matter production was a 24°C day and 18°C night. Height growth was optimum for white spruce at 24°C. An increase of light intensity from 450 to 1000 ft - c greatly increased dry matter production and stem diameter, but had no effect on height growth. Sitka spruce was more shade tolerant than white spruce.

K.W. Picea glauca (white spruce), artificial regeneration, dry matter production, germination, growth increment, height growth, light intensity, nurseries, root growth, root-shoot ratio, temperature, [Picea sitchensis].

300. Cayford, J.H. 1957. Influence of the aspen overstory on white spruce growth in Saskatchewan. Canada, Forestry Branch, Forest Research Division, Tech. Note 58. 12 pp.

In young and intermediate-aged white spruce-aspen stands, an aspen overstory may reduce height and diameter growth of white spruce, slow growth rate, and lower the quality of suppressed white spruce. Silvicultural treatments such as releasing the white spruce understory may be advisable.

K.W. Picea glauca (white spruce), growth increment, release growth, suppression, [Populus tremuloides].

301. Cayford, J.H. and R.M. Waldron. 1962. Some effects of leaf and needle litter on greenhouse germination of white spruce and jack pine seed. Forestry Chronicle 38(2):229-231.

Much of the mineral soil exposed in seedbed treatment becomes covered with litter. A greenhouse study tests the influence of this litter on germination. The highest white spruce regeneration resulted from sowing on mineral soil and covering with a thin layer of leaf litter, and the lowest resulted from sowing on needle litter. Only 82% of white spruce seedlings on leaf treatments became established, while on needle and mineral soil, 99% became established. Nearly all jack pine seeds that germinated became established. All litter treatments were effective in conserving soil moisture. These results may not be applicable in the field.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, germination, litter, seedbed, seedling, seedling survival, soil moisture, [Pinus banksiana].

302. Chalupa, J. and D.A. Fraser. 1968. Effect of soil and air temperature on soluble sugars and growth of white spruce (Picea glauca) seedlings. Canadian Journal of Botany 46:65-69.

12-month-old seedlings of white spruce were grown for the next 5 months at 50°, 70°, 80°, 90°, and 100°F soil temperatures in an air temperature of about 70°F. Others were transfered to cold rooms. This was done in order to test the effect of soil and air temperature on soluble sugars and growth at the 50°-70°F and 65°-70°F soil-air temperatures. Seedlings exposed to 34°-34°F for a month showed a greater increase in soluble sugars than other treatments. Indications are that exposure to low temperatures can cause changes in sugar composition, possibly associated with developing frost hardiness. A bibliography of 26 articles is cited.

K.W. Picea glauca (white spruce), air temperature, frost hardiness, seedling growth, seedlings, soil temperature, soluble sugars.

303. Cook, D.B. 1941. Five seasons's growth of conifers. Ecology 22:285-296.

Growth of seedlings of several species including white spruce was measured in New York. Active growing period for all spruce species measured was 50-60 days. Growth curves are consistent but exceptional deficiency in rainfall retards growth. Normal weather fluctuations have little influence.

K.W. Picea glauca (white spruce), climate, growth, growing season, growth pattern, precipitation.

304. Cook, J.D. 1954. Some aspects of the reproduction of Engelmann spruce. Univ. Wyomying, M.Sc. Thesis.

305. Cormack, R.G.H. 1953. A survey of coniferous forest succession in the eastern Rockies. Forestry Chronicle 29(3):218-232.

Two trends of coniferous forest succession in the Eastern Rockies after fire are recognized: 1) spruce and pine to climax, 2) pine to climax. Each trend is divided into 4 stages named after the most characteristic ground vegetation species.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), fire, regeneration, succession.

306. Cram, W.H. and H.A. Worden. 1957. Maturity of white spruce cones and seeds. Forest Science 3(3):263-269.

Specific gravity and moisture content are positively correlated (0.98) in the cones of white spruce, both providing accurate indices of maturity in cone and seed. At Indian Head, Sask., natural dispersal occurs at the end of August or beginning of September, about 98 days after pollen shed. Size of seed, yield, and germination increase in the last 4 weeks before dispersal and the maximum yield of seedlings per cone is got from harvesting 3-6 days before this date.

K.W. Picea glauca (white spruce), cone maturity, germination, pollen shed, seed dispersal, seed size.

307. Crossley, D.I. 1953. Seed maturity in white spruce. Canada, Forestry Branch, Forest Research Division, Silv. Res. Note 104.

In a white spruce seed study, cone colour was not a reliable index of maturity. Reliable indices are firmness of cone, colour of testa, and brittleness of seed. If cone crop is light and may be lost to squirrels, cone collection may commence much earlier than normal. Seed not shaken out of the cones by normal extraction methods is usually of as high a quality as that removed and is therefore worth sowing if further extraction costs are not excessive.

K.W. Picea glauca (white spruce), economics, seed collection, seed extraction, seed maturity, seed viability.

308. DeGrace, L.A. 1947. The basis of regeneration work in the subalpine region. Canada, Forestry Branch, Unpubl. Rept.

309. Eis, S. 1967. Cone crops of white and black spruce are predictable. Forestry Chronicle 43:247-252.

By late August, reproductive buds of white spruce and male buds of black spruce can be distinguished macroscopically by size and shape. Using information gained from an investigation of bud morphology, a failure or a poor cone crop may be forecast accurately.

K.W. Picea glauca (white spruce), Picea mariana (black spruce), artificial regeneration, cone crop, seed production.

310. Eis, S. 1967. Establishment and early development of white spruce in the interior of British Columbia. Forestry Chronicle 43(2):174-177.

Compares survival and growth of white spruce seedlings and juvenile trees on the seedbeds, three forest sites and a range of light conditions in the central interior of British Columbia. For germination, the most favourable seedbed was mineral soil, in shade, on moist and wet sites; for survival, mineral soil, dry habitat, partial shade; for growth, mineral soil, moist habitat, full light exposure.

K.W. Picea glauca (white spruce), ecology, habitat, insolation, regeneration, seedbed, seedling survival.

311. Eis, S. 1970. Root-growth relationships of juvenile white spruce, alpine-fir, and lodgepole pine on three soils in the interior of British Columbia. Canada, Forest Service, Publ. 1276. 10 pp.

Root systems of trees up to five feet in height were excavated. Under restrictive soil conditions, the soil had a controlling effect on the shape of the root system. In deep, permeable soils, owing to ecotypic variations, the root forms of all species varied from very shallow to very deep tap-root type. For all species, only 7% to 11% of the total root length was greater than 0.6 mm in diameter. In relation to tree height, spruce had the greatest lateral root spread. Foliage weight of spruce was twice root weight.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), roots, seedbed, soil, tap-root ratio.

312. Eis, S. and J. Inkster. 1972. White spruce cone production and prediction of cone crops. Canadian Journal of Forest Research 2(4):460-465.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

In September preceding the seed year, reproductive buds of white spruce can be recognized with the naked eye. The numbers of ovulate buds are a good indication of the prospective cone crop. This advance information facilitates seedbed preparation for natural regeneration, seed collection, and artificial reforestation.

K.W. Picea glauca (white spruce), artificial regeneration, cone crop, regeneration, seed collection, seed production.

313. Farrar, J.L. and D.A.G. Knight. 1967. Loss of frost hardiness in white and black spruce. Univ. Toronto, Forest Research Review. p. 6.

Black and white spruce seedlings were subjected to a temperature of 16°F at weekly intervals during flushing. No damage was evident until flushing began. Even than, no damage occurred until new shoots (including needles) were more than 1 cm long. All new shoots longer than 1 cm were killed. In most cases, older foliage remained alive. No differences were observed between the two species.

K.W. Picea glauca (white spruce), Picea mariana (black spruce), artificial regeneration, flushing, frost damage, planting.

314. Farrar, J.L., J.J. Balatinecz and C. Barnfield. 1968. The effect of temperature on wood formation in spruce seedlings. Univ. Toronto, Forest Research Review. p. 6.

Temperatures of 55, 70, and 85°F were applied to whole spruce seedlings when cambial activity was just beginning and after the cambium had been active for some weeks. Preliminary results indicated that white spruce was more sensitive to both low and high temperatures. Both high and low temperatures seem to be associated with reduced radial tracheid diameters. However, tracheid wall thickness decreased with increasing temperature.

K.W. Picea glauca (white spruce), cambium, seedling growth, temperature, wood formation.

315. Fraser, D.A. 1962. Apical and radial growth of white spruce at Chalk River, Ontario, Canada. Canadian Journal of Botany 40:659-668.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

Discusses an investigation of apical and radial growth and the developmental anatomy of vegetative and reproductive buds. Includes a brief literature review. Gives detailed findings for growth and provides a discussion of the influence of temperature fluctuations on vegetative and reproductive growth.

K.W. Picea glauca (white spruce), apical growth, radial growth, temperature.

316. Fraser, J.W. 1970. Cardinal temperatures for germination of six provenances of white spruce seed. Canada, Forest Service, Publ. 1290. 10 pp.

12 temperature treatments at 5 degree intervals from 45°F to 100°F were used for white spruce seeds to determine cardinal temperatures for germination. Seeds did not germinate below 45°F or above 95°F. Some germination did occur at 45°F and 90°F but it was too slow to be of use. Results indicate that for maximum germination 28 days after seedling, temperatures were: 55-60°F for seed from Davie Lake, B.C. and Moosonee, Ont.; 55-65°F from Chelson, N.Y., 65-70°F from Petawawa and Napanee, Ont.; and 65-75°F from Acadia, N.B.

K.W. Picea glauca (white spruce), germination, latitude, provenance, seed, temperature.

317. Fraser, J.W. and J.L. Farrar. 1957. Frost hardiness of white spruce and red pine seedlings in relation to soil moisture. Canada, Forestry Branch, Forest Research Division, Tech. Note 59. 5 pp.

Seedlings of all strains of both species, grown from seed, were less resistant to frost after they had been subjected to soil drought. Spruce suffered less damage than pine. In moist soil, the best pine strain survived at a rate equal to the poorest spruce strain.

K.W. Picea glauca (white spruce), artificial regeneration, drought, frost, germination, seeding, seedling mortality, seedlings, soil moisture, [Pinus resinosa].

318. Garman, E.H. 1929. Natural reproduction following fires in central B.C. Forestry Chronicle 5(3):29-44.

After forest fires, aspen, willow and birch form forest tree cover, replacing fire weed. Regeneration of spruce and fir was considered inadequate, 75% of all burned sites being understocked. Spruce averaged less than 800 seedlings/acre in all forest types. Regeneration was not established on exposed mineral soil subject to excessive evaporation or under dense herbaceous and shrubby vegetation on good soils; both conditions probably limited the soil moisture.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), forest fires, regeneration, soil moisture, succession, vegetative competition, [Populus tremuloides].

319. Glerum, C. and J.L. Farrar. 1965. A note on internal frost damage in white spruce needles. Canadian Journal of Botany 43:1590-1591.

Artificial-freezing tests were carried out to test the various effects of frost on several coniferous species. This note reports the effect of frost on the internal structure of white spruce needles. Collapse of mesophyll tissues occurred immediately after thawing. A description of the damaged cells is included.

K.W. Picea glauca (white spruce), frost damage, mesophyll, needles.

320. Glerum, C. and J.L. Farrar. 1966. Frost ring formation in the stems of some coniferous species. Canadian Journal of Botany 44:879-886.

Two and three-year-old seedlings of several coniferous species were subjected to artificial-freezing, then examined. Frost rings were often found in seedlings on stems where no external evidence of frost injury was noted. Characteristic features of frost rings are described, the rings being divided into two main parts: inner part of frost-killed cells, outer part of abnormally formed cells grown after the frost. Results showed the most actively growing cells to be most susceptable to frost damage.

K.W. Picea glauca (white spruce), frost damage, frost rings, seedling growth.

321. Glerum, C. and G. Peirpoint. 1968. The influence of soil moisture deficits on seedling growth of three coniferous species. Forestry Chronicle 44(5):26-29.

Rising 3-0 seedlings of red pine, white spruce, and larch were subjected to two drought periods in a growth chamber. The four treatments were: control, 1, 6, and 15 atmospheres of soil moisture tension. Even the 15 atmosphere treatment did not affect the length of the terminal leader or the stem diameter.

K.W. Picea glauca (white spruce), diameter growth, drought, leader growth, seedling growth, soil moisture, [Larix laricina, Pinus resinosa].

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

322. Glerum, C., J.L. Farrar and R.L. McLure. 1966. A frost hardiness study of six coniferous species. Forestry Chronicle 42:69-75.

Discusses an experiment conducted to test the frost hardiness of six coniferous species by seedling to artificial frost. The seedlings were exposed to various temperatures in a dry-ice chamber from one to one and one-half hours. Some preliminary trials were also carried out on 2-2-1 and 2-2-2 white spruce. Results demonstrated a linear relationship between frost damage and temperature. Differences may exist between species, but were not observed in this experiment. All showed less frost damage as temperatures were increased. A small increase in frost hardiness occurred, as can be expected with the onset of dormancy.

K.W. Picea glauca (white spruce), Picea mariana (black spruce), Pinus banksiana (jack pine), Pinus resinosa (red pine), Pinus strobus (white pine), Larix laricina (Eastern larch), frost damage, frost hardiness, seedlings, temperature.

323. Griffith, B.G. 1931. The natural regeneration of spruce in central British Columbia. Forestry Chronicle 7(4):204-219.

Work commenced in 1926 at Aleza Lake, Prince George Forest Region to investigate causes of poor restocking of spruce in the spruce-balsam type of central British Columbia. Three separate studies were made: 1) securing of information as to the composition of the mature forest and to the proportions of species in its understory; 2) a study of the groundcover in the forest, with identification of its herbaceous and shrubby flora; 3) an investigation of seedbed conditions and the effects of root competition on the germination and survival of spruce seedlings under natural conditions of forest cover. Trenching of the soil in plots was attempted, but had no appreciable effect on the establishment of seedlings.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), ecology, regeneration, scarification, seedbed, site treatment, trenching, vegetation.

324. Hart, A.C., H.G. Abbott and E.R. Ladd. 1968. Do small mammals and birds affect reproduction of spruce and fir. U.S. Dept. Agric., Northeastern Forest Experiment Station, Res. Pap. NE-110. 8 pp.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

Spruce-fir stands in the northeast reproduce to fir rather than spruce. A study of spruce-fir reproduction using various combinations of protection from small mammals and ground feeding birds, showed no evidence of preferential feeding on spruce seeds rather than fir. Further research is needed.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), birds, mice, regeneration, seed consumption, seeding, voles, wildlife.

325. Heit, C.E. 1950. Physiology of germination. New York State Agric., Experiment Station, Rept. 1949. pp. 42-45.

Picea glauca and Picea glauca var. albertiana did not germinate promptly and completely at temperatures of 20°C or below. The smaller seeded Picea species were found to be sensitive to moisture during germination.

K.W. Picea glauca (white spruce), germination, seed moisture, seed storage, storage temperature.

326. Hellmers, H., M.K. Genthe and F. Ronco. 1970. Temperature affects growth and development of Engelmann spruce. Forest Science 16:447-452.

30 different combinations of day and night temperatures were used for seedlings of Engelmann spruce to test the effect of temperature on growth and development. Results indicate night temperature is a key factor in control of growth and development, since the higher the night temperature, the faster the seedlings grew. Day temperatures had their greatest effect on bud development and seedling survival. Day temperatures of 19° and 23°C with a 23°C night temperature produced the best growth. The 35°C day temperature tended to inhibit terminal bud formation, and also caused the highest mortality, particularly when combined with 3°C or 7°C night temperatures. Comparisons with results from studies of redwood are made and 12 references are cited.

K.W. Picea engelmannii (Engelmann spruce), seedling growth, seedling mortality, seedling survival, temperature, [Sequoia sempervirens].

327. Hellum, A.K. 1966. Seed weight and size and form of germination in white spruce. Abstr. in Bull. Ecological Soc. Amer. 47(3): 103.

Seed weight is positively correlated to both cotyledon number and hypocotyl length in white spruce. Seeds lighter than 0.00145 g produce germinants <20 mm tall, while those heavier than 0.00405 g produce germinants >28 mm tall under lab conditions. Seeds of average weight germinated 2-3 days before lighter or heavier seeds. Adverse site conditions may obliterate influence of seed weight on size of germinants. Average total range in germinant size was controlled partly by soil moisture and shade and partly by cotyledon number or seed weight.

K.W. Picea glauca (white spruce), germination, seed weight, seedling size, shade, soil moisture.

328. Hellum, A.K. 1967. Periodicity of height growth in white spruce reproduction. Forestry Chronicle 43(4):365-371.

A one-year study of white spruce seedlings in Alberta shows that seasonal height growth is positively correlated with length of growing period, and size and length of terminal bud. Bud size is closely related to seedling height, but is also affected by environmental factors and by genetic variability among seedlings.

K.W. Picea glauca (white spruce), growth increment, regeneration, seedling growth, seedlings.

329. Hellum, A.K. 1971. A simple distribution pattern for seed weights in white spruce from Alberta. In: Proc. 12th Meeting of the Committee on Forest Tree Breeding in Canada, 1970, part 2, ed. E.K. Morgenstern. pp. 147-150.

Seed weight in Picea glauca varies with latitude in Alberta. Three zones were established: 49° - 53°N, and 57° - 60°N. Seeds from the central zone were by and large the lightest (1.99 mg/seed), while those from the other zones were 2.26 and 2.20 mg/seed, respectively.

K.W. Picea glauca (white spruce), provenance, seed weight, seedling growth.

330. Hesselmann, H. 1939. [Difficulties and their causes in the regeneration of Norway spruce on sites with a rich herbaceous ground flora.] Bot. Notiser. 199. pp. 413-422. (Abstr. F.A. 2:207).

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

Failure of regeneration is attributed by some, not to insufficiency of light under herbaceous vegetation, but to soil factors, especially high degree of nitrification in humus. This study shows no effects of nitrification on regeneration, but mortality was strongly correlated with lack of light. With adequate light, dosages up to 200 mg nitrate nitrogen/litre of soil showed increased growth and no increased mortality. There are also inhibiting effects from other species which should be investigated.

K.W. Picea abies (Norway spruce), germination, light nitrogen, regeneration, seedling mortality, soil nutrients, vegetative competition.

331. Horton, K.W. 1958. Seasonal leader growth of lodgepole pine in the subalpine forest of Alberta. Forestry Chronicle 34(4):382-386.

The weekly leader growth of young lodgepole pine saplings, 5-6 ft. high, in Alberta, showed similar patterns but different growth rates according to aspect of the site. The seasonal growing period consistently started in early May and was 12 weeks long, but within this period the distribution of growth differed widely from year to year. A direct relationship existed between weekly growth and corresponding mean weekly temperatures, except towards the end of the growing season.

K.W. Pinus contorta (lodgepole pine), climate, ecology, leader growth, phenology, seedling growth.

332. Illingworth, K. and J.W.C. Arlidge. 1960. Interim report on some forest site types in lodgepole pine and spruce-alpine fir stands. B.C. Forest Service, Res. Note 35. 44 pp.

Complete report, including descriptions of physiography, geology, and climate of study areas, methods of study, supporting data, analysis, description of site types and their value and use in relation to silviculture and management.

K.W. Abies lasiocarpa (subalpine fir), Pinus contorta (lodgepole pine), Picea glauca (white spruce), forest management, silviculture.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

333. Jablanczy, A. 1969. Photomorphogenesis in germinants of four species of conifer in different light regimes. Canada, Forestry Service, Forest Research Lab, Fredericton, Internal Rept. M-52.

White, red and black spruce and balsam fir seedlings were subjected to four different light regimes. All four species were able to survive in all light regimes, but showed different growth and development. Response to increasing amounts of light was greatest for black spruce germinants, followed by white spruce, balsam fir, and red spruce. The order of shade tolerance is reversed.

K.W. Picea glauca (white spruce), artificial regeneration, light regimes, seedling growth, [Abies balsamea, Picea mariana, Picea rubens].

334. Jablanczy, A. and G.L. Baskerville. 1969. Morphology and development of white spruce and balsam fir seedlings in feather moss. Canada, Forestry Service, Forest Research Lab, Fredericton, Info. Rept. M-X-19. 10 pp.

Follows the development of spruce and fir seedling development in feather moss, white spruce stands. Gives some indication of growing conditions encountered.

K.W. Picea glauca (white spruce), regeneration, seedbed, seedling morphology, [Abies balsamea].

335. Jones, J.R. 1972. Moisture stresses in Arizona mixed conifer seedlings. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Pap. RM-86. 8 pp.

Dry season moisture stresses were measured in wild seedlings of Douglas fir, ponderosa pine, Engelmann spruce, and subalpine fir. Seedlings less than 15 cm tall had higher stresses than larger trees. There was no increasing trend of stresses through the dry season on sites and seedling sizes sampled and day to day variability seemed a function of day to day weather differences. Species differences were small but significant.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Pseudotsuga menziesii (Douglas fir), moisture stress, regeneration, seedling growth, seedling survival, soil moisture.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

336. Kastrukoff, M. 1950. Effect of periodic drought on survival of white spruce. Canada, Forestry Branch, Unpubl. MS.

337. Kayll, A.J. 1960. Effects of flooded soils on growth and development of northern spruce and pine seedlings. Duke University, M.Sc. Thesis.

338. Korstian, C.F. 1921. Relation to precipitation to height growth of forest tree samplings. Utah Academy of Science, Arts, and Letters, Proc. 2:259-266.

339. Kos, J. 1947. [Natural seeding of forest areas by light, flying seeds.] Lesn. Práce 2 (5):155-172. (Abstr. F.A. 9:299).

Using Norway spruce as an example, considers dynamics of fall of winged seeds. Discusses air movements and seed dispersal with chief reference to differences in stand structure. Air movements most favourable to seed deposition require some irregularity of stand structure. Lists of conditions under which natural regeneration can and cannot be expected are given in great detail.

K.W. Picea abies (Norway spruce), regeneration, seed deposition, seed dispersal, wind.

340. Lees, J.C. 1972. Site factors contributing to the spruce regeneration problem in Alberta's mixedwood. In: Regeneration of white and Engelmann spruce. Canada, Forest Service, Pacific Forest Research Centre, British Columbia, Info. Rept. BC-C-69. pp. 8-14.

Two factors are required for spruce regeneration, 1) a receptive seedbed of mineral soil or rotten wood, and 2) freedom from vegetative competition, and these must be met in the mixedwood section. These were ensured by wildfire, but now various silvicultural techniques must replace the old system of natural regeneration. The results of experimental studies and silvicultural treatments are reviewed.

K.W. Picea glauca (white spruce), artificial regeneration, fire, planting, regeneration, scarification, seedbed, soil, vegetative competition.

341. Logan, K.T. 1969. Growth of tree seedlings as affected by light intensity. IV. Black spruce, white spruce, balsam fir, and eastern white cedar. Canada, Forestry Service, Publ. 1256. 12 pp.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

All species were grown for nine years in 13%, 25%, 45% and 100% full light. White spruce seedlings were tallest when grown in 45% and 100% light. Balsam fir was most shade tolerant. White spruce reached its maximum weight in full light. The increased growth at high light intensities resulted from increased amounts of foliage per seedling rather than from any increase in production per gram of foliage.

K.W. Picea glauca (white spruce), artificial regeneration, growth increment, height increment, light intensity, planting, [Abies balsamea, Picea mariana].

342. Long, H.D. 1945. Forest regeneration (problems of control). Canadian Pulp and Paper Organization, Woodlands Section Index 804(F-2). 2 pp.

Gives a summary of information concerning conditions that favour or hinder germination of seed and survival of seedlings of various species including white spruce.

K.W. Picea glauca (white spruce), germination, regeneration, seed, seeding, seedling survival, silviculture.

343. McCullough, H.A. 1948. Plant succession on fallen logs in a virgin spruce-fir forest. Ecology 23:508-513.

A 5 acre area was studied in an investigation of plant succession on fallen logs. Three types of conditions were found: mesic, xeric, and bog. 153 logs were studied, grouped into eight classes of decay. Climax species of the area were Englemann spruce and subalpine fir. Survival of seedlings of either of these species had slight chance, but it did occur. Fallen logs are first invaded by lichens and liverworts, then mosses. Herbaceous species follow, then low shrubs. Establishment of the spruce and fir seedlings does not depend on this succession as it can occur on logs at almost any stage of decay.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), decay, fungi, herbs, lichen, liverworts, logs, plant succession, seedling, survival, vegetation.

344. Marshall, R. 1931. An experimental study of the water relations of seeding conifers with special reference to wilting. Ecological Monographs 1(1):39-98.

Experiments were performed on several conifers, primarily Norway spruce and pine, but also on white spruce and others. Two stages of wilting were observed: a critical stage of wilting (permanent wilting) and a stage of withering, at which the stems and leaves become brittle. The permanent wilting stage is that at which seedlings could not recover unless soil were adequately watered. Results were useful primarily in planning more thorough experimentation.

K.W. Picea glauca (white spruce), seedling growth, water relations, wilting, [Picea abies, Pinus sylvestris].

345. Meeker, V.K. 1949. Reproduction of Engelmann spruce in the Central Rocky Mountains. Colorado State Univ., M.Sc. Thesis.

346. Minore, D. 1968. Effects of artificial flooding on seedling survival and growth of six northwestern tree species. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Note PNW-92. 12 pp.

Seedlings of several species, including lodgepole pine were inundated in tanks for various lengths of time in both winter and summer. Winter flooding for 1-4 weeks severely injured only Douglas fir. Summer flooding for 4-8 weeks caused high mortality in all species. Many pine were judged flood tolerant, Douglas fir extremely intolerant.

K.W. Pinus contorta (lodgepole pine), Pseudotstuga menziesii (Douglas fir), artificial regeneration, flooding, planting, seedling mortality.

347. Newton, M. 1964. Seedling survival and vegetative competition. In: Western Reforestation, Western Forestry and Conservation Assoc., Proc. Western Reforestation Co-ordinating Committee, Annual Rept., 1964. pp. 39-42.

Discusses for seedlings in general, the relationships between seedlings and their associates and strives to illustrate how the manipulation of vegetation may have a substantial influence on the severity of habitat. These relationships involve moisture consumption, influence on soil and air temperatures near the surface, light interception, and phenology and growth habit. Each are discussed separately and interactions considered. Much of competition effect is avoided by prompt restocking or use of selective herbicides.

K.W. artificial regeneration, herbicides, light interception, planting, soil moisture, vegetative competition.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

348. Nienstaedt, H. 1958. Receptivity of female strobili of white spruce. Forest Science 4:110-115.

Female strobili of Wisconsin white spruce were studied. Results indicate that white spruce strobili are receptive during a period of 3-5 days. Pollen shedding coincides fairly well to receiptivity. Weather conditions during period of pollination are very important in determining size of natural seed crop.

K.W. Picea glauca (white spruce), pollen production, seed crop.

349. Noble, D.L. 1972. Effects of soil type and watering on germination, survival, and growth of Engelmann spruce - a greenhouse study. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station Res. Note RM-216. 4 pp.

Watering treatment affected both germination and survival; soil type affected survival only. Root elongation was significantly different between soils with adequate water, but top height and total plant dry weight were not significantly related to either soils or watering treatment.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, germination, greenhouses, irrigation, seedling growth, seedling survival, soil.

350. Noble, D.L. 1973. Age of Engelmann spruce seedlings affects ability to withstand low temperature: a greenhouse study. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note RM-232. 4 pp.

Spruce seedlings were exposed to 5^{o}, 15^{o}, and $25^{o}F$ cold treatments at 6 development stages - 2 weeks through 12 weeks at 2 week intervals. All seedlings survived the $25^{o}F$, but no seedlings survived the $5^{o}F$. At $15^{o}F$, few seedlings 2-8 weeks old survived, but most seedlings 10-12 weeks old survived. No correlation could be found between cold resistance and moisture content.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, cold hardiness, greenhouse, seedling age, seedling moisture, seedling survival, temperature.

351. Patten, D.T. 1963. Light and temperature influence on Engelmann spruce seed germination and subalpine forest advance. Ecology 44:817-818.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

Lodgepole pine has an optimum germination temperature of 77°F and Engelmann spruce of between 70°F and 80°F. For Engelmann spruce, germination was inhibited below 35°F. At 45-50°F germination started later than optimum. Germination percentage at 35°F, and 35-50°F was considerably higher when illuminated. However, light is relatively unimportant at optimum temperatures.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), germination, germination temperature, insolation, seed, succession, temperature.

352. Payne, L.A. 1960. Studies in forest pathology. XXII Nutrient deficiencies and climatic factors causing low volume production and active deterioration in white spruce. Canada, Dept. Agriculture, Forest Biology Div., Publ. 1067. 24 pp.

Summarizes a study of edaphic and climatic factors associated with deterioration and low volume growth of white spruce in Quebec. 133 plots were established to study variations in environment and tree health. Results showed soil temperature had no part in the deterioration and mortality observed. Poor growth was found to be related to quite stable soil characteristics while deterioration and mortality were associated with extended periods of low rainfall. The degree of deterioration was related to the depth and extent of rooting. Application of the deficient minerals produced improvements in growth and in drought resistance.

K.W. Picea glauca (white spruce), climate, drought resistance, growth, mortality, nutrient deficiency, volume growth.

353. Phelps, V.H. 1967. How much spruce seed next year? Canada, Dept. Forestry, Forest Research Lab, Victoria. Timber Talks 24.

Outlines morphological characteristics of spruce buds which enable prediction of cone crops the fall before the cones mature. Reliable prediction needs periodic re-examination.

K.W. Picea glauca (white spruce), Picea mariana (black spruce), cone crop.

354. Place, I.C.M. 1953. The influence of seedbed conditions on the regeneration of spruce and balsam fir. Yale University, Ph.D. Thesis. 267 pp.

355. Place, I.C.M. 1955. The influence of seedbed conditions on regeneration of spruce and balsam fir. Canada, Forestry Branch, Bull. 117. 87 pp.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

Reports effects of various natural seedbeds on the germination and early growth of red, white and black spruce and balsam fir in New Brunswick. Especially relevant are sections dealing with the effect of seedbed on seedling establishment and the effect of seedbed treatment on germination and seedling growth. A review of literature is included.

K.W. Picea glauca (white spruce), germination, regeneration, root growth, seedbed, seedling growth, silviculture, soil moisture, vegetative competition.

356. Prochnau, A.E. 1960. E.P. 459 - Seed production of spruce in relation to its morphological characteristics (spruce-alpine fir type). B.C. Forest Research Review. pp. 13-14.

No relationship was found to exist between tree morphology and seed production. Also reported 1956 - p. 15, 1957 - p. 17, 1958 - pp. 17-18, 1959 - p. 25.

K.W. regeneration, seed production, tree morphology.

357. Prochnau, A.E. 1960. E.P. 460 - Seed production of conifers in relation to climate in the central interior of British Columbia. B.C. Forest Research Review. p. 14.

Attempts to determine a relationship between climate and seed production of white spruce. A relationship between temperature at the time of bud differentiation and following years' cone crop seems to exist. Also reported 1956 - p. 15, 1957 - p. 18, 1958 - p. 18, 1959 - pp. 25-26.

K.W. climate, cone crop, regeneration, seed production.

358. Reineke, L.H. 1941. Fruiting of ten year old conifers. U.S. Dept. Agric., Northeastern Forest Experiment Station, Tech. Note 47. 3 pp. (Abstr. F.A. 4:226).

Gives data on cone production in relation to tree height for young white spruce, red pine and eastern white pine grown in plantations.

K.W. Picea glauca (white spruce), cone production, tree height.

359. Revel, J. 1969. Early prediction of a white spruce seed crop in the Prince George Forest District, April, 1968. B.C. Forest Research Review. pp. 110-112.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

Describes process of prediction of good seed crop in 1968 and characteristics of seed trees at that time. Suggests that method of forecasting seed crops should be continued on a limited scale for several years in order to assess its usefulness in planning cone collections and selecting areas to be allowed to regenerate naturally.

K.W. Picea glauca (white spruce), cone crops, regeneration, seed production, seed trees.

360. Revel, J. 1970. E.P. 675 - Cone and seed maturity on white spruce in the North Central Interior. B.C. Forest Research Review. p. 21.

The objectives of this study were to determine the pattern of cone and seed maturation in selected white spruce stands and find more reliable field indices for determining cone and seed maturity in the field. It was found that germination of seed gathered early in the season was less than that gathered at a later date. Also reported 1969 - pp. 23-24.

K.W. Picea glauca (white spruce), cone maturity, germination, seed, seed maturity, seed production.

361. Roche, L. 1964. E.P. 610 - Photoperiodic response in white and Engelmann spruce. B.C. Forest Research Review. pp. 31-33.

Evaluates the geographic variation in photoperiodic response of 13 provenances of interior spruce. Also reported 1963 - p. 23.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), photoperiod, provenance.

362. Roche, L. 1967. Spruce provenance research in British Columbia. In: Proc. 10th Meeting of the Committee on Forest Tree Breeding in Canada, 1966, part 2. pp. 107-121.

Reports three separate experiments: 1) geographic variation in spruce cone scale morphology, 2) geographic variation in white and Engelmann spruce seedlings in a coastal nursery, and 3) variation in embryo development in diverse spruce provenances and its effect on germination behaviour and early growth.

K.W. Picea glauca (white spruce), Picea engelmannii (Engelmann spruce), artificial regeneration, climate, germination, provenance, seedling growth, seedling mortality.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

363. Roe, E.I. 1946. Extended periods of seedfall of white spruce and balsam fir. U.S. Dept. Agric., Lake States Forest Experiment Station, Tech. Note 261.

Seed collections were made until mid-November and then not until the following May. There was more balsam seed than white spruce in the May collection. The course of seed dispersal is tabulated. Results show about 7/8 of the white spruce seed had fallen by late October, but only 1/2 the balsam seed had. Seedfall for both species was complete by mid-June.

K.W. Picea glauca (white spruce), seed, seed dispersal, seedfall, [Abies balsamea].

364. Roe, E.I. 1952. Seed production of a white spruce tree. U.S. Dept. Agric., Lake States Forest Experiment Station, Tech. Note 373. 1 p.

White spruce produces good cone crops at irregular intervals from 2-6 years. Average production of viable seed per cone for a 15" dbh. tree 75 years old growing in Minnesota was 22.8 seeds. Total cone production was 11,874 with a total yield of 271,000 viable seeds, about 1 lb of commercial clean seed.

K.W. Picea glauca (white spruce), cone production, seed production.

365. Roeser, J. Jr. 1932. Transpiration capacity of coniferous seedlings and the problem of heat injury. J. For. 30(4):381-395.

Tests were made to check earlier results of experiments dealing with the effect of combined heat and drying, and the effect of moisture available to roots in relation to resistance to heat. The later tests study, a) resistance to stem injury from contact with a superheated soil surface 'ground level construction', and b) transpiration capacities of various species under different degrees of heat exposure. Results show that under normal temperature exposure, lodgepole and spruce seedlings transpire more freely than western yellow pine and Douglas fir in the first year of growth. In low temperatures and high humidity, spruce and Douglas fir proved more efficient in their use of water. It appears that western yellow pine is more quickly stimulated to increase transpiration under conditions of extreme exposure than other species.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Dougla fir), heat injury, heat resistance, seedling damage, transpiration capacity, [Pinus ponderosa].

366. Roeser, J. Jr. 1940. The water requirement for Rocky Mountain conifers. J. For. 38:24-26.

Seedlings of 6 species were grown in containers for ten years and supplied with water at regular intervals. Greatest water loss per day was recorded for Engelmann spruce, followed by Douglas fir, pinon pine, ponderosa pine and limber pine. Engelmann spruce is one of the best efficient trees tested.

K.W. Picea engelmannii (Engelmann spruce), Pseudotsuga menziesii (Douglas fir), irrigation, seedling growth, water use, [Pinus spp.].

367. Rowe, J.S. 1953. Viable seeds on white spruce trees in midsummer. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 99. 2 pp.

White spruce is able to retain a small proportion of seeds in cones which persist for the better part of a year. Fire can serve as a stimulus for the release of this seed.

K.W. Picea glauca (white spruce), cones, fire, seed, seedfall.

368. Shirley, H.L. 1936. Lethal high temperatures for conifers and the cooling effect of transpiration. Jour. Agric. Res. 53:239-258.

From tests of various species 1-4 years of age including white spruce, it can be concluded that resistance to excessive heat increases with increasing age and increasing size or mass of plant. Tops are more resistant than roots. With 2 hour exposure, the maximum temperature needles can stand is 49°C, while temperatures of up to 44.3°C do not cause severe damage to tops in exposures up to 5 hours duration. Damage may result to roots in this time. External killing temperature is higher in dry air than moist air. (54°C at 15% r.h. v.s. 50°C at 85% r.h.). Cooling effect of transpiration was probably crucial in this. White spruce excelled in its ability to recover from heat injury.

K.W. Picea glauca (white spruce), air temperature, drought, relative humidity, seedling mortality, [Pinus banksiana, Pinus strobus, Pinus sylvestris].

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

369. Shirley, H.L. 1943. Is tolerance the capacity to endure shade. J. For. 41:339-345.

Survival of white spruce and various pine species under forest canopies and their rank in the successional series are dependent primarily upon shade tolerance which has been defined as the ability of seedlings to survive in light of low intensity. Relative shade tolerance can be tested by determining the number of years (or months) seedlings will survive when exposed to 2-8% of total sunlight.

K.W. Picea glauca (white spruce), regeneration, seedling survival, shade tolerance, succession, [Pinus sp.].

370. Stoeckeler, J.H. 1938. Soil adaptability of white spruce. J. For. 36:1145-1147.

White spruce commonly occurs in slightly to moderately acid soils with good moisture relations. Earlier studies of soil requirements showed the trees to be found on soils with silt and clay content of 25%, pH of 5.2, and total nitrogen content of 0.257. The species has also been found in moderately calcareous soils. The writer analysed two soil profiles, both of which show rather high pH and calcareous nature of lower soil. It appears that white spruce is more lime-tolerant than previously supposed.

K.W. Picea glauca (white spruce), lime tolerance, soil adaptability, soil nutrients, soil pH, soil profile.

371. Toumey, J.W. and E.J. Neethling. 1924. Insolation a factor in the natural regeneration of certain conifers. Yale University, School of Forestry, Bull. 11. 63 pp.

372. Tunstell, G. 1944. Natural regeneration of white spruce. Canada, Forest Service, Unpubl. MS.

373. U.S. Dept. Agric. 1957. Shade is beneficial to Engelmann spruce initial seedling survival. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Annual Rept. 1956. pp. 6-7.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

A study of 1-year-old seedlings showed that heat girdling caused by high soil surface temperatures was responsible for 25 to 65% of total mortality. Heat girdling was appreciably reduced by using both shades, providing 50% shade, in July and August. Shading had no noticeable effect on drought losses, and differences in moisture in the top 3 in. of soil on shaded and unshaded seedbeds were insignificant because of frequent and well distributed summer rains. Mortality from soil movement caused by heavy summer rains was next in importance. Weeding had no significant effect on survival.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, heat girdling, nurseries, planting, seedling mortality, shading, soil moisture, soil temperature, weeding.

374. U.S. Dept. Agric. 1962. Photosynthesis of spruce seedlings favoured by partial shade. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept. 1961. pp. 26-27.

Three-year-old Engelmann spruce seedlings were exposed to three light conditions: full sun, partial shade, full shade. Results suggest that the optimum light intensities were between 3,000 and 12,000 foot candles for all shade treatments in July and September, with a higher optimum in September than June. In September, seedlings under full sun assimilated CO_2 slowest at all light intensities, while those under partial shade assimilated CO_2 the fastest.

K.W. Picea engelmannii (Engelmann spruce), light intensity, light requirement, planting, photosynthesis, seedling growth, shade.

375. U.S. Dept. Agric. 1963. Photosynthesis of spruce seedlings favoured by partial shade. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept. 1962. pp. 26-27.

Three year old seedlings of Engelmann spruce were grown in pots under 3 light conditions and then subjected to various light intensities. At 3000 ft. candles, seedlings grown under partial shade took up CO_2 fastest and seedlings grown in full light took up least. At 1500 foot candles, seedlings grown under full shade took up most. At 12,000 ft. candles, seedlings grown under full shade took up least. Optimum intensities were between 3000 and 12,000 ft. candles in both July and Sept. for all shade treatments, and optimum was higher in September than in June.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

K.W. Picea engelmannii (Engelmann spruce), insolation, light intensity, photosynthesis, shading.

376. U.S. Dept. Agric. 1968. Dehydration not responsible for winter mortality of spruce seedlings. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept. 1967. p. 37.

Seedlings of Engelmann spruce have a high over-winter mortality when not shaded during summer months. Experiments have shown that water stress alone was not responsible for high winter mortality. Potted seedlings survived a foliage water deficit of up to 58%.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, dehydration, planting, seedling mortality.

377. U.S. Dept. Agric. 1971. Environment factors greatly influence Engelmann spruce establishment and survival. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept. 1970. p. 4.

Presents summaries of 3 studies on Engelmann spruce. Results indicate that precipitation is a critical factor for seedling survival. At least 1 inch of favourably distributed precipitation is needed monthly for survival in significant numbers. Seedlings can withstand very high moisture stress but drought is probably not a cause of heavy mortality in spruce plantations. At a water deficit of 10% or less, apparent photosynthesis is at the maximum rate and dark respiration at 55-100% of maximum. From this point, both figures recede to minimum rates for both processes at 20% water deficit.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, drought, photosynthesis, planting, precipitation, seeding mortality.

378. Wagg, J.W.B. 1962. Notes on food habits of small mammals of the white spruce forest. Canada, Dept. Forestry, Forest Research Branch, Mimeo, Alberta 62-11. 14 pp.

Peromyscus maniculatus and Clethrionomys gapperi showed a daily maximum seed consumption of lodgepole pine of about 1000 seeds and of white spruce of 2000 seeds. Meadow voles, Microtus sp. readily ate lodgepole pine and white spruce seedlings after germination, as did Clethrionomys gapperi.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

K.W. Picea glauca (white spruce), mice, seed, seed consumption, seedlings, voles.

379. Waldron, R.M. 1962. White spruce growth in relation to environment. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo Man.-Sask. 62-11. 99 pp.

White spruce saplings, about fourteen-years-old and seven ft. tall were examined on three plots. Information was obtained on various climatic factors, and terminal growth measurements were taken at various intervals during a five-year period. Initiation of terminal growth appeared related to both mean air temperature prior to growth and day length. Total growth appeared related to climatic conditions during previous and current growing seasons. There was a definite correlation between night growth and minimum air temperature. This was accompanied by a less definite relationship between day growth and maximum air temperature.

K.W. Picea glauca (white spruce), climate, growth, growth increment, phenology, soil temperature, temperature.

380. Waldron, R.M. 1965. Annual cone crops of white spruce in Saskatchewan and Manitoba, 1923-1964. Canada, Dept. Forestry, Forest Research Branch, Mimeo 65-MS-11. 34 pp.

During 27 years of observation there were 2 years with heavy crops, 11 years with medium crops, 12 years with light crops and 2 years with nil crops. The longest interval without a moderate or heavy cone crop was 4 years. Scarification can be carried out annually since mechanically prepared seedbeds remain suitable for germination for up to 5 years and even in light cone crops years, sufficient seed will fall in some stands to result in 40-60% stocking.

K.W. Picea glauca (white spruce), cone crop, regeneration, scarification, seed production, seedbed, seedfall.

381. Waldron, R.M. 1965. Cone production and seedfall in a mature white spruce stand. Forestry Chronicle 41(3):314-329.

Dominant and co-dominant trees in Manitoba produce heavier cone crops and produce them more freely than intermediates. Intermediates produced heavier and more frequent cone crops than released trees. Seedfall varied in period of study from 10,000/acre to 5,625,000/acre. Seed soundness was highest in years of heavy seedfall and lowest in years of light or nil seedfall. Seedfall generally begins in early August with peak seedfall occurring in late August or early September. Air temperature, insolation, and precipitation, however, play a strong determining role in this. Early and late falling seed was not as sound as that which fell during the period of peak seedfall.

K.W. Picea glauca (white spruce), climate, cone crop, seed viability, seedfall.

382. Werner, R.A. 1964. White spruce seed loss caused by insects in interior Alaska. Canadian Entomologist 96(11):1462-1464.

Cone collections were made annually when seeds were fully developed but undispersed. The cones and seeds were dissected and examined for insect damage. Results showed six species of insects that damaged the cones and seeds (each is named and type of damage each causes is described). Damage occurred principally in one year of the five year study. A new seed and cone insect was recorded for the first time from Alaska.

K.W. Picea glauca (white spruce), cones, insect damage, seed.

383. Zasada, J.C. 1971. Frost damage to white spruce cones in interior Alaska. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Note PNW-149. 7 pp.

Cone and seed production is examined for several white spruce stands in Alaska after a late May frost killed or damaged developing conelets. In view of the infrequent good seed years of this species, such phenomena are potentially serious.

K.W. Picea glauca (white spruce), cone production, frost damage, regeneration, seed production.

384. Zasada, J.C. and L.A. Viereck. 1970. White spruce cone and seed production in interior Alaska, 1957-1968. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Note PNW-129. 11 pp.

Estimates of seedfall per acre, seed dispersal over time, cone production by individual trees, number of seeds per cone and per tree and cone crop ratings are reported from white spruce stands in interior Alaska. Observations show that very good seed years may be separated by at least 10-12 years, although, during this interval, individual stands may produce from one to several fair or good cone crops.

c) INFLUENCES OF FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

K.W. *Picea glauca* (white spruce), cone crop, regeneration, seed crop, seed dispersal, seed production, seedfall.

III. ARTIFICIAL REGENERATION

Artificial regeneration is regarded as re-establishment of forest cover by direct intervention of man, through direct seeding or by planting of young trees.

A. SEED COLLECTION AND HANDLING

This section deals with all aspects of artificial regeneration specifically concerned with seed prior to sowing.

i) SEED COLLECTING, SELECTING, AND GRADING

Seed to be used either in nurseries for the production of growing stock or the field for direct sowing is subjected initially to various procedures. Cones may simply be collected and all seed extracted for use, or more selective procedures such as size grading may be used. The papers in this section deal principally with the outcome of such selective measures, primarily with respect to germination and seedling growth. The influences of the physical process of handling the seeds during selection and grading is also explored by some papers. In addition, several papers concerning seed tree selection criteria for white spruce are included.

i) SEED COLLECTING, SELECTION, AND GRADING, cont'd.

385. Anon. 1956. Seed collection. Special supplement to Forestry Chronicle, March 1950. pp. 35-47.

Data presented from all provinces of Canada for: species collected and amounts needed; periodicity of seed crops; extraction of seed from cones; cleaning of seed; preparation of hardwood seed; storage; and longevity of seed of different species.

K.W. seed, seed extraction, seed production, seed storage.

386. Allen, G.S. 1958. Factors affecting the viability and germination behaviour of coniferous seed. III. Forestry Chronicle 34(3):283-298.

The processing of seeds and their extraction from cones in nurseries has been found to be a partial cause of erratic germination rates. Various treatments on seeds of, among other species, Picea glauca and Abies lasiocarpa are tested by determining post-treatment germination. Extensive results are given and a discussion is included.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), germination, seed treatment, seeds, stratification.

387. Bates, C.G. 1930. The production, extraction and germination of lodgepole pine seed. U.S. Dept. Agric., Tech. Bull. 191. 92 pp.

Seed production of lodgepole pine in two localities was studied over a period of ten years. Results showed that the production of seed by lodgepole pine is greater than that of western yellow pine and Douglas fir in the areas studied. Different varieties of pine appeared to germinate faster than others, but when a selected group of similar quality seeds all from the same locality was studied, no differences were observed. However, seeds of different localities showed variation in speed of germination. Recommendations are made that seed be taken from the locality in which it is expected seeding on planting will take place.

K.W. Pinus contorta (lodgepole pine), germination, seed extraction, seed production, [Pseudotsuga menziesii Pinus ponderosa].

i) SEED COLLECTING, SELECTION, AND GRADING, cont'd.

388. Burgar, R.J. 1964. The effects of seed on germination, survival and initial growth in white spruce. Forestry Chronicle 40(1):93-97.

The larger the white spruce seed, the larger will be the resultant seedling, after the first season's growth. However, seed size affects neither the germination nor the survival rate in this species.

K.W. Picea glauca (white spruce), germination, regeneration, seed size, seedling growth, seedling survival.

389. Kiss, G.K. 1967. E.P. 670 - A programme for producing genetically improved seed of interior spruces. B.C. Forest Service E.P. 670, Unpubl. Rept. 17 pp.

Since natural regeneration of spruce in the B.C. interior is very unreliable, supplementary artificial regeneration is absolutely necessary, despite its cost. The need for seedlings is such that even culls are grown for an additional year and planted out. This paper puts forward a scheme by which genetically improved seed of white spruce and Engelmann spruce will be available in commercial quantities as soon as possible.

K.W. Picea glauca (white spruce), Picea engelmannii Engelmann spruce), artificial regeneration, genetic improvement, nurseries, planting, seed selection, seedlings.

390. Kiss, G.K. 1971. An approach to the improvement of the white and Engelmann spruce complexes of British Columbia. In: Proc. 12th Meeting of the Committee on Forest Tree Breeding in Canada, 1970, Part 2, ed. E.K. Morgenstern. pp. 151-152.

Outlines project, the main objective of which is the production at the earliest possible date, of genetically improved seed of white and Engelmann spruces in commercial quantities.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), artificial regeneration, seed production, seeding.

391. Kiss, G.K. 1972. E.P. 670 - Selection of white and Engelmann spruce for seed orchards. B.C. Forest Research Review. pp. 20-21.

i) SEED COLLECTING, SELECTION, AND GRADING, cont'd.

Continuing series of progress reports describing establishment and management of a study to select phenotypically superior trees from natural stands and breed them, and to establish a Picetum containing exotic spruces. Also reported 1969 - pp. 46-47, 1970 - p. 43, 1971 - pp. 36-38.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), seed orchards, seed production, seed selection.

392. Kiss, G.K. 1972. Selecting spruce for seed orchards. In: White spruce, the ecology of a northern resource. Canada, Forestry Service, Northern Forest Research Centre, Alberta, Info. Rept. NOR-X-40. pp. 40-44.

Describes a tree improvement program developed by the B.C. Forest Service for white and Engelmann spruce in the interior of British Columbia. In the program, above average trees are selected in wild stands, and grafted clones are established in seed orchards. Each tree is progeny-tested. Progress to date is described.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), seed orchards, seed production, seed selection, tree improvement.

393. Nienstaedt, H. and J.P. King. 1969. Breeding for delayed budbreak in Picea glauca (Moench) Voss - potential frost avoidance and growth gains. Proc. 2nd World Consult. Forest Tree Breeding, Washington, D.C., 1969. 1:61-80.

For northern Wisconsin, selection and breeding of the two latest flushing cones would increase frost avoidance by 43%. Simultaneous selection for rapid growth could also be made.

K.W. Picea glauca (white spruce), breeding, frost damage, nurseries, seedling growth.

394. Rohmeder, E. 1939. [The relative growth of young trees raised from different sizes of seed.] Forstwissenschaftliches Centralblatt 61:43-59. (Abstr. F.A. 1:89).

The influence of size of seed on growth of 3 year old spruce seedlings was pronounced in only a few seedlings. Hereditary factors appear to be much more important than seed size.

K.W. Picea sp. (spruce), artificial regeneration, seed size, seedling growth.

i) SEED COLLECTING, SELECTION, AND GRADING, cont'd.

395. Rohmeder, E. and C.Y. Chen. 1939. [Germination tests with spruce seeds of different sizes.] Forstwissenschaftliches Centralblatt 61:177-184. (Abstr. F.A. 1:89).

No essential differences could be detected between the germination of seeds of different sizes collected from the same tree either in the same or in different seed years, except that occasionally the germination of large seed was inferior and somewhat slower.

K.W. Picea sp. (spruce), germination, seed size.

396. Schell, G. 1960. [The effect of speed of germination in seeds of different size on general vigour of spruce seedlings.] Allgemeine Forst-und-Jagdzeitung 131(2):34-37. (Abstr. F.A. 21:396).

Spruce seed of good quality was graded into 6 size classes and allowed to germinate. Germinated seeds were then planted out in seven groups according to speed of germination. Speed of germination and survival rate increased with seed size and survival rate increased, independently of seed size with speed of germination. Mean weight and height of plant after 1 and 3 years were correlated with seed size, but not, with speed of germination.

K.W. Picea sp. (spruce), germination, seed grading, seed size, seedling growth, seedling survival.

397. Teich, A.H. 1971. Research on the genetic basis of white spruce improvement, Petawawa, 1968-1970. In: Proc. 12th Meeting of the Committee on Forest Tree Breeding in Canada, 1970, Part 2, ed. E.K. Morgenstern. pp. 95-99.

Reports progress in white spruce research at Petawawa, including analyses of provenance experiments, identification and recommendations of superior seed sources, analyses of single tree progeny tests, and a cost benefit study of white spruce improvement.

K.W. Picea glauca (white spruce), artificial regeneration, breeding, germination, nurseries, seed source, spacing, temperature.

398. Vicent, G. 1939. [The variability of conifer seeds and of plants raised from them.] Forstwissenschaftliches Centralblatt 61: 250-255. (Abstr. F.A. 1:89).

i) SEED COLLECTING, SELECTION, AND GRADING, cont'd.

Seedling size in Czechoslovakian spruce and fir in initial stages of growth is directly affected by seed weight. Seeds from the middle portions of cones give largest seedlings. Both spruce and fir produced their heaviest seeds at 60-100 years. In spruce, cone length, seed weight and initial stature of the progeny all decreased with increasing elevation of the seed bearers above sea level.

K.W. Picea abies (Norway spruce), seed size, seedling growth, seedling size.

399. Wagg, J.W.B. 1962. Viability of white spruce seed from squirrel-cut cones. Canada, Dept. Forestry, Forest Research Branch, Mimeo Alberta 62-9. 22 pp.

Cones taken from caches of red squirrels showed slightly greater germination than seed collected from cones on trees. Thus, such caches may be used as a good source of white spruce seed.

K.W. Picea glauca (white spruce), artificial regeneration, cone caches, germination, seed collecting, seed viability, squirrels.

ii) SEED STORAGE

The influences of seed storage upon germination, germinative energy, and post germination seedling growth are reported by papers in this section. Factors of seed storage which are investigated are principally duration and temperature.

ii) SEED STORAGE, cont'd.

400. Ahola, V.K. [The duration of germinability in pine and spruce seed.] Metsät. Aikak 1951(2/3):47-48. (Abstr. F.A. 14:42).

Tests on stored pine and spruce seed showed that: seed having a germination of 85-95% when fresh can, under sealed storage, retain a satisfactory level of viability for 10-15 years; resin sealed bottles are better than cans; and seeds with an initial germination below 80% and any seed, however good, not in air tight storage should be used within 2-3 years.

K.W. Picea sp (spruce), Pinus sp. (pine), germination, seed storage, seed viability.

401. Allen, G.S. 1957. Storage behaviour of conifer seeds in sealed containers held at 0^{o}F, 32^{o}F and room temperature. J. For. 55(4):278-281.

Twenty-seven seed lots representing 11 species, including Picea glauca and Picea engelmannii, were stored in sealed vials for periods of 5-7 years at temperatures of 0^{o}F, 32^{o}F, and fluctuating room temperature. Indications are that all species can be stored at 0^{o}F or 32^{o}F without loss. Seed at room temperature lost all viability in 5-7 years.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), Pseudotsuga menziesii (Douglas fir), artificial regeneration, cedar, cold storage, fir, germination, hemlock, larch, pine, seeds, viability.

402. Allen, G.S. and W. Bientjes. 1954. Studies on coniferous tree seed at the University of British Columbia. Forestry Chronicle 30(2):183-196.

The paper describes a pretreatment and test for Douglas fir that gives reproducible results. Tests for seed of other species, including Abies lasiocarpa, are suggested, which have similar value. Preliminary results from seed storage studies are given for several coniferous species.

K.W. Abies lasiocarpa (subalpine fir), artificial regeneration, germination, nurseries, seed pretreatment, seed storage, stratification.

403. Barton, L.V. 1935. Storage of some coniferous seeds. Boyce Thompson Institute Contr. 7:379-404.

ii) SEED STORAGE, cont'd.

Basically concerned with experiments performed on pines. However a small portion devoted to white spruce. Drying of seeds had no effect on seed quality up to 5 years, at which time, excellent seedling production was obtained under all conditions. Low temperature pre-treatment was not effective for fresher seeds or seeds stored only one year, but became increasingly effective with storage and was most effective after 5 years, when it increased germination from 21 to 88%. Storage temperatures were $-5^{\circ}C$ and $-15^{\circ}C$.

K.W. Picea glauca (white spruce), germination, seed dessication, seed storage, storage temperature, stratification, [Pinus spp.].

404. Barton, L.V. 1953. Seed storage and viability. Contr. Boyce Thompson Inst. 17(2):87-103.

Effects of extended storage under various conditions on the viability of various plant and tree species including Picea glauca are reported. Results show the advantage of reduced moisture content and sealed containers. Rapid deterioration took place at laboratory temperature and at $5^{\circ}C$ in a saturated atmosphere. High germination capacity was retained for 5 years in sealed storage at $5^{\circ}C$ and for 10 years or longer at $-4^{\circ}C$.

K.W. Picea glauca (white spruce), germination, seed storage, storage temperature.

405. Cram, W.H. 1949. A study of seed dormancy of white and Norway spruce. In: Report of Forest Nursery Station, Indian Head, 1948. Canada Dept. Agric.

406. Göskin, A. 1942. [Age determination on seed of spruce and pine.] Forestwissenschaftliches Centralblatt 64:111-117. (Abstr. F.A. 4:102).

Pine and spruce seed stored for several years germinate more slowly than fresh seed. Various methods of determining age of seed are given.

K.W. Picea sp. (spruce), Pinus sp. (pine), germination, seed, seed age.

407. Heit, C.E. 1941. Storage of conifer seed. New York Nursery Notes 10:2-3.

ii) SEED STORAGE, cont'd.

Spruces are relatively intolerant of poor seed storage conditions. Best conditions are afforded by storage in a sealed container at 34-38°F and an initial seed moisture content below 8%.

K.W. Picea spp. (spruce), germination, seed moisture, seed germination.

408. Holmes, G.D. and G. Buszewicz. 1958. The storage of seed of temperature forest tree species. Forestry Abstracts 19:313-322, 455-476.

A complete review of literature on seed storage, treating all species considered in this bibliography. Covered are seed longevity in mature, factors affecting longevity and keeping qualities of seed, seed storage methods, methods of preparation for storage, and effect of seed storage on viability of seed and genetic quality of plants.

K.W. germination, seed storage, seed viability, storage methods.

409. Loebel, M. 1940. [A small experiment on the storage of conifer seed in humus.] Forstwissenschaftliches Centralblatt 1940: 237-242. (Abstr. F.A. 4:101).

Experiments on the storage of coniferous seed in spruce humus and humous quartz sand from a pine stand showed that this form of storage gave only a low germination percent after 10 years, and after 12-13 years, germination was practically nil.

K.W. germination, seed storage, storage media.

410. Rudolf, P.O. 1952. Low temperature seed storage for western conifers. U.S. Dept. Agric., Lake States Forest Experiment Station, Misc. Rept. 20. 8 pp.

Gives data on seed year frequency, and cold storage results from several published sources for various conifers including Picea engelmannii.

K.W. Picea engelmannii (Engelmann spruce), germination, seed production, seed storage.

411. Schubert, G.H. 1952. Germination of various coniferous seeds after cold storage. U.S. Dept. Agric., California Forest and Range Experiment Station, Forest Res. Note 83. 7 pp.

ii) SEED STORAGE, cont'd.

Seed of many species was stored in tins at 41°F for various lengths of time. Care was taken to ensure proper seed treatment before storage. Stratification and germination tests were carried out after various periods of storage. Neither Engelmann spruce nor subalpine fir germinated after 14 years storage. Data for all trials are tabulated.

K.W. Abies lasiocarpa (subalpine fir), Picea englemannii (Engelmann spruce), Pinus contorta (lodgepole pine), germination, seed storage, stratification.

412. Schubert, G.H. 1954. Viability of various coniferous seeds after cold storage. J. For. 52(6):446-447.

Seeds of many coniferous species, including Abies lasiocarpa and Picea engelmannii, were stored at 41°F for various periods of time, up to 21+ years. All germination tests involved initial stratification for 60 days at 36°F. Termination tables are given for all species.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), cold storage, germination, seed stratification, seed viability, seeds.

413. Simak, M. 1966. [Chromosome changes in aging seed.] Skogen 53(2):28-30. (Abstr. F.A. 27:432).

Describes and illustrates in Norway spruce and Scots pine, some of the commonest aberrations in chromosome behaviour resulting from seed storage.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), chromosome change, seed storage.

iii) SEED TREATMENTS AND GERMINATION

The papers in this section report the effects of all methods of seed treatment employed between seed collection and sowing. Such treatments include soaking in water or various solutions, stratification, and other methods to hasten germination or increase germination percent, and also various seed coating treatments to protect the seeds from damage by moulds (molding) or consumption by other organisms. All such treatments have an effect upon germination and/or post-germination seedling growth.

iii) SEED TREATMENT AND GERMINATION, cont'd.

414. Anon. 1948. The pre-treatment of forest seed to hasten germination. Forestry Abstracts 10(2):153-158, 10(3):281-285.

A complete review of treatments used in hastening germination of forest trees species. Included is a section on the theory of seed dormancy as well as reviews of such treatments as scarification, soaking, stratification, and various chemical treatments.

K.W. artificial regeneration, germination, scarification, seed soaking, seeds, stratification.

415. Anon. 1948. Studies of direct seeding [in Ontario]. Forestry Chronicle 24(4):332.

As a result of seed coating, significantly increased survival due to protection from fungi and insects seems to be certain, there is some protection from mice, and coated seeds are definitely less attractive to squirrels. Experiments are now in hand on the addition of trace elements to the coating and choice of fungicide. Germination of seeds on the surface of the ground seems to be improved. There also appears to be a definite increase in the life of seeds in ordinary storage.

K.W. artificial regeneration, fungicides, germination, seed coating, seed consumption, seeding, stratification, wildlife.

416. Barton, L.V. 1930. Hastening the germination of some coniferous seeds. American Journal of Botany 17:88-116.

Prior to germination, cutting tests of the embroys of numerous coniferous seeds were conducted. The seeds were germinated at alternating temperatures, both in ovens and outside. Results indicated a generally favourable effect of low temperature stratification on seed germination. Plantings made after strafication at 5°C for two months appeared to save time and produce more complete seedling stands in the majority of cases.

K.W. Pinus contorta (lodgepole pine), germination, seed, seed treatment, stratification, temperature.

417. Barton, L.V. 1954. Effect of pre-soaking on dormancy of seeds. Contr. Boyce Thompson Institute 17(7):435-438.

Seeds of various species, including Pinus contorta were soaked in different amounts of tapwater at 5 and 20°C for different periods before stratification. None of the treatments hastened germination.

iii) SEED TREATMENT AND GERMINATION, cont'd.

K.W. Pinus contorta (lodgepole pine), germination, seed, seed soaking, stratification.

418. Berry, D.W. 1952. Pumice as a medium for stratifying seeds. Oregon Board of Forestry, Res. Note 5. 7 pp.

Pumice compares favourably with sand and peat for moisture holding capacity, its weight is less than a third that of sand, and it can be obtained in relatively sterile conditions.

K.W. germination, pumice, seed, stratification, stratification material.

419. Brayshaw, T.C. 1953. An approach to the determination of moisture requirements for the germination of seeds of Douglas fir, Ponderosa pine and Engelmann spruce. U.B.C. Forest Club Res. Note 8. 5 pp.

Works on the question of the relationship between soil moisture availability and germination. Seeds were germinated after soaking in sucrose solutions of various osmotic pressures and corresponding moisture availability levels. Engelmann spruce had a poorly marked threshold of germination extending to pF values <3.9.

K.W. Picea engelmannii (Engelmann spruce), Pseudotsuga menziesii (Douglas fir), germination, pF values, seed, soil moisture.

420. Burridge, L.O.W. and E.Jorgensen. 1971. Wetting agents: not always a plus in seed germination. Forestry Chronicle 47:286-288.

Describes a study designed to determine the effects of non-ionic surfactants on tree seed germination and subsequent radicle growth. Two different non-ionic surfactants were used to moisten seeds of eight species. The number of seeds which germinated varied indirectly with the concentration of surfactant used. An increase in surfactant concentration delayed the beginning of germination and extended the time necessary for maximum germination of several species. Picea glauca appeared quite sensitive to the surfactants, giving different results for each treatment level. Increasing surfactant concentration also reduced root radicle growth in all species. It is thought that the surfactants may affect water uptake and potassium balance, as well as nutrient movement.

iii) SEED TREATMENT AND GERMINATION, cont'd.

K.W. Picea glauca (white spruce), germination, non-ionic surfactants, potassium, root growth, seed, wetting agents.

421. Carlson, L.W. and J. Belcher. 1967. Greenhouse evaluation of seed treatment chemicals for the control of conifer seedling damping off. Bi-Monthly Research Notes 23(6):45-46.

Various fungicides were used to treat seeds of conifer species, including white spruce, to control damping off. Results are tabulated. Control of damping off in all tests was rather poor, however, such a greenhouse test is very useful as a preliminary to actual field testing in that it gives an indication of those chemicals that are obviously not useful.

K.W. Picea glauca (white spruce), damping off, fungi, fungicides, germination, seedbed.

422. Carlson, L.W. and J. Belcher. 1969. Seed and soil treatments for control of conifer seedling damping off. Bi-Monthly Research Notes 25(1):4-5.

The chemicals Captan and Arasan were applied to seeds of four conifer species, including Picea glauca, and in another experiment, to the soil in which they were growing. Effects on germination are tabulated. Significant control of damping off was achieved in all species except Picea glauca. Possible reasons for this are given.

K.W. Picea glauca (white spruce), damping off, fungicides, germination.

423. Carmichael, A.J. 1958. Determination of maximum air temperature tolerated by red pine, jack pine, white spruce and black spruce seed at low relative humidities. Forestry Chronicle 34:387-392.

Discusses a study designed to determine the tolerance of seeds of several conifers to various temperature-humidity combinations. A test cabinet was constructed in which temperature and humidity could be controlled. Results showed that a temperature of 180°F resulted in a greater reduction in number of seeds germinated, compared with the 120°F and 150°F. The tests indicate that high temperatures are more damaging when combined with high humidities and applied over a long period of time. The safe limits of exposure for each of the four species tested are given.

iii) SEED TREATMENT AND GERMINATION, cont'd.

K.W. Picea glauca (white spruce), Picea mariana (black spruce), Pinus banksiana (jack pine), Pinus resinosa (red pine), air temperature, exposure, exposure tolerance, germination, humidity, temperature tolerance.

424. Cayford, J.H. and R.M. Waldron. 1966. Storage of white spruce, jack pine and red pine seed treated with arasan, endrin, and aluminum flakes. Tree Planters Notes 77:12-16.

All treated seed, both depth and surface sown, except for surface sown white spruce, produced fewer normal germinates per 100 seed sown, and the reduction were 5-22%. After 1 year of storage for surface sown treated seed there were somewhat fewer normal jack pine and red pine germinates but 80% more normal white spruce germinates than after no storage.

K.W. Picea glauca (white spruce), arasan, endrin, fungicides, germination, pesticides, seed, seed treatment, seeding, seeding method, [Pinus banksiana, Pinus resinosa].

425. Cayford, J.H. and R.M. Waldron. 1967. Effects of captan on the germination of white spruce, jack and red pine seed. Forestry Chronicle 43(4):381-384.

Captan 50-W, a fungicide with certain rodent repellent qualities, is phytotoic to seeds, but its effect on germination varies depending upon sowing method. It significantly increased germination of surface sown seed and decreased germination of depth sown seed. For both sowing methods, it increased the proportion of abnormal germinants. The net effect was the decrease in number of normal germinants for both sowing types.

K.W. Picea glauca (white spruce), artificial regeneration, captan, fungicide, germination, seeding, seeding method, [Pinus banksiana].

426. Cram, W.H. 1951. Spruce seed viability: dormancy of seed from four species of spruce. Forest Chronicle 27(3):349-357.

Investigates the influence of stratification and/or storing under different temperatures and for different periods upon the germination of seed from four spruce species, including Picea glauca.

K.W. Picea glauca (white spruce), germination, seed storage, stratification, [Picea spp.].

427. Crossley, D.I. and L. Skov. 1951. Cold soaking as a pre-germination treatment for white spruce seed. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 59. 4 pp.

iii) SEED TREATMENT AND GERMINATION, cont'd.

White spruce seed was subjected to cold soaking for various periods between ten to twenty days, with water changing as an additional variable. Seeds were then germinated and counted. A period of about thirty days was necessary for complete germination after cold soaking. Cold soaking gave significantly greater germination than unsoaked controls, with the twenty day period better than shorter periods. Changing water lowered the rate of germination as compared to unchanged samples.

K.W. Picea glauca (white spruce), artificial regeneration, cold soaking, germination, seed seed treatment.

428. Curtis, J.D. 1958. Germinative capacity of Engelmann spruce seed. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Res. Note 58. 3 pp.

Engelmann spruce seed was collected from various sources and stored from October to March at $36^{\circ}F$. Some seed was stratified in moist sphagnum for 5 weeks before germination. Stratification produced a slightly higher average of viability - 62.9% v.s. 60.5% for unstratified but also increased germinative energy. After 8 days, 93.3% of total germination had occurred in the stratified seed lot and only 60.1% in the unstratified.

K.W. Picea engelmannii (Engelmann spruce), germination, germinative energy, seed, seed storage, stratification.

429. Day, R.J. and S.T. Griffiths. 1967. The effects of stratification method, seed size and weight on the germination and growth of white spruce seedlings. Univ. Toronto, Forest Research Review. p. 8.

A comparison of the germination of standard cold stratified white spruce with size-graded hydrogen peroxide stratified seed showed that those subjected to the H_2O_2 treatment gave a higher germination percentage, but had inferior growth. The effect of size grading was to increase seedling size. Size grading did not effect vitality.

K.W. Picea glauca (white spruce), artificial regeneration, germination, H_2O_2, seedling grading, seedling growth, stratification.

430. Delevoy, G. 1948. [Note on a test of preventative treatments of the soil and conifer seeds, against damping off.] Bull. Soc. For. Belg. 55(7):238-243. (Abstr. F.A. 10:184).

iii) SEED TREATMENT AND GERMINATION, cont'd.

Various treatments of soil and of seed to prevent damping off in nurseries were tried, both alone and in combination. Both seed treatments tried proved harmful, and these harmful effects were in almost all cases aggravated by soil treatments. Formic acid treatment of the soil alone appeared to be efficaceous in protecting untreated spruce seed.

K.W. Picea sp. (spruce), damping off, formic acid, germination, nurseries, seed treatment, seedbed treatment.

431. Dobbs, R.C. 1971. Effect of thiram - endrin formulations on the germination of jack pine and white spruce seed in the laboratory. Tree Planters Notes 22(3):16-18. (REPR).

Total germination of jack pine was reduced and of white spruce was prevented by treatments containing endrin liquid or its solvent. Thiram had no effect on jack pine germination but significantly reduced white spruce treatment. Endrin powder did not significantly affect germination of either species.

K.W. Picea glauca (white spruce), artificial regeneration, endrin, germination, seed, seeding, thiram.

432. Edgren, J.W. 1968. Potential damage to forest tree seed during processing, protective treatment, and dissemination. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Note PNW-89. 8 pp.

Seed is susceptible to damage each time it is handled. Damage may be inflected during various steps in processing, treatment with chemicals, or dissemination by seeding devices. There is evidence that seed damage is cumulative. Thus, each new bump or treatment may bring the seed closer to death. Some present practices cause damage to seed, but the contribution to impaired germination from each possible source of damage is not known.

K.W. artificial regeneration, germination, seed damage, seed dissemination, seed handling, seeding.

433. Farrar, J.L. 1961. Stratification tests in Picea glauca and Pinus strobus. Univ. Toronto, Forest Research Review. p. 10.

iii) SEED TREATMENT AND GERMINATION, cont'd.

Seeds were stratified at 34-38°F in a roll of damp cloth wrapped in plastic sheeting. Stratification for 28 days gave higher and prompter germination than controls. Only after 140 days of stratification did seed begin to deteriorate seriously.

K.W. Picea glauca (white spruce), Pinus strobus (white pine), artificial regeneration, germination, nurseries, stratification.

434. Grover, R. 1962. Effect of gibberellic acid on seed germination of elm, Scotch pine, Colorado and white spruce. Forest Science 8(2):187-190.

Gibberellic acid had no effect upon germination of white spruce seeds in any concentration applied.

K.W. Picea glauca (white spruce), germination, gibberellic acid, growth regulators, seed.

435. Heit, C.E. 1961. Laboratory germination and recommended testing methods for 16 spruce (Picea) species. Association of Official Seed Analysts 51:165-171.

White spruce is one of the most dormant species, but 20°C-30°C alternating temperature with artificial light resulted in maximum accurate germination within 21 days without pre-chilling treatment.

K.W. Picea glauca (white spruce), germination, seed dormancy, seed treatment, stratification.

436. Hellum, A.K. 1968. A case against cold stratification of white spruce seed prior to nursery seeding. Canada, Forestry Branch, Publ. 1243. 12 pp.

Cold stratified seeds of white spruce were lower in total germination than unstratified seeds and had irregular rates of nursery germination. Cold stratification caused only a slight increase in total dry weight and taproot length in one-year-old germinants of white spruce.

K.W. Picea glauca (white spruce), artificial regeneration, germination, nurseries, seeding, seedling growth, stratification.

437. Hocking, D. 1972. Effects of stratification of Alberta white spruce and lodgepole pine seeds on emergence in operational seedbeds. Bi-monthly Research Notes 28(4):26-27.

iii) SEED TREATMENT AND GERMINATION, cont'd.

Stratified and non-stratified seeds of Picea glauca and Pinus contorta were sown and examined for germination. Final seedling stands were significantly superior in more non-stratified seedlots than stratified seedlots, for both Picea glauca and Pinus contorta. While those results for lodgepole pine confirm normal practice, the results for white spruce were complex and not wholly consistent. Explanations are given.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, germination, seeding, seedling survival, stratification.

438. Huss, E. 1950. [Damage to seeds by dewinging.] Medd. Skogsforskn Inst., Stockholm 39(3):1-56. (ABSTR.).

Germination capacity of spruce and pine seeds was found to decrease and in some cases disappear after a short dewinging period. It decreased more rapidly when dewinging was carried out at a greater speed. The germination capacity seemed to decrease more rapidly at the beginning than at the end of the treatment. Blows or dropping reduced germination capacity. It is possible that some chemical change is responsible. Roughly handled seeds give weaker plants. It is estimated that 10-20% of the yearly seed harvest is destroyed by dewinging.

K.W. Picea sp. (spruce), Pinus sp. (pine), germination, seed, seed damage, seed dewinging.

439. Johnson, L.P.V. 1946. Effects of chemical treatments on the germination of forest tree seeds. Forestry Chronicle 22(1):17-24.

Chemical treatments of many different kinds were tested, in comparison with stratification and presoaking, for their effects on seedling growth rate and those on germination of seeds of many forest trees, including Picea glauca.

K.W. Picea glauca (white spruce), chemical seed treatment, germination, pre-soaking, seedbed, seed treatment, seedling growth, stratification.

440. Jones, L. and K. Havel. 1968. Effect of methyl bromide treatments on several species of conifer seed. J. For. 66(11): 858-860.

iii) SEED TREATMENT AND GERMINATION, cont'd.

Imported (from Europe) seed of several species, including Picea glauca, were subjected to several fumigations with methyl bromide. Results showed that seed should have a low moisture content before fumigation. Unfumigated seed with a 15% moisture content had a significant reduction in germination at the end of three weeks.

K.W. Picea glauca (white spruce), fumigation, germination, methyl bromide, seed, [Pinus sp., Picea sp.].

441. Karlbag, S. 1953. [Treatment of pine and spruce seed to stimulate germination.] Skr. K. Skogshögsk., Stockholm, No. 11. 42 pp.

Soaking increases germination percent by 30-60% under most conditions, and germination rate is often increased. No significant differences were found between various soaking media of pH 5-6, which is optimum. Spruce seed soaked for 24 hrs. gave better results than when soaked for 12 hrs. This was not found in pine. Treating seed with Germisan and seedbed with Kerol to reduce damping off, did not reduce germination.

K.W. Picea sp. (spruce), Pinus sp. (pine), germination, seed, seed soaking, seed treatment.

442. Lakon, G. 1955. [The effect of de-winging processes on the viability of spruce seed.] Saatgutwirtschaft, Stuttgart 7(6):175-176.

Careful wet de-winging of spruce seed did not affect immediate germinative capacity, but greatly depressed it over a period of 2 years.

K.W. Picea spp. (spruce), germination, seed de-winging, seed treatment.

443. Larsen, J.A. 1918. Comparison of seed testing in sand and in the Jacobsen germinator. J. For. 16:690-695.

Compares the use of sand and the Jacobsen germinator as methods of testing seed germination. In the germinator, seeds were placed on a layer of filter paper overlaying a wollen mat and a cotton mat with moisture, heat and air circulation controlled. In the other test, seeds were placed on the sand and covered with water to keep them from drying. In the germinator, a higher percentage of seeds germination, results were more uniform, and it was easier to duplicate and standardize. Studies are underway to explain why germination was more rapid in the germination.

iii) SEED TREATMENT AND GERMINATION, cont'd.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), germination, seed, seed testing, seedling mortality, seedling survival.

444. Leslie, A.P. 1947. Coated seeds for forest renewal. Canadian Pulp and Paper Assoc., Proc. Woodlands Section 29:37-38.

Coating seeds of white spruce and other species with powdered feldspar and/or flyash before aerial sowing improves keeping qualities of seed and germination without soil covering when moisture and temperature conditions are favourable. Attack by rodents is reduced. The addition of repellants and fungicides to the coating further increases the margin of protection.

K.W. Picea glauca (white spruce), artificial regeneration, aerial seeding, fungicides, seed coating, seed germination.

445. MacArthur, J.D. 1962. Germination of white spruce seed at low temperature. Canada, Dept. Forestry, Forest Research Lab, Quebec, Mimeo Que. 62-4. 4 pp.

During stratification at 40°F for a period of a year, many white spruce seeds germinated. Silvicultural implications are discussed.

K.W. Picea glauca (white spruce), germination, silviculture, stratification.

446. MacGillivray, H.G. 1955. Germination of spruce and fir seed following different stratification periods. Forestry Chronicle 31(4):365.

Germination tests were made for various species, including white spruce seed, stratified for different times. Results of the tests are tabulated. Severe loss of viability occurs at stratification times greater than 14 months.

K.W. Picea glauca (white spruce), artificial regeneration, germination, seed, seed viability, stratification.

447. Markova, I.A. 1968. [Pre-treatment of seed with trace elements.] Lesn. Hoz. 1968(5):48-50. (Abstr. F.A. 30:261).

iii) SEED TREATMENT AND GERMINATION, cont'd.

Seeds of spruce and pine soaked for 18-20 hours in solutions of salts of Cu, B, Mo, Mn, Co, Z, or mixture did not show significantly improved germination or germinative energy but did show improved seedling growth as expressed by seedling dry weight.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), germination, seed, seed treatment, seedling growth.

448. Phipps, H.M. 1969. Artificial light - a possible pretreatment method for dormant white spruce. Tree Planters Notes 20(2):9-10.

Tests indicate that artificial light may be a time-saving and effective pretreatment for some white spruce seed. The light treatment effect is to a large extent retained after drying and storing in a refrigerator for as much as 25 days.

K.W. Picea glauca (white spruce), germination, light, seed, seed storage, stratification.

449. Roche, L. 1964. E.P. 622 - Factors affecting germination behaviour of interior spruce. B.C. Forest Research Review. pp. 33-35.

Investigates the influences of diverse environments on the germination of seeds from 13 different provenances, and the extent to which seed quality influences germination behaviour. Germination behaviour of each provenance various within and between temperature treatments. Effectiveness of stratification varied with provenance and temperature.

K.W. Picea sp. (spruce), germination, provenance, regeneration, seed quality, stratification.

450. Rudolf, P.O. 1950. Cold soaking - a short cut substitute for stratification? J. For. 48(1):31-32.

Explanatory tests indicate that cold water soaking of seeds of some Lake State conifers, including white spruce, for one or two weeks may be as effective in overcoming internal dormancy as cold stratification for one to three months.

K.W. Picea glauca (white spruce), dormancy, germination, seeds, seed-soaking, stratification, [Abies sp., Larix sp., Pinus sp., Picea sp.].

iii) SEED TREATMENT AND GERMINATION, cont'd.

451. Santon, J. 1970. Effect of stratification on germination of freshly harvested seed of several spruce and pine species in eastern Canada. Canada, Forestry Service, Petawawa Forest Experiment Station, Chalk River, Info. Rept. PS-X-17. 22 pp.

Seeds of several species, including white spruce were stratified at 34°-38°F for various periods. Only 4.8% of unstratified seed germination, compared to 33.5%, 54.8%, 52.8% and 62.0% of seed stratified for 1, 2, 3, and 4 weeks, respectively. It is felt that the minimum stratification time for white spruce is at least 4 weeks.

K.W. Picea glauca (white spruce), artificial regeneration, germination, seeding, stratification, [Picea sp., Pinus sp.].

452. Shivanagi, N.V. and D. Hocking. 1968. Individually specific effects of cold stratification upon germination of geograhically distinct seed lots of Alberta white spruce. Canada, Forestry Branch, Forest Research Lab, Calgary, Internal Rept. A-13. 13 pp.

An average increase of 12% in total germination might be obtainable by stratification, but only at periods highly specific for each seed lot. There is a mild trend towards faster germination with increasing time of stratification. The time before germination begins tends to be reduced by an average of 2.5 days for any period of strafification. Recommends that good seed lots be used without stratification.

K.W. Picea glauca (white spruce), artificial regeneration, germination, seed, stratification.

453. Shoup, J.M. 1967. Effect of various powders on the field germination of white spruce and jack pine seed. Canada, Forestry Branch, Forest Research Lab, Manitoba, Internal Rept. MS-55. 5 pp.

Tests the influence of baby powder on the germination of field sown white spruce and jack pine. Germination for both species was low. Influences of baby powder, Captan 50W and A.E.A. treated seed are tabulated.

K.W. Picea glauca (white spruce), baby powder, captan, germination, herbicides, seed treatment.

454. Shoup, J.M. 1968. Effects of various powders on the field germination of white spruce and jack pine seed. Canada, Forestry Branch, Forest Research Lab, Internal Rept. MS-75. 4 pp.

iii) SEED TREATMENT AND GERMINATION, cont'd.

Experiment to test results of the addition of baby power on seed germination of field sown white spruce and jack pine. Plots were scalped and cultivated. Seeds were treated with, 1) Captan 50W, 2) a mixture of Arasan 75, Endrin 75W and aluminum flakes or, 3) baby powder. At Riding Mountain, baby powder did not significantly increase germination over the other treatments.

K.W. Picea glauca (white spruce), artificial regeneration, baby powder, captan, endrin, fungicides, germination, seed treatment, seeding, [Pinus banksiana].

455. Shoup, J.M. 1968. Effects of various powders on the field germination of white spruce and jack pine seed. Canada, Forestry Branch, Forest Research Lab, Manitoba, Internal Rept. MS-80. 3 pp.

Due to plot contamination, reports results for jack pine only.

K.W. Picea glauca (white spruce), artificial regeneration, baby powder, germination, herbicides, seed treatment, seeding, [Pinus banksiana].

456. Shumilina, Z.K. 1940. [General methods of stratification for the seed of tree and shrub species.] Lesnoe. Khozyaystvo. Moskva 1940(2):32-36. (Abstr. F.A. 2:36).

Outlines principles evolved from foreign and Russian experience. Evidence shows that peat is the best substance for stratification, with pure, washed sand an acceptable substitute. Temperature and moisture requirements are stated, and Russian experience outlines.

K.W. artificial regeneration, germination, seed, stratification, stratification media.

457. Stewart, M. and K. Illingworth. 1961. E.P. 522 - Experimental seeding of spruce, Nelson Forest District. B.C. Forest Research Review. p. 32.

Reports an unfinished experiment dealing with the influence of seed poisoning for control of small mammals upon the germination of seed broadcast at various rates. The experiment was unsuccessful as a result of poor or no germination in either the control or experimental plots. Also reported 1959 - p. 50, 1960 - p.37.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, germination, mammals, poisoning, seed, seed consumption, seeding.

iii) SEED TREATMENT AND GERMINATION, cont'd.

458. Trappe, J.M. 1961. Strong hydrogen perioxide for sterilizing coats of tree seed and stimulating germination. J. For. 59(11):828-829.

Soaking for 1/2 - 1 hour in a 35% solution of H_2O_2 effectively sterilized conifer seed surfaces. Most species tested withstand >1 hour without apparent injury. Soaking for 1/2 - 2 hours, depending on thickness of seed coat, also markedly stimulated rate of germination.

K.W. germination, hydrogen perioxide, seed soaking, seed sterilization.

459. Waldron, R.M. and J.H. Cayford. 1965. Effects of seed treatments with fungicides and repellents on the germination of white spruce, jack and red pine. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 65-MS-4. 30 pp.

A study of the influences of Captan 50W, Arasan-75, Dexon, Chemagro 2635, and a bird and rodent repellent mixture of Arasan 75, Endrin, and aluminum flakes on the germination of white spruce and red and jack pine was made. Captan 50-W was toxic to tree seeds, but the degree of influence depended upon the manner of sowing seed. In many cases it hastened germination, but in all cases, it reduced the number of normal germinants. Dexon and Chemagro reduced germination and caused a marked abnormality in 90% of the germinants, while Arasan had effects similar to those of Captan. Treatment with Arasan-Endrin-aluminum reduced white spruce and red pine normal germinants, but increased those of jack pine.

K.W. Picea glauca (white spruce), artificial regeneration, biocides, fungicides, germination, seed, seeding, seedling growth, [Pinus banksiana, Pinus resinosa].

460. Waldron, R.M. and J.H. Cayford. 1967. Improved germination of white spruce seed by increasing moisture content with absorptive powders. Forestry Chronicle 43(2):140-154.

Greenhouse studies have shown that pelleting white spruce seed with baby powder and Captan 50W significantly increased germination under exposed conditions. When Captan 50W was used, the germinants were largely abnormal. Increased germination was apparently due to more rapid absorption of water and the development of a moisture uptake system resistant to evaporative stresses.

iii) SEED TREATMENT AND GERMINATION, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, baby powder, captan, germination, seeding, soil moisture, water conservation.

461. Yli-Vakkuri, P. 1959. [Machines for abrading seed wings and their influence on the germinative capacity of the seed.] Acta Forestalia Fennica 68:1-13. (Abstr. F.A. 20:545).

Abrasion by two de-winging machines on seed of pine and spruce causes slight or in some cases even serious injuries. Slight injuries to 5% of seed may have to be accepted in machine de-winging.

K.W. Picea sp. (spruce), Pinus sp. (pine), germination, seed, seed damage, seed de-winging.

B. SEEDLINGS AND THE NURSERY

This section is concerned with all aspects of nursery production of tree seedlings for artificial regeneration. Included are seeding, methods of seedbed cultivation, fertilization, weeding and all aspects of seedling treatment in preparation for planting in the field. Some relevant greenhouse and laboratory studies are also included. Many descriptive articles are included in this section.

i) BARE ROOT STOCK

Nursery production of normal planting stock and transplants is dealt with in this section.

i) BARE ROOT STOCK, cont'd.

462. Anon. 1951. Root rot of *Picea glauca* in nurseries. New York State Conservation Dept., Rept. 1950. p. 68. (Abstr. F.A. 13:279).

Disease occurs mainly in 1 and 2 year-old seedbeds. Often due to excessive increase in soil fertility caused by the over-use of cover crops.

K.W. *Picea glauca* (white spruce), nurseries, root-rot, soil fertility.

463. Anon. 1959. The effects of fertilizers on the growth of white spruce seedlings at St. Williams, Ont. Ontario, Dept. of Lands and Forests, Tech. Bull. T17-6A. 3 pp.

464. Anderson, S.A. 1972. E.P. 680.02 - Spacing effects upon the development of rising 2 + 0 interior spruce and lodgepole pine at Red Rock Research Centre. B.C. Forest Research Review. pp. 30-32.

Studies the effects of various spacings on the development of 2 + 0 spruce and 2 + 0 pine seedlings at Red Rock Nursery and Research Centre. 3 types: broadcast-sown spruce, drill-sown spruce and drill-sown pine, were all thinned to various density levels. Seedlings were lifted at 2 + 0, oven-dried, and weighed, and root collar diameter was measured. All results are given in detail. Generally, results indicate that seedling dry weight and stem diameter increased as seedbed density is reduced.

K.W. *Picea glauca* (white spruce), *Pinus contorta* (lodgepole pine), artificial regeneration, nurseries, seedling growth, seedlings, spacing, thinning.

465. Armit, D. 1964. Dunemann seedbeds at Telkwa. B.C. Forest Research Review. pp. 59-60.

White spruce seed was planted in the Dunemann system in an attempt to reduce frost heaving. It was noted that such a system does reduce frost heaving, and requires much less weeding. The costs, however, are no less than normal seedling growing. The seedlings are vigorous but small, and would probably be better as 3 + 0 stock. Also reported 1960 - p. 51, 1961 - p. 38. Author in 1960, K. Illingworth.

K.W. *Picea glauca* (white spruce), artificial regeneration, Dunemann system, frost heaving, nurseries, planting, seedbed, seedlings.

i) BARE ROOT STOCK, cont'd.

466. Armit, D. 1968. E.P. 649 - White spruce planting stock study, Fort Babine, 1965. B.C. Forest Research Review. pp. 73-74.

Four classes of one white spruce provenance grown at Telkwa Nursery are examined for differences in survival, early development, and response to environment. All data for each stock are tabulated and recommendations for use are made. Also reported 1966 - pp. 69-70.

K.W. Picea glauca (white spruce), artificial regeneration, planting, provenance, seedling survival.

467. Armson, K.A. 1960. White spruce seedlings: the growth and seasonal absorption of nitrogen, phosphorous and potassium. Univ. Toronto Press, Forestry Bull. 6. 37 pp.

During the first two growing seasons, white spruce seedlings were studied to determine growth and changes in nitrogen, phosphorous and potassium content. Relative growth rates and net assimilation rates were calculated for the seedlings. During the second growing seaon, ammonium sulphate, ammonium phosphate, and potassium sulphate were applied in two applications, one month apart. Results showed growth and assimilation rates as lower in the second year. If the size, relative growth rate, and time between samples is taken into account, it appears that there was no evidence of a seasonal periodicity of absorption of nitrogen and potassium. However, phosphorous showed two periods of high uptake rates per year, one in May-June and one in August-Sept.

K.W. Picea glauca (white spruce), fertilization, nutrient uptake, nitrogen, potassium, phosphorous, seedling growth.

468. Armson, K.A. 1962. The growth of white spruce seedlings in relation to temperature summation indices. Forestry Chronicle 39(4):439-444.

The growth of white spruce seedlings in an Ontario nursery was measured during the first two growing seasons. The relationships between seedling growth and time, when expressed in degree-days, were exponential. A discussion of the advantage of using such a relationship is included.

K.W. Picea glauca (white spruce), artificial regeneration, growth increment, planting, seedlings, temperature.

i) BARE ROOT STOCK, cont'd.

469. Armson, K.A. 1965. The effects of soil fertility and seedbed density on the growth of white spruce and red pine seedlings. Univ. Toronto, Forest Research Review. p. 2.

White spruce and red pine seedlings were grown at Orono Nursery for two growing seasons at 3 different fertility levels and 4 seedbed densities. For white spruce, both increase in fertility and decrease in seedbed density resulted in heavier and taller seedlings. Growth of white spruce is limited by nitrogen supply and white spruce, especially at low fertility levels is much less efficient than red pine at absorbing nitrogen from soil. Total seedling dry matter production increased with increase in seedbed density.

K.W. Picea glauca (white spruce), artificial regeneration, fertilization, nitrogen, nurseries, planting density, seedling growth, [Pinus resinosa].

470. Armson, K.A. 1968. The effects of fertilization and seedbed density on the growth and nutrient content of white spruce and red pine seedlings. Univ. Toronto, Faculty of Forestry, Tech. Note 10. 16 pp.

Seeds of white spruce and red pine were sown in nursery in Nov. 1962. Fertilization at 3 levels with N, P and K and thinning to four seedbed densities was carried out in mid 1963. Sampling was done in late 1964. For both species there was an increase in seedling weight with decreasing seedling density. In white spruce, with exception of lowest density there was an increase in weight at a given density with increase in fertility. Red pine does note show this. Height of white spruce increases generally with decrease in density and increase in fertility. Red pine heights were unaffected by density or fertility. For both species, the only significant increases in shoot / root ratios occurred at highest density and fertility levels.

K.W. Picea glauca (white spruce), artificial regeneration, fertilization, nurseries, planting, phosphorous, potassium, seedling growth, seedling weight, shoot root ratio, thinning, [Pinus resinosa].

471. Armson, K.A. and T.I.W. Bell. 1965. The effects of pre-treatment on the growth of white spruce seedlings. Univ. Toronto Forest Research Review. p. 4.

i) BARE ROOT STOCK, cont'd.

White spruce seedlings grown in the nursery under various combinations of fertility and seedbed stocking were lifted, subjected to a period of chilling and replanted in a greenhouse under conditions simulating spring planting. Height and diameter growth were measured throughout growing season. Seedlings from highest fertility level and seedbed stocking of 20 per $ft.^2$ gave greatest growth response.

K.W. Picea glauca (white spruce), artificial regeneration, chilling, fertilization, nureries, planting, planting density, seedling growth, seedling pre-treatment.

472. Aun, H. 1944. [Experiments in raising plants by a patented process.] Forstarchiv 20:59-60. (Abstr. F.A. 7:465).

Reviews the Dunemann seedbed method of raising seedlings. Trials in Germany with many species indicate that growing stock raised in this manner is superior to that raised by ordinary nursery means. The economics of the use of this system are not investigated.

K.W. artificial regeneration, Dunemann seedbed, nurseries, planting, seedling growth, seedling quality.

473. Bamford, A.H. 1970. Innovations in present nursery production of conventional planting stock. Forestry Chronicle 46(6): 481-486.

Nursery production and all contributing factors are examined with respect to technical innovations and developments. All aspects of nursery production are examined and key points of these aspects are emphasized.

K.W. artificial regeneration, economics, nurseries.

474. Bell, T.I.W. 1968. Effect of fertilizer and density pretreatment on spruce seedling survival and growth. G.B. Forestry Commission: Forest Record 67. 35 pp.

White spruce seedlings gave the best results in survival and field growth, where the heaviest of three fertilizer rates was applied (120 lbs. N, 360 lbs. P per acre). There was an indication that time of fertilizer application affected survival but differences in results were slight. Heavy fertilization applied to stock grown at 20 per $ft.^2$ is optimum treatment for planting stock production.

i) BARE ROOT STOCK, cont'd.

K.W. Picea glauca (white spruce), fertilization, growing density, nitrogen, nurseries, phosphorous, planting stock, potassium, root growth, seedling growth, seedling survival.

475. Bjørkman, E. 1953. [Factors arresting growth of spruce after planting on forest land in N. Sweden.] Norrlands SkogsvFörb. Tidskr. 1953(2):285-316. (Abstr. F.A. 15:43).

Plants put out on sites poor in nutrients give better growth if they have received a moderate dose of fertilizer in the nursery; excessive treatment with fertilizers in the nursery is associated with higher mortality after transplanting; 2 + 0 seedlings grow more strongly than 3 + 0 plants, but mortality is higher among the former, probably because they are rather small to handle without damage during planting; and mortality for both 2 + 0 and 3 + 0 plants from poorer nursery sites is higher than for those from better sites.

K.W. Picea sp. (spruce), artificial regeneration, fertilization, mycorrhizae, planting, planting stock, seedling mortality, site type, soil,

476. Bloomberg, W.J. 1963. Use of organic residue in forest nurseries. Canada, Dept. Forestry, Bi-Monthly Progress Rept. 19(6):4.

Organic residues such as hay and mushroom manure have been added to nursery soils to reduce frost-heaving or increase growth. However, growth of various fungi has followed applications in many instances and some have been pathogenic. Of the types of mulches used, fresh sawdust seems preferable. Recommendations for routine assays of the microbial content of materials intended as additives are made.

K.W. Pseudotsuga menziesii (Douglas fir), fungal infection, fungi, microbial content, mulching, nurseries, organic residues.

477. Boyd, R.J. 1971. Effect of soil fumigation on production of conifer nursery stock at two northern Rocky Mountain Nurseries. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Res. Pap. INT-9. 19 pp.

Soil fumigation improved production of Douglas fir, western white pine, Engelmann spruce and ponderosa pine stock at two northern Rocky Mountain nurseries. Benefits more than compensated for cost of fumigation. Fumigation also provided more predictable and uniform seedling stands. Late summer application of methyle-bromide based fumigants has provided the most dependable overall improvement in nursery operations.

K.W. Picea engelmannii (Engelmann spruce), Pseudotsuga menziesii (Douglas fir), artificial regeneration, fumigation, herbicide, nurseries, planting, seedling mortality, [Pinus monticola, Pinus ponderosa].

478. Burgar, R.J. 1963. Black and white spruce benefit from shading in 1-0 year. Ontario Dept. of Lands and Forests, Nursery Note 2. 4 pp.

By erecting shades which give 50% shade, over newly germinated white and black spruce seedbeds the adverse effects of sun and wind on the seedlings are reduced. Since the shading results in higher seed to 1-0 survival rate of these two species, the process will be continued.

K.W. Picea glauca (white spruce), Picea mariana (black spruce), artificial regeneration, nurseries, seedbed, seedling survival, shading.

479. Clausen, J.J. and T.T. Kozlowski. 1966. Effect of atrazine on water relations of needles of white spruce nursery stock. Forest Science 12(3):338-341.

Effects of atrazine on water relations of needles of 2-2 and 3-0 Picea glauca were studied in the nursery. The current years needles of 2-2 plants decreased significantly in water content after treatment at 16 lb./acre but not at 4 or 8 lb./acre. The 3-0 seedlings were sensitive to all treatments, but the greatest decrease in moisture content resulted from 16 lb./acre treatment.

K.W. Picea glauca (white spruce), herbicide, nurseries, seedling mortality, seedlings, water relations.

480. Cockerill, J. 1957. Experiments in the control of the damping off at the nursery, Orono, Ontario. Forestry Chronicle 33(3):201-204.

i) BARE ROOT STOCK, cont'd.

Soil acidification treatment using ferrous sulphate and sawdust mulch were not effective in controlling damping off losses in forest nursery seedbeds at Orono, Ontario. Soil fumigation with methyl bromide resulted in reduced pre-emergence losses and consequent higher emergences of seedlings. This treatment, however, failed to provide adequate protection during a period of severe damping off. Total mortality in fumigated beds was comparable to that recorded in untreated beds. The failure of methyl bromide to provide continued protection during the period of severe damping off limits its use as a control treatment.

K.W. damping off, fungi, fungicide, mulching, nursery, seedbed, seedling mortality.

481. Cockerill, J. 1961. The effect of chlordane and thiram on damping off and seedling growth. Forestry Chronicle 37(3):211-216.

Chlordane, applied to seedbeds of red pine to control white grub infestation, increased seedling mortality due to damping off in these beds. Losses were significantly reduced when the seed was pelleted with thiram prior to sowing. Neither chlordane nor thiram, alone or in combination, had any apparent adverse effect on seedling growth, root development, or the formation of mycorrhizae.

K.W. artificial regeneration, chlordane, damping off, fungicides, pesticides, seedling mortality, thiram, [*Pinus resinosa*].

482. Devitt, B. 1970. Developments in nursery practices: an illustrated review and report on current nursery practices. In: Western Reforestation, Western Forestry And Conservation Assoc., Proc. Western Reforestation Co-ordinating Committee, Ann. Rept. 1970. pp. 30-34.

Outlines all aspects of current nursery practice in British Columbia.

K.W. artificial regeneration, containers, fertilization, herbicides, irrigation, lifting, nurseries, planting, root pruning, seeding, seedling grading, seedling storage.

i) BARE ROOT STOCK, cont'd.

483. Dickson, A., A.L. Leaf and J.F. Hosner. 1960. Seedling quality - soil fertility relationships of white spruce and red and white pine in nurseries. Forestry Chronicle 36(3):237-241.

An index based on combined morphological features of seedlings was used to relate seedling quality to different levels of nursery soil fertility, as determined by soil and seedling analyses. Nutrient content on a per seedling basis was closely related to seedling quality.

K.W. Picea glauca (white spruce), nurseries, seedbed, seedling grading, seedling quality, seedlings, soils, [Pinus resinosa, Pinus strobus].

484. Edwards, D.G. 1973. Effect of a soil wetting agent on germination of four important British Columbia conifers. Forestry Chronicle 49(3):126-129.

Five concentrations of Soil Wet were tested in vitro on the germination of conifer seeds including those of white spruce and lodgepole pine. Germination of all species was completely inhabited by 1% solution of soil wet and significantly reduced by 0.1%. There was no significant effects with 0.01% or 0.001%. Germination rate was also affected but in a minor way. 0.1% solution sigificantly reduced radical length in Douglas fir and both spruces. In Sitka spruce, 0.01% increased radical length, and both 0.01% and 0.1% increased hypocotyl length. Since 0.1% is recommended for greenhouse and nursery soil preparation, a definite phytotoxicity will be noted if soil characteristics do not alter the situation.

K.W. Picea glauca (white spruce), Picea sitchensis (Sitka spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, containers, germination, planting, phytotoxicity, soil, wetting agent.

485. Etter, H.M. 1969. Growth, metabolic components and drought survival of lodgepole pine seedlings at three nitrate levels. Can. J. Plant Sci. 49:393-402.

Lodgepole pine seedlings were grown for 6 weeks in controlled environment using nutrient solutions giving 2 rates of nitrate. Increased nitrate produced plants with smaller root/leaf weight ratios and higher moisture contents in the leaves. Seedlings grown at the highest nitrate level had lowest survival when the three treatments were held without watering for a two week period. However, nitrate level altered drought survival less if the three treatments were stressed to the same final moisture content in the growth medium.

i) BARE ROOT STOCK, cont'd.

K.W. Pinus contorta (lodgepole pine), drought, fertilization, irrigation, nitrogen, seedling survival.

486. Etter, H.M. 1971. Nitrogen and phosphorus requirements during the early growth of white spruce seedlings. Canadian Journal of Plant Science 51:61-63.

Describes an experiment designed to determine whether white spruce would respond to different external levels of nitrogen or phosphorus in conditions similar to those used in a previous study with lodgepole pine. Plants were grown in perlite vermiculite and harvested 6 weeks after sowing. Nutrient solutions were added to each plant Results showed that increases in nitrogen supply caused growth responses in the leaves but not in roots, but stem dry weights didn't show significant differences. Conclusions were that high nitrogen on phosphorus nutrition levels cannot be used for promoting root growth in the first 6 weeks of growth. A solution containing 50-60 ppm N as ammonium nitrate, and 6-7 ppm P is adequate.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), nitrogen, phosphorus, root growth, seed, seedling growth.

487. Girouand, R.M. 1970. Vegetative propagation of spruce. Bi-Monthly Research Notes 26(4):41.

Examines the ability of various species of spruce, including Picea glauca, to root from cuttings. Details of the experiment are given together with a table of results. Picea glauca proved intermediate among spruce species in root formation.

K.W. Picea glauca (white spruce), artificial regeneration, cuttings, rooting, vegetative propagation.

488. Grover, R. 1968. Response of conifer seedlings and weeds to seedbed fumigants. Canadian Journal of Plant Science 48(2): 189-196.

Allyl alcohol, dazomet, metam, and MeBr containing 2% chloropicrin were tested at 3 rates each as pre-sowing treatments for weed control and to measure tolerance of 3 species including white spruce to treatments. Most treatments gave 80-90% weed control, but weeds that did escape, grew well. Most treatments did not affect emergence and growth of conifers.

i) BARE ROOT STOCK, cont'd.

K.W. Picea glauca (white spruce), fumigation, germination, herbicides, nurseries, seedbed, seedling growth, [Pinus sylvestris, Picea pungens.]

489. Hanover, J.W. and D.A. Reicosky. 1972. Accelerated growth for early testing of spruce seedlings. Forest Science 18(1): 92-94.

A method is described for accelerating juvenile growth and development of trees for early progeny evaluation and plantation establishment. Picea pungens and Picea engelmannii were grown in a Michigan greenhouse under controlled conditions of temperature, nutrient levels, water, and continuous light. The seedlings were ready for outplanting in permanent genetic test plantation after 8 months. The seedlings had a greater than 90% survival after the first winter.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, greenhouse, planting, planting stock, seedings, [Picea pungens.]

490. Hocking, D. 1971. Preparation and use of a nutrient solution for culturing seedlings of lodgepole pine and white spruce, with selected bibliography. Canada, Forest Service, Northern Forest Research Centre, Alberta, Info. Rept. NOR-X-1. 14 pp.

A nutrient solution is described which gives good growth of lodgepole pine and white spruce seedlings. This medium will be of use in preparing large numbers of seedlings for outplanting.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, culturing, nutrient solution, planting, seeding, seedlings.

491. Hoffmann, F. 1967. [The fertilizing and nutrition of spruce transplants.] Archiv. Forstw. 16(2):141-158. (Abstr. F.A. 29:8).

N fertilization in the nursery caused increased height growth only during the first year after planting out, but fertilized plants kept their height superiority over controls in succeeding years.

K.W. Picea sp. (spruce), calcium, fertilization, magnesium, nitrogen, phosphorus, planting, potassium, seedling growth.

i) BARE ROOT STOCK, cont'd.

492. Holmes, G.D. and R. Faulkner. 1955. Experimental work in nurseries. Forest Research Commission, Forest Research Report, 1953/54. pp. 5-18.

Scots pines, lodgepole pine and Japanese larch were lifted at monthly intervals from November to March and stored without refrigeration by a variety of methods. Best results were obtained from heeled in outdoor storage.

K.W. Pinus contorta (lodgepole pine), artificial regeneration, planting, seedling storage, [Larix leptolepis, Pinus sylvestris].

493. Jeglum, J.K. 1970. The effect of pH, form of nitrogen, and anti-biotics on the growth of conifer seedlings in water culture. Canada, Forestry Service, Forest Research Lab, Sault Ste. Marie, Internal Rept. O-21. 11 pp.

Water culture experiments combining various treatments of pH (3-7), forms of nitrogen (NO_3 and NH_4) and anti-biotics (with and without streptomycin and auremycin) were carried out for seedlings of 4 conifer species including white spruce. pH exerted highly significant influences on growth and shoot/root ratios, based on dry weight values. The best growth and lowest shoot/root ratios occurred at pH levels 4, 5, and 6. Form of nitrogen had no apparent effect on dry weight but NO_3 supplied plants always had higher root/shoot ratios than NH_4 supplied plants. Anti-biotics generally inhibited growth but much more so with NH_4 supplied plants.

K.W. Picea glauca (white spruce), anti-biotics, ammonium-N, artificial regeneration, nitrate-N, nurseries, pH, seedling growth, seedlings, water culture, [Larix sp., Picea sp., Pinus sp.].

494. Jones, E.W. 1968. A note on the dimension of shoots and roots of planting stock. Forestry 41(2):199-206.

An analysis of data suggests that in planting stock of Pinus and Picea spp. raised in nurseries, the top-root ratio increases from the first year. Transplanting checks height growth the more severely, the longer the time that has elapsed since the last transplanting, but growth in weight and diameter is much less affected so that the shoot of a transplant is shorter and heavier than that of a seedling of the same height. The top/root ratio of a transplant is much less than that of a seedling of the same age.

i) BARE ROOT STOCK, cont'd.

K.W. Picea sp. (spruce), Pinus sp. (pine), planting stock, seedling growth, top/root ratio, transplants.

495. Knight, H.A.W. 1956. E.P. 382 (Plot 2) - Acidification of an alkaline nursery soil. B.C. Forest Research Review. pp. 27-28.

Various treatments to lower soil pH were applied to nursery soil planted with ponderosa pine, Engelmann spruce, and Douglas fir. The value of acidifcation of plant growth was not apparent under the material and environmental conditions of the experiment.

K.W. Picea engelmannii (Engelmann spruce), nurseries, seedling growth, soil, soil pH, [Pinus ponderosa, Pseudotsuga menziesii].

496. Knight, H.A.W. 1958. E.P. 382 - Gibberellic acid application to Engelmann spruce seedlings. B.C. Forest Research Review. pp. 34-35.

Gibberellic acid was sprayed monthly in several different concentrations upon several plots of 1-0 Engelmann spruce seedlings so that 2-0 seedlings could be used as growing stock. However, no significant top or root growth was apparent from any concentration.

K.W. Picea englemannii (Engelmann spruce), gibberellic acid, growing stock, growth regulators, seedling growth, seedlings.

497. Korstian, C.F. 1923. Control of snow molding in coniferous nursery stock. Jour. Agric. Res. 24(9):741-748.

All classes and species grown in the Cottonwoods nursery except for lodgepole pine were subject to this disease. Susceptibility was greatest among young seedlings. The disease can be controlled by a protective framework preventing seedlings from being bent flat.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), fungi, nurseries, snow molding.

498. Korstian, C.F. 1925. Some ecological effects of shading coniferous nursery stock. Ecology 6:48-51.

i) BARE ROOT STOCK, cont'd.

Experiments to determine optimum shade for seedlings of Engelmann spruce, Douglas fir, lodgepole pine and western yellow pine were conducted. Nursery beds were broadcast seeded then covered with lath screens to give 1/4, 1/2, and 3/4 shade. Control beds were exposed to full sunlight. The highest germination and survival for Engelmann spruce occurred under 3/4 shade and lowest in the open, but seedlings in 3/4 shade were too small for good development. Considering both survival and vigor, 1/2 shade was best for both Douglas fir and Engelmann spruce, while lodgepole pine and western yellow pine could be grown without shade. A brief discussion of the effects of shade on the physiology of the seedlings is presented and nursery stock be grown specifically for the particular field site where it is to be used.

K.W. Picea englemannii (Engelmann spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), germination, nurseries, seedling growth, seedling survival, seedling vigor, seedlings, shading, [Pinus ponderosa].

499. Korstian C.F. and N.J. Fetherholf. 1921. Control of stem girdle of spruce transplants caused by excessive heat. Phytopathology 11:485-490.

Stem girdle is caused by excessive heat. Frequent watering has a slight preventative effect in lowering the temperature of the surface soil, but the results are only temporary. Control of stem girdle (in Utah) by inclining the trees slightly to the south at the time of transplanting is the best and most efficient method of control.

K.W. Picea englemannii (Engelmann spruce), artificial regeneration, girdling, planting, soil temperature.

500. Kozlowski, T.T. 1963. Nursery weed control in white spruce seedlings and transplants. Wisconsin College of Agriculture, Forest Research Note 103. 5 pp. (ABSTR.).

Herbicides were applied at various dosages to bed of 1 + 0, 2 + 2, and 3 + 0 white spruce. Strazine, simazine, propazine, and prometryne controlled weeds satisfactorily, but injured and killed seedlings, particularly at higher concentrations, atrazine being most harmful. Dacthal, Vegadex, Eptam and Randox controlled weeds satisfactorily without such injury, but only with Dacthal and Vegadex was the dry weight of 1 + 0 seedlings greater than that of controls. Dacthal controlled weeds best amongst older seedlings.

i) BARE ROOT STOCK, cont'd.

K.W. Picea glauca (white spruce), herbicides, nurseries, seedling growth, seedling mortality, weed control.

501. Kozlowski, T.T. and J.E. Kuntz. 1963. Effects of Dacthal, propazine, Vegedex and Eptam on nursery weed control and tree development. Wisconsin College of Agriculture, Res. Note 90. 3 pp. (ABSTR.).

Tests at various application rates generally controlled weeds adequately and caused no damage to 2 + 0 seedlings of various species including white spruce. Best control was obtained with propazine and Dacthal.

K.W. Picea glauca (white spruce), herbicides, nurseries, seedling damage, weed control.

502. Lacaze, J.F. 1968. [Influence of transplanting deformations of the root system on the growth of spruce plants in the nursery.] Rev. for. franc. 20(9):580-582. (Abstr. F.A. 30:463).

2 + 0 seedlings of Norway spruce were transplanted correctly and with roots bent at two intensities. 2 years later, a substantial growth reduction and earlier flushing of the terminal bud were found in the bent root seedlings, the effect varying with the intensity of the bend. Such seedlings would be more liable to frost damage.

K.W. Picea abies (Norway spruce), frost damage, nurseries, planting, root damage, seedling growth.

503. Lafond, A. 1958. The production of tree seedlings by hydroponics. Pulp and Paper Magazine of Canada 59(6):204-205.

Black spruce and Norway spruce were grown hydroponically with great success in Quebec. Seedling production almost equalled germination capacity, at a cost lower than for nursery plants. Norway spruce grew 4-6 in., with a root system 3-5 times that of nursery stock, in one summer. 1000 of these seedings planted in poor ground with strong grass competition showed <3% deaths at 12 months.

K.W. artificial regeneration, hydroponics, planting, planting stock, seedling survival, [Picea abies, Picea mariana, Pinus banksiana].

504. Leech, R.H. 1961. Moisture relations of nursery stock. Ontario Dept. of Lands and Forests, Res. Pap. 45. n.p. (ABSTR.).

i) BARE ROOT STOCK, cont'd.

Among various treatments, watering nursery beds one half hour before lifting resulted in decreased survival and growth.

K.W. artificial regeneration, irrigation, lifting date, planting, seedling growth, seedling mortality, seedling storage.

505. McLeod, J.W. 1953. Covering nursery seedbeds to encourage germination of coniferous seed. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 98. 2 pp.

Three materials, sphagnum moss, burlap, and cellophane were used as coverings for seedbeds for red pine and white spruce to encourage germination of unstratified seed. In general, covering seedbeds with burlap and cellophane led to best germination and seedling growth. Because of difficulty in handling cellophane, burlap is considered best.

K.W. Picea glauca (white spruce), artificial regeneration, germination, seedbed covering, seedling, seedling survival, stratification, [Pinus resinosa].

506. Matthews, R.G. 1972. A look at shoots in roots in the nursery. In: Proceedings of a workshop on container planting in Canada. Canada, Forestry Service, Info. Rept. DPC-X-2. pp. 72-76.

Outlines procedures in B.C. nurseries for fertilization and root, pruning of lodgepole pine, Douglas fir, and white spruce. Generally, the graphs included show that increasing fertilizer rate from 300/100 gal. to 9 oz./100 gal. increases shoot weights without a corresponding increase in root weight, thus resulting in unbalanced shoot-root ratios.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, fertilization, nurseries, nutrients, planting, root pruning, seeding.

507. Meagher, M.D. and K.A. Armson. 1963. The effect of phosphorus placement on the growth of white spruce seedlings. J. For. 61(2):918-920.

White spruce seedlings were grown in a sandy soil that received super-phosphate at four rates placed three ways in the soil. Placing the fertilizer in a band of soil one inch below the surface produced the greatest seedling

i) BARE ROOT STOCK, cont'd.

growth of all fertilizer levels. Surface placement resulted in least growth, and mixing the fertilizer throughout the entire rooting volume gave intermediate results.

K.W. Picea glauca (white spruce), artificial regeneration, fertilization, phosphorous, seedbed, seedling growth, seedlings.

508. Mikola, P. 1956. [The effect of sowing density on seedling quality of pine and spruce in nurseries.] Metsät. Aikäk. 1956(5): 177-180. (Abstr. F.A. 18:197).

Results from Finnish Nurseries show that sparse sowing gives better seedlings.

K.W. Picea sp. (spruce), Pinus sp. (pine), nurseries, seeding density, seedling quality.

509. Mullin, R.E. 1963. Growth of white spruce in the nursery. Forest Science 9(1):68-72.

Root development of seedling Picea glauca was studied in nursery seedbeds in Ontario in the third growing season. Oven-dry weight increased four-fold and top-root ratio more than doubled. Root elongation rate curves were observed, the maximum rate occurring in the spring and the minimum during shoot growth.

K.W. Picea glauca (white spruce), artificial regeneration, nurseries, root development, seedling growth, seedlings, top-root ratios.

510. Mullin, R.E. 1965. Effect of mulches on nursery seedbeds of white spruce. Forestry Chronicle 41(4):454-465.

Several kinds of seedbed mulch were used in an experiment to study frost heaving of Picea glauca in an Ontario nursery. Sawdust mulch permitted highest germination and survival, but in this test, produced small, poorly balanced trees. It was better on almost all counts than presently used rye straw. Heaving was a minor cause of mortality over 3 years of study. Shading of seedbeds did not reduce this.

K.W. Picea glauca (white spruce), artificial regeneration, frost heaving, germination, mulching, nurseries, seedbed, seedling survival.

i) BARE ROOT STOCK, cont'd.

511. Mullin, R.E. 1968. A note on the field success of Dunemann stock. J. For. 66(9):668-669.

Survival of Dunemann 2 + 0 white spruce after 5 and 10 years was significantly higher than that of regular 2 + 1 plants. 2 + 2 plants gave best growth and survival.

K.W. Picea glauca (white spruce), Dunemann system, nurseries, planting, seedling growth, seedling survival, [Pinus resinosa].

512. Mullin, R.E. and R.H. Leech. 1959. A field test of Dunemann stock. Ontario, Dept. Lands and Forests, Res. Rept. 41. 25 pp.

Compares Dunemann 2-0 stock of white spruce and pine with regular 2-2 and 2-1 stock. When outplanted Dunemann stock had greater mortality than 2-2 stock of all species, and poorer height growth in white spruce and red pine. Dunemann stock of white spruce had less mortality than 2-1 stock but also less height growth.

K.W. Picea glauca (white spruce), artificial regeneration, Dunemann seedlings, planting, seedling growth, seedling survival.

513. Němec, A. 1939. [The influence of manuring with compost upon the growth of spruce in nurseries.] Lesnicka Práce 18:148-156. (ABSTR.).

Compost manuring of 3 year-old spruce transplants at the rate of 30 $kg/100m^2$ had a beneficial effect on most soils, except those with a lime deficiency which needed additional artificial fertilizers. Artificial fertilizers are generally better than compost.

K.W. Picea sp. (spruce), composting, fertilization, nitrogen, nurseries, seedling growth, transplants.

514. Němec, A. 1939. [Research on the influence of nitrogen fertilizing upon the growth of spruce in forest nurseries.] Bodenk. Pfl. Ehrnähr. 16:98-112. (Abstr. F.A. 2:137).

Effects of unbalanced nitrogen fertilization using $NaNO_3$, $Ca(NO_3)_2$ and $(NH_4)_2SO_4$ on growth and mortality of spruce seedlings was investigated. The effect on growth did not depend directly on the nitrogen content of the soil but was determined largely by the degree of acidity and the nutrient supply. Considerable increase of growth was obtained on very acid soils having a favourable P content. Mortality was not increased if treatments and transplanting were properly separated. In general, $NaNO_3$ and $Ca(NO_2)_2$ gave better survival in very acid and $(NH_4)_2SO_4$ in slightly acid to neutral soils.

i) BARE ROOT STOCK, cont'd.

K.W. Picea sp. (spruce), fertilization, nitrogen, nurseries, phosphorous, seedling growth, seedling mortality, soil pH.

515. Nienstaedt, H. 1966. Dormancy and formancy release in white spruce. Forest Science 12:374-384.

Discusses a study involving three factors and their interactions: date at which chilling began, length of chilling, and photoperiod subsequent to chilling. Results showed Picea glauca to have typical dormancy of winter buds. Dormancy can be broken by chilling 4-8 weeks at 36°F to 40°F, with younger plants requiring more chilling than older ones. More chilling is also needed if first exposure is in July. Long photoperiods compensate in part for lack of chilling, and will sometimes extent the growth period.

K.W. Picea glauca (white spruce), bud dormancy, chilling, dormancy release, photoperiod, seedling growth.

516. Nienstaedt, H. 1967. Chilling requirements in seven Picea species. Silvae Genetica 16:65-68.

About 25 seeds of each species of provenance tested were planted in 2 1/2" pots and growth under long day conditions for about four months. Then short day conditions were applied. After two months, chilling treatments were begun. Results showed treatment with long photoperiod compensates for lack of chilling in all species tested. Within species variation in chilling requirement was noted, but all species appeared to need from 6 to 8 weeks of chilling in order to break dormancy promptly when returned to growing conditions.

K.W. Picea glauca (white spruce), Picea engelmannii (Engelmann spruce), bud dormancy, chilling, photoperiod, planting, seed, seedling growth, [Picea sp.].

517. Nordin, E. 1945. [The planting and care of nurseries.] Skogen 32:349-351, 366-368. (Abstr. F.A. 7:466).

A condensed account of nursery practice, including sections on siting, preparatory cultivation, layout of beds, seed disinfection, sowing, care of individual species, transplanting, weeding, manuring, spraying, frost heaving, and distribution of produce.

K.W. artificial regeneration, nurseries.

i) BARE ROOT STOCK, cont'd.

518. Phipps, H.M. 1969. The germination of several tree species in plastic greenhouses. U.S. Dept. Agric., North Central Forest Experiment Station, Res. Note NC-83. 2 pp.

First year results of growing tree seedlings in plastic greenhouses show that germination and survival of white spruce were variable and not significantly different from germination and survival of the control seedlings outdoors.

K.W. Picea glauca (white spruce), artificial regeneration, germination, greenhouses, seedling growth, seedling survival.

519. Phipps, H.M. 1973. Growth response of some tree species to plastic greenhouse culture. J. For. 71(1):28-30.

In a Lake States nursery, seedlings of various species, including Picea glauca, were grown from seed for two seasons in a plastic greenhouse, under an extended growing season and a season of normal length, with and without supplemental heat. Greenhouse treatments increased growth of white spruce and allowed higher survival after outplanting. Supplement heat had no effect in normal season treatment.

K.W. Picea glauca (white spruce), artificial regeneration, germination, greenhouse, planting, seedling survival.

520. Place, I.C.M. 1952. Comparative growth of spruce and fir seedlings in sandflats. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 64. 4 pp.

Tabulates data obtained for several species, including Picea glauca when seeds were germinated out-of-doors in sandflats. At the end of one year, balsam fir was much more robust than any spruce, the mortality rate of which was correspondly greater. Among the spruces tested, white spruce is the most aggressive.

K.W. Picea glauca (white spruce), artificial regeneration, ecology, seedbed, seeding, seedling growth, seedling survival, soil, [Abies balsamea, Picea sp.].

521. Pollard, D.F.W. and A.H. Teich. 1972. A progeny test of rapidly grown white spruce seedlings. Bi-Monthly Research Notes 28(3):19-20.

i) BARE ROOT STOCK, cont'd.

Outlines the process of growing white spruce seedlings rapidly so that they might be transplanted after only one year. It is felt that seedlings grown this way are winter-hardy, and results showed both quality and survival of the seedlings were excellent.

K.W. Picea glauca (white spruce), artificial regeneration, seeding, seedling growth, stratification, transplanting.

522. Roche, L. 1966. E.P. 623 - The growth behaviour of interior spruce in the nursery, B.C. Forest Research Review. pp. 36-40.

Reports results of experiments to determine response of seed of various provenances of white and Engelmann spruce to nursery soil. In all cases, growth was superior on an artificial soil mix than on standard nursery soil. Conclusions and growth trends are reported in detail. Also reported 1964 - pp. 36-37, 1965 - pp. 19-23.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), artificial regeneration, growth, planting, provenance, soil.

523. Smith, R.S., Jr. 1964. Implication of nursery diseases on planting practices. In: Western Reforestation, Western Forestry and Conservation Assoc., Proc., Western Reforestation Co-ordinating Committee, Annual Rept., 1964. pp. 12-14.

Diseases associated with a seedling in the nursery are not necessarily left behind when the seedling is outplanted, but may travel with the seedling to cause further damage in the plantation. Furthermore, these diseases may spread from the infected seedling to surrounding vegetation.

K.W. disease, nurseries, seedling mortality.

524. Solberg, K.H. 1968. [Application of N fertilizer to 2 + 2 spruce in autumn.] Arskr. Norske Skogplantesk 1967. pp. 15-19. (Abstr. F.A. 30:264).

In an attempt to reduce growth check and mortality from outplanting, Norway spruce was treated in the nursery with various concentrations of calcium ammonium nitrate in Sept. 1966 before outplanting in May 1967. Results of measurements in Sept. 1967 showed that leader length of all except the lowest concentration treatment was significantly greater than that of untreated controls.

i) BARE ROOT STOCK, cont'd.

K.W. Picea abies (Norway spruce), fertilization, nitrogen, nitrate N, planting check, seedling growth, seedling mortality.

525. Talli, A.R. 1967. Growth and nutrition of Picea glauca (Moench) Voss. seedlings. Dissert. Abstr. 27B(9):2949.

Gives results of a study of the effect of various amounts of N, P, and K fertilizers on 1 + 0 and 2 + 0 plants, including effects on seedling dry weight, height, diameter, shoot-root ratio, quality index and concentrations and contents of N, P, K, Ca, Mg, and Na in first or second year needles, stems and roots.

K.W. Picea glauca (white spruce), fertilization, nitrogen, phosphorous, potassium, seedling growth.

526. Timonin, M.I. 1963. Chlorosis of white spruce seedlings in Saskatchewan nursery. Bi-Monthly Progress Rept. 19:2.

Seedlings affected by chlorosis were treated with acidic and basic nitrogenous fertilizers and iron and magnesium chelates, alone or in combinations. Results indicated that application of 364 lbs/acre of $(NH_4)_2SO_4$ or 164 lb/acre of urea corrected the chlorosis. The application of the chelates had no effect on the chlorosis. Application of the nitrogenous fertilizers also improved growth of the seedlings.

K.W. Picea glauca (white spruce), ammonium chelates, chlorosis, fertilizers, nitrogen, seedling growth, urea.

527. Tinus, R.W. 1971. Growth of ponderosa pine, white spruce, and blue spruce under clear and red fluorescent plastic. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note RM-184. 4 pp.

Pinus ponderosa, Picea glauca and Picea pungens tended to be larger and heavier when grown under a covering of red florescent plastic than when grown under clear polyethylene, although in most cases, the differences were not statistically significant. The effects of reduced temperature and altered spectrum were not separated.

K.W. Picea glauca (white spruce), artificial regeneration, germination, nurseries, plastic covering, seedling growth, seedling mortality, [Picea pungens, Pinus ponderosa.]

i) BARE ROOT STOCK, cont'd.

528. Toumey, J.W. and E.J. Neethling. 1923. Some effects of cover over coniferous seedbeds in Southern New England. Yale University, School of Forestry, Bull. 9.

529. Tyystjärvi, P. 1967. [Seedlings grown in plastic greenhouses and their growth in the forest.] Metsät. Aikäk. 84(4):133-134. (Abstr. F.A. 28:848).

At the end of the first growing season, 1 + 1 and 2 + 1 pine and spruce planted out from the greenhouse into the forest showed equal survival and superior total height and height increment to plants of the same age from open grown. Possible disadvantages are the risk of growth disturbances in pine and the slenderness of greenhouse-grown spruce plants.

K.W. Picea sp. (spruce), Pinus sp. (pine), greenhouses, planting, planting stock, seedling growth, seedling survival.

530. U.S. Dept. Agric. 1944. Annual report of the Allegheny Forest Experiment Station, 1943. p. 22. (Abstr. F.A. 6:161).

Primary requisites for successful bare-root transplanting of trees during the growing seasons are given as adequate protection of roots against drying, proper planting, heavy tap pruning of hardwoods and supplementary watering during first year if rain is inadequate. Liberal application of fertilizers during the dormant period before lifting will favour increased survival.

K.W. artificial regeneration, fertilization, irrigation, planting, planting stock, seedling packing, seedling survival.

531. U.S. Dept. Agric. 1944. Annual report of the Allegheny Forest Experiment Station, 1943. pp. 20-21. (Abstr. F.A. 6:161).

Field survival during drought years has been increased by as much as 20% by restriction amount of nitrogen and maintaining a proper balance between nitrogen, phosphorous and potassium during the growing period, and by applying large amounts of fertilizer during the dormant period 1-5 months before lifting for planting in the field.

K.W. artificial regeneration, drought resistance, fertilization, N, P, K, planting, nurseries, seedling survival.

i) BARE ROOT STOCK, cont'd.

532. Vaartaja, O. 1954. Correction of chlorosis in [white] spruce seedbeds. Bi-Monthly Progress Reports 10(5):2.

Application of liquid N fertilizer to seedbeds after emergence is far superior to application before sowing. Repeated treatment is necessary in dense seedling stands. Shading the beds with screens decreased chlorosis though to a lesser degree than fertilizer treatment.

K.W. Picea glauca (white spruce), artificial regeneration, chlorosis, fertilization, nitrogen, planting, seedling quality, shading.

533. Vaartaja, O. 1955. Effect of soil amendment, fertilizer, and fungicide on growth of seedlings. Bi-Monthly Progress Rept. 11(3):2.

These were significant improvements in growth and colour of spruce and pine for treatments, alone and combined, with peat, forest humus, captan fungicide and NH_4NO_3. A combination of peat, fungicide and N produced an almost 4-fold increase in height of seedlings.

K.W. Picea glauca (white spruce), Pinus sp. (pine), captan, fertilization, fungicides, nitrogen, nurseries, seedbed, seedling growth.

534. Vaartaja, O. 1965. Biological control of seedling diseases in nursery soils. Canada, Dept. Forestry, Forest Research Lab, Ontario, Info. Rept. O-X-3. 11 pp.

A review of work done in this field over the last 50 years.

K.W. diseases, fungi, nurseries, seedling mortality.

535. van den Driessche, R. 1968. Growth analysis of four nursery grown conifer species. Canadian Journal of Botany 46:1389-1396.

One-year old seedlings were used for a study examining relative growth rate (RGR) patterns, stem extension growth, net assimilated rate (NAR), and needle area ratio (F). Seasonal patterns of RGR in Sitka spruce and Douglas fir were similar, but different patterns and lower rates were noted for white spruce. Differences in NAR had a greater effect on RGR than those in F during June, particularly in white spruce.

i) BARE ROOT STOCK, cont'd.

K.W. Picea glauca (white spruce), Pseudotsuga menziesii (Douglas fir), needle area, net assimilation rate, seedling growth, stem extension, [Picea sitchensis, Tsuga heterophylla].

536. Van den Driessche, R. 1969. E.P. 655 - Fertilizer applications for white spruce at Red Rock Nursery. B.C. Forestry Research Review. pp. 55-57.

Reports experiment to determine suitable levels of N, P, and K fertilizer applications for spruce. Analysis of data on 1-0 seedlings showed that N fertilizer was most effective in increasing seedling growth. P fertilizer had some influence at moderate levels. There was no detectable effect of K treatments, and no significant interaction between nutrients. During the second year of growth, further applications of N and K fertilizers were given. K treatment again had no significant effect. N was effective at a rate of 40 lbs/acre in increasing growth of 2-0 seedlings. Over two years, 80 lbs/acre gave somewhat greater than 40 lbs/acre. Also reported 1968 - pp. 49-50.

K.W. Picea glauca (white spruce), artificial regeneration, fertilization, nitrogen, nursery, phosphorous, potassium, seedling growth.

537. Van den Driessche, R. 1969. Forest nursery handbook. B.C. Forest Service, Res. Note 48. 44 pp.

Summarizes research work and nursery procedures developed since 1960 by the B.C. Forest Service. Information was gathered from experiments, literature, and experience. Trees dealt with are Douglas fir, hemlock, Sitka spruce, white spruce, and lodgepole pine. Topics covered are sowing, fertilization, soil pH, organic matter, rotation, weed control, soil sterilization, irrigation, growth periodicity, transplanting, dormancy, soil and plant tissue analysis, soil and seedling sampling, and choice of nursery sites.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), nurseries, nursery practice.

538. Van den Driessche, R. 1971. Response of conifer seedlings to nitrate and ammonium sources of nitrogen. Plant and Soil 34:421-439.

i) BARE ROOT STOCK, cont'd.

Discusses a study designed to determine growth responses to Douglas fir, western hemlock, white spruce, and Sitka spruce to nitrate and ammonium N sources. Both sand and artificial soil cultures were used. For all but the Sitka spruce, growth was greater with ammonium alone than nitrate alone. Growth at different pH's showed pH 5.4 to be more favourable than 0.5 for all species. Increases in the proportion of ammonium N supply resulted in increases of seedling tissue N concentration, particularly in roots. Detailed studies of Douglas fir responses are included.

K.W. Picea glauca (white spruce), Pseudotsuga menziesii (Douglas fir), ammonium, nitrates, seedling growth, soil pH.

539. Voigt, G.K. and S.A. Wilde. 1963. Field survival and growth of tree seedlings raised in biocide treated nursery soils. J. For. 61(6):438-440.

Jack pine and white spruce seedlings raised in nursery soils treated with varying amounts of Hg_2Cl_2, chlordane, Stoddard solvent, mineral fertilizers, and with the F and H humus layers from a hardwood/hemlock stand were planted out in central and North Wisconsin. After several years, no clearcut relationships between seedbed treatment and field performance was evident.

K.W. Picea glauca (white spruce), fungi, nurseries, planting, seedling growth, soil, soil fumigation, [Pinus banksiana].

540. Wahlenberg, W.G. 1929. Relation of quantity of seed sown and density of seedlings to the development and survival of forest planting stock. Jour. Agric. Res. 38:219-227.

For best development of seedlings at Savenac Nursery, there should be fewer than 120 3-0 Engelmann spruce seedlings per square foot of seedbed surface.

K.W. Picea engelmannii (Engelmann spruce), frost resistance, height growth, planting, planting stock, seedling density, seedling growth.

541. Wahlenberg, W.G. 1930. Experiments in the use of fertilizers in growing forest planting material at the Savenac Nursery. U.S. Dept. Agric., Circ. 125. 38 pp.

Fertilization of Engelmann spruce seedlings in the nursery is outlined, including early history of efforts to improve planting stock and the use of various fertilizer types and regimes. Also described are tests for germination and the success of various planting stocks when outplanted.

i) BARE ROOT STOCK, cont'd.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, fertilization, germination, nitrogen, nurseries, planting, seedlings, soil productivity.

542. Yeatman, C.W. 1970. CO_2 enriched air increased growth of conifer seedlings. Forestry Chronicle 46(3):229-230.

Seedlings of white spruce, Norway spruce, Jack pine and Scots pine grown in nutrient solution were subject to various light intensities and CO_2 concentrations. Light and CO_2 had independent effects on seedling growth. Spruces showed a greater response to CO_2 than did pine, but pine responded more to increase of light intensity. Supplementary CO_2 and lighting might be used to increase growth of conifer seedlings in the greenhouse.

K.W. Picea glauca (white spruce), Picea abies (Norway spruce), CO_2, greenhouse, insolation, seedling growth, [Pinus banksiana, Pinus sylvestris].

ii) CONTAINER STOCK

All papers in this section deal with the production of containerized seedlings in the nursery. Articles on production and preparation of different types of containers and the influences of container type and size upon seedling growth in the nursery and in the field are included.

ii) CONTAINER STOCK, cont'd.

543. Anon. 1959. Growing planting stock in tubes in the greenhouses. Univ. Toronto, Faculty of Forestry, Forest Res. Rept., 1958. pp. 9-11.

Three types of containers were used to grow tree seedlings in the greenhouse in order to shorten time before out-planting to less than 12 months. Many species were used, including white spruce, which grew well in all types of containers. Seedlings in larger containers grew faster, but with 20 cm of depth, 6 cm^2 provides enough space to raise seedlings to transplant size. Root systems developed well. Growth after planting out was highly satisfactory.

K.W. Picea glauca (white spruce), artificial regeneration, containers, greenhouse, planting, root growth, seedling growth, tubes.

544. Anon. 1966. New method of forest seedling production. Finnish Paper and Timber 17(5):78-79.

Describes peat-ribbon planting of seedlings and the preparation of ribbons. Claimed advantages are ease of transportation, saving of space in nurseries, and possibility of planting out at any time of the year.

K.W. planting, planting method, seedlings, seedling handling.

545. Anon. 1966. Seedlings in buns: reforestation study. B.C. Lumberman 50(6):50.

Outlines experiments concerning growth of seedlings in polyurethane-foam "buns" with the correct mixture of plant nutrients mixed in with them.

K.W. artificial regeneration, containers, nutrients, planting.

546. Anon. 1967. Provisional instructions for growing and planting seedlings in tubes. Revised 1967. Ontario Dept. Lands and Forests, Toronto. 83 pp.

547. Anon. 1970. [A new method of raising plants.] Skogen 57(14/15): 350. (Abstr. F.A. 32:89).

Describes setting up and use of paper pots for spruce and pine in Sweden.

K.W. Picea sp. (spruce), Pinus sp. (pine), containers, paperpots, planting.

ii) CONTAINER STOCK, cont'd.

548. Ackerman, R.F. 1967. Growing lodgepole pine and white spruce container planting stock under reduced light intensities. Bi-Monthly Research Notes 23(4):30-31.

Light gradient produced by growing lodgepole pine and white spruce at reduced light level, associated with tiering, had a significant effect on growth of lodgepole pine, top and root, and a measurable effect on the growth of white spruce tops. The growth loss was small in spruce compared to that shown by lodgepole pine. The data given suggests that it is feasible to produce lodgepole pine and white spruce planting stock in tiered conditions.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, greenhouse, growth increment, light gradient, seedlings.

549. Ackerman, R.F. and J.R. Gorman. 1969. Effect of seed weight on the size of lodgepole pine and white spruce container planting stock. Pulp and Paper Magazine of Canada 70:167-169.

Positive correlations have been noted between seed size and seedling size during the first year of growth, so the study described was carried out to determine the feasibility of more rigid control of seed size before planting. Seed samples of white spruce and lodgepole pine were obtained and divided into four weight classes. Results showed that increasing seed weight of 1 mg increased total seedling weight (at 8 weeks) by 15% to 16%.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), container planting, seed weight, seedling size, seedling weight.

550. Alm, A.A. and R. Schantz-Hansen. 1967. Tubelings for tomorrow. American Forests 73(9):16-18.

Gives a detailed description of the tubes, and of the tube planting technique. The tubeling method is fast and relatively inexpensive, and should be useful in solving reproduction problems.

K.W. artificial regeneration, economics, planting, seedlings, tubelings, tubes.

551. Bonin, P. 1972. La culture des plants en recipients. Foret et Conservation 38(1), 38(2).

K.W. containers, nurseries.

ii) CONTAINER STOCK, cont'd.

552. Bouclouse, M.E. 1970. Effect of tube dimension on root density of seedlings. Bi-Monthly Research Notes 26(3):29-30.

Article deals with Picea mariana, but has relevance to root system development in white spruce. Equations are given to help determine optimum tube dimensions for maximum regeneration efficiency. Other parameters besides those given should also be considered.

K.W. artificial regeneration, planting, root density, tubes, [Picea mariana].

553. Boudoux, M. 1973. Influence des dimensions du contenant sur la croissance des semis de Picea mariana. Canada, Forestry Service, Laurentide Forest Research Center, Quebec, Info. Rept. Q-F-X-32. 28 pp.

Containers of 22 size groups were used to grow Picea mariana seedlings in a growth chamber over a period of 18 weeks. Diameter and height of the container were found to influence significantly and differentially the seedling growth.

K.W. artificial regeneration, containers, seedling growth, tubes, [Picea mariana].

554. Boudoux, M. 1969. Un mouveau type de plantube. Canada, Forest Service, Quebec, Rapp. Interne Q-F-1. 7 pp.

No conclusions can be drawn at the point of writing concerning an experiment to evaluate the planting container described herein. It is, however, possible to state that tube dimensions exert a signficant influence on the root system of seedlings.

K.W. Picea mariana (black spruce), artificial regeneration, containers, planting, root growth, tubes.

555. Cayford, J.H. 1972. Container planting systems in Canada. Forestry Chronicle 48(5):235-239.

Outlines process of development of container planting systems across Canada, giving examples and illustrations of systems used. Some advantages of the systems are briefly mentioned. 51 references are listed.

K.W. container planting.

556. Carman, R.D. 1967. An industrial application of the container planting technique. Pulp and Paper Magazine of Canada, Woodlands Review 68(4):WR-181 - WR-188.

ii) CONTAINER STOCK, cont'd.

Describes operation in Alberta where lodgepole pine and white spruce seedlings are raised in split styrene tubes in an artificially lit and heated greenhouse for 4 weeks after germination and in cold frames for a further 4 weeks before continuous planting from May to Sept. Methods and economics of the technique are discussed in detail.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, containers, economics, greenhouses, seedling mortality, tubes.

557. Chedzoy, J.C. 1968. Pre-sowing, stratifying spruce and pine seed in plastic containers proves best in Alberta, Canada, Test. Tree Planters Notes 18(2):1-3.

Pre-sowing and stratifying seed in plastic containers seems to be the best technique for producing both lodgepole pine and white spruce seedlings at this time. The 60-day stratification periods allow the highest germination. Seed germinated better in plastic containers than in cardboard, mainly because the drainage was poorer in cardboard.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), containers, germination, pre-sowing, seed, stratification.

558. Crossley, D.I. 1969. Container planting in Alberta. In: Western Reforestation. Proc. Western Reforestation Co-ordinating Committee, Western Forestry and Conservation Assoc. pp. 29-33.

Outlines research and operations in container planting in Alberta. All stages are covered, from germination of seed to planting out, for both white and lodgepole pine. Main problems are wildlife, soil heaving and planting crew negligence. Survival for white spruce after 3 years averages 64% and for lodgepole pine 67%. Advantages and disadvantages of container planting are discussed in detail. Main limiting factors are vegetative competition with small seedlings, heavy soils subject to heaving, and deep duff.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, containers, frost heaving, planting, seedling survival, tubes, vegetative competition, wildlife.

ii) CONTAINER STOCK, cont'd.

559. Edey, C.E. and D. Hocking. 1971. Pilot scale rearing of tree seedlings in the B.C./CFS styroblock and then planting in the foothills of Alberta, 1970. Canada, Forestry Service, Forest Research Lab, Edmonton, Internal Rept. A-45. 21 pp.

BC/CFS styroblocks were used in a pilot study for establishment of white spruce, Engelmann spruce, lodgepole pine and jack pine in North Alberta and Saskatchewan. Details of rearing and planting methods are given. Results indicate very good growth of all species. In comparison with split plastic tubes, seedling number plantable was fewer because of block dimensions, but stock quality was improved. Appendices contain all site data.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), Pinus banksiana (jack pine), Pinus contorta (lodgepole pine), artificial regeneration, containers, planting, rooting medium, styroblocks, tubes.

560. Endean, F. 1970. Talk presented at Inland Empire Forestry Conference, Sept. 1970. np.

Discusses container seedlings or "assisted seedlings". Various types of containers and their advantages and drawbacks are mentioned.

K.W. artificial regeneration, containers, planting.

561. Farrar, J.L. 1960. Effect of substrate depth on the growth of seedlings of Picea mariana, Pinus banksiana, Larix laricina and Betula lutea. Univ. Toronto, Forest Research Rept. p. 7.

Seedlings were grown in tubes of three different depths in sterile medium and nutrient solution. After 6 months seedlings in shorter tubes were smaller. Advantages of deeper medium was probably related to water supply.

K.W. artificial regeneration, containers, container size, nurseries, seedling growth, tubes.

562. Froland, Å. 1970. [Production of planting stock in peat ribbons.] Årsskr. Norske Skogplantesk. 1969. pp. 86-92. (Abstr. F.A. 32:88).

Describes trial of this method with 2 + 1 and 2 + 2 Scots pine and Norway spruce in Norway. Discusses production, costs, spacing of plants on the ribbon, plant testing, and comparison with bare root stock. Plants given a long period of forcing in a plastic greenhouse gave the best subsequent growth.

ii) CONTAINER STOCK, cont'd.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), bare root stock, economics, peat ribbons, planting, spacing, seedling production.

563. Heiberg, S.O. 1934. Briquette planting. J. For. 32(3):333-336.

Ball planting, a method of planting stock from which the soil has not been removed, has been dependable, in that the roots of plants properly lifted are hardly damaged and are planted in their natural position. This method is used frequently with natural reproduction where it is too thin or too thick. Several experiments are described and the method of producing soil cubes or briquettes is described. Disadvantages are weighted, but the process appears a good one, although it is regarded as still in the experimental stage. Experimentation is apt to be somewhat expensive, since no new machines have been made, and only the original machines can be used. An alternate method of using pots that could dissolve after planting is briefly discussed.

K.W. ball planting, briquette planting, economics, planting.

564. Hermann, R.K. 1969. Growth of tree seedlings in peat pellets. Tree Planters Notes 20(1):8-9.

Describes Jiffy-7 peat pellet. Seedlings of ponderosa pine or Douglas fir raised in these pellets should be transplanted after 4-6 weeks.

K.W. Pseudotsuga menziesii (Douglas fir), containers, Jiffy pots, planting, root growth, [Pinus ponderosa].

565. Hocking, D. 1972. Current rearing knowledge. In: Proceedings of a workshop on container planting in Canada. Canada, Forestry Service, Info. Rept. DPC-X-2. pp. 48-66.

Deals with all aspects of rearing seedlings in nurseries, from a consideration of seed and seed source, through stratification, germination, and growth. Contains tabulated data from various experiments, published and unpublished, on various aspects of seedling growth and survival as influenced by such variables as substrate, tube size, hardening off, nutrient regime, photoperiod, air temperature, soil temperature, drought, etc.

K.W. air temperature, artificial regeneration, containers, drought, nurseries, nutrients, planting, seedbed, seeding, soil moisture, soil temperature.

ii) CONTAINER STOCK, cont'd.

566. Hocking, D. 1970. Talk presented to Inland Empire Forestry Confernence, Sept. 1970. n.p.

Outlines processes used in growing tubed seedlings in the greenhouse including fertilization. Maintenance of a desirable shoot/root ratio within bounds of container is highly difficult. Irrigation and temperature regimes are discussed with respect to this problem.

K.W. artificial regeneration, containers, fertilization, irrigation, nurseries, seedlings, temperature, tubes.

567. Kay, W.C., D.L. Mitchell, J.C. Wood, A. Sacuta, S.M. Creighton and M. Worsley. 1970. Development of seedling containers with a removable casing. Proc. Inland Empire Forestry Conference, Sept., 1970. n.p.

Outlines unsatisfactory aspects of various rigid walled containers and process of development of removable casings. Tests have been made and data are presented concerning the influence of rooting medium density on seedling growth and a comparison is made of 3/4" tubelings, with and without tubes as compared to a 1" poly-casing with punctured skins. Preliminary data indicate that 1" poly containers have a survival rate 50% greater than tubelings. Frost heaving was greatest in tubelings with tubes.

K.W. _Picea glauca_ (white spruce), _Pinus contorta_ (lodgepole pine), _Pseudotsuga menziesii_ (Douglas fir), artificial regeneration, containers, frost heaving, planting, seedling mortality, tubes.

568. Kinghorn, J.M. 1969. Container systems in British Columbia. _In_: Western Reforestation. Proc. Western Reforestation Co-ordinating Committee, Western Forestry and Conservation Association. pp. 44-48.

Reports history of tubelings and outlines tube planting as it is done in British Columbia. Dealt with are raising of seedlings, storage, and actual planting operations. Fertilization and the use of fungicides are mentioned. Principle problems encountered have been related to frost heaving.

K.W. artificial regeneration, containers, fertilization, frost heaving, planting, seedling mortality, seedling survival.

ii) CONTAINER STOCK, cont'd.

569. Kokočinski, C.H. 1968. Growing tubed seedlings in the Kenona Forest District. Forestry Chronicle 44(1):18-20.

Outlines the process of preparing tubed seedlings. Aspects of soil preparation, tube loading, seeding and tending and growing are briefly covered.

K.W. artificial regeneration, containers, nurseries.

570. Logan, K.T. 1973. Height growth of white spruce transplanted from BC/CFS styroblocks. Canada, Forestry Service, Bi-Monthly Res. Notes 29(1):7.

Seedlings may be transplanted from styrofoam blocks between ages of 3-13 weeks with no appreciable effect on subsequent height growth. After 13 weeks, branch and leader growth of seedlings in blocks declined and subsequent growth was not as good.

K.W. Picea glauca (white spruce), artificial regeneration, containers, planting, seedling growth, styroblocks.

571. Loitenen, J. 1966. Peatpot use reduces Finnish seedling losses. World Wood 7(5):6-7, 38.

Pine seedlings, planted in peat pots ensure almost complete success of pine plantings at low cost. Planting period may be increased to 2-3 months and 1 year seedlings can be planted successfully. Description of entire operation is included.

K.W. Pinus sp. (pine), containers, peat pots, planting, planting stock, seedling growth, seedling mortality.

572. Low, A.J. and R.M. Brown. 1972. Production and use of ball-rooted planting stock in Sweden and Finland. Forestry Commission: Research and Development Paper 87. 25 pp.

Reports recent developments and use of ball rooted planting stock studied in Sweden and Finland in 1971. Four methods of obtaining ball rooted stock were examined and each is described with assessments of the success achieved with it as well as its relevance to British conditions. Use of plastic greenhouses is also described.

K.W. artificial regeneration, ball rooted stock, containers, greenhouses, nurseries, seedling growth, seedlings.

ii) CONTAINER STOCK, cont'd.

573. Matthews, R.G. 1971. Container seedling production: a provisional manual. Canada, Forestry Service, Pacific Forest Research Centre, Victoria, Info. Rept. BC-X-58. 57 pp.

A compendium of materials and techniques which have proven successful for growing coniferous seedlings, including white spruce, in containers with a small soil capacity. The 4 ½ inch bullet container is most commonly used. Covered in the report are container types, seedling production, growing media, seeding, germination, cultural techniques and preparation for planting and transport as well as a description of the advantages of container use.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, containers, economics, germination, growing media, planting, seedling culture, seedlings.

574. Mitchell, D.L., D. Hocking and W.C. Kay. 1972. Reforestation with tree seedlings grown in extruded peat cylinders: Part I - Mechanical aspects of process. Trans. American Society of Agricultural Engineers 15(1):36-39. (ABSTR.).

Describes process of creating peat filled plastic cylinders. Containers filled with a growth medium of uniform predetermined compaction are produced and controlled variation in container volume and growth medium density is produced. Growth of lodgepole pine seedlings in containers thus made is equivalent or superior to growth in similar containers filled manually.

K.W. Pinus contorta (lodgepole pine), containers, planting, plastic cylinders, seedling growth.

575. Mitchell, D.L., D. Hocking and W.C. Kay. 1971. Reforestation with tree seedlings grown in extruded peat cylinders. Research Council of Alberta-Edmonton, Publ. 71-169.

576. Reese, K.H. 1968. Tubed seedling production. Canadian Pulp and Paper Association, Woodlands Section, Index 249(F-2). 2 pp.

Describes tubeling production of various species, including white spruce in Ontario.

K.W. Picea glauca (white spruce), containers, planting, planting stock, tubes.

ii) CONTAINER STOCK, cont'd.

577. Saul, G.H. 1968. Copper safely controls roots of tubed seedlings. Tree Planter's Notes 19(1):7-9.

Sheets of metallic copper, copper armoured fibre, or copper paint, when used on the inside of the holding trays, will apparently restrict the elongation of seedling roots without detrimental effects on the seedlings. Thus seedlings can be held in tubes for prolonged periods of time.

K.W. Picea glauca (white spruce), artificial regeneration, copper, growth retardants, planting, root growth, tubes, [Picea mariana, Pinus resinosa, Pinus strobus].

578. Scarratt, J.B. 1973. Containerized seedlings: relation between container size and production period. Bi-Monthly Res. Notes 29(1):4-6.

Shows that 9/16 and 3/4 in. diameter tubes cause severe restriction of growth of seedlings. Use of tubes of larger diameter results in faster growth and shortened production periods. Use of 2 in. diameter tubes is, however, economically unsound. Therefore production of white spruce and jack pine container stock, 1 1/4 in. diameter tubes are best.

K.W. Picea glauca (white spruce), artificial regeneration, containers, economics, planting, tubes, tube size, [Pinus banksiana].

579. Scarratt, J.B. 1972. Effect of tube diameter and spacing on the size of tubed seedling planting stock. Canada, Forestry Service, Forest Research Lab, Sault Ste. Marie, Info. Rept. O-X-170. 10 pp.

White spruce seedlings were grown for 16 weeks in 3 sizes of plastic tube (9/16, 3/4, and 1 1/4 inch diameter) at 3 spacings (close packed, 1 inch and 4 inches, respectively between tubes). Growth was severely restricted in 9/16 and 3/4 inch tubes and at all spacings improvement in seedling size was obtained by use of 1 1/4 inch tubes. Poor growth is attributed to restricted root volume. Most effective alternative for improving seedling growth was use of 1 1/4 inch diameter tubes at normal spacings.

K.W. Picea glauca (white sruce), artificial regeneration, containers, nurseries, planting, root growth, seedlings, seedling growth, tubes, tube size.

ii) CONTAINER STOCK, cont'd.

580. Scarratt, J.B. 1972. Container size affects dimensions of white spruce, jack pine planting stock. Tree Planters Notes 23(4):21-25.

The 9/16 inch plastic tubes currently used restrict seeding growth from an early age. Growth is only slightly better in the 3/4 inch diameter tubes and here also, growth restriction starts early. Such adverse effects continue after outplanting. However use of larger tubes of 1 1/4" and 1 1/2" diameter, though biologically advantageous, are economically and tactically at a disadvantage.

K.W. Picea glauca (white spruce), artificial regeneration, containers, economics, planting, seedling growth, tube size, [Pinus banksiana].

581. Schneider, G., D.P. White and R. Heiligmann. 1970. Growing coniferous seedlings in soilless containers for field planting. Tree Planters Notes 21(3):3-7.

Jack pine seedlings were grown in two sizes of watered and fertilized woodpulp blocks for 8 weeks, then planted in soil for 8 weeks. Best results were obtained when seedlings were sown in larger pulpwood blocks fertilized every 2 weeks. Growth in smaller blocks was comparable to that in split tubes. Following planting, root development was acceptable with either block size, but superior with larger blocks.

K.W. Pinus banksiana, artificial regeneration, containers, planting, root growth, seedling growth, seedlings, soilless blocks, tubes.

582. Tinus, R.W. 1970. Growing seedlings in controlled environment. In: Western Reforestation, Western Forestry and Conservation Assoc., Proc. Western Reforestation Co-ordinating Committee, Annual Rept., 1970. pp. 34-37.

Gives detailed outline of the growth of seedlings, including those of lodgepole pine, Engelmann spruce and Douglas fir in controlled environments. In practice this technique is used for the production of containerized seedlings, and greenhouses are used. Light, temperature, (and their interactions), CO_2 enrichment, soil, mineral nutrition, water and mycorrhizae are dealt with. There is an extensive bibliography.

K.W. artificial regeneration, containers, greenhouses, planting, seedling rearing.

ii) CONTAINER STOCK, cont'd.

583. White, D.P. 1969. Container systems for forest trees. In: Western Reforestation. Proc. Western Reforestation Co-ordinating Committee, Western Forestry and Conservation Assoc. pp. 34-38.

Outlines current research in eastern north America on tube-type containers. Included are tables showing characteristics of desireable container system for forest trees, advantages of container systems over bare-root stock, and potential uses of container grown trees.

K.W. artificial regeneration, containers, planting, seedling growth, tubes.

584. White, D.P. and G. Schneider. 1972. Soilless container system developed for growing conifer seedlings. Tree Planters Notes 23(1):1-4.

Seedlings can be produced in this container with shoot dimensions comparable to seedlings raised in split plastic tubes or by direct seeding. Root development is much more diffuse than in conventional tubes and thus leads to less frost heaving. Less frequent waterings are required by this system, but more bench space is needed.

K.W. Picea glauca (white spruce), Pinus banksiana (jack pine), containers, frost damage, planting, root growth, seedling growth, soilless block.

iii) SEEDLING SELECTION

This section deals with the influence of seedling selection upon post-planting seedling growth and survival. The most common criteria are seedling size, quality and age.

iii) SEEDLING SELECTION, cont'd.

585. Dickson, A., A.L. Leaf and J.F. Hosner. 1960. Quality appraisal of white spruce and white pine seedling stock in nurseries. Forestry Chronicle 36(1):10-13.

Total seedling weight, shoot weight, and root weight in grams, on an oven-dry basis, root collar diameter in millimeters and height in centimeters were used to develop an integrated index of seedling quality.

K.W. Picea glauca (white spruce), nurseries, seedlings, seedling grading, [Pinus strobus].

586. Gutschick, V. 1968. [Experience with large conifer planting stock.] Alligemeine Forstzeitschrift 23(9):148-150. (Abstr. F.A. 29:450).

It is estimated that plantations with large growing stock (2 + 3 plants grown at wide spacings) would need 40% less working time and be 30% cheaper to establish than plantations with smaller stock.

K.W. Picea sp. (spruce), economics, planting stock, seedling growth, seedling size.

587. Haugberg, M. 1967. [Grading experiments with 2 + 2 transplants of Norway spruce.] Skogbrukets og Skogindustrienes Forskningsforening, Oslo. 27 pp. (Abstr. F.A. 29:644).

Culling of smallest plants (<15 cm in height) gives increased survival and growth of the planting stock, that the effectiveness of grading increases as the height limit for culls is raised and that grading 2 + 0 plants is not effective.

K.W. Picea abies (Norway spruce), culling, planting, planting stock, seedling grading, seedling growth, seedling survival.

588. Kartelev, V.G. 1966. [Effect of pine seedling quality on the survival and growth of mechanically planted plantations.] Lesn. Ž., Arhangel'sk 9(1):37-41. (Abstr. F.A. 28:274).

Survival of planted 1 + 0 Scots pine seedlings was directly related to seedling diameter and root length, and inversely related to height.

K.W. Pinus sylvestris (Scots pine), planting, planting stock, seedling growth, seedling size, seedling survival.

iii) SEEDLING SELECTION, cont'd.

589. Mullin, R.E. 1959. An experiment on culling and grading of white spruce nursery stock. Part A. The percentage of cull. Ontario, Dept. Lands and Forests, Res. Rept. 38. 62 pp.

A three year study of percentage of cull of 2-2 white spruce stock showed great variability within lifting crews, between crews, between nurseries, and between years. There were significant differences in survival between cull and acceptable stock of the three nurseries which changed in order and magnitude at the two planting sites. This implied interactions between survival capacities of the stock and the properties of the planting sites.

K.W. Picea glauca (white spruce), artificial regeneration, culling, planting, seedling grading, seedling survival.

590. Mullin, R.E. and J. Svaton. 1972. A grading study with white spruce nursery stock. Commonwealth Forestry Review 51(1): 62-69.

Tenth year survival and height of white spruce is related to measurements of length of top, stem diameter and root length at time of planting. Results show a highly significant increase in survival and height with increase in initial top length and stem diameter. Correlations of survival and height with initial root length are less close. Minimum nursery height of 6" and minimum stem diameter of 3/16" are recommended for planting stock.

K.W. Picea glauca (white spruce), height growth, planting, planting stock, seedling grading, seedling growth, seedling survival.

591. Pomeroy, K.B., F.K. Green and L.B. Burkett. 1949. Importance of stock quality in survival and growth of planted trees. J. For. 47:706-707.

Field run seedlings were sorted into four grades, then hand planted in a 4x6 ft. spacing. Survival varied with the stock. Poorer grades suffered higher mortality than the better stock. Differences in survival and growth seemed to diminish as the seedlings grew older. Thus, recommendations are made for the planting of better quality stock initially.

K.W. planting, seedling grading, seedling mortality, seedling survival.

iii) SEEDLING SELECTION, cont'd.

592. Schmidt-Vogt, H. 1970. [The use of large plants as means of improving the efficiency of artificial regeneration.] Allgemeine Forstzeit-schrift 25(10):195-200. (Abstr. F.A. 31:754).

Large spruce plants tended to be more sensitive to water loss during transport, and to have higher first year, but lower subsequent mortalities. Results on different sites depended on weather, but large plants appeared to do better than small plants on wetter sites and less well on dry sites. Economically the use of large plants is considered promising.

K.W. Picea abies (Norway spruce), planting, planting stock, seedling grading, seedling growth, seedling size, seedling survival, site type, soil moisture.

593. Schmidt-Vogt, H. and P. Gürth. 1969. [The characteristics of planting stock and the success of planting. I. Planting trials with Norway spruce and Scots pine of different heights and diameters.] Allgemeine Forst-und Jagdzeitung 140(6):132-142. (Abstr. F.A. 31:79).

Describes results of trials with 2 + 2 spruce and 2 + 1 pine of different height and basal diameter, grown at different spacings, and 3-year results of trials with 2 + 2 spruce raised at equal spacing, sorted into height (39-72 cm) and diameter (5.8-9.8 mm) classes and planted on different sites. The taller plants had lower mortalities and were generally superior to the smaller ones, especially on weed infested sites. Though the taller plants suffered a greater check in height growth, the smaller ones did not catch up to them. Planting check was much less for plants with larger diameters, and the importance of diameter increased with initial height. Check in diameter growth lasted for a shorter period than that in height.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), planting, planting check, planting stock, seedling grading, seedling size, spacing, vegetation.

594. Silversides, C.R. 1948. Does careful selection and treatment of planting stock pay. Pulp and Paper Research Institute of Canada, Woodlands Research Index 40(F-2). 3 pp.

iii) SEEDLING SELECTION, cont'd.

Seedlings, when lifted are graded into minus (50%), average (40%) and plus (10%). All minus seedlings are destroyed and the seedlings are transplanted. After one year the process is repeated and all minus seedlings (5%) are again discarded. Remainder are grouped into average and elite. Average stock is planted on better sites, elite on poorer or drier sites or where there is considerable vegetative competition. Mortality of plants selected in this way is only 5% and they can be planted at spacings much wider than those normally employed. Planting stock is not washed as mycorrhizae are rubbed or washed off when roots are placed in water.

K.W. artificial regeneration, mycorrhizae, nurseries, planting, planting stock, seedling grading, seedling mortality, vegetative competition.

iv) SEEDLING STORAGE AND HANDLING

After lifting and before planting, it is often expedient to store seedlings for a certain period of time. The papers in this section report the influence of storage period, storage temperature, storage and packing materials, and pre-storage treatment upon the post-planting growth and survival of seedlings. In addition, some papers in this section deal with lifting methods and post-storage handling methods. The influence of duration of root exposure before planting on seedling growth and survival is of special note.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

595. Anon. 1944. Tree seedling package. American Nurseryman 80(3):5-6.

Description of a new package for forest tree seedlings, using interwoven veneer mats, bale tie wire, and moist sphagnum moss. The advantages are enumerated.

K.W. packaging, seedling storage.

596. Anon. 1954. Refrigerate your nursery stock. Michigan State Univ., Nursery Notes. (ABSTR.).

A general description of the process of cold storage of seedlings.

K.W. artificial regeneration, nurseries, planting, seedling, storage.

597. Anon. 1961. [Storage and treatment of plants.] Skogbr. Skogind. Forsk. Foren., Asberet, 1960. pp. 7-8. (ABSTR.).

Studies of cold stored plants during winter showed: growth must have stopped and trees reached a state of "winter ripeness" to endure storage at 0°C and 2°C and needles must be dry to prevent molding when storage temperature is kept above 0°C.

K.W. artificial regeneration, cold storage, dormancy, nurseries, planting, seedling storage.

598. Anon. 1965. [Storage trials with spruce plants.] Skogbr. Skogind. Forsk. Foren., Arsberetning, 1964. (ABSTR.).

Rapid freezing of stored plants gave unfavourable results on outplanting. Storage at 0°C and 1°C until Jan. 10, and at -6°C thereafter gave best results. Brassicol had an unfavourable effect during storage below freezing.

K.W. Picea sp. (spruce), artificial regeneration, fungicides, nurseries, planting, seedling mortality, storage temperatures.

599. Abbott, H.G. and E.J. Eliason. 1968. Forestry tree nursery practices in the United States. J. For. 66(9):704-711.

A general survey and review dealing with packing and shipping of seedlings and cold storage practice.

K.W. artificial regeneration, seedling packing, seedling storage, seedlings.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

600. Aldhous, J.R. 1964. Cold storage of forest nursery plants. An account of experiments and trials: 1958-1963. Forestry 37(1):47-63.

Details given for experiments with cold storage of many species. All species tested can be safely cold-stored at 2°C for up to 6 months in poly bags, if seedlings are fully dormant, heathly and dry when placed in storage. Results varied with temperature, time of storage and species. Lower temperature storage had an adverse effect on survival.

K.W. artificial regeneration, planting, seedling storage, seedlings.

601. Aldhouse, J.R. 1966. Storage and handling of nursery plants. Cold storage of seedlings. Forestry Commission, Forest Research Report, 1965. pp. 17-18.

Seedlings of various tree species lifted and stored at 6 week intervals from October to May showed better results at 2°C than at -5°C. Some species grew better after storage than without storage.

K.W. artificial regeneration, planting, seedling storage, seedlings.

602. Aldhous, J.R. 1967. Cold storage of seedlings. Forestry Commission, Forest Research Report, 1966. pp. 24-25.

Various species of seedlings were lifted from October to May at 6 week intervals and stored at 2°C and -5°C. All species survived and grew better after storage at 2°C than at -5°C. All species lifted during or after December showed adequate survival.

K.W. artificial regeneration, lifting date, planting, seedling storage, seedlings.

603. Aldhous, J.R. and J. Atterson. 1961. Handling and storage of plants. Use of polythene (sic) bags for transport and storage. Storage of plants at low temperatures. Forestry Commission, Forest Research Report, 1960. pp. 25-27.

Storage of seedlings at -5°C or for more than 6 months gave unsatisfactory results. Best results were shown with spruces, pines and larches at 2°C for less than 6 months.

K.W. artificial regeneration, planting, seedling storage, seedlings.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

604. Aldhous, J.R. and J. Atterson. 1962. Cold storage of surplus seedlings. Forestry Commission, Forest Research Report, 1961. p. 21.

Summarizes data presented by Aldhous & Atterson (1961) q.v.

K.W. artificial regeneration, planting, seedling storage, seedlings.

605. Aldhous, J.R. and J. Atterson. 1963. Storage of plants at low temperatures. Forestry Commission, Forest Research Report, 1962. pp. 20-22.

Summarizes results reported by Aldhous and Atterson (1961) q.v. Those seedlings which had begun to flush before lifting survived poorly.

K.W. artificial regeneration, flushing, planting, seedling growth, seedling mortality, seedlings.

606. Aldhous, J.R. and J. Atterson. 1964. Handling and storage. The transport of plants. Cold storage of plants. Forestry Commission, Forest Research Report, 1963. pp. 22-23.

When seedlings are exposed to sunlight, polyethylene bags with kraft or cloth outer covers keep seedlings cooler than do uncovered bags.

K.W. artificial regeneration, nurseries, planting, seedling storage.

607. Andreason, O. and U. Thofte. 1963. [Storing plants in plastic bags.] Skogen 50(4):72-74, 81. (ABSTR.).

Results from storing plants at low temperatures in plastic bags were generally better than from storage in peat litter.

K.W. artificial regeneration, nurseries, planting, plastic bags, peat litter, seedling storage.

608. Bailey, V.K. 1961. Storage of nursery stock. American Nurseryman 113(1):12.

General article related to overwinter storage. No experimental data given.

K.W. artificial regeneration, nurseries, planting, seedling storage.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

609. Baldwin, H.I. and A. Pleasonton. 1952. Cold storage of nursery stock. Fox Forest Notes 48. 2 pp. (ABSTR.).

3-0 white pine, red pine, white spruce and balsam fir were stored with their roots surrounded by sphagnum, covered with heavy wax paper, and packed in cartons. Highest survival was obtained with all species at temperatures just above freezing. Quick freezing at 0-10°F gave total loss. White pine withstood storage best, then white spruce, red pine and balsam fir. Spring storage was better than autumn storage.

K.W. Picea glauca (white spruce), artificial regeneration, nurseries, planting, seedling mortality, seedling storage, [Abies balsamea, Pinus resinosa, Pinus strobus].

610. Barkved, M. 1970. [Resistance to drying out and field establishment capacity of Norway spruce planting stock.] Årsskr. Norske Skogplantesk, 1969. pp. 69-81. (Abstr. F.A. 32:91).

Plantings were made during April, May and June after 10, 30, and 60 min. exposure to sunlight with or without subsequent immersion of the seedlings in water for 24 hours. Plant height and leader length were evaluated after 4-5 growing seasons. Cold stored plants showed greater survival than those lifted directly. Plants immersed in water before planting grew better than those not so treated.

K.W. Picea abies (Norway spruce), exposure, growing stock, seedling growth, seedling storage, seedling survival, soaking.

611. Bjorkman, E. 1956. [Storing pine and spruce plants.] Norlands SkogsvFörb. Tidskr. 4:465-483. (ABSTR.).

Storing pine and spruce in plastic bags prevented desiccation at controlled temperatures for up to 1 1/2-8 mos. with best results at 0°C. At 2-3°C molds jeopardized survival, and at -3°C survival dropped off for the longer storage period. Mortality was higher for temperatures -10 to -20°C. Extreme changes in temerature upon removal from refrigeration increased mortality. Treatment with a pentachloraphenol preparation for mold control proved satsifactory for 2 months storage at 2-3°C.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

K.W. Picea sp. (spruce), Pinus sp. (pine), artificial regeneration, mold, nurseries, planting, plastic bags, seedling mortality, seedling storage, storage temperature.

612. Bland, W.A. 1962. Use of clay solution in seedling packaging. Tree Planters Notes 51:15.

Dipping tree roots in a suspension of sand-free fire brick or pipe clay kept roots moist during cold storage for up to 6 weeks without moss.

K.W. artificial regeneration, nurseries, planting, seedling storage.

613. Bradley, K. 1959. Refrigerated storages. American Nurseryman 110(5):104.

General comments given relative to overwinter cold storage, with no experimental data presented. Mentions need for good air circulation, as dead spots can heat up 2-3°F.

K.W. artificial regeneration, nurseries, planting, seedling storage.

614. Breen, J.R.C. 1968. Overwinter refrigerated storage of nursery stock. Ontario Dept. of Lands and Forests, Weekly Rept. District of Lindsay, for week ending Nov. 4, 1968. (ABSTR.).

Reports on overwinter storage of white spruce and jack pine seedlings in bundles at 32-34°F. Results of planting included.

K.W. artificial regeneration, nurseries, planting, seedling storage.

615. Brennaman, D.L. 1965. Automatic mudding of seedling roots. Tree Planters Notes 71:1-4.

Dipping roots in clay kept them moist longer than those on untreated plants and reduced heating within bundles of seedlings.

K.W. artificial regeneration, nurseries, planting, root dipping, seedling storage.

616. Bunting, W.R. 1970. Overwinter cold storage of nursery stock. Northeastern Area State and Private Forests, Proc. Northeastern Area Nurseryman's Conference, Orono, Maine. pp. 45-49. (ABSTR.).

White spruce, red pine, and white pine stored better overwinter at -3°C than at 1.5°C and survival and height growth were better for trees stored in polyethylene bags than for those stored in bales, trays, or with bales inserted in polyethylene bags. White spruce and white pine stored in bags and kept at -3°C survived and grew better than freshly dug controls.

K.W. Picea glauca (white spruce), artificial regeneration, nurseries, planting, plastic bags, seedling growth, seedling storage, [Pinus resinosa, Pinus strobus].

617. Burgar, R.J. and N.F. Lyon. 1968. Survival and growth of stored and unstored white spruce planted through the frost free period. Ontario Dept. of Lands and Forests, Res. Rept. 84. n.p. (ABSTR.).

Spring cold storage did not affect survival of white spruce, but growth decreased progressively for plantings during late spring and summer.

K.W. Picea glauca (white spruce), artificial regeneration, nurseries, planting, planting date, seedling growth, seedling mortality, seedling storage.

618. Chedzoy, J. 1968. Storage requirements for nursery stock. Proc. Intermountain Nurseryman's Assoc., 8th Annual Meeting. pp. 66-68. (ABSTR.).

Lodgepole pine and white spruce survived overwinter cold storage better when lifted in October rather than in late September. Spring storage for 1 month in kraft-polyethylene bags at 1-2°C proved satisfactory.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, lifting data, nurseries, planting, seedling growth, seedling mortality, seedling storage, storage bags.

619. Cram, W.H., C.H. Lindquist and A.C. Thompson. 1966. Tree packing and storage studies. Tree Nursery, PFRA, Indian Head, Sask., 1965 Summer Rept. pp. 12-14. (ABSTR.).

Among several methods tested, polyethylene wrappings provided best protection against dissociation during storage. Mudding roots was not as good as packing with wet moss. Survival in fall transplanting increased with later data of lifting and was positively correlated with decreasing moisture content (fresh weight basis), which indicates improved maturity of the plants.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

K.W. artificial regeneration, lifting date, nurseries, planting, root covering, seedling growth, seedling mortality, seedling storage.

620. Deffenbacher, F.W. and E. Wright. 1954. Refrigerated storage of conifer seedlings in the Pacific Northwest. J. For. 52:936-938.

Reports results of survival tests in the nursery and field, which indicate survival of trees is not impaired by cold storage for up to six month periods. Cold storage temperatures must be from 33° to 35°F and humidity from 90% to 95%, with adequate air circulation maintained.

K.W. Abies procera (noble fir), Picea sitchensis (Sitka spruce), Pinus ponderosa (ponderosa pine), Pseudotsuga menziesii (Douglas fir), cold storage, humidity, nurseries, seedling storage, seedling survival.

621. DeVries, H.H. 1966. Storage of nursery stock. Ontario Dept. of Lands and Forests, Proc. Nurseryman's Meeting, Swastika District. pp. 34-36. (ABSTR.).

A general discussion without experimental data.

K.W. seedling storage.

622. Dierauf, T.A. and R.L. Marlev. 1967. Clay dipped v.s. bare rooted seedling survival. Virginia Division of Forestry, Occasional Rept. 27. n.p. (ABSTR.).

Clay dipping increased seedling survival slightly but even clay dipped stock required protection from exposure.

K.W. artificial regeneration, nurseries, planting, root dipping, seedling mortality, seedling storage.

623. Dimpflmeier, R. 1969. [Agricol, a new preparation to keep forest planting stock fresh during storage and transport.] Forstwissenschaftliches Centrablatt 88(2):80-96. (Abstr. F.A. 30:655).

Dipping 2 + 2 spruce in a 1.25% aequeous solution of Agricol, a form of Na alginate, gave promising results for seedling handlings. Survival to the end of the second growing season after planting was 80% after 2 days in a shed v.s. 0% for untreated controls, 75% after 7 hours in the open v.s. 0% for controls, and 95% after 3 hours in the open v.s. 20% for controls. Growth was less for all stored seedlings than unstored, but Agricol treated seedlings were superior to untreated control seedlings.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

K.W. Picea sp. (spruce), planting, root dipping, seedling growth, seedling storage, seedling survival, water loss.

624. Eliason, E.J. 1962. Damage in overwinter storage checked by reduced moisture. Tree Planters Notes 55:5-7. (ABSTR.).

Recommends procedures for overwinter storage based on past experience.

K.W. seedling damage, seedling storage.

625. Eliason, E.J. and D. Carlson. 1962. Tests with tree packing materials. Tree Planters Notes 54:17-18. (ABSTR.).

Tests of sphagnum, excelsior, and chopped hay as packing on trees stored up to 5 weeks at 50-70°F showed no significant difference in survival related to differences of packing materials.

K.W. artificial regeneration, nurseries, packing material, seedling storage, seedling mortality.

626. Evans, R.L. 1962. Material handling comes to the nursery. Tree Planters Notes 53:15.

Describes a handling system for overwinter cold storage.

K.W. seedling storage.

627. Faulkner, R. and J.R. Aldhous. 1957. Handling and storage of plants. Forestry Commission, Forest Research Report, 1956. p. 35.

When wrapped in various materials and exposed for 10 or 20 days, survival of seedlings with moisture content exceeding 80% (dry weight basis) was over 90%. Those with moisture content below 30% did not survive. Polyethylene wrapping gave best results.

K.W. artificial regeneration, nurseries, planting, seedling moisture, seedling mortality, seedling storage.

628. Faulkner, R. and J.R. Aldhous. 1958. Handling of plants. Forestry Commission, Forest Research Report, 1957. pp. 34-36.

Continues studies of relation between seedling moisture content and survival during varying periods of storage.

K.W. artificial regeneration, nurseries, planting, seedling moisture, seedling mortality, seedling storage.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

629. Faulkner, R. and J.R. Aldhous. 1959. Plant handling and storage. Forestry Commission, Forest Research Report, 1958. pp. 35-37.

Storage in polyethylene bags under open sheds for varying periods from mid-November to mid-May gave generally satisfactory results for late lifted, early planted stock. Stock having wet foliage at time of lifting gave poorer results, although molding was not considered a great hazard.

K.W. artificial regeneration, lifting date, molding, nurseries, planting, seedling mortality, seedling storage.

630. Flint, H.L. and J.J. McGuire. 1962. Response of rooted cuttings of several woody ornamental species to overwinter storage. Proc. Amer. Horticultural Society 80:625-629. (ABSTR.).

Survival of rooted white spruce cuttings was improved when dusted with Captan before storage for 6 months at 32°F or 40°F.

K.W. artificial regeneration, Captan, cuttings, fungicides, nurseries, planting, seedling storage.

631. Hamm, H.W. and C.H. Lindquist. 1969. Tree storage and packing. Tree Nursery, PFRA, Indian Head, Saskatchewan, Summer Rept., 1968. p. 18. (ABSTR.).

For Colorado blue spruce and Scotch pine stored over-winter in sealed polyethylene bags for 204 days, mudding roots greatly reduced survival compared to plant with washed and untreated roots. Storage at 24°F reduced survival as compared to storage at 35°F, especially for pine. Poorer survival at 24°F appeared to result from desiccation of the seedlings.

K.W. artificial regeneration, planting, plastic bags, root treatment, seedling mortality, seedling storage, [Picea pungens, Pinus sylvestris].

632. Hocking, D. 1972. Effect and characteristics of pathogens on foliage and buds of cold stored white spruce and lodgepole pine seedlings. Canadian Journal of Forest Research 1(4): 208-215.

Molding of cold-stored, spring-lifted seedlings of white spruce reached an index of 71.7 and of lodgepole pine an index of 35.6 during 10 weeks of storage. Mortality and reduced growth after planting out were directly related to degree of molding. 10 significant fungal species were isolated from moldy seedlings, all of which grew at 5°C and 8 of which grew at 0°C. Storage at 0°C reduced molding to less than 50% that at 25°C.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), fungi, molding, seedling growth, seedling storage, seedling survival.

633. Hocking, D. 1972. Nursery practices in cold storage of conifer seedlings in Canada and the United States. Tree Planters Notes 23(2):26-29.

Most nurseries are equipped with cold storage, temperatures being kept in the range 33-40°F but not controlled within narrow limits. Stored stock is always wrapped with roots covered in water proof material and for longer periods, the whole seedling is usually enclosed in a poly bag or wooden crate. Roots are usually packed in sphagnum or peat moss. Most species have been kept successfully for 4-7 months.

K.W. nurseries, growing stock, seedling storage, storage facilities.

634. Hocking, D. and B. Ward. 1971. Late lifting and storage over-winter frozen in plastic bags gives good survival of white spruce in Alberta. Tree Planters Notes. (ABSTR.).

Stock lifted Oct. 20 survived better than stock lifted Oct. 13. Plastic bags prevented desiccation, with or without added peat moss. Molding was almost wholly absent during storage for 203-214 days at -3°C. Best survival was 87% for stock packaged in plastic bags without peat. Observations of starch content showed a consistent trend towards decreasing starch with increasing duration of storage. At time of planting, starch was still present in roots of seedlings in all treatments.

K.W. Picea glauca (white spruce), artificial regeneration, fungi, lifting date, planting, seedling mortality, seedling starch content, seedling storage.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

635. Hocking, D. and B. Ward. 1972. Late lifting and freezing in plastic bags improve white spruce survival after storage. U.S. Dept. Agric., Tree Planters Notes 23(3):24-26.

White spruce may be stored for up to 7 months if seedlings are dormant (achieved by late lifting), desiccation is prevented by packaging in plastic bags and molding and metabolic activity are minimized by storage at sub-freezing temperature.

K.W. Picea glauca (white spruce), artificial regeneration, cold storage, dormancy, lifting date, planting, seedling mortality, seedling storage.

636. Hopkins, G.M. 1938. Survival of nursery stock after cold storage. Fox Forest Notes 11. n.p. (ABSTR.).

Storage of white spruce and white pine at 31-33°F from fall through mid-July led to poor survival, which suggests that stock stored overwinter must be planted earlier in the year.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting date, seedling mortality, seedling storage, [Pinus strobus].

637. Jacobsson, F. 1955. [Winter storage of plants lifted in autumn.] Skogen 42(7):126-127. (ABSTR.).

Plants were stored successfully in open wooden boxes at outdoor temperature, or healed in at the planting sites.

K.W. artificial regeneration, lifting date, planting, storage method, seedling storage.

638. Jankowski, E.J. 1966. New seedling packing material available. Tree Planters Notes 79:9.

A blanket of felted wood fibres retained moisture well, proved easier and cleaner to store and use than sphagnum, and was less expensive.

K.W. artificial regeneration, economics, packing material, planting, seedling storage.

639. Jorgensem, E. and W.K.L. Stanek. 1962. Overwinter storage of coniferous seedlings as a means of preventing late frost damage. Forestry Chronicle 38(2):192-202.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

Seedlings of several species, including Picea glauca were stored in root cellars the air temperatures of which were 12-40°F. Temperatures in root zones of bales were 12° - 34°F. Pines show a greater tendency to desiccation than did spruce. For white spruce, plants stored for 5 months were more resistant to late spring frost occurring after planting than was spring lifted stock.

K.W. Picea glauca (white spruce), artificial regeneration, desiccation, frost resistance, lifting date, planting, seedling mortality, seedling storage, storage temperature.

640. Laber, B. 1972. [Trials with spruce in 'pflanz-frisch' transports bags.] Allgemeine Forstzeitschrift 27(9/10):164. (Abstr. F.A. 33:716).

Three methods of storing 2 + 2 spruce stock, in dark opaque poly bags, in clear plastic bags, and in uncovered bundles, were investigated. Moisture losses after 14 days in shade were 2, 6, and 25% respectively for the three methods and in sun, 12 and 39% for two first two. In planting tests 4, 14, 28 or 42 days after storage in these conditions, the percent of healthy survivors was much higher for those stored in opaque bags than for other treatments, although stock with bare roots dipped in Agricol gave better results, especially for long storage.

K.W. Picea sp. (spruce), flushing, moisture loss, root dipping, seedling growth, seedling storage, storage methods.

641. Leslie, A.P. 1945. Storage of planting stock over winter. Ontario Dept. of Lands and Forests, Res. Rept. 5. n.p. (ABSTR.).

Various coniferous species were stored at or near freezing in an insulated unrefrigerated storage room, or at 14°F or 0°F under refrigeration. Storage at or near freezing gave generally satisfactory results. Fast freezing to 0°F killed nearby all trees. Slow freezing to 14°F gave satisfactory results for nearly all species.

K.W. artificial regeneration, planting, seedling mortality, seedling storage, storage temperature.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

642. Limstrom, C.A. 1963. Forest planting practice in the central States. U.S. Dept. Agric., Agric. Handbook 247. n.p. (ABSTR.).

Recommends: 1) store at 33-35°F if trees are held more than one week, 2) do not stock bundles, 3) minimize storage time.

K.W. seedling storage.

643. Lindberg, S.O. 1951. A new method for storing plants. Skogen 38(12):128-130. (ABSTR.).

Under refrigerated storage, plants can be kept up to 10 weeks while waiting for planting sites to thaw in northern Sweden.

K.W. artificial regeneration, planting, seedling storage, storage time.

644. Lindquist, C.H. 1970. Plant storage studies. Tree Nursery PFRA, Indian Head, Saskatchewan, 1969, Summer Rept. pp. 17-18. (ABSTR.).

Delaying lifting in fall up to October 28 (last date tested) progressively improved survival, especially for stock stored without covers. For storage at 35°F, survival was better among plants kept under polyethylene covers than in open, and those stored without moss than with moss packing.

K.W. artificial regeneration, lifting date, packing material, planting, seedling mortality, seedling storage.

645. Lindquist, C.H. and T. Elliot. 1968. Spring storage of conifer transplants. Tree Nursery, PFRA, Indian Head, Saskatchewan, 1967 Summer Report. pp. 28-29. (ABSTR.).

Survival was twice as good among transplants lifted May 3 and stored at 34°F, than among stock lifted May 19.

K.W. artificial regeneration, lifting date, seedling mortality, seedling storage.

646. Luck, R.H. 1959. A second look at a nursery stock packaging experiment. Forestry Chronicle 35(1):36-49.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

Method of packing stock stored without refrigeration only slightly influenced survival and did not affect growth. Lengthening storage adversely affected both survival and growth.

K.W. artificial regeneration, planting, seedling growth, seedling mortality, seedling storage, storage method.

647. Mullin, R.E. 1956. Moisture retaining materials for nursery stock packaging. Ontario Dept. Lands and Forests, Res. Rept. 34. 43 pp.

Sphagnum moss, locally collected moss, poplar excelsior, and poplar excelsior treated with a wetting agent were tested as moisture retaining material in bales of nursery stock. Bales were stored at various periods up to 4 1/2 weeks. Materials cauased no significant differences in mortality at the end of the first growing season. There was an increasing loss of stock with storage.

K.W. artificial regeneration, packing material, planting, seedling growth, seedling mortality, seedling storage.

648. Mullin, R.E. 1958. An experiment with wrapping materials for bales of nursery stock. Ontario, Dept. Lands and Forests, Res. Rept. 37. 31 pp.

Three wrapping materials for bales of nursery stock were examined with respect to the effect on survival of white-spruce 2-2 stock. Burlap, burlap with waxed paper, and .004 inch blue polyethylene were used. Several storage periods up to 6 weeks were used. Storage was in an open shed. No difference in survival of stock due to wrapping showed itself. Survival of stock decreased with increasing time of storage.

K.W. Picea glauca (white spruce), artificial regeneration, planting, seedling storage, seedling survival, wrapping material.

649. Mullin, R.E. 1966. Overwinter storage of baled nursery stock in northern Ontario. Commonwealth Forestry Review 45(3): 224-230.

Reports comparison of growth of white spruce and red pine nursery stock baled and stored from Dec. to March below $0^{o}C$ (min. $-15^{o}C$), with that of unstored stock after planting out in experimental plots. Survival and growth of both species were adversely affected by storage which made white spruce more susceptible to frost damage. Seedlings (3 + 0) were much inferior to transplants (2 + 2).

iv) SEEDLING STORAGE AND HANDLING, cont'd.

K.W. Picea glauca (white spruce), frost damage, planting, regeneration, seedling growth, seedling storage, seedling survival, [Pinus resinosa].

650. Mullin, R.E. and W.R. Bunting. 1972. Refrigerated overwinter storage of nursery stock. J. For. 70(6):354-358.

Three year seedlings of white spruce, red pine, and white pine were lifted in late November and stored by various methods. The "frozen polybag method was the most promising method and white spruce seedlings given this treatment survived better after planting than did spring lifted seedlings. It is tentatively suggested that the cold-stored and frozen stock was able to withstand handling and holding better than freshly lifted stock.

K.W. Picea glauca (white spruce), planting, lifting date, seedling storage, seedling survival, [Pinus strobus, Pinus resinosa].

651. Oglaend, I. 1961. Planter i plastpose. Norske Skogbruk 7(19): 655. (ABSTR.).

Unrefrigerated spring storage in soaked plastic bags was satisfactory for 1 month, but after 2 months, mold severely damaged stock.

K.W. artificial regeneration, planting, plastic bags, seedling mortality, seedling storage.

652. Oldenkamp, L. and B.C.M. van Elk. 1967. [The storage period of forest plants.] Proefstn. Boomkwe., Boskoop, Jaarb. 1966. n.p. (Abstr. F.A. 29:554).

Conifers were stored at 1°C or -2°C between lifting dates from October to February, and planting dates from March to September. Best survival and growth were obtained with plants lifted in mid-January and planted in April. Almost all plants lifted in October died, especially when stored at -2°C.

K.W. artificial regeneration, lifting date, planting, planting date, seedling growth, seedling mortality, seedling storage, storage temperature.

653. Oldenkamp, L., H. Blok and B.C.M. van Elk. 1969. [Cold storage of tree seedlings.] Ned. Bosbouw. Tijdschr. 41(1):23-29. (ABSTR.).

Tested lifting and planting dates and storage temperatures for several conifers, plus for Douglas fir the influence of wrapping in polyethylene and fertilization with N and K before lifting. Lifting after December but before February was generally best. Storage at 1°C was generally better than at -2°C. Fertilization of Douglas fir before lifting had no influence on survival upon outplantings after storage.

K.W. artificial regeneration, lifting date, planting, seedling storage, seedling survival, storage temperature, [Pseudotsuga menziesii].

654. Ostermann, M. 1964. [Further experience in delaying the growth of nursery plants by deep freezing.] Forst-und Holz. 18(19): 406-409. (ABSTR.).

Storage for up to 8 months at -5°C gave generally good results even with hardwoods, but not for Douglas fir from German seed.

K.W. artificial regeneration, hardwoods, planting, seedling storage, seedling survival, storage temperature, [Pseudotsuga menziesii].

655. Ostermann-Holstenbek. 1959. Die verlängente pffanzzeit; Nordwestdeutscher forstverein-bericht über die tagung in Kiel. Berliner Tag. Nordwestdtsch. Forstver. 1959(1960):70-75. (Abstr. F.A. 22:237).

For a wide range of species, seedlings and transplants showed good survival and growth after storage for from 105 days to a full year at -2 to -8°C.

K.W. artificial regeneration, planting, seedling growth, seedling mortality, seedling storage, storage duration, storage temperature, transplants.

656. Pollard, D.F.W. 1973. Growth of white spruce seedlings following cold storage. Forestry Chronicle 49(4):183.

Four year-old white spruce seedlings were held in cold storage at 4°C to 8 weeks into flushing season in 1970. All seedlings survived and annual height increments were measured in 1970, 1971 and 1972. Treatment had an immediate effect in 1970 by reducing height growth up to 40%. The longer flushing was delayed the more height growth suffered. Similar results were evident in 1971 but by 1972, previous delays of 2 and 4 weeks were apparently beneficial.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

K.W. Picea glauca (white spruce), flushing, nurseries, planting, planting stock, seedling growth, seedling storage.

657. Radulescu, S. and Stanescu, C. 1968. [Winter storage of conifer seedlings in polythene bags.] Rev. Pădurilor 83(7):342-345. (Abstr. F.A. 31:79).

Reports successful experiments of lifting seedlings of spruce, pine and larch (2-4 years old) in autumn and storing them in sealed polyethene bags at not >10°C. Planting out in May gave 98% survival.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), lifting, planting, plastic bags, seedling storage, seedling survival.

658. Read, R.A. 1968. Storage requirements for nursery stock. Proc. 8th Annual Meeting, Intermountain Nurseryman's Assoc. pp. 56-63.

A general review with recommendations.

K.W. seedling storage.

659. Revel, J. 1971. E.P. 668 - Planting of white spruce throughout the growing season in the North Central Interior. B. C. Forest Research Review. pp. 63-64.

Both 2 +) and 2 + 1 cold storage and 2 + 1 freshly lifted plants were planted on clearcut and burned subalpine forest sites at two week intervals (June 13 - Oct. 3). Freshly lifted seedlings survived well at all planting dates for all plantings (1968, 1969, 1970). Cold storage seedlings increased in mortality from August plantings onwards, the greatest mortality occurring in August. Tables of total height, leader growth, survival, and normality are given for all stocks and planting dates. Also reported 1969 - p. 82, 1970 - pp. 73 -75.

K.W. Picea glauca (white spruce), artificial regeneration, cold storage, planting, planting date, seedling growth, seedling mortality, seedling storage, seedling survival.

660. Rusten, A. 1965. [Winter storage of plants.] Norsk. Skogplantesk. Årsskr. 1964(1965):31-32. (ABSTR.). (For. Abstr. 27(3): 38-54).

iv) SEEDLING STORAGE AND HANDLING, cont'd.

Gives general comments concerning overwinter cold storage, including use of fungicides, bundling, plant containers, wrappings and temperature and humidity of cold storage depots.

K.W. artificial regeneration, cold storage, containers, fungicides, seedling storage, storage temperature.

661. Sandvik, M. 1957. [Problems concerning storing and transport of spruce plants.] Norsk. Skogbr. 6:1-4. (ABSTR.).

Results from fall lifting and heeling-in overwinter were better than those for spring lifting.

K.W. artificial regeneration, lifting date, seedling mortality, seedling storage.

662. Sandvik, M. 1959. [Winter storage of planting stock in a shed or in cold storage.] Norsk. Skogbr. 4(8):231-233. (ABSTR.).

During two different years, experiments to store 2-0 Siberian larch, 2-0 pine and 2-0 and 2-2 spruce, for 7 months under various conditions, showed good survival with larch stored on an earth floor of a shed at uncontrolled above freezing temperature, larch stored in a moist atmosphere at uncontrolled temperature, and pine and spruce stored at 1-4°C with relative humidity at 99-100%. Storage at 0-2°C and 80% relative humidity resulted in drying out and heavy mortality of larch and spruce. Pine stored from Oct. 29 to May 27 at 1-4°C and 99-100% relative humidity grew twice as fast as did non-dormant seedlings transplanted directly from seedbeds.

K.W. Picea sp. (spruce), artificial regeneration, lifting date, planting, seedling growth, seedling mortality, seedling storage, storage duration, storage humidity, storage temperature, [Larix sp., Pinus sp.].

663. Schmidt-Vogt, H. 1963. [First experiments in delaying growth of forest plants by cold storage.] Forst-und Holzw. 19(5): 85-86. (Abstr. F.A. 25:502-504).

Seedlings of various species were lifted in Nov., Dec., and Feb., and kept for 2-8 months in a cold room at 1-2°C and 90-95% relative humidity before being planted out in April, May, June and July. After 2 years, mean survival was 89%. Length of storage and bundling versus no bundling, had no effect on survival. Survival was best (95%) for seedlings planted in July, and poorest among those planted in June.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

K.W. artificial regeneration, cold storage, lifting date, planting, seedling mortality, seedling storage, storage duration, [Larix sp., Picea sp., Pinus sp.]

664. Shearer, R.D. 1970. Storage of western larch, ponderosa pine, and lodgepole pine planting study. U.S. Dept. Agric., Inter-Mountain Forest and Range Experiment Station, Unpubl. File Rept. 2470. Silvic. Proc. (4100). (ABSTR.).

Bags of seedlings were stacked in storage. Within stacks 5-6 bags deep, temperatures were 7-14°F warmer than ambient temperatures of 35°F.

K.W. Pinus contorta (lodgepole pine), seedling storage, storage temperature, [Larix sp., Pinus sp.].

665. Simon, C.L. [96]. Effects of lifting date, cold storage, and grading on survival of some coniferous nursery stock. J. For. 59(6):449-450.

A study to test the effect of lifting date, cold storage, and grading on the survival of nursery grown trees including Picea engelmannii was made in Colorado. No differences in overall survival of any species could be attributed to cold storage. Survival of spruce was not influenced by lifting date. Above average grade stock of all species survived significantly better than below average stock.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, cold storage, lifting date, nurseries, planting, seedlings, seedling grading, seedling size, seedling survival, [Pinus sp.].

666. Slayton, S.H. 1970. Storing baled red pine, black spruce, and white spruce overwinter feasible in Upper Michigan. Tree Planters Notes 21(4):15-17.

Red pine, black spruce, and white spruce were stored at 27-30°F and 97-100% relative humidity, in sphagnum packed bales. Overwinter storage showed decreased first year survival, but by the third year, results were comparable to fresh dug controls. At 33-35°F some mold developed on the stored plants.

K.W. Picea glauca (white spruce), artificial regeneration, molding, planting, seedling mortality, seedling storage, storage temperature, [Picea mariana, Pinus resinosa].

iv) SEEDLING STORAGE AND HANDLING, cont'd.

667. Staal, E. 1964. [Storing plants in water.] Skogen 51(4):108. (Abstr. F.A. 25:3491).

Seedlings survived outplanting satisfactorily after 8 weeks storage (packed close together) in shallow water within containers or ditches. For storage exceeding one week, water should be cool and plants shaded.

K.W. containers, planting, seedling storage, seedling survival, storage duration, water storage.

668. Stefansson, E. 1949. [Storage experiments with Norway spruce plants.] Skogen 36(9):117-118. (ABSTR.).

Good first year survival was observed with 3-0 plants stored unrefrigerated for 14 days indoors or out and packed with sphagnum in paper wrapped bundles or in boxes. After 26 days indoor treatments molded and outdoor treatments desiccated.

K.W. Picea abies (Norway spruce), molding, packing material, planting, seedling mortality, seedling storage, storage duration.

669. Stoeckeler, J.H. 1950. How long can conifers be held in spring by cold storage. U.S. Dept. Agric., Lake States Forest Experiment Station, Tech. Note 343. 1 pp.

Seedlings of various species including white spruce were lifted on May 3 and stored at 50°F for 1, 2, 3, 4, and 5 weeks before transplanting. In another experiment seedlings were lifted weekly from May 3 to June 7 and transplanted immediately. First year survival of white spruce seedlings dropped to 93% after 4 weeks and 81% after 5 weeks storage. Survival of all trees lifted and planted immediately was 95% or above. Later transplanting appeared to affect growth adversely.

K.W. Picea glauca (white spruce), lifting date, planting, seedling growth, seedling storage, seedling survival, transplanting.

670. Toy, S.J. and J.P. Mahlstede. 1960. Prolonging dormancy of nursery stock by increasing the concentration of carbon dioxide in the storage atmosphere. Journal of the American Society of Horticultural Science 75:774-784.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

671. Trampe, W.P. 1960. Chemical treatment of nursery stock for better storage. Minnesota Nurseryman's News 7:9-10. (ABSTR.).

Recommends use of Captan or pentachloronitrobenzene to control molds especially of Botrytis sp.

K.W. Botrytis sp., fungicides, molds, seedling storage.

672. Tutygin, G.S. and A.V. Veretennikov. 1968. [The effect of duration of cold storage on the survival and growth of seedlings.] Lesn. Ž. 11(6):11-14. (Abstr. F.A. 31:643).

2-0 seedlings of Scots pine and Norway spruce were lifted in the spring before growth started, and stored for up to 84 days at 0-3°C and 90-92% relative humidity. Observation of needle pigments, survival, and height growth inidcated that pine should not be stored more than 40 days and spruce not more than 53 days.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots Pine), lifting date, planting, seedling growth, seedling mortality, seedling storage, storage duration.

673. Venn, K. 1967. [A preliminary study of spraying spruce plants to control fungus attack during cold storage.] Norske Skogbruk 13(21):553, 559-560. (Abstr. F.A. 29:2257).

During storage at -2°C, untreated plants escaped fungus injury as well as 2-2 plants sprayed with fungicide in the nursery beds before lifting, or those dipped before packing. At temperatures above 0°C, even treated plants were damaged.

K.W. fungicides, molding planting, seedling damage, seedling storage, seedling treatments.

674. Williston, H.L. 1964. Seedling storage in refrigerated cars. Tree Planter's Notes 65:20.

Seedlings in polyethylene-lined kraft bags or bales, could be stored in refrigerated railway cars for 3 1/2 months. At 20-60°F, temperature was higher inside bundles and bags than in the air around them, but inside the bags, the temperature changed slower than that of the surrounding air.

K.W. cold storage, planting, plastic bags, seedling storage, storage temperature.

iv) SEEDLING STORAGE AND HANDLING, cont'd.

675. Wilner, J. 1953. Study of effect of storage and time of transplanting on survival of certain broadleaf and evergreen seedlings. Forest Nursery Station, Indian Head, Saskatchewan, Canada, 1953. (ABSTR.). (For. Abstr. 17(1):371). [n.p.]

Presents tabular data for 3 years studies under prairie conditions with various species, including white spruce.

K.W. Picea glauca (white spruce), planting, seedling storage, seedling survival, [Picea sp., Pinus sp.].

(v) SEEDLING TREATMENTS

Papers in this section report the influence of seedling treatments, especially root and/or shoot pruning, carried out after lifting, upon the growth and survival of seedlings after plantings.

v) SEEDLING TREATMENT, cont'd.

676. Day, R.J. and R.M. Rogers. 1969. A comparison of seedling lifting methods at the Swastika Nursery. Univ. Toronto Forest Research Review. p. 9.

Jack pine and white spruce seedlings were lifted in fall 1968 by conventional blade and potato digger type mechanical lifters. Root surface area was measured and both species then potted and grown in a greenhouse. The potato digger was best for both species since more fine root was retrieved from the bed contributing to a significantly larger root surface area for digger lifted seedlings. Root regeneration was best from digger lifted spruce, poorest from blade lifted pine.

K.W. Picea glauca (white spruce), Pinus banksiana (jack pine), artificial regeneration, lifting, nurseries, planting, root damage, root regeneration.

677. Farrar, J.L. and G.D.Huntley. 1969. The effect of root pruning on root extension growth of Pinus banksiana and Picea glauca seedlings. Univ. Toronto, Forest Research Review. pp. 5-6.

Seedlings at 1-0 and 2-0 were severely root pruned at time of transplanting to leave only 3 main laterals and no long root tips. On white spruce, root system quickly became functional in new environment. Active new root tips were found on the 1-0 seedlings after week and on the 2-0 seedlings after 2 weeks. During the next few weeks the more vigorous roots grew nearly 3 mm/day. The jack pine nearly all died.

K.W. Picea glauca (white spruce), artificial regeneration, root growth, root pruning, seedling mortality, transplanting.

678. Hedemann-Gade, E. 1948. [Should plants be root-pruned?] Skogen 35(5/6):73. (Abstr. F.A. 10:188).

Root pruning of various intensities was carried out on Norway spruce stock, both at time of transplanting and time of planting out. Growth was in general remarkably little affected, and only in plants losing 3/4 of their root system was check noticeable. Best practice for 2-2 stock is to root prune severely when transplanting at 2 years of age. Such plants run little risk of root rot and need no further pruning before planting out.

v) SEEDLING TREATMENT, cont'd.

K.W. Picea abies (Norway spruce), artificial regeneration, nurseries, planting, root damage, root pruning, root rot, seedling growth.

679. Mullin, R.E. 1957. Experiments with root and top pruning of white spruce nursery stock. Ontario Dept. of Lands and Forests, Res. Rept. 36. 31 pp.

Top pruning by itself had no effect on survival in the nursery or in the field. Heavy root pruning was detrimental, moderate root pruning ineffective and machine root pruning was beneficial to survival in the nursery. Root pruning treatments by themselves had no effects in the field. Root pruning with top pruning did not have any effect in the nursery but top pruning with moderate root pruning gave higher survival in the field than the control. Survival was further increased by repeating the root pruning later in the season. This should be done to 2-2 white spruce when in the 2-1 stage.

K.W. Picea glauca (white spruce), artificial regeneration, planting, pruning, root pruning, seedling survival.

680. Mullin, R.E. 1960. Effect of root and top pruning on size and planting success of white spruce nursery stock. Yale University, Ph.D. Thesis. 146 pp.

681. Mullin, R.E. 1966. Root pruning of nursery stock. Forestry Chronicle 42(3):256-264.

Studies the influences of root pruning at different stages of growth, and at two different depths, on 3-0 stock of white spruce and white pine. Mortality, seedling size, and growth were measured. Root pruning in nursery showed no mortality, but did show decreased height growth. Root pruning of white spruce after flushing increased survival and growth after planting over that of unpruned stock. White pine was not affected. There was no significant effect of differing plant depth.

K.W. Picea glauca (white spruce), artificial regeneration, growth increment, nurseries, planting, root pruning, seedling survival, seedlings, [Pinus strobus].

682. Mullin, R.E. 1973. Root and top pruning of white spruce at the time of planting. Forestry Chronicle 49(3):134-135.

v) SEEDLING TREATMENT, cont'd.

All pruning practices applied between lifting and planting inhibited growth at some stage. Considering also the indication of lower survival from root pruning it is suggested that the practice of root clipping of white spruce may be detrimental and should be discontinued pending further study.

K.W. Picea glauca (white spruce), artificial regeneration, planting, root pruning, seedling growth, seedling survival, top pruning.

683. Stanasov, B. 1969. [Studies on root pruning of conifer seedlings.] Gorskostop Nauka, Sofija 6(3):27-35. (Abstr. F.A. 31:525).

Survival and growth of 2- and 3 year-old pine and spruce seedlings root pruned to root lengths of 10 or 20 cm immediately before planting, were equal or superior to those of unpruned controls. Generally roots should be pruned to 20 cm and root diameter at the point of pruning should not exceed 1 mm.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scotch pine), root pruning, seedling growth, seedling survival.

684. Sutton, R.F. 1967. Influence of root pruning on height increment and root development of outplanted spruce. Canadian Journal of Botany 45(9):1671-1682.

Three year seedlings of white and Norway spruce of two size classes were planted; untreated; with all lateral roots pruned to 5 cm; pruned flush with main root; and all roots pruned to 10 cm from root collar. Survival was good except when pruned to the main root and first and second year growth were not affected by treatment. Increases of root length of >1000% that of controls were noted for pruned white spruce.

K.W. Picea glauca (white spruce), root growth, root pruning, seedling growth, seedling survival, [Picea abies].

685. U.S. Dept. Agric. 1939. Top-pruning of conifer stock a doubtful operation. U.S. Dept. Agric., Lake States Forest Experiment Station, Tech. Note 145. 1 p.

Mortality was considerably increased by top pruning coniferous nursery stock just before planting out. Top pruning some months in advance of planting gave no significant difference in survival.

K.W. nurseries, planting, planting stock, pruning, seedling mortality.

C. ESTABLISHING THE YOUNG FOREST

All aspects of planting and sowing in the field by artificial means are included in this section. Subsections deal with the influences of pre- and post- regeneration site treatments, and of factors in the natural environment on seed germination and seedling growth and survival in the field.

i) INFLUENCES OF METHODS AND SEASON OF SOWING

Papers in this section deal exclusively with the results of direct seeding in the field as a method of artificial regeneration. Date of sowing is evaluated with respect to seed germination and seedling growth and survival. Methods of sowing are described and their influences upon the success of regeneration evaluated. Also included are studies comparing seeding and planting as alternate methods of artificial regeneration.

i) INFLUENCES OF METHODS AND SEASON OF SOWING, cont'd.

686. Anon. 1946. Walking stick seed planter. Timberman 47(10): 62, 64.

Describes a new seeding tool for reforestation.

K.W. artificial regeneration, seeding.

687. Ackerman, R.F. 1959. A comparison of methods of direct seeding on mountain lithosols. Canada, Forestry Branch, Forest Research Division, Mimeo 59-11. 15 pp.

Tests methods of restoring forest cover to denuded mountain lithosols in Alberta. Of the three species tested, white spruce, lodgepole pine and Douglas fir, only lodgepole pine gave good results. The northeast aspect was found most favourable for germination and subsequent survival. Soil cultivation was considered necessary and results were best when lodgepole pine was sown in the fall.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, birds, cultivation, insects, seedbed, seeding, seedling mortality, soil.

688. Bathern, R. 1939. [Sowing versus planting.] Tidsskraft Skogbruk 47:271-275. (Abstr. F.A. 1:255).

Good results were obtained from patch sowing of Norway spruce in small mounds covered with gravel. Seedlings raised in this way were not stifled by accumulated litter and escaped frost heaving.

K.W. Picea abies (Norway spruce), artificial regeneration, economics, frost heaving, seeding, seeding method, seedling growth.

689. Blyth, A.W. 1955. Seeding and planting of spruce on cutover lands of the subalpine region of Alberta. Canada, Forestry Branch, Forest Research Division, Tech. Note 2. 11 pp.

Planting was the most successful method of regeneration, with 55-80% survival after 5 years. For broadcast and spot seeding, the average degree of success for all conditions was 25% and 21% respectively. Natural seeding was a failure, averaging only 2% success. Ground treatment had no effect upon the success of planting, but for regeneration by seeding produced superior results. Natural regeneration was unsatisfactory on all ground treatments. Seed stratification resulted in earlier germination but had no significant effect on final survival. Protection of seed from rodents was essential. Seeding success was hampered by ground vegetation.

i) INFLUENCES OF METHODS AND SEASON OF SOWING, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, germination, planting, regeneration, rodents, seeding, seedling mortality, site treatment, spot seeding, stratification, vegetative competition.

690. Boekhoven, L.W.D. 1964. Direct seeding of conifers with cereals as nurse crop. Canada, Dept. Forestry, Forest Research Lab, Sault Ste. Marie, Mimeo 64-0-18. 12 pp.

Reports experiment to assess nurse crop effect of 3 farm cereals, rye, oats, and alfalfa, raked and unraked, with direct seeding of jack pine and white spruce. Alfalfa raked with jack pine gave the highest germination and significantly better survival. In both treatments white spruce gave poor results - possibly white spruce - alfalfa produced the best results. Highest frost damage was found in white spruce seedlings.

K.W. Picea glauca (white spruce), alfalfa, artificial regeneration, cereals, germination, mulch, nurse crop, oats, rye, seeding, seedling survival, [Pinus banksiana].

691. Canada, Forest Service. 1941. Silvicultural research operations 1940-1941. Canada, Dominion Forest Service, Silvic. Res. Note 6b. 29 pp.

Experiments undertaken in Alberta show that spring sowing is preferable to fall sowing for white spruce and Douglas fir. Fall sowing gives better results for birch.

K.W. Picea glauca (white spruce), Pseudotsuga menziesii (Douglas fir), artificial regeneration, germination, seeding, time of seeding.

692. Clark, M.B. 1960. E.P. 521 - Experimental seeding of spruce, Kamploops Forest District. B.C. Forest Research Review. p. 37.

Broadcast seeding of poisoned and unpoisoned spruce seed (with a germination rate of 72-74% in the lab) at three rates was carried out. However, because of high temperature and low precipitation, only negligible germination resulted from seeding. Also reported 1959 - p. 49.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, germination, pesticides, seeding.

i) INFLUENCES OF METHODS AND SEASON OF SOWING, cont'd.

693. Clark, M.B. 1969. Direct seeding experiments in the southern interior of British Columbia. B.C. Forest Service, Res. Note 25. 7 pp.

Douglas fir and spruce seed was spot and broadcast sown on small areas within the subalpine and interior wet belt regions. Satisfactory germination and survival was obtained in 2 of 3 years of sowing. Stocking in prepared, sown, and covered spots was 25% for spruce and 46% for Douglas fir, following a sowing rate of 7-10 treated seeds/spot. It is estimated that if 60% of an area is favourable seedbed then broadcast sowing may be used, otherwise seed spot sowing is best. Mineral seedbed is best for survival.

K.W. Picea engelmannii (Englemann spruce), Pseudotsuga menziesii (Douglas fir), artificial regeneration, germination, rodents, seed quality, seedbed, seedling survival, spot seeding.

694. Clark, M.B. 1970. Direct seeding - possibilities and limitations. Unpublished paper presented at Interior Tree Farm Foresters Meeting, Prince George, B.C., Sept. 1970.

695. Clark, M.B. 1970. E.P. 677 - A test of spot seeding techniques and season of sowing. B.C. Forest Research Review. pp. 66-67.

Designed to compare effectiveness of Panama "walking stick" seeders with conventional hand seeding of mattock screefed spots, and to test the effect of the season of sowing when sowing Douglas fir and Engelmann spruce. The Panama seeder was faster, but not significantly so. It was, however, significantly lower with respect to seedling survival, though not to germination. Seed treatment improved the performance of Douglas fir; spruce was not affected. Fall-sown seed produced better results than spring-sown seed, probably because of specific weather conditions at this time.

K.W. Picea engelmannii (Engelmann spruce), Pseudotsuga menziesii (Douglas fir), artificial regeneration, planting, screefing, seeding, seeding date, seeding method, seedling survival.

696. Clark, M.B. 1972. E.P. 677.2 - A test of the walking stick type seeder. B.C. Forest Research Review. pp. 47-48.

Attempts to determine whether spot seeding by the Panama seeder is more practical and economical than planting on certain sites considered uneconomically plantable. On the basis of stocking, after one year, spring planting and sowing were significantly better than fall planting and sowing. On the basis of cost per stocked spot, there is no difference between seeding and planting or between seasons. Also reported 1971 - p. 57.

K.W. Pseudotsuga menziesii (Douglas fir), artificial regeneration, economics, planting, planting date, planting method, seeding.

697. DeCoincy, A. 1948. [A new sowing gun.] Rev. Eaux et For. 87(3): 151-154. (Abstr. F.A. 10:185).

Describes use of a new implement for seeding.

K.W. artificial regeneration, economics, seeding.

698. Hattersley, J.G. 1953. A method of direct seeding in rodent infested areas of summer drought. J. For. 51(8):579.

Describes a method of seeding which protects seed from birds and rodents, reduces evaporation and does not prevent development of the seedling.

K.W. artificial regeneration, drought, seeding, seeding method, seed consumption.

699. Heit, C.E. 1941. Sow coniferous tree seeds this fall: laboratory tests indicate which species will give best results. New York Agricultural Experiment Station, Quart. Bull. 7(4):2, 10.

For conditions similar to those in New York State, fall sowing is recommended in preference to spring sowing for those species of conifers whose seeds show a dormant nature. Advantages of fall sowing include increased field germination, increased vigour of seedlings and reduction in weeds.

K.W. artificial regeneration, germination, seeding, seeding date, seedling vigour, weeds.

700. Helmers, A.E. 1946. Fifth-year results of direct seeding with western red cedar (sic) and Engelmann spruce. U.S. Dept. Agric., North Rocky Mountain and Range Experiment Station, Res. Note 42. 4 pp.

i) INFLUENCES OF METHODS AND SEASON OF SOWING, cont'd.

Satisfactory stocking was gained in Idaho by direct seeding of Engelmann spruce without rodent protection on fresh burns. Stocking ranged from 68% to 39%. In areas of low stocking, drought was the chief cause of mortality.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, drought, seeding, seedling mortality, stocking.

701. Holt, L. 1955. The Brohm hand seeder. Pulp and Paper Research Institute of Canada, Woodlands Research Index 96. 17 pp.

Provides a description of the specifications costs, and operating methods of the "walking stick" or Brohm Hand Seeder. Gives results of five field trials, one using white spruce seeds, two using red pine, one using black spruce, and one using black and white seed. Results indicate that success of the hand seeder depends on several factors, among them placing the seed in a good location, at a desired depth. The hand seeder allows for getting desired depths, and eliminates bending by the operator. The major disadvantage appears to be the need to plant a large number of seeds in each spot in order to ensure establishment of seedlings.

K.W. Picea glauca (white spruce), germination, pelleting, planting, seed, seeding, seedling survival, site treatment, [Picea mariana, Pinus resinosa].

702. Horton, K.W. and J.P. Flowers. 1965. A mechanical forest seeding technique. Canadian Forest Industries 85(3):66-69.

Use of an adaptation of furrow seeding involving a modified corn seeding unit attached behind a bulldozer is described as an economic method of reforestation. Use with white spruce is proposed. Main mortality, in trials was from frost heaving. It is thought that this will be minimized in operation and that vegetation competition will not be a problem for some years after seeding.

K.W. Picea glauca (white spruce), artificial regeneration, economics, frost heaving, scarification, seeding, seedling mortality, vegetative competition, [Pinus banksiana, Pinus resinosa, Pinus strobus].

i) INFLUENCES OF METHODS AND SEASON OF SOWING, cont'd.

703. Huss, E. 1959. [Depth of sowing and covering, and comparisons between sowing in drills and broadcast sowing with light raking in of the seed.] Svenska SkogsvForen. Tidskr. 57(3):415-425.

Sowing in covered drills resulted in higher plant percentage than broadcast sowing on prepared patches with subsequent raking in, particularly in loose or dry soils. Mortality was greater in covered drills. Experiments on covering indicate that a cover of 5-8 mm of mineral soil is generally the best, and that poor seed was more adversely affected by too much cover than good.

K.W. Picea sp. (spruce), Pinus sp. (pine), germination, seeding, seedling survival, soil covering.

704. Krewaz, J. 1958. A standard for spot seeding. Forestry Chronicle 34(4):380-381.

Constructs tables to provide a minimum number of seeds per seed spot, with maximum viability per spot.

K.W. germination, seeding, seed spots.

705. Leslie, A.P. 1953. Direct seeding as a means of reforestation. Canadian Pulp and Paper Association, Woodlands Section Index 1298(F-2). 5 pp.

Deals with direct seeding particularly in Ontario but general remarks apply to other areas. Recognized factors in successful seeding are adequate moisture, suitable soil texture, proper cultivation, by fire or machine and burying of seeds, protection of seeds and seedlings, proper seed selection and preparation. Includes extensive reference list. Two experimental situations are cited.

K.W. artificial regeneration, regeneration, seeding.

706. McKeever, D.G. 1942. Results of direct seeding of western red cedar and Engelmann spruce in the northern Rocky Mountain region. U.S. Dept. Agric., North Rocky Mountain Forest and Range Experiment Station, Res. Note 21. 9 pp.

Spot sowing without rodent protection gave moderate success with both species on favourable sites. Seedlings of both species require surface soil moisture and are easily lost through erosion. When sown, seeds should be placed on and covered lightly with mineral soils to prevent rodent attraction.

i) INFLUENCES OF METHODS AND SEASON OF SOWING, cont'd.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, erosion, germination, rodents, seeding, seedling survival, soil moisture.

707. Malahovec, P.M. 1963. [The effect of sowing depth on field germination, in relation to time of sowing.] Lesn. Ž., Arhangel'sk 6(6):9-12. (Abstr. F.A. 25:558).

Scots pine and Norway spruce seeds were sown at various depths at 15 day intervals between May 15 and Sept. 15. Field germination was generally highest for all sowing dates and for both species at depths of 0.5-2.0 cm. There were large differences within this range varying with sowing date and soil composition and conditions.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), germination, planting, planting date, planting depth, soil.

708. Pesterev, A.P. 1952. [Aerial sowing as a means of restocking felled areas in the north of Russia.] Lesn. Hoz. 5(9);29-32. (Abstr. F.A. 16:505).

Aerial sowing of spruce and pine seeds on clear cut and burned areas proved successful and inexpensive and resulted in a very even distribution of seed. It is important to sow early in spring, on snow or moist ground so that seed may be washed into the soil. Best results occurred on disturbed ground where vegetation had been removed by skidding and/or burning.

K.W. Picea sp. (spruce), Pinus sp. (pine), aerial sowing, artificial regeneration, burning, clear felling, economics, germination, seedbed, seeding, slash burning.

709. Richardson, J. 1972. Seed-spotting black spruce throughout the growing season. Canada, Forestry Service, Newfoundland Forest Research Centre, St. Johns, Info. Rept. N-X-69. 16 pp.

In the year studied, no sowing date was significantly superior. Generally seeding prior to mid-July gave better results than seeding after that date. Fresh sites with organic matter depths of 1/2" or less provided the most satisfactory conditions for germination and establishment of seedlings.

K.W. artificial regeneration, germination, seedbed, seeding, seeding date, [Picea mariana].

i) INFLUENCES OF METHODS AND SEASON OF SOWING, cont'd.

710. Schopmeyer, C.S. 1939. Direct seeding in the western white pine type. U.S. Dept. Agric., Northern Rocky Mountain Forest and Range Experiment Station, Applied Forest Note 90. 10 pp.

Fall sowing in screened spots on clear cut and burned areas, resulted in 60% germination of white pine, ponderosa pine and Engelmann spruce. Spring sowing resulted in less than 25% germination. Rodents chose pine seeds over spruce. Mortality of Engelmann spruce seedlings in the first year was high as a result of drought and insolation. Engelmann spruce should be sown in fall when possible and limited to moist sites. Screening is not important.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, rodents, screens, seed consumption, seeding, seedling mortality, soil moisture, wildlife, [Pinus spp.].

711. Schopmeyer, C.S. and A.E. Helmers. 1947. Seeding as a means of reforestation in the Northern Rocky Mountain region. U.S. Dept. Agric., Circular 772. 31 pp.

Autumn sowing of Engelmann spruce on burned cutovers gave better initial stocking than spring sowing. Cultivation of seed spots at time of sowing did not improve germination or survival. Stocking was better when seeds were protected from rodents. Costs were substantially lower than planting 2-2 stock.

K.W. artificial regeneration, cultivation, germination, rodents, seeding, seeding date, seedling survival, slash burning.

712. Soos, J. 1970. Results of some reforestation trials in Clearwater Rocky Foests, Alberta. Proc. Inland Empire Forestry Conference, Sept. 1970. n.p.

Describes results of various planting and seeding trials, involving containers, direct seeding and conventional planting. In all cases scarification was carried out. Also examined were results of fall lifting and winter storage of seedlings and means of root packing. All data are tabulated.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, containers, planting, root packing, scarification, seeding, tubes, [Pinus sylvestris].

i) INFLUENCES OF METHODS AND SEASON OF SOWING, cont'd.

713. Stein, W.I. 1964. Seed-spotting revival of an old technique. In: Western Reforestation, Western Forestry and Conservation Assoc., Proc. Western Reforestation Co-ordinating Committee, Annual Rept., 1964. pp. 18-20.

Outlines history of seed-spotting, and states that further research and development of this technique should take place. In many areas, it is much less expensive than planting, while it is useful in rocky areas where planting is impractical. Much work remains to be done on technique, however.

K.W. artificial regeneration, rodents, seed consumption, seedbed, seeding, seed-spotting.

714. Tackle, D. 1961. Ten-year results of spot seeding and planting lodgepole pine. U.S. Dept. Agric., Intermountain Forest and Range Experiments Station, Res. Note 83. 6 pp.

Comparison of results of spot seeding lodgepole pine and hand planting 1-1 nursery stock. Screened seed-spots had a 69% stocking as compared to 58% on unscreened seed-spots. Dominant seedlings on unscreened spots were however, significantly larger and taller than those on screened spots. Survival of 1-1 stock was 96%. Mean height of tranplants after 10 years was 5.0 ft., or about 1 1/2 ft. more than the average height of dominants on unscreened seed-spots.

K.W. Pinus contorta (lodgepole pine), planting, screening, seeding, seedling growth, seedling survival, spot seeding.

715. Tiren, L. 1946. [Artificial regeneration in Norrlands.] Norrlands Skogsvförb. Tidskr. 1946(2):269-307. (Abstr. F.A. 9:302).

A complete resumé, in lecture form, of artificial regeneration of conifers, especially spruce and pine, in North Sweden. Dealt with are various methods of sowing and planting after artificial preparation and a discussion of the relative merits of sowing and planting.

K.W. Picea sp. (spruce), Pinus sp. (pine), artificial regeneration, fertilization, mulching, planting, planting method, scarification, seeding.

i) INFLUENCES OF METHODS AND SEASON OF SOWING, cont'd.

716. Wahlenberg, W.G. 1925. Reforestation by seed sowing in the Northern Rocky Mountains. Jour. Agric. Res. 30:637-641.

Of all early direct seeding experiments in the northern Rocky Mountains, only 6% were successful or partly successful. Engelmann spruce made an extremely poor showing. Douglas fir was much better adapted to success than any other local species.

K.W. Picea engelmannii (Engelmann spruce), Pseudotsuga menziesii (Douglas fir), artificial regeneration, frost heaving, germination, rodents, seeding, seedling survival, soil moisture.

717. Wiksten, Å. 1948. [On some factors of importance to sowing results and preliminary results of some experiments with covered patch sowing.] Medd. Skogsforskn. Inst., Stockholm 37(4):34 pp. (Abstr. F.A. 11:47).

Covered patch sowing, in which a layer of organic material is spread over the seed patch after sowing is recommended in reducing the danger of drought and frost heaving. Costs must yet be evaluated.

K.W. artificial regeneration, desiccation, economics, frost heaving, mycorrhizae, patch sowing, seed spots, seeding,

ii. INFLUENCES OF PLANTING

Planting of seedlings and transplantings as a means of artificial regeneration, various planting methods, orientation of planting, planting tools and planting dates are reported and/or evaluated by papers in this section. Principal criteria for evaluation are seedling growth and survival, especially during the first five years after planting.

a) BARE ROOT STOCK

All papers in this section report results of planting with bare root stock, whether seedlings, transplants or wildlings. Comparisons of two or more types or ages of growing stock are involved.

ii) INFLUENCES OF PLANTING, cont'd.

718. Anon. 1956. Motorized tree planter bores holes in earth. B.C. Lumberman 40(12):18.

Describes a newly developed tree planter which is slightly faster than other methods and which gives greater survival of planting stock. Holes are bored in the ground, the seedlings placed in the holes and roots covered. In a test, 94% of the stock planted in this fashion survived while only 40% of the hand-planted seedlings lived through one winter.

K.W. artificial regeneration, planting, planting machine, seedling survival, seedlings.

719. Ackerman, R.F. and H.J. Johnson. 1962. Continuous planting of white spruce throughout the frost-free period. Canada, Dept. Forestry, Forest Research Branch, Tech. Note 117. 13 pp.

Plantings were made weekly from May to October, 1952-1954, in Alberta, to investigate the possibility of continuous planting of white spruce throughout the frost-free period. Mortality and height growth were measured through 1959. Mortality to 1959 was acceptable for all planting dates. All significant differences in mortality and height growth favoured earlier planting since, as a general trend, mortality increased and height growth decreased progressively with deferment of planting date. The effect of the month of planting on current height growth was still evident in the fifth year after planting.

K.W. Picea glauca (white spruce), artificial regeneration, frost, growth increment, mortality, planting, planting date, root growth.

720. Armit, D. 1965. E.P. 537 - Spacing trials in the Prince Rupert Forest District. B.C. Forest Research Review. p. 30.

Reports experiment to study effects of initial spacing on growth and development of white spruce plantations. Four spacings, 4'x4', 8'x8', 12'x12' and 16'x16' were used. Weeding was carried out during early seedling growth, and as a result some problems with seedling survival because of lack of shade and mulching were experienced. In 1965, it was determined that at least 10 years development was necessary for spacings wider than 4'x4' before there will be any observable influence of spacing on growth and development. Also reported 1960 - p. 41, 1962 - p. 19, 1963 - pp. 21-22, 1964 - p. 29. Author in 1960, K. Illingworth.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, growth increment, planting, seedling survival, spacing, weeding.

721. Armit, D. 1968. E.P. 603 - A comparison of planting bar and mattock planting of white spruce. B.C. Forest Research Review. pp. 68-69.

Determines the effect of five methods of planting on the rate of planting, initial growth, survival, and cost per established seedling. Stock was 2 + 0 white spruce planted in the Prince Rupert District. Lowest time to plant one 50-seedling row was 24 min., with a mattock and no scarification. The highest was 119 min. for mattock, scarification, and mounding. After one year, mattock and bar planting on unscreefed spots appeared to give superior production and lower cost per residual seedling. It later appeared that screefing before planting has no discernable advantage over non-screefing in terms of survival, nor does time of planting. All results are tabulated. Also reported 1964 - pp. 28-29, 1965 - pp. 32-34, 1967 - pp. 68-70.

K.W. Picea glauca (white spruce), artificial regeneration, economics, mounding, planting, planting method, seedbed, screefing, seedling survival.

722. Armit, D. 1968. E.P. 630 - Spacing effects on increments of individual trees in overstocked juvenile stands of lodgepole pine. B.C. Forest Research Review. pp. 80-81.

Study of increment and growth habits of selected trees in relation to 6 artificially created spacings in overstocked juvenile stands of lodgepole pine. Paried dominants were selected, one tree at the centre, the other at the perimeter of a circle in which all other trees were cleared. Radii were 3.5', 5', 7' and 10'. Two cleaning regimes were used, one single, the other a repeated operation. An uncleaned control was kept. Three years after establishment there were no effects attributable to cleaning that could be observed. All pairs in all treatments were free growing. Also reported 1965 - pp. 38-40.

K.W. Pinus contorta (lodgepole pine), cleaning, growing habit, growth, spacing.

ii) INFLUENCES OF PLANTING, cont'd.

723. Armit, D. 1970. A planting trial with white spruce, Fort Babine. B.C. Forest Service, Res. Note 50. 5 pp.

Various types of planting stock of white spruce taken from seed originating near Fort St. James, were tested on the west shore of Babine Lake on areas largely destroyed by fire in 1952. Planting quality was noted as only adequate at the time of planting in 1964. Severe losses were expected at the end of the first year. Subsequent mortality through 1969 was very low, survival levels having stabilized. All classes of stock showed satisfactory survival, although survival of 2 + 1 R class was significantly lower than the other three classes tested. Height growth of different stocks varied significantly. 2 + 0 seedlings were most economical but 2 + 1 L grew best.

K.W. Picea glauca (white spruce), artificial regeneration, fire, growth increment, mortality, planting, seedbed, seedling grading.

724. Armit, D. 1970. Comparison of mattock and bar-planting methods with white spruce in North Central British Columbia. B.C. Forest Service, Res. Note 53. 12 pp.

Five planting methods were tested in Prince Rupert Forest District to determine production, survival, growth and cost of regeneration of white spruce seedlings. Tests were observed over four years. As a planting tool, the mattock proved to be more effective than the planting bar. Screefing did not apparently increase survival or growth. Seedling survival was principally lowered by smothering and light competition by vegetation.

K.W. Picea glauca (white spruce), artificial regeneration, competition, economics, mattock, planting, planting bar, scarification, screefing, seedling survival, smothering, vegetation.

725. Armson, K.A. 1958. The effects of two planting methods on the survival and growth of white spruce (Picea glauca (Moench) Voss) in eastern Ontario. Forestry Chronicle 34(4):376-379.

Seedlings were planted at the bottom of ploughed furrows and in the upturned furrow slice. Eight years after planting, there was no difference in survival between treatments, but the height growth of trees on the furrow slice was significantly greater than that of the plants in the furrows. The difference apparently resulted from water saturation of the root zone of the furrow planted trees during the winter.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, furrowing, growth increment, planting, soil, soil moisture.

726. Badalov, P.P. 1970. [The growth of young spruce plantations established by deep planting in the Vaccinium myrtillies forest type in the Leningrad region.] Lesn. Ž. 13(5):145-148. (Abstr. F.A. 32:511).

Height increment of deep planted spruce was markedly inferior to that of normally planted stock for the first few years, and remained inferior for at least 8-11 years. The root systems of some plants were excavated and are described.

K.W. Picea abies (Norway spruce), planting depth, seedling growth.

727. Bella, I.E. 1968. Growth of white spruce planted in the Turtle Mountains. Forest Chronicle 44(3):45-46.

Plantations of white spruce and Scots pine, planted in 1912 as 4 year-old seedlings and 2 year-old seedlings respectively, at 4 x 4 spacings are examined. Includes a diameter tally of all living trees by 1 inch classes, height measurements and radial growth measurcments at breast height on 15 - 20 trees per plot and height growth measurements on two dominant trees per plot.

K.W. Picea glauca (white spruce), artificial regeneration, growth increment, planting, spacing, [Pinus sylvestris].

728. Bonner, E. 1960. Reforestation problems in eastern spruce forests. Forestry Chronicle 36(2):153-155.

Outlines reforestation procedures presently used in eastern Canada. Various species of spruce black, white, and Norway are recommended stock to be planted usually being 2-2. Cutovers should be planted immediately. Fall and spring planting gives good results but is entirely dependent upon adequate moisture. Survival averages 83% at the end of 1 year and 74% at the end of 5 years.

K.W. Picea glauca (white spruce), Picea mariana (black spruce), Picea abies (Norway spruce), artificial regeneration, economics, logging, planting, planting stock, regeneration.

729. Bornebusch, C.H. 1941. [Experiments on planting Norway spruce by different methods.] Dansk Skovforen. Tideskr. 26(3):97-107.

ii) INFLUENCES OF PLANTING, cont'd.

In Danish trials, 2-2 stock proved generally superior to 2-0 stock, having a lower mortality and maintaining its lead in growth. Spade dug planting pits were best, followed in order by mattocked pits and T-notching with a spade.

K.W. Picea abies (Norway spruce), artificial regeneration, economics, planting, planting methods, planting stock, seedling mortality, spacing.

730. Børset, O. 1947. [Choice of plantation spacing.] Tidsskr. Skogbr. 55(12):315-332. (Abstr. F.A. 10:187).

Reviews, mostly from Scandinavian literature, the advantages of close and wide spacing. States that spacings of 2m should be applicable on a large scale and in special cases 2.5m -3m can be justified. Much contemporary literature states that spacings of 1.6m -1.7m are more suitable for maximum yield. Klem (F.A. 9:2184, F.A. 10:1019) states that an increase of spacing from 1.5m to 2.0m caused a drop in total volume yield of 7%, which is economically permissible considering the returns.

K.W. artificial regeneration, economics, planting, spacing, volume growth, wood yield.

731. Brace, L.G. 1963. The influence of planting method and planting stock height on the establishment and early growth of white spruce. Canada, Dept. Forestry, Petawawa Forest Experiment Station, Chalk River, Mimeo 63-P-13. 18 pp.

After 9 growing seasons, no apparent difference in survival and growth of planted Picea glauca could be attributed to planting method. Growth and variability in height were related to height and quality of planting stock. Planting stock less than 0.5 ft. tall grew poorly on the planting site studied.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting method, planting stock, seedling grading, seedling growth, seedling mortality.

732. Brace, L.G. 1964. Early development of white spruce as related to planting method and planting stock height. Canada, Dept. Forestry, Forest Research Branch, Publ. 1049. 15 pp.

After nine growing seasons, no practical difference in survival and growth of white spruce could be attributed to method of planting in a test of two planting methods, one that disposed the seedling roots in a horizontal plane

ii) INFLUENCES OF PLANTING, cont'd.

close to the soil, and the other, a conventional one, that places the roots vertically. Growth and variability in height were related to height of planting stock. Planting stock less than 0.5 ft. tall grew poorly on planting site studied.

K.W. Picea glauca (white spruce), artificial regeneration, growth increment, planting, planting method, planting stock, roots, seedbed, seedling survival.

733. B.C. Forest Service. n.d. Minimal storage and planting instructions. B.C. Forest Service Pamphlet. 1 p.

Gives complete instructions concerning the requirements of seedlings and how they are to be met by the planters. Areas to avoid because of poor regenerating characteristics are noted.

K.W. nurseries, planting, regeneration, seedlings.

734. Clark, M.B. 1957. E.P. 428 - Survival studies of spruce transplants. B.C. Forest Research Review. p. 38.

A cut and burned area at Bolean Lake was planted in fall 1952 and spring 1953 with 2 + 2 Engelmann spruce. There was no apparent difference between survival of spring and fall plantings. Also reported 1956 - pp. 34-35.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, planting, planting date, seedling survival.

735. Clark, M.B. 1963. E.P. 428 - Plantation trials, Kamloops Forest District. B.C. Forest Research Review. pp. 25-26.

Compares survival of spring and fall plantings of nursery grown spruce and Douglas fir seedlings on burned and logged areas. Spring plantings of Engelmann spruce and Douglas fir produced reasonable survival by 1960. Fall plantings of ponderosa pine produced very low survival. All survival data are tabulated. Also reported 1959 - p. 51, 1960 - p. 39, 1961 - p. 28, 1962 - p. 27.

K.W. Picea engelmannii (Engelmann spruce), Pseudotsuga menziesii (Douglas fir), artificial regeneration, planting, planting date, seedling survival, [Pinus ponderosa].

736. Clark, M.B. 1972. E.P. 661 - Engelmann spruce spacing trials in the Kamloops Forest District. B.C. Forest Research Review. p. 60.

ii) INFLUENCES OF PLANTING, cont'd.

Two acre plots for 6'x6', 8'x8', 10'x10', and 12'x12' Engelmann spruce were planted with 2+2 stock. By 1971, the plots were too badly damaged for coherent study. Also reported 1967 - p. 72, and 1968 - p. 74.

K.W. Picea engelmannii (Engelmann spruce), growth increment, planting, seedling mortality, spacing.

737. Clark, M.B. and C.F. Thompson. 1972. E.P. 682 - Extended planting trials with mudpack stock in the southern Interior, 1969. B.C. Forest Research Review. pp. 51-52.

2+0 Douglas fir and Engelmann spruce were planted as bare-root and mudpack stock, and survival data was tabulated. Generally, bare-root stock performed better than mudpack stock. In all cases, survival of early planting dates was poorer than that of later dates. Also reported 1970 - pp. 76-77, 1971 - pp. 64-65.

K.W. Picea engelmannii (Engelmann spruce), Pseudotsuga menziesii (Douglas fir), artificial regeneration, bare-root stock, planting, seedling survival.

738. Coates, H.G. 1972. E.P. 660 - Species and spacing trials in the Montane Transition Forest Zone. B.C. Forest Research Review. pp. 59-60.

1+1 lodgepole pine, 1+1 Douglas fir and 2+1 white spruce seedlings were planted at 7'x7', 10'x10' and 13'x13' spacings. The next year, one plot of 5'x5' spacing was added. Tables of all spacings, height growth, and survival of all species are given. To date, lodgepole pine is growing very well, spruce is growing poorly. Also reported 1968 - p. 74, 1969 - p. 81, 1970 - p. 73. Author in 1968 - 1970, J. Revel.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, planting, seedling growth, spacing.

739. Coates, H.G. 1972. E.P. 674 - Influence of age class and season of planting on survival and leader growth of lodgepole pine planting stock. B.C. Forest Research Review. pp. 50-51.

2+0 and 1+1 seedlings were planted on a logged and burned area 30 miles west of Prince George. Survival after 5 years was significantly lower for fall planted 2+0 stock. 1+1 stock height growth was greater than that of 2+0 stock but probably not significantly so from an economic stand point. Also reported 1968 - p. 75, 1969 - p. 84. Author in 1968 - 1969, J. Revel.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Pinus contorta (lodgepole pine), artificial regeneration, planting, planting stock, seedling grading, seedling growth, seedling survival.

740. Cooley, J.H. 1969. Transplants do better than seedlings, but ---. Tree Planters Notes 20(3):8-11.

A test comparing 2 - 1 and 2 - 2 white spruce stock with 3 - 0 seedlings shows that transplanting and holding white spruce 1 year in the transplant bed materially increases its chance for survival in the field. But holding the stock for a second year after transplanting increases its chance for survival little if at all. Seedling, that reach a height of 8.6" or more after 3 years in the seedbed, survive nearly as well as either 2 - 1 or 2 - 2 transplants of equivalent size and grow about as fast as transplants.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting stock, seedling growth, seedling survival, transplants.

741. Crossley, D.I. 1956. The possibility of continuous planting of white spruce throughout the frost-free period. Canada, Forestry Branch, Forest Research Division, Tech. Note 32. 31 pp.

Weekly planting of white spruce was undertaken in Alberta throughout the frost-free seasons of 1952, 1953, and 1954. Mortality has been low - highest when soil at time of planting was very dry. Height growth has been variously depressed depending on period of planting. A concomitant effect is chlorotic foliage and short needles. Results have been encouraging and suggest possibility of continued planting throughout frost-free period, at least in years of normal or above normal precipitation.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting date, precipitation, seedling mortality, soil.

742. Cucoş, V. 1968. [The use of spruce transplants in afforestation.] Rev. Pădurilor 83(2):65-68. (Abstr. F.A. 29:644).

Experiments with different types of planting stock demonstrated the superiority of transplants over seedlings in survival and vigor. They also require less tending after planting out. The difference increased with increased unsuitability of the planting site.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea sp. (spruce), planting, planting stock, seedling growth, site type, transplants.

743. Cushman, W.H. and R.H. Weidman. 1937. Survival increased by carefulness in planting. U.S. Dept. Agric., Northern Rocky Mountain Forest Range Experiment Station, Applied Forestry Note 81.

744. Decie, T.P. 1961. E.P. 505 - Planting white spruce throughout the growing season. B.C. Forest Research Review. p. 25.

White spruce was planted at Aleza Lake in an attempt to find a relationship between climate and planting success of white spruce throughout the growing season. Seedlings planted in 1957, a wet year, showed no significant difference in survival between planting dates. In 1958, a dry year, seedlings planted early in summer showed high mortality. It was found that all plantings flushed 3 - 4 weeks after planting and still showed signs of active growth by Oct. 20, but that later plantings produce severe winter mortality. Problems were noted as a result of seedling storage. Also reported 1958 - p. 46, 1959 - p. 53, 1960 - p. 40. Author in 1958, A.E. Prochnau.

K.W. Picea glauca (white spruce), artificial regeneration, flushing, planting, planting date, seedling mortality, seedling storage, seedling survival.

745. Decie, T.P. 1962. E.P. 573 - Planting white spruce throughout the growing season, 1960. B.C. Forest Research Review. pp. 22-23.

Provides information on the survival and behaviour of dormant stock planted at intervals throughout the growing season. It was felt that spruce stock held in cold storage should be planted as early as possible, and not later than the middle of June, since later plantings are susceptible to frost damage. Neither size of stock nor nursery treatment have any bearing on survival during the first year in the field. Also reported 1961 - p. 26.

K.W. Picea glauca (white spruce), artificial regeneration, frost damage, planting, planting date, seedling growth, seedling survival.

ii) INFLUENCES OF PLANTING, cont'd.

746. Eis, S. 1966. Survival and growth of white spruce wildings and coastal nursery seedlings in the interior of British Columbia. Forestry Chronicle 42(4):346-349.

Survival and development of outplanted 2 - 0 and 2 - 1 white spruce nursery stock, transplanted 3 - 0 and 4 - 0 wildlings, and 3 - 0 and 4 - 0 undisturbed wildlings are compared in the Prince George District. Mortality was negligible in all areas. Planting check caused a 47% reduction in height increment during the first year and 15% during the second year after planting. Insignificant differences were found between plants on an undisturbed soil surface and those on exposed mineral soil.

K.W. Picea glauca (white spruce), artificial regeneration, growth increment, planting, planting stock, seedlings, seedling survival, transplants, wildlings.

747. Evert, F. 1971. Spacing studies - a review. Canada, Forestry Service, Forest Management Institute, Info. Rept. FMR-X-37. 95 pp.

A critical study involving a description and brief evaluation of past and present spacing practices and studies in various countries. As yet, few conclusive results have been derived from such studies, although there is an obviously significant relationship between initial tree spacing and various tree characteristics. Recommendations are made to allow more significant and detailed information concerning tree and stand growth to be derived from a given experiment.

K.W. artificial regeneration, seedling growth, spacing.

748. Gillespie, D.R. 1971. Spacing trial of lodgepole pine, 1968. B.C. Forest Research Review. p. 74.

Two provenances of lodgepole pine (2+1) were established at various spacings (6'x6' - 12'x12') in the Prince George area on a plot logged and burned. To date there have been no apparent growth results. Also reported 1969 - pp. 83-84, 1970 - p. 76. Author in 1969, D. Armit.

K.W. Pinus contorta (lodgepole pine), artificial regeneration, logging, planting, slash burning, spacing.

749. Guillebaud, W.H. 1951. Norway spruce spacing plots at Wessling, Bavaria. Forestry 24(2):121-126.

ii) INFLUENCES OF PLANTING, cont'd.

Norway spruce was planted in 1910 at various spacings from 3'7" to 6'7", with one plot at 13' interplanted later. Spacing has had no apparent effect on height growth and other factors, including volume growth, have responded as expected. There is a slight reduction of total yield with increased spacing. 97% of interplanted trees in 13' spacing were killed by suppression. Concludes that optimum spacing for spruce is 4'6" to 5'3".

K.W. Picea abies (Norway spruce), artificial regeneration, planting, seedling growth, spacing.

750. Hall, J.P. 1969. 1968 results of four planting research projects. Canada, Forestry Service, Forest Research Lab, St. Johns, Internal Rept. N-18. 14 pp.

Summarizes results to date of four planting projects in black and Sitka spruce. Data suggest that, for methods used, capsule planting will not be successful, heavy losses being caused by frost, vegetative competition and temperature and moisture extremes. Planting black spruce on imperfectly-drained sites treated with a scarifier may produce acceptable results if care is taken.

K.W. artificial regeneration, capsules, containers, frost heaving, planting, scarification, seedbed, soil, temperature, vegetative competition, [Picea mariana, Picea sitchensis].

751. Hattie, R.N. 1970. E.P. 699.2 - Mudpack trials, 1968/1969. B.C. Forest Research Review. p. 75.

Compares 1+0 and 2+0 mudpack stock with 2+0 bare root stock when planted throughout spring and summer. Normal spring-lifted 2+0 bare root stock has the highest survival.

K.W. artificial regeneration, mudpacks, planting, planting method, seedling survival.

752. Haugberg, M. 1962. [Study of spruce and pine planting stock of different ages.] Årsskr. Norske Skogplantesk, 1961. pp. 27-32. (Abstr. F.A. 24:53).

Conclusions 2-6 years after planting variously aged spruce seedlings and transplants were that 2+2 plants show better survival, are more resistant to drought and grow as well as 2+3 plants. They are more resistant to drought and competition by other plants than 2+1 stock. 2+1+1 and 2+2+1 grow equally well and are perhaps as drought resistant as 2+2 plants. Results for pine, four years after planting were best for 2+1 plants, especially with augur planting.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea sp. (spruce), Pinus sp. (pine), drought resistance, planting, planting stock, planting method, seedling grading, seedling growth, seedling survival, vegetative competition.

753. Hedemann-Gade, E. 1948. [Sensitivity of roots of nursery plants to insolation.] Skogen 35(9):110. (Abstr. F.A. 10:189).

Effects on lifted plants of exposure to strong sunlight for periods of one hour were tested using 1-0 and 2-0 Norway spruce and 1-0 Scots pine. No plants were affected by exposure up to 15 minutes. An exposure of 30 min. had practically no effect on 2-0 spruce or 1-0 pine but caused 50-65% mortality in 1-0 spruce. Exposure for longer than 30 min. was deleterious in all cases.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), artificial regeneration, insolation, planting, root exposure, seedling mortality.

754. Hedemann-Gade, E. 1960. [A study of 3-year-old spruce transplants.] Skogen 47(4):72-73. (Abstr. F.A. 21:405).

1+2 planting stock had great variability in height (9-37 cm) with a mean of 21.7 cm. 2+1 seedlings had a much narrower range, but a mean height of only 12.1 cm. However, 1+2 plants had a less compact root system, less suitable for outplanting than that of the 2+1 stock.

K.W. Picea abies (Norway spruce), planting, planting stock, root growth, transplants, vegetative competition.

755. Hedemann-Gade, E. 1960. [Sensitivity of roots of nursery plants to insolation.] Skogen 47(5):105. (Abstr. F.A. 21:406).

2+0 spruce, lifted while still dormant, were resistant to at least one hour's exposure, whereas mortality of those lifted after growth had started was 20% by the next fall. 1+0 pine was very susceptible, mortality figures after 15 min. exposure, being 20% for dormant seedlings and 100% for growing seedlings.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), artificial regeneration, dormancy, insolation, lifting date, planting, root exposure, seedling mortality.

ii) INFLUENCES OF PLANTING, cont'd.

756. Hedemann-Gade, E. 1967. [Comparative testing of 2+0 and 1+1 Scots pine plants from the same seed lot, planted simultaneously in the same manner on comparable plots.] Sveriges SkogvFörb. Tidskr. 65(6):605-624.

Six years after planting, 78% of the seedlings and 93% of the transplants survived, the transplants being 28% taller.

K.W. Pinus sylvestris (Scots pine), planting, planting stock, seedling growth, seedling survival, transplants.

757. Hughes, E.L. 1968. Planted spacing study in Antigonish County, Nova Scotia. Canada, Forestry Branch, Forest Research Lab, Fredericton, Internal Rept. M-32. 5 pp.

Introduces a planted spacing study of white spruce. 2-2 white spruce seedlings were planted at spacings of 4'x4', 5'x6', 7'x7', and 8'x8'. Periodic reports will be made.

K.W. Picea glauca (white spruce), artificial regeneration, planting, spacing.

758. Illingworth, K. 1964. E.P. 626 - Engelmann spruce planting trials - 1964. B.C. Forest Research Review. p. 50.

Attempts to determine the optimum periods for planting Engelmann spruce in the Nelson Forest District and to acquire familarity with problems associated with spruce reforestation in this region.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, planting, planting date.

759. Jameson, J.S. 1956. Planting of conifers in the Spruce Woods Reserve, 1904-1929. Canada, Forestry Branch, Forest Research Division Tech. Note 28. 29 pp.

Gives description of the planting area, in some detail. 204 acres were used to determine the species and method most suitable for large scale planting. Seedlings of Scots pine, jack pine, lodgepole pine, white spruce, and Norway spruce were used. Results indicate that jack pine had the best survival rate (40%), while spruce and Norway spruce were complete failures. Losses were due to small animals, drought and heat, competition and winter kill. Planting in furrows and in cedar mats were the most successful methods, the former being best.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), drought, planting, seedling growth, seedling mortality, vegetative competition, [Picea abies, Pinus banksiana, Pinus sylvestris].

760. Jarvis, J.M. 1964. Regenerating cutover X_2B and V_2 sites by planting and seedling on scalped strips, Manitoba Paper Company limits. Canada, Dept. Forestry Forest Research Lab, Manitoba, Mimeo 64-MS-3. 5 pp.

Progress report of an experiment testing the regeneration of species, including white spruce, both by planting and seeding, and by using different planting techniques.

K.W. Picea glauca (white spruce), artificial regeneration, fungicides, planting, scalping, seeding, [Picea mariana, Pinus banksiana].

761. Kantor, J. 1947. [A study of the difference between natural regeneration and planted seedlings.] Lesn. Práce 26(4):141-147. (ABSTR.).

Natural 4 year old Norway spruce seedlings in a thinned stand were compared with autumn and spring planted 4 year old seedlings on a cutover. Best results over 3 years with respect to height growth, survival, and freedom from browsing were given by natural seedlings. Autumn planting gave intermediate and spring planting, poor results.

K.W. Picea abies (Norway spruce), artificial regeneration, browsing, planting, planting date, planting stock, regeneration, seedling growth, seedling survival, thinning, wildlings.

762. Kiaer, T. 1941. [Natural versus cultivated forest.] Tidsskrift Skogbruk 49:67-75. (Abstr. F.A. 3:300).

A series of forest stands of spruce-pine have developed in Norway under nearby like conditions, except that some were planted, some were derived from natural regeneration with or without preparation of the soil, and some were sown after various site treatments. planted stands of both spruce and pine are slightly better than natural ones and direct sowing is least satisfactory.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea sp. (spruce), Pinus sp. (pine), artificial regeneration, planting, regeneration, scarification, seeding, site treatment, tree quality.

763. King, J.P., H. Nienstaedt and J. Macon. 1965. Super-spruce seedlings show continued superiority. U.S. Dept. Agric., Lake States Forest Experiment Station, Res. Note LS-65. 2 pp.

In spruce 1956, in Wisconsin, 357 tallest 2+2 white spruce were transplanted and each paired with a seedling of average height growth. After 7 growing seasons, the mean height of the tall seedlings was 3.80 ft. and of the average seedlings 2.59 ft. In 1964, frost injury on the tall seedlings was 56% v.s. 66% on the average seedlings.

K.W. Picea glauca (white spruce), frost damage, nurseries, planting, planting stock, seedling grading, seedling growth, transplants.

764. Kolabinski, V.S. 1965. Regenerating cutover X_2B and V_2 site by planting and seeding on scalped strips, Manitoba Paper Company Limits. Canada, Dept. Forestry, Forest Research Lab, Manitoba Internal Rept. MS-7.

Introduces experiment to test regeneration of several species, including Picea glauca, by seeding and planting and to test several planting methods. This report covers all the work done in 1964.

K.W. Picea glauca (white spruce), artificial regeneration, planting, seeding, seedling survival, [Picea mariana, Pinus banksiana].

765. Kolabinski, V.S. 1966. Regenerating cutover X_2B and V_2 sites by planting and seeding on scalped strips, Manitoba Paper Company Limits. Canada, Dept. Forestry Research Lab, Manitoba, Internal Rept. MS-31. 9 pp.

Gives details of an experiment studying regeneration of white spruce and black spruce by planting on scalped strips, and of jack pine, balsam fir, white psruce and black spruce by seeding on scalped strips. Also compares effectiveness of seeding, hole planting, and slit planting on these sites. The report summarizes work done in 1965 and early 1966.

K.W. Picea glauca (white spruce), artificial regeneration, germination, planting, seeding, seedling survival, [Abies balsamea, Picea mariana, Pinus banksiana].

ii) INFLUENCES OF PLANTING, cont'd.

766. Kolabinski, V.S. 1967. Regenerating cutover X_2B and V_2 sites by planting and seeding scalped strips, on limits of Abitibi Manitoba Paper Limited. Canada, Forestry Branch, Forest Research Lab, Manitoba, Internal Rept. MS-53. 8 pp.

Continuing report of project initiated in 1963. Outlines work done in 1966-1967 on regeneration of white spruce.

K.W. Picea glauca (white spruce), artificial regeneration, planting, seeding.

767. Lüpke, B.V. 1972. [Root regeneration, and dry matter production after planting, of young spruce in different conditions of freshness.] Allgemeine Forst-und Jagdzeitung 143(8):172-176. (Abstr. F.A. 34(2):84).

Ten 2+2 spruce plants per treatment were exposed to dry air in a warm room for 0, 30, or 150 minutes before planting, without protection, with roots or shoots in platic bags, and with roots dipped in Agricol. Treatments had little or no significant effect on root regeneration and dry matter production after 5 weeks. Duration of exposure had more effect than had treatment on water satuaration deficits at planting time. Mortality differed only for unprotected exposure for 150 minutes.

K.W. Picea sp. (spruce), planting, root exposure, root growth, seedling growth, seedling mortality.

768. MacArthur, J.D. n.d. Planting methods to overcome strong competition from dense, herbaceous vegetation. Canada, Dept. Forestry Forest Research Branch, Contrib. 638. [n.p.] (ABSTR.).

On a plante des semis (2-2) d'épinette de Norvège selon six methodes differentes de combattre la forte compétition d'une dense vegetation herbacée; sur monticules isolés, sur billon ou butte, par plaques de 18 po. x 18 p. x 1 po. d'ou la végétation était éradiquée par rangée temoin, par sillon simple, and par sillon double. La méthode sur monticules solés est la meillure de toutes. La méthode billon est la seconde. Les places témoins (ou les semis ont été plantés dans l'herbe) donnent de meilleurs resultats que le sillon simple, mais de pires resultates que les plaques éradiquées ou la sillon double.

K.W. Picea abies (Norway spruce), artificial regeneration, planting, planting methods, seedling growth, vegetative competition.

ii) INFLUENCES OF PLANTING, cont'd.

769. MacArthur, J.D. 1963. Planting methods to overcome strong competition from dense herbaceous vegetation. Canada, Dept. Forestry, Forest Research Lab, Quebec, Mimeo 63-Q-21. 8 pp.

The method of planting which gave best survival of Picea abies on a moist rich site with dense herbaceous vegetation was planting on mounds. Ridge planting was second best. Methods which elevate trees in relation to competing vegetation generally increase survival.

K.W. artificial regeneration, planting, planting method, seedling survival, vegetative competition, [Picea abies].

770. MacArthur, J.D. 1964. Planting methods to overcome strong competition from dense herbaceous vegetation. Tree Planters Notes 66:25-29.

Six methods of planting 2-2 Norway spruce were tested on a site characterized by deep rich, moist soil, and dense growth of herbaceous vegetation. Two of the six methods (mound and ridge) were used to elevate the planted trees above competing vegetation, three (scalp, single furrow, and double furrow) were used to reduce competition above and below ground, and one (control) was used to show effects of normal competition. After four seasons, survival and condition of planted trees were best in mound planting and ridge planting was a reasonably close second. Scalp and control planting were of doubtful value, and furrow planting was quite unsatisfactory. Evidently, raising the planted trees in relation to the ground line significantly reduces mortality caused by competition and smothering while lowering the trees below it increases losses.

K.W. artificial regeneration, planting, planting methods, seedling survival, vegetative competition, [Picea abies].

771. MacArthur, J.D. 1966. Comparative survival and growth of five conifers ridge-planted on a wet site. Forestry Chronicle 42(2):143-148.

Ridge-planting was found to be effective in reforesting poorly drained land in Quebec. Among other species, white spruce showed significantly better survival and growth on ridges than in control planting. White spruce survived well, but grew slowly. Norway spruce, black spruce, and white pine (Pinus strobus) grew best.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, planting, ridge-planting, seedling growth, seedling survival, [Picea abies, Picea mariana, Pinus strobus].

772. Melzer, E.W. 1968. [Preliminary results of comparative tests with angle planting and with the planting of large Norway spruce planting stock.] Arch. Forstw. 17(12):1239-1261. (Abstr. F.A. 30:655).

First year results in Germany suggest that angle planting did not significantly affect growth, but slightly increased mortality compared with the traditional set mound method, and that, of three sizes of stock, 2+2 did not differ significantly, while 2+3 showed much better growth and somewhat fewer losses.

K.W. Picea abies (Norway spruce), angle planting, planting, planting method, planting stock, seedling age, seedling growth, seedling mortality.

773. Mork, E. 1959. [The most important factors affecting spruce planting results.] Norsk. Skogbruk 4(8):219-222. (Abstr. F.A. 20:555).

Flat root planting in Norway gave better survival after 15 years than did vertical wall hole planting (82% v.s. 78%). Best survival and height growth was seen in spruce planted in early May and early August. Poorest results were obtained from spruce planted in mid-June.

K.W. Picea sp. (spruce), artificial regeneration, planting, planting date, planting method, seedling growth, seedling survival.

774. Mork, E. 1971. [Regeneration experiments with planting, scarification and direct sowing compared with natural regeneration of Norway spruce on site classes C and D.] Medd. Norske Skogforsøksv. 28(4)No. 104:245-294. (Abstr. F.A. 32:706).

On clear felled strips in Norway, planting of 2+2 Picea abies, scarification and sowing, natural regeneration, and scarification to prepare for natural regeneration were evaluated. Planting saved 6 or 7 years over the other treatments to reach a height of 1.3 meters. Satisfactory natural regeneration was apparent on about half of the cleared strips.

K.W. Picea abies (Norway spruce), artificial regeneration, clear felling, planting, regeneration, scarification, seeding, seedling growth.

ii) INFLUENCES OF PLANTING, cont'd.

775. Mork, E. and E. Bjørgung. 1954. [Investigation on different planting methods for 4 year transplanted spruce.] Medd. Norske Skogforsoksv. 12(3) (No. 43):305-389. (Abstr. F.A. 16:59).

Various planting methods were tested for survival, growth and cost of planting of 2-2 spruce seedlings. In E. Norway, flat root and vertical wall planting gave the lowest mortality. In other parts of Norway there was no significant difference in mortality between planting methods and in other areas, spade planting and notch planting gave high mortality. Cost of planting varied with area and mortality.

K.W. Picea sp. (spruce), artificial regeneration, economics, planting, planting methods, seedling mortality.

776. Mullin, R.E. 1963. Planting check in spruce. Forestry Chronicle 39(3):252-259.

2-0 white spruce seedlings were transplanted at various stages of development. Results confirmed that damage and loss of part of the root system is a result. Causes are not yet definite. Site preparation is encouraged to reduce duration of check influence. A discussion of results is included.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting check, site treatment, transplanting.

777. Mullin, R.E. 1964. Reduction in growth of white spruce after outplanting. Forestry Chronicle 40(4):488-493, 502.

Several age classes of nursery stock were sampled both before and after the 1963 growing season. Check was found to reduce leader length by about 50% in the first year after outplanting. Other experiments indicate that in many instances, outplanting influence continues for ten years or more.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting check, seedling age, seedling growth.

778. Mullin, R.E. 1966. Influence of depth and method of planting on white spruce. J. For. 64(7):466-468.

Gives tenth year survival and height data, representing three experiments which compared methods of planting (wedge, slit, cone, and T) and depths of planting (-2, -1, 0, +1, +2 inches) of Picea glauca on abandoned farmland in Ontario. Duration of planting check appeared related to competition of other plant species and no planting method or depth showed any real difference in overcoming it.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, growth increment, planting, planting check, planting depth, seedling survival.

779. Mullin, R.E. 1967. Root exposure of white spruce nursery stock. Forestry Chronicle 43(2):155-160.

Deals with the effects of root exposure on white spruce, and gives consideration to differences in the state of dormancy. 2-0 Picea glauca in "active" and "dormant" states were exposed for varying lengths of time. Mortality was greater for "active" seedlings and increased with length of exposure. Growth of even "dormant" stock was reduced with exposures of greater than 1/2 hour.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting stock, root exposure, seedling mortality, seedlings.

780. Mullin, R.E. 1971. Some effects of root dipping, root exposure, and extended planting dates with white spruce. Forestry Chronicle 47(2):90-93.

A planting experiment of 3-0 Picea glauca was initiated in Ontario to examine the effects of dipping the roots in water immediately on lifting and of exposure of roots to air for periods of up to three hours. The results are examined in terms of second year growth and survival. Dipping was beneficial to growth and survival. Increased time of exposure caused considerable reduction in survival and growth.

K.W. Picea glauca (white spruce), growth increment, planting, planting date, root dipping, root exposure, seedling survival.

781. Mullin, R.E. 1968. Comparison between seedlings and transplants in fall and spring plantings. Ontario Dept. of Lands and Forests, Res. Rept. 85. 40 pp.

Four species, including white spruce were tested to compare survival and growth of seedlings and transplants with several age classes in each category. In general, after 5 years, 2-2 stock of all species survived and grew best. Spring planting was found best for pines, but fall and spring planting of spruces was equally successful. The need for adequate site selection and control of ground vegetation was also apparent in the success of all species.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting date, planting stock, seedling growth, seedling survival, site selection, vegetation.

782. Mullin, R.E., T.T. Schweitzer and L.M. Morrison. 1954. Report on planting depths and methods experiments. Ontario Dept. Lands and Forests, Research Rept. 26. 27 pp.

Planting experiments for various species including Picea glauca using 5 planting depths and 4 planting methods were carried out. Picea glauca showed no significant effects of planting depth. The wedge method of planting proved best for all species, hole planting and T-notch planting should be avoided at all costs.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting method, planting depth, seedling survival.

783. Mulloy, G.A. and G.C. Cunningham. 1945. Planning a planted forest. Forestry Chronicle 21:127-129.

Proposes triangular rather than square planting in order to produce a more naturally spaced stand which will also be easier to thin.

K.W. artificial regeneration, planting, planting regime, thinning.

784. Munkøe, J.C.H. 1944. [Choice of spacing for conifers.] Dansk. Skovforen. Tidsskr. 29(8):293-318.

Concludes that for Norway spruce, rectangular spacings between 1.5 m x 1.5 m and 2 m x 2 m are economically advantageous and will yield a product of satisfactory quality.

K.W. Picea abies (Norway spruce), artificial regeneration, planting, spacing, wood quality.

785. Phelps, V.H. 1941. Memorandum on the establishment of white spruce seedlings on different soil media. Canada, Forest Service, Unpubl. M.S.

786. Revel, J. 1967. Effect of transplanting lodgepole pine and Douglas fir at Telkwa Nursery. B.C. Forest Research Review. p. 100.

ii) INFLUENCES OF PLANTING, cont'd.

Douglas fir and lodgepole pine are worthwhile species in reforestation in the Prince George area. Certainly, on some Cornus-Moss sites, lodgepole pine gives higher yields and shorter rotations. Transplanting produces excellent planting stock of both species, 1+1 stock being more vigorous and having a better shoot/root ratio than 2+0 stock.

K.W. Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, nurseries, planting, seedling growth, seedlings, shoot-root ratio, transplanting.

787. Revel, J. 1970. E.P. 549 - Spacing and growth studies - white spruce. B.C. Forest Research Review. p. 71.

In 1959, 4 15-acre blocks of 2+0 white spruce were planted at spacings of 4'x4', 8'x8', 12'x12', and 16'x16' to demonstrate effects of initial spacing on growth and development of plantations. In 1965, 2+1 white spruce seedlings were planted at 7'x7', 10'x10' and 13'x13' spacings on a burned site. All results to date have been tabulated. Also reported 1960 - p. 41, 1966 - p. 64, 1967 - p. 67. Reports of 1960 by T.P. Decie.

K.W. Picea glauca (white spruce), artificial regeneration, growth increment, planting, seedling growth, spacing.

788. Robinson, P.E. 1970. E.P. 669.1 - Mudpack trials, 1968/1969. B.C. Forest Research Review. p. 75.

Reports field trials to measure survival and production of seedlings planted with roots wrapped in a peat-clay mixture. Mudpacks have shown no increase, to date, in planting cost, and survival is no greater than from normal planting methods.

K.W. artificial regeneration, economics, mudpacks, planting, seedling survival.

789. Ronco, F. 1972. Planting Engelmann spruce: a field guide. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Pap. RM-89A. 11 pp.

Provides planter with techniques needed to establish Engelmann spruce seedlings successfully.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, planting, seedling survival.

ii) INFLUENCES OF PLANTING, cont'd.

790. Rotty, R. 1958. Three rocks for better planting survival. Tree Planters Notes 33:3-5.

Spanish workers, when planting pines, place 3 rocks as close to the seedling as possible. High survival is achieved despite adverse factors. The stones conserve moisture, reflect heat, protect the tree from weed growth and total destruction by browsing and may prevent frost heaving.

K.W. artificial regeneration, browsing, planting, planting methods, seedling survival, vegetative competition.

791. Rotty, R. 1958. Better survival with oversize hole digging. Tree Planters Notes 33:6-11.

Spanish workers dig a hole several times larger and deeper than needed for tree itself. This enables large amounts of water to be absorbed without flooding the seedling and provides a large loosened volume of soil to favour root growth.

K.W. planting, planting method, seedling survival, soil moisture.

792. Rudolf, P.O. 1940. Further comments on "why forest plantations fail". J. For. 38:442-443.

Maintains that the slit method of planting contributes to tree mortality in plantations in Michigan and elsewhere. Such mortality raises plantation cost. Furthermore, it is held that this planting method does not favour optimum root development.

K.W. Pinus sp. (pine), artificial regeneration, planting, planting method, root development, seedling mortality.

793. Rudolf, P.O. and S.R. Gevorkiantz. 1935. Seedlings or transplants. J. For. 33:979-984.

Four distinct areas were chosen for planting sites, and each is briefly described. One 2.5 acre plot was laid out and planted with 12 alternate 25 tree rows of 2-0 and 2-1 Norway pine. Results show that results with 2-1 pine stock are sufficiently superior to those obtained with 2-0 stock to justify economically the use of the former on poorer sites, but on other sites, it is more economical to plant 2-0 trees more densely. Data was analyzed by the "analysis of variance" method, and showed that transplant stock is superior in survival and height growth.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. economics, height growth, planting, planting stock, seedling growth, seedling survival, transplants, [Pinus resinosa].

794. Sagreiya, K.P. 1944. Triangular versus square planting. Indian Forester 70:283-289. (Abstr. F.A. 6:161).

Outlines advantages of triangular planting. Shows that such a method more closely resembles natural distribution and that it is easier to thin. Planting is more expensive however.

K.W. artificial regeneration, economics, planting, planting regime, spacing, thinning.

795. Schantz-Hansen, T. 1945. The effect of planting methods on root development. J. For. 43(6):447-448.

The experiment reported in this article indicates that when 2-2 stock of red pine, white pine, jack pine, and white spruce was used in sandy soil, the method of planting apparently did not seriously affect either survival or root development.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting methods, root growth, seedling mortality, [Pinus spp.].

796. Schmidt-Vogt, H. 1970. [Trials comparing hole and angle planting of spruce.] Forst-und Holzw. 25(5):81-84. (Abstr. F.A. 31:756).

Hole planting gives slightly better survival and growth, particularly for small plants on weed infested fresh sites. Even for fresh and moderately fresh sites, however, the cheaper angle planting method can be recommended, especially if large plants are used.

K.W. Picea sp. (spruce), planting, planting method, planting stock, seedling survival, vegetation.

797. Schopmeyer, C.S. 1940. Survival in forest plantations in the Northern Rocky Mountain Region. J. For. 38:16-24.

Between 1910 and 1937, over 1,150 plantations were established in Montana, Idaho, and Washington. Spring-planting of western white and ponderosa pine gave 7% and 10% higher survival, respectively, than fall-planted trees of the same species. There appeared no significant difference in survival between age classes of either species. Seven references are cited.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea engelmannii (Engelmann spruce), nurseries, planting, planting date, seedling survival, [Pinus spp.].

798. Singh, P. and J. Richardson. 1973. Armillaria root in seeded and planted areas in Newfoundland. Forestry Chronicle 49(4):180-182.

The presence of Armillaria varied with the method of planting used and with the species, being especially present in all plantations established with bare root stock. It was absent on areas planted with containers. Data for white spruce and black spruce showed 5.1% infection in bare root planted plots, 0% in seed spotted areas, and 0.1% in broadcast seeded areas. Results showed higher rates for other species.

K.W. Picea glauca (white spruce), Armillaria sp., artificial regeneration, containers, fungus, infection, planting, scarification, seeding, [Picea mariana].

799. Söderström, V. 1959. [Causes of plant mortality in the first year with different planting methods.] Norrlands SkogsvFörb. Tidskr. 1959(2):103-216. (Abstr. F.A. 21:59).

Various planting methods with or without soil cultivation were carried out. During the first year after planting, mortality was higher where no cultivation had been done, but differences between treatments were insignificant after 6 or 7 growing seasons. Differences in mortality between two groups were generally insignificant. Plant mortality was closely related to drought and on one site, to frost. Plants on uncultivated land were more susceptible to drought. Generally, plant cover and degree of seedling mortality were positively correlated for both treatments. After 6 or 7 years, growth showed no significant difference between treatments. In almost all cases, root growth was significantly better on cultivated spots. For spruce, in many cases, slant planting was best on grass fire sites, and vertical planting on grassy sites.

K.W. Picea sp. (spruce), Pinus sp. (pine), cultivation, frost damage, planting, planting method, root growth, seedling growth, seedling mortality, soil moisture, vegetative competition.

ii) INFLUENCES OF PLANTING, cont'd.

800. Söderström, V. 1959. [Preliminary studies on soil temperatures and root growth of young conifers on planting spots and in the natural vegetation of cleared areas.] Svenska SkogsvFören. Tidskr. 57(1:2):171-198; 281-302. (Abstr. F.A. 21:59).

Available soil warmth for root development of planted seedlings is greatest for those planted vertically on scalped areas, slightly less for those planted on a slant with roots horizontally near the borderline of mineral soil and humus, and much the least for vertical planting without scalping. All differences were greatest in spring. Soil temperature may be an important factor in root growth of spruce, while it appears that soil moisture is determinant in pine growth.

K.W. Picea sp. (spruce), Pinus sp. (pine), planting, planting methods, root growth, soil, soil moisture, soil temperature, vegetative competition.

801. Stiell, W.M. 1955. The Petawawa plantations. Canada, Forestry Branch, Tech. Note 21. 46 pp.

Describes plantation area in detail. Includes survey of white spruce plantations at Petawawa. Problems encountered include suppression by old field trees and alder re-growth. Youngest cone bearing trees were about 20 years old. Average survival for plantation (mostly 2-2 stock planted in furrows in the spring) was 91.3%. Survival in open furrows was 92% as compared with 79% in closed furrows. Survival of 2-0 stock has been low. Various different spacings have been used: there is a general trend towards greater diameters at wider spacings and higher site classes for a given age.

K.W. Picea glauca (white spruce), artificial regeneration, furrowing, planting, plantations, seedling growth, seedling mortality, spacing.

802. Stiell, W.M. 1958. The effect of planting method on survival and development of spruce. Canada, Forestry Branch, Forest Research Division, Binder 327. 19 pp.

Three years after initiation of a planting experiment with white spruce, neither survival nor height growth indicate that there is any advantage in using either saddle or half-saddle planting method. It is tentatively concluded that wedge method is preferable for reasons of economy and simplicity of planting.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea glauca (white spruce), economics, planting, planting method, seedling growth, seedling survival.

803. Stiell, W.M. 1958. A planting method experiment with white spruce. Pulp and Paper Magazine of Canada, Woodlands Review 59(6):207-208.

Various methods of planting white spruce were tested at Petawawa Experiment Station. Survival after 3 years was over 90% with all methods except saddle planting in the fall which showed considerably greater mortality. There seems to have been little association between planting method and height growth. Wedge planting was the simplest and easiest method used and is therefore recommended.

K.W. Picea glauca (white spruce), economics, planting, planting method, seedling growth, seedling mortality.

804. Stiell, W.M. 1958. Pulpwood plantations in Ontario and Quebec. Canadian Pulp and Paper Association, Woodlands Section, Index 1770 (F-2). 42 pp.

Describes a survey of plantations established in Ontario and Quebec. Plantations ranged in age from 1-32 years, and were mostly white spruce. Furrow planting did not seem to give better results than spot planting. Machine planting was unsuitable on cutovers. Most mortality occurred within 4 years of planting. Mortality was generally low. Usual causes were site factors, establishment factors, and competition factors. Full overhead cover hindered growth of white spruce. Initial growth of white spruce was variable and not consistent to site.

K.W. Picea glauca (white spruce), furrowing, machine planting, planting, seedling growth, seedling mortality, mortality, soil, vegetative competition, [Pinus banksiana, Picea mariana].

805. Stiell, W.M. 1960. A co-operative experimental planting project in Ontario. Pulp and Paper Magazine of Canada 61(2):114-117.

Compares saddle and half saddle planting methods with various conventional methods for planting white and black spruce. On the evidence to date, the saddle and half saddle methods are too difficult and costly to justify general adoption.

K.W. Picea glauca (white spruce), economics, planting, planting methods, [Picea mariana].

ii) INFLUENCES OF PLANTING, cont'd.

806. Stiell, W.M. 1969. Crown development in white spruce plantations. Canada, Forestry Branch, Publ. 1249. 12 pp.

Branch development and needle distribution within crowns were studied on forty-three white spruce, ranging in age from thirteen to forty-one years-old, and representing planted spacings of 3'x3', 4'x4', 5'x5', 6'x6' and 7'x7'. Total oven-dry foliage weight is most closely correlated with stem diameter at the base of the live crown and with an expression combining diameter at breast height with crown length. Variables of height, age, spacing, and crown class had little or no effect on the relationship.

K.W. Picea glauca (white spruce), artificial regeneration, crown development, foliage, growth increment, planting, spacing.

807. Stiell, W.M. and A.B. Berry. 1967. White spruce plantation growth and yield at the Petawawa Forest Experiment Station. Canada, Forestry Branch, Publ. 1200. 15 pp.

Presents yield tables for unmanaged white spruce plantations by five year age classes up to forty years from planting, for five planted spacings and four site index classes.

K.W. Picea glauca (white spruce), artificial regeneration, growth increment, planting, plantations, seeding, spacing.

808. Stoeckeler, J.H. and G.A. Limstrom. 1950. Reforestation research findings in northern Wisconsin and Upper Michigan Lake Station Forest Experiment Station, Sta. Pap. 23. 6 pp.

Summarizes the results of experimental and pilot plantings 1937-1949 in Wisconsin and Michigan. Planting of all species including white spruce is much more effective than direct seeding. Transplants of white spruce had greater survival and height growth than seedlings. Spring planting was superior to fall planting. White spruce had 7-12% better survival in scalps than in furrows. On wet, poorly drained mineral soils, survival of black and white spruce was increased by 12-32% and height growth doubled by planting trees on turned over furrow slice rather than in scalps or furrows.

K.W. Picea glauca (white spruce), artificial regeneration, furrowing, planting, planting date, planting stock, seeding, seedling growth, seedling survival, soil moisture.

ii) INFLUENCES OF PLANTING, cont'd.

809. Sutton, R.F. 1967. Influence of planting depth on early growth of conifers. Commonwealth Forestry Review 46(4):282-295.

Picea glauca seedlings planted 10.0 cm deeper than in the nursery, grew significantly more in height in their first year than those seedlings planted 5.0 cm deeper or at the same depth as in the nursery. Depth of planting significantly affected second year height growth also. Increased height growth did not make up for decrement due to deep planting. Within 3 months, more than half the deep planted trees had developed adventitious roots.

K.W. Picea glauca (white spruce), planting, planting depth, root formation, seedling growth, [Picea abies].

810. Sutton, R.F. 1968. Ecology of young white spruce (Picea glauca (Moench) Voss). Cornell Univ., Ph.D. Thesis. Also Canada, Forestry Branch, Forest Research Lab, Ontario, Internal Rept. 0-10. 500 pp.

A complete review of young white spruce, including botany, and ecology, a detailed review of root system form and development, a series of experiments designed to provide evidence concerning some possible causes of spruce check, and major constraints on growth and development of outplanted spruce. The relationship between these constraints and spruce check are discussed. The purpose of the entire work is to improve predictability of the occurrence of check after spruce outplanting.

K.W. Picea glauca (white spruce), artificial regeneration, ecology, planting, planting check, regeneration, root growth, seedling survival, silviculture.

811. Sutton, R.F. 1969. Site influenced variation in flushing time of white spruce. Bi-Monthly Research Notes 25(4):36-37.

Differences in planting position of white spruce seedlings caused marked variation in flushing date and behaviour. Three positions were investigated, sod, overturned spoil, and furrow bottom, all on a level site. Site conditions were found to vary greatly between the three positions, with respect to soil fertility, soil temperature and soil moisture, soil aeration and air temperature. The last two conditions were probably most effective in influencing time of flushing.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, flushing, planting, seedbed, soil aeration, soil fertility, soil moisture, soil temperature, temperature.

812. Thompson, C.F. 1972. E.P. 626 - Engelmann spruce planting trials. B.C. Forest Research Review. pp. 49-50.

Two grades of 3+0 Engelmann spruce were planted at various times throughout the growing season. Best survival of 3+0 seedlings was from planting large stock immediately after snow melted from the site in the spring. There is a visible decline in survival of seedlings as planting date becomes later, due to increased severity of conditions after planting and deterioration of stored seedlings. By 1971, it was found that best survival occurred in seedlings planted after mid-September when post-planting conditions improved. Also reported 1969 - p. 78, 1970 - p. 72, 1971 - p. 61.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, planting, planting date, seedbed, seedling survival.

813. Tutygin, G.S. 1966. [Effect of planting date on survival of Pinus sylvestris and Picea abies plantations.] Lesn. Ž., Arhangel'sk 9(6):164. (Abstr. F.A. 28:653).

Tabulates data on the survival of 2 year stock planted in the Archangel region between May 20 and Aug. 15. Survival was >96% for planting on or before June 1 and then decreased for later planting dates, but increased again for the planting on Aug. 15.

K.W. Picea sp. (spruce), Pinus sp. (pine), planting, planting date, seedling survival.

814. Tutygin, G.S. 1969. [Late summer and autumn planting of Scots pine and Norway spruce.] Lesn. Ž., Arhangel'sk 12(2):148-149. (Abstr. F.A. 31:527).

Tabulates survival of 3 year old seedlings planted out at 10 day intervals from Aug. 10 to Oct. 20 in the Archangel region. It is concluded that planting can be done safely in late summer, after the seedlings have stopped growing, and in the first half of September, providing that there is no danger of frost heaving.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), frost heaving, planting, planting date, seedling survival.

815. Visanov, A.V. 1971. [Some problems in designing automatic tree-planting machines for conifers.] Canada, Forestry Branch, Translation TR-202. 10 pp.

Reviews details of Russian tree-planting machines with attendant disadvantages. Shows how these could be improved to more efficiently meet the demands of conifer regeneration.

K.W. artificial regeneration, economics, mechanical planters, planting.

816. Vyse, A.H. 1970. Planting rates increased in British Columbia with new planting gun and bullets. Tree Planters Notes 22(1):1.

Describes new gun used at Cowichan Lake.

K.W. artificial regeneration, planting, planting gun.

817. Walker, N.R. 1966. Planting spruce and pine - Interlake Area, Manitoba. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Internal Rept. MS-14. 14 pp.

Outlines a planting experiment in Manitoba involving four species, including Picea glauca. Outlines planting methods used in 1965 and reviews survival in 1965 of 1960 plantations.

K.W. Picea glauca (white spruce), artificial regeneration, economics, herbicides, nurseries, planting, scalping, scarification, seedling survival, [Picea sp., Pinus sp.]

818. Walters, J. 1961. The planting gun and bullet: a new tree planting technique. Forestry Chronicle 37(2):94-95.

Describes the planting gun and its various advantages over more conventional methods of planting.

K.W. artificial regeneration, planting, planting gun.

819. Walters, J. 1963. An improved planting gun and bullet: a new tree planting technique. Tree Planters Notes 57:1-3.

ii) INFLUENCES OF PLANTING, cont'd.

Describes planting gun and its advantages.

K.W. artificial regeneration, planting, planting gun.

820. Walters, J. 1968. Planting gun and bullet (a new mechanical system for forest regeneration). Agricultural Engineering 49(6):336-339.

Describes technique of planting with gun and bullet. Discusses relative merits of seeding, bare root planting, ball planting, and container planting from standpoints of effectiveness and economics.

K.W. artificial regeneration, economics, planting, planting methods, seeding, seedling survival.

821. White, S.B. 1955. Interim survival study on plantations - Prince and Jarvis locations. Forest Library, Northwest Ontario, Res. Note 2. 2 pp. (Abstr. F.A. 17:218).

Survey of 3 year old plantations of white and black spruce showed a total mortality of 20%, the two main causes being smothering by grass and over-deep planting. In the circumstances 6'x6' planting would give adequate stocking while 8'x8' would not.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting depth, seedling mortality, spacing, vegetative competition, [Picea mariana].

822. Wiksten, Å. 1950. [Research on transplanting pine and spruce.] Norrlands SkogsvFörb. Tidskr. 1950(2):231-268. (Abstr. F.A. 13:387).

In transplanting: 1) roots should be exposed as little as possible, at most 5-10 min. to drying put. Puddling the roots often gives good protection for up to 30 min. 2) transplanting should be done as soon as possible after frost danger is past, 3) the transplanting season for large plants is longer than for medium plants.

K.W. Picea sp. (spruce), Pinus sp. (pine), artificial regeneration, frost damage, nurseries, regeneration, root exposure, seedling growth, transplanting.

823. Wilde, S.A. and A.R. Albert. 1942. Effect of planting methods on survival and growth of plantations on well drained sandy soils of central Wisconsin. J. For. 40:560-562.

ii) INFLUENCES OF PLANTING, cont'd.

Various planting methods were carried out with jack pine and red pine, using deep and shallow furrows, unscalped slits, and holes using spades and additional humus soil. Slit planting gave poorest results. Deep furrows gave best height growth and survival. Holes produced no better results than any but slit planting and were much more expensive. No significant difference was observed in survival or in rate of growth in furrows ploughed in different directions.

K.W. artificial regeneration, furrowing, planting, planting method, seedling growth, seedling survival, [Pinus banksiana, Pinus resinosa].

b) CONTAINER STOCK

Papers in this section are principally concerned with evaluation of containerized seedlings as a means of artificial regeneration. Studies include comparative tests of bare root stock and containers, evaluations of various container types as means of artificial regeneration, and comparisons of different container types and shapes with respect to post-planting seedling growth and survival.

ii) INFLUENCES OF PLANTING, cont'd.

824. Ackerman, R.F. 1965. A field test of bullet planting in Alberta. Canada, Dept. Forestry, Forest Research Lab, Calgary, Mimeo 65-A-6. 68 pp.

Reports 1862, 1963, and 1964 experiments determining the effects of age of seedlings and month of container planting on the survival of white spruce and lodgepole pine seedlings. Other factors examined were the influences of scarification, of containers themselves v.s. non-container planting, and of different types of plastic containers. 1-0 or 2-0 seedlings were generally those transplanted. All variables are discussed at length, and recommendations for future study are made. Recommendations for bullet planting are also made.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, bullets, containers, fertilizers, germination, irrigation, nurseries, nutrition, planting, scarification, seedbed, seedlings.

825. Ackerman, R.F., D.I. Crossley, L.L. Kennedy and J. Chedzoy. 1965. Preliminary results of a field test of bullet planting in Alberta. Canada, Dept. Forestry, Forest Research Branch, Publ. 1098. 20 pp.

Field tests using plastic, bullet-shaped containers, were initiated at various sites in west-central Alberta. Preliminary survival results indicate that unfertilized lodgepole pine and white spruce seedlings, eight weeks of age and older, can be successfully planted throughout the frost-free season on a wide range of sites and seedbeds. Further development is recommended.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, bullets, planting, seedling survival.

826. Arnott, J.T. 1969. Survival of bare-root and container-grown black spruce in Quebec. Bi-Monthly Research Notes 25(2): 16-17.

Tubelings were raised initially in a controlled environment chamber, then moved to a greenhouse and later planted outside. Survival of tubeling and bare-root stock was evaluated in 3 vigor classes: healthy, unhealthy due to death of terminal bud and/or shoot, and dead due to frost heave or other factors. First year survival of tubelings was much less than bare-root stock. It is stressed that these are initial results and more conclusive evidence will be available in the next few years.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Bare root planting, containers, frost heaving, planting, seedling mortality, tubes, [Picea mariana].

827. Børresen, E. 1967. [Jiffy pots in forestry.] Norsk. Skogbruk 13(5):173-176. (Abstr. F.A. 28:649).

Spruce (3+0) and pine (2+0) were transplanted from seedbeds into jiffy pots and grown on for a year before planting out in the field. Tabulated results show lower mortality and better growth after 1-6 years in potted seedlings planted out in fall or spring, compared with bare root stock planted out in the spring.

K.W. Picea sp. (spruce), Pinus sp. (pine), containers, jiffy pots, planting, seedling growth, seedling mortality.

828. Callin, G. 1971. [Manual planting of rooted plants.] Sveriges SkogsvFörb. Tidskr. 69(2):183-214. (Abstr. F.A. 33:80).

Planting was done more efficiently with plants grown in molded polyethylene trays than with bare root stock or plants in paper pots. Survival of paper pot and polyethylene tray stock after 1 year was better for plantings in screefed patches than for those in humus. Both screefing tools used gave good survival.

K.W. Picea sp. (spruce), Pinus sp. (pine), containers, paper pots, planting, polythene trays, screefing, seedbed, seedling survival.

829. Crossley, D.I. and R.D. Carman. 1964. Experiences in container planting in Alberta. In: Western Reforestation, Western Forestry and Conservation Assoc., Proc. Western Reforestation Co-ordinating Committee, Annual Rept., 1964. pp. 25-28.

Outlines advantages of container planting and covers initial experiment in Alberta, in which container lodgepole pine and white spruce and 1-0 stock were planted. Survival percentages for most seedling lots after 3 years was 60-85%, very little less than 1-0 stock. Only 4-week-old tubelings showed high mortality. Main causes of mortality here were rodents, frost and smothering. Later experiments also reported, show that on almost all sites, container seedlings give results comparable to 2-0 bare root stock. A further experiment measures relative suitability of different container types. Results indicate containers are very useful.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, bare root stock, containers, frost damage, planting, rodents, seedbed, seedling survival, tubes, vegetative competition.

830. Day, R.J. and D.A. Cameron. 1968. The effect of frost heaving on different tube shapes for tubed seedlings. Univ. Toronto, Forest Research Review. p. 5.

Plastic dummies of 4 geometric shapes; a cylinder, cone, inverted cone, and multiple cone, were inserted in two soil types. Freezing treatment showed the inverted cone to be significantly the most severely heaved. All other shapes gave similar results. It appears that frost heaving cannot be overcome by modification of the tube shape.

K.W. artificial regeneration, containers, frost heaving, tubes, tube shape.

831. Day, R.J. and K.S. Giel. 1970. Effect of wind on water loss from tubed seedlings of jack pine and white spruce (Pinus banksiana Lamb. and Picea glauca (Moench) Voss.). Univ. Toronto, Forest Research Review. p. 7.

Two wind speeds (4 & 7 kph) were applied to tubes of 1.3 and 1.9 mm. in diameter. Wind increased water loss by evaporation but had little effect on transpiration. Smaller tubes lost 38% and bigger tubes 58% of contained moisture in first day. Tubes not exposed to wind lost 20%. Silicone rubber soil coating and non-ionic wetting agent are recommended for use in exposed sites.

K.W. Picea glauca (white spruce), Pinus banksiana (jack pine), artificial regeneration, containers, evaporation, planting, moisture loss, soil moisture, transpiration, tubes.

832. Day, R.J. and J. Skoupy. 1971. Moisture storage capacity and post-planting patterns of moisture movement from seedling containers. Canadian Journal of Forest Research 1(3):151-158.

Studies water movement from 3 types of containers filled with peat or peat and loam into sand and loam soils obtained from planting sites. With all container types, there was a rapid outward movement of 15-39% of moisture initially stored in the containers to the surrounding soil within a few days of planting. Results suggest that the path and eventual location of moisture may be more important for seedling survival than the amount of moisture moving into the surrounding soil. The Ontario tube minimizes moisture loss found in the other two types. Suggests future tube designs.

K.W. containers, planting, seedling survival, soil moisture, tubes, water loss.

833. Dixon, G. and H.J. Johnson. 1969. Preliminary evaluation of pilot-scale container planting in the foothills of Alberta - 1967 planting. Canada, Forestry Branch, Forest Research Lab, Edmonton, Internal Rept. A-19. 22 pp.

Presents first year survival results of container-planted white spruce and lodgepole pine established in 1967. Average survival of white spruce was 68% while that of lodgepole pine was 45%. There was a much higher survival of spruce on scarified plots than on unscarified plots. Survival was also related to soil depth, moisture regime, competing vegetation, and the number of seedlings per container.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, containers, planting, scarification, seedbed, seedling survival, soil, soil moisture, vegetative competition.

834. Endean, F. 1972. Assessment of different types of containers for growing seedlings in Alberta. In: Proceedings of a workshop on container planting in Canada. Canada, Forestry Service, Info. Rept. DPC-X-2. pp. 119-128.

Deals with two species, lodgepole pine and white spruce. Of the two, white spruce is much more sensitive to out-planting in Alberta conditions even when 2+0 bare-root stock. Seedlings of container origin do not seem to do well outside the container. Plugs and solid tubes have been shown to be similar. The better performance of over-wintered stock is taken as an indication of the need for more robust and better adjusted seedlings.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, containers, growth increment, planting, plugs, seedling survival, tubes.

ii) INFLUENCES OF PLANTING, cont'd.

835. Endean, F. 1973. Conical container improves seedling growth on dry sites. Tree Planters Notes 24(1):26-29.

Conical container produced lodgepole pine seedlings which were markedly superior in growth rate to those produced in 3/4 x 3 1/4" polystyene tubes. Many more roots were outside the conical containers at excavation.

K.W. Pinus contorta (lodgepole pine), artificial regeneration, containers, growth, planting, root growth, tubes.

836. Fraser, J.W. and W.W. Wahl. 1969. Frost and tubed seedlings. Canada, Forestry Branch, Petawawa Forest Experiment Station, Info. Rept. PS-X-12. 13 pp.

If tubelings are planted on bared mineral soil later than August, damage by soil heaving can be expected when appreciable frost occurs. The degree of heaving depends upon soil type and can be reduced slightly by lubrication. Whether or not earlier planting will permit the trees to become more firmly anchored by a better developed root system and resist heaving is still to be investigated.

K.W. artificial regeneration, containers, frost heaving, planting, soil, tubes, [Pinus resinosa].

837. Haig, R.A. 1972. Assessment of factors affecting the survival of tubed seedlings, Cupa Lake, Ontario 1967-1970. Canada, Forestry Service, Great Lakes Forest Research Centre, Internal Rept. 0.35. 20 pp.

Based on the criterion of survival after 4 years, the performance of tubed seedlings of white spruce, black spruce and jack pine planted in the White River area were; site type, relation of planting time to time of site preparation, age of stock at planting, depth of organic layer on planting site, drainage of planting site. Survival of individual tubed seedlings was dependent on seedbed and soil moisture at planting spot and the location of planting spot with respect to site preparation furrows.

K.W. Picea glauca (white spruce), artificial regeneration, containers, drainage, furrowing, seedbed, seedling survival, soil moisture, tubes, [Picea mariana, Pinus banksiana].

ii) INFLUENCES OF PLANTING, cont'd.

838. Harris, R.W. 1968. Factors affecting root development of container grown trees. Proc. 43rd International Shade Tree Conference, 1967. pp. 304-314. (ABSTR.).

Deals mainly with the ill effects of excessive soil temperature and especially of those caused by south and west aspects of container sides.

K.W. containers, planting, root growth, soil temperature.

839. Heino, J. 1972. [Regeneration with roll plants.] Skogen 59(1): 18-19. (Abstr. F.A. 33:716).

Outlines use of peat ribbons as containers for spruce and pine. Survival of spruce to date has been poorer than that of bare root stock. The reverse, however, is true of pine. Production costs are at least 20% lower than for bare root stock.

K.W. Picea sp. (spruce), Pinus sp. (pine), bare root stock, economics, peat ribbons, planting, seedling survival.

840. Johnson, H.J. 1972. Performance of container stock in Alberta. In: Proceedings of a workshop on container planting in Canada. Canada, Forestry Service, Info. Rept. DPC-X-2. pp. 100-118.

Evaluates seedling survival of lodgepole pine and white spruce as it is affected by time and various types of planting containers. Generally, a form of plug container was found to be more effective than were enclosed, root-restricting containers.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, containers, planting, plugs, seedling survival.

841. Johnson, H.J. and G. Dixon. 1968. Preliminary evaluation of pilot scale container planting in the foothills of Alberta - 1966 planting. Canada, Forestry Branch, Forest Research Lab, Alberta, Internal Rept. A-11. 14 pp.

Evaluates container planting of white spruce and lodgepole pine in regard to problem conditions and recognition of aspects of container planting requiring further research. 63 plots were established, each with 100 seedlings. Average survival for spruce was 81% and 65% and for pine 80% and 71%, for 1965 and 1966 plantings respectively. Mortality and injury were largely due to smothering, trampling, and frost in spruce, and frost and smothering in pine. There appears to be a relationship between the number of seedlings per container, and survival, the greater the number, the greater the survival rate.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), containers, frost damage, seedling growth, seedling mortality, seedling survival, smothering.

842. Johnson, H.J. and F. Marsh. 1967. Preliminary evaluation of pilot-scale container planting in the foothills of Alberta. Canada, Forestry Branch, Forest Research Lab, Info. Rept. A-X-11. 15 pp.

Reports first year survival results of white spruce and lodgepole pine seedlings planted in plastic containers on a cutover area. Average survival was 81% for spruce and 80% for pine. Greatest mortality was caused by animals. Results of a trial of multi-seedling containers are also tabulated, indicating a trend toward greater survival percentages with a greater number of seedlings per container for both species.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, containers, frost damage, planting, seedbed, seedling mortality, wildlife.

843. Kinghorn, J.M. 1970. The status of container planting in western Canada. Forestry Chronicle 46(6):466-469.

Defines and describes various types of container plantings used in western Canada. Outlines the progress of current research in the evaluation of containers. At the time of writing, there have been few conclusions concerning the utility of containers.

K.W. artificial regeneration, containers, planting, silviculture.

844. MacArthur, J.D. 1968. Container planting with bullets - and lazy susan. Pulp and Paper Magazine of Canada 69(1):91-93.

Demonstrates with Douglas fir a new method of loading the planting gun. Two problems with bullet planting encountered frequently are frost heaving and smothering by vegetative competition. Bullet planting lengthens the planting season, reduces planting shock and provides a uniform quality of work.

K.W. artificial regeneration, containers, frost heaving, planting, planting gun, seedling survival, vegetative competition.

ii) INFLUENCES OF PLANTING, cont'd.

845. Scarratt, J.B. 1972. Relationship between size at planting and growth of white spruce tubed seedlings. Canada, Forestry Service, Forest Research Lab, Sault Ste. Marie, Info. Rept. O-X-168. 15 pp.

White spruce tubed seedlings, 6, 8, 10, 12, 14 and 16 weeks old (from sowing) were planted in mid-July on lightly scarified silt in north Ontario. After 2 years, seedlings less than 10 weeks of age when planted, were inferior in all respects to seedlings in the 4 older age classes, and in many cases exhibited symptoms of planting check. Best results were obtained with seedlings 12 weeks old or older when planted.

K.W. Picea glauca (white spruce), artificial regeneration, containers, planting, planting stock, seedling growth, seedlings, tubes.

846. Skoupy, J. and R.J. Day. 1969. The water relations of soils in three container types before and after planting. Univ. Toronto Forest Research Review. p. 9.

The effect of three types of tree seedling containers peat pot, styrene tube, and reticulate polyethylene tube, on the movement of water to and from the container after establishment in soil was studied.

K.W. artificial regeneration, containers, peat pots, tubes, water relations.

847. Soos, J. 1967. First year mortality of container planting in the Clearwater-Rocky Mountain House Forest, Alberta. Canada, Forestry Branch Forest Research Lab, Alberta, Info. Rept. A-X-7. 42 pp.

First year results of experimental plantings of white spruce to test practicability of container planting in Alberta, showed 10% mortality on scarified cutover areas and 11% under young aspen stands. Under-planting in an 80-year-old aspen stand resulted in 43% mortality. Plastic containers were consistently the best in both the field and the greenhouse. Mineral soil and rotten wood were the best media for growth for both white spruce and lodgepole pine.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, containers, logging, planting, scarification, seedbed, seedling mortality, soil.

ii) INFLUENCES OF PLANTING, cont'd.

848. Soos, J. 1967. Early mortality of container planting in the Peace River Forest, Alberta. Canada, Forestry Branch, Forest Research Lab, Alberta, Info. Rept. A-X-12. 35 pp.

White spruce and lodgepole pine were grown in three types of containers and planted on scarified and unscarified areas. Slightly better survival was obtained for both species and all types of containers on unscarified areas as compared to scarified areas. Mortality rates were highest in phenylformaldehyde and acetate containers and lowest in new plastic containers for both species. Generally, mortality of spruce seedlings was lower than that of pine in plastic containers and higher in other types.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, containers, planting, scarification, seedbed, seedling mortality, seedling survival.

849. Tatlow, R. 1969. Capsuled tree planting. The Truck Logger, Jan. 1969. pp. 26-27.

Mud containers are put around tree roots in a cylinder in the capsuling process. Seedlings planted by this method have shown 80% survival. Recommendations are made for growing seedlings inside the capsules for a short time prior to fall planting to allow roots to become established. Further studies are planned.

K.W. Picea engelmannii (Engelmann spruce), Pseudotsuga menziesii (Douglas fir), capsule planting, containers, planting, root growth, seedling survival, [Abies sp., Pinus sp., Tsuga sp.].

850. Ter Bush, F.A. 1971. Some observations on container planting in Canada. Tree Planters Notes 22(3):8-12.

Describes various container planting trials, both experimental and operational, together with survival results from container planting of various species. Economics are dealt with.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, container type, containers, economics, planting, seedbed, seedling growth, seedling mortality.

ii) INFLUENCES OF PLANTING, cont'd.

851. Thompson, C.F., M.B. Clarke and S.G.J. Homoky. 1972. E.P. 684 - Container, mudpack, and bare-root planting trials in the interior. B.C. Forest Research Review. pp. 52-55.

Tested the survival of lodgepole pine, white spruce and Douglas fir when planted in Prince Rupert and Prince George Districts as 2+0 bare-root, 2+0 mudpack, 1+0 bullet and 1+0 plug stocks. Survival of mudpacked stock was poorest in all cases. Container survival was fair to good, but in poor condition in many cases. Bare-root stock survival was fair. All data is tabulated. Also reported 1970 - p. 77, 1971 - pp. 65-68. Authors in 1970-1971 D. Gillespie, H. Coates, M.B. Clark, and C.F. Thompson.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, bullets, containers, mudpacks, planting, plugs, seedling survival, seedlings.

852. Thompson, C.F., M.B. Clark, H. Coates and S.G.J. Homoky. 1972. E.P. 697 - Trials of container grown and bare-root seedlings in the interior of British Columbia (Fall 1970 and Summer 1971). B.C. Forest Research Review. pp. 55-57.

Compares survival and stock conditions of 2+0 bare-root seedlings with 1+0 bullet-grown and planted seedlings and styrofoam 1+0 container-grown seedlings planted as plugs, when planted in fall and late spring to summer. Generally, spruce seedling survival is better than pine. Plug seedlings seem better than bare-root stock or bullets. Complete tabulation of survival data. Also reported 1971 - p. 68-69.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, bare-root stock, bullets, containers, planting, planting date, plugs, seedling survival, seedlings.

853. Toman, J. 1970. Ball planting - a short history and some perspectives. Proc. Inland Empire Forestry Conference, Sept. 1970. n.p.

History of ball planting with an extensive bibliography. Points out some advantages and disadvantages of using various different types of containers. Proposes a method of producing good planting stock in quantity.

ii) INFLUENCES OF PLANTING, cont'd.

K.W. artificial regeneration, ball planting, containers.

854. Van Eerden, E. 1972. Field performance of container grown seedlings in Interior Forests. In: Study review statements, Pacific Region, 1972-1973, Canada, Forestry Service. pp. 365-371.

Study review statement of a project initiated in 1967 to study use of various container planting systems and the feasibility of extending the planting season in the interior of B.C. Various planting operations have been carried out. Latest experiments indicate that survival and growth rates of spring planted stock are superior to those of seedlings planted in autumn. Preliminary indications are that plugs have a potential of 10-15% improvement in survival relative to bullet seedlings. Further results will be published later. Also reported 1969-1971.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), bullets, containers, planting, planting date, plugs, seedling growth, seedling survival.

855. Van Eerden, E. 1972. Influences affecting container seedling performance near Prince George, British Columbia. In: Proceedings of a Workshop on container planting in Canada. Canada, Forestry Service, Info. Rept. DPC-X-2. pp. 92-100.

Reviews survival after planting of various types of containers with species including white spruce, lodgepole pine, and Douglas fir. Survival of plugs is superior, and growth is faster than for bullets and frost-heaving is almost negligible. It is stressed that container-grown stock should meet minimum size requirements to ensure survival. Survival of spring planting has been found to be better than that of later plantings, but each planting operation should be guided by the individual needs of each site to be regenerated.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, browsing, bullets, competition, containers, drought, planting, plugs, seedbed, seedling mortality, seedling survival, soil, vegetation.

ii) INFLUENCES OF PLANTING, cont'd.

856. Vyse, A.H., G.A. Birchfield and E. Van Eerden. 1971. An operational trial of the styroblock reforestation system in British Columbia. Canada, Forestry Service, Info. Rept. BC-X-59. 34 pp.

Lodgepole pine in styroblocks were planted out in the central interior of British Columbia. Early planting production totals ranged from 990-1820 trees/man day. Average planting speeds ranged from 3.1 - 6.2 trees/min./man. Problems encountered with extraction of plug seedlings and planting quality were encountered. All problems encountered can be solved and improved planted performance can be expected.

K.W. Pinus contorta (lodgepole pine), artificial regeneration, containers, planting, styroblocks, work study.

857. Walters, J. 1969. Synthetic ball planting on the University of British Columbia Research Forest, Haney. Tree Planters Notes 20(1):10-13.

Summarizes results of planting trials with Douglas fir seedlings grown in balls of polyurethane foam. Drought was the main factor responsible for high mortality (44%) in the first growing season after planting out, and frost heaving (10%) in winter.

K.W. drought, frost heaving, planting, planting method, seedling mortality, [Pseudotsuga menziesii].

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION

Various post-planting treatments of seedlings, seedbeds, and planting sites are described and evaluated by papers in this section with respect to seedling growth and survival.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

858. Anon. 1956. Mulching and screening of white spruce seed spots on cutover lands. Pulp and Paper Magazine of Canada 57(6): 183.

Survival on mulched and screened seed spots established 4 years earlier was much higher (87% stocking) than on spots screened but not mulched (37%), mulched but not screened (19%), and unprotected (12%).

K.W. Picea glauca (white spruce), artificial regeneration, cutovers, mulching, screening, seed spots, seeding, seedling survival.

859. Anon. 1970. [Weed control in young plantations.] Forst-und Holzw. 25(8):157-176. (Abstr. F.A. 31:760).

Includes various papers dealing with the use of various herbicides to aid seedling growth and survival on various plantations in Germany.

K.W. herbicides, planting, regeneration, vegetation, weed control.

860. Ahrens, J.F. 1967. Improving herbicide selectivity in transplanted crops with root dips of activated charcoal. Weed Abstracts 16(6):No. 2138.

Simazine at 4-12 lb/acre and bromacil at 1-3 lb/acre killed an established Poa praetensis sod treated in April in preparation for the planting 3 weeks later of Picea glauca. Bromacil at 2 lb/acre and dichlorobenil granular 6 lb/acre were applied the day after planting. Tolerance of simazine was greatly increased by root dipping, which also showed promise with dichlorobenil applied after planting and bromacil 1 lb/acre applied before planting.

K.W. Picea glauca (white spruce), grasses, herbicides, planting, root dipping, seedling survival, vegetation, weeding.

861. Alexander, R.R. and D.L. Noble. 1971. Effects of watering treatments on germination, survival and growth of Engelmann spruce: a greenhouse study. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note RM-182. 6 pp.

There was no significant survival after 24 weeks until 1.0 or more inches of water was received monthly, applied at intervals throughout the month, whereas few seedlings survived until 2.0 inches of water was received monthly in a single watering.

K.W. Picea engelannii (Engelmann spruce), irrigation, seedling mortality, soil moisture.

862. Armson, K. 1961. The effects of applying fertilizers at various times during the growing season on the size and quality of spruce and pine seedlings. Univ. Toronto, Forest Research Rept. p. 2.

White and black spruce and white and red pine seedlings were established. Purpose of experiment is to discover whether the growth of these seedlings can be altered when a given amount of fertilizer is applied at different times during the growing season. Tentative results indicate that for spruces, largest seedlings were produced by 5 equally spaced fertilizer applications throughout growing season. For pines, two or three applications in early and mid summer largest seedlings.

K.W. Picea glauca (white spruce), artificial regeneration, fertilization, fertilizing schedule, nurseries, planting, seedling growth, [Picea mariana, Pinus resinosa, Pinus strobus].

863. Armson, K.A. 1961. The effect of varying levels of nitrogen and phosphorus in the growth of spruce and pine seedlings. Univ. Toronto, Forest Research, Review. p. 2.

Experiment was initiated using four levels of N and P in all combinations. Species tested included Picea glauca. Reported in Reviews for other years.

K.W. Picea glauca (white spruce), fertilization, nitrogen, phosphorus, seedling growth, [Picea mariana, Pinus resinosa, Pinus strobus].

864. Armson, K.A. 1963. The effects of levels and times of fertilizer application on the growth of white spruce seedlings. Proc. Soil Sci. Soc. Amer. 27(5):596-597.

White spruce seedlings were treated with four levels of nitrogen and phosphorus in combination on three different time schedules: "periodic" - fertilizer applied in 5 doses from May to September; "normal" - fertilizer applied in May, June, July and; "summer and fall" - fertilizer applied in May, June, September. Results showed seedling height, shoot/root ratio and dry weight increased as amount of fertilizer increased. Time concentrations of P were not affected by treatment, but foliar N concentration increased as fertilizer level increased more in the "periodic" and "summer and fall" schedule than in the "normal" schedule.

K.W. Picea glauca (white spruce), fertilization, foliar nutrients, nitrogen, phosphorus, seedling growth, seedling height, seedling weight.

865. Armson, K.A. 1964. A study of the root development of white spruce seedlings. Univ. Toronto, Forest Research Review. p. 7-8.

Seedlings growing on soil banded with 100 lbs/acre of P as triple superphosphate were sampled at 10-14 day intervals from germination to day 65. Differential growth responses to fertilizer as measured by total dry weight was evident by day 35. Differences in total root length and surface are also became evident and increased with time. Root development was stimulated below the fertilized layer. Root soil volume ratio increased threefold from first sampling to day 64.

K.W. Picea glauca (white spruce), artificial regeneration, fertilization, nurseries, phosphorus, root growth, root-soil volume ratio, seedling growth.

866. Armson, K.A. 1966. The growth and absorption of nutrients by fertilized and unfertilized white spruce seedlings. Forestry Chronicle 42(2):127-136.

Fertilizer treatments were applied to the soil of a seedbed before planting white spruce seeds and during the first two growing seasons. During the second season, 100 lbs.N/acre and 200 lbs. P/acre were added. The fertilized seedlings made use of a greater portion of the effective growing season and had a growth rate curve differing from that of the unfertilized control. Explanations are put forward.

K.W. Picea glauca (white spruce), artificial regeneration, fertilizers, growth increment, nitrogen, phosphorus, seedlings.

867. Armson, K.A. 1967. Review of forest fertilization in Canada. Canada, Forestry Branch, Publ. 1186. 175 pp.

Contains 85 case history reports of forest fertilization experiments in Canada, including experiments concerned with aiding the regeneration and growth of Picea glauca.

K.W. Picea glauca (white spruce), artificial regeneration, forest management, planting, regeneration, seeding, silviculture.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

868. Armson, K.A., K.H. Reese and R.D. Carman. 1963. Time of fertilizer application affects size of conifer seedlings. Tree Planters Notes 59:9-12.

A given amount of fertilizer (NPK) was applied in 1, 2, 3, or 5 applications between May and September during the first two growing seasons. The results indicate that treatments incorporating earliest fertilizer applications resulted in the largest seedlings. Late applications resulted in increased levels of N in foliage, but no corresponding increase in P or K.

K.W. Picea glauca (white spruce), fertilization, foliar nutrients, nitrogen, phosphorus, potassium, seedling growth.

869. Batsch, W.W. 1969. Frost-heaving in conifer seedbeds as affected by soil fertility treatments. Bi-Monthly Research Notes 25(2):17.

Various fertilization treatments were added to the soil of a white spruce plantation. Damage from frost heaving was found to be greatest in untreated control plots (59%) and least in soil treated with mineral fertilizers and peat (17%). There was also a definite negative correlation between seedling size and frost-heaving damage. Soil fertility then, for both these reasons, is a key factor in nursery production.

K.W. Picea glauca (white spruce), artificial regeneration, fertilization, frost-heaving, nurseries, planting, soil fertility.

870. Chaudhry, M.A. 1973. Chemical spot disseminator: a new aid in reforestation. Tree Planters Notes 24(1):12-15.

Dybar and simazine spread by a newly designed unit in three foot diameter spots showed a complete eradication of a wide variety of weeds in a clearcut white spruce area. Spots thus treated, devoid of weeds with partial coverage all around, provide ideal conditions for early establishment of white spruce.

K.W. Picea glauca (white spruce), artificial regeneration, clear felling, dybar, economics, herbicides, planting, scarification, simazine, vegetative competition.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

871. Day, R.J. and J.D. Walker. 1967. The effect of n-heptane on coniferous seedlings grown in plastic (styrene) containers. Univ. Toronto, Forest Research Review. p. 9.

1+0 seedlings of various species including white spruce were tested with n-heptane foliar spray and effectiveness of n-heptane in shattering containers was also tested. All seedlings sprayed with n-heptane died. Those treated by spraying the pot only were not affected. Though cracking of pots occurred, only in a few instances did roots penetrate to the outer soil.

K.W. Picea glauca (white spruce), artificial regeneration, containers, n-heptane, planting, seedling mortality, tubes.

872. Deitschmann, G.H. and E.W. Pruett. 1960. First year control of weeds in forest plantings. Proc. 17th Annual North Central Weed Control Conference 13. (Abstr. F.A. 24:575).

Discing, mowing, hand cultivation and various herbicides were used as treatments for plots planted with various species. Best control of invading weeds was given by cultivation. Cultivation also preserved soil moisture more effectively than any other treatment. At the end of the year, cultivated plots showed best tree growth and survival.

K.W. cultivation, discing, herbicides, seedling growth, seedling survival, soil moisture, weeding, [Pinus banksiana, Pinus strobus, Populus sp.].

873. Deppenmeier, E. 1970. [Improved tendings of young plantations by chemical weed control.] Forst-tech Inform. 1970(2/3): 9-17. (Abstr. F.A. 31:760).

Report on a meeting discussing problems of mixed infestation and secondary weeds following chemical treatment. Contains abridged versions of various papers.

K.W. herbicides, infestation, vegetation.

874. Fabricius, L. 1941. [On covering the soil with plant materials.] Forstwissenschaftliches Centralblatt 63:97-100. (Abstr. F.A. 3:212-213).

In 1929, three years after planting, the heavy weed growth in a spruce-pine plantation was covered with litter from the neighborhood at a rate of 7 kg/m^2. The trees here maintained their superior height and volume growth as compared with untreated controls. In 1940, mean heights of the 50 tallest pine and 20 tallest spruce were 90.6% and 289.8% greater than corresponding heights on controls. The beneficial effect is ascribed to the dying-off of covered weeds and action of litter and weeds as a manure.

K.W. Picea sp. (spruce), Pinus sp. (pine), green manuring, seedling growth, soil, vegetative competition.

875. Foiles, M.W. 1961. Effects of thinning seed spots on growth of three conifers in the Inland Empire. J. For. 59:501-503.

Several seedlings were established in prepared seed spots after direct sowing. Thinning to several degrees was carried out in some spots to test the effects of seed spot density on growth. Results show that diameter growth decreased as the number of seedlings per plot increased, as did height growth. However, thinning is not recommended. It is advisable only in the same circumstances as make thinning of natural stands advisable. The benefits of thinning, such as increased diameter, may be obtained by sowing fewer seeds per spot, but further study is necessary.

K.W. Picea engelmannii (Engelmann spruce), Pinus monticola (white pine), Pinus ponderosa (ponderosa pine), seed spots, seeding, seedling growth, stand density, thinning.

876. Fowells, H.A. and R.K. Arnold. 1939. Hardware cloth seed spot screens reduce high surface soil temperatures. J. For. 37: 821-822.

Near surface soil temperatures were measured under and beside cloth screen cones, which are commonly used to protect seed-spots from bird and rodent predation. Results showed a significant difference between the soil temperature under the cones and that in the open, indicating that the screen cones may not only protect the seedlings, but provide favourable shade. They may also reduce mortality due to high soil temperature.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

K.W. screening, seed spots, seeding, seedling mortality, shading, soil temperature.

877. Fraser, J.W. 1967. Algin, and petroleum mulches for seed spots. Canada, Dept. Forestry, Petawawa Forest Experiment Station, Chalk River, Info. Rept. PS-X-3. 13 pp.

Exposed seed spots were mulched with an algin mulch to investigate conflicting results about its effectiveness in improving germination. Seed spot temperature under algin mulch were as much as 30°F lower than on unmulched spots, but the mulch was ineffective in promoting germination. Seed spot temperatures under petroleum mulch were 10°F higher than unmulched spots. Germination failed.

K.W. algin, artificial regeneration, germination, mulching, petroleum, seeding, soil temperature, [Pinus sp.].

878. Fraser, J.W. 1968. Mulches and seed spot temperatures. Forestry Chronicle 44(6):64-65.

Reports results of testing two mulch types, algin and petroleum, on seed spot temperatures in an area scarified to mineral soil. Results are evaluated with respect to germination and survival.

K.W. artificial regeneration, germination, mulching, seeding, seedling survival.

879. Fraser, J.W. and A. Bickerstaff. 1962. Algin mulch for seed spots. Forestry Chronicle 38(4):448-449.

Tests to determine the feasibility of using an algin derivative as a mulch to improve seed spot microenvironments have been carried out. Tests indicated that the mulch aided in conserving soil moisture and reducing surface temperatures without having any chemical or physical inhibiting effect on germination and establishment. More extensive field trials are planned.

K.W. algin mulch, germination, mulching, seed spots, seeding, soil moisture, soil temperature, [Pinus resinosa].

880. Fraser, J.W. and A. Bickerstaff. 1963. More on algin mulch for seed spots. Canada, Dept. Forestry, Petawawa Forest Experiment Station, Mimeo 63-P-15.

Experimental plots 18" square were seeded with untreated red pine seed and treated in various combinations of the following treatments: mulching: a) no mulch, b) 2% Keltex-$CaCl_2$ (an algin mulch), c) 3% Keltex-$CaCl_2$; seedbed: a) unscarified, b) scarified; protection: a) screened, b) unscreened. A second experiment using the same treatments with the omission of the 2% mulch was carried out, when all seeds were dusted with red lead (Pb_3O_4) as added protection from birds and rodents. Results are varied, but it appears that germination on exposed seed spots was not improved by mulching with Keltex.

K.W. algin mulch, germination, mulching, scarification, seed spots, seed viability, seeding, [Pinus resinosa].

881. Gagnon, J.D. et M. Boudoux. 1968. Données nouvelles sur la fertilisation des plantations d'epinette blanche a Grand'mère, Quebec. Canada, Forestry Service, Forest Research Lab, Quebec, Info. Rept. Q-X-5. 18 pp.

Application of farmyard manure applied at time of plantation of white spruce has a beneficial effect for only a short time, probably no more than 5-10 years after application.

K.W. Picea glauca (white spruce), artificial regeneration, fertilization, manuring, planting, seedling growth.

882. Gagnon, J.D. et M. Boudoux. 1968. Effet retardé et limité de la furmure organique sur la croissance de l'epinette blanche à Grand-mère. Revue Bimestrielle de Recherches 24(5):42-43.

On sandy soil at Grand-mère white spruce plantations were fertilized with barnyard manure. It was found that fertilization with manure influenced growth only from 5-10 years after application. After 40 years, tree growth on all plots was essentially the same.

K.W. Picea glauca (white spruce), fertilization, manuring, planting, seedling growth, soil.

883. Goebel, C.J. 1965. Effect of herbicides on seedling development in an Iowa conifer plantation. Iowa State Journal of Science 40(3):303-313. (Abstr. F.A. 27:668).

Divron (2 lb/acre), 24-D, simazine or amiben (4 lb/acre) were applied before and/or after planting various species of spruce and pine. Simazine in granular form applied after planting, without any pre-planting treatment, was most suitable, though all treatments resulted in a significant increase in height growth of plants. Cultivation gave best control of weed growth, but cost more than chemical treatment.

K.W. Picea sp. (spruce), Pinus sp. (pine), cultivation, economics, herbicides, planting, seedling growth, weeding.

884. G.B. Forestry Commission. 1969. Indirect nutritional effects of herbicides. G.B. Forestry Commission, Forest Research Rept. 1968. p. 80.

N content of needles of various species on chemically and hand-weeded plots is tabulated. N contents on chemically weeded plots were consistently higher for all species in plots established in the open. In plots established in light shade, weed growth is less vigorous and the effect might be expected to be smaller. However, the impression of improved N content as a result of fairly complete weed control is clear.

K.W. artificial regeneration, foliar N, herbicides, planting, weed control.

885. Gregory, R.A. 1966. The effect of leaf litter upon establishment of white spruce beneath paper birch. Forestry Chronicle 42(3):251-255.

Evaluates the effect of leaf smothering upon establishment of white spruce in Alaska. Protection by a cloth screen significantly improved survival through the first four growing seasons, after which most seedlings were large enough to avoid being crushed or smothered by falling leaves.

K.W. Picea glauca (white spruce), Populus tremuloides (trembling aspen), regeneration, screening, seedling smothering, seedling survival.

886. Grover, R. 1968. Effect of chemical weed control on the growth patterns of conifer transplants. In: Weed Abstracts 17(2): No. 715.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

Competition to white spruce from annual weeds reduced height, fresh weight and stem diameter of 2-year-old transplants but not survival. Over a 2 year period, weed control averaging 60% was necessary for optimum growth of the two spruce species examined. Several treatments were used on experimental plots, all of which gave at least 70% control and none of which reduced growth of spruce.

K.W. Picea glauca (white spruce), herbicides, seedling growth, seedling survival, vegetation, weeds.

887. Heidmann, L.J. 1967. Herbicides for preparing ponderosa pine planting sites in the southwest. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note RM-83. 4 pp.

In tests of dalapon, its bisester, simazine, amitrole, amitrole-T, and ammonium thiocyanate in Arizona, all except the last effectively killed perennial grasses. Control was cheapest with dalapon. Residual toxicity of herbicides to seedlings needs study.

K.W. herbicides, seedling mortality, vegetation, weed control, [Pinus ponderosa].

888. Helmers, A.E. 1948. Early results from thinning seed spots. U.S. Dept. Agric., North Rocky Mountain Forest and Range Experiment Station, Res. Note 58. 5 pp.

Although number of seedlings per seed spot had little effect on height growth, it had a profound effect on diameter growth of various species, including Engelmann spruce, originating from direct seeding.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, seed spots, seeding, seedling growth, thinning.

889. Hoffmann, G. 1965. [Physiological studies on plants as a basis for determining the best times for tending in plantations.] Sozial. Forstw., Berlin 15(10):294-299. (Abstr. F.A. 27:447).

Discusses effect of shading and root competition by weeds and presents a preliminary E German timetable of preferred and permissible dates for mechanical weeding in spring for various species in order of timing based on prelimianry results of studies of seasonal growth of roots and shoots and on the assumption that weeding should precede or coincide with, the period of most active root growth.

K.W. Picea sp. (spruce), Pinus sp. (pine), planting, root competition, shading, vegetation, weed control.

890. Hoyer, B. 1971. [Chemical site preparation and plantation tending with Sys 67 Omnidel in the Schleiz State forest.] Sozial. Forstw. 21(7):212-214. (Abstr. F.A. 33:82).

Moist sites infested with Calamagrostis sp. in E. Thuringia were sprayed with dalapon in the winter half years 1968/1969 or 1969/1970. Control lasted 2-2 1/2 years. Damage to planted Picea abies was noted only under exceptional conditions.

K.W. Picea abies (Norway spruce), herbicides, planting, seedling survival, vegetation, weed control.

891. Hunt, L.O. 1963. Evaluation of various mulching materials used to improve plantation survival. Tree Planter's Notes 57:19-22.

Various mulches were tested with various planted species, including lodgepole pine. It was concluded that, in the conditions of the experiment, any opaque mulch material 2 ft. sq. that shades out grass and weeds, is effective in increasing initial survival. Cultivation alone was ineffective.

K.W. Pinus contorta (lodgepole pine), economics, planting, mulching, seedling survival, vegetation, [Abies grandis, Abies concolor].

892. Huss, E. 1969. [Combining fertilizers and weed-killers in spruce plantations.] Forstarchiv 40(6):107-114. (Abstr. F.A. 31:82).

Tests with 1+2 spruce on 4 sites heavily infested with various grosses and other weeds, and treated with chemical or mechanical weed control and/or fertilizing at 50g NPK per plant showed great variation in first year results. Chemical weed control increased average basal diameter by 26% on fertilized and unfertilized plots, but had no effect on height growth. Mechanical weeding had no effect on growth. Fertilizing increased diameter by 6% on weeded and unweeded plots, and height growth by 10%. Fertilization caused considerable losses.

K.W. Picea sp. (spruce), diameter growth, fertilization, height growth, herbicides, nitrogen, phosphorus, planting, potassium, seedling growth, seedling mortality, weed control.

893. Ivanova, Z.V. 1966. [Physiological and chemical basis for tending (weed control) in forest plantations.] Lesn. Hoz. 19(10):32-35. (Abstr. F.A. 28:464).

Soil and vegetation samples from clear felled plots planted with 2+0 Scots pine and hand weeded, treated with simazine at 5 kg/ha, or not treated, were analyzed. Absolute dry weight of weeds on untreated control and twice that on hand weeded plots.

K.W. Pinus sylvestris (Scots pine), herbicides, planting, soil, soil nutrients, weed control.

894. Iyer, J.G. 1964. Effect of craig mylone herbicide on the growth of white spruce seedlings. Tree Planters Notes 66:4-6.

Seedbeds of white spruce were treated with Craig mylone at 580 lbs/acre of 50-D and 350 lbs/acre of 85-W, about one month before seeding, leaving untreated beds to serve as controls. 3 years later, white spruce seedlings on untreated beds were much shorter and fairly uniform in height growth. The stock on treated beds had some seedlings exceeding 20 inches in height, but a much higher coefficient of variability.

K.W. Picea glauca (white spruce), drought, herbicides, mycorrhizae, seedling growth, vegetation competition, weed control.

895. Kokkonen, M. 1964. [Use of paper collars in the control of weeds in plantations.] Metsät, Åikak. 1964(4):164-166. (Abstr. F.A. 26:244).

Collars made from squares 20x20, 30x30 or 40x40 cm of various materials were tested for protection of planted seedlings. Fixing with weights or stakes was found necessary, and is best done in early spring. No weeds developed under collars. Light coloured collars might cause abnormal evaportation and consequent seedling damage on open sites. Observations after 1 summer show no increased seedling growth.

K.W. heat damage, paper collars, planting, seedling growth, seedling survival, vegetative competition.

896. Kramer, H. 1968. [The treatment and assessment of young spruce stands.] Allgemeine Forstzeitschrift 23(28):495-501. (Abstr. F.A. 30:71).

Presents data on various types of thinning in young planted spruce stands as well as a model for row thinning.

K.W. Picea sp. (spruce), diameter growth, height growth, planting, seedling growth, spacing, thinning.

897. Krauch, H. 1938. Does screening of seed spots do more than protect the spots against rodents and birds? U.S. Dept. Agric., Pacific Southwestern Forest and Range Experiment Station, Res. Note 49. 4 pp.

898. Lunt, H.A. 1946. Effect of fertilizer treatment on field planted spruce. Proc. Soil Sci. Amer. 10:406-409.

2-1 nursery stock of white and Norway spruce were planted and measured to determine the effect of, a) previous fertilization in the nursery and b) fertilization at time of field planting on subsequent growth and survival. Results indicate that there was no significant difference in survival and growth with the different time of application of the fertilizer. Norway spruce survived better than the white spruce, and of the three treatments on Norway spruce alone, testing types of fertilizer, the 7-10-3 fertilizer produced the highest percentage of green trees. In general, Norway spruce showed higher survival percentages and less response to treatment than white spruce.

K.W. Picea glauca (white spruce), Calcium, fertilization, fertilization date, magnesium, nitrogen, phosphorus, potassium, seedling growth, seedling survival.

899. MacArthur, J.D. 1957. The effects of manure on a white and Norway spruce plantation at Grand-mère, Quebec. Canada, Forestry Branch, Forest Research Division, Tech. Note 64. 15 pp.

A plantation of white and Norway spruce covering three acres was established in June, 1920, to test the effects of farmyard manure on growth. Manure was spread at the rate of 15 and 30 tons/acre, and ploughed in before planting. In white spruce, the mean annual increment to 1956 was about three times that of the control. Norway spruce increment was also increased threefold. Doubling the amount of manure did not increase growth in either white or Norway spruce. Norway spruce grew far more and was healthier than white spruce.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

K.W. Picea glauca (white spruce), fertilization, growth increment, manuring, seedling growth, seedling mortality, [Picea abies].

900. McFee, W.W. 1967. Ammonium and nitrate as nitrogen sources for Pinus radiata and Picea glauca. Dissert. Abstr. 28B(2):439.

Spruce seedlings grown in soil, water, or exchange resins showed greater growth response to NH_4-N than to NO_3-N, regardless of the pH of the medium. Increasing root zone temperatures in solution cultures increased growth and N-content of tops. In solution cultures, varying N concentrations had little effect on growth. Growth of spruce seedlings in sandy soil was inhibited by addition of $NaNO_3$ of 50 lb N/acre or NH_4Cl of 30 lb N/acre, probably because of high salt concentration in soil solution.

K.W. Picea glauca (white spruce), ammonium-N, fertilization, nitrogen, nitrate-N, seedling growth, soil, [Pinus radiata].

901. Miller, C.I. 1940. An economical seed spot protector. J. For. 38:733-734.

Describes construction of a cloth screen which, when placed over a seed spot, allows 80% of full sunlight to pass through.

K.W. screening, seed spots, seeding.

902. Mullin, R.E. 1972. Effects of cultivation after planting in establishment of white spruce plantations. Proc. VIIth World Forestry Congress, Pap. 29.

903. Mullin, R.E. 1973. Post-planting cultivation aids old field white spruce plantations. Tree Planters Notes 24(1):6-7.

Pre-planting cultivation, post-planting cultivation, addition of S and fertilizer and a combination of the previous two treatments, were applied to an old field planting of 3-0 white spruce. At the end of 5 years, post planting cultivation gave highly significantly better survival rates than all other treatments as well as greater height growth. White spruce did not benefit from fertilization.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, cultivation, fertilization, planting, seedling growth, seedling mortality, sulphur.

904. Muñoz, J.E. and L.W. Hill. 1967. The use of herbicides for site preparation and their effects on tree survival. U.S. Dept. Agric., Institute of Tropical Forestry, Res. Note ITF-12. 6 pp.

Herbicides can be used for site preparation on steep erodable land where minimum soil disturbance is desirable. Picloram is most effective.

K.W. herbicides, picloram, site treatment.

905. Olberg, R. 1969. [Control of mixed weeds in plantations: experience with Prefix, Gramoxone, and Regione.] Allgeimeine Forstzeitschrift 24(11):208-211. (Abstr. F.A. 30:658).

Discusses herbicide use on various soils in S.W. Germany, including timing, dosages, tolerance of forest plants, etc. Paraquat and diquat are the most useful herbicides.

K.W. herbicides, vegetation, weed control.

906. Pruett, E.W. and G.E. Gatherum. 1961. Control of herbaceous vegetation in forest planting. Proc. Iowa Acad. Sci. 68:153-161. (ABSTR.).

Various methods were tested for elimination of grass and weed competition on planting sites for various hardwood and softwood species. Seedling survival and height growth were greatest on plots cultivated when needed. Various herbicides used all proved inferior to cultivation and at least two types may have been toxic.

K.W. cultivation, herbicides, planting, seedling growth, seedling survival, vegetative competition, weed control.

907. Richards, N.A. 1970. Adverse effects from mulching spruce seedlings. Tree Planters Notes 21(1):11-12.

For relatively heat sensitive tree species, such as white spruce, excessive temperatures above light-coloured or reflective mulch surfaces can sometimes offset any benefits from improved environmental conditions under the mulch. This hazard is reduced by shading. In one experiment, 50% of 3-0 white spruce seedlings with a white fiberglass mulch succumbed, while mortality of unmulched control was 0%.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, insolation, mulching, planting, seedling mortality.

908. Roediger, K.J. 1969. [Two year trials on the effect of herbicides on the growth of plantations.] Forsttech. Inform., Mainz 1969 (2/3):13-16. (Abstr. F.A. 30:658).

Treatment with herbicides in two successive years was greatly superior to single applications. Fertilization did not always increase increment in chemically treated plots, but tended to have positive after - effects in the following year. Mechanically weeded plots grew less well than controls. Prefix gave the most consistent results, averaging 23% higher increment than controls over a 2-year period. Gramoxone also gave good results and a new 2, 4, 5-T salt was promising in summer applications.

K.W. fertilization, herbicides, seedling growth, vegetation, weed control.

909. Ronco, F. 1970. Shading and other factors affect survival of planted Engelmann spruce seedlings in central Rocky Mountains. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note RM-163. 7 pp.

Engelmann spruce seedlings survived best when healthy vigorous stock was shaded in the field, but shading in nursery or hardening beds before outplanting did not increase field survival. Stock from the nursery and hardening beds survived equally well if healthy seedlings were planted. After field planting, solarization caused most mortality; gopher and frost losses were high in some years.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, frost damage, hardening, planting, pre-planting treatment, seedling mortality, solarization, wildlife.

910. Roy, D.F. and G.H. Schubert. 1953. K-screen seed spots. U.S. Dept. Agric., California Forest and Range Experiment Station, Forest Res. Note 88. 2 pp.

Evaluates a "K-screen" as protection for seeds germinating in the field. Although light and convenient, and useful in protecting seed from rodents, screens are susceptible to damage by deer and livestock and hamper germination and seedling survival.

K.W. artificial regeneration, germination, screening, seed spots, seeding, wildlife.

911. Sieder, P. 1968. [Rationalizing weeding by chemical pretreatment of whole sites in upland zones.] Sozial. Forstw., Berlin 18(8):248-250, 256. (Abstr. F.A. 30:260).

Reviews recent East German literature on the use of dalapon. Experiments show that application is best in early spring because working conditions are easiest and control effects last longest, but some delay is necessary before planting. Subsequent invasion of forbs is not considered a serious problem.

K.W. application time, dalapon, herbicides, vegetation, weed control.

912. Sieder, P. 1970. [Tending of plantations in the winter half year.] Sozial. Forstw. 29(2):42-45, 63-64.

Shows the advantages of treatment with dalapon in late autumn or early spring and discusses methods of application.

K.W. application time, dalapon, herbicides, vegetation, weed control.

913. Skoklefald, S. 1970. [Experiments on seedbed improvement by the use of N fertilizers.] Tidsskr. Skogbr. 78(4):427-438. (Abstr. F.A. 132:720).

Urea or dicyandiamide was applied to spots sowed or allowed to regenerate naturally. At two locations, spot scarification gave better germination and seedling survival than spot fertilization. Dicyandiamide showed no positive effect on seedling establishment, and where applied at 200 kg N/dekare it increased seedling mortality and did not effectively reduce ground vegetation. Mortality of advance growth at one locality increased with increasing rates of urea above 30 kg N/decare and was highest when fertilization was applied to moist vegetation.

K.W. advance growth, dicyandiamide, nitrogen, scarification, seeding, seedling growth, seedling mortality, urea, vegetation, weed control.

914. Spencer, D.A. 1954. Rodents and direct seeding. J. For. 52(11): 824-826.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

Describes the problem of rodents and birds feeding on seeds distributed by direct seeding. Gives examples of two new rodenticides: thallium sulphate and sodium fluoroacetate. If properly used, these can give 95% control of rodents, but unfortunately, the effects are not long lasting enough. New seed treatments, repellants (non-lethal), have shown that seed-eating is reduced without depleting the resident rodent population so far as to allow other new individuals into the area. There are numerous hazards for use of repellants such as tetramine, and further study is in progress.

K.W. rodents, rodenticides, repellants, seeding.

915. Stephens, G.R. Jr. 1965. Accelerating early height growth of white spruce. J. For. 63(9):671-673.

Effects of nitrogen, soil temperature, and soil moisture were tested on the height growth of field planted white spruce seedlings. Soil temperature and moisture were regulated by mulching. Moist soil produced better growth than dry soil. Soil temperature had little effects on height growth and fertilization did not increase it appreciably. After 3 years, mortality of spruce seedlings in sod was 6 times that of seedlings where competition was eliminated.

K.W. Picea glauca (white spruce), artificial regeneration, fertilization, mulching, nitrogen, planting, seedling growth, seedling mortality, seedlings, soil moisture, soil temperature, vegetative competition.

916. Stiell, W.M. 1962. Pellet fertilizing white spruce at planting. Canada, Dept. Forestry, Petawawa Forest Experiment Station, Chalk River, Mimeo, Pet. 62-12. 16 pp.

Planted 2-2 white spruce seedlings were fertilized with a urea-formaldehyde pellet at the time of planting. No important differences between fertilized and unfertilized trees were found for survival, damage or height growth over the first two growing seasons.

K.W. Picea glauca (white spruce), artificial regeneration, fertilization, nitrogen, phosphorus, planting, seedling growth, seedling survival, survival, urea.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

917. Sutton, R.F. 1965. Stand improvement with white spruce planted with concurrent Dybar (Fenuron) herbicide treatment. Forestry Chronicle 41(1):108-111.

Attempts, conducted in Ontario, to determine whether treatment of shrub competition with non-selective Dybar could safely be carried out concurrently with planting of white spruce. Various application distances from the seedlings were investigated. Survival of white spruce was not affected significantly by any of the treatments. Consequently, it is thought that non-selective Dybar can be used at the time of planting to aid establishment of white spruce. Subsequent growth of spruce is largely dependent upon the density of the total live canopy.

K.W. Picea glauca (white spruce), artificial regeneration, herbicides, planting, vegetative competition.

918. Sutton, R.F. 1969. Chemical control of competition in plantations. Forestry Chronicle 45:252-256.

Function of weed control is to divert growth resources from weed into crop species. Two main types of competition will need controlling in plantations, a) gross and other non-woody weeds before canopy closure, and b) woody weeds. Woody weeds are usually controlled from the air, while non-woody weeds are usually controlled from the ground. Examples of appropriate chemicals and treatments are given.

K.W. ecology, herbicides, thinning, vegetative competition, weed control.

919. Sutton, R.F. 1972. Constraints on the growth of young white spruce. In: White spruce, the ecology of a northern resource. Canada, Forest Service, Northern Forest Research Centre, Alberta, Info. Rept. NOR-X-40. pp. 24-39.

Nitrogen fertilization, weed control, and irrigation were used in experimental plantings with two stocks on three different soils to illustrate restraints on growth of young white spruce. Response of all plantings to irrigation was meagre. Fertilization generally produced minor depressive effects on all stocks and soil types. Competing vegetation reacted more vigorously than did the trees themselves. Weed control had a definite positive effect on growth increment on both stocks. Fertilization and weed control were found to interact.

K.W. Picea glauca (white spruce), artificial regeneration, fertilization, growth increment, irrigation, nitrogen, planting, seedlings, vegetative competition, weed control.

920. Swan, H.S.D. 1962. The mineral nutrition of the Grand-mère plantations. Pulp and Paper Research Institute of Canada, Woodlands Research Index 131. 14 pp.

Gives description of plantations and brief resumé of previous experiments dealing with mineral nutrition. Results from the current experiment, investigating the nutrient status of trees in 5 vigor classes, indicates that potassium and nitrogen deficiencies are growth limiting, and other elements may also be limiting factors if in insufficient amounts.

K.W. growth, mineral nutrition, nitrogen, nutrient deficiency, potassium.

921. Swan, H.S.D. 1962. The scientific use of fertilizers. In: Fonds de Rechérches Forestiéres de l'Université Laval, Bull. 5. pp. 13-24.

Outlines process of diagnosing and correcting deficiencies of soils in forest plantations. Outlines various experiments being conducted in greenhouse studies concerning white spruce, black spruce, jack pine and western hemlock and the elements nitrogen, phosphorus, potassium and magnesium. Results and illustrations are included for most experiments. Results of field experiments with white spruce are also given. Economically, forest fertilization is concluded to be a sound technique.

K.W. Picea glauca (white spruce), economics, fertilization, magnesium, nitrogen, phosphorus, potassium, seedling growth, seedling mortality, seedling vigour.

922. Swan, H.S.D. 1969. Fertilizers, their role in reforestation. Pulp and Paper Research Institute of Canada, Woodlands Paper 9. 12 pp.

A review of literature on the use of fertilizers in seed orchards, forest nurseries, young plantations and semi-mature stands. Warns against uncritical adoption of hypothesis that only N need be applied and against the use of aircraft for fertilizer application in research studies.

K.W. artificial regeneration, fertilization, nitrogen, regeneration.

923. Tamm, C.O. 1968. [The effect of urea and calcium ammonium nitrate on spruce plantations.] Skogen 55(1):21. (Abstr. F.A. 29:456).

Results of fertilizer application in 1963 in a stand established in 1955, after clear felling and burning, showed a greater response in plants treated with calcium ammonium nitrate. The poor response to urea is attributed to the effect of the burning, which caused a reduction in soil organisms capable of decomposing urea. Poor growth of spruce after planting is also attributed to the effect of burning on soil biota.

K.W. Picea sp. (spruce), burning, fertilization, nitrate-N, nitrogen, planting, seedling growth, urea.

924. U.S. Dept. Agric. 1959. Artificial regeneration tried in beetle-killed spruce stands. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept. 1958. pp. 47-53.

Reports a series of experiments in the White River Plateau. Lodgepole pine mortality after 1 year was 24% - that of Engelmann spruce was 41%. Watering had no apparent influence on survival of lodgepole pine - 90% of watered and 87% of unwatered survived at the end of the second summer. Survival of spruce was significantly increased by watering. Shading with shingles throughout the summer improved overwinter survival of spring planted Engelmann spruce. Lodgepole pine survival was also increased by shading and/or mulching. Above average planting stock of spruce and pine survived better than below average grades when planted immediately after lifting. No significant difference in any species was found to be associated with 6 different lifting dates when planting was done immediately after lifting. Stored seedlings varied in survival performance with lifting date, species, and planting attitude.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), artificial regeneration, insolation, lifting date, mulching, planting, planting stock, seedbed, seeding, seedling grading, seedling storage, shading, soil moisture.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

925. U.S. Dept. Agric. 1961. Seed spotting holds little promise for reproduction beatle-killed stands. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept., 1960. p. 21.

Spruce seedings have been a uniform failure. Lodgepole pine seed spotting has resulted in a 3 year survival rate of 3-13%. However, 44.5% of shaded and sawdust mulched seed spots were still stocked.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), artificial regeneration, mulching, seed spots, seeding, seedling survival, shading.

926. U.S. Dept. Agric. 1964. Planted ponderosa pines survive best on herbicide-treated plots. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept. 1963. p. 22.

Survival after one year of planted ponderosa pine was better than on scalped plots with dalapon, simazine or amitrol T and worse with amitrol or NH_4 thiocyanate. All treatments were better than controls.

K.W. Pinus ponderosa (ponderosa pine), herbicides, planting, seedling survival, weeding.

927. Van Elk, B.C.M. and H. Detz. 1965. [Application of top dressings to Picea abies transplants.] Jaarb. Proefsta. Boomkwek. Boskoop 1964. pp. 77-78. (Abstr. F.A. 27:442).

Fertilizer was applied before planting with 2+0 plants and a top dressing of 3 ½ kg of NPK was applied in the fall. Flushing in the next year was earlier than in controls (with some dangerof frost damage), height growth was greater, and foliage was a darker green.

K.W. Picea abies (Norway spruce), fertilization, flushing, nitrogen, phosphorus, planting, potassium, seedling growth.

928. Viro, P.J. 1966. Manuring of young plantations. Commun. Inst. For. Fenn. 61(4):30 pp. (Abstr. F.A. 27:665).

Fertilizers were applied to spruce (2+2) and pine (1+1) transplants, either at time of planting or 2-3 years later, and also to young natural reproduction. Various fertilizer application methods were tried. The seedlings tolerated only small amounts of easily soluble N and K; they withstood P better and Ca well. When fertilizers were mixed with the soil of the planting hole, seedling mortality even with small dosages was often very high and growth response negligible. Fertilizers spread on surface did not kill seedlings so easily, but even then growth response was small. As a result of research, no subsurface application of fertilizers is recommended for morainic soils in Finland.

K.W. Picea sp. (spruce), Pinus sp. (pine), calcium, fertilization, nitrogen, phosphorus, planting, potassium, seedling growth, seedling mortality.

929. Viro, P.J. 1967. [Forest manuring on mineral soils in Finland.] Medd. Norske Skogforsøksv. 23(85):111-36. (Abstr. F.A. 29: 456).

N increases volume increment of young spruce and pine by highly significant amounts of generally increases height increment significantly on all but the most fertile sites, whereas P, K, and Ca have little effect. Fertilizer treatment of seedling stands is of doubtful economic value.

K.W. Picea sp. (spruce), Pinus sp. (pine), calcium, economics, fertilization, nitrogen, phosphorus, planting, potassium, seedling growth.

930. White, D.P. 1960. Effect of fertilization and weed control on the establishment, survival and early growth of spruce plantations. Trans. 7th International Congress of Soil Science 3:355-362.

931. White, D.P. 1965. Survival, growth and nutrient uptake by spruce and pine seedlings as affected by slow release fertilizer materials. In: Forest Soil Relationships in North America. Oregon State Univ. Press, Corvallis, Ore. pp. 47-63.

In results in the field, fertilizers (except those applied in perforated plastic sacks) decreased survival, most loss occurring in the first two weeks after planting. Mortality was lower for seedlings planted out in paper maché pots with or without perforated sacks. White spruce showed significant growth increases in the second year as a result of several treatments. In a sandy soil, fertilization caused no increased mortality of white spruce when a 2-inch barrier was placed between fertilizer and roots. Results are tabulated.

K.W. Picea glauca (white spruce), containers, fertilization, nitrogen, phosphorus, planting, potassium, seedling growth, seedling mortality, soil.

iii) INFLUENCES OF FERTILIZERS, HERBICIDES AND POST-PLANTING CULTIVATION, cont'd.

932. Zechentmayer, R.D. 1971. Plastic baskets in seedspot protection. Tree Planter's Notes 22(3):4.

Plastic baskets can be used instead of wire cages for protecting seed spots. These baskets are lighter and cheaper, reducing cost of protection per seed spot by 81%. They also break up after about a year. Their chief problem is the difficulty of anchoring them firmly to the soil.

K.W. economics, seeding, screening.

(iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES

Papers in this section report the effect of timber harvesting, slash disposal and site preparation methods. These procedures modify natural site factors in both favourable and unfavourable ways and thereby influence the methods and success of artificial regeneration.

933. Armit, D. 1968. E.P. 635 - Direct seeding on scarified clear cut strips, Taltapin Lake. B.C. Forest Research Review. pp. 61-63.

Spot seeding of Douglas fir, white spruce, and lodgepole pine was carried out on scarified cutover lodgepole pine-white spruce area near Burns Lake. 31% of seed spots (3ft. square - 15 ft. apart) were on mineral soil, 20% on mixed organic matter and mineral soil, 12% on disturbed organic matter, 12% on disturbed forest floor and 25% on undisturbed forest floor. Two years after establishment natural regeneration was non-existent. Results indicated that direct seeding is only economically feasible where forest floor is disturbed with exposure of mineral soil, and/or organic matter. Douglas fir survival was highest. Pine height growth was greatest. Also reported, 1966 - pp. 57-58.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, height growth, scarification, seed spots, seedbed, seeding, site preparation, seedling mortality, soil.

934. Arnott, J.T., J.D. MacArthur and A. Demers. 1971. Seeding of five conifers on prepared seed spots in Quebec. Pulp and Paper Magazine of Canada 72(7):90, 92-93.

Spot seeding of 5 coniferous species, including white spruce on 5 types of prepared seedbeds was carried out over a 3 year period in Quebec. Five years after seeding, results indicate that site preparation is essential. Species establishment was dependent on the type of seedbed preparation, growth of seedlings was not.

K.W. Picea glauca (white spruce), artificial regeneration, furrowing, germination, scarification, seed spots, seedbed, seeding, seedling survival.

935. Barring, V. 1964. [The effect of scalping, and some other problems when planting Norway spruce and Scots pine.] Studia Forestalia Suecica, No. 25. 80 pp. (Abstr. F.A. 27:57).

Scalping improved survival, particularly on unburned ground, and slightly increased height growth in both spruce and pine. Degree of scalping (removing vegetation only or humus as well) had only a slight effect, and spot size affected only height growth. The influence of planting methods is small.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), height growth, planting, planting method, scalping, seedling survival.

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

936. Bjørgung, E. 1957. [Experiments on sowing and scarifying in Evenstad State Forest.] Medd. Norske Skogforsoksvesen 15(1):(No. 49):105-119. (Abstr. F.A. 19:363).

Various means of site preparation were carried out; 1) removing humus and breaking up mineral soil to 15 cm; 2) removing humus but leaving mineral soil undisturbed; 3) removing vegetation and mixing humus and soil; and 4) no treatment. Some plots were sown and others left to natural regeneration. For both spruce and pine the first treatment was the best. The second was significantly poorer than the first for spruce, but as good as the first for pine. The third treatment was significantly less effective than any other treatment but the control for both species. Both species responded better when seeds were covered with soil. Results of natural seeding were poor.

K.W. Picea sp. (spruce), Pinus sp. (pine), germination, humus, regeneration, scarification, seedbed, seeding, seedling survival, site treatment.

937. Branovickij, M.L. 1959. [Artificial regeneration trials on areas cleared by concentrated fellings.] Lesn. Ž., Arhangenl'sk 2(1):65-71. (Abstr. F.A. 21:580).

Direct sowing and planting gave satisfactory results for both spruce and pine in clear cuts. Aerial seeding, however, is only effective on recently felled areas, where the soil has been uniformly disturbed or scarified. Even here, birch and/or aspen may later invade the site and impair results.

K.W. Picea sp. (spruce), Pinus sp. (pine), artificial regeneration, burning, clear felling, invasion, planting, scarification, seedbed, seeding, vegetation.

938. Cayford, J.H. 1961. Furrowing improves first year survival of planted spruce and pine in Manitoba. Tree Planters Notes 48:13-14.

Furrowing before planting in Manitoba increased first year survival of planted white spruce, black spruce and jack pine by a great deal, especially for spruce. The benefit was especially seen on ridge planting sites. Furrowing probably increases the amount of soil moisture available to transplants.

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, furrowing, planting, seedling survival, site preparation, soil moisture, [Picea mariana, Pinus banksiana].

939. Cayford, J.H. 1961. Planting spruce and pine, Interlake Area, Manitoba. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Misc. Rept. 2. 13 pp.

Progress report of the planting experiment begun in 1957. Describes the work undertaken in 1961. Reports the survival of various plantings and reasons for mortality.

K.W. Picea sp. (spruce), Pinus sp. (pine), planting, seedling survival.

940. Cayford, J.H. 1963. Planting spruce and pine, Interlake Area, Manitoba. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 63-MS-6. 14 pp.

Progress report of a planting experiment begun in 1957. Four species including white spruce were planted in various sites differentiated by soil moisture. Report tabulates growth and survival data to 1962. The influence of ground preparation was found to increase survival of all planted species.

K.W. Picea glauca (white spruce), artificial regeneration, cultivation, planting, seedling growth, seedling survival, site preparation, soil moisture, [Pinus sp.].

941. Cayford, J.H. 1964. Planting spruce and pine, Interlake Area, Manitoba. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 64-MS-21. 15 pp.

A progress report on a study carried out since 1958 on planting four species, including Picea glauca. Survival percentages are tabulated for 1960 and 1962 planting, both made on prepared furrows. There was no correlation between site and survival of black spruce or white spruce.

K.W. Picea glauca (white spruce), artificial regeneration, furrowing, growth increment, planting, seedbed, seedling survival, [Picea mariana].

942. Cayford, J.H. 1965. Planting spruce and pine, Interlake Area, Manitoba. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 65-MS-20. 24 pp.

Describes work undertaken in 1964, presents the results of the 1964 survival counts for the 1959, 1961, and 1963 plantations, and outlines work plans for 1965. Also presents a site classification for the experimental area. For the 1959 plantation, white spruce seedling survival on furrowed areas was greater than that on unfurrowed areas, as was height growth. Survival of white spruce from the 1961 plantation is very poor.

K.W. Picea glauca (white spruce), artificial regeneration, furrowing, planting, scarification, seedling survival, [Picea sp., Pinus sp.].

943. Duffy, P.J.B. and Z. Nemeth. 1967. Plantations of white spruce under aspen on different soils, Mixedwood Section, Alberta. The Athabaska Plantations - Establishment Report, 1966. Canada, Forestry Branch, Forest Research Lab, Calgary, Internal Rept. A-7. 20 pp.

Describes scarification and planting of white spruce seedlings under an aspen/balsam poplar stand in Alberta. No results are given.

K.W. Picea glauca (white spruce), artificial regeneration, planting, scarification, [Populus spp.].

944. Gagnon, J.D. 1969. Soil improvement trials using scarification and fertilization in stagnant white spruce plantations, Quebec, Canada. Plant and Soil 30(1):23-33.

A clear cut area was scarified and partly fertilized with 100 lbs/acre NPK and 10 lbs/acre of compost in 1958. Fertilization was repeated on part of the area in 1962. In 1959, 2-2 white spruce were planted on scarified and fertilized ground and on adjacent untreated ground. Scarification had, after 3 years, considerably increased height growth of white spruce. Fertilization had no appreciable influence.

K.W. Picea glauca (white spruce), artificial regeneration, bacteria, composting, fertilization, nitrogen, phosphorus, planting, potassium, scarification, seedling growth.

945. Gantimurov, I.I. and D.D. Osin. 1941. [The influence of cultivating the soil in forest plantations upon its properties in relation to forest growth.] Trud. vesesoyriz. nauchno-issledov. Inst. Lesnogo Khozyaystvo. 24:129-159. (Abstr. F.A. 7:457).

Evaluates four types of cultivators with respect to their effect on seedbed form and fertility and resultant weed growth. Most effective was a spiral cultivator which resulted in good soil texture, improved nitrification, and little weed growth.

K.W. artificial regeneration, site preparation, soil fertility, soil texture, weed growth.

946. Gayle, W.B. and W.W. Gilgan. 1951. The effect of slash burning on germination and primary survival of lodgepole pine and Douglas fir. U.B.C. Forestry Club, Res. Note 2. 3 pp.

Seed was sown in flats in soil taken from a Douglas fir stand and treated in various ways. Lowest and slowest germination occurred in burned, unleached soil. Moderately burned, leached soil gave highest germination for both species tested.

K.W. Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, burning, germination, seeding, seedling survival, soil, soil pH.

947. Haig, R.A. 1959. Result of an experimental seeding in 1920 of white spruce and jack pine in western Manitoba. Forestry Chronicle 35:5-12.

In 1920, varying amounts of white spruce and jack pine seed were sown on a series of small plots located on a well prepared seedbed of mineral soil. In 1957, the spruce plots supported a dense and thrifty stand.

K.W. Picea glauca (white spruce), artificial regeneration, seedbed, seeding, seedling growth, seedling survival, [Pinus banksiana].

948. Haig, R.A. 1969. Operational trials of site preparation and planting methods in the Goulais River area, Ontario. Canada, Forestry Service, Forest Research Lab, Sault Ste. Marie, Info. Rept. O-X-111. 23 pp.

Survival of planted stock was tested in cutover spruce-fir forests after several methods of site preparation. V-bladed bulldozer followed by machine planting was most efficient as judged by survival and cost, followed in order by angle dozer blade with hand planting, N-blade with hand planting and shark-fin drums and hand planting. In all cases survival was high.

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting method, scarification, scarification type, site preparation.

949. Hennessey, G.R. 1966. Converting aspen stands to white spruce by planting and seeding on scalped strips, Manitoba. Canada, Forestry Branch, Forest Research Lab, Manitoba, Internal Rept. MS-39. 30 pp.

Tests hypothesis that aspen stands can be converted to mixed coniferous-deciduous stands by planting or seeding Picea glauca on scalped strips. Results are tabulated for all regeneration areas.

K.W. Picea glauca (white spruce), artificial regeneration, herbicides, planting, scalping, seeding, [Populus tremuloides].

950. Hennessey, G.R. 1968. Early survival and growth of planted and seedbed white spruce as affected by seedbed types occurring on scalped strips prepared in aspen stands, Manitoba. Canada, Forestry Branch, Forest Research Lab, Manitoba, Internal Rept. MS-70. 56 pp.

Effects of three seedbed types - mineral soil, mixed mineral soil and humus and humus occurring on scalped strips in aspen stands, on early survival and growth of seeded and planted white spruce. Methods are given and results tabluated, including germination and seedling mortality on different soil types.

K.W. Picea glauca (white spruce), artificial regeneration, frost heaving, herbicides, planting, scalping, seedbed, seeding, seedling mortality, soil, [Populus tremuloides].

951. Holt, L., H.S.D. Swan and G.F. Weetman. 1956. Forest soil scarification. Pulp and Paper Research Institute of Canada, Woodlands Research Index 98. 47 pp.

Various different methods of forest soil scarification were carried out on burned and unburned cutovers and under an even aged mixedwood, all in Ontario. Qualities of seedbeds were assessed by sowing with seed of white and black spruce. Conclusions reached were: scarification is very beneficial for seed germination but does not ensure seedling survival; all machines tested were faster and less expensive than manual scarification; and the Imset scarifier, described in the article operated fastests, cost least, and gave best results.

K.W. Picea glauca (white spruce), economics, germination, scarification, scarification methods, seedbed, seedling survival.

952. Homoky, S.G.J. 1972. E.P. 636 - Lodgepole pine stock planting trial. B.C. Forest Research Review. pp. 18-19.

Three provenances and two ages (1+1, 2+0) of lodgepole pine planting stock were planted on screefed and unscreefed spots at 2400-3300 ft. in the Prince Rupert District. 1+1 transplants of both provenances had greater survival and height growth than 2+0 stock. Height and height increment after 5 years were significantly greater on screefed spots. Also reported, 1968 - pp. 71-73, 1969 - pp. 80-81, 1970 - pp. 72-73. Author 1968-1969, D. Armit, 1970, D. Gillespie.

K.W. Pinus contorta (lodgepole pine), artificial regeneration, height growth, planting, provenance, screefing, seedbed, seedling growth, seedling survival.

953. Horton, K.W. 1963. Experimental seeding of conifers in scarified strips. Canada, Dept. Forestry, Forest Research Lab, Sault Ste. Marie, Mimeo 63-0-4. 16 pp.

Spruce stocking after three seeding treatments; direct seeding in spots and lightly covering the seed, surface broadcasting, and broadcasting and raking, on scarified strips, was unacceptable. Mortality was high with all techniques. Unprepared natural seedbeds broadcast with seed produced unsatisfactory stocking for all species. Freshly scarified seedbeds are somewhat more effective in producing regeneration than one-year-old seedbeds.

K.W. Picea glauca (white spruce), artificial regeneration, scarification, seeding, seeding method, seedling survival.

954. Horton, K.W. and B.S.P. Wang. 1965. Experimental seeding of conifers in scarified strips. Canada, Dept. Forestry, Forest Research Lab, Sault Ste. Marie, Mimeo 65-0-12. 15 pp.

Direct seeding experiment in scrub aspen on sandy soil shows that site preparation is essential for successful regeneration. Strip scalping by bulldozer was found to be most effective. Sowing techniques which vary seed are preferable to surface broadcasting or raking of seed.

K.W. Picea glauca (white spruce), artificial regeneration, germination, scarification, seeding, seedling survival, site preparation, [Picea mariana, Pinus banksiana].

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

955. Horton, K.W. and B.S.P. Wang. 1969. Experimental seeding of conifers in scarified strips. Forestry Chronicle 45(1):22-29.

Study aimed at finding an efficient method of restocking cutover burned sites by direct ground seeding in Ontario. Four years of experiments showed site preparation to be essential for success. Recommendations are given concerning preparation and planting techniques found to be most useful. White spruce germinated more poorly than did jack pine.

K.W. Picea glauca (white spruce), artificial regeneration, scarification, seedbed, seeding, seeding date, site treatment, [Pinus banksiana].

956. Huss, E. and M. Sinko. 1969. [The effect of controlled burning of planting sites.] Sveriges SkogsvFörb. Tidskr. 67(4): 385-424. (Abstr. F.A. 30:644).

The effect of burning on fresh sites in Sweden on the mean height of pine and spruce after 5 and 10 years was strongly correlated with the time lag between burning and sowing and with site quality. The effectiveness of burning decreased with increasing time between burning and sowing, from maximum effect for sowing in the same season to little or no effect for sowing 5 years after burning. For the poorest sites mean 10 year heights were less than on unburned controls no matter what the time lag. Burning increased survival rates for pine sown in the same season and spruce sown 0-2 years after burning.

K.W. Picea sp. (spruce), Pinus sp. (pine), burning, seeding, seeding date, seedling growth, seedling survival, site type.

957. Jarvis, J.M. 1962. The effect of scalping and cultivating treatments (prior to planting) on the survival and growth of white spruce transplants, mesic clay loams, Riding Mountain Forest Experimental area. Canada, Dept. Forestry, Forest Research Division, Mimeo Man.-Sask. 62-19. 8 pp.

Outlines the purpose of the experiment and contains a brief review of pertinent literature.

K.W. Picea glauca (white spruce), cultivation, scalping, seedbed, seedling growth, seedling survival, soil.

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

958. Jarvis, J.M. 1963. Regenerating cutover X_2B and V_2 sites to white and black spruce by planting and seeding scalped strips, Manitoba Paper Company Limits. Canada, Dept. Forestry, Forest Research Lab, Manitoba Mimeo 63-MS-23. 7 pp.

Project plan for experiment later carried out to ensure adequate regeneration of white or black spruce stands on cutover areas. Poor regeneration at the time of writing is blamed on poor seedbed conditions and a deficiency of seed.

K.W. Picea glauca (white spruce), artificial regeneration, planting, regeneration, scarification, seedbed, shelterwood cutting, [Picea mariana, Populus sp.].

959. Jarvis, J.M. 1966. Seeding white spruce, black spruce, and jack pine on burned seedbeds in Manitoba. Canada, Dept. Forestry, Publ. 1116. 8 pp.

Germination on seedbeds created by fire was higher for jack pine than for either white spruce or black spruce. Seedbed type had no effect on germination, but did influence stocking after two growing seasons. In general, stocking was highest on mineral soil, intermediate on humus, and lowest on partly decomposed duff.

K.W. Picea glauca (white spruce), artificial regeneration, germination, seedbed, seeding, seedling survival, slash burning, stocking, [Picea mariana, Picea banksiana].

960. Kill, A.D. 1971. Prescribed fire effects in subalpine spruce-fir slash. Canada, Forest Service, Northern Forest Research Centre, Alberta, Info. Rept. NOR-X-3. 30 pp.

Evaluates slash burning in clear cut spruce-alpine fir as a method of reducing fire hazards, increasing planting crew efficiency, and reversing site deterioration trends. Fire hazard was greatly reduced, but it is estimated that, under moisture conditions tested no more than 20% of the duff layer will be removed by burning. Recommendations for burning times and methods are given.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), artificial regeneration, duff, economics, planting, prescribed burning, seedbed, slash, slash burning.

961. Kolehmainen, V.A. 1958. [Sowing on the snow crust.] Skogen 45(18): 537-538, 541. (Abstr. F.A. 20:223).

Broadcast sowing of pine and spruce on snowcrust was carried out in Sweden. On burnt over areas <5 ha. in extent, 1.5 kg spruce or pine seed per ha. is needed and on larger areas 2 kg/ha., but less seed can be used if soil surface is loosened. Spruce should be sown 1-2 years after burning to allow germination of birch which will give protection from frost. Plant distribution is generally even.

K.W. Picea sp. (spruce), Pinus sp. (pine), artificial regeneration, burning, germination, seedbed, seeding.

962. Lees, J.C. 1963. The relative effectiveness of various equipment for scarification in spruce-aspen stands. Canada, Dept. Forestry, Forest Research Lab, Calgary, Mimeo 63-A-6. 4 pp.

Variously scarified seedbeds were sown with white spruce seeds. Germination and survival were tallied after one year. Both tractor and toothed blade and Seaman tiller show excellent results and will be further investigated. Highest survival after one year was 83.5% with Seaman tiller.

K.W. Picea glauca (white spruce), artificial regenertation, germination, scarification, scarification method, seedbed, seedling survival.

963. Lindman, B. and S. Nordström. 1965. [Planting in fresh slash.] Skogen 52(4):68-69, 71. (Abstr. F.A. 26:559).

Comparisons were made of two pairs of plots planted with 2+2 spruce; immediately after felling in slash; and 1 and 3 years after felling. Two years after planting, those seedlings planted in slash had higher survival, greater mean height and greater leader length than those planted on area felled 3 years previously. Similar results were found 8-9 years after planting in a comparison of slash planted and 1 year old clear cut planted seedlings. Both delayed plantings needed weeding. Danger of infestation of seedlings from old slash can be minimized.

K.W. Picea sp. (spruce), clear felling, fungus, infestation, planting, seedling growth, seedling survival, site preparation, slash.

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

964. Logan, K.T. 1951. Development of one-year-old Norway spruce and white spruce planted beneath a girdled mixedwood stand. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 53. 2 pp.

One-year-old Norway spruce and white spruce seedlings were planted beneath a girdled mixedwood stand on a good site at Petawawa Experiment Station. Spacing of the seedlings was 1.5'x10'. Thirteen years after planting, about 40% of the seedlings were still alive despite intense vegetative competition. It is felt that the planted trees will eventually surpass the extensive natural reproduction present on the site.

K.W. Picea glauca (white spruce), artificial regeneration, planting, regeneration, seedling growth, seedling survival, vegetative competition, [Populus sp., Picea abies].

965. Logvinenko, N.I. 1971. Trial in growing Norway spruce plantations without any soil preparation on felled areas where no sward has formed.] Lesn. Ž. 14(2):10-12. (Abstr. F.A. 33:283).

Survival and height and diameter growth for the first 8 years were greater where 3 year old seedlings were planted without any soil preparation than in stands planted on hand-dug patches or on ploughed strips.

K.W. Picea abies (Norway spruce), cultivation, logging, planting, seedling growth, seedling survival, site pareparation.

966. Lotan, J.E. 1964. Initial germination and survival of lodgepole pine on prepared seedbeds. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Res. Note INT-29. 8 pp.

Nine methods of seedbed preparation were tested in Montana and Idaho to determine which method provided best conditions for germination and survival of lodgepole pine. Thorough preparation of seedbed, directed towards conserving soil moisture, considerably improved both germination and survival.

K.W. Pinus contorta (lodgepole pine), cultivation, germination, herbicides, scarification, seed dissemination, seedling survival, site preparation, slash burning.

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

967. Lotan, J.E. and A.K. Dahlgreen. 1971. Hand preparation of seedbeds improves spot seeding of lodgepole pine in Wyoming. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Res. Note INT-148. 6 p.

Hand prepared, 12 inch square seed spots greatly reduced the amount of seed required to spot seed lodgepole pine on slopes less than 45% in the Abies lasiocarpa/Vaccinium scoparium habitat type in Wyoming. Percentage of spots stocked after 3 years were: 72% for scalped 12 in. sq. on level, 64% for scalped 12 in. sq. on the slope, 38% for scalped 5 in. sq. on the slope, and 10% for ash-duff seedbeds.

K.W. Pinus contorta (lodgepole pine), artificial regeneration, germination, scalping, seedbed, seeding, seeding survival, soil.

968. McLeod, J.W. 1953. Direct seeding of white spruce on a controlled burn in southern New Brunswick. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 97. 3 pp.

White spruce seed was sown on a clear cut and burned spruce-fir forest, and covered with either sawdust or a screen. Either covering improves success of direct seeding with white spruce. Sawdust is preferable since it is much less expensive.

K.W. Picea glauca (white spruce), artificial regeneration, clear felling, economics, germination, mulching, prescribed burning, seedbed covering, seeding, seedling survival.

969. McLeod, J.W. 1961. Planting white spruce on haul roads in Northwestern New Brunswick. Canada, Dept. Forestry, Forest Research Branch, Mimeo 61-20. 4 pp.

Plantations of various ages and provenances of white spruce on logging roads in New Brunswick were carried out. Three to seven years after planting, all plantations had satisfactory survival except where subject to strong competition. Survival was better on bulldozed roads than on strip roads but growth was poorer due to areas of exposed sub-soil.

K.W. Picea glauca (white spruce), artificial regeneration, logging, logging roads, planting, planting date, seedbed, seedlings, soil, vegetative competition.

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

970. McLeod, J.W. 1964. Planting white spruce on wet brushy land. Canada, Dept. Forestry, Forest Research Branch, Publ. 1067. 4 pp.

Describes experiment in New Brunswick which tests a method of planting wet brushy land with white spruce by creating zig-zag ridges with a caterpillar tractor and planting the following spring with 2+2 white spruce. Ten years later, the results showed a much higher survival rate and better height growth on plots prepared by the tractor.

K.W. Picea glauca (white spruce), artificial regeneration, cultivation, planting, seedling growth, seedling survival, site treatment.

971. Marcois, L. and J.M. Veilleux. 1966. Estimates of changes in the properties of humus and their influence on regeneration after controlled burning. Report of the sub-committee on slash disposal and prescribed burns for the year 1965. National Research Council, Jan. 1966, Appendix 4:7-12. (ABSTR.).

Black spruce plantations grew far better and had less mortality than did a naturally regenerated population of the same age on burned over ground.

K.W. Picea mariana (black spruce), artificial regeneration, burning, humus, planting, regeneration, seedling growth, seedling mortality.

972. Mesheckok, B. 1964. [Planting on plough ridges on [drained] wet peatland reduces frost damage to planted trees.] Norsk Skogbruk 10(2):50-53. (Abstr. F.A. 25:395).

Spruce planted on plough ridges was less heavily damaged than that planted on unploughed strips. Measurements showed that ploughed land absorbed more warmth during the day than land with ground vegetation intact.

K.W. Picea sp. (spruce), frost damage, planting, ploughing.

973. Prochnau, A.E. 1961. Direct seeding of white spruce, alpine fir, Douglas fir, and lodgepole pine in the central interior of British Columbia. M.Sc.F. Thesis, University of Washington.

See A.E. Prochnau 1963. B.C.F.S. Res. Note 37.

974. Prochnau, A.E. 1963. Direct seeding experiments with white spruce, alpine fir, Douglas fir and lodgepole pine in the central interior of British Columbia. B.C. Forest Service, Res. Note 37.

Various factors affecting germination and early survival and growth of several species at Aleza Lake, Prince George were studied. Conclusions were: 1) preparation of mineral soil seedbeds is essential to good establishment of all species under conditions tested; 2) mineral seedbed was best for seedling survival, mixed seedbed best for height growth of seedlings; 3) hand prepared seed spots should be at least 12"x12" in size; 4) logged area was best for spruce and alpine fir, burned area for Douglas fir and lodgepole pine; 5) only alpine fir showed promise as a species for use on mounds of swampy equisetum-sphagnum type; 6) rainfall in spring and early summer of the first growing season had a strong influence on regeneration.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, climate, planting, scarification, seedbed, seeding, seedling growth, seedling survival, soil, vegetation.

975. Prochnau, A.E. 1963. E.P. 387 - Factors affecting the reproduction of conifers in the spruce-alpine fir type. B.C. Forest Research Review. pp. 38-39.

Compares reproduction after direct seeding of spruce, alpine fir, lodgepole pine and Douglas fir in the spruce-alpine fir type under virgin stand, 12 in. diameter limit cutting and clear cut slash-burned stands. Seed treatment and seedbed disturbance were also tested. Conclusions were: 1) preparation of mineral soil seedbeds is essential to good establishment of all species; 2) a mineral seedbed is best for survival, a mixed seedbed is best for height growth; 3) seed spots should be at least 12" x 12"; 4) logged areas presented best conditions for the regeneration of spruce and alpine fir, and burned areas for Douglas fir and lodgepole pine; 5) rainfall in the early spring and summer has a strong influence on regeneration; 6) best time for seeding spruce and Douglas fir is May 1 - June 1. Also reported 1956 - p. 14, 1957 - p. 15, 1958 - pp. 13-14.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, clear felling, diameter limit cutting, precipitation, scarification, seedbed, seeding, seedling survival, slash burning.

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

976. Prokop'ev, M.N. 1964. [Forest plantations on concentrated clear fellings.] Izdatel'stvo 'Lesnaja Promyslennost, Moscow. 144 pp. (Abstr. F.A. 27:53).

A manual on site preparation, plantation establishment by direct sowing and planting, and tending of young plantations. The information given is from investigations on Scots pine and Norway spruce in the southern and central Taiga zones of European Russia.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), artificial regeneration, planting, seeding, site preparation.

977. Revel, J. 1969. E.P. 638 - Seeding trials in the Prince George Forest District. B.C. Forest Research Review. p. 70.

Examines results of a number of trials underway to investigate and develop seeding techniques suited to certain conditions found in the Prince George Forest District, including investigating the feasibility of broadcasting lodgepole pine seed on snow in areas logged and burned. Also reported 1966 - pp. 58-59, 1968 - p. 63.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, planting, seeding, seedling survival.

978. Richardson, J. 1970. Broadcast seeding a burned cutover after light scarification. Canada, Forestry Service, Forest Research Lab, St. Johns, Info. Rept. N-X-58. 21 pp.

Burned cutovers normally do not regenerate satisfactorily to softwood cover because of a lack of seed source and presence of thick humus layer restricting germination and seedling establishment. However, seedling, in some cases with scarification allows satisfactory regeneration of black spruce on such sites. Scarification both improves seedbed and reduces vegetative competition.

K.W. artificial regeneration, humus, scarification, seedbed, seeding, vegetative competition, [Picea mariana].

979. Richardson, J. 1970. Seed spotting several spruce species on burned land in western Newfoundland. Canada, Forestry Service, Info. Rept. N-X-48. 19 pp.

Discusses a seed spotting experiment established on a non-reproducing burned cutover, in order to determine which species would be most suitable for seeding such areas. 30 one acre blocks were established and seeds were placed in screefed spots. Results indicate that black and white spruce will regenerate successfully when seed spotted on burned cutover sites. Red spruce regeneration was good on shallow soils but poor elsewhere, site conditions affected results, and led to the conclusion that unless pre-sowing site preparation is planned, only the dry to fresh sites with shallow humus layers should be seeded.

K.W. Picea glauca (white spruce), burning, cutting, regeneration, screefing, seeding, seedling survival, site preparation, spot seeding, [Picea spp.].

980. Richardson, J. 1971. Seed spotting black spruce on scarified scalps. Canada, Forestry Service, Newfoundland Forest Research Centre, B.C., Info. Rept. N-X-66. 12 pp.

Seed spotting of black spruce on scalped areas in the fall results in adequate stocking in all parts of the scalp but the top. Application of fertilizer may be necessary to achieve satisfactory growth.

K.W. artificial regeneration, germination, scalping, seeding, stocking, [Picea mariana].

981. Richardson, J. 1972. Direct seeding on a prescribed burn in western Newfoundland. Canada, Forestry Service, Newfoundland Forest Research Centre, St. Johns, Info. Rept. N-X-82. 15 pp.

Under certain conditions, direct seeding can be a satisfactory method of establishing black spruce following prescribed burning of a balsam fir cutover. The most important limiting factor is the depth of organic mantle, satisfactory stocking being achieved only where less than 3" deep. Scalping proved the best seedbed preparation. Broadcast seeding on unprepared surface did not produce satisfactory stocking. Seeding immediately after burning was better, but not conclusively so, than waiting 3 years after burning.

K.W. artificial regeneration, prescribed burning, scalping, seedbed, seeding, [Abies balsamea, Picea mariana].

982. Richardson, J. and V. Chaffrey. 1970. Broadcast seeding and seedspotting black spruce on scarified and unscarified ground. Canada, Forestry Service, Forest Research Lab, St. Johns, Int. Rept. N-26. 8 pp.

Introduces an experiment which will be re-measured in 1972.

K.W. artificial regeneration, scarification, seedbed, seeding, seed-spotting, [Picea mariana].

983. Sinko, M. and E. Jakabffy. n.d. [Some results from orientating experiments with soil ploughing and deep pitting of the soil before planting.] Skogshogskolan Inst. för Skogsföryngring, Misc. Publ. 6, 66 pp. Engl. Summary.

Survival and increment after radical soil preparation were better than the results of conventional planting. The deep pitting of soil stimulated growth further. The result of ploughing was not good, probably because of unfitness of soil.

K.W. artificial regeneration, planting, ploughing, seedling growth, seedling survival, site treatment.

984. Skoklefald, S. 1965. [Trials with various seedbed treatments in connection with direct sowing of Norway spruce and Scots pine.] Medd. Norske Skoforsøksvesen 20(4):No. 75. pp. 205-247. (Abstr. F.A. 27:662).

Seedbeds were given the following treatments; vegetation left intact; vegetation removed by hand; vegetation treated with $CaCN_2$; humus layer removed. Pine and spruce seed were sown broadcast to give conditions resembling natural seedfall. Removal of humus layer gave best conditions for germination and survival, hand weeding also gave good results, but use of a herbicides was largely unsuccessful. Maximum mortality was in the year after germination. Germination was best on the thinnest humus, but much lower on humus than where humus was removed.

K.W. Picea sp. (spruce), Pinus sp. (pine), artificial regeneration, germination, herbicides, humus, scarification, seeding, seedling mortality, soil, weed control.

985. Smith, J.H.G. and M.B. Clark. 1960. Growth and survival of Engelmann spruce and alpine fir on seed spots at Bolean Lake, B.C. 1954-1959. Forestry Chronicle 36(1):46-49.

Seed spots established in the spring of 1953 were remeasured in August 1959. Two site types, wet and dry; three degrees of light, full shade, part shade and full sun; and five seedbeds: mineral soil, burned soil, moss, litter, and rotted wood, were tested with alpine fir and Engelmann spruce seed plantings. The results, given in the article, indicate a need for seedbed disturbance to ensure adequate regeneration. The article concludes that planting might be more effective than seeding in ensuring regeneration.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), artificial regeneration, germination, planting, scarification, seedbed, seeding, seedling mortality.

986. Solov'ev, B.P. 1969. [Increasing soil fertility for forest plantation by special site preparation.] Lesn. Hoz. 22(5): 26-31. (Abstr. F.A. 31:513).

Describes method of preparing planting sites on felled areas which are wet or seasonally waterlogged. Bulldozer makes up to 250 mounds/acre each 0.8 m high and 3 m x 1.5 m in area. At age 5 years, the height of planted Scots pine is 50-100% greater than that of plantations established on conventional ploughed strips.

K.W. Pinus sylvestris (Scots pine), mounding, planting, seedling growth, site preparation, soil moisture.

987. Soos, J. and T.C. Mueller. 1970. Success of scarification and seeding in Clearwater-Rocky Forest, Alberta. Canada, Forestry Service, Forest Research Lab, Edmonton, Internal Rept. A-32. 24 pp.

In the experiments carried out, winter scarification was unsuccessful and scarification, in general, was not intense enough to allow adequate stocking of Picea glauca and Pinus contorta, even though seedfall was adequate. Recommendations for scarification, artificial regeneration, and utilization of mixedwood stands are made.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, planting, regeneration, scarification, seedbed, seedfall, seeding, soil, vegetative competition.

988. Stoeckeler, J.H. 1947. Planting poorly-drained wet sites. U.S. Dept. Agric., Lake States Forest Experiment Station Tech. Note 276. 1 p.

Poorly drained soil in which a white spruce plantation had previously failed was furrowed with a Killefer plow. Planting of various species was done on top of the plow lay. After 8 seasons, survival of 2-2 white spruce was 79% at the top of the plow lay, 50% at the bottom of the furrow, and 47% on a scalp. Height after 8 years was 3.7 ft. 1.7 ft. and 2.3 ft. for the three areas respectively. Success of plow lay planting was attributed to better aeration, better drainage, less burial by soil washing, higher fertility due to planting on a double layer of organic matter, less frost heaving, less smothering by dead undergrowth, and less trampling by deer walking down furrows.

K.W. Picea glauca (white spruce), artificial regeneration, drainage, frost damage, furrowing, planting, seedling growth, seedling survival, soil moisture, trampling.

989. Suvorsov, V.I. 1965. [Investigation of conifer plantations established by planting the seedlings on the furrow slices or in the furrows on clay loam soils.] Sborn. Rabot lesn. Hoz. Vsesojuz. Naučˇ - Issled. Inst. Lesovod. 50:21-43. (Abstr. F.A. 29:645).

It is best to plant spruce and pine seedlings on the invested plough furrow slices, which should be 20-30 cm. thick and 50-70 cm. wide.

K.W. furrowing, planting, seedling survival.

990. Toumey, J.W. and R. Keinholz. 1931. Trenched plots and forest canopies. Yale Univ., School of Forestry, Bull. 30.

991. Tucker, R.E., J.M. Jarvis and R.M. Waldron. 1968. Early survival and growth of white spruce plantations, Riding Mountain National Park, Manitoba. Canada, Forestry Branch, Publ. 1239. 26 pp.

Transplant survival of 2-2 and 2-3 white spruce stock was better on fresh to moist sites that had been scalped or disced before planting, than on wetter sites or untreated ground. Height growth showed no relation to site but was better on areas disced before planting than on areas treated by other methods. Summer-planted transplants survived and grew as well as spring or fall-planted transplants. Elk trampling caused much mortality, and frost reduced height growth, especially in low areas.

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, cultivation, elk, frost, growth increment, planting, planting date, scalping, seedbed, seedling mortality, seedling survival, soil, soil moisture, wildlife.

992. Uggla, E. 1967. [The effect of controlled burning on a thin raw humus layer.] Sveriges SkogsvFörb. Tidskr 65(2):155-170. (Abstr. F.A. 28:641).

Spruce sown on a burned plot showed initial fast growth but was overtaken in height, dbh and vigour at age 8 by spruce sown on unburned plots. Nutrient differences between plots were comparatively small. The difference in growth was attributed mainly to vegetative changes, especially replacement of moisture conserving mosses with those that have an adverse effect on the water holding capacity of the humus.

K.W. Picea sp. (spruce), burning, humus, seeding, seedling growth, soil moisture, soil nutrients, succession.

993. Vézina, P.E. and L. Robitaille. 1970. Étude des méthodes de coupe et autres traitments sylivicoles experimentés au Quebec. Government due Quebec, Ministére des Terres et Forêts, Service de la Recherche, Memoire 2. 372 pp.

Report brings together the results of silvicultural research undertaken by various agencies in the forests of Quebec. Conclusions and results of 148 projects are here included, many concerning site treatments and reforestation.

K.W. artificial regeneration, planting, regeneration, seeding, site treatment.

994. Waldron, R.M. 1961. Seeding white spruce at the base of aspen. Forestry Chronicle 37(3):224-227, 233.

Natural regeneration of white spruce in aspen and spruce-aspen stands is poor for various reasons. Tests were therefore made of three methods of seeding white spruce in the humus layer, in moss, and on scalps, as the base of aspen in dense young and open mature stands. Scalps at the base of trees were more favourable than the other treatments for germination and seedling survival.

K.W. Picea glauca (white spruce), artificial regeneration, germination, scalping, seeding, seedling survival, [Populus tremuloides].

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

995. Waldron, R.M. 1962. Converting aspen stands to white spruce by planting and seeding on scalped strips, Manitoba. Canada, Dept. Forestry, Forest Research Division, Manitoba, Mimeo Man.-Sask. 62-16. 13 pp.

Project plan of an experiment to determine whether aspen stands can be converted by planting or seeding white spruce on scalped strips.

K.W. Picea glauca (white spruce), artificial regeneration, planting, scalping, seedbed, seeding, [Populus tremuloides].

996. Waldron, R.M. 1962. Early survival and growth of planted and seeded white spruce as affected by seedbed types occurring on scalped strips prepared in aspen stands, Manitoba. Canada, Dept. Forestry, Forestry Research Division, Manitoba, Mimeo, Man.-Sask. 62-17. 3 pp.

Outlines experiment to be undertaken, testing the influences of soil moisture regime and seedbed types on the growth and survival of planted and seeded white spruce.

K.W. Picea glauca (white spruce), artificial regeneration, planting, scarification, seedbed, seeding, site preparation, soil moisture, [Populus tremuloides].

997. Waldron, R.M. 1963. The effect of pre-planting ground treatment on early survival and growth of planted white spruce. Canada, Dept. Forestry, Forest Research Branch, Manitoba, Mimeo 63-MS-8. 5 pp.

Three treatments, 1) scalping to mineral soil, 2) discing with an Athen plough, and 3) undisturbed, were tested for their effectiveness on early survival and growth of Picea glauca. 2-2 and 2-3 stock were used. After ten years, transplant survival was highest on scalped plots and equal on disced and undisturbed plots. Survival of 2-2 stock was higher than 2-3 stock. 2-2 stock of scalped plots gave highest (67%) survival. First year mortality of 2-3 stock was greater than that of 2-2 stock. Mortality of transplants was highest on undisturbed plots and lowest on scalped plots.

K.W. Picea glauca (white spruce), artificial regeneration, discing, planting, planting stock, scarification, seedbed, seedling age, seedling mortality, soil, vegetation.

998. Waldron, R.M. 1963. Planting white spruce in cutover and undisturbed white spruce-aspen stands in Manitoba. Canada, Dept. Forestry, Forest Research Lab, Manitoba Mimeo 63-MS-9. 6 pp.

Reports effects of residual stand density, moisture regime, lesser vegetation, ground treatment, and size of planting stock on early survival of Picea glauca set out in cutover and undisturbed Picea glauca - Populus tremuloides stands. Transplant survival increased with decreasing crown cover and decreased as moisture regimes increased. It was highest in short herbs and lowest in grass. Survival was higher on mineral soil than on undisturbed seedbeds. Large (2-3) stock survived slightly better than small (2-2) stock. Silvicultural applications of these results are made.

K.W. Picea glauca (white spruce), artificial regeneration, crown cover, planting, seedbed, seedling survival, seedlings, soil moisture, vegetation, [Populus tremuloides].

999. Waldron, R.M. 1964. Converting aspen stands to white spruce by planting and seeding on scalped strips, Manitoba. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 64-MS-16. 34 pp.

Introduces and describes treatments applied to several areas in order to test the hypothesis that aspen stands can be converted to mixed coniferous-deciduous stands by planting or seeding white spruce on scalped strips. Growth and survival rates during the first year are given for some areas.

K.W. Picea glauca (white spruce), artificial regeneration, fungicide, germination, planting, seeding, seedling growth, seedling mortality, strip cutting, [Populus tremuloides].

1000. Waldron, R.M. 1964. Early survival and growth of planted and seeded white spruce, as affected by seedbed types occurring on scalped strips prepared in aspen stands, Manitoba. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Mimeo 64-MS-19. 33 pp.

Three seedbed types were studied, mineral soil, mixed mineral soil and humus and humus. Results for white spruce and jack pine are tabulated. The results obtained from seeding and planting were highly variable, depending upon not only seedbed treatment, but also upon factors such as soil moisture, climate, and vegetation.

K.W. Picea glauca (white spruce), artificial regeneration, browsing, frost-heaving, planting, seedbed, seeding, seedling growth, seedling mortality, site preparation, soil moisture, [Pinus banksiana].

1001. Waldron, R.M. 1964. The effect of pre-planting ground treatment on early survival and growth of white spruce. Tree Planters Notes 65:6-8.

After scalping, discing, or no site treatment, 2-2 and 2-3 white spruce stock were planted in Manitoba. First year mortality of 2-3 stock was greater than that of 2-2 stock, especially on treated areas. During the following years, transplant mortality was highest on undisturbed plots and lowest on scalped plots. After 10 years, transplant survival was highest on scalped plots and about equal on disced and undisturbed plots. Survival of 2-2 stock was higher than that of 2-3, 2-2 stock on scalped plots had highest survival (67%). Height growth was not influenced by type of stock or pre-planting treatment.

K.W. Picea glauca (white spruce), height growth, planting, planting stock, scarification, seedling growth, seedling survival, site treatment, vegetative competition.

1002. Wilton, W.C. 1963. Seeding and planting to red spruce and Sitka spruce of typical balsam fir pulpwood cutover land following three site preparations. Canada, Dept. Forestry Forest Research Lab, St. Johns, Mimeo 63-N-4. 6 pp.

Introduces an experiment established in 1962.

K.W. artificial regeneration, planting, scarification, seeding, [Picea pungens, Picea sitchensis].

1003. Wilton, W.C. and J. Richardson. 1965. Establishment report of broadcast seeding on a 1961 burn by cyclone seeder following ground scarification. Canada, Dept. Forestry, Forest Research Lab, St. Johns, Mimeo 65-N-2. 13 pp.

iv) INFLUENCES OF HARVESTING AND SITE PREPARATION PROCEDURES, cont'd.

There is no significant difference noted in success between broadcast seeding of black spruce seed on scarified and unscarified beds. Both have shown themselves to be successful. Effects of providing our improved seedbed by scarifying were offset by negative effects of scarification on natural regeneration.

K.W. artificial regeneration, regeneration, scarification, seedbed, seeding, [_Picea mariana_].

(v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT

Successful artificial regeneration of forests depends largely upon an interaction of natural site factors, many of which may be modified by man's actions. Such factors are examined and evaluated by the papers in this section, many of which are reports of greenhouse or laboratory simulations of situations not easily isolated in field studies.

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

1004. Armit, D. and D. Gillespie. 1970. E.P. 672 - Effects of altitudinal and latitudinal displacement of white and Engelmann spruce provenances: Prince Rupert Plantations. B.C. Forest Research Review. p. 38.

Growth and survival data are tabulated for various provenances of white and Engelmann spruce. Also reported 1968 - pp. 42-44, 1969 - pp. 41-42.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), artificial regeneration, planting, provenance, seedling growth.

1005. Badalov, P.P. 1965. [The effect of the podzolic [A_2] horizon upon the growth of Picea abies.] Lesn. Hoz. 18(5):49-51. (Abstr. F.A. 27:442).

Compares the growth of 2 year seedlings planted on furrow slices in the inverted A_2 horizon and in furrow slices with this horizon removed. Although the difference in height increment between seedlings planted in different conditions began to decrease after six years, the inhibiting effect of the A_2 horizon was still considerable after 8 years.

K.W. Picea abies (Norway spruce), artificial regeneration, furrowing, height growth, planting, podzol.

1006. Clark, M.B. 1970. E.P. 662 - Effect of altitudinal and latitudinal displacement of white and Engelmann spruce provenances: Kamloops plantations. B.C. Forest Research Review. pp. 37-38.

Four provenances of 2+0 spruce were planted at five elevations. There was a significant difference of planting stock survival at all elevations tested (2,100 ft., 3,400 ft., 3,500 ft., 4,000 ft.). A seed lot from 1,400 ft. had the greatest mortality of all elevations. Growth and survival data of all seed lots are tabulated. Also reported 1968 - p. 42, 1969 - p. 41.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), artificial regeneration, elevation, planting, provenance, seedling mortality.

1007. Coates, H.G. 1972. E.P. 688 - Douglas fir provenance plantations - Prince George Forest District. B.C. Forest Research Review. pp. 21-22.

Various provenances of B.C. Douglas fir were planted near northern species limit at Buckhorn Lake. Survival, height growth, and frost damage for various plantings are tabulated. Also reported 1970 - p. 44, 1971 - p. 38.

K.W. Pseudotsuga menziesii (Douglas fir), artificial regeneration, frost damage, planting, provenance, seedling growth, seedling mortality.

1008. Curry, E. and R.L. Farrar. 1961. Root development of spruce transplants in relation to depth of planting, type of soil material and moisture regime. Univ. Toronto, Forest Review. p. 8.

Black and white spruce seedlings, aged 2-0 were transplanted into containers of soil and grown in a greenhouse for five months. The wetter the soil, the poorer was root growth. In soil near permanent wilting point, there was high mortality and poor root development of survivors. On wet soil, root tips were shorter and thicker than in drier soils. Adventitious root development was associated with deep planting and wet soil.

K.W. Picea glauca (white spruce), Picea mariana (black spruce), artificial regeneration, planting, root development, seedling mortality, soil, soil moisture.

1009. Decie, T.P. 1961. E.P. 442 - Scattered plantation trials, Prince George District. B.C. Forest Research Review. p. 45.

Plantations of various species in different seedbed conditions showed great variation in mortality. Competition from vigorous brush growth and damage from snow-press were serious factors in mortality, even where scarification preceeded planting. Also reported 1958 - p. 45, 1959 - p. 52.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), artificial regeneration, planting, scarification, seedling mortality, snow press, vegetative competition.

1010. Dobbs, R.C. and R.G. McMinn. 1973. Hail damage to a new white spruce and lodgepole pine plantation in central British Columbia. Forestry Chronicle 49(4):174-175.

A violent hailstorm of ten minutes duration caused some extensive damage to 86% of a spruce-lodgepole pine plantation in the Prince George area. Greater damage was done to lodgepole pine than to white spruce. In general, older and larger plants suffered greater damage than younger and smaller seedlings. It was found that 3 year old seedlings suffered greater defoliation and wounding than 2 year old seedlings of the same size. Surrounding vegetation seems to have had an effect in reducing damage to planted trees.

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), artificial regeneration, hailstorms, planting, seedling damage, seedling mortality, vegetation.

1011. Duffy, P.J.B. and Z. Nemeth. 1965. Plantations of white spruce under aspen on different soils, Foothills section, Alberta. The Rocky Mountain House Plantations - Establishment Report, 1965. Canada, Dept. Forestry, Forest Research Lab, Alberta, Internal Rept. A-1. 22 pp.

Introduces an experiment to study the effects of site and initial spacing on planting check seedling mortality and periodic growth. Survival and growth of planted stock are not reported.

K.W. Picea glauca (white spruce), artificial regeneration, planting, seedbed, seedling growth, seedling mortality, soil, spacing, [Populus sp.].

1012. Eis, S. 1965. The influence of microclimate and soil on white spruce seedling development in the interior of British Columbia. Canada, Dept. Forestry, Forest Research, Lab, Victoria, Misc. Publ. 9. 5 pp.

Mortality of transplanted spruce seedlings was small. Transplanting slowed down initiation of growth as well as subsequent growth rate. After one growing season, height increment of transplanted spruce was 52% of local wildings. Strong 2-0 plants were found superior to 2-1 plants of similar size. Relative height increments of transplants and wildlings corresponded roughly to site indices of various habitats.

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, planting, planting stock, seedbed, seeding growth, seedling mortality, site index, transplants.

1013. Eis, S. 1970. Spruce or pine on dry spruce sites. Distributed to Interior Foresters, Prince George, B.C. Mimeo. 10 pp.

1014. Fabricius, L. 1954. [Has the moon any influence on germination and first year development of spruce and pine sowings.] Forstwissenschaftliches Centralblatt 73(5/6):142-151. (Abstr. F.A. 16:203).

The moon has no influence on the growth of seedlings. Weather at sowing time and during early growth was much the most important factor influencing their development.

K.W. Picea sp. (spruce), Pinus sp. (pine), artificial regeneration, germination, moon, seeding, seedling growth, weather.

1015. Farrar, J.L. and C. Glerum. 1964. Effects of frost on some coniferous species. Univ. Toronto, Forest Research Review. p. 12. (1965 - p.6), (1966 - p.5).

Tests were conducted on a rising 2-2-2 white spruce stock with dry ice. After being exposed to frost, the trees were observed for several days and after 3 weeks the external damage was ocularly estimated. An attempt was made to correlate the estimated damage with freezing temperatures obtained.

K.W. Picea glauca (white spruce), frost, frost damage, seedlings.

1016. Gagnon, D. 1961. Rainfall and the width of annual rings in planted white spruce. Forestry Chronicle 37(2):96-101.

The influence of monthly rainfall on the mean annual ring width in a 31-year-old Picea glauca plantation in Quebec was studied. Analysis indicated that current mean annual ring width is closely related to the mean monthly precipitation during June, July, and August of the previous year. Other factors may also be involved.

K.W. Picea glauca (white spruce), annual rings, artificial regeneration, growth increment, planting, rainfall.

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

1017. Godman, R.M. 1953. Moss retards regeneration in southeast Alaska. U.S. Dept. Agric., Alaska Forest Research Centre, Tech. Note 18: 1 p.

Artificial seeding trials showed only 1/5 as many seeds germinated in moss as in mineral soil, and those had 28% lower survival. Poor germination is attributed to the lack of moisture caused by the moss air spaces causing higher temperatures and also directly to the moss, as it acts as a mechanical barrier to seed, either reaching a moist seedbed or pushing up through the moss after germination.

K.W. germination, moss, regeneration, seed, seedbed, seeding, seedling mortality, [Picea sp., Thuja sp., Tsuga sp.].

1018. Gustafson, F.G. 1943. Influence of light upon tree growth. J. For. 41:212-213.

Twenty-five 2-2 transplants of white spruce and red pine were planted under various light intensities. Results obtained over 8 years indicate that light is an important factor in the growth of white spruce on a good site having ample water supplies. Light intensity of 75% full sun produces best growth of seedlings of this species. Diameter and height growth of pines increase with light intensity up to full sunlight.

K.W. Picea glauca (white spruce), artificial regeneration, light intensity, planting, seedling growth, seedling survival, soil moisture, [Pinus resinosa].

1019. Kizenkov, V.E. 1964. [Aerial sowing of spruce on 3-year-old burn inthe Archangel region.] Lesn. Ž. Arhangel'sk 7(6):25-28. (Abstr. F.A. 27:442).

Aerial sowing was carried out in May 1962, on an area where the previous spruce stand had been clear felled in 1958-1959. No seed trees were left, the slash was burned in heaps and fires burned >67% of the area in 1959. Evaluation of sowing in late summer of 1962 and 1963 clearly showed the beneficial effect of shelter (herbs, shrubs, broadleaved pioneers, stumps, fallen stems, etc.) on survival and condition of spruce.

K.W. Picea sp. (spruce), aerial sowing, burning, germination, seeding, seedling survival, vegetation.

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

1020. Korstian, C.F. 1921. Evaporation and soil moisture in relation to forest planting. Utah Academy of Science, Arts and Letters Proc. 2:116-117.

1021. Leaf, A.L. and T. Keller. 1956. Tentative technique for determining the influence of soil on the growth of forest plantations. Proc. Soil Sci. Soc. Amer. 20:110-112.

Provides explanations of methods used to: a) determine the influence of soil on the growth of red pine and white spruce plantations, b) check the ecological homogeneity of the plantations, and c) estimate the rate of growth. Foliar analysis and ground water analysis supplement lab and field work. Accurate density estimates of nurse stands is stressed.

K.W. Picea glauca (white spruce), Pinus resinosa (red pine), foliar analysis, ground water, mensuration, seedling growth, soil, stand density.

1022. Lees, J.C. 1963. Tolerance of white spruce seedlings to flooding. Canada, Dept. Forestry, Forest Research Lab, Calgary, Mimeo 63-A-2. 8 pp.

Two-year-old white spruce seedlings were more tolerant to flooding than one-year-old seedlings, but all died after 14 days immersion. A few seedlings of both ages could withstand repeated flooding of fairly short periods. The influence of flooding is cumulative. Ultimately all seedlings died. Mortality is essentially the outcome of the degeneration of waterlogged roots.

K.W. Picea glauca (white spruce), artificial regeneration, flooding, planting, scarification, seedling mortality, soil, waterlogging.

1023. Lees, J.C. 1964. Tolerance of white spruce seedlings to flooding. Forestry Chronicle 40(2):221-225.

One and two-year-old white spruce seedlings growing in trays were immersed in water for varying periods to simulate the flooding of bulldozer scarified areas in the field in Alberta. Total mortality followed the longest immersion (14 days), but small percentages survived shorter periods of immersion. Two-year-old seedlings are more tolerant of flooding than are one year-old seedlings.

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

K.W. Picea glauca (white spruce), artificial regeneration, flooding, planting, scarification, seedling mortality.

1024. Lees, J.C. 1971. Tolerance of white spruce seedlings to flooding on three occasions during the 1966 growing season. Canada, Forestry Service, Forest Research Lab, Edmonton, Internal Rept. A-46. 4 pp.

Three-year-old white spruce seedlings immersed for 3-10 days are better able to tolerate such flooding as would occur on scarified land later in the growing season. Ten days under water in the field killed 28% - 40% of the seedlings.

K.W. Picea glauca (white spruce), artificial regeneration, flooding, planting, seedling mortality, seedlings.

1025. Lindquist, C.H. 1970. Cutworm damage to summer planted white spruce tubelings. Bi-Monthly Research Notes 26(6):56.

In Ontario, after planting white spruce on a month-old burn, cutworm destroyed 40% of the plantings. Note records species involved and attempts to explain origin of this infestation. It is felt that in North Ontario, summer plantings following spring burns will always be susceptible to cutworms.

K.W. Picea glauca (white spruce), cutworms, infestation, planting, seedling mortality, tubes.

1026. MacHattie, L.B. and K.W. Horton. 1963. Influences of micro-climates on mortality and growth of planted white spruce, jack pine, and white pine. Forestry Chronicle 39(3):301-312.

Relationships between some microclimatic factors, mortality and growth of planted conifers were studied on the north and south aspects of ridge in Eastern Ontario. It is shown that interactions between meteorological and physiographic factors complicate the classification of local climate for plantation purposes. Correlations between mortality of jack pine and white spruce and maximum temperature, and those between height growth of white pine and mean temperature of the previous summer are suggestive rather than conclusive.

K.W. Picea glauca (white spruce), artificial regeneration, microclimate, planting, seedling growth, seedling mortality, [Pinus banksiana, Pinus strobus].

1027. Moreau, R. and J. Poly. 1967. [Regeneration of spruce in the high ranges of the Jura.] C.R. Acad. Sci., Paris 264D(14): 1789-1791. (Abstr. F.A. 29:64).

After 5 years, seedlings planted on sites weeded twice a year show good survival and growth; the addition of mycelium of Boletus luteus to the soil had little or no effect. Sowing spruce on soil after cultivation was also very effective. Survival of plants on sites covered by plastic sheeting was good. It is concluded that lack of natural regeneration in the area was good. It is concluded that lack of natural regeneration in the area is largely due to weed growth (competition for light and moisture, lack of rooting space, and toxic effects of Umbelliferae and Compositae).

K.W. Picea sp. (spruce), mycorrhizae, planting, regeneration, seeding, seedling growth, seedling survival, vegetative competition, weed control.

1028. Mueller-Dombois, D. 1964. Effect of depth to water table on height growth of tree seedlings in a greenhouse. Forest Science 10:306-316.

Discusses a greenhouse study designed to determine the effect of depth to water table and grass competition on growth of planted tree seedlings, and to allow comparisons with a study similar except in the absence of grass competition. Two soils were tested, loamy sand and sand, and much greater production was observed on the loamy soil, although greater height growth did not occur. Grasses grew more vigorously, suppressing seedlings on the sandy loam when at optimum depth to water table. On sand, there appeared to be little effect from grass competition.

K.W. Picea glauca (white spruce), greenhouses, planting, seedling growth, soils, vegetative competition, water table.

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

1029. Mullin, R.E. 1969. Effects of competition on post-planting growth of potted white spruce. Tree Planters Notes 20(1): 19-22.

In all experiments, using competition of grasses, maple, and black spruce, the presence of other plants in a shared environment reduced growth of white spruce, showing inhibitory effects of competition. Factors other than competition for water were involved but not identified. In the grass root studies, only the presence of grass reduced the growth of white spruce, and inhibitory root exudates were not found.

K.W. Picea glauca (white spruce), planting, seedling growth, soil moisture, vegetative competition, [Picea mariana, Acer saccharum].

1030. Nilov, V.N. 1970. [The appearance and mortality of spruce seedlings on felled areas.] Lesn. Ž. 13(4):129-132. (Abstr. F.A. 32:290).

Seeds of Picea abies were sown in May on plots clear felled 3-4 years previously and carrying different types of vegetation at time of sowing. Number of seedlings was assessed in June, July, August, and September. Conditions for regeneration were best on Carex/Polytrichum type, next best on herb-bog type and Calamagrostis type and worst on broad-leaved herb type. On all types, conditions for spruce regeneration were significantly worse on patches without living ground vegetation than among sparse mosses: below the canopy of herbaceous plants, germination of seeds was higher and mortality of seedlings lower than on open patches. Only below Calamagrostis did more spruce seedlings die than on patches without herbaceous cover.

K.W. Picea abies (Norway spruce), artificial regeneration, clear felling, seeding, seedbed, site type, vegetation.

1031. Phu, T.D. 1970. La croissance de l'épinette blanche (Picea glauca (Moench) Voss) dans les plantations de l'hydro-Québec à Drummondville (Quebec). Canada, Forestry Service, Forest Research Lab, Quebec, Info. Rept. Q-F-X-11. 21 pp.

White spruce plantations are divided into 3 site classes based on yearly height increment. This classes correlate well with soil type and in some cases the intensity of vegetative competition.

K.W. Picea glauca (white spruce), artificial regeneration, height increment, planting, seedling growth, site type, soil, vegetative competition.

1032. Place, I.C.M. 1952. The influence of bracken fern on establishment of spruce and fir seedlings. Canada, Forestry Branch, Forest Research Division, Silv. Leaflet 70. 4 pp.

The influence of bracken on the establishment of seeded spruce and balsam fir was tested at the Acadia Forest Experiment Station, New Brunswick. On both a fresh and a wet red spruce and balsam fir site, dense growth of bracken fern appeared to be detrimental to the germination and early survival of spruce and fir seedlings.

K.W. artificial regeneration, Pteridium sp., seeding, soil moisture, vegetative competition, [Abies balsamea, Picea rubens].

1033. Prochnau, A.E. 1960. E.P. 520 - Experimental seeding of spruce, Prince George Forest District. B.C. Forest Research Review. pp. 36-37.

Spruce seed was broadcast sown on the Buckhorn Lake burn in 1958, a dry year, and broadcast sown and spot sown on the Lin burn in 1959, a very wet year. For the 1958 plantings, 70% of seedlings were on mineral soil, 24% on burned humus, and 6% on rotted wood; for the 1959 plantings, 14% of seedlings were on mineral soil, 67% on burned humus, and 19% on rotted wood. Also reported 1959 - p. 49.

K.W. Picea glauca (white spruce), artificial regeneration, germination, planting, seedbed, seeding, seedling survival.

1034. Radvanyi, A. 1966. Destruction of radio-tagged seeds of white spruce by small mammals during summer months. Forest Science 12(3):307-315.

2000 seeds of Picea glauca were radio-tagged and placed in their environment in early June on two cutover in Alberta. After 17 weeks, about 91% were recovered. Of the seeds recovered, 21% showed no change, 6% had germinated, 24% had dried up and 49% had been destroyed

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

(35% by mice, 9% by chipmunks, 3% by shrews, and 2% by insects). Destruction and drying up accounted for 73% of recovered seeds.

K.W. Picea glauca (white spruce), artificial regeneration, germination, logging, mammals, seed destruction, seeding, seeds, wildlife.

1035. Radvanyi, A. 1972. Small mammals and regeneration of white spruce in western Alberta. In: White spruce, the ecology of a northern resource. Canada, Forestry Service, Northern Forest Research Centre, Alberta, Info. Rept. NOR-X-40. pp. 21-23.

Small mammal populations in Alberta are such that direct seeding without adequate seed treatment would be futile. Despite current methods, nearly 50% of spring sown seed is destroyed by small mammals within 3 months.

K.W. Picea glauca (white spruce), artificial regeneration, germination, mammals, seed destruction, seeding, wildlife.

1036. Revel, J. 1970. E.P. 646 - Effects of altitudinal and latitudinal displacement of white and Engelmann spruce provenances. B.C. Forest Research Review. p. 37.

2+0 seedlings of 13 white spruce and Engelmann spruce provenances were planted at Buckhorn Lake, Prince George. Later, in 1969, more provenances were added to the study. A continuous record of flushing, dormancy, survival, height and leader growth, and frost damage is maintained. Also reported in 1966 - pp. 43-44, 1967 - p. 44, 1968 - pp. 39-41, 1969 - pp. 39-40. L. Roche was co-author in 1966.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), artificial regeneration, planting, provenance, seedling growth, seedling mortality.

1037. Ronco, F. 1961. Planting in beetle-killed spruce stands. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note 60. 6 pp.

Lodgepole pine and Engelmann spruce seedlings were planted in an effort to reforest a stand killed 1939-1952. Spruce seedlings survived at 10,500 ft. when planted in partial shade but not in light. Most mortality took place in first winter and summer. Light damage appeared to affect photosynthetic mechanism. Neither drought nor frost heaving were important causes of mortality. Lodgepole pine seedlings survived well without special treatment. They tolerated strong light and were not benefited by shading.

K.W. Picea englemannii (Engelmann spruce), Pinus contorta (lodgepole pine), artificial regeneration, irrigation, planting, seedling mortality, shading.

1038. Ronco, F. 1967. Lessons from artificial regeneration studies in a cutover beetle-killed spruce stand in western Colorado. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Note RM-90. 8 pp.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), artificial regeneration, frost damage, germination, mulching, planting, regeneration, seedbed, seeding, seedling mortality, site preparation, vegetation, wildlife.

1039. Ronco, F. 1968. The influence of high light intensity on the survival of planted Engelmann spruce. Dissert. Abstr. 29: 429B-430B.

Open grown Engelmann spruce on cutovers in Colorado were chlorotic, while partially shaded spruce and lodgepole pine grew well. Photosynthetic rates of spruce in shaded areas were higher than those in non-shaded areas but not significantly so. Solarization is considered to be the cause of mortality. Other factors, however, including high leaf temperature, food reserves, CO_2 vapour pressure, and non-lethal water stress may trigger factors critical in this phenomenon.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), artificial regeneration, drought, planting, regeneration, seedling mortality.

1040. Ronco, F. 1970. Chlorosis of planted Engelmann spruce seedlings unrelated to nitrogen content. Canadian Journal of Botany 48:851-853.

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

Seedlings from planting trials, established over a four year period, were analyzed in order to study the possible relationship of chlorosis to nitrogen content. Shade-tolerant Engelmann spruce seedlings became chlorotic when exposed to direct sunlight regardless of where planted. Shaded seedlings in the same conditions remained green. Results showed nitrogen content to be similar in both shaded and unshaded seedlings regardless of growing conditions, so chlorosis was attributed to solarization, not nitrogen deficiency.

K.W. Picea engelmannii (Engelmann spruce), chlorosis, nitrogen content, planting, seedling damage, shade tolerance, solarization.

1041. Ronco, F. 1970. Influence of high light intensity on survival of planted Engelmann spruce. Forest Science 16:331-339.

Presents results of studies on photosynthesis and needle water deficits. Photosynthesis was higher for Engelmann spruce seedlings in shade than in the open, but not much different from lodgepole pine seedlings. Spruce reached near-maximum photosynthesis at a lower ft.-c. value than the pine, and respiration and photosynthesis was highest at moisture deficits less than 10%. Results indicate solarization may be associated with high mortality in plantations at elevations over 10,000 ft. and it occurs in unshaded spruce, having a deleterious effect on photosynthesis.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), light intensity, needle water deficit, photosynthesis, seedling damage, solarization.

1042. Rowe, W.H. 1940. The causes of failures in young plantations. Quarterly Journal of Forestry 34:162-166. (Abstr. F.A. 2:211).

A brief indication of the variety of factors that may contribute to the death of young trees after planting out.

K.W. artificial regeneration, planting, seedling mortality.

1043. Smith, C.F. and S.E. Aldous. 1947. The influence of mammals and birds in retarding artificial and natural reseeding of coniferous forests in the U.S. J. For. 45(5):361-369.

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

Describes several factors involved in the failures of reseeding operations, primarily the destruction by rodents and seed-eating birds. Reduction control of animal life has not been very successful, yet it is hoped that new toxic agents will increase the effectiveness of the method. Repellent materials have not been very successful, but may be improved, while the best protection has so far been mechanical, i.e., where screens covering the seeds and new seedlings, the only drawback being the expense. Recommendations are made for further investigations. 65 references are cited.

K.W. birds, economics, pest control, regeneration, repellents, rodents, screening.

1044. Stoeckeler, J.H. 1945. Nutrients in duff and humus layers increase growth of forest plantations. U.S. Dept. Agric., Lake States Forest Experiment Station, Tech. Note 226. 1 p.

Chemical analysis of aspen stands in Wisconsin showed that duff and humus layers had respectively 46 and 24 times as much organic matter, 27 and 15 times as much nitrogen, 23 and 15 times as much available potassium and 5 and 3 times as much available phosphorus as the A_2 layer.

K.W. duff, humus, soil, soil nutrients, soil organic matter, [Picea mariana, Pinus resinosa, Populus sp.].

1045. Stoeckeler, J.H. 1965. Spring frost damage in young forest plantings near La Crosse, Wisconsin. J. For. 63(1):12-14.

Observations of effects of spring freezing on 13 tree species, including white spruce in second and third year plantations near La Crosse, Wisconsin. White spruce is moderately sensitive to spring frosts.

K.W. Picea glauca (white spruce), artificial regeneration, frost, nurseries, seedling mortality, seedlings.

1046. Thompson, C.F. 1972. E.P. 683 - Effects of altitudinal displacement of white and Engelmann spruce, Nelson Plantations. B.C. Forest Research Review. p. 21.

Provenance trials. Height growth and survival data tabulated. Also reported 1970 - p. 39.

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), artificial regeneration, planting, provenance, seedling growth, seedling survival.

1047. U.S. Dept. Agric. 1967. Climatic and biotic conditions influence artificial regeneration of conifers. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept., 1966. pp. 6-7.

Lessons concerning planting and seeding of lodgepole pine and Engelmann spruce in Colorado are outlined.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), artificial regeneration, frost heaving, fungus, germination, planting, seeding, seedling survival, shading, soil moisture, wildlife.

1048. U.S. Dept. Agric. 1970. Shade is critical for planted spruces. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Annual Rept., 1969. p. 26.

Field shade consistently increased survival of planted Engelmann spruce in several planting trials. Various pre-planting shade treatments had no effect. Unshaded seedlings were more susceptible to frost damage, but principle source of mortality was solarization.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, frost damage, planting, seedling mortality, shading, solarization.

1049. Waldron, R.M. 1958. A study of the survival of seeded white spruce in relation to micro-habitat, Riding Mountain, Canada, Forestry Branch, Forest Research Division, Unpubl. MS. (ABSTR.).

White spruce seed sown in poplar and in mixedwood stands showed no significant difference in germination or subsequent seedling growth between A soil horizon and B soil horizon. Seeds surface sown suffered high mortality as a result of animal consumption. Germination of seed sown at the north side of aspen was slightly better than on south side.

K.W. Picea glauca (white spruce), Populus tremuloides (trembling aspen), germination, micro-climate, seed consumption, seedbed, seeding, seedling growth, soil.

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

1050. Weetman, G.F. and N.B. Nykvist. 1963. Some more humus, regeneration, and nutrition problems and practices in North Sweden. Pulp and Paper Research Institute of Canada, Woodlands Research Index, 1939, Tech. Rept. 317. 15 pp.

Summarizes briefly some of the current ideas and findings relating to more humus and soils in North Sweden, how they are used as a basis for silvicultural practice, and what are some of their implications for Canadian forest practice. Problems associated with the use of clear cutting, controlled burning, scarification and fertilization, are outlined.

K.W. artificial regeneration, planting, regeneration, scarification, seeding, silviculture, soil organic matter, soils.

1051. Wilde, S.A. 1966. Soil standards for planting Wisconsin conifers. J. For. 64:389-391.

Minimum soil fertility standards are given for the planting of various species, including white spruce. Such figures for white spruce are: site index - 52, pH range 4.7 - 6.5, silt and clay % - 35%, organic matter - 35%. Exchange capacity me/100g - 12.0, total N - 0.12%, available P-40 lbs/A, available K-130 lbs/A, exchangeable Ca - 3.0 me/100g, exchangeable Mg-0.70 me/100 g. All pine species had lower demands.

K.W. Picea glauca (white spruce), artificial regeneration, planting, soil nutrients, soil pH, soil structure.

1052. Wilde, S.A. and W.E. Patzer. 1940. The role of soil organic matter in reforestation. Journal of the American Society of Agronomy 32:551-562.

A study was made in Wisconsin of the effect of organic matter content of podzolized sandy soils of the growth young plantations of several species including Picea glauca. In these soils, organic matter content showed a close relationship with total N and available P and K contents. Absolute minimum requirement of soil organic matter for white spruce growth is 3.0%.

K.W. Picea glauca (white spruce), regeneration, soil, soil nutrients, soil organic matter.

v) RESPONSE OF SEEDLINGS TO FACTORS IN THE NATURAL ENVIRONMENT, cont'd.

1053. Youngberg, C.T. 1966. Silvicultural benefits from brush. Proc. Soc. Amer. Foresters Meeting, 1965. pp. 55-59.

Presents results of some studies under different cover types in central Oregon, showing the effect of cover type on date at which soil moisture reaches permanent wilting point in the seedling root zone, maximum soil temperature recorded at 2 in. below the surface, nutrient content of soil in the seedling root zone, and N uptake by Douglas fir seedlings. In most situations where brush and weed species are being eradicated little or no thought is being given to the possible side effects of this practice or to the loss of beneficial effects exerted the species being eradicated.

K.W. regeneration, soil moisture, soil temperature, vegetation, weed control, [*Pseudotsuga menziesii*].

IV. GENERAL ASPECTS

Included in this section are discussions of silviculture and forest management with reference to spruce forests in general, as well as descriptions of the ecology and silvics of relevant species. In addition, there are some articles of a general or abstract nature concerning silviculture from the standpoint of economics, planning, decision making, and simulation modeling. Appropriate descriptions of plantations and forest areas are also included.

IV. GENERAL ASPECTS, cont'd.

1054. Alberta Forest Service. 1966. Reforestation procedures and requirements for timber quota holders. Alberta, Forest Service, Forest Management Branch, Misc. Publ. 1. 16 pp.

Informs crown timber quota holders in Alberta about requirements of reforestation necessary to maintain constant timber supply. Included are regulations and sections describing scarification, seeding (both natural and artificial), seed procurement, seed source, planting and planting procedures, stocking requirements and the economics of the process.

K.W. Picea sp. (spruce), Pinus sp. (pine), artificial regeneration, economics, planting, regeneration, scarification, seed, seed source, seeding.

1055. Alexander, R.R. 1958. Silvical characteristics of Engelmann spruce. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Sta. Pap. 31. 20 pp.

Describes Engelmann spruce, its biology, ecology and life history.

K.W. Picea engelmannii (Engelmann spruce), ecology, silviculture, succession.

1056. Alexander, R.R. 1958. Silvical characteristics of subalpine fir. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Sta. Pap. 32. 15 pp.

Describes subalpine fir from a taxonomic, ecological and silvicultural standpoint. Life history is described in detail. Average germination of subalpine fir seed is 38%. Seedbed requirements are fairly broad, fir having a fairly large seed and being capable of producing a fairly vigorous root system.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), ecology, regeneration, seed viability, silviculture.

1057. Bates, C.G. 1912. Silvicultural system of management for central Rocky Mountain forests. Proc. Soc. Amer. Foresters 7:106-116.

Presents a survey of systems of management applicable to various species in the Rocky Mountains, including Engelmann spruce.

K.W. Picea engelmannii (Engelmann spruce), silviculture.

IV. GENERAL ASPECTS, cont'd.

1058. Brown, K.B. 1940. Spruce regeneration - the Maritimes. Forestry Chronicle 16(2):68.

A discussion of the article by H.D. Long (q.v.). Concludes that the status of spruce regeneration is not crucial.

K.W. Picea sp. (spruce), regeneration.

1059. Candy, R.M. 1938. Growth and regeneration surveys in Canada, 1918-1936. Canada, Forest Service, Bull. 90. 49 pp.

Gives case histories of many regeneration studies in Canada, but none in British Columbia. Various spruce-fir types are covered in the different provinces. General recommendations are made.

K.W. economics, logging, regeneration, silviculture.

1060. Carlisle, A. and A.H. Teich. 1971. The economics of the genetic improvement of white spruce. In: Proc. 12th Meeting of the Committee on Forest Tree Breeding in Canada, 1970, part 2, ed. E.K. Morgenstern. pp. 225-238.

Describes and discusses some of the benefits that can be derived from tree improvement programs and the cost of such programs. Describes a cost benefit model for white spruce plantations grown mainly for pulp.

K.W. Picea glauca (white spruce), artificial regeneration, economics, genetics, planting, selective breeding.

1061. Cayford, J.H. and A. Bickerstaff. 1968. Man-made forests in Canada. Canada, Forestry Branch, Publ. 1240. 68 pp.

Reviews history of afforestation and reforestation in Canada since 1900 and projects the future. Reports species performance in artificial regeneration situations and outlines silvicultural techniques to be used in both afforestation and reforestation. Dealt with briefly are various methods of site treatment, such as scalping and use of herbicides and also various silvicultural techniques, including thinning and pruning.

K.W. afforestation, artificial regeneration, fungi, herbicides, pesticides, planting, scalping, scarification, seeding, silviculture, site treatment.

IV. GENERAL ASPECTS, cont'd.

1062. Croome, G.C.R. 1968. The use of a flow chart in identifying problems in artificial regeneration research. Canada, Forestry Branch, Forest Research Lab, Fredericton, Internal Rept. M-38. 17 pp.

Presents a flow chart showing the relationships of all factors associated with artificial regeneration. All major factors are discussed and gaps in research are pointed out. Such a flow chart formalizes the field of regeneration so that individual studies can be related to one another and to the subject as a whole.

K.W. artificial regeneration, fertilization, flow chart, model, planting, regeneration, seeding.

1063. Dana, S.T. 1930. Timber growing and logging practice in the northeast. U.S. Dept. Agric., Tech. Bull. 166. 112 pp.

Complete guide to silviculture in the eastern U.S.A. including a description of logging and regeneration practices in spruce-fir forests.

K.W. Picea glauca (white spruce), artificial regeneration, logging, planting, regeneration, seeding, silviculture, slash burning.

1064. Daniel, T.W. 1962. The middle and southern Rocky Mountain region. In: Regional Silviculture of the United States, ed. J.W. Barrett. Ronald Press, New York. pp. 334-405.

Considers all forests of this region, including Engelmann spruce-alpine fir, in detail, as well as the characteristics of the region as a whole. Included for each forest type are ecology, successional status, growth rates, rotation ages, and cultural practices. Clear cutting is recommended for spruce-alpine fir, especially of mature and over-mature stands. Advance reproduction, which often provides excellent stocking, must be maintained during logging. Principle problem in regeneration is vegetative competition. Planting is recommended.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), advance growth, ecology, regeneration, silviculture, vegetative competition.

1065. Davis, R.B. 1966. Spruce-fir forests of the coast of Maine. Ecological Monographs 36(2):79-94.

IV. GENERAL ASPECTS, cont'd.

Describes the coastal spruce-fir forest type in Maine, and includes an analysis of stand structure and development and a distribution survey of spruce and fir in the coastal region. Attempts to account for this distribution in terms of "environmental correlates". During the first 50 years of stand development, growth rates of spruce decline rapidly then more slowly afterward. Uniform size and age classes begin to break down at about 75-100 years of age. White spruce has a distinctive role along the shores, populating blowdowns and other extensive openings.

K.W. Picea glauca (white spruce), age class, geographical distribution, growth rate, size class, stand development, stand structure.

1066. de Grace, L.A. 1950. Application of silviculture in British Columbia. Forestry Chronicle 26(3):237-239.

A general article describing silviculture in central and eastern British Columbia, with respect to future exploitation of forests.

K.W. silviculture.

1067. Deters, M.E. 1962. The northern Rocky Mountain Region. In: Regional Silviculture of the United States, ed. J.W. Barrett. Ronald Press, New York. pp. 406-459.

Describes Engelmann spruce-alpine fir forest type its ecology and silviculture. Mineral soil seedbed is essential for regeneration in clear cut openings. Maximum width of clear cut blocks to be naturally seeded should be 20 chains. Reduction of this figure would give more dependable stocking under normal conditions. Rodents are no problem in spruce regeneration. Slash should be disposed of on clear cuts by piling and burning which also aids seedbed preparation. Broadcast burning is no longer considered acceptable.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), ecology, regeneration, seed dispersal, seedbed, silviculture, site preparation, slash burning.

1068. Farstad, L. and D.G. Laird. 1954. Soil survey of the Quesnel, Nechako, Francois Lake and Bulkley - Terrace Areas. B.C. Dept. of Agric., Rept. 4 of B.C. Soil Survey.

K.W. soil.

IV. GENERAL ASPECTS, cont'd.

1069. Garman, E.H. 1956. E.P. 440 - Identification of spruce. B.C. Forest Research Review. p. 39.

Derives conclusion that many of trees sampled were neither white spruce nor Engelmann spruce but a hybrid of the two. Mentions other western hybrids.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), distribution, ecology, hybridization, [Picea sitchensis].

1070. Garman, E.H. 1957. The occurrence of spruce in the interior of British Columbia. B.C. Forest Service, Tech. Publ. T.49. 31 pp.

Attempts to differentiate between Picea glauca, Picea engelmannii and intermediates. Keys to the interior of B.C. according to species occurrence.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), hybridization.

1071. Griffith, B.G. 1940. Spruce regeneration - British Columbia. Forestry Chronicle 16(2):83-84.

A discussion of the article by F.S. MacKinnon (q.v.). Respective areas of Picea canadensis (sic) and Picea glauca are not yet worked out. Modifies and corrects Mr. MacKinnon's terminology.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), regeneration.

1072. Haddock, P.G. 1961. Silvicultural views on the Canadian spruce forests. For. Chron. 37:376-388.

Discusses many aspects of the silvical characteristics, ranges, yield, and management of spruce forests in Canada, citing numerous references. Includes a rather detailed discussion of forest management, involving such things as method of cutting, seedbed preparation, and yields. Stresses that as much emphasis must be placed on improvement and protection of the lands as is put on logging efficiency. An extensive bibliography is included.

K.W. Picea sp. (spruce), forest management, logging, silvical characteristics, silviculture.

IV. GENERAL ASPECTS, cont'd.

1073. Holman, H.L. and H.A. Parker. 1940. Spruce regeneration - the Prairie Provinces. Forestry Chronicle 16(2):79-83.

A discussion of the article by V.H. Phelps (q.v.). Extends Mr. Phelp's argument to the province of Alberta, which varies somewhat from the normal Prairie situation. Principally concerned with regeneration after fire and logging. Finds study difficult in the absence of a guiding theory.

K.W. Picea sp. (spruce), fire, logging, regeneration, seedbed, soil.

1074. Holst, M.J. 1965. Forest tree breeding and genetics at the Petawawa Forest Experiment Station. In: Proc. 9th Meeting of the Committee on Forest Tree Breeding in Canada, 1964, part 2. pp. 63-107.

Includes details of various experiments with white spruce, including provenance trials and breeding experiments.

K.W. Picea glauca (white spruce), breeding, climate, genetics, nurseries, provenance, [Abies sp., Larix sp., Pinus sp., Populus sp.].

1075. Horton, K.W. 1959. Characteristics of subalpine spruce in Alberta. Canada, Forestry Branch, Forest Research Division, Tech. Note 76. 20 pp.

The spruce forests of the Alberta Rocky Mountain region are examined as to taxonomy, ecology, and silviculture. Ecological and silvicultural highlights of the spruce-fir type in general are reviewed. For most stands clear cutting is suitable. Uneven-aged stands are best for single tree selection. Spruce natural reproduction is shown to be inadequate in most undisturbed stands. The advantages of scarification are discussed in brief.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), artificial regeneration, clear felling, ecology, logging, planting, regeneration, scarification, selection cutting, silviculture.

IV. GENERAL ASPECTS, cont'd.

1076. Jarvis, J.M. 1963. Some problems that affect white spruce silviculture in west central Canada. M.Sc. Thesis, Univ. of Manitoba. 70 pp.

K.W. Picea glauca (white spruce), silviculture.

1077. Jensen, H. 1942. [New ways of producing high grade forest seed.] Skogen 29:73-77. (Abstr. F.A. 5:177).

In order to obtain seed from selected strains in a relatively short time, it is possible by artificial means to develop "dwarf trees" that will produce a heavy crop of fruit at an early age. An added advantage is that seed can be harvested from the ground. Strangulation can be used for this purpose and good results have been obtained from white spruce.

K.W. Picea glauca (white spruce), seed, seed tree culture, seed trees.

1078. Kelley, C.C. and L. Farstad. 1946. Soil survey of the Prince George area. B.C. Dept. of Agric., Rept. 2 of soil survey.

K.W. soil.

1079. Le Barron, R.K. 1952. Silvicultural practices for lodgepole pine in Montana. U.S. Dept. Agric., North Rocky Mountain Forest and Range Experiment Station, Sta. Pap. 33. 19 pp.

Deals with general management considerations, watershed management particularly, and discusses silvicultural problems. Recommendations are made for timber marking and cutting practices for particular types of stands, such as mature and overmature. Slash disposal and erosion prevention are also discussed.

K.W. Pinus contorta (lodgepole pine), clear cutting, forest management, regeneration, slash disposal, watersheds.

1080. Le Barron, R.K. and G.M. Jemison. 1953. Ecology and silviculture of the Engelmann spruce-alpine fir type. J. For. 51(5):349-355.

The Engelmann spruce-alpine fir type has specific characteristics and silviculture requirements. The authors discuss silvicultural systems best adapted to the spruce-fir stands of the Rocky Mountains.

IV. GENERAL ASPECTS, cont'd.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), ecology, regeneration, silviculture.

1081. Long, H.D. 1940. Spruce regeneration in Canada. I: The Maritimes. Forestry Chronicle 16(1):6-9.

Studies the problem of failing spruce regeneration in the maritimes. Discusses management systems that might alleviate this problem. Includes a literature review.

K.W. Picea sp. (spruce), forest management, regeneration.

1082. Lyons, R.W. 1925. Artificial regeneration of white spruce. Forestry Chronicle 1(2):9-19.

Explains process of decision making in artificial regeneration in Quebec. Descriptions are included of methods of seed selection, planting, cultivation, etc., in the regeneration of pulpwood stands. Yield tables are given for operations already carried out.

K.W. Picea glauca (white spruce), artificial regeneration, cultivation, growth increment, nurseries, planting, seed selection, seeding.

1083. McGregor, J.J. 1948. Some improved techniques in nurseries and on planting sites. Forestry Abstracts 10(1):3-10.

A resumé of new techniques for re-forestation, both European and American with an extensive bibliography. Dealt with are all aspects of nursery technique, transfer of planting stock, various types of site preparation, sowing and planting.

K.W. artificial regeneration, nurseries, planting, planting stock, seeding, seedling storage, site preparation.

1084. McKinnon, F.S. 1938. The relative importance of white spruce in the forests of the Upper Fraser River Valley. B.C. Forest Service, Res. Note 5. 4 pp.

In the forests of the Prince George region, white spruce is predominant over Engelmann spruce by a factor of 2167 to 22.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce).

IV. GENERAL ASPECTS, cont'd.

1085. Moss, A. 1960. Spruce silvicultural management for the future. Forestry Chronicle 36(2):156-162.

An extensive study of the future of Engelmann spruce management, covering all types of management currently in use. Puts forward probable future usages best adapted to supplying a continuous yield. Post harvest site treatment and seeding are dealt with.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, forest management, planting, regeneration, scarification, seeding, silviculture, slash burning.

1086. Nickerson, D.E. 1969. Reforestation and afforestation research in Newfoundland 1950-1968. Canada, Forestry Service, Forest Research Lab, St. Johns, Info. Rept. N-X-34. 35 pp.

Traces history of reforestation and afforestation in Newfoundland. Includes a review of pertinent literature. Included also is a list of investigations and experiments with a brief summary of work done and conclusions reached.

K.W. artificial regeneration, logging, reforestation, regeneration, slash burning.

1087. Nienstaedt, H. 1957. Silvical characteristics of white spruce (Picea glauca). U.S. Dept. Agric., Lake States Forest Experiment Station, Sta. Pap. 55. 23 pp.

Reports the distribution, habitat conditions, life history, races, hybrids, and other features, giving special attention to seeding habits, seedling development and later growth.

K.W. Picea glauca (white spruce), ecology, habitat, regeneration, seed, seedling growth.

1088. Oosting, H.J. and J.F. Reed. 1952. Virgin spruce-fir forest in the Medicine Bow Mountains, Wyoming. Ecological Monographs 22:69-91.

A summary of literature on subalpine forest conditions throughout the Rocky Mts. is used as a background for a phytosociological description of virgin Engelmann spruce-subalpine fir forests. Eight stands were studied and showed a low proportion of rare species and a somewhat uniform dispersal of the least common species within and among stands. A homogeneity within stands as well as of all stands is indicated. More seedlings of fir than spruce were noted, although survival of spruce is greater in all size classes up to the canopy. No significant phytosociological differences were found to be correlated with site, exposure, or altitude.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), ecology, plant sociology, seedling survival, site type, vegetation.

1089. Phelps, V.H. 1940. Spruce regeneration in Canada. IV: The Prairie Provinces. Forestry Chronicle 16(1):30-37.

Reaches many conclusions concerning the regeneration of white spruce as it is affected by logging, fire, soil, stand density, seedbed, vegetation, wind, etc.

K.W. Picea glauca (white spruce), fire, logging, regeneration, seedbed, soil.

1090. Pratt, R.H.M. 1964. Silvicultural operations, Riding Mountain Forest Experiment Area, Fiscal Year 1963-1964. Canada, Dept. Forestry, Forest Research Lab, Manitoba. Mimeo 64-MS-20. 17 pp.

Outlines progress of silvicultural operations at Riding Mountain during 1963-1964. Regeneration surveys of white spruce showed stocking was greatly increased by seedbed treatment. Other silvicultural operations outlined were planting, seeding, thinning and release of white spruce, logging, pruning of white spruce, and the use of herbicides and mechanical means to kill hardwoods which impede spruce regeneration.

K.W. Picea glauca (white spruce), artificial regeneration, herbicides, planting, pruning, regeneration, scalping, seeding, selective logging, site preparation, thinning, [Populus sp.].

1091. Pratt, R.H.M. 1965. Silvicultural operations - Riding Mountain Forest Experimental Area. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Internal Rept. MS-8. 15 pp.

Outlines silvicultural operations carried out during 1964-1965 fiscal year. Some treatments previously used, such as pre-scarification, are here found to be unsatisfactory. Extensive reports on regeneration of white spruce and planting experiments are included.

K.W. Picea glauca (white spruce), artificial regeneration, economics, growth increment, nurseries, planting, pre-scarification, pruning, regeneration, scarification, seeding, silviculture, thinning, [Populus sp.].

1092. Pratt, R.H.M. 1966. Silvicultural operations, Riding Mountain Forest Experimental Area. Canada, Dept. Forestry, Forest Research Lab, Manitoba, Internal Rept. MS-30. 16 pp.

Outlines silvicultural operations in white spruce/ aspen carried out at Riding Mountain Forest Experimental area during 1965-1965. Discussed are regeneration, pruning, logging, thinning and use of herbicides. Scalping is the best technique found to give white spruce regeneration.

K.W. Picea glauca (white spruce), herbicides, logging, pruning, regeneration, silviculture, thinning, [Populus sp.].

1093. Pratt, R.H.M. 1967. Silvicultural operations - Riding Mountain Forest Experimental Area, 1966. Canada, Forestry Branch, Forest Research Lab, Manitoba, Internal Rept. MS-56. 12 pp.

Summary of the programme carried out 1966-1967.

K.W. Picea glauca (white spruce), regeneration, scarification, seedling growth, shelterwood cutting, silviculture.

1094. Pratt, R.H.M. 1969. Silvicultural operations, Riding Mountain Forest Experimental Area, 1968. Canada, Forestry Branch, Forest Research Lab, Manitoba, Internal Rept. MS-88. 13 pp.

Continuing report on silvicultural operations in Riding Mountain Experimental Area. Includes regeneration of white spruce.

K.W. Picea glauca (white spruce), advance growth, artificial regeneration, planting, regeneration, scarification, seedling mortality, silviculture.

1095. Pratt, R.H.M. 1970. Silvicultural operations, Riding Mountain Forest Experimental Area, 1969. Canada, Forestry Service, Forest Research Lab, Manitoba, Internal Rept. MS-106. 17 pp.

A resumé of silvicultural operations and experiments, including those associated with the regeneration of white spruce in Riding Mountain Forest in 1969.

IV. GENERAL ASPECTS, cont'd.

K.W. Picea glauca (white spruce), felling, herbicides, regeneration, scarification, seedbed, shelterwood, soil, [Populus sp.].

1096. Raeburn, J. 1940. Spruce regeneration - Ontario. Forestry Chronicle 16(2):74-76.

A discussion of the article by J.B. Miller (q.v.). Generally agrees with Miller and quotes figures which substantiate his article.

K.W. Picea sp. (spruce), regeneration.

1097. Richardson, A.H. 1941. Forest tree planting. Ontario Dept. Lands and Forests, Bull. 1. 81 pp.

Deals with all aspects of forest establishment, including economics, site preparation, regeneration cutting, seed selection, and nursery growth and post planting site treatment. Includes a section describing tree species suitable for planting in Ontario.

K.W. artificial regeneration, economics, planting, seeding, site preparation, species selection.

1098. Roberts, E.H. and H.P. Eisler. 1940. Spruce regeneration - the Prairie Provinces. Forestry Chronicle 16(2):76-79.

A discussion of the article by V.H. Phelps (q.v.). Gives additional information concerning sub-types of stands existing on the prairies and discusses spruce regeneration in these areas. Calls for additional research and covers areas not touched in Phelp's article.

K.W. Picea glauca (white spruce), logging, regeneration, seedbeds, soil.

1099. Robinson, E.W. 1970. Plans and progress of artificial regeneration in British Columbia. Forestry Chronicle 46(6):479-481.

Gives a report on development in techniques of artificial regeneration in B.C., with projections to the future. Economics and improvements in stock, seeding techniques and planting techniques are dealt with.

K.W. artificial regeneration, economics, planting, seeding.

IV. GENERAL ASPECTS, cont'd.

1100. Roche, L. 1969. A genecological study of the genus Picea in British Columbia. New Phytotologist 68:505-554.

Describes a study which is an investigation of variation in a plant species in relation to its environment. It is divided in two parts, the first (part A) dealing with geographic variation in immature spruce populations. Seed was sown in a nursery and growth was observed for two growing seasons. Part B deals with geographic variation in mature spruce stands. A collection of spruce cones was obtained from areas through B.C. and were assessed for cone scale morphological variation. Results show the influence of environmental factors, such as altitude, on variation within the white-Engelmann spruce complex. Regions of hybridization between species are discussed and recommendations for silvicultural management of spruce species in B.C. are made.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), dormancy, flushing, geographic variation, germination, photoperiod, planting, seed, seeding, silviculture, site, [Picea spp.].

1101. Roche, L. 1970. The silvicultural significance of geographic variation in the white-Engelmann spruce complex in British Columbia. Forestry Chronicle 46:116-125.

Various spruce provenances representing various degrees of hybridization of white, Sitka and Engelmann spruce were grown in a coastal nursery. An assessment of growth behaviour of all provenances showed a strong correlation between time of entering dormancy and geographic origin. A high correlation between time of entering dormancy and total growth is also demonstrated. High elevation provenances showed a rosette appearance. Recommendations are made regarding growth of interior spruce in coastal nurseries.

K.W. Picea glauca (white spruce), Picea engelmannii (Engelmann spruce), hybridization, nurseries, provenance, seedling growth, [Picea sitchensis].

1102. Ronco, F. 1972. Planting Engelmann spruce. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Res. Pap. RM-89. 24 pp.

IV. GENERAL ASPECTS, cont'd.

Recommendations are provided to aid the forest manager in regenerating Engelmann spruce by planting in the central and southern Rocky Mountains. Reforestation operations covered include storage, transportation, microsite selection, site preparation, planting, plantation protection, and record keeping. The physiological and silvicultural requirements of spruce are discussed with respect to the harsh environment of the spruce-fir-zone so that planting principles can be better understood.

K.W. Picea engelmannii (Engelmann spruce), artificial regeneration, environment, planting.

1103. Rowe, J.S. 1959. Forest regions of Canada. Canada, Forest Service, Bull. 123. 71 pp.

Contains description of the two areas under consideration, the interior subalpine section and the Montane Transition Section. All important tree species and elements of geographic history are given.

K.W. Abies lasiocarpa (subalpine fir), Picea sp. (spruce), ecology.

1104. Rowe, J.S. 1972. Forest regions of Canada. Canada, Forest Service, Publication 1300. 172 pp.

Contains descriptions of the two areas under consideration the interior subalpine section and the Montane Transition Section. All important tree species and elements of geological history are given.

K.W. Abies lasiocarpa (subalpine fir), Picea spp. (spruce, ecology.

1105. Roy, H. 1940. Spruce regeneration in Canada. II - Quebec. Forestry Chronicle 16(1):10-20.

Makes observations upon present systems of forest harvesting and finds that they do not in any way favour spruce reproduction.

K.W. Picea sp. (spruce), forest management, regeneration.

1106. Rudolf, P.O. 1950. Forest plantations in the Lake States. U.S. Dept. Agric., Tech. Bull. 1010. 171 pp.

Describes reforestation experiments in the Lake States region. The physical characteristics of the region are described and a brief resumé of past plantings is presented. Direct seeding was tried and results indicate that it should be used as a supplement, not a substitute, for planting. Silvics of recommended species are described. Methods and times of planting are discussed.

K.W. Picea glauca (white spruce), plantation, planting, regeneration, seeding, silviculture.

1107. Siren, G. 1971. [Views on the mechanization of forest regeneration.] Canada, Forestry Branch, Translation TR-213. 42 pp.

A Swedish article dealing with recent advances in the mechanization of forest regeneration. Dealt with in the paper are mechanized planting, use of greenhouses for growth of seedlings, slash disposal and site treatment, nurseries, and containers. All these are discussed with respect to efficiency of regeneration and economics.

K.W. artificial regeneration, economics, greenhouses, mechanical planters, nurseries, planting, scarification, seedlings, slash burning.

1108. Stanec, W. 1966. Occurrence, growth, and relative value of lodgepole pine and Engelmann spruce in the interior of British Columbia. Univ. Brit. Col., Faculty of Forestry, Ph.D. Thesis. pp. 252.

Classification of B.C. forests, as well as silvics, effects of fire upon succession, forest association, distribution, and productivity classes of the two species are described. Volume growth was calculated using Hohenadl's form factor. 124 sample plots were used, located in the interior Douglas fir and Engelmann spruce-alpine fir biogeoclimatic zones. Stem-analyses, height age studies, basal area and stand volume studies were undertaken. Young lodgepole pine had a faster growth increment than the spruce, as is shown in the data tables. Trends of utilization and management for the species, both present and future, are discussed. It appears that planting of lodgepole pine will cost less than Engelmann spruce, and the trees are equally well-suited for establishment. It should yield a higher volume/acre and a higher rate of return of invested capital.

IV. GENERAL ASPECTS, cont'd.

K.W. Picea engelmannii (Engelmann spruce), Pinus contorta (lodgepole pine), economics, forest management, forest utilization, growth increment, wood yield.

1109. Sudworth G.B. 1916. The spruce and balsam fir trees of the Rocky Mountain region. U.S. Dept. Agric., Bull. 327. 43 pp.

Describes ecology, geographic distribution and physical characteristics of all spruce and fir species growing within Rocky Mountain region.

K.W. Picea engelmannii (Engelmann spruce), Picea canadensis (white spruce), distribution, ecology, [Abies sp., Picea sp.].

1110. Sutton, R.F. 1969. Silvics of white spruce (Picea glauca) (Moench) Voss). Canada, Forestry Branch, Publ. 1250. 57 pp.

Gives a detailed discussion of distribution, evolution and phylogeny, diagnostic characteristics, reproduction, and regeneration, with special attention to both natural and artificial regeneration. Phenology is discussed, and habitats described. Associated tree species and inimicalities are also considered.

K.W. Picea glauca (white spruce), ecology, habitat, regeneration, silviculture.

1111. Tackle, D. 1961. Silvics of lodgepole pine. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Misc. Publ. 19(rev.). 24 pp.

Provides information about the habitat conditions of lodgepole pine, the climatic, edaphic, physiographic, and biotic aspects. The life history is described discussing seeding habits, vegetative reproduction, seedling development and sapling state to maturity. Injurious agencies are also discussed. Attention is given to variation in races and hybrids of the lodgepole pine.

K.W. Pinus contorta (lodgepole pine), ecology, silviculture.

1112. Taylor, T.M.C. 1959. The taxonomic relationship between Picea glauca (Moench) Voss and P. engelmannii Parry. Madrono 15:112-115.

IV. GENERAL ASPECTS, cont'd.

Materials were collected from about 70 randomly selected trees, and cones and twigs were taken from both north and south sides of the trees. Detailed analysis was performed. Results showed many diagnostic features between "engelmann" and "glauca" are merely extremes of a series of intermediates. Literature is cited giving further evidence of taxonomic relationships.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), morphology, taxonomy.

1113. U.S. Dept. Agric. 1965. Silvics of forest trees of the United States. U.S. Dept. Agric., Agricultural Handbook 271. 762 pp.

A general reference, concerning all forest trees native to the U.S.A.

K.W. ecology, silvics.

1114. U.S. Dept. Agric. 1973. Silvicultural systems for the major forest types of the United States. U.S. Dept. Agric., Handbook 445. 114 pp.

Summarizes the 37 major types in the U.S.A. and the silvicultural systems which appear feasible for each.

K.W. forest types, silviculture.

1115. Viereck, L.A. 1970. Forest succession and soil development adjacent to the Chena River in interior Alaska. Arctic and Alpine Research 2:1-26.

A study was conducted on four stands on varying aged river deposits, comparing them to a climax stand in a higher, older terrace, in order to show changes in soil and vegetation on the flood plains of the Chena River. Successional stands were a 15 year old willow stand, a 50 year old balsam poplar stand, a 120 year old white spruce and a 220 year old white spruce/ black spruce stand. The terrace stand was mainly black spruce. Evidence suggests that as the white spruce stands get older, and permafrost develops, black spruce and bog replace the white spruce stands. Conditions of soil, moisture and accompanying vegetation allowing establishment of each species is described.

K.W. Picea glauca (white spruce), climate, forest succession, soil, [Picea mariana].

IV. GENERAL ASPECTS, cont'd.

1116. Walton, J.R. 1940. Spruce regeneration-Quebec. Forestry Chronicle 16(2):68-74.

A discussion of the article by H. Roy (q.v.) with respect to the forests of the Sageuenay District. Criticizes the original article as being unrealistic and questions the necessity of regenerating pure spruce stands.

K.W. Picea sp., insects, regeneration, [Abies balsamea].

1117. Westveld, M. 1953. Ecology and silviculture of the spruce-fir forests of eastern North America. J. For. 51:422-430.

Using the climax forest as a guide to growing the species best suited to climate and site, a silvicultural system for managing the spruce-fir forests of eastern North America is presented. Included are discussions of ecology, cutting systems and their adaptation to stand conditions, stand improvement measures and protection measures.

K.W. Abies balsamea (balsam fir), Picea glauca (white spruce), regeneration, silviculture, thinning, [Picea mariana, Picea rubens].

1118. Zasada, J.C. 1973. Interior Alaska white spruce. In: Silvicultural systems for the major forest types of the United States. U.S. Dept. Agric., Agric., Handbook 445. pp. 20-21.

Describes white spruce type in Alaska. Natural regeneration depends on infrequent good seed crops and seedbed conditions. Site preparation after logging, usually clear cutting or shelterwood felling is considered best to obtain adequate regeneration.

K.W. Picea glauca (white spruce), ecology, logging, regeneration, seedbed, silviculture.

V. SEMINARS, SYMPOSIA, BIBLIOGRAPHIES AND LITERATURE REVIEWS

Individual papers in symposia which are included in this section are placed in their appropriate category described in the bibliography.

V. SEMINARS, SYMPOSIA, BIBLIOGRAPHIES AND LITERATURE REVIEWS, cont'd.

1119. Anon. 1970. Reforestation. In: Forestry Reader. Canadian Council of Resource Ministers, Montreal, 1970, Papers 7-16. 74 pp.

Background papers on various aspects of reforestation including the use of prescribed fire, site preparation, chemical herbicides, hand and machine planting, container planting, direct seeding, tree improvement and economics.

K.W. artificial regeneration, burning, containers, economics, genetics, herbicides, planting, seeding, site preparation.

1120. Anon. 1973. Northern interior logging seminar, Prince George, B.C., Feb. 28, Mar. 1-2, 1973.

Seminar deals with problems of spruce regeneration in the Prince George area. Discussed were nurseries in B.C., planting of trees by various methods including containers, the applicability of seedlings to areas other than the origin, problems of pathogens (i.e. nematodes), and competing vegetation, and conflicting interest of hydrology.

K.W. Picea glauca (white spruce), artificial regeneration, containers, hydrology, nurseries, pathogens, regeneration, vegetation.

1121. Christensen, E.M. and M.J. Hunt. 1965. A bibliography of Engelmann spruce. U.S. Dept. Agric., Intermountain Forest and Range Experiment Station, Res. Pap. INT-19. 37 pp.

Emphasizes ecology of Engelmann spruce. Is complete to 1963. Contains very brief annotations.

K.W. Picea engelmannii (Engelmann spruce), ecology.

1122. Dahms, W.G. and G.A. James. 1955. Brush control on forest lands. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Pap. 13. 81 pp.

A review of selected references, containing a bibliography of 239 articles dealing with chemical methods of brush control and their various methods of application, mechanical methods and biological methods. Review is keyed to the Pacific Northwest but contains material which is universally applicable.

K.W. brush control, burning, herbicides, silviculture, vegetation.

V. SEMINARS, SYMPOSIA, BIBLIOGRAPHIES AND LITERATURE REVIEWS, cont'd.

1123. Dobbs, R.C. 1972. Regeneration of white and Engelmann spruce. Canada, Forest Service, Pacific Forest Research Center, British Columbia, Info. Rept., BC-X-69. 77 pp.

A literature review, including an extensive bibliography, concerned with regeneration of white spruce and Engelmann spruce, particularly in the British Columbia interior. Covered are the silvics of white spruce and Engelmann spruce as well as reports of experiments concerning regeneration silviculture of both species. 170 references are listed.

K.W. Picea engelmannii (Engelmann spruce), Picea glauca (white spruce), artificial regeneration, ecology, forest management, planting, regeneration, seeding, silviculture.

1124. Gürth, P. 1970. [Forest planting stock and success in the establishment of plantations: a literature review.] Allgemeine Forst-und Jagdzeitung 141(5):91-104. (Abstr. F.A. 31:754).

Covers size, type, and root-shoot ratio, physiological characteristics and conditions, and root development - water uptake, and transpiration after planting with special reference to spruce.

K.W. Picea sp. (spruce), planting, planting stock, seedling grading.

1125. Hesmer, H. ed. 1950. [The technique of spruce growing.] Verlag M & H. Schaper, Hannover. 197 pp. (ABSTR.).

A symposium dealing with different aspects of spruce growing.

K.W. Picea sp. (spruce), silviculture.

1126. Hildahl, V., R. Pratt and A. Campbell. 1968. Bibliography of forest research. Canada, Forestry Branch, Forest Research Lab, Manitoba, Liaison and Services Note MS-L-2. 65 pp.

K.W. bibliography.

1127. Hocking, D. and R.D. Nyland. 1971. Cold storage of coniferous seedlings. N.Y. State Univ., College of Forestry at Syracuse, Applied Forest Research Institute, Res. Rept. 6. 70 pp.

Basically a literature review and annotated bibliography concerning the successful storage of coniferous seedlings. Successful storage is dependent upon: dormancy at time of lifting, retention of seedling moisture, retention of seedling carbohydrate reserves, prevention of molding, good seedling handling. Requirements of good cold storage facilities are outlined.

K.W. artificial regeneration, planting, seedling storage, seedlings.

1128. Holt, L. 1955. White spruce seedbeds as related to natural regeneration. Pulp and Paper Research Institute of Canada. 28 pp.

A digest of the published literature on Picea glauca, quoting 41 items treating factors affecting seed germination and seedling survival.

K.W. Picea glauca (white spruce), germination, regeneration, seedbeds.

1129. Jarvis, J.M., G.A. Stenker, R.M. Waldron and J.C. Lees. 1966. Review of silvicultural research, white spruce and trembling aspen cover types. Mixedwood forest section, Boreal Forest Region, Alberta - Saskatchewan - Manitoba. Canada, Forestry Branch Publ. 1156. 189 pp.

Describes ecology of forest type, gives review and summary of research results and presents case histories of all related projects undertaken by the department. Contains review of regeneration process and results in white spruce-aspen stands.

K.W. Picea glauca (white spruce), artificial regeneration, forest management, herbicides, planting, regeneration, scarification, seeding, silviculture, site treatment, slash burning, [Abies sp., Populus sp.].

1130. Johnson, H.J., C.F. Cerezke, F. Endean, G.R. Hillman, A.D. Kill, J.C. Lees, A.A. Loman and J.M. Powell. 1971. Some implications of large scale clear cutting in Alberta - a literature review. Canada, Forest Service, Northern Forest Research Centre, Alberta, Info. Rept. NOR-X-6. 114 pp.

Reviews most of the available information regarding, among other things, stand re-establishment after clear felling. Spruce and fir show themselves to be rather difficult to regenerate on cutovers outside stand margins.

V. SEMINARS, SYMPOSIA, BIBLIOGRAPHIES AND LITERATURE REVIEWS, cont'd.

K.W. Abies lasiocarpa (subalpine fir), Picea glauca (white spruce), clear felling, climate, erosion, hydrology, insects, regeneration, sedimentation, seedling mortality, slash burning, [Populus sp.].

1131. McMinn, R.G. ed. 1972. White spruce: the ecology of a northern resource, Proceedings of a Symposium. Canada, Forestry Service, Northern Forest Research Centre, Alberta, Info. Rept. NOR-X-40. 44 pp.

Deals with regeneration and silviculture of white spruce over its entire North American range and attempts to relate white spruce to other North American spruces. Factors in regeneration dealt with by various papers include site, soil temperature, mammals and various aspects of nursery growth.

K.W. Picea glauca (white spruce), artificial regeneration, ecology, nurseries, planting, regeneration, seedbed, seeding, silviculture.

1132. Ronco, F. 1961. Selected bibliography of Engelmann spruce and subalpine fir. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Sta. Pap. 57. 58 pp.

Covers American and Canadian literature published through 1959, pertaining especially to management of Engelmann spruce-alpine fir stands. Contains 512 citations.

K.W. Abies lasiocarpa (subalpine fir), Picea engelmannii (Engelmann spruce), artificial regeneration, forest management, regeneration, silviculture.

1133. Sjolte - Jørgensen, J. 1967. The influence of spacing on the growth and development of coniferous plantations. International Review of Forestry Research 2:43-94.

A literature review of the subject with reference to many species, the most common being Picea abies and Pinus sp. A summary of individual growth factors influenced by spacing is included. Also included is a very extensive bibliography.

K.W. artificial regeneration, planting, spacing.

V. SEMINARS, SYMPOSIA, BIBLIOGRAPHIES AND LITERATURE REVIEWS, cont'd.

1134. U.S. Dept. Agric. 1957. Summary of Engelmann spruce seminar at Fraser Experimental Forest, Aug. 30-31, 1956. U.S. Dept. Agric., Rocky Mountain Forest and Range Experiment Station, Mimeo Rept. 17 pp.

1135. Waldron, R.M. ed. 1972. Proceedings of a workshop on container planting in Canada. Canada, Forestry Service, Info. Rept. DPC-X-2. 168 pp.

Presents current status of container planting in the various provinces of Canada, including a report on the relative usefulness of various types of containers. Also contains several research papers on container planting.

K.W. artificial regeneration, container planting, planting.

1136. Weetman, C.F. 1958. Forest seeding and planting techniques and equipment. Pulp and Paper Research Institute of Canada, Tech. Rept. 74. 130 pp.

Literature survey of developments in techniques and equipment used in artificial reforestation work in North America. Included are discussions of forest tree seed origin and quality, forest site preparation, formation of stands by direct seeding, nurseries, and formation of stands by planting.

K.W. artificial regeneration, culling, economics, herbicides, nurseries, planting, scarification, seed quality, seeding, site preparation, slash disposal.

1137. Zasada, J.C. and R.A. Gregory. 1969. Regeneration of white spruce with reference to interior Alaska: a literature review. U.S. Dept. Agric., Res. Pap. PNW-79. 37 pp.

Diameter limit cutting seems to be the best method for regeneration of white spruce in this area as residual trees limit area of ground exposed to possible mechanical disturbance.

K.W. Picea glauca (white spruce), diameter limit cutting, regeneration, residual stand, soil damage.

VI. INDEXES

AUTHOR INDEX

(Junior Author Reference Numbers are Underlined)

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SUBJECT INDEX

Citations are referred to by reference number (on the left of each page), not page number.

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SPECIES INDEX

All species within the bibliography may also be found under their common names within the subject index.

SPECIES INDEX, cont'd.

SPECIES INDEX, cont'd.

VII. APPENDICES

APPENDIX I

SOURCES OF INFORMATION

Most published information was obtained from university and government libraries. The following agencies were contacted in person.

1. Government of Canada
   Department of Environment
   Pacific Forest Research Laboratory, Victoria;
   Pacific Forest Products Laboratory, Vancouver.

2. Government of the Province of British Columbia
   Department of Lands, Forests and Water Resources, Victoria,
   Forest Service Library.

3. Municipal Offices and Agencies
   Victoria Public Library

4. University sources
   University of British Columbia, Vancouver,
   Library, Department of Agriculture and Forestry, Department of Botany; University of Victoria, Library, Department of Biology; Simon Fraser University, Library.

The following journals and periodicals were searched and/or cited.

Acta Forestalia Fennica

Allgemeine Forst-und-Jagdzeitung

Allgemeine Forstzeitschrift

Allgemeine Forstzeitung

American Forests

American Lumberman

American Pulpwood Association Technical Papers

Annales des Sciences Forestierès

Archiv für Forstewesen

Årsbok Svenska Flottledsforb

Aus dem Walde

APPENDIX I, cont'd.

Biologiceskie Nauki

Biology Abstracts

Botanisk Tidsskrift

Botanicesky Zurnal

British Columbia Dept. Recreation and Conservation, Commerical Fisheries Branch, Pamphlets

British Columbia Forest Service Forest Management Notes

British Columbia Forest Service Research Notes

British Columbia Forest Service Research Reviews

British Columbia Forest Service Technical Publications

B.C. Lumberman

Bulletin du Comité des Forets

Bulletin of the Experimental Forests, Tokoyo University of Agriculture and Technology

Bulletin, Tokyo University Forests

California Agriculture

California Fish and Game

California Fish and Game Association Reports

Canada, Department of Forestry Publications

Canada, Forest Branch, Forest Research Division, Internal Reports

Canada, Forest Branch, Forest Research Division, Technical Notes

Canada, Forest Branch, Silvicultural Leaflets

Canada, Forest Branch, Silvicultural Research Notes

Canada, Forest Management Institute Information Reports

Canada, Forest Service Information Reports

Canadian Entomologist

APPENDIX I, cont'd.

Canadian Journal of Research

Canadian Pulp and Paper Association, Woodlands Section

Commonwealth Forestry Review

Communications Instituti Forestalis Cechosloveniae

Dansk Skovforenings Tidsskrift

Dissertation Abstracts

Ecological Monographs

Ecology

Forest Farmer

Forest Industries

Forest Log

Forest Products Journal

Forest Science

Forestry Abstracts

Forestry Chronicle

Forst-und Holzwirt

Forstarchiv

Forstwissenschaftliches Centralblatt

Hokkaido Forest Products Research Institute Reports

Hokkaido University, Research Bulletins of the College Experiment Forests

Holzforschung und Holzverwertung

Illinois Research

International Association of Scientific Hydrology Bulletins (Reprint)

International Botanical Congress

International Journal of Air and Water Pollution

APPENDIX I, cont'd.

International Pacific Salmon Fisheries Commission Progress Reports

International Union of Forest Research Organizations Reports

International Holzmarkt

Journal of Agricultural Research

Journal of the Air Pollution Control Association

Journal of American Botany

Journal of the American Water Works Association

Journal of Ecology

Journal of Forestry

Journal of Geophysical Research

Journal of Soil and Water Conservation

Journal of Water Pollution Control

Journal of Wildlife Management

Lesnoe Hozjajstvo

Lesnicka Práce

Lesnaja Promyslennost

Lesnoj Zurnal

Lesnoj Zurnal Arhangel'sk

Lesovedenie

Malayan Forester

Meddelelser, Norkse Skogsforsøksvesen

Meguro Forest Experiment Station Bulletins

Michigan Agricultural Experimental Station Quarterly Bulletins

Minnesota Forest Research Notes

Nature

APPENDIX, cont'd.

Naucnye Trudy, Leningradskaja Oredena Lenina

Lesotehniceskaya Akademija im S.M. Kirova

Naucni Trudove Viss Lesotehniceski Institut

Nederlands Bosbouw Tijdschrift

New Hampshire Forest Department, Fox Forest Notes

New York (State) College of Forestry, Applied Forestry Research Institute, Research Reports

New Zealand Journal of Forestry Science

Norrlands SkogsvFörb. Tidskr.

Norsk Skogbruk

Norsk Tidsskift

Northwest Science

Oregon State Board of Forestry, Research Bulletins

Oregon State College, Oregon Forest Products Lab, Bulletins

Oregon State University, Water Resources Research Institute Bulletins

Pedobiologia

Pedology

Pennsylvania Game News

Pennsylvania State University, School of Forestry Resources, Research Briefs

Plant and Soil

Pocvovedenie

Práce, Instytut Badawyczy Lesnicteva

Práce Vyzkumneho Ustavu Lesniho Hospodanstiv a Myslivosti

Proceedings of the American Institute of Fishery Research Biologists

Proceedings of the American Society of Civil Engineers

Proceedings of the Federal Inter-Agency Sedimentation Conference

APPENDIX I, cont'd.

Proceedings of the Society of American Foresters

Proceedings of the Western Forest Conservation Association

Proceedings of the Western Snow Conference

Proceedings of the Soil Science Society of America

Progressive Fish Culturalist

Pulp and Paper

Pulp and Paper Magazine of Canada

Quarterly Journal of Chinese Forestry

Revista Padurilor

Sbornik Csl. Akademie Zemedelske (Lesn.)

Sbornik Rabot po Lesnomu Hozjajstvu, Vsesojuznyj Naucno - Issledovatel'-
skij Institut Lesovodstva i Mehanizacii Lesnogo Hozjajstvo

Sbornik Vedeckeko Lesnickeho Ustavu Vyske Skoly Zemedelkse v. Praze

Sbornik Vysoke Skoly Zemedelske v. Brno (Rada C)

Science

Science in Alaska, Proceedings of the Alaskan Scientific Conference

Science News

Scottish Forester

Silva Fennica

Skogen

Skogsagaren

Smithsonian Institute Annual Report

Southern Lumberman

Sylwan

Tidsskrift for Skogbruk

APPENDIX I, cont'd.

Timber of Canada

Timberman

Transactions of the American Fisheries Society

Transactions of the Colorado-Wyoming Academy of Science

Transactions of the Illinois State Academy of Science

Transactions of the North American Wildlife Association

Truck Logger

Trudy Instituta Lesnoe

Trudy Vsesojuznogo Naucno - Issledovatel'skogo Instituta Zascity Rostenij

Unasylva

University of British Columbia, Forestry Club Research Notes

University of Michigan, School of Forestry and Conservation, Bulletins

U.S. Department of Agriculture Bulletins

U.S. Department of Agriculture Miscellaneous Publications

U.S. Department of Agriculture, Forest Service, Alaska Forest Research Centre Station Papers and Technical Notes

U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Annual Reports Research Notes and Station Papers

U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station, Technical Notes

U.S. Department of Agriculture, Forest Service, North Rocky Mountain Forest and Range Experiment Station, Research Notes and Station Papers

U.S. Department of Agriculture, Forest Service, Northern Forest Experiment Station, Research Papers and Research Notes

U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Annual Reports, Research Notes and Technical Papers

U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station Research Notes and Research Papers

APPENDIX I, cont'd.

U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Annual Reports, Research Notes and Station Papers

U.S. Federal Water Quality Association Annual Reports

U.S. Weather Bureau, Monthly Weather Review Supplement

Washington Farmer

Water Resources Research

West Coast Lumberman

Western Association of State Game and Fish Commissioners, Annual Conference

Western Conservation Journal

Western Reforestation Co-ordination Committee, Annual Proceedings

Weyerhaeuser Timber Company, Forest Research Notes

World Wood

APPENDIX II

Terms of reference of contract, executed on February 1, 1974, in the city of Victoria, Province of British Columbia, Canada.

BETWEEN: Her majesty the Queen, in right of Canada, hereinafter referred to as "Her Majesty", represented by the Director, Canadian Forest Service, Pacific Forest Research Centre, hereinafter referred to as "The Director",

OF THE FIRST PART,

and Biocon Research Ltd., Multidisciplinary Environmental Survey Associates, of the City of Victoria, hereinafter referred to as "Consultant",

OF THE SECOND PART,

Witnesseth that in consideration of the covenants and agreements herein contained, the parties covenant and agree as follows:

1) The Consultant will on or before the 28th day of February, 1974, carry out to the satisfaction of the Director the following work:

To prepare, on behalf of the department of the Environment, Pacific Forest Research Centre, an annotated (Webster's definition) bibliography containing those referrences pertinent to regeneration of logged areas in spruce-balsam cover types in North Central Interior of British Columbia.

Scope of Study

The objective is to compile an annotated bibliography of selected references pertaining to regeneration of logged areas in spruce-balsam cover types in the North Central Interior of British Columbia. Work under this contract will provide a basis for preparation of a guideline publication on regeneration addressed to the management forester. Artificial and natural regeneration, including preparatory site treatment, of commercial forest species is to be stressed.

APPENDIX II, cont'd.

Regeneration, in the context of this contract, means re-establishment of commercial forest cover. Stress is to be given to white spruce, lodgepole pine and subalpine fir. North Central Interior, given the cover type constraint, essentially coincides with the Interior Subalpine and Montane Transition sections of the Cariboo, Prince George and Prince Rupert (Interior) Forest Districts.

General Study Procedure

The contractor is to search the relevant forestry literature and select references for annotation and compilation according to their pertinence to the envisioned guideline publication. The bibliography will include sufficient numbers of references to adequately cover all categories of interest for development of the proposed guidelines. It is anticipated that this may be approximately 650 references.

ADDENDA

The following references were obtained after compilation was well underway. They are not included in the Subject or Author Index.

Boudoux, M. and A. Gonzalez. 1971. Production accélerée au moyen de l'urée de semis de Picea mariana en contenants. Canada, Forestry Service, Laurentide Forest Research Centre, Quebec, Info. Rept. Q-X-F-18. 37 pp.

Black spruce seedlings were grown in wood containers of different dimensions and tested with urea-based nutrient solutions of different concentrations. Marked interactions were observed between growth of seedlings, dimension of container and nitrogen concentration. Under certain conditions, urea accelerated growth rate by 100% but mortality occurred at high urea concentrations.

K.W. Picea mariana (black spruce), containers, fertilization, nitrogen, seedling growth, seedling mortality, seedlings, urea.

Mitchell, D.L., D. Hocking and W.C. Kay. 1971. Reforestaticn with tree seedlings grown in extruded peat cylinders. Part 1. Mechanical aspects of the process. American Society of Agricultural Engineers, Paper 71-169. 17 pp.

Peat is compressed and extruded as a continuous cylinder for seedling containers. Construction of equipment, factors influencing production rates, extrusion performance with various peats, and preliminary economic evaluation of the process are discussed.

K.W. container production, containers, economics, seedling production.

Moden, W.L. Jr. and D.W. Works. 1971. Container seedlings - minus the container. American Society of Agricultural Engineers, Paper 71-170. 6 pp.

An extruded soil media tube has been used as a container for conifer seedling transplants. First year survival data has indicated this container concept may be the answer for future container plantings.

K.W. containers, seedling production, seedling survival.

Tinus, R.W. 1971. A greenhouse nursery system for rapid production of container planting stock. American Society of Agricultural Engineers, Paper 71-166. 17 pp.

A highly automated greenhouse container system has been built to achieve maximum growth by optimizing temperature, light, water, mineral nutrients, CO_2, symbionts, and pest control. Its unusual structure, cost, and operation from November 1970 to June 1971 are described.

K.W. containers, economics, greenhouses, planting stock, seedling production.

Walters, J. 1969. Precision sowing of forest tree seed for container planting. American Society of Agricultural Engineers, Paper 69-604. 6 pp.

The need for machines capable of precision sowing of forest tree seed is outlined against the background of the present status of container planting. Recent attempts to develop equipment for precision sowing of forest tree seed into containers are described.

K.W. container planting, mechanized seeding, seeding.

Walters, J. 1971. Aerial planting of tree seedlings. American Society of Agricultural Engineers, Paper 71-173. 8 pp.

The economical, mechanical, and biological advantages of planting tree seedlings from aircraft are discussed on a theoretical basis. Container and fin design is discussed and small scale planting experiments from balloon, helicopter, and fixed wing aircraft are described.

K.W. aerial planting, artificial regeneration, planting, planting methods, seedling survival.

Works, D.W. and R.J. Boyd, Jr. 1971. Using infrared irradiation to decrease germination time and to increase percent germination in various species of western conifer trees. American Society of Agricultural Engineers, Paper 71-312. 10 pp.

Infrared irradiation of seeds can be an effective treatment for western white pine, ponderosa pine and others to break "hard seed" dormancy. An optimum treatment does not injure the seed nor reduce viability during storage.

K.W. irradiation, seed, seed dormancy, [Pinus monticola, Pinus ponderosa].

ADDENDA, cont'd.

White, D.P. and G. Schneider. 1971. A soilless regeneration system for growing coniferous seedlings. American Society of Agricultural Engineers, Misc. Publ. 1. 11 pp.

Discusses use of containers for artificial regeneration. The principle advantage of soilless containers over tubes is that the container functions as the growing medium and consequently root development is near natural.

K.W. artificial regeneration, container type, containers, economics, root growth, seedling survival.