INFLUENCES OF INITIAL SPACING UPON FOREST PRODUCTION

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by

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TABLE OF CONTENTS

INTRODUCTION

As planting as a method of artificial regeneration becomes increasingly prevalent, there will occur an increasing demand for knowledge concerning the influence of initial spacing of seedlings upon subsequent growth patterns and wood production.

This bibliography facilitates retrieval by forest workers of information concerning these influences. While the bibliography specifically seeks to serve those concerned with planting in the Pacific Northwest, it has relevance for most other temperate areas of the world.

The bibliography was compiled following intensive searches through government and university libraries. It includes all available published and unpublished literature from the temperate regions of the world, up to February, 1974. Where doubt existed as to a publication's relevance, it was included. Those using the bibliography can best decide such an article's utility.

Titles occur only once in the bibliography and are arranged in alphabetical order by author. Key wording, an extensive subject index and a species index ensure that information is readily retrieved by the user. Each reference is keyworded for its major and minor information content. Most articles are abstracted. However, those of a more general nature are only annotated. No annotation or abstract is given where the publication or an abstract thereof could not be obtained, or where the title itself provides adequate information. Some articles, especially from foreign sources, were seen only in abstract. These are indicated by the abbreviation ABSTR., followed by a citation to the title, volume, and page or abstract 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 verbotion. The contributions of Biological Abstracts and Forestry Abstracts (indicated by B.A. and F.A. respectively) are gratefully acknowledged.

The information in this bibliography is made more accessible by cross referenced indexes to subjects, species and authors. The keywords provide the basis for the subject index and cover a wide range of the effects of various initial spacings. Judicious use of the subject and species indexes allows rapid access to information on specific topics.

BIBLIOGRAPHY

1. Anon. 1906. [Dense or open plantations?] Forestry Quarterly 4:48.

Review of article (1905, Zeitschrift für Forst-und Jagdwesen, (Apr.):227-239 referring to the tendency of using fewer individuals per acre when planting or sowing. In sowing, only one-fourth the amount of seed is now used. Practical reasons for this have not been found and advantages appear doubtful. Sparse planting is shown to be unnatural judging by the lack of density of young growth.

K.W. initial spacing, planting density.

2. Anon. 1909. [Dense or open plantations] J. For. 7:202-203.

Reviews article by Dittmar (1909, Zeitschrift für Forst-und Jadgwesen (Jan):34-48) advocating return to use of larger quantities of seed and plants in plantations. Results from both dense and open positions show better development occurred in the open than in the denser position in the nursery.

K.W. Picea sp. (spruce), Pinus sp. (pine), initial spacing, planting density.

3. Anon. 1911. Planting Distance. Quarterly Journal of Forestry 5:226-231.

K.W. initial spacing, planting density.

4. Anon. 1915. [Current forestry problems] Forestry Quarterly 13:387-389.

Reviews article by Borgman (1915, Tharandter Forstliches Jahrbuch 66:129-154) on various methods of cultivating spruce, especially concerned with the influence of initial spacing. Experimental data indicates that a decrease in numbers under spacing improves results. For normal spruce sites, wide spacing may not be advantageous with early and severe thinnings. Notes that basal area is not a reliable basis for judgement of production.

K.W. Picea sp. (spruce), growth increment, initial spacing, thinning, thinning intensity.

5. Anon. 1918. [Current problems in forestry] J. For. 16:464.

Reviews article (1915, Tharandter Forstliches Jahrbuch, 66:129-215) on spruce spacing trials. Greatest total volume was reached at 2 3/4 ft., greatest value at 4 1/2 ft, and greatest timber wood production at 3 1/3 ft. Height and diameter growth and shaft form were best in wider more open spacings. (Also reviewed in Forestry Quarterly 13(3):387-389).

K.W. Picea sp. (spruce), basal area growth, diameter growth, height growth, initial spacing, tree form, volume growth, wood production.

6. Anon. 1940. Fiftieth annual report, Jan. 1 to Dec. 31, 1939. of the Agricultural Experiment Station of the Alabama Polytechnic Institute pp. 30-32. (ABSTR. F.A. 4:27).

   Of a number of spacing distances tested in the planting of slash and loblolly pine, it was found that 6x6' spacing best fulfilled the requirement for an adequate number of trees from which to select about 150 vigorous, well formed trees per acre as a final crop.

   K.W. Pinus elliottii (slash pine), Pinus taeda (loblolly pine), initial spacing, wood production.

7. Anon. 1945. New Zealand State Forest Service: annual report of the Director of Forestry for the year ended Mar. 31, 1945. p. 2.

   Pinus radiata should not be planted at 8'x8' spacing on pumice lands, but at a closer interval. It should be managed on at least a 40 year cycle and some stands on as much as a 70 year rotation.

   K.W. Pinus radiata (radiata pine), forest management, initial spacing, rotation, soil.

8. Anon. 1951. [The spacing of poplar plantations] Action For. Pisc. 160:1-2. (ABSTR. F.A. 12:2907).

   A discussion of the various biological and economic factors involved in the choice of spacing.

   K.W. Populus sp. (poplar), initial spacing.

9. Anon. 1953. Free growth experiments. Directorate of Forestry, Queensland, Rept. 1952/1953. p. 9. (ABSTR. F.A. 15:3532).

   Gives a table showing number of stems/acre no longer free growing at various ages, for loblolly pine, slash pine and Araucaria. The Araucaria enters the zone of suppression at a later age than the other two species. The normal planting spacing of 8'x8' or 9'x8' cause all three species to enter the zone at a very early age.

   K.W. Araucaria cunninghamii, Pinus elliottii (slash pine), Pinus taeda (loblolly pine), initial spacing, suppression, vegetative competition.

10. Anon. 1954. Initial espacements. Dept. Forestry, South Africa, Rept. 1952/1953. p. 13. (ABSTR. F.A. 16:4050).

    A comparison was made between planting at 7'x7' plus thinning at 7 years from 890 to 300 stems/acre, with thinning of a 9'x9' planting at the same age. The loss in mean diameter growth in the closer spacing was more than compensated for by the more rapid growth following the heavier thinning, this yielding an additional 300 ft.^{3} /acre of pulpwood without any sacrifice in timber production.

    K.W. Pinus caribaea (slash pine), diameter growth, initial spacing, thinning, thinning intensity, wood production.

11. Anon. 1954. Silvicultural research: initial spacing. New Zealand Forest Service, Forest Research Note 1(11):6. (ABSTR. F.A. 16: 1964).

To systematize the thinning of stands with different initial spacing, the criterion of relative spacing (distance between trees x 100/height of stand) has been adopted. A detailed investigation showed importance of thinning intensity combined with stand maintenance between upper and lower limits, eg. making 50% thinnings and keeping stand between 20 and 30% relative spacing at a mean of 25%.

K.W. initial spacing, silviculture, spacing, thinning, thinning intensity.

12. Anon. 1956. Effect of initial spacing on growth of Pinus radiata. Forestry and Timber Bureau, Australia, Rept. 1955. p. 29. (ABSTR. F.A. 18:2806).

After 15 years study of radiata pine growth at different initial spacings, it was concluded that: although total volume/acre is a rectilinear function of spacing, a quadratic equation is indicated for the regression of volume to 4 in. u.b/acre on spacing, with a probable trend towards a rectilinear relationship as age increases; the straight line regression of taper on spacing may be merely a corollary of that of mean dbh on spacing; current annual increment of b.a. is not independent of b.a./acre except for a brief period, between 12 and 14 years, when the slope of this regression is reversing.

K.W. Pinus radiata (radiata pine), basal area growth, initial spacing, taper, volume growth.

13. Anon. 1956. The effect of very close initial spacing on the growth of Pinus radiata. Forest and Timber Bureau, Australia, Rept. 1955. p. 25. (ABSTR. F.A. 18:2805).

One half of an old nursery was thinned in 1940, 1943, and 1952. The unthinned half originally carried 6000 trees/acre. Volume production of thinned plots (including thinnings) as measured in 1955 as greater than that of the unthinned plot, but not significantly so. The dbh of the 300 largest trees/acre averages 11.8"in the thinned and 9.9"in the unthinned plot.

K.W. Pinus radiata (radiata pine), diameter growth, initial spacing, thinning, volume growth.

14. Anon. 1959. [Early regulation of spacing in practice and research]. Norsk Skogbr. 5(19):522-524, 527. (ABSTR. F.A. 21:1784).

Describes stand regeneration practices being carried out in Norway. Normally, 1-2 plants were removed for each one left. Leader increment on an area treated in 1954 at 11-13 years was below that of untreated controls for the first two growing seasons and well above it thereafter. This abnormally high increment is expected to decrease to normal within a few years.

K.W. Picea sp. (spruce), economics, height growth, regeneration, spacing, thinning.

15. Anon. 1960. [Spacing trials with spruce and provenance trials with pine laid out by the Skogsforskningsinstut at Frösö, Jutland.] Norrlands SkogsvForb. Tidskr. 1960(4):429-459. (ABSTR. F.A. 22:3056).

A spacing trial for spruce was set out in 1916 using 3m, 2m and 1.5m spacings. Value per ha in 1956 was greatest for 2m spacings.
K.W. Picea sp. (spruce), economics, initial spacing, wood production, wood value.

16. Anon. 1962. Initial planting espacements. Forestry Dept., Kenya, Rept. 1961. p. 14. (ABSTR. F.A. 24:2002).

Six pine and three cypress species were planted in 1951 at initial spacings of 6x6, 7x7, 8x8, and 9x9 ft. and left for 10 years unthinned and unpruned. It is demonstrated that the 6x6 ft. spacing does not result in self pruning, has no significant effect on height growth and definitely reduces diameter increment.
K.W. Cupressus sp. (cypress), Pinus spp. (pines), diameter growth, height growth, initial spacing, self pruning.

17. Anon. 1968. [Spacing in forest plantations] Dům Techniky Československé Vedecko-technické Společonosti, Ceske Budějovice. 123 pp. (ABSTR. F.A. 31:4442).

Contains papers on problem of spacing in plantations in Cechoslovakia.
K.W. Picea abies (Norway spruce), initial spacing, symposium.

18. Anon. 1971. [Proceedings of the first Argentine Forest Congress - 6 to 11 October 1969 Session A-III.] Servicio Nacional Forestal, Buenos Aires. pp. 177-226. (ABSTR. F.A. 33:4393).

K.W. initial spacing, planting density, symposium.

19. Abetz, P. and O. Merkel. 1968. [Branch thickness and stem eccentricity in Norway spruce line plantings]. Allgemeine Forst-und Jagdzeitung 139(6):138-145. (ABSTR. F.A. 30:567).

Studies 15 stands of Norway spruce (60-70 years old), originally spaced at 2-4 m within and 0.8-1.2 m between rows. Stem eccentricity showed no relationship to initial spacing, but appeared dependent on wind conditions. There was no significant difference in thickness of the 5 thickest branches on the lower 10 m of the stem between those parallel to and at right angles to the rows.
K.W. Picea abies (Norway spruce), branching, branch thickness, initial spacing, wind.

20. Adams, W.R. Jr. 1928. Studies in tolerance of New England forest trees. VIII - Effect of spacing in a jack pine plantation. Vermont Agric. Expt. Sta., Bull. 282:1-55. (ABSTR. F.A. 3:15136).

Root competition for available mineral matter and soil moisture in a plantation of Pinus banksiana with 2, 4, 6, and 8' spacing influenced development of individual trees. Average diameter growth increased with increased spacing but there was little difference in height growth for 4', 6',and 8' spacings. Aids to decision making with respect to thinning are given.

K.W. Pinus banksiana (jack pine), diameter growth, foliar nutrients, height growth, initial spacing, thinning, vegetative competition.

21. Adema, K. 1968. [An exploitation survey of poplar plantations] Populier, Wageningen 5(1):4-6. (ABSTR. F.A. 29:3831).

Gives tables of expenditure, yields and profits of plantations spaced at 4x4, 5x5, 6x6, 7x8 m (having different rotation periods) concluding that in the Netherlands, 4x4 and 6x6 m gave best financial results.

K.W. Populus sp. (poplar), economics, initial spacing, wood yield.

22. Anderson, M.L. 1947. A method of forest planting by groups. Journal of the Oxford University Forestry Society 2:63-66. (ABSTR. F.A. 9:1552).

Advocates planting trees in dense groups separated by unplanted areas. It is felt that this method has definite promise in growing broadleaved species with coniferous nurses and that it might be useful on poor ground.

K.W. fire, initial spacing, site preparation.

23. Anderson, M.L. 1951. Spaced group-planting and irregularity of stand structure. Empire Forestry Review 30(4):328-341. (ABSTR. F.A. 13:2091).

Results of a system of planting by dense widely spaced groups, established in England and Scotland in 1929-1932, are very promising. It is thought that such a system will lead to establishment of stands irregular in composition and age.

K.W. initial spacing, stand establishment.

24. Anderson, M.L. 1953. Spaced group planting. Unasylva 7(2):55-63. (ABSTR. F.A. 15:241).

K.W. initial spacing, planting density.

25. Ando, T. 1968. [Ecological studies on the stand density control in even-aged pure stand]. Forest Experiment Station, Meguro, Tokyo, Bull. 210:1-153. (ABSTR. F.A. 30:564).

A comprehensive study of mathematical models expressing relationships between initial planting density and mean height, basal area, and stem volume. Yield index curves and tabular thinning schedules are presented for several species.

K.W. basal area growth, growth curves, height growth, initial spacing, stand density, thinning, volume growth.

26. Ando, T. et al. 1968. [Studies on the system of density control of sugi (Cryptomeria japonica) stand]. Forest Experiment Station, Meguro, Tokyo, Bull. 209:1-76. (ABSTR. F.A. 30:563).

A comprehensive study of four methods of managing sugi, dealing with planting density, thinning intensity, and rotation. Details of each are given, but no statement is made as to which method is best.

K.W. Cryptomeria japonica (sugi), forest management, initial spacing, rotation, thinning, thinning intensity.

27. Arend, J.L. 1955. Development of closely spaced red pine, white pine, and Norway spruce after 40 years. U.S. Dept. Agric., Lake States Forest Experiment Station, Tech. Note 439. 1 p.

Measurements on unthinned red pine, white pine, and Norway spruce, 41 years after planting out at about 0.5' x 2.5' showed that growth of the two pines had been similar and that of spruce rather less. Self pruning has not been very effective. Damage to spruce by rabbits was severe.

K.W. Picea abies (Norway spruce), Pinus resinosa (red pine), Pinus strobus (white pine), growth increment, initial spacing, rabbits, self pruning, wildlife.

28. 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.

A very detailed description of site ecology and the establishment of the study in 10-12 year old lodgepole pine is given. Spacings of 3.5, 5, 7 and 10' radius are planned. Both single and double cleaning regimes will be used. Within two years, crown closure was evident on 3.5 and 5' radius plots , so these were cleaned to 7.5' and 10' radius. No significant differences in tree development are yet attributable to cleaning regimes. Also reported 1965.

K.W. Pinus contorta (lodgepole pine), cleaning regimes, growth increment, site ecology, spacing, thinning, thinning intensity.

29. Atanasov, B. 1963. [Investigations on the age of canopy closure in Pinus nigra plantations, with regard to choice of optimum planting density]. Isv. Inst. Gorata Bŭlg. Akad. Nauk., Sofia 12:147-171. (ABSTR. F.A. 25:3501).

    When planted on cultivated strips 1.5 or 2m apart, plants should be 0.7 m apart on site classes I and II (closer on poorer sites) in protective afforestation and 1m apart in commercial afforestation. When planted on cultivated patches 0.7 m x 1 to 1.0 x 1.0 m, and 1.5 m apart, 3 seedlings per patch should be planted on better, and 5 per patch on poorest site classes.

    K.W. Pinus nigra (Corsican pine), initial spacing, planting density.

30. Atansov, B. 1964. [Investigations on the age of canopy closure of Pinus sylvestris plantations in connection with the choice of initial planting density] Gorskostop. Nauka 1(6):19-29. (ABSTR. F.A. 27:3863).

    K.W. Pinus sylvestris (Scots pine), canopy closure, planting density.

31. Baldwin, H.I. 1958. Growth of red pine at different spacings. Second Report. Fox Forest Notes 70. 2 pp. (ABSTR. F.A. 20:4517).

    Though total production through 23 years after planting was greatest in densest stands (4'x4'), and least in most widely spaced (8'x8'), the latter had the highest mean dbh and greatest number of trees of 8" dbh/acre. Dominant heights were about equal.

    K.W. Pinus resinosa (red pine), diameter growth, height growth, initial spacing, stand density, wood production.

32. Baldwin, H.I. and B.S. Tropp. 1948. Effect of spacing on growth of a Norway pine plantation. Fox Forest Notes 35. 2 pp. (ABSTR. F.A. 10:2566).

    Wide spacing or early thinning is necessary to maintain diameter growth in Pinus resinosa plantations. Height growth was not affected by spacing in the first decade after planting. Better form might be produced at closer spacing but costs of establishment are halved by using 8'x8' spacing rather than 6'x6' spacing.

    K.W. Pinus resinosa (red pine), diameter growth, economics, height growth, initial spacing, thinning, tree form.

33. Bartoli, M. 1971. [First results (at 11 and 15 years) of a planting density experiment on Douglas fir]. Revue Forestiere Française 23(6):605-608. (ABSTR. F.A. 34:272).

    Spacing did not affect height of dominants after 15 years.

    K.W. Pseudotsuga menziesii (Douglas fir), dominants, height growth, initial spacing.

34. Bartoli, M. and N. Decorert. 1971. [Spacing of plantations. Review and first results of an experiment with Douglas fir]. Ann. Sci. For. 28(1):59-81. (ABSTR. F.A. 33:2517).

Douglas fir was planted at spacings of 1.5 x 1.5 m, 2.0 x 2.0 m, 2.5 x 2.5 m, and 3.0 x 3.0 m in 1955. When measurements were made in 1966, there was no evidence that spacing affected height growth or mortality among trees, but it certainly affected diameter, basal area, volume, stem form, and mortality of low branches.

K.W. Pseudotsuga menziesii (Douglas fir), basal area growth, diameter growth, height growth, initial spacing, seedling mortality, tree form, volume growth.

35. B'Chvarov, D. and P. Petkov. 1972. [Initial density in Pinus nigra plantations in the E. Rhodope mountains] Gorskostopanska Nauka 9(3):25-34. (ABSTR. F.A. 34:3397).

Gives data on tree classes and dimensions in light plantations in Bulgaria aged 17-21 years and having 1100-5880 trees/ha. Mean dbh was related to density as follows, $y = (12{,}600/x) + 5.74$. The number of low quality stems decreased with increasing density.

K.W. Pinus nigra (corsican pine), diameter growth, planting density, stand density, tree quality.

36. Bechtold, J. 1967. [Spacing in Scots pine plantations] Allgemeine Forstzeitschrift 22(11/12);201-202. (ABSTR. F.A. 28:5590).

A general discussion, strongly advocating and listing the advantages of 1 m square planting, ie. 10,000 plants/ha.

K.W. Pinus sylvestris (Scots pine), initial spacing.

37. Becking, J.H. 1958. [Plant spacing in poplar stands] Ned. Bosb. Tijdschr. 30(8):241-243. (ABSTR. F.A. 20:461).

Value of poplar plantations spaced at 4x4 m and 4x8 was roughly the same after planting costs had been deducted, but the 4x4 m spacing is better as regards properties of the final timber, since there is more opportunity for selection in thinning. In addition the thinnings provide pulpwood.

K.W. Populus sp. (poplar), economics, initial spacing, planting costs, thinning, wood quality.

38. Beda, G. 1968. [The choice of spacing with special reference to Norway spruce] Mitt. Schweiz. Forstl. Versuchsw. 4(1): 80 pp. (ABSTR. F.A. 30:2255).

A theoretical and literature study of the effect of spacing on productivity for which no satisfactory long term data exist. Various specific matters are discussed and recommendations made. For the Swiss plateau a rectangular initial spacing of 2 m x 1 m is recommended.

K.W. Picea sp. (spruce), growth increment, initial spacing, literature review, wood production.

39. Bennett, F.A. 1960. Spacing and early growth of planted slash pine. J. For. 58(12):966-967.

Comparison of eight spacings of old-field planted slash pine at seven years of age showed that competition of a significant degree developed during the fifth year at a density of 500-550 trees/acre, with the effect of stand density intensifying in the 6th and 7th years. Diameter growth is not correlated with spacing configuration (square v.s. rectangular) and height growth is not correlated with stand density. The crown ratio percent after 7 years is in direct proportion to stand density.

K.W. Pinus elliottii (slash pine), diameter growth, height growth, initial spacing, spacing configuration.

40. Bennett, F.A. 1963. Growth and yield of planted conifers in relation to initial spacing and stocking. Proc. Soc. Amer. Foresters Meeting, 1962. pp. 22-26.

Relative growth and yield data for 6 species including southern pines and Douglas fir shows a remarkable similarity for all species in relation to spacing. At age 20-35, the yield in the round from an initial 200 trees/acre was > 50%, and that from 600 trees 90-98% of that from 1000 trees/acre. For most species m.a.i. cullminates at 18-20 years.

K.W. Pinus spp (pines), Pseudotsuga menziesii (Douglas fir), growth increment, initial spacing, planting density, wood yield.

41. Berenhauser, H. 1971. [Spacing in plantations of Pinus elliottii and Pinus taeda] Floresta 3(2):21-27. (ABSTR. F.A. 33:4394).

Makes recommendations on initial spacing and tending of Brazilian plantations of slash pine and loblolly pine for pulpwood and sawtimer production.

K.W. Pinus elliottii (slash pine), Pinus taeda (loblolly pine), initial spacing, tending, wood production.

42. Berry, A.B. 1964. Development of red pine planted at seven spacings. Canada, Dept. Forestry, Petawawa Forest Experiment Station, Chalk River, Mimeo 64-P-11. 18 pp.

In 1953, red pine was planted at various spacings from 4'x4' to 14'x14'. Results to date show that: 1) time of crown closure depends on spacing and rate of growth; 2) form of the trees at closer spacings has been affected by density; 3) diameter growth of closely spaced trees is retarded, and 4) basal area and volume at this age are directly related to number of trees per acre with the exception of the 4'x4' stand.

K.W. Pinus resinosa (red pine), artificial regeneration, crown closure, diameter growth, growth increment, initial spacing, stand density, tree form, volume growth.

43. Berry, A.B. 1969. Development of red pine at various spacings during first 14 years after planting. Canada, Forestry Branch, Petawawa Forest Experiment Station, Chalk River, Internal Rept. PS-11. 27 pp.

In 1953, red pine plantations were established at spacings of 4'x4' to 14'x14'. Basal area, total volume and foliage weight were closely linked to spacing, as were individual tree size, taper, form class, and onset of recession of live crown.

K.W. Pinus resinosa (red pine), basal area growth, foliage weight, growth increment, initial spacing, taper, tree form, volume growth.

44. Berry, A.B. 1970. Spacing of red pine affects upper stem and crown growth. Bi-Monthly Research Notes 26(5):50-51. (ABSTR. F.A. 32:4234).

Measurements in a 16 year old red pine stand at Petawawa, initially spaced at 4'x4' - 14'x14', show that the more closely spaced trees tend to have smaller diameters and narrow crowns in the free growing top than occur in corresponding whorls of trees at wider spacings, although the reduction in radial growth is less in the part of the stem above the point of contact between the crowns than in the part below.

K.W. Pinus resinosa (red pine), crown growth, diameter growth, initial spacing, tree form.

45. Bickerstaff, A. [1942]. The growth and development of red pine plantations: the effect of spacing; establishment report Project P-98. Canada, Dominion Forest Service, Unpubl. MS. n.p.

K.W. Pinus resinosa (red pine), growth increment, initial spacing, tree development.

46. Bondarenko, N.Y. and L.V. Eterevskoya. 1972. [The spacing of Scots pine in plantations]. Lesnoe Khozyeystvo 1972(11):33-34. (ABSTR. F.A. 34:4549).

Describes an investigation of growth of plantations 8 years old with initial tree spacings of 1.5 x 0.7, 2.5 x 0.6 and 3.0 x 0.5 m, on sandy soil. Results, based on root growth, indicate that 2.5 x 0.6 m is the best spacing.

K.W. Pinus sylvestris (Scots pine), initial spacing, root growth, soil.

47. Bonnemann, A., J. Huss, and H. Warth. 1971. [Initial spacing of European larch] Forstarchiv 42(6):116-122. (ABSTR. F.A. 33:643).

Though basal area, volume and stem form at 22 years were best for larch planted at 1 x 1 m spacing, and height only slightly inferior, this spacing is not considered satisfactory because diameters were small. With 3 x 3 m spacing, stem form and branching habit were unsatisfactory. Spacing of 1.5 x 1.5 m to 2 x 2 m are though best.

K.W. Larix sp. (larch), branching, diameter growth, height growth, initial spacing, tree form, volume growth, wood quality.

48. Borgman. 1915. Forstliche Tagesfragen. Tharandter Forstliches Jahrbuch 66:129-154.

Discusses various methods of cultivating spruce, especially the influence of initial spacing. (Reviewed 1915, Forestry Quarterly 13:387-389).

K.W. Picea sp. (spruce), growth increment, initial spacing, thinning, thinning intensity.

49. Børset, O. 1947. [Choice of plantation spacing]. Tidsskr. Skogbruk 55(12):315-332. (ABSTR. F.A. 10:1019).

Reviews advantages of close and wide spacings. Agrees with Klem (q.v.) that spacings should be increased in most cases. A spacing of 2 m should be applicable on a large scale and in special cases one of 2.5-3.0 m might be justified. Klem, in an answer, states that spacings of 1.6-1.7 m, or on good sites 2.0 m, are as much as can be recommended.

K.W. Picea abies (Norway spruce), economics, growth increment, initial spacing, wood production.

50. Box, B.H., N.E. Linnartz and M.B. Applequist. 1964. Univ. La State, La Forestry School, Forestry Note 60. 2 pp. (ABSTR. F.A. 27:2097).

Loblolly pine was planted at spacings of 6'x6', 8'x8', 9'x9', 10'x10', and 12'x12'. After 11 years, the greatest volume per acre was found at the closest spacing, and the largest volume per tree at the widest. Heavy branching and the need for artificial pruning developed at the wider spacings.

K.W. Pinus taeda (loblolly pine), branching, initial spacing, pruning, volume growth.

51. Braastad, H. 1968. [Interesting comparisons of yield in sparse and dense spruce plantations] Norsk. Skogbr. 14(9):209-212. (ABSTR. F.A. 30:566).

Measurements were made between 1923 and 1967 in two stands: one planted at 5.5 m x 3 m and having 508 trees/ha in 1967;and one sown, having 5164 trees/ha in 1923 reduced by thinning to 575 trees/ha in 1962. Total yield at 50 years (1968) on the planted stand was 65% of that on the sown stand, but if yield of first thinning on the sown stand (0.5 m^3/tree) was disregarded, yield of planted stand was 79.3% of that of the sown stand. Knot diameter and number of knots per tree was greater on planted trees.

K.W. Picea sp. (spruce), initial spacing, stand density, wood quality, wood yield.

52. Braastad, H. 1970. [A spacing experiment with Picea abies] Medd. Norske Skogforsøksv. 28(5) No. 105. 295-329. (ABSTR. F.A. 32: 5952).

For Norway spruce planted at spacings of 1.25, 1.75, and 2.25 m in 1936 and thinned in 1970, it cannot be concluded that spacing caused differences in height increment. Volume yield at 34 years of age was 16-20% less on plots with widest than on those with closest initial spacing. Yield of merchantable wood from each plot differed only slightly, the differences being accounted for by trees of small dimensions.

K.W. Picea abies (Norway spruce), height growth, initial spacing, thinning, volume growth, wood yield.

53. Braathe, P. 1952. [The effect of plant spacing on stand development and yield in Norway spruce forests] Medd. Norske Skog-forsøksv 11(2) No. 39:425-469. (ABSTR. F.A. 15:3531).

Plots were laid out in 44-48 year old stands originally planted at various spacings (1.25 x 1.40 m - 3.5 x 3.5 m). By the time of investigation, several thinnings had reduced difference in numbers on different plots. There was no real evidence of variation of height with spacing. The plots with the widest spacings showed the highest crown ratio. Diameter increments remained high in all plots until stands closed. Thereafter there was little difference in diameter growth between spacings. Greatest total volume production was on densest plots but much of this was small. Taper was least on closely spaced plots.

K.W. Picea abies (Norway spruce), diameter growth, economics, height growth, initial spacing, taper, tree form, volume production.

54. Bradley, K.F. 1972. E.P. 534: Spacing trial of Douglas fir. B.C. Forest Research Review. pp. 58-59.

2+0 Douglas fir seedlings were planted at spacings of 6, 8, 12 or 15' on a 30% slope in various plots. After five years (1964) much variation in height due to grouse browsing was apparent. Planting costs are analyzed with 12' x 12' spacing showing lowest cost. After another eight years, it became apparent that there is a gradual decline in height growth as slope increases. Spacing had no apparent influence on height growth. Also reported, 1959, 1964, co-author, G.C. Warrack, 1959, 1964.

K.W. Pseudotsuga menziesii (Douglas fir), height growth, initial spacing, planting cost, slope.

55. Bradley, K.F. 1972. E.P. 429: Spacing trials of pure and mixed coastal species. B.C. Forest Research Review. p. 58.

Douglas fir, western hemlock and grand fir were planted in pure and mixed stands at spacings of 9, 12 and 15' over a few years period, survival was poor especially for hemlock which was eliminated from the trials. Eight years after planting, Douglas fir shows best height growth and vigor in all plots. Height growth, leader growth and survival tabulated for all plots. Also reported, 1959, 1964. Co-author, G.C. Warrack, 1959, 1964.

K.W. Abies grandis (grand fir), Pseudotsuga menziesii (Douglas fir), Tsuga heterophylla (western hemlock), height growth, initial spacing, seedling survival.

56. Bramble, W.C., H.N. Cope and H.H. Chisman. 1949. Influence of spacing on growth of red pine in plantations. J. For. 47:726-732.

Growth of red pine spaced 5' x 5', 6' x 6', 6' x 8' and 10' x 10' in plantations was studied for a 25-year period. The greatest diameter growth was observed in the two widest spacings and an increase in d.b.h. was also noted, being greatest in the 10' spaced plots. Height was similar for all spacings. A lower quality wood is produced in the wider spacings, but can be improved by early pruning. There were no signs of deterioration in the wider spaced stands up to 25 years of age.

K.W. Pinus resinosa (red pine), diameter growth, growth increment, height growth, initial spacing, pruning, wood quality.

57. Byrnes, W.R. and W.C. Bramble. 1955. Growth and yield of plantation grown red pine at various spacings. J. For. 53:562-565.

Third in series of reports, describes conditions of red pine plots spaced 5'x5', 6'x6', 6'x8' and 10'x10'. Diameter growth was significantly higher in 6'x8' and 10'x10' plots. In the various spacings height growth seemed related up to the 16th year, then up to the 25th year wider spacings gave a greater increase in height growth. In 30 years 10'x10' spacings yielded greatest volume, more than double that of the 6'x8' spacing.

K.W. Pinus resinosa (red pine), diameter growth, height growth, initial spacing, volume growth, wood yield.

58. Cersosimo, F.J. and J. Alonso. 1962. [A study of planting distances for Eucalyptus tereticornis] Rev. Invest. For., Buenos Aires 3(1):41-94. (ABSTR. F.A. 26:2160).

Presents detailed results of measurements in 1952, 1954, and 1960 of stands established by planting one year plants at 1.5'x 1.5', 2.0' x 2.0', 2.0' x 3.0' and 3.0' x 3.0' in 1946. It is probably wiser to use wider spacings. Growth compared favourably with that of the species in its native habitat in Australia.

K.W. Eucalyptus sp. (Eucalyptus), growth increment, initial spacing.

59. Chrosciewicz, Z. 1971. The growth response of young jack pine to moderate and extreme stand densities. Bi-Monthly Research Notes 27(1):6.

Jack pine was established by slash scattering to produced a 10 year stand of moderate density (4,800 trees/acre), and by seeding to produce an extreme density of 388,700 trees/acre. Average diameters and heights of stand at 10 years were inversely related to existing stand densities. Moderately dense stand consisted mainly of dominants and co-dominants while dense stand showed strong signs of suppression.

K.W. Pinus banksiana (jack pine), diameter growth, height growth, seeding density, stand density, suppression.

60. Clark, M.B. 1970. E.P. 689- Douglas fir spacing trial, Kamloops forest District. B.C. Forest Research Review. pp. 77.

Initiation of a spacing experiment is described. Seedlings have shown a very high mortality and trials may have to be abandoned.

K.W. Pseudotsuga menziesii (Douglas fir),initial spacing, mortality.

61. Clark, M.B. 1971. E.P. 690- Western larch spacing trials, Kamloops Forest District. B.C. Forest Research Review. pp. 74-75.

240 larch were planted in 1967 at 6, 8, 12 and 16 foot square spacings. Mortality was high and the project abandoned.

K.W. Larix occidentalis (western larch), initial spacing, mortality.

62. Clark, M.B. 1972. E.P. 661- Engelmann spruce spacing trials in the Kamloops Forest District. B.C. Forest Research Review. pp. 60.

2+2 Engelmann spruce were established at 6, 8, 10 and 12 foot square spacings. However, fire damaged the site 5 years later and the study was discontinued. (Also reported in 1967).

K.W. Picea engelmannii (Engelmann spruce), fire, initial spacing.

63. Coates, H.C. 1972. E.P. 660- Species and spacing trials in the montane transition zone. B.C. Forest Research Review. pp. 59-60.

Final progress report on growth of 1+1 lodgepole pine, 1+1 Douglas fir and 2+1 white spruce seedlings planted at 7, 10 and 12 ft^2 spacings on various soil types. Results are confused by rabbit browsing and later plantings. (Previously reported by J. Revel, B.C. Research Review 1968, p. 74; 1969, p. 81; and 1970, p. 73).

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), browsing, height growth, initial spacing, mortality, rabbits, stand history, soil, wildlife.

64. Constantinescu, N. 1958. [Remarks on poplar growing] Scweiz. Z. Forstw. 109(3):187-193.

Cites examples from Rumanian trials to show that under certain conditions poplars do respond in height and diameter growth to early thinning, and that plantations with close intial spacing, first thinned at 4-5 years and again every 2-3 years, exceed in total yield, those initially widely spaced.

K.W. Populus sp. (poplar), diameter growth, height growth, initial spacing, thinning, wood yield.

65. Cram, W.H. and C.A. Morgan. 1961. Survival and growth of shelterbelt trees at three spacings. Forestry Chronicle 37(2):187-191.

Seedlings of Caragana arborescens, Acer negundo, Ulmus americana, Populus deltoides, and Fraxinus lanceolata were planted in 3 row shelterbelts at spacings of 4', 8', and 16'. Survival of caragana, maple, and ash were not materially influenced by spacing, but that of elm increased from 91 to 100% and of cottonwood from 0 to 25%, as spacings increased from 4' to 16'. Maximum height of caragana and ash was obtained at 8' spacings, while that of maple and elm was obtained at the 16' spacing.

K.W. hardwoods, height growth, initial spacing, mortality, shelterbelts.

66. Cromer, D.A.N. and C.K. Pawsey. 1957. Initial spacing and growth of Pinus radiata. Forestry and Timber Bureau, Australia, Bull. 36. 42 pp.

Draws conclusions from various experiments. Presents detailed statistical analysis of results from these experiments. There is a straight line regression of mean dbh on spacing.

K.W. Pinus radiata (radiata pine), diameter growth, growth increment, initial spacing, stand density, taper.

67. Curro, P., Z. Sertmehmetoğlu, and O. Acar. 1965. [Investigations on the effect of spacing Populus x euramericana cv. 'I-214'] Tek. Yay. Kavok. Araşt. Enst., Izmit No. 2. 19 pp. (ABSTR. F.A. 28:3781).

Cai. of 20 sample trees of 8 year old poplar grown at four spacings. At the widest spacing of 5x8 m, the rotation for maximum rate of volume yield was calculated to be 14.6 years, giving an average yield of 32.5 m^3/ha/year. At the closest spacing of 3x4 m, optimum rotation was 9.9 years and yield 19.8 m^3/ha/year. Wood fibre lengths and length/width ratios were found to decrease significantly with increases in plantation density.

K.W. Populus sp. (poplar), growth increment, initial spacing, rotation, stand density, volume growth, wood yield.

68. Curtis, R.O. and D.L. Reukema. 1970. Crown development and site estimates in a Douglas fir plantation spacing test. Forest Science 16(3):287-301.

Relationships among stem and crown dimensions of Douglas fir were examined 43 years after planting on site IV land at initial spacings of 4'x4' through 12'x12'. Average dbh, height, and crown dimensions of largest trees and of comparable crown classes all increased consistently with increase in initial spacing.
K.W. Pseudotsuga menziesii (Douglas fir), crown growth, diameter growth, height growth, initial spacing, site index, stand density.

69. Dan'šin, I.I. 1966. [Effect of high initial plantation density on the formation of young stands and the growth of Scots pine on the lower Don region] Sborn. Rabot Lesn. Hoz. Vsesojuz. Nauč.-Issled. Inst. lesovod. 51:36-48. (ABSTR. F.A. 29:5577).

Investigations in this droughty region have shown that the best results are achieved with initial densities of 7,000-10,000 plants/ha, but that even very dense stands (37,000 trees/ha at age 12-14) were not only not killed by a series of severe droughts, but indeed still possessed enough well developed trees to form highly productive stands.
K.W. Pinus sylvestris (Scots pine), drought, mortality, planting density, stand development.

70. Dittmar. 1909. [Dense or open planting] Zeitschrift für Forst-und Jagdwesen (Jan):34-48.

Advocates return to the use of larger quantities of seed and plants in plantations. Results from dense and open positions show better development in the open. (Reviewed 1909, J. For. 7:202-203).
K.W. Picea sp. (spruce), Pinus sp. (pine), initial spacing, planting density.

71. Dittmar, O. and E. Knapp. 1964. [The choice of spacing for Scots pine plantations] Sozial. Forstw., Berlin 14(7):210-215. (ABSTR. F.A. 26:564).

Effect of spacing is appraised from various standpoints on basis of various plots established at densities of 6,200 - 40,000/ha. Rectangular planting is highly recommended. In the area discussed, a spacing of 1.4 x 0.4 m is highly recommended for veneer timber.
K.W. Pinus sylvestris (Scots pine), initial spacing, wood production.

72. Doi, K., T. Horiuchi, and M. Okanoue. 1970. [The effect of group planting on the protection of sugi (Cryptomeria japonica) seedlings against cold damage]. Jour. Japanese Forestry Society 52(4):120-125. (ABSTR. F.A. 32:2480).

Spacings with circular plantings were evaluated through November and December with respect to protection of plants from frost damage. At the end of December there was almost 100% survival of 1+1 seedlings in the two innermost circles (mean spacings 0.25 and 0.38 m) and most of the 1+2 seedlings also survived in the third and fourth circles (mean spacings 0.53 and 0.75 m). Outside these limits, however, losses were heavy.

K.W. Cryptomeria japonica (sugi), frost damage, initial spacing, seedling mortality.

73. Dumm, G. 1971. [The effect of initial spacing on branch formation and risk of snow breakage in spruce] Allgemeine Forstzeitschrift 26(8):150-152 (ABSTR. F.A. 32:5953).

Natural reduction of stem numbers, and increase of growing space on the best spruce sites were so rapid that, regardless of initial spacing (1.9 x 1.8 m or 1.5 x 1.5 m), the maximum branch thickness exceeded 20 mm in the first 5 m of stem. At 10 m it averaged 22.6 mm, suggesting that no economically practicable spacing would ensure a maximum branch diameter of 20 mm. Reduction of stem numbers during the first 25 years had been faster for the close spacing. From the point of view of snow breakage, wider spacing appeared to be preferable.

K.W. Picea sp. (spruce), branching, growth increment, initial spacing, snow breakage, [thinning].

74. Echols, R.M. 1960. Effect of growing space on wood specific gravity in loblolly pine. Proc. Soc. Amer. Foresters Meeting, 1959. pp. 140-143.

Loblolly pine was planted at initial spacings of 4'x4', 6'x6', 8'x8' and 10'x10'. At 20 years, light, medium, and heavy thinnings were made in each plot. Some were deferred to 25 years when rest of plots were rethinned. At 20 years there was no significant difference between spacings in wood specific gravity. Diameter growth was greatest at widest spacing and least at closest. During the 10 years following thinning, wood specific gravity did change, greatest gain being in 6'x6' spacing. 8'x8' spacing had highest volume increment.

K.W. Pinus taeda (loblolly pine), diameter growth, growth increment, initial spacing, spacing, thinning, thinning intensity, volume growth, wood density, wood quality.

75. Eklund, B. 1956. [An experiment in sowing and planting pine at different spacings] Medd. Skogsforskn. Inst., Stockholm 36(10); 98 pp. (ABSTR. F.A. 18:1572).

Pine planted in 1906 at various spacings and also patch sown at two different spacings were compared. Mean diameter and mean height increased with wider spacing; b.a. and volume yield markedly decreased, but if self thinned dead wood was excluded, optimum yield at 50 years was obtained from the 1.5 m spacing.

K.W. Pinus sp. (pine), diameter growth, height growth, initial spacing, natural thinning, sowing density, volume growth, wood yield.

76. Enghardt, H.G. 1970. Growth of 40 year planted loblolly pine. Forests and People, Alexandria, La. 20(3):38-41. (ABSTR. F.A. 32:6014).

Board ft. yields were greatest with wide (10'x10') spacing and heavy thinning. Unthinned stands at wide spacing also did well financially. For quality, however, 5'x6' and 8'x8' spacings are better.

K.W. Pinus taeda (loblolly pine), initial spacing, thinning, thinning intensity, wood quality, wood yield.

77. Erteld, W. 1967. [Crown characteristics as indicators of growth potential in young pine stands at various spacings] Sozial. Forstw. 17(8):236-239. (ABSTR. F.A. 29:566).

Scots pine planted at 1 x 1 m had best height, dbh and volume growth after 19 years, but had poorer crown characteristics than those planted at 1.3 x 0.4 m. Good quality stands can be expected from natural regeneration, despite greater stocking density, provided appropriate thinning is carried out.

K.W. Pinus sylvestris (Scots pine), diameter growth, height growth, initial spacing, natural thinning, stand density, stand quality, volume growth.

78. Eversole, K.R. 1955. Spacing tests in a Douglas fir plantation. Forest Science 1(1):14-18.

Records from a 27 year old spacing test plantation of Douglas fir indicate that wide spacing in plantations has little effect on total stem cubic volume in the first 27 years, but greatly increases board foot volume. Average diameter is greatly increased by wide spacing. Wide spacing also produces a taller dominant and co-dominant stand and greater limb size. Planting costs per tree are nearly the same regardless of spacing. In many cases, 10'x10' or 12'x12' spacings are urged.

K.W. Pseudotsuga menziesii (Douglas fir), branching, diameter growth, height growth, initial spacing, planting costs, volume growth.

79. Evert, F. 1971. Spacing studies - a review. Canada, Forestry Service, Forest Management Institute, Inform. Rept. FMR-X-37. 95 pp.

A critical study involving a description and brief evaluation of past and current spacing practices and studies in a few countries having a substantial planting programme. These studies have confirmed that there is an association between the initial spacing of stands and various tree and stand characteristics. From the standpoint of decision making, however, formal spacing studies have contributed few conclusive results. Recommendations are made in an attempt to overcome this problem. A brief review of Canadian spacing studies is presented.

K.W. decision making, forest management, growth characteristics, growth increment, initial spacing, silviculture.

80. Faber, P.J. 1971. [Stand density and development of young pine stands] Ned. Bosb. Tijdschr. 43(5):91-104. (ABSTR. F.A. 33:644).

It is concluded that an initial density of greater than 5000 or less than 4000 plants/ha cannot be recommended and also that it is neither feasible nor necessary to avoid pre-commercial thinnings entirely.

K.W. Pinus sp. (pine), planting density, thinning.

81. Fabricius, L. 1934. Zur frage der pflanzweite. Forstwissenschaftliches Centralblatt 56(2):70-72. (ABSTR. B.A. 9:5670).

A stand of spruce planted about 1830 and spaced 1.8 m x 6 m has about the same volume as neighboring closely spaced stands and the average dbh of the trees is considerably larger (40 cm v.s. 34 cm in 1925). The trees in the open stand are well cleared of lower branches.

K.W. Picea sp. (spruce), branching, diameter growth, initial spacing, volume growth.

82. Fakirov, V. 1972. [Growth and yield of hybrid black poplar plantations planted at various initial densities on drained sites near the Danube] Gorskostop. Nauka, Sofija, 9(2):3-20. (ABSTR. F.A. 34:2845).

Plantations were established at initial spacing of 3x3 to 8x8 m on sites with water table at 1 m. Data for the first seven years showed little variation between clones. Spacings of 4x4 m appeared to be most suitable.

K.W. Populus sp. (poplar), growth increment, initial spacing.

83. Farinatti, A. 1965. [Two techniques or two schools of thought? Some reflections on spacing] Forêt Privée, Paris 42, 43:35-51, 33-39. (ABSTR. F.A. 27:571).

Discusses the advantages and disadvantages of wide and close spacing in conifer plantations, taking into account site conditions, establishment costs, thinning, end products etc, and illustrating the argument by a detailed account of one plantation of each type.

K.W. economics, initial spacing, site conditions, wood production.

84. Fekete, Z. 1955. [A note on the Robinia problem] Erdö 4(1):12-18. (ABSTR. F.A. 18:388).

Wide plantings (2x2 m) of Robinia in Hungary are urged.

K.W. Robinia sp. (acacia), initial spacing.

85. Fernandez, A.E. 1961. [Influence of spacing in the cultivation of Pinus elliottii in the Panama delta] Proc. 1ª Revn. Reg. Conif. Asoc. For. Argent., Buenos Aires. pp. 75-78. (ABSTR. F.A. 24:3613).

Pines were planted at spacings of 2xl m, 3xl m, and 2x3 m. At 6 years of age, volume/ha. was 350 m^3 for 2xl m, 260 m^3 for 3xl m, and 151 m^3 for 2x3 m while dbh averaged 12.9 cm, 14.4 cm, and 15.8 cm. respectively.

K.W. Pinus elliottii (slash pine), diameter growth, initial spacing, volume growth.

86. Filho, O.A.G. 1957. [Increment of Araucaria angustifolia (preliminary note)] Rev. Agric., Pinacisaba 32(2):79-82. (ABSTR. F.A. 21: 3096).

Plots were established 1952 in Brazil at spacings of lxl m, 1.5x 1.5 m and 2x2 m. Measurements made in 1956 showed the following mean diameter increments over 4 years; 31 mm, 35 mm, and 42 mm respectively.

K.W. Araucaria sp. (araucaria), diameter growth, initial spacing.

87. Filho, O.A.G. 1962. [Cultural characteristics of Pinus elliottii. (preliminary note)] Rev. Agric., Piracicaba 37(1):21-23. (ABSTR. F.A. 25:5030).

A spacing of 1.5 x 1.5 m is recommended for slash pine at São Paulo. This spacing in an experimental plot, produced a m.a.i. of 13.225 m^3/ha in 6 years.

K.W. Pinus elliottii (slash pine), growth increment, initial spacing.

88. Filho, O.A.G. 1966. [Spacing of Pinus elliottii] Silvicultura em São Paulo 4/5(4):235-257. (ABSTR. F.A. 29:569).

Concludes that stand density affects diameter growth after the fourth year; that a spacing of 6 m^2/tree will produce thinnings for pulpwood during the first ten years; for pulpwood stands on a short rotation, allowing 6 m^2/tree, no thinnings are necessary and the stand can be clear felled, and for longer rotations, successive thinnings are necessary.

K.W. Pinus elliottii (slash pine), diameter growth, initial spacing, stand density, wood production.

89. Filho, O.A.G. 1967. [Pinus caribaea var bahamensis (preliminary note)] Silvicultura em São Paulo 6:141-143. (ABSTR. F.A. 30:5648).

Height growth at 1 1/2 years of age was unaffected by spacing. No fox tailing was evident.

K.W. Pinus caribaea (slash pine), height growth, initial spacing, tree form.

90. Florence, R.G. and J.R. McWilliam. 1956. The influence of spacing on seed production. Zeitschrift für Forstgenetik und Forst pflanzenzuchtung 5:97-102. (ABSTR. F.A. 18:338).

For maximum seed production by slash pine and Araucaria cunninghamii, optimum production of viable seed demands wide spacing. Maximum seed per acre is produced at spacings of 19' x19' and 20'x20' respectively for the two species.

K.W. Araucaria sp. (araucaria), Pinus elliottii (slash pine), initial spacing, seed production.

91. Foil, R.R., T. Hansbrough, and R.G. Merrifield. 1964. Development of loblolly pine as affected by early cultural treatments. North Louisiana Hill Farm Experiment Station, Hill Farm Facts 5. 5 pp. (ABSTR. F.A. 26:3679).

In 1955, treatments in 2 acre plots of 6 year old loblolly pine, at 4x4', 6x6', 6x8', 8x8', and 10x10' were: a) 400 trees/acre pruned to half height; b) thinned to 400 trees/acre; c) thinned to 400 trees/acre and pruned to half height. At 11 years of age, initial spacing had not significantly affected cord vol.acre except in thinned treatments at 4x4'. After a second thinning at 11 years to 100, 200, or 300 trees/acre, measurements at 14 years showed volumes of respectively 7.9, 10.8 and 15.3 cords/acre.

K.W. Pinus taeda (loblolly pine), initial spacing, pruning, thinning, thinning intensity, volume growth.

92. Fortunatov, N.I. 1949. [Patch planting of pine] Agrobiologiya 1949(1): 92-101. (ABSTR. F.A. 11:251).

Scots pine were planted in patches 1 x 1 m in size, spaced at 5 x 5.6 m, and in rows at a spacing of 1.5 x 0.5 m. Diameter growth of patched plants was much superior to row planted as was height growth. The patch planted trials also showed good natural pruning of stems. At 11 years, the patch planted stand was open, with a total volume of 34 m^3/ha as opposed to the row planted plots 68 m^3/ha. It is felt that patches should be spaced at 3.5 x 2.5 m.

K.W. Pinus sylvestris (Scots pine), diameter growth, height growth, initial spacing, natural pruning, patch planting, row planting.

93. Gathy, P. 1965. [Spacing in plantations] Bull. Soc. For. Belg. 72(8/9):325-332. (ABSTR. F.A. 27:2096).

Gives data on dimensions and yield of a 51 year old spruce plantation in Belgium, planted at 5 x 2.5 m and thinned once. The figures compare favourably with those in standard yield tables.

K.W. Picea sp. (spruce), initial spacing, growth increment, thinning, wood yield.

94. Gavrilov, A.P. 1963. [The plantation trials in Akshuatski forest district] Lesn. Hoz. 16(4):73-76. (ABSTR. F.A. 24:596).

Compares growth and yield by assortments of Siberian larch (spaced 4.3 x 4.3 m and 2.1 x 2.1 m), Norway spruce (spaced 2.1 x 2.1 m) and Scots pine (spaced 2.1 x 1.2 m).

K.W. Larix sibirica (Siberian larch), Picea abies (Norway spruce), Pinus sylvestris (Scots pine), initial spacing, growth increment, wood yield.

95. Georgopoulos, A. 1952. [The spacing of poplar plantations] Schweiz. Z. Forstw. 103(6/7):212-224. (ABSTR. F.A. 14:311).

Experience in Greece has shown that close spacing followed by thinnings is best both financially and silviculturally. On good sites, a spacing of 2 x 2 m is recommended and on inferior sites, particularly on sandy soils, 3 x 4 m.

K.W. Populus sp. (poplar), economics, initial spacing, silviculture, soil, thinning.

96. Georgopoulos, A. 1959. L'espacement dans la plantation de peupliers et le populiculture intensive. 10th Session, International Poplar Commission, 1959. No. FAO/CIP 95E (Add. 2), 4 pp.

After 4 years, plots in east Macedonia spaced 2.5 x 3 m had nearly twice the basal area of plots spaced 5 x 6 m and nearly 1/3 of the basal area could be taken in a first thinning.

K.W. Populus sp. (poplar), basal area growth, initial spacing, thinning, wood production.

97. Gillespie, D.R. 1971. E.P. 537- Spacing trials in the Prince Rupert Forest District. B.C. Forest Research Review pp. 73-74.

Initial square spacing of 4, 8, 12 and 16' were set up in 1959 in the Babine Lake area. Stand development and the treatments applied to the developing stand were recorded as well as the stand history. High mortality is noted. In 1965, it was noted that stand closure is likely to occur on 4x4' spacing during the next 5 years, even with good release growth. At least ten years growth will be necessary and wider spacing before spacing will have any observable influence on growth and development. By 1971, no crown closure had occurred. The number of trees over 4.5' is greatest on 4' spacing. 12x12' has no trees over 4.5'. Height growth and survival to June 1970 are tabulated. (Previously reported by K. Illingworth: p. 41, 1960; and D. Armit; p. 19, 1962; p. 21-22, 1963; p. 29, 1964; and p. 30, 1965).

K.W. crown closure, height growth, initial spacing, seedling survival.

98. Gillespie, D.R. 1971. E.P. 671- A spacing trial of lodgepole pine (1968). B.C. Forest Research Review. p. 74.

2+1 lodgepole pine were planted on uniform soil at square spacings of 6, 8, 10 and 12'. Survival data after one growing season is tabulated. (Also reported - 1969, 1970. Additional authors - Armit, D. 1969).

K.W. Pinus contorta (lodgepole pine), initial spacing, seedling survival, soil.

99. Giordano, A. 1965. Effect of the spacing of trees on the growth of pine plantations and soil fertility. M.S. Thesis, Univ. Wisconsin, Madison 44 pp.

K.W. Pinus sp. (pine), growth increment, initial spacing, soil fertility.

100. Giordano, A. and S.A. Wilde. 1966. [Spacing in plantations in relation to soil and to economic return] Monti e Boschi 17(5): 7-16 (ABSTR. F.A. 28:3779).

Results of a study in Wisconsin of the growth of red pine and jack pine plantations (15-34 years old) at various spacings on coarse non podzolized sands and strongly podzolized sandy soils showed that on the less coarse sands of the first category spacings of $<$ 6'x6' retarded diameter growth and necessitated unprofitable thinning, while on podzols spacings $\geq$ 8'x8' reduced increment, increased percent of branches and decreased timber value. Suggestions for such sites include planting at 4'x8' or 5'x8'.

K.W. Pinus banksiana (jack pine), Pinus resinosa (red pine), branching, diameter growth, economics, growth increment, initial spacing, soil, thinning, wood quality.

101. Godman, R.M. and J.H. Cooley. 1970. Effect of initial spacing on jack pine growth and yield. Michigan Acad. 2(4):107-111.

Evaluation made 22 years after planting at various spacing indicates that spacing at 9'x9' could be the most profitable, especially for pulpwood production.

K.W. Pinus banksiana (jack pine), growth increment, initial spacing, wood production.

102. Godnev, L.E. 1966. [Plantation density as a factor in performance on mossy pine forest site types of the Buzuluk forest] Sborn. Rabot Lesn. Hoz. Vsesojuz. Nauč-Issled. Inst. Lesovod 51:23-35. (ABSTR. F.A. 29:5576).

Advocates heavy planting density (with later thinning) to combat vegetation.

K.W. Pinus sp. (pine), planting density, vegetative competition.

103. Grah, R.F. 1960. Effects and initial stocking on financial return from young growth Douglas fir. Hilgardia 29:613-679.

Range of initial stocking did not affect net volume production at normal harvesting ages, but did affect quality, understocked stands having larger knots and excessive amounts of fast grown material. The effect of pruning in up-grading logs was greatest in fully stocked stands.

K.W. Pseudotsuga menziesii (Douglas fir), economics, initial spacing, planting density, pruning, stand model, value increment, volume growth, wood yield.

104. Grah, R.F. 1961. Relationship between tree spacing, knot size, and log quality in young Douglas fir stands. J. For. 59(4):270-272.

In natural young Douglas fir stands, average knot size increases with increase in average spacing. The relation is linear between average tree spacings of 4'x4' to 26'x26' (the range covered by this study).

K.W. Pseudotsuga menziesii (Douglas fir), initial spacing, knot size, site index, wood quality.

105. Guilkey, P.C. and A.H. Westing. Effects of initial spacing on the development of young jack pine in northern lower Michigan. Michigan Academy of Science, Pap. 41. pp. 45-50. (ABSTR. F.A. 18:4017).

Spacing experiments were made, planting jack pine at spacings of 1½'x 1½', 3'x3', 5'x5', 7'x7' and 9'x9'. After 15 years diameter growth was suppressed in the first two spacings, a preliminary thinning will be necessary in the 5'x5' spacing before a commercial thinning is practicable. A stand density of 7'x7' is regarded as most satisfactory. Trees spaced at 9'x9' are too heavy limbered to yield good sawtimber.

K.W. Pinus banksiana (jack pine), diameter growth, initial spacing, suppression, wood quality.

106. Guillebaud, W.H. 1951. Norway spruce spacing plots at Wessling, Bavaria. Forestry 24(2):121-126.

Translation of Vanselow, K, 1950 (Q.V.)
K.W. Picea abies (Norway spruce), branching, diameter growth, height growth, initial spacing, tree form, wood production.

107. Guimaraes, R.F. 1965. [Observations on diameters, heights, survival and weight of the wood in Eucalyptus saligna at various initial spacings] An. Bras. Econ. Flor., Inst. Nac. Pinho 17:31-45. (ABSTR. F.A. 29:3833).

Statistical analysis after 8 years growth of eucalyptus plantations at 11 different spacings, shows that spacings < 2x2 m are unfavourable, wider spacings giving better increment and survival and easier tending and extraction. Wood density was not affected by the spacing.
K.W. Eucalyptus sp. (eucalyptus), diameter growth, growth increment, height growth, seedling survival, wood density.

108. Hall, M.J. 1959. The effect of stocking density, site quality and age on volume of pulpwood produced per acre. APPITA, Melbourne 13(1):22-29. (ABSTR. F.A. 21:851).

In a spacing trial in radiata pine, established in 1950, at 6'x6', 7'x7', 9'x5', and 9'x6', it was found that total basal area increases with site quality and stocking density for at least the first 8 years.
K.W. Pinus radiata (radiata pine), basal area growth, initial spacing, site quality.

109. Hall, M.J. 1964. Initial spacing in Pinus radiata (D. Don) for pulpwood production at Langford, Victoria. APPITA, Melbourne 18(3):122-127. (ABSTR. F.A. 26:3642).

A replicated spacing trial with initial stockings from 800-1200/ acre was established in 1950. Measurements at 12 years and before first thinning showed that stand volume to 3" diameter u.b. was increased by 105 ft^3 for each additional 100 stems/acre. The mean diameter of all stems fell by 0.23" for the same rise in stocking, but there was no significant fall in the mean diameter of the largest 100 trees/acre. It was concluded that closer initial spacings will lead to higher first thinnings yields without significantly affecting vigour of the residual crop, but a market is required for small first thinnings at 11-12 years.
K.W. Pinus radiata (radiata pine), diameter growth, initial spacing, thinning yield, volume growth, wood production.

110. Hanafin, M. 1969. Sitka spruce planting at 9'x9' at Jervaulx Forest in 1943. J. For. Comm. 1968/1969 (36):57. (ABSTR. F.A. 32:5956).

Planting at this spacing will give large profits from the poles removed at first thinning.

K.W. Picea sitchensis (Sitka spruce) economics, initial spacing, profits, wood yield.

111. Hansbrough, T., R.R. Foil, and R.G. Merrifield. 1964. The development of loblolly pine planted at various initial spacings. North Louisiana Hill Farm Experiment Station, Hill Farm Facts 4, 4 pp. (ABSTR. F.A. 26:3644).

Tabulates, for ages up to 12 years, survival, mean dbh and total height, b.a./acre, and total and merchantable cord volume/acre of loblolly pine planted in 1950 at spacings of 4'x4' to 10'x 10'. At age 12, differences in merchantable volume/acre are small.

K.W. Pinus taeda (loblolly pine), initial spacing, volume growth, wood production.

112. Harms, W.R. 1962. Spacing-environmental relationships in a slash pine plantation. U.S. Dept. Agric. Southeastern Forest Experiment Station, Sta. Paper 150, 16 pp.

Slash pine were planted at spacings of 6'x6', 8'x8', and 15'x15'. Similar correlations were found in the 6th and 7th growing seasons between diameter growth and available soil moisture, maximum air temperature, evaporation, and elapsed days from Jan.1. None of these factors explained the differences in diameter growth between spacings. Differences were attributed to the interaction of light and photosynthetic surfaces.

K.W. Pinus elliottii (slash pine), diameter growth, growth increment, initial spacing, light competition, photosynthesis, soil moisture, vegetative competition.

113. Harms, W.R. and A.B. Collins III. 1965. Spacing and twelve year growth of slash pine. J. For. 63(12):909-912.

Comparison at age 12 of eight spacings of old field planted slash pine shows average tree diameter is positively correlated with spacing. Through the seventh year, relationship is linear. Beginning in the eighth year and intensifying through the twelve year, the relationship is curvilinear. Beginning with the eleventh year, tree height is positively correlated with spacing. There is a positive curvilinear relationship between crown ratio and spacing. Configuration of spacing has not yet affected diameter growth. Merchantable volume yield does not yet show a clear relationship to spacing.

K.W. Pinus elliottii (slash pine), diameter growth, height growth, initial spacing, spacing configuration, volume growth, wood yield.

114. Haslund, O. 1947. [Yield and quality of Norway spruce woods] Tidsskr. Skogbr. 55(12):333-335. (ABSTR. F.A. 10:1018).

Stresses high production of dry wood produced by close spacing and suggests that from this point of view, costs of close spacing are not too high. More research is necessary on spacings. Dry pruning is considered to be of little value and green pruning dangerous due to risk of decay.

K.W. Picea abies (Norway spruce), economics, initial spacing, pruning, wood production.

115. Haveraaen, O. 1960. [Early regulation of spacing] Tidsskr. Skogbr. 68(2):49-97. (ABSTR. F.A. 22:516).

Mean height and diameter increment of young pine and spruce in 1953-1959 were higher on regulated than on untouched plots, the widest spacing (within the range 1.0 m - 3.0 m) giving the most increment. On plots spaced at 3.0 m, height increment during the first 6 years was about 40% and diameter increment 100% higher than on controls. Height increment was greatest in trees tallest at time of regulation. Wood quality decreased with increased spacing.

K.W. Picea sp. (spruce), Pinus sp. (pine), diameter growth, height growth, spacing, stand regulation, wood quality.

116. Hawley, R.C. 1922. A progress report of the results secured in treating pure white pine stands on experimental plots at Keene, New Hampshire. Yale Univ., School of Forestry. Bull. 7. 9 pp.

K.W. Pinus strobus (white pine), initial spacing.

117. Hawley, R.C. 1927. A second progress report of the results secured in treating pure white stands on experimental plots at Keene, New Hampshire. Yale School of Forestry Bull. 20. 23 pp.

K.W. Pinus strobus (white pine), initial spacing.

118. Heding, N. 1969. [Reduction in stem number and diameter increment in unthinned Norway spruce stands at various spacings: an estimate of the economic yield from the first thinning] Forstl. Forsøgsv. Denmark 32(2):189-243. (ABSTR. F.A. 31:6401).

Numbers of live stems per ha. in unthinned stands and stand diameters are plotted against stand height for different original densities. The economic consequences of various initial spacings and of delaying the first thinning (assuming that the dead standing trees can be removed and are used) are discussed. Computations are based on the further assumption (for which there is good evidence) that diameter development differs little between dense stands thinned conventionally and stands established with low stem numbers. It is suggested that on good sites, higher plant numbers may be economically justified, especially if small thinnings are converted as fencing material.

K.W. Picea abies (Norway spruce), diameter growth, initial spacing, thinning, thinning intensity, wood production.

119. Herbignat, A. 1954. [Advice on planting distances to use in poplar plantations] Bull. Soc. For. Belg. 61(2):92-107. (ABSTR. F.A. 15:3534).

Dense plantations (5 x 5 m or less) are to be avoided. Plantations for production of small or medium peeler logs at 20-25 years may be spaced 6 x 6 or 7 x 7 m, but such plantations of Populus robusta often show ill effects of crown competition by 12 years. Spacings recommended are 8 x 8 m to 10 x 10 m in uniform stands, 9 x 9 m to 10 x 10 m for coppice with standards, and not less than 5 m in single and double rows.

K.W. Populus robusta (poplar), crown competition, initial spacing.

120. Herpka, I. 1965. [Production of wood on a 3 year rotation]. Topola, 9(48/49):16-29. (ABSTR. F.A. 27:2098).

1 + 0 Populus x canadenensis were planted in Jugoslavia at spacings of 120 x 100, 180 x 40, 180 x 60, and 180 x 80 cm. Volume harvested at the end of three years were 140, 156.3, 139.9, and 149.8 m^3/ha. In the 180 x 80 cm spacing, 41% of volume was in diameter classes 6-8 cm and 23% in diameter classes 8-10 cm. Volume table is presented and costs are discussed.

K.W. Populus sp. (poplar), diameter growth, initial spacing, volume growth, wood production.

121. Hetherington, J.C. 1969. E.P. 571- Trials of tree species and initial spacing on the west coast of Vancouver Island. B.C. Forest Review, p. 75.

Progress report on Douglas fir, sitka spruce, western hemlock and western red cedar planted at three spacing levels, 9'x9', 12'x12' and 15'x15' on valley bottom sites. A year later, there were no significant differences between spacings in survival rates. A tabulation of survival and height growth and a summary of stand history is given after seven years. Previously reported in 1962, 1963.

K.W. Picea sitchensis (Sitka spruce), Pseudotsuga menziesii (Douglas fir), Thuja plicata (western red cedar), Tsuga heterophylla (western hemlock), height growth, initial spacing, seedling survival, site type.

122. Heywood, F.J. 1943. Thoughts dealing with proper spacing for planting pines. Naval Stores Review 52(45):8, 10. (ABSTR. F.A. 6:231).

Spacing of slash pine plantations at 6'x6', 6'x8', or 8'x8' instead of previous 20'x20' has several advantages. The stand is self pruned, there is considerable return from pulpwood produced in thinnings, and residual trees are usually tall and straight enough to be used as poles or sawtimber after use for turpentining. Turpentining is, however, delayed several years over the previous 20'x20' spacing.

K.W. Pinus caribaea (slash pine), gum yield, initial spacing, self pruning, wood production.

123. Hickok, K.H. and R.J. Hutnik. 1966. Dry matter production and energy conversion in red pine plantations of different spacings. Pa. State Univ., School of Forestry Resources, Res. Brief 1(2): 48-52. (ABSTR. F.A. 28:356).

Dry matter productivity of 40 year old red pine varied with spacing, but not significantly. 46% of productivity was main stem material and 54% branch material, and these ratios were unaffected by spacing.

K.W. Pinus resinosa (red pine), dry matter productivity, initial spacing.

124. Homoky, S.G.J. 1972. E.P. 570- Sitka spruce spacing trial. B.C. Forest Research Review. p. 59.

Progress report on results of spruce plantings in 1961, at 6, 9, 12 and 15 ft^2 with outline of stand history. Spacing appeared to have no influence on height or diameter increment. (Previously reported by D. Armit: 1962, p. 20; 1963, p. 22; 1964, pp. 29-30; 1967, pp. 67-68; 1968, p. 67-68)

K.W. Picea sitchensis (Sitka spruce), height growth, initial spacing, insects, stand history.

125. Homoky, S.G.J. 1972. E.P. 613- Western hemlock trial. B.C. Forest Research Review. p. 59.

Progress report on three year old wildlings of western hemlock planted at 6, 9, 12 and 15 foot square spacings. During the first year, mortality was severe. Survival continued to be low. Attempts at maintaining full stocking are described but the project was abandoned in 1972. (Previous results reported by D. Armit: 1964, p. 30; 1965, pp. 34-35; 1966, p. 65; 1967, p. 71; 1968, p. 70).

K.W. Tsuga heterophylla (western hemlock), initial spacing, mortality.

126. Iliev, A. and B. Bogdanov. 1970. [Growth and yield of poplar plantations as a function of stand density] Gorsko Stopanstvo 26(3):10-17. (ABSTR. F.A. 31:6340).

Tabulates and graphs the dimensions and yields at age 12 of plantations of mixed hybrid black poplars established at various square spacings. Volume production was greatest at 3x3 m and decreased with increased spacing, volume at 10x10 m being only 61% of that at 3x3 m. For production of medium sized building timbers, spacing of 3x3, or 4x4 m are recommended with a rotation of 8-10 years, for large building timber, spacings of 5x5 to 7x7 m are recommended with a rotation of 12-15 years.

K.W. Populus sp. (poplar), initial spacing, volume growth, wood production.

127. Iliev, A. et al. 1966. [Effect of density on the growth and productivity of poplar plantations] Nauč. Trud. Lesoteh. Inst., Sofija 14:41-48. (ABSTR. F.A. 28:3782).

In planted poplar, at 7 years the closest spacing (3x3 m) had produced the greatest volume, some 3 or 3.5 times that of spacings > 8x8 m. Spacings of 3x3 m or 4x4 m are advised for production of medium sized building timber and spacings of 5x5 m or 6x6 m with a short rotation for large building timber.

K.W. Populus sp. (poplar), initial spacing, volume growth, wood production.

128. Illingworth, K. 1973. E.P. 692- Shore pine spacing and provenance trial. B.C. Forest Research Review. p. 75.

Six provenances of shore pine were planted at 1.5, 2.5 and 3.5 meters square spacing. The experiment continues. (Also reported 1971).

K.W. Pinus contorta (lodgepole pine), initial spacing, provenance.

129. Illy, G. and B. Lemoine. 1970. [Stand density, competition and cooperation in Pinus pinaster. I. First results of a planting experiment with irregular spacing] Ann. Sci. For. 27(2):127-155. (ABSTR. F.A. 32:4233).

Measurements 1, 2, 3 and 4 years after planting at different spacings showed that differences in spacing have various distinct effects on early flowering of Pinus pinaster. A high planting density markedly affects mid height diameter, stem volume and crown diameter, competition between trees 4 years after planting (mean height 2.15 m) being absent only at spacings > 3.59 m and stem volume per ha increases with increasing stand density throughout the range of spacings compared.

K.W. Pinus pinaster, diameter growth, flowering, initial spacing, planting density, vegetative competition, volume growth.

130. Isaac, L.A. 1937. 10 years growth of Douglas fir spacing test plantations. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Note 23:6.

K.W. Pseudotsuga menziesii (Douglas fir), growth increment, initial spacing.

131. Jayne, B.A. 1958. Effect of site and spacing on the specific gravity of wood on plantation-grown red pine. Tappi 41(4): 162-166.

Red pine was planted on two highly different sites at spacings of 4x4', 6x6', and 8x8'. Site types were good and poor. Trees on the poor site produced wood of significantly higher density and with a higher percent of latewood than those on the good site. On neither site did spacing significantly affect wood density. Volume production on the good site was four times that on the poor site in the first 35 years.

K.W. Pinus resinosa (red pine), initial spacing, site quality, volume growth, wood quality, wood density.

132. Jones, E.P. 1961. Wide spacing of slash pine produces early gum and sawtimber yields. U.S. Dept. Agric., Southeastern Forest Experiment Station, Res. Note 169. 2 pp.

At age 26, a stand planted at 15'x15' in Georgia and thinned at ages 19 and 26 produced 39.1 cords/acre. In addition about 8.5 barrels of resin/acre were produced in 2 cycles of 5-6 years, starting at ages 13 and 20.

K.W. Pinus elliottii (slash pine), gum yield, initial spacing, thinning, wood yield.

133. Karlin, V.R. 1963. [Sensible utilization of the area when growing forest plantations] Lesn. Ž. Arhangel'sk 6(5):41-44. (ABSTR. 25:5031).

From observations of many mixed oak plantations in the Don region, concludes that dense plantations (15,000-20,000 plants/ha) with rows 3 m apart are the best from both the silvicultural and economic aspects.

K.W. Quercus sp. (oak), economics, planting, planting density.

134. Karschon, R. 1960. Effects of spacing and irrigation on yield of Eucalyptus and Casuarina. La-Yaaran 10(1/4):9-11, 61-68. (ABSTR. F.A. 22:3060).

Shows advantage of wider spacing in production of wood chips, posts, pulpwood, and poles in E. camaldulensis spaced at 2x2 and 3x3 m.

K.W. Eucalyptus camaldulensis (Eucalyptus), initial spacing, irrigation, wood yield.

135. Kaushik, R.C. 1960. Indication for espacement in deodar. Proc. 9th Silv. Conf., Dehra Dun 1956, Pt. 1. pp. 208-211. (ABSTR. F.A. 23:524).

Proves that wide spacing (12x12') results in significantly better diameter and height growth and wood quality, with a great saving in cost, than the closer spacings currently in vogue.

K.W. Deodar, diameter growth, economics, height growth, initial spacing, wood quality.

136. Kennedy, R.W. 1966. Wide spacing results in better quality. Forestry Chronicle 42(3):317.

Widely spaced stands of softwoods maintain a relatively fast growth rate throughout a fixed rotation, resulting in a proportionally smaller amount of low quality core wood.
K.W. initial spacing, rotation, wood production, wood quality.

137. Kiellander, C.L. 1956. [Suitable spacing for planting spruce in south Sweden] Skogen 43(9):267-268, 291. (ABSTR. F.A. 17:3906).

Concludes from past and present experiments, that except in special conditions, 1.5 m x 1.5 m is the maximum desirable spacing.
K.W. Picea sp. (spruce), initial spacing.

138. Kislova, T.A. 1971. [Economic evaluation of plantations of different density] Lesn. Ž. 14(2):124-127. (ABSTR. F.A. 33:2516).

A theoretical analysis of the method of calculating optimum initial density. Equations are developed for relating various expenditures to initial density of plantation.
K.W. economics, planting density.

139. Kjersgård, O. 1964. [A Norway spruce spacing trial] Forstl. Forsögsv. Danmark 29(1):55-68. (ABSTR. F.A. 26:3641).

Planted in 1941 at seven different spacings (0.5 x 0.5 to 2.5 x 2.5 m) the plots were measured in 1954, 1955, 1958 and 1961. Indications were at 25 years, that wider spacing gave increased d_g (diameter corresponding to mean b.a. of stand) and h_L (mean height by Lorey's formula), decreased b.a., lower form factors, and lower stemwood increment up to 17 years only.
K.W. Picea abies (Norway spruce), basal area growth, diameter growth, height growth, initial spacing, tree form.

140. Kjersgård, O. 1972. [A Norway spruce spacing trial on a heath site] Forstlige Forsøgvesen i Danmark 33(1):1-9. (ABSTR. F.A. 34:3973).

Reports an assessment, at age 30, of a trial comparing various spacings from 0.5 x 0.5 m to 2.25 x 2.25 m. Results confirmed that diameter and height of the b.a. mean tree tended to increase, but b.a. and volume decreased with increased spacing.
K.W. Picea abies (Norway spruce), basal area growth, diameter growth, height growth, initial spacing, volume growth.

141. Klem, G.G. 1942. Effect of planting space on the quality of spruce wood and sulphite pulp. Medd. norske Skogsforsøksv. 8(2):No. 28:257-293. (ABSTR. F.A. 5:253).

For planting distances up to 2.5 m, there was little difference in yield of pulp by weight, or in tensile or bursting strength for 31-39 year old spruce in a plantation. Tearing strength of the pulp decreased as the planting distance increased from the minimum (1.25 m) to the maximum (3.50 m). A planting distance of 1.50 - 1.70 m is recommended for lowland spruce.

K.W. Picea sp. (spruce), initial spacing, pulpwood, wood quality.

142. Klem, G.G. 1947. [Spacing, yield, and quality] Tidsskr. Skogbruk 55(8/9):237-241. (ABSTR. F.A. 9:2184).

Tabulates results for 5 initial spacings in Norway spruce, 3.5 m, 2.5 m, 2.0 m, 1.5 m and 1.25 m. Diameter growth was greatest at widest spacing, but height growth was not appreciably affected. Wood quality was best at close spacing, as was total yield in m^3/ha. Pulp quality was best at closer spacings. Spacings for Norway spruce of 1.6 - 1.7 m, or of 2.0 m on suitable sites, are recommended.

K.W. Picea abies (Norway spruce), diameter growth, height growth, initial spacing, taper, wood production, wood quality.

143. Klem, G.G. 1947. [Time and Norwegian afforestation plans] Tidsskr. Skogbruk 55(10/11):298-300. (ABSTR. F.A. 10:1020).

Suggests possibility of increasing spacing for afforestation with Norway spruce, from 1.4 m to 2.0 m. Effects on pulp and timber quality and production would not be serious and such disadvantages would be small compared to gain from smaller cost of establishment, and earlier timber production.

K.W. Picea abies (Norway spruce), economics, initial spacing, wood production, wood quality.

144. Klem, G.G. 1952. The effect of plant spacing on the quality of spruce timber. Medd. norske Skogforsøksv. 11(3):No. 40:473-506. (ABSTR. F.A. 3338).

Various spacings from 1.25 m x 1.40 m to 3.5 m x 3.5 m of spruce were examined for wood quality and growth increment. As time from planting increased, generally, differences in wood quality and growth between different spacings decreased. In general, timber quality decreased with increased spacing. No relationship was found between lignin content and spacing.

K.W. Picea sp. (spruce), growth increment, initial spacing, wood production, wood quality.

145. Knable-Urban, J. 1963. [Investigation spacing in planting beech] Forstarchiv 34(6):157-164. (ABSTR. F.A. 25:599).

Planted stands can yield as high a quality and quantity as other types. Although no general rule for spacing can be given, owing to variability of site, it is felt that wide spacing is beneficial.

K.W. Fagus sp. (beech), initial spacing, wood yield, wood quality.

146. Kolar, M. 1961. Influence of form of plantation on growth of Eucalyptus camaldulensis Dehn. In: Contributions on Eucalypts in Israel. National and University Institute of Agriculture, Jerusalem, pp. 23-29. (ABSTR. F.A. 23:3563).

Compares a roadside plantation spaced at 2.5 x 2.5 m and a forest plantation spaced at 2x2 m. No significant difference in form factor was found, but more closely spaced trees were slightly taller for each diameter class, and their total yield and particularly sawtimber percent were greater.

K.W. Eucalyptus sp. (Eucalyptus), height growth, initial spacing, tree form, wood yield.

147. Kolpikova, N.M. 1958. [Influence of orientation of the rows on the growth of Scots pine plantations] Trud. Inst. Les. 39:133-145. (ABSTR. 21:3092).

Investigations were made in 12-13 year old pine plantations to see whether orientation (rows running N-S or E-W) had any influence on performance. Results showed that on level clay-loam soils of the Moscow region, planting or sowing in N-S rows had an advantage, increasing stem volume of young stands by 15%. Extra growth results from improved micro-climatic conditions.

K.W. Pinus sylvestris (Scots pine), growth increment, planting, planting orientation.

148. Kondrat'ev, P.S. 1959. [New data on the growth of pine plantations at different densities] Izv. Timirjaz. Sl'Hoz. Akad., Moskva 2:141-154. (ABSTR. F.A. 21:1749).

Trial plots of Scots pine were planted at several different densities in 1879 and 1901. Data are tabulated on mortality and mean heights and diameters at several ages up to 1956, and also on the rate of canopy closure. Results indicate that on these sod-podzolic sites, optimum planting density is 4000-5000 plants/ha.

K.W. Pinus sylvestris (Scots pine), diameter growth, height growth, mortality, planting density, soil.

149. Koucký, R. 1966. [The effect of plant spacing on the growth and quality of pure Norway spruce stands] Lesn. Práce 45(2):80-85. (ABSTR. F.A. 28:2196).

Recommends an initial density of 5000-10,000 plants/ha, but states that more research is needed. Presents inconclusive results of a spacing study.

K.W. Picea abies (Norway spruce), initial spacing.

150. Kramer, H. 1960. [Plantation spacing trials] Forst-und Holzwirt 15(23, 24):496-500, 512-518. (ABSTR. F.A. 22:3055).

Reviews many spacing trials in Germany with Scots pine and Norway spruce. Recommendations for various sites are given. Square spacing is considered superior to row planting.

K.W. Picea abies (Norway spruce), Pinus sylvestris (Scots pine), initial spacing, row planting, site quality.

151. Kramer, H. 1966. Crown development in conifer stands in Scotland as influenced by initial spacing and subsequent thinning treatment. Forestry 39(1):40-58.

Gives for Norway spruce, Sitka spruce, and Douglas fir, development curves of crown percent according to top height, thinning grade and quality class. It shows the effect of different thinning grades on the crown surface (and crown volume) of the mean tree and the whole stand, together with the relationship between volume increment and crown surface. The contribution of different canopy classes to the total increment of the stand is assessed.

K.W. Picea abies (Norway spruce), Picea sitchensis (Sitka spruce), Pseudotsuga menziesii (Douglas fir), canopy class, crown class, growth increment, height growth, initial spacing, thinning, thinning grade, volume growth.

152. Kramer, H., P.H. Dong, and H.J. Rusack. 1971. [Stem quality in spruce stands established at wide spacings] Allgemeine Forst- und Jagdzeitung 142(2):33-46. (ABSTR. F.A. 32:5954).

Branch thickness did not differ significantly from comparable conventional stands for row spacing of up to 3 m, site and genetic effects apparently predominating, but row spacings > 4 m increased the % of C stems (> 20 mm diameter). In three districts, mean maximum branch diameter did in fact increase with spacing, and a relation between dbh and initial spacing could be observed up to a high stand age. Row planting did not, but wind did affect stem cross sections. Dense planting within the rows reduced branch diameter between the rows. Recommendations are given on maximum spacings for given row distances.

K.W. Picea sp. (spruce), branch diameter, initial spacing, row spacing, stem form, wind.

153. Krinand, R.M. 1971. 12x12 initial spacing best in cottonwood plantations. Tree Planters Notes 22(3):17-19.

Report summarizes 7 years growth data in a Mississippi plantation indicating that 12x12' spacing might be close to optimum.

K.W. Populus deltoides (cottonwood), growth increment, initial spacing.

154. Krstinic, A. and M. Vidakovic. 1971. [Effect of dense planting on the growth of Salix alba] Topola 15(83/85):37-40. (ABSTR. F.A. 33:2518).

Rooted cuttings of willow were planted at 1x1 m, 2x2 m, 2x1 m, and 1x2 m in 1963. By 1970 it was concluded that dense planting did not give good results.

K.W. Salix sp. (willow), growth increment, initial spacing.

155. Kryszczynski, Z. 1968. [Spacing in plantations as an important aspect of forestry] Sylwan 112(1):25-40. (ABSTR. F.A. 30:568).

Reviews Polish, Russian, and German opinions on initial spacing and advocates wider spacing, i.e. 3x3 m for Scots pine.

K.W. Pinus sylvestris (Scots pine), initial spacing, literature review.

156. Larquiá, A. 1971. [Mensurational data from a very closely spaced plot of Pinus elliottii in Misiones] Notas tec. INTA, Cerro. Azul. No. 8 n.p. (ABSTR. F.A. 32:5957).

Gives growth data for a plantation established at an initial spacing of 1 m x 1 m. Stocking at 8 years was 63% of the original, mean height was 13 m and 50% of stand had a diameter greater than 12 cm. At age 8, there seemed to be no stagnation.

K.W. Pinus elliottii (slash pine), diameter growth, height growth stem form, survival.

157. Latham, J.A. 1965. The effects of spacing on the development of lodgepole pine in the Manning Park area of B.C. BSF Thesis, U.B.C. Faculty of Forestry, BSF Thesis. 58 pp.

K.W. Pinus contorta (lodgepole pine), initial spacing.

158. Lauffenburger. 1952. [Plantation density for Scots pine in producing quality wood] Rev. for. franc. (1):41-54. (ABSTR. F.A. 13: 2961).

To produce pine sawtimber in the Vosges area, an initial density of 20,000 - 30,000 trees/ha. is advisable, followed by heavy and economically profitable thinning at 35 years.

K.W. Pinus sylvestris (Scots pine), economics, initial spacing, stand density, thinning.

159. Lebkov, V.F. 1962. [The effect of initial stand density on the assortment structure and age of technical maturity in Scots pine] Lesn. Ž. Arhangel'sk 5(5):37-42. (ABSTR. 24:3614).

The maximum reduction possible in the technical rotation for normal stands through regulating the initial density comes to only 10-20 years, depending on the size of the timber required. Even this modest reduction can only be achieved by reducing planting spots to a minimum, by virtually renouncing thinnings and intermediate fellings, and by accepting a sharp drop in wood quality. Limited regulation of density during stand growth can accelerate maturity by only 5-10 years, which is of no practical importance.

K.W. Pinus sylvestris (Scots pine), rotation, stand density, wood quality.

160. Lemmien, W. 1950. A spacing study of red pine in Michigan. Michigan Agricultural Experiment Station, Quarterly Bull. 32(3):360-363.

A spacing of 8'x8' was more satisfactory than 6'x6' being easier to tend and producing good pulpwood at first thinning. Spacing of 10'x10' will probably produce less merchantable wood than 8'x8'. Pruning was necessary at all spacings.

K.W. Pinus resinosa (red pine), initial spacing, pruning, thinning, wood production.

161. Lemmien, W.A. and V.J. Rudolph. 1959. Growth and yield of red pine in three spacings. Michigan Agric. Experiment Station, Quarterly Bull. 42(2):421-427. (ABSTR. F.A. 21:3095).

Growth and yield of 25 year old red pine stands spaced at 6'x6', 8'x8' and 10'x10' was studied. Portions of the stand were thinned in 1947 and again in 1954. After 25 years of growth, the 10'x10' spacing appears superior to the other two spacings because it has produced larger crop trees and almost as much merchantable volume per acre. Thinnings in the wide spacings are more easily applied, since there are fewer unmerchantable trees in the stand. Planting costs are lower and access is easy.

K.W. Pinus resinosa (red pine), diameter growth, initial spacing, thinning, volume growth, wood yield.

162. Little, S. and H.A. Somes. 1958. Results 18 years after planting loblolly pines at different spacings. U.S. Dept. Agric., Northeastern Forest Experiment Station, Forest Res. Note 80, 3 pp.

Loblolly pines were planted at spacings of 4, 5.7, 8, and 11.3'. As measured 18 years later, only at the closest spacing did competition cause some mortality. The closer the original planting, the greater the basal areas and total cordwood volume. However, when only pines of 6" dbh and larger are considered, the 8' spacing gave greatest volume. Average diameter of planted pines increased from 4.5" at 4' to 7.7" at 11.3'. Height growth was relatively uninfluenced by spacing.

K.W. Pinus taeda (loblolly pine), basal area growth, branching, diameter growth, height growth, initial spacing, mortality, vegetative competition, volume growth, wood production.

163. Lowrey, A.L. 1956. Sitka spruce at Bachelor's lodge. Irish Forester 13(2):70-71.

A note on growth at 16 years of Sitka spruce planted in cleared woodland at 9'x9' spacing. Average annual growth bh is 6" and average height is 28'.

K.W. Picea sitchensis (Sitka spruce), growth increment, initial spacing.

164. Mackenzie, A.M. 1951. Spacing experiments in conifers. G.B. Forestry Commission, Forest Research Report 1950, pp. 59-61.

Early spacing trials in most commercial grown species of Great Britain are discussed. Results showed that variation of spacing between 3 1/2 and 8' had no significant effect on height growth. Percentage survivals were similar for all spacings on a given height, but denser plantings of European larch suffered most from die-back. Crown spread, branch thickness and individual stem diameter increased with wider spacing, while stem form, length of bole, and taper were better in closer spacing. Spacing should be varied according to site conditions.

K.W. crown growth, diameter growth, height growth, initial spacing, site quality, taper, wood quality.

165. Maeglin, R.R. 1967. Effect of tree spacing on weight yields for red pine and jack pine. J. For. 65(9):647-650.

Maximum weight yields were primarily a function of usable volume for 15 year old stands of red pine and jack pine. Data gathered on plantations of various spacings in Wisconsin showed that specific gravity of wood showed no definite relationship to stand density for either species. For both species, "optimum" yields occurred at 6'x6' spacings.

K.W. Pinus banksiana (jack pine), Pinus resinosa (red pine), economics, initial spacing, volume growth, wood yield.

166. Mähring, K. 1968. [The Devil and Beelzebub (Spruce spacing and tending in the Harz range)] Forst-und Holzwirt 23(6):101-104. (ABSTR. F.A. 29:5575).

Observations on spruce stands aged 32-36 years, established at square spacings of 1.4, 1.5, or 2.0 m indicated that wider spacing did not greatly reduce incidence of snow breakage or red-deer damage, but increased extent and severity of wound rot after deer barking. Moreover, while stem breakages at the point of a barking wound tended to decline with increasing age in closely spaced stands, they tended to increase in widely spaced stands.

K.W. Picea sp. (spruce), decay, deer damage, initial spacing, snow breakage.

167. Mancu, G. 1966. [Poplar planting density] Rev. Pădurilor 81(10): 547-552. (ABSTR. F.A. 28:2780).

Gives establishment costs for poplar at various spacings on medium quality soil. A spacing of 4 x 2 m is recommended.

K.W. Populus sp. (poplar), economics, initial spacing.

168. Mann, W.F. Jr. 1971. Early yields of slash pine planted on a cutover site at various spacings. U.S. Dept. Agric., Southern Forest Experiment Station, Res. Pap. SO-69, 16 pp. (ABSTR. F.A. 34:2203).

Tabulates basal area, volume, average dbh, and diameter distribution at 14 years of age for slash pine plantations of site indices (50) of 80-115, planted at spacings giving 200-2500 trees/acre.

K.W. Pinus elliottii (slash pine), basal area growth, diameter growth, initial spacing, site index, volume growth, wood yield.

169. Mann, W.F. Jr. and T.R. Dell. 1971. Yields of 17 year old loblolly pine planted on a cutover site at various spacings. U.S. Dept. Agric., Southern Forest Experiment Station, Res. Pap. SO-79, 9 pp.

Tabulates basal areas, volumes in ft^3, average dbh, and diameter distributions for plots of loblolly pine planted at spacings giving 300-1200 trees/acre.

K.W. Pinus taeda (loblolly pine), basal area growth, diameter growth, initial spacing, volume growth.

170. Mareš, V. 1968. [Comparison of nest and individual plantings of Pinus sylvestris in the Křivoklate region] Lesn. Čas., 14(3): 239-254. (ABSTR. F.A. 31: 653).

The initial superiority of nest plantings (up to 9 plants per nest) has not fulfilled expectations. The individual plantings (at 1x1 m) have now equalled their height growth are are superior as regards stem straightness and branching.

K.W. Pinus sylvestris (Scots pine), branching, height growth, initial spacing, nest planting.

171. Mathauda, G.S. 1964. The influence of initial spacing on early mortality and growth in the Casuarina plantations at Balukhand, Puri Division, Orissa. Indian Forester 80(8): 446-452. (ABSTR. F.A. 16:432).

Statistical analysis for 7 years data from planting date indicates that increase of spacing from 6'x6' to 9'x9' significantly reduces mortality and increases diameter increment. The further increase from 9'x9' to 12'x12' does not produce significant differences.

K.W. Casuarina equisetifolia (casuarina), growth increment, initial spacing, mortality.

172. May, J.T., S. Rahman, and R.H. Worst. 1973. Effects of site preparation and spacing on planted slash pine. J. For. 71(6): 333-335.

Areas, site treatments and spacing significantly affect height and diameter growth, total cubic volume and fusiform rust infestion of planted slash pine in Georgia. The best growth, greater volume and higher rust infection were on better drained sites. Site preparation increased height and diameter growth on all sites.

K.W. Pinus elliottii (slash pine), diameter growth, fusiform rust, height growth, initial spacing, site quality, site treatment, volume growth.

173. Meikle, O.A. and E.L. Hughes. 1967. Spacing study in a dense young red spruce-fir stand at Hart Lake, Nova Scotia. Canada, Forestry Branch, Forest Research Lab, Fredericton, Int. Rept. M-19. 23 pp.

Reports thinning and spacing experiments carried out in a 16 year old spruce-fir stand to give spacings of 4'x4', 6'x6', 8'x8' and 10'x10'. Stands will be re-measured over the next five years.

K.W. Abies balsamea (balsam fir), Picea rubens (red spruce), growth increment, initial spacing, mortality, thinning.

174. Melton, R.E. and K.F. Schell. 1969. Scotch pine stand stagnation and recuperation. Pennsylvania Agricultural Experiment Station, Progress Rept. 299. 8 pp.

Records the marked capacity of stagnating 20 year old Scots pine plantations originally planted at 6'x6' spacing to respond to thinning. Basal area values of 65-90 ft^2/acre are recommended for Scots pine < 30 years old on low quality sites.

K.W. Pinus sylvestris (Scots pine), growth increment, initial spacing, site quality, thinning.

175. Melzer, E. 1952. [A contribution to the discussion on group method (with particular reference to spruce)] Wald 2(10): 313-318. (ABSTR. F.A. 17:2751).

Compares relative plant losses, after a short period, in 8 series of circular groups varying in size, spacing, and number of seedlings per group, on a weed infested clear felling in Tharandt. Some support is found for the view that dense groups fare better on such sites.

K.W. initial spacing, seedling mortality.

176. Miletić, Š. 1961. [Poplar plantations on periodically flooded land at close and wide spacings] Topola, Beograd 5(24):6-8. (ABSTR. F.A. 24:491).

Poplars planted at 2.5 x 2.5 m had a mean height of 13.44 m and dbh of 14.33 cm after 6 growing seasons v.s. 15.12 m and 20.73 cm for those at 5x5 m.

K.W. Populus sp. (poplar), diameter growth, height growth, initial spacing.

177. Minckler, L.S. 1970. Spacing, thinning, and pruning practices for young cottonwood plantations. U.S. Dept. Agric., North Central Forest and Range Experiment Station, Res. Note NC-95. 4 pp.

The 5 year growth of cottonwood trees planted at 5 spacing levels is summarized. Wide spacing resulted in better diameter and height growth but less total wood production per acre than close spacing. Early thinning of closely spaced trees did not maintain diameter growth equal to that of trees with initial wide spacing.

K.W. Populus deltoides (cottonwood), diameter growth, height growth, initial spacing, pruning, thinning, thinning regime, wood production.

178. Mojko, M.F. 1967. [The influence of orientation of the rows on the growth and productivity of Quercus robur plantations] Lesn. Hoz. 1967(4):40-42. (ABSTR. F.A. 29:570).

Presents and discusses data on height and volume increment showing that in the conditions of periodic drought occurring in the Ukraine, rows running W.E. create improved microclimatic conditions and increase productivity by 20%.

K.W. Quercus sp. (oak), height growth, microclimate, planting orientation, volume growth, wood production.

179. Mojrov, S.L. 1968. [Effect of initial density of spruce plantations on the subsequent growth of the stand] Lesn. Hoz. 1968(5):26-29. (ABSTR. F.A. 30:2256).

Reports results of a study on 17 plots in Norway spruce plantations aged 58-63 years, established by planting at 1200-7700 plants/ha. It is concluded that on clay-loams of the northern forest steppe the initial planting density should be 2000-3000 plants/ha and optimum N (number of plants at age 60) is 600-700 stems/ha.

K.W. Picea abies (Norway spruce), growth increment, planting density, soil, thinning.

180. Molino, O. 1972. [Yield from pines planted at different initial spacings] Boletín, Asociación de Plantadores Forestales de Misiones No. 7:61-66. (ABSTR. F.A. 34:2844).

All pines tested except for Pinus patula gave greatest volume increment at initial spacings of 2x2 m. Pinus patula gave greater yield at 3x3 m. Generally, 3x3 m produced a greater proportion of trees in the higher diameter classes than other spacings.

K.W. Pinus spp. (pines), diameter class, initial spacing, volume growth, wood yield.

181. Mork, E. 1949. [Piece work planting, planting distances and plant ages for spruce] Tidsskr. Skogbr. 57(2/3):81-89. (ABSTR. F.A. 13:2084).

Series of trials has been laid out for spruce planted at distances of 1.4, 1.6, 1.8, and 2.0 m. In the meantime, a planting density of 400 plants/dekare on the best lowland site classes is recommended.

K.W. Picea sp. (spruce), initial spacing, planting, planting density.

182. Morrow, R.R. 1964. Another look at plantation spacing. U.S. Dept. Agric., Tree Planters Notes 67:13-15.

Discusses spacing from silvicultural and economic standpoints. Effects of various spacings are reviewed.

K.W. forest management, initial spacing, wood production.

183. Morse, V.E. 1962. Economic model for optimal initial spacing in forest plantations. Univ. N.Y., College of Forestry at Syracuse, M.Sc. Thesis. np.

K.W. economic model, initial spacing, plantation.

184. Mráček, Z. 1967. [Retrospective research of spacing in Norway spruce plantations] Comm. Inst. For. Csl. 5:141-151. (ABSTR. F.A. 30:3921).

K.W. Picea abies (Norway spruce), initial spacing.

185. Mráček, Z. 1967. [Spacing in Norway spruce plantations] Lesn. Práce 46(2):53-56. (ABSTR. F.A. 28:5589).

Presents and discusses comparative data on height and diameter increment, volume and assortment yields, and wood quality, for stands aged 29-74 years planted at 3333-10,000 seedlings/ha. For conditions in Czechoslovakia, the author recommends planting 3-4 year seedlings at 4000-6000/ha.

K.W. Picea abies (Norway spruce), diameter growth, height growth, planting density, volume growth, wood quality.

186. Mráček, Z. 1968. [Spacing and quality of Norway spruce stands] Lesn. Cas. 14(9/10):789-801. (ABSTR. F.A. 31:6338).

A study was made of stem quality in 19 plantations aged 25-74 years, initially established in square or rectangular spacing at 2200-10,000 plants/ha. Results suggest that the effect of spacing on number of high quality trees/ha tends to disappear with age. The upper limit for planting density should be 6000 trees/ha.

K.W. Picea abies (Norway spruce), initial spacing, planting density, stand quality.

187. Mráček, Z. 1968. [The effect of spacing on the productivity of Norway spruce stands] Práce. Vyzkum. Ust. Lesn. Hosp. Mysl., Zbrslav-Strnady 36:197-215. (ABSTR. F.A. 31:2477).

Uses data from various experiments to demonstrate the difficulty of making a retrospective evaluation of the effect of initial spacing on the components of quantitative production. Since the effect on assortment yield is clearly definable, spacing should be based on assortment requirements.

K.W. Picea abies (Norway spruce), initial spacing.

188. Mráček, Z. 1969. Influence of spacing on the quality of Scots pine stands. Comm. Inst. For. Csl. 6:99-109. (ABSTR. F.A. 32:4236).

It was concluded from studies in 33 stands aged 16-74 years, that close spacing is essential, except for races that do not form many large branches. A planting density of 15,000-20,000 trees/ha is recommended, and at 1.2 - 1.5 x 0.5 - 0.33 m to facilitate mechanized tending.

K.W. Pinus sylvestris (Scots pine), branching, initial spacing, planting density, silviculture.

189. Mráček, Z. 1970. [Trial plot established to examine the effect of spacing on stand quality] Lesnictvi 16(6):513-523. (ABSTR. F.A. 33:6169).

For Norway spruce in Czechoslovakia, medium spacing (1.5 m x 1.5 m or 4444 plants/ha) is recommended.
K.W. Picea abies (Norway spruce), initial spacing, stand quality.

190. Munger, T.T. 1946. The spacing in plantations. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Note 34, pp. 3-4.

Average diameter of planted Douglas fir over the first 20 years increases with width of spacing, and in the 12'x12' plot is about twice that on the 4'x4' plot. The wider the spacing the greater the average height of all trees. The closer the spacing the greater the basal area and cubic volume of the stand. There is a progressive increase in crown width from close to wide spacing. The diameter of the limbs at breast height is progressively greater with wider spacing. The growth of bracken, annuals and shrubs is much greater in the wide spacing.
K.W. Pseudotsuga menziesii (Douglas fir), crown width, diameter growth, height growth, initial spacing, vegetation, volume growth.

191. Munkøe, J.C.H. 1944. [Choice of spacing for conifers] Dansk Skovforen. Tidsskr. 29(8):293-318. (ABSTR. F.A. 8:241).

A review of literature, in which it is concluded that for Norway spruce, rectangular spacing between 1.5 x 1.5 m and 2 x 2 m is economically advantageous and will yield a product of satisfactory quality. Closer spacing would be desirable for production of Christmas trees or fine straight timber. Wider spacing might lower timber quality. For Scots pine a spacing of 1.3 x 1.3 m is recommended. Sitka spruce should be spaced at 1.5 x 1.5 m, Abies spp. at 1.8 x 1.8 m, Larch at 2.5 x 2.5 m, and Douglas fir at 1.25 x 1.25 m.
K.W. Larix sp. (larch), Picea abies (Norway spruce), Picea sitchensis (Sitka spruce), Pinus sylvestris (Scots pine), Pseudotsuga menziesii (Douglas fir), initial spacing, wood production, wood quality.

192. Najdenova-Janeva, C. 1969. [Effect of stand density on stem taper in Populus x regenerata] Gorsko Stopanstvo 25(4):21-23. (ABSTR. F.A. 31:654).

Tabulates form quotients for various spacings and dbhs.
K.W. Populus sp. (poplar), initial spacing, taper.

193. Nelson, T.C. 1952. Early competition in slash pine plantations. U.S. Dept. Agric., Northeastern Forest Experiment Station, Res. Note 10. 2 pp.

Competition in a 6'x6' plantation of slash pine may begin by the third year after planting. Diameter growth of individual trees is reduced, but height growth after 7 years is not affected. Results showing d.b.h. and b.a. for 2-7 years after planting at 6'x6' and 12'x12' are graphed.

K.W. Pinus elliottii (slash pine), competition, diameter growth, height growth, initial spacing.

194. Neuzorov, J.M. 1970. [Effectiveness of Scots pine plantations at different planting densities] Lesn. Hoz. 1970(6):29-32. (ABSTR. F.A. 32:672).

As regards yields and value, the best initial densities are 13,300-20,000 plants/ha, and 13,300 is regarded as the practical optimum.

K.W. Pinus sylvestris (Scots pine), planting density, value production, wood yield.

195. Nylinder, P. 1958. [Aspects of spruce wood quality with reference to the sulphite process] Svensk PappTidn. 61(18B):712-717. (ABSTR. F.A. 20:4516).

Concludes that for the sulphite pulp industry, differences in knot content, branch thickness and weight of dry matter caused with a range of spacings from 1-2 m are of minor importance.

K.W. Picea sp. (spruce), initial spacing, wood quality.

196. Nylinder, P. 1958-1959. [Aspects of quality production I-III] Skogen 45(4, 23); 46(3):100-102; 714, 717-718; 54-57. (ABSTR. F.A. 20:3125).

Studies variation of branch thickness and knot content in pine and spruce at different spacings. Differences in branch thickness between spacings were greatest towards butt and smallest towards top. Within spacings, branch diameter increased with stem diameter, and a correlation was found between branch diameter and ring width. Knot content increased with increasing height of tree and increasing stem diameter and spacing. Little difference was found in the amount of dry matter produced in trees at spacings up to 2 m x 2 m.

K.W. Picea sp. (spruce), Pinus sp. (pine), branching, diameter growth, initial spacing, taper, wood production, wood quality.

197. O'Connor, A.J. 1935. Forest research with special reference to planting distances and thinning. British Empire Forestry Conference, 1935, Pap. 3. 30 pp.

Inquiry into the problem of developing a method which would use a limited number of plots in a relatively short space of time to provide all necessary facts for a complete exposition on the effect of available growing space on tree development in a given locality.

K.W. growth increment, initial spacing, thinning, wood quality, wood production, wood yield.

198. Oksbjerg, E.B. 1960. [Spacing of spruce on good sites in South Sweden] Svenska SkogsvForen. Tidskr. 58(2):57-68. (ABSTR. F.A. 21:3094).

A lecture based on data from trial plots and other stands concluded that wider spacings (i.e. 2.5 x 2.5 m), are preferable because the greater diameters achieved at a given age more than compensate for loss in stand volume and quality.

K.W. Picea sp. (spruce), diameter growth, economics, initial spacing, taper, volume growth, wood quality.

199. Oksbjerg, E., G. West-Nielsen and J. Lundberg. 1969. [A plant spacing study in Gedhus plantation] Hedeselsk. Tidsskr. 90(6):123-129. (ABSTR. F.A. 30:5647).

Spruce planted at 1.5 x 1.25 m had reached a height of 310 cm, while when spaced at 3.0 x 1.8 m, a height of 395 cm was reached. In both plots, trees weeded or planted with larch as a nurse crop were about 15% taller than those planted with mountain pine.

K.W. Picea abies (Norway spruce), height growth, initial spacing, nurse crop, weeding.

200. Oldenkamp, L. 1968. [The silvicultural basis for adopting wider plant spacings in conifers] Ned. Bosb. Tijdschr. 40(5):186-206. (ABSTR. F.A. 29:5574).

Discusses the merits of wide spacing v.s. narrow spacing, and stresses the need, when wide spacings are used of choosing species and methods of establishment suited to the site, and of using good planting stock.

K.W. conifers, initial spacing, silviculture.

201. Peno, D. and D. Meskovic. 1967. [Dependence of the yield of a (Populus) I-214 plantation on the soil and planting density] Jelen, Beograd 1967(6):5-36. (ABSTR. F.A. 29:5580).

Presents data from the first 4 years of growth at spacings of 3x3 m and 6x6 m on 4 different site classes in Jugoslavia.

K.W. Populus sp. (poplar), growth increment, initial spacing, site class.

202. Petch, A.M. 1964. The use of wider planting distances. Quarterly Journal of Forestry 58(4):360-361.

Discusses the advantages of spacing conifers further apart than the distances now conventionally used in Britain.
K.W. initial spacing, planting.

203. Petrini, S. 1932. [An experiment with different spacing in planting spruce] Skogen 19(15):360. (ABSTR. B.A. 7:16748).

At 28 years, all plots were thinned except one planted at 2 m x 2 m which had not yet closed. Thinning should have been carried out earlier in the 1 m x 1 m spacing, but even when made, no merchantable products were yielded. With wider spacing, some products were salable. The closest spacing which can be recommended is 1.5 m x 1.5 m.
K.W. Picea sp. (spruce), economics, spacing, thinning, wood yield.

204. Pinčuk, A.M. 1961. [Features of the growth of Scots pine in plantations of various density] Lesn. Hoz. 14(1):63-64. (ABSTR. F.A. 23:523).

Pine was planted at 2, 4, 8, 16 and 32 thousand plants/ha on old arable sandy land near Moscow. It was concluded on basis of mortality and growth over 10 years that 8-16 thousand plants produces best spacing under these conditions.
K.W. Pinus sylvestris (Scots pine), growth increment, initial spacing, mortality, planting, soil.

205. Polashev, I., I. Manolova and V. Nikolov. 1973. [Growth and yield of populus deltoides at different spacings on sites away from the rivers in the N.E. part of the Thrace/Tundzha poplar region] Gorskostopanska Nauka 10(1):35-43. (ABSTR. F.A. 34:4550).

Gives details of performance up to age 12 of plantations established at 2x2, 3x3, 4x4, 5x5, and 6x6 m in east Bulgaria. Stemwood volume per ha at age 12 decreased with increasing spacing, and m.a.i. was only 4.84 m^3/ha at 2x2 m spacing, falling to 2.38 m^3/ha for the 6x6 m spacing.
K.W. Populus sp. (poplar), initial spacing, site quality, volume growth.

206. Poljakov, E.G. 1967. [The influence of initial density on the growth and productivity of Alnus glutinosa plantations in the Ukrainain Poles'e] Lesn, Z., Arhangel'sk 10(6):35-37. (ABSTR. F.A. 30: 3932).

Gives data on mean diameter and height, standing volume and increment, for stands aged 23-25 years, established at initial densities of 1666, 5000, and 10,000 plants/ha. For maximum stand productivity, initial density should be $\leq$ 10,000 plants/ha, but in plantations aimed at production of larger logs it should be nearer to, but $\leq$ 5000 plants/ha.

K.W. Alnus sp. (alder), diameter growth, height growth, planting density, stand productivity, timber production.

207. Prevosto, M. 1963. [A contribution to the economic study of spacing in poplar plantations] Cellulosa e Corta 14(3):5-20. (ABSTR. F.A. 24:4946).

From study of several plantations of poplar it was deduced that m.a.i. of timber from dense stands (1252 trees/ha) on a 6 year rotation was greater than that from a similar stand on a 10 year rotation, and much greater than that from a widely spaced (357 trees/ha) one on a 10 year rotation, but the mean financial return of the latter was much greater than the other two.

K.W. Populus sp. (poplar), economics, growth increment, initial spacing, profit, rotation, stand density.

208. Ralston, R.A. 1953. Some effects of spacing on jack pine development after 25 years. U.S. Dept. Agric., Lake States Forest Experiment Station, Tech. Note 388. 1 p.

Twenty five years after planting, jack pine seedlings set out at a spacing of 6'x6' have developed more satisfactorily than others planted at 4'x4' or 8'x8'. Trees at 8'x8' spacing have developed orchardlike crowns.

K.W. Pinus banksiana (jack pine), basal area growth, branching, diameter growth, height growth, initial spacing, tree form, wood production.

209. Ralston, R.A. 1953. Some effects of spacing on jack pine development in lower Michigan after 25 years. Michigan Acad. Sci., Pap. 38: 137-143. (ABSTR. F.A. 16:1695).

Plantations on poor sites with an initial spacing of 6'x6' will yield sufficient merchantable volume for a commercial thinning when a thinning is needed for a silvicultural point of view. Height growth is unaffected but diameter increases with wider spacing. Spacings wider than 8'x8' however, are undesirable. A total of 600-700 stems/acre at 25 years seems to be best stocking for maximum return.

K.W. Pinus resinosa (red pine), diameter growth, height growth, initial spacing, thinning, wood production.

210. Ralston, R.A. 1954. Some effects of stand density on the height growth of red pine on poor sites in northern lower Michigan. Michigan Acad. Sci. Pap. 39:159-165. (ABSTR. F.A. 16:1696).

Pinus resinosa height growth was retarded by close spacing. After 35 years, the dominant trees in a plantation spaced at 4'x4', 6'x6', 6'x8' and 8'x9' averaged 25.4, 29.8, and 31.5'. respectively in total height.

K.W. Pinus resinosa (red pine), height growth, initial spacing.

211. Rasper, E. 1971. [Economy in the use of planting stock in Scots pine plantations] Sozial. Forstw. 21(1):26. (ABSTR. F.A. 32: 5958).

Describes planting of Scots pine in a pattern of 4 planted rows alternating with one blank row, and discusses cost saving and other advantages gained with hardly any loss of quality.

K.W. Pinus sylvestris (Scots Pine), economics, initial spacing, row planting.

212. Reukema, D.L. 1959. Some recent developments in the Wind River Douglas fir plantation spacing tests. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Note 167. 7 pp.

Douglas fir was planted at spacings of 4'x4' to 12'x12'. Wider spacings produced taller trees. For the portion of the stand made up of merchantable size trees, both cubic volume and board foot volume increase with wider spacing. Portion of total cubic volume which is merchantable increases rapidly with increasing spacing, being 22% at 4'x4', and 87% at 12'x12'.

K.W. Pseudotsuga menziesii (Douglas fir), height growth, initial spacing, volume growth, wood production.

213. Reukema, D.L. 1967. The yield and density aspect - does dense spacing really produce the most volume. In: Western Reforestation. Western Forestry and Conservation Association, Proc. Western Reforestation Co-ordinating Committee, 1966. pp. 23-26.

Indications are that planting or precommercially thinning trees to uniform, fairly wide spacing will result in stands which yield more total volume than unmanaged or densely spaced stands.

K.W. initial spacing, stand density, thinning, wood production, wood yield.

214. Reukema, D.L. 1970. Forty year development of Douglas fir stands planted at various spacings. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Res. Pap. PNW-100. 21 pp.

Reviews development of Douglas fir stands in the Wind River area. Gross h.a. increment and gross volume have, since the last measurement, tended to increase with increased spacing, and during the period 1960-1965, were respectively 59 and 117% greater for the 12'x12' than for the 4'x4' spacings. Merchantable volume is substantially greater for the wide spacings. Height and diameter increment of the 100 largest trees per acre is also greater at wide spacings. Trees at close spacings were more susceptible to storm damage. At close spacing, few trees reached a size justifying their removal in commercial thinnings.

K.W. Pseudotsuga menziesii (Douglas fir), basal area growth, diameter growth, height growth, initial spacing, storm damage, volume growth.

215. Revel, J. 1970. E.P. 660- Species and spacing trials in the montane transition zone. B.C. Forest Research Review. p. 73.

Progress reports on growth response of 1+1 lodgepole pine, 1+1 Douglas fir and 2+1 white spruce planted at 7, 10, and 13' square spacings on various soil types. Lodgepole pine showed best growth and vigour, Douglas fir was satisfactory, but white spruce showed very slow growth even after 3 growing seasons. (Also reported 1968, p. 74; 1969, p. 81. Final conclusions reported by H.C. Coates, 1972, p. 59-60).

K.W. Picea glauca (white spruce), Pinus contorta (lodgepole pine), Pseudotsuga menziesii (Douglas fir), browsing, height growth, initial spacing, mortality, rabbits, stand history, soil, wildlife.

216. Revel, J. 1971. E.P. 549- Spacing and growth studies - white spruce. B.C. Forest Research Review. p. 74.

Progress reports on 2+0 white spruce planted at 4x4, 8x8, 12x12, and 16x16'. Fire destroyed the site in 1961 and it was replanted in 1965 at 7x7, 10x10, and 13x13'. Tabulations of survival and height growth were made after five and six years of growth respectively. There was no variation between spacings. (Previously reported - 1960, 1966, 1967, 1970. Co-author T.P. Decie, 1960).

K.W. Picea glauca (white spruce), height growth, initial spacing, seedling survival.

217. Richter. 1964. [Reflections on plant spacing for Norway spruce] Forst-und Holzw. 19(4):61-65. (ABSTR. F.A. 25:3500).

Discusses the trend towards wide spacing to reduce establishment and thinning costs, and argues that such savings are likely to be offset by other factors.

K.W. Picea abies (Norway spruce), economics, initial spacing, thinning.

218. Rojas y Rojas, J.M. and E. Rojas Valero. 1962. [Poplar and the classic method of growing it] Montes, Madrid 18(104):113-116. (ABSTR. F.A. 23:5138).

Three plantations of poplars of various combinations of two different clones were established in Spain, two at a spacing of 1.8 x 1.8 m, one being both varieties interplanted, and one at a spacing of 4x5 m. Mean annual increments for the three plantations at age 5 are given.

K.W. Populus sp. (poplar), initial spacing, thinning, volume growth.

219. Roussel, L. 1970. [The density of spruce plantations] Bull. Soc. For. Franche-Comté 35(4):90-93. (ABSTR. F.A. 32:4232).

Discusses the merits of various densities and regular and irregular initial spacings for Norway spruce plantations in relation to date from Sweden, Czechoslovakia, and Germany on increment and yield at different ages; and to considerations of access, windthrow, early mechanical thinning, type of produce grown, and wood quality.

K.W. Picea abies (Norway spruce), growth increment, initial spacing, planting density, windthrow, wood quality, wood yield.

220. Rudolph, V.J., J.N. Bright and T.D. Stevens. 1965. A spacing study of planted yellow poplar in Michigan. Michigan Agricultural Experiment Station, Quarterly Bull. 47(4):615-622.

Comparison of yellow poplar planted at 8'x8', 10'x10', 12'x12' and 14'x14' showed that total height in the two closer spacings was equal to that in the wider spacings, but average potential merchantable height was greater. There were significantly fewer multiple stems in the close spacings.

K.W. Liriodendron tulipifera (yellow poplar), height growth, initial spacing, tree form, wood production.

221. Russell, T.E. 1958. Spacing - its role in the growth of planted slash pine. Southern Lumberman 197(2465):115-117. (ABSTR. F.A. 20:3126).

Analyses plots established at 4, 5, 6 and 13' square spacings. Concludes that the commonly used spacing of 6'x8' is the best compromise between total volume production and early yield.

K.W. Pinus elliottii (slash pine), initial spacing, wood yield.

222. Russell, T.E. and H.J. Derr. 1956. Longleaf height unaffected by stand density. U.S. Dept. Agric., Southern Forest Experiment Station, Southern Forestry Note 101. p. 2.

Longleaf pine were planted at initial densities of 2,500, 1,600, 1,150 and 250 trees/acre. Survival was low. Height growth over 20 years shows no variation with initial spacing.
K.W. Pinus palustris (longleaf pine), height growth, initial spacing, planting density, seedling survival.

223. Sadnovičij, F.P. 1964. [Effect of width between rows on tree diameter] Lesn. Hoz. 17(10):39-40. (ABSTR. F.A. 26:3643).

Statistical studies in Scots pine plantations aged 23 years, site class I, revealed that mean diameter in cm. is 5.5 + 1.1x where x is width between rows in meters.
K.W. Pinus sylvestris (Scots pine), diameter growth, initial spacing, row width.

224. Sadnovičij, F.P. 1964. [The effect of the spacing between rows on the performance of Scots pine plantations] Lesn. Hoz. 17(4): 45-46 (ABSTR. F.A. 26:2157).

On an old field site, planted in 1940, seven different row spacings were used, tree spacing within the rows being 0.7 - 0.8 m in all cases. In 1962, the best in terms of number of trees, basal area, and standing volume per ha was 1.4 - 1.5 m, between rows, but with a spacing of 2.9 m - 3 m after every 4th row.
K.W. Pinus sylvestris (Scots pine), basal area growth, initial spacing, volume growth.

225. Sagreiya, K.P. 1944. Triangular versus square planting. Indian Forester 70:283-289.

Triangular planting results in a tree distribution more like that obtained under natural conditions than does square planting, and is therefore to be preferred from a physiological point of view. Triangular planting has the advantage over square planting that mechanical thinning of the crops can be carried out to various intensities in such a way that the plants retained have equal freedom to grow on at least two sides.
K.W. initial spacing, thinning.

226. Sakamoto, T. 1969. [Ten year growth at different spacing of Larix leptolepis and other 7 species] Oji Inst. For. Tree Impr., Tech. Note 77, 24 pp. (ABSTR. F.A. 33:6168).

Results of study show that initial stand density of 3000 trees/ha can be recommended for Larix leptolepis.
K.W. Larix leptolepis (Japanese larch), planting density, wood production.

227. Salik, C. 1955. [Results of the nest method of regeneration in the transformation of pure spruce plantations in the Cadca forest district] Lesn. Bratislava 2(4):135-143 (ABSTR. F.A. 16:4049).

Height increment for nest planted seedlings on worked soils over a 2 year period was 2.3 times that on unworked soils. Size and spacing of nests should be $\leq$ 1.2 m square and $\leq$ 1.5 m apart.

K.W. Picea sp. (spruce), cultivation, height increment, initial spacing, nest planting,

228. Schenstrom, S.R. 1957. [Spacing, thinning, and rotation of Salix alba var. caerulea in the Paraná delta] Rev. For. Argent. 1(3):91-96. (ABSTR. F.A. 19:397).

Measurement of 2 year old plantations with initial spacings of 3 x 1.5 m, 3 x 2 m, and 3 x 3 m, showed that the 3 x 2 m spacing produced as great a volume per ha as the 3 x 1.5 m and is therefore to be recommended. Increment increases up to 4 years of age, when a 50% thinning should be made. A rotation of 10 years produced the greatest volume of sawtimber and the highest financial returns.

K.W. Salix sp. (willow), economics, initial spacing, rotation, thinning, wood production.

229. Schmith, T.B. 1953. [How many pines per hectare should we plant?] Chile Madero 3(6):7. (ABSTR. F.A. 15:1318).

It is advantageous to reduce spacing of radiata pine from 2 m x 2 m to 1.5 m x 1.5 m in order to obtain small timber for pulpwood. With this spacing, 2000 trees/ha may be removed between the ages of 8 and 14 years. Silviculturally, no harm arises so long as the whole stand rotation is not shortened.

K.W. Pinus radiata (radiata pine), economics, initial spacing, rotation, thinning, wood production.

230. Schonau, A.P.G. 1970. Planting, espacement, and pruning of Eucalyptus grandis on a low quality site. South African Forestry Journal 1970 (73):11-15. (ABSTR. F.A. 32:674).

Compares spacings (9 x 7, 8, 9, or 10 ft) and various pruning regimes. Results were assessed at 7 1/2 years. Higher stand densities yielded a greater volume of timber, but severe live pruning reduced potential timber yield by 25%.

K.W. Eucalyptus sp. (eucalyptus), initial spacing, pruning, volume growth, wood production.

231. Seibt, G. and L.B. Angeles. 1971. [A Norway spruce spacing trial at Kinn] Allgemeine Forst-und Jagdzietung 142(1):12-30. (ABSTR. F.A. 32:5955).

Under circumstances of trial, the stand with the densest spacing was clearly superior in financial yield, both gross and net, even though volume differences tended to even out with age, and height and diameter growth were better in the wider spacings. Square spacings appeared to be better than rows as regards canopy closure, yield to pole stage, and stand stability.

K.W. Picea abies (Norway spruce), diameter growth, height growth, initial spacing, profit, stand density, wood production.

232. Senda, S., K. Nakamura, S. Takahara, and T. Satoo. 1952. [Some aspects of growth in stands (a preliminary report): an analysis of pine stands with different spacings] Tokyo Univ., Forestry Bull. 43, pp. 49-57. (ABSTR. F.A. 14:3337).

Spacings of 0.5, 1.0, 1.5, and 2.0 m were used in planting 1 year old Pinus densiflora seedlings. After 12 years, average dbh, size of crown, live crown ratio, stem wood volume weight of needles per tree and volume of branches per tree were shown to have decreased with increasing planting density. Mortality, volume of stem wood and basal area, at bh ∠ unit area, annual stem wood production/unit wt. of needles and ratio of stem wood to total wood increased with increasing stand density.

K.W. Pinus densiflora (Japanese red pine), diameter growth, spacing, volume growth, wood production.

233. Šindelář, J. 1969. [Pinus sylvestris stands established by nest planting] Lesnictví 15(10):871-892. (ABSTR. F.A. 32:673).

A detailed comparative assessment, at age 15 years, of nest planting and row plantings in Czechoslovakia. The nest plantings have shown no superiority in growth, row plantings (1.2 x 0.6 m) are superior as regards stem form and branching.

K.W. Pinus sylvestris (Scots pine), branching, growth increment, initial spacing, nest planting, row planting, stem form.

234. Singer, F.P. and R.J. Hutnik. 1966. Accumulation of organic matter in red pine and Norway spruce plantations of various spacings. Pa. State Univ., School of Forest Resources, Res. Brief 1(1): 22-28. (ABSTR. F.A. 28:355).

Three plots, aged 42 years, and initially spaced at 6'x6', 6'x8', and 10'x10' were studied. Both species showed some accumulation pattern in relation to spacing. Biomass was greater in denser stands. Leaf weight was, however, fairly constant in all spacings.

K.W. Picea abies (Norway spruce), Pinus resinosa (red pine), biomass accumulation, initial spacing, leaf weight.

235. Siren, G. 1956. [The treatment of pine seedling stands] Metsät. Aikak. 1956(1):5-12. (ABSTR. F.A. 17:2794).

Recommends patch sowing at 2.0-2.5 m spacing which should give 1800-2500 trees/ha. Only competitors most dangerous to dominants should be removed in thinning. Thinning when stand reaches a height of 1.3-5.0 m is recommended. Results of a thinning experiment in which number of trees was reduced from 24,000 to 2,900/ha without any loss of volume increment are presented. The same results can be obtained by removing only the most serious competitors (mainly co-dominants) of dominant trees; the trees of the lowest crown layer disappear naturally.

K.W. Pinus sp. (pine) initial spacing, patch sowing, thinning, thinning intensity, volume increment.

236. Sjolte-Jorgensen, J. 1967. The influence of spacing on the growth and development of coniferous plantations. International Review of Forest Research 2:43-94.

Reviews effect of spacing on individual volume factors, volume production, quality and heart rot, and discusses economic importance of spacing.

K.W. economics, initial spacing, literature review, wood production, wood quality.

237. Smith, J.H.G. 1971. Productivity of western Canadian forests and their potentials for improvement. In: Symposium A 5.3, Twelfth Pacific Science Congress, Canberra, Australia, Aug. 18-Sept.3. 19 pp.

Presents data on natural productivity of commercially important tree species in British Columbia. Results of limited research suggest that the best method of intensifying management of these forests is to grow stands from initially wide spacings to become fully stocked and crowded at harvest time.

K.W. forest management, initial spacing, silviculture, wood production.

238. Smith, J.H.G. and G. Blom. 1970. Poplar spacing trials show way to gains in wood yield. Canadian Forest Industries 90(7): 40-41.

Reviews literature on poplar spacing trials [in B.C.] and gives details of growth and yield of poplar and cottonwood planted at spacings of 6, 12, 18, 24, and 32 ft. Indications are that the spacing should be at least 12 ft. and possibly 18 ft. for cottonwood.

K.W. Populus 'grandis' (poplar), Populus trichocarpa (black cottonwood), growth increment, initial spacing, wood yield.

239. Smith, J.H.G. and J. Walters. 1957. The influence of spacing on cost of planting Douglas fir. Forestry Chronicle 33(4):392-394.

A spacing study made in the U.B.C. Research Forest, showed that the cost of planting an individual seedling increased with increased spacing, but total planting cost decreases with increased spacing.

K.W. Pseudotsuga menziesii (Douglas fir), initial spacing, planting cost.

240. Smith, L.F. 1956. Early returns from a slash pine plantation. Southern Lumberman 193(2417):212-213. (ABSTR. F.A. 18:2804).

Diameter growth of longleaf pine planted at various spacings in 1941 was greater on the widest spacing than on the closest spacing by 2 inches, but b.a., cordwood production, and financial returns were generally highest at the closer spacings.

K.W. Pinus palustris (longleaf pine), diameter growth, economics, initial spacing, planting, wood production.

241. Smith, L.F. 1967. Effects of spacing and site on the growth and yield of planted slash pine. U.S. Dept. Agric., Southern Forest Experiment Station, Res. Note SO-63, 4 pp.

Slash pine was planted in 1941 at various spacings from 4.6-9.3' on the sites (cut-over and old field) in southern Mississippi. On both sites, the yield at 21 years was highest on plots with the closest spacing.

K.W. Pinus elliottii (slash pine), growth increment, initial spacing, site type, wood yield.

242. Stahelin, R. 1950. Effect of spacing on quality of lumber [of Southern pines] Alabama Agricultural Experiment Station, Biennial Rept. 1947-1948. pp. 28-29. (ABSTR. F.A. 13:3804).

Includes a table showing relation between spacing and degree of knottiness in the first 16' log of 16 year old plantation pines.

K.W. Pinus sp. (pine), initial spacing, wood quality.

243. Stawecka, W. 1971 [Effect of spacing on the increment of Populus 'Marilandica' in a plantation in the Vistula valley] Prace Inst. Bad. Lesn. No. 398/400, pp. 29-53. (ABSTR. F.A. 33:646).

Volume production of poplar established at square spacings of 2-6 m, was greatest at 4 x 4 m. This spacing also gave best financial results.

K.W. Populus sp. (poplar), economics, initial spacing, volume growth, wood production.

244. Steedley, A.G. 1958. Wide tree spacing versus medium spacing. Naval Stores Rev. 68(5):7. (ABSTR. F.A. 20:1770).

A comparison of timber and resin returns over a period of 21 years from two slash pine plantations spaced originally at 12'x12' and 15'x15'. The 12'x12' plantation showed greater financial yield.

K.W. Pinus elliottii (slash pine), economics, initial spacing, wood yield.

245. Stern, R.C. 1972. Poplar growing at close spacing. Timber Grower 44:20-24. (ABSTR. F.A. 34:273).

Profitability assessments for three different sets of rotations, three different delivery costs, and various interest rates indicate that growing at close spacing is reasonably profitable and that coppicing may be even more so, particularly if the markets are not too distant. (Also in Quarterly Journal of Forestry 66(3):230-235.)

K.W. Populus sp. (poplar), initial spacing, profit, rotation.

246. Stevenson, D.D. and R.A. Bartoo. 1939. The effect of spacing on the growth of Norway pine plantations - a progress report. J. For. 37:313-319.

Offers different opinions of correct spacing. There appears to be a general trend toward wider spacings and data from experiment using 5x5, 6x6, 6x8, and 10x10' spacing showed more rapid growth on the 10x10' spaced trees. Wide spacing seems desirable when pruning can be practiced and early thinnings are not practical.

K.W. Pinus sylvestris (Scots pine), growth increment, initial spacing, pruning.

247. Stiell, W.M. 1963. Twenty-year growth of red pine planted at three spacings. Canada, Dept. Forestry, Forest Research Branch, Petawawa Forest Experiment Station, Chalk River, Mimeo. Pet. 63-P-12. 25 pp.

Plantations of Pinus resinosa were established at spacings of 7'x7', 10'x10', and 12'x12' at Petawawa Forest Experiment Station. Larger crowns, thicker branches, greater diameters breast height, and lower form classes were associated with wider spacing. Average height was the same for all spacings. Greater basal area and more volume per acre were associated with closer spacing as were much higher planting costs.

K.W. Pinus resinosa (red pine), branching, diameter growth, height growth, initial spacing, planting cost, volume growth.

248. Stiell, W.M. 1966. Red pine crown development in relation to spacing. Canada, Dept. Forestry, Publ. 1145, 44 pp.

Trees at spacings of 5'x5', 7'x7', 10'x10', and 14'x14' were measured in plantations over the period 17 to 37 years from seed. Little mortality occurred during this 20 years, and individual crown size tended to stabilize, with smaller crowns occurring at closer spacings. Other details are noted.
K.W. Pinus resinosa (red pine), crown growth, diameter growth, height growth, initial spacing, thinning, volume growth.

249. Stiell, W.M. 1968. Spacing and survival tables for plantations. Tree Planters Notes 19(3):18-21.

Contains tables such as: trees/acre at square spacings; range in trees/acre for average spacings; survival standards for average spacings, trees/acre according to % survival; and survival % according to number of trees/ha.
K.W. initial spacing, survival tables.

250. Stiell, W.M. 1971. Comparative cone production in young red pine planted at different spacings. Canada, Forestry Service, Publ. 1306. 8 pp.

A red pine plantation established at several spacings produced first heavy cone crop at age 18. Cone crops increased with tree size within each spacing, no cones being found on trees < 5" diameter. Both number of cones per tree in a given dbh class and total number of cones per acre increased markedly with spacing up to 21'x21'.
K.W. Pinus resinosa (red pine), cone production, crown growth, initial spacing.

251. Sudnicyna, T.N. 1967. [The N nutrition of Scots pine in plantations of different density] Lesoved., Moskva 1967(2):67-73. (ABSTR. F.A. 28:5591).

Tabulates data on N uptake at age 17 for sample trees on plots planted at 2000, 8000, and 32,000 stems/ha.
K.W. Pinus sylvestris (Scots pine), nutrient uptake, planting, planting density.

252. Sutton, W.R.J. 1968. Economics of initial spacing. New Zealand Forest Research Institute Report, 1967. pp. 37-38.

Land expectation values at 3%, 5%, and 8% interest rates for both early and late thinning models were calculated for various initial spacings of Pinus radiata. 6'x6' and 8'x8' spacings were significantly less profitable than any wider spacing, but differences were greater with late thinning. Net returns for wider spacings were all very similar. Possibly the range of 10'x6' to 12'x12' would give optimum returns.

K.W. Pinus radiata (radiata pine), economics, growth increment, initial spacing, profit, wood quality.

253. Sutton, W.R.J. 1968. Initial spacing and financial return of Pinus radiata on coastal sands. New Zealand Journal of Forestry 13(2):203-219.

Financial returns for various spacings of radiata pine were determined. It was concluded that, so long as the adopted initial spacing is in the range 10'x6' to 12'x12', high net returns can be anticipated. Branch size and malformation need some investigation.

K.W. Pinus radiata (radiata pine), branching, economics, growth increment, initial spacing, profit, tree form, wood production.

254. Sutton, W.R.J. 1970. Effects of initial spacing on branch size of Pinus radiata. New Zealand Forest Research Institute Report, 1969. pp. 41-42.

The influence of various spacings on wood quality is assessed for different site indices.

K.W. Pinus radiata (radiata pine), initial spacing, site index, wood quality.

255. Suvorov, V.I. 1958. [Influence of meteorological factors on diameter growth of Pinus sylvestris in pure stands of different density] Sborn. Rabot Lesn. Hoz. Vsesojuz. Nauč-Issled. Inst. Lesovod 37:154-168. (ABSTR. F.A. 22:485).

Investigations in 1954-1955 in stands planted in 1915 in a mossy pine forest type at densities of 8,800; 26,300; and 39,500 seedlings/ha showed that m.a.i. (diameter) decreased with increasing plant density.

K.W. Pinus sylvestris (Scots pine), climate, diameter growth, planting, density, rainfall.

256. Suvorov, V.I. 1958. [Temperature and moisture regime of air and soil in Pinus sylvestris plantations of different densities in the Buzuluk forest] Sborn. Rabot Lesn. Hoz. Vsesojuz. Nauč.-Issled. Inst. Lesovod 35:130-143 (ABSTR. F.A. 22:484).

Plantations were established in 1948 at 6,666 and 40,000 seedlings/ha. M.a.i. (volume/ha) was significantly greater and weed trouble less for the more dense plantation when examined 1954-1956. M.a.i. (height and diameter) was greater in the less dense stand.

K.W. Pinus sylvestris (Scots pine), climate, diameter growth, height growth, planting density, soil moisture, volume growth.

257. Szodfridt, I. 1960. [A spacing trial with Populus x serotina in Tolnasziget] Erdo 9(7):247-251. (ABSTR. F.A. 22:3059).

Trials at 2x2, 4x4, 6x6, and 8x8 m showed (at 10th year of local conditions) 2x2 to yield greatest volume, and 4x4 m to yield greatest value. For mechanical cultivation, planting at 3 x 1.5 m is recommended.

K.W. Populus x serotina (poplar), economics, initial spacing, volume growth, wood yield.

258. Szymanski, S. 1971. [More on the 'revolutionary' ideas of wider spacing in Scots pine plantations] Sylwan 105(1):69-77. (ABSTR. F.A. 32:5959).

Concludes that 3 m x 3 m spacing is quite unsuitable for Scots pine.

K.W. Pinus sylvestris (Scots pine), initial spacing.

259. Taller, M. 1952. Planting distances of Aleppo pine trees in a forest. La Yaaran 3(1):29, 35. (ABSTR. F.A. 14:2197).

A spacing of 2 m x 2 m is optimum.

K.W. Pinus sp. (Aleppo pine), initial spacing.

260. Thonon, H. 1963. [The increment of Corsican pine as a function of initial spacing] Bull. Soc. For. Belg. 70(3):172-185. (ABSTR. F.A. 24:4945).

Measurement of height and diameter increment in several plantations indicated that the close initial spacing usual in Belgium (1x1 m) is undesirable. Such plantations need release at about 10 years old, whereas working plan prescriptions do not envisage a first thinning before 15-20 years. Spacing at 1.5 x 1.5 m or even 2x2 m is recommended.

K.W. Pinus nigra (Corsican pine), diameter growth, height growth, initial spacing, thinning.

261. Timofeev, V.P. 1959. [Growing larch at different planting densities] Izv. Timirjoz. Sel'hoz. Akad. Moskva 2:123-140. (ABSTR. F.A. 21:1748).

One year seedlings of Siberian larch were planted at regular spacings giving densities of 25, 50, 100, and 200 plants/m^2 in 1947. In 12 years, the total air dry weight of material produced was 35.25, 25.78, 19.15, and 20.18 kg/m^2 and number of trees still living in 1957 were 13, 17, 16 and 21 trees/m^2. Similar results from another experiment are reported. The manifold adverse effects of very dense planting are discussed.

K.W. Larix sp. (larch), competition, growth increment, initial spacing, mortality, planting density.

262. Timofeev, V.P. 1961. [Effect of stand density and tree growth classes on the formation of productive stands] Lesn. Hoz. 14(10):16-21. (ABSTR. F.A. 23:3560).

Tabulates data on survival, height, diameter and growth classes at age 9, and on duration of growth and daily height increment for years 1957-1960 of larch, pine, spruce, and box planted in 1954 at 4, 12, 24, 48 and 100 plants/4m^2.

K.W. Larix sibirica (Siberian larch), Picea abies (Norway spruce), Pinus sylvestris (Scots pine), diameter growth, height growth, mortality, planting density.

263. Trifunović, D. 1961. [Research into the effect of poplar stand density on total diameter and volume increment in the Danube region of Bačka and Banat, and the Tisa and Sava regions of lower Srem] Šumarstvo 14(11/12):465-484. (ABSTR. F.A. 23:5139).

A study on 22 plots of hybrid poplar with mean initial densities of 2500, 1500 and 650 stems/ha over 30 years (ages 5-35). The plots with lowest initial density showed greatest total increment, especially after 25 years.

K.W. Populus sp. (poplar), diameter growth, height growth, planting density.

264. Tronco, G. 1967. [Dense or widely spaced poplar stands?] Ital. Agric. 104(11):1141-1162. (ABSTR. F.A. 29:3832).

In the Po valley, similar financial yields can be expected after 10 years from dense coppice stands at 3 x 3 m (2-5 year rotations) or open stands at 6 x 6 m (10 year rotation). The wider spacing permits a heavy stocking of cattle.

K.W. Populus sp. (poplar), financial yield, initial spacing, rotation.

265. Tuset, R. 1962. [Growth data from widely spaced poplar plantations] Silvicultura, Uruguay 17:15-27. (ABSTR. F.A. 24:2007).

At both 7 and 10 years of age there were more poplar of higher diameter classes in 6x6 m than in 5x5 m spacing, but total volume after 10 years was 13.5% greater in 5x5 m spacing.

K.W. Populus sp. (poplar), diameter growth, initial spacing, volume growth.

266. U.S. Dept. Agric. 1941. Twentieth annual report of the Southern Forest Experiment Station, Jan. 1, 1940 - Dec. 31, 1940. pp. 13-14.

Closely spaced (5'x5') slash pine plantations gave results superior to those of wider spaced (8'x8' and 6'x6') plantations in yields from thinnings, number and size of residual trees, wood quality, natural pruning, and ease of marking and removal of thinnings.

K.W. Pinus elliottii (slash pine), initial spacing, planting, residual stand, thinning, thinning yields, wood production, wood quality.

267. U.S. Dept. Agric. 1952. Stand density and development of young jack pine. U.S. Dept. Agric., Lake States Forest Experiment Station, Rept. 1951. p. 11.

Jack pine seedlings were planted at several spacings from 1½' x 1½' to 9'x9'. At the end of 10 years a spacing of about 5'x5' or 1500 trees/acre seems best. Minimum acceptable stocking is 800 trees/acre.

K.W. Pinus banksiana (jack pine), initial spacing, stand density.

268. U.S. Dept. Agric. 1954. Some effects of spacing on height growth (of red pine). U.S. Dept. Agric., Lake States Forest Experiment Station, Rept. 1953. p. 24.

After 35 years, dominant red pines in a plantation spaced 4'x4' were shorter than those at wide spacings from 6'x6' to 8'x9'. Differences were attributed to competition for soil moisture.

K.W. Pinus resinosa (red pine), height growth, initial spacing, soil moisture, vegetative competition.

269. U.S. Dept. Agric. 1956. Development of jack pine plantations affected by spacing. U.S. Dept. Agric., Lake States Forest Experiment Station, Rept. 1955. pp. 47-48.

Jack pine were planted at spacings of 1½'x1½', 3'x3', 5'x5', 7'x7', and 9'x9'. Diameter growth was seriously retarded by close spacing. Height growth of dominants was not affected by spacing.

K.W. Pinus banksiana (jack pine), diameter growth, dominants, height growth, initial spacing.

270. U.S. Dept. Agric. 1958. Growing space needs are flexible. U.S. Dept. Agric., Lake States Forest Experiment Station, Rept. 1957. pp. 19-20.

A discussion of initial spacing and thinning.

K.W. initial spacing, plantations, thinning.

271. U.S. Dept. Agric. 1958. 6x7 ft. spacing satisfactory for loblolly pine. U.S. Dept. Agric., Northeastern Forest Experiment Station, Rept. 1957. p. 28.

Eighteen years after planting loblolly pine at four spacings (4'x4' - 11'3"x11'3") average diameter ranged from 4.5" at 4'x4' spacing to 7.7" at 11'3" x 11'3" spacing. Trees in the former were spindly and at the latter excessively branchy. Cordwood volume ranged from 10.2 cords/acre for the widest spacing to 17.8 cords/acre for the narrowest spacing. Volume of trees $\geq$ 6" dbh was greatest for 8'x8' spacing. It was concluded that existing practice of planting at 6'x7' is satisfactory.

K.W. Pinus taeda (loblolly pine), branching, diameter growth, initial spacing, volume growth.

272. U.S. Dept. Agric. 1958. Spacing - increment study in ponderosa pine. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Rept. 1957. p. 30.

Experiment introduction.

K.W. Pinus ponderosa (ponderosa pine), growth increment, initial spacing.

273. U.S. Dept. Agric. 1958. Spacing of planted Douglas fir. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Rept. 1957. pp. 26-27.

In a 32 year old plantation in Washington with spacings of 4'x4' and 12'x12', b.a. was smaller with wider spacing (160 ft.^{2} at 4'x4', 110 ft.^{2} at 10'x12'), while board foot volume and average height were much higher.

K.W. Pseudotsuga menziesii (Douglas fir), height growth, initial spacing, volume growth.

274. U.S. Dept. Agric. 1962. Initial spacing in plantations. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Rept. 1961. p. 59.

Average height and average diameter both increase markedly as initial spacing is widened from 4'x4' to 12'x12'. Total volume is apparently independent of initial spacing but merchantable volume is directly related.

K.W. Pseudotsuga menziesii (Douglas fir), diameter growth, height growth, thinning, volume growth, wood production.

275. U.S. Dept. Agric. 1969. Forty-year growth and yield of spaced Douglas fir. U.S. Dept. Agric., Pacific Northwest Forest and Range Experiment Station, Rept. 1968. pp. 18-19.

In 1925, Douglas fir were planted at various spacings from 4'x4' to 12'x12'. Since age 23, growth has been greater on wide spacings and differences are increasing with time. Growth per acre during the past 5 years was 940 ft.^{3} on the 12'x12' spacing compared to 435 ft.^{3} on the 4'x4' spacing. Both height growth and diameter growth are greatest on widest spacing. However, growth rate is beginning to decline, even at widest spacing due to increased competition.

K.W. Pseudotsuga menziesii (Douglas fir), diameter growth, height growth, initial spacing, thinning, volume growth.

276. Van den Driessche, R. 1971. Growth of one year old Douglas fir plants at four spacings. Annals of Botany 35(139):117-126.

Douglas fir was planted at spacings of 2x2" to 12x12" in both fertilized and unfertilized plots. Mean dry weight of seedlings increased up to spacings of 5x6" but decreased thereafter. Net assimilation rate showed a similar pattern. Fertilizers increased final dry weight, height and leaf are index, and increased the proportion of dry matter devoted to stem production at close spacing, and the root % of all spacings. At closest spacings, plant size was limited more by light than by nutrient supply.

K.W. Pseudotsuga menziesii (Douglas fir), fertilization, height growth, initial spacing, seedling weight.

277. Vanselow, K. 1942. [Influence of spacing on the development of pure Norway spruce plantations] Forstwissenschaftliches Centralblatt 64:23-37, 49-59. (ABSTR. F.A. 4:102).

From observations of 35 year old unthinned spruce established at spacings of 1x1 m to 4x4 m, it was found that spacings narrower than 1.3-1.4 m square gave high mortality and are considered unsuitable. Average height of stands was not influenced by spacing, but mean diameter was greater in wider spaced plantations. Stem form deteriorated and branching increased where spacing exceeded 1.5-1.6 m square.

K.W. Picea sp. (spruce), branching, diameter growth, economics, height growth, mortality, planting.

278. Vanselow, K. 1950. [The influence of spacing on the development of pure spruce stands, II] Forstwissenschaftliches Centralblatt 69(9):497-527. (ABSTR. F.A. 13:2089).

Spacing ranging from 3'7" to 6'7" was evaluated in a series of tests with Norway spruce. Spacing has no apparent effect on height growth, but dbh, stem form, branching and average volume per tree increase with increased spacing. There is some indication of reduction of total yield with increased spacing. Optimal initial spacing is thought to be between 4'6" and 5'3".

K.W. Picea abies (Norway spruce), branching, diameter growth, height growth, initial spacing, stem form, wood production.

279. Vanselow, K. 1956. [The influence of spacing on the development of pure spruce stands, III] Forstwissenschaftliches Centralblatt 75(7/8):193-207.

K.W. Picea sp. (spruce), diameter growth, height growth, initial spacing.

280. Veiga, A. De Arruda 1955. [Preliminary note on the initial spacing of Cupressus lusitanica] Rev. Agric. Papaciaba. 30(7/12):199-208. (ABSTR. F.A. 18:387).

Statistical analyses of results of initial spacing on height and diameter growth of C. lusitanica show no significant variation between spacings of 1x1 m and 1.5x1.5 m.

K.W. Cupressus lusitanica, diameter growth, height growth, initial spacing.

281. Videla Pilasi, E.O. 1966. [Spacing in plantations and the ecological and economic factors involved in afforestation plans for Chile and Argentina] Ciencia Investigacion 22(4):159-175. (ABSTR. F.A. 29:3829).

K.W. initial spacing, thinning, wood production.

282. Vinh, N.Q., Q.V. Nguyen and E.W. Melzer. 1970. [The spacing of Scots pine from the viewpoint of yield studies and silviculture] Arch. Forstw. 19(5):479-498. (ABSTR. F.A. 32:2481).

Growing space per plant at time of planting (22-65 years previously) within the range of 0.25 - 4.00 m^2 had no significant influence on total timber and stemwood yields of the stands. Diameter and height growth, and thinning yields were correlated with growing space.

K.W. Pinus sylvestris (Scots pine), diameter growth, height growth, initial spacing, thinning yield, wood yield.

283. Walters, G.A. and T.H. Schubert. 1969. Saligna eucalpytus growth in a five-year-old spacing study in Hawaii. J. For. 67(4): 232-234.

Trees planted at various spacings all made very rapid height and diameter growth. In five years, trees in all spacings averaged over 72' in height; dominant and co-dominant trees averaged over 85'. Diameter growth rate, unlike height growth varied with spacing. Average dbh ranged from 6.2" at 8'x8' spacing to 7.9" at 14'x14' spacing. Average figures for dominant and co-dominant trees at these spacings were 7.5" and 8.9" respectively.

K.W. Eucalyptus sp. (eucalyptus), diameter growth, height growth, initial spacing.

284. Wambac, R.F. 1967. A silvicultural and economic appraisal of initial spacing in red pine. Dissert. Abstr. 28B(6):2210.

Higher financial returns might be obtained from wider initial spacings than those normally used. Site quality has more effect on financial returns than initial spacing, thinning intensity, length of rotation, etc.

K.W. Pinus resinosa (red pine), economics, initial spacing, profit, rotation, site quality, thinning intensity.

285. Wardle, P.A. 1967. Spacing in plantations: a management investigation. Forestry 40(1):47-69.

Discusses the effect of variation in the initial spacing of planted conifers on volume and quality, on variation and costs of operations, and on revenue and profitability.

K.W. forest management, initial spacing, profit, wood production.

286. Ware, L.M. and R. Stahelin. 1946. How far apart should pines be planted. Southern Lumberman 173(2177):191-193. (ABSTR. F.A. 8:2396).

Spacings of 6'x6', 6'x8' and 8'x8' with good survival and a spacing of 10'x10' with survival of 90% will furnish a sufficient number of loblolly and longleaf pines to guarantee a good yield. Where a good pulpwood market exits, 6'x6' spacing is best. 4'x4' spacing is too close and 10'x10' produces poor quality lumber. Longleaf pine should be planted closer than loblolly or slash pines.

K.W. Pinus elliottii (slash pine), Pinus palustris (longleaf pine), Pinus taeda (loblolly pine), economics, initial spacing, wood quality, wood yield.

287. Ware, L.M. and R. Stahelin. 1948. Growth of southern pine plantations at various spacing. J. For. 46:267-274.

An experiment was begun in 1932 to study the influence of spacing and time of later thinning on yield of slash, longleaf, and loblolly pines on abandoned fields. Spacings were 4'x4', 6'x6', 6'x8', 8'x8', 9.6'x9.6', 12'x12' and 16'x16'. Measurements were made at the end of the 14th year. Total wood production was roughly related to density of stocking. Spacing had no influence on height growth. Crowding retards diameter and volume growth and wide spacing stimulates it, especially for loblolly pine. Wood production is measured.

K.W. Pinus elliottii (slash pine), Pinus palustris (longleaf pine), Pinus taeda (loblolly pine), diameter growth, height growth, initial spacing, thinning, thinning date, volume growth, wood production.

288. Wauthoz, V. 1960. Boisements de mélèzes du Japon: ecartement des plants. Bull. Soc. For. Belg. 67(3):136-140. (ABSTR. F.A. 21:4361).

A study of costs of establishment, and thinning costs and returns, up to 30 years for plantations spaced at 1.5 m x 1.5 m and 2 m x 2 m indicate that the latter is more economical.
K.W. Larix leptolepis (Japanese larch), economics, initial spacing, thinning.

289. Weihe, J. 1963. [Spacing of spruce plantations] Allgemeine Forstzeitschrift 18(18):290-294. (ABSTR. F.A. 24:4944).

Crown/stem diameter ratio is shown to be independent of site class, but to increase with increasing dryness of site or climate. The best initial spacing, designed to give full canopy closure at a given diameter, will therefore have to be wider on a dry than on a moist site.
K.W. initial spacing, site index, soil moisture.

290. Wentzel, K.F. 1966. [Close spacing in spruce plantations - why dark rooms?] Allgemeine Forstzeitschrift 21(38):644-646. (ABSTR. F.A. 28:2195).

Author criticizes tendency towards close (1x1 m) spacing and supports recommendations for wider spacing (< 5000 plants/ha.).
K.W. Picea sp. (spruce), initial spacing.

291. Whitesell, C.D. 1970. Early effects of spacing on loblolly pine in Hawaii. U.S. Dept. Agric., Pacific Southwest Forest and Range Experiment Station, Res. Note PSW-223. 3 pp.

Mean height of loblolly pine planted at various spacings in 1961 was 30 ft. for all spacings by 1968. Mean dbh and b.a. ranged from 5.3" and 193 ft.^{2}/acre at 6' to 7.6" and 98 ft.^{2}/acre at 12' spacing. Trees planted at 12' spacing had 27% more live crown than did trees planted at 6' spacing.
K.W. Pinus taeda (loblolly pine), basal area growth, crown area, diameter growth, height growth, initial spacing.

292. Wielizka, Z. 1950. [Spacing, quality and yield of Araucaria angustifolia plantations] An. Bras. Econ. Flor., Inst. Nac., Pinho 3(3):283-290. (ABSTR. F.A. 13:3803).

A 1 m x 1 m plantation showed a height growth at 7 years practically equivalent to that of a 2 m x 2 m plantation at 15 years.
K.W. Araucaria angustifolia, height growth, initial spacing, wood production, wood quality.

293. Wiksten, A. 1965. [A spacing experiment with planted Norway spruce] Rapp. Uppsats. Instn. Skogsprod. Skogshogsk., Stockholm, No.7. 87 pp. (ABSTR. F.A. 27:572).

Evaluation at age 55 of a trial established in 1898 at 5 spacings from 1x1 m to 2x2 m, thinned since 1927 so as to arrive at approx. the same basal area on each plot, indicated that the wider spacings were greatly superior economically to the closer, because of lower establishment costs. The value yield of the most widely spaced plot however, was only slightly higher than that of the most closely spaced plot, which had a volume yield about 25% higher (most of the excess being in unmerchantable dimensions) and a higher percent of select grade timber.

K.W. Picea abies (Norway spruce), initial spacing, thinning, value production, wood production, wood quality.

294. Wilde, S.A. 1964. Plantation spacing and site conditions. U.S. Dept. Agric., Tree Planters Notes 65:12-13.

Reviews advantages and disadvantages of wide spacing in plantations. Recommends more research.

K.W. growth increment, initial spacing, vegetative competition, wood quality.

295. Wilde, S.A. 1968. Tree spacing in forest plantations as related to soils and revenue. Univ. Wisconsin, College of Agriculture, Bull. 589. 22 pp.

Optimum spacing depends largely on the nature of the soil, its productive capacity, and the actual or potential biomass of the weed cover. The poorer the soil, the wider should be the tree spacing. Furthermore, the proper distance among planted trees may vary considerably depending on tree species, age of planting stock, and method of ground preparation.

K.W. initial spacing, planting density, planting stock, site index, site preparation, soil, soil fertility.

296. Wilde, S.A. et al. 1968. Tree spacing in forest plantations as related to soils and revenue. Univ. Wisconsin, College of Agricultural and Life Sciences, Research Division, Bull. 589. 22 pp. (ABSTR. F.A. 31:652).

On coarse sands, planting pine at spacings closer than 6'x6' retarded diameter growth, delayed production of merchantable timber and usually necessitate unprofitable thinning. Plantations on non-podzolic soils, established at 6'x6', or even 8'x4' invariably produced quantities of merchantable timber similar to or greater than those produced by denser stands. Planting at 8'x8' or wider spacings on strongly podzolized, weed infested soils, however, also indicated the possibility of financial loss because of a reduced growth rate and production of excessively branched trees yielding low quality timber.

K.W. Pinus banksiana (jack pine), Pinus resinosa (red pine), Pinus strobus (white pine), economics, initial spacing, soil, wood production, wood quality.

297. Wood, A.S. 1949. Establishment of oak. Quarterly Journal of Forestry 43(2):80.

Advocates pit planting oak seedlings at spacings of 5'x6' as opposed to Commission recommendations of 2'x4' spacing, provided there is plentiful scub as a nurse crop.

K.W. Quercus sp. (oak), initial spacing.

298. Wood, R.F. and M. Nimmo. 1951. Spacing of oak in plantations. G.B. Forestry Commission, Forest Research Rept., pp. 55-59.

Spacings of 4'x2' in oak are wasteful. A spacing of 4'x4' gives satisfactory stocking given good conditions and treatment. Bunch plantings at wide centres (5'x3') gave the best stocking and distribution of desirable stems, but there was no advantage in increasing the number of plants per bunch from 3 to 6.

K.W. Quercus sp. (oak), growth increment, initial spacing.

299. Yuruki, T. 1962. [Influence of planting densities and patterns on the growth of sugi (Cryptomeria japonica D. Don)] Kyushu Univ., Forestry Rept. 16:145-154. (ABSTR. F.A. 24:2003).

Seedlings were planted singly or in bunches at various spacings. After 28 months, fresh weights per unit area differed little between single plants or bunches, but decreased with closer spacing of the bunches, and generally with increasing number of plants per bunch. At a given spacing, bunches weighed much the same whatever the number of plants per bunch. Neither spacing nor bunching had affected height growth considerably.

K.W. Cryptomeria japonica (sugi), bunch planting, growth increment, height growth, initial spacing.

300. Zakopal, V. 1955. [Development of nest plantings compared with single plantings in the Krivoklatsko forest areas, devastated by natural causes] Lesn. Práce 34(2):58-62. (ABSTR. F.A. 17:379).

Multiple plant nests of Scots pine were superior to single plants in rooting, diameter, height increment, and lateral growth.

K.W. Pinus sylvestris (Scots pine), diameter growth, height growth, nest planting.

AUTHOR INDEX

AUTHOR INDEX, cont'd.

AUTHOR INDEX, cont'd.

SUBJECT INDEX

Citations are referred to by reference number, not page number.

SUBJECT INDEX, cont'd.

SUBJECT INDEX, cont'd.

SPECIES INDEX

SPECIES INDEX, cont'd.