THE NICAUBA RESEARCH FOREST

A RESEARCH AREA FOR BLACK SPRUCE IN QUEBEC

Part II: Research program objectives

by

G. J. Frisque and J. T. Arnott

FOREST RESEARCH LABORATORY
QUEBEC REGION, QUEBEC
INFORMATION REPORT Q-X-19

CANADIAN FORESTRY SERVICE
DEPARTMENT OF FISHERIES AND FORESTRY
NOVEMBER, 1970

THE NICAUBA RESEARCH FOREST

A RESEARCH AREA FOR BLACK SPRUCE IN QUEBEC

Part II: Research Program Objectives

by

G.J. Frisque and J.T. Arnott

FOREST RESEARCH LABORATORY

QUEBEC REGION, QUEBEC

INFORMATION REPORT Q-X-19

CANADIAN FORESTRY SERVICE

DEPARTMENT OF FISHERIES AND FORESTRY

NOVEMBER 1970

CONTENTS

CONTENTS (PART I)

FOREST LAND SURVEY

INTRODUCTION

The objective of the research program now underway in the Nicauba Research Forest is to obtain information which will make possible the most economical and efficient management of the black spruce forests.

Following a regeneration survey (Hatcher, 1964), it was concluded that one of the major problems in the region was the reforestation of burned, cutover forest. The large, logged areas destroyed by fire in the northern coniferous forest present a formidable problem in reforestation. In the same way, black spruce is not regenerating in many areas where formerly natural regeneration could be expected.

The obtention and successful establishment of black spruce regeneration involve both short- and long-term studies. The short-term program deals mainly with the ecology of black spruce regeneration, the long-term study deals with silvicultural methods and seed production.

The forest land survey (Part I of this report, Jurdant and Frisque, 1970) provides the framework for all the studies carried out at Nicauba. The specific objectives of the program are the study of:

a) the silvicultural methods and treatments favouring regeneration of black spruce. This involves strip and patch cuttings, scarification and controlled burning.

b) the seed production and dispersal characteristics of black spruce in virgin stands and in experimental cuttings in relation to the type and size of cuts.

c) the periodical survey, by the milacre sampling method, of regeneration established following the silvicultural treatments.

d) the ecology of black spruce regeneration. This study involves meteorological observations in virgin stands and in cutover, scarified and burned areas. The establishment of regeneration is correlated with the microenvironmental factors. At the same time, the meteorological environment created by different degrees of stand opening is determined.

e) the phenological characteristics of both young and mature black spruce are assessed in order to determine the period of bud opening, flower and cone formation, shoot and diameter growth.

f) the importance of layering with respect to stand development.

g) the artificial regeneration of burned areas by tubed-seedlings after different types of site preparation.

In addition to the first three studies, which are long-term projects, a range-wide black spruce provenance trial incorporating numerous individual seed tree collections from the Nicauba Region has been implemented.

CURRENT RESEARCH PROJECTS

A. LONG-TERM PROJECTS

1. Silvicultural treatments

These consist of experimental cuttings, scarification and controlled burning.

a) Experimental cuttings

Economic necessity has been the principal reason why the clear cutting system has been used for black spruce. The fact that most black spruce forests are situated at great distances from industrial centres, coupled with the fact that most companies do not have intensive road systems for wood harvesting in these areas, has required high unit area production to make the operation economically competitive with other species (Vincent, 1965). This has resulted in extensive cutover areas where no valuable seed trees, or groups of trees, have been left to provide at least some measure of seed for the regeneration of these stands.

From a silvicultural standpoint, it would be much more practical to adopt some variation of the clear cutting system. Heinselman (1957) states that "where the stand is reasonably

windfirm, a more reliable sil-
vicultural practice for swamp spruce
may be clear cutting in patches

or strips laid out so that none
of the open area is more than
150 feet from a seed source".

The same author (Heinselman, 1959) goes on to say that 4 to 6 years following logging, results show black spruce regeneration (new seedlings only) to be 2,671 trees per acre in clear cut patches, 1,329 in clear cut strips, 1,867 in shelterwood, 388 in light thinning and 83 in uncut stands.

Of the above-mentioned silvicultural practices, strip and patch cuttings appear to be the methods most compatible with the mechanized harvesting techniques now being employed. Despite the fact that strip and patch clear cuttings pose some of the same problems as clear cutting extensive areas, i.e. dense slash, destruction of advance growth by logging equipment, they do provide some improvement through increased seed availability, reduction in exposure and the creation of better microclimatic conditions. Experimental cutting systems were initiated at Nicauba in 1968 and must continue until 1970 to determine the suitability of present day machinery in strip and patch cutting operations. Furthermore, these experimental cuts give the framework for the regeneration survey and ecological behavior of this regeneration in relation with the environment created by the cuts.

In 1968, the experimental cuttings (photos 1 to 4) consisted of:

a) strip cut: two series of strips, 2 and 4 chains wide.

There were 3 replications of the 2-chain wide strip and 2 replications of the 4-chain wide strip. With the latter, insufficient area prevented the establishment of the third replication. The total area logged was 22.5 acres.

b) elliptical patches: three replications with a total area of 7.5 acres.

c) circular patches: three replications with a total area of 4.0 acres.

d) clear cut: normal company operation 40 acres.

The 34 acres experimentally cut in the Research Forest and the adjacent 40-acre clear cut, made a total of 74 acres for the 1968 season. The total volume logged within the Research Forest was 570 cunits (cuts + roads + landings). At the end of the 1968 logging season, it was proved conclusively that patch cuttings of the size involved were incompatible with present-day harvesting techniques. Loggers and company supervisors found the system difficult to execute on a satisfactory basis with the articulated wheeled skidders employed. Thus, patch cutting was not continued in the 1969 program. It should be noted, however, that patch cutting creates a better microenvironment for natural regeneration than strip cutting.

In 1969, the experimental cutting program was continued and strip cuttings were extended into the area northwest of Lac Epave.

PHOTO 1: Elliptical cut before cutting

PHOTO 2: Elliptical cut after cutting

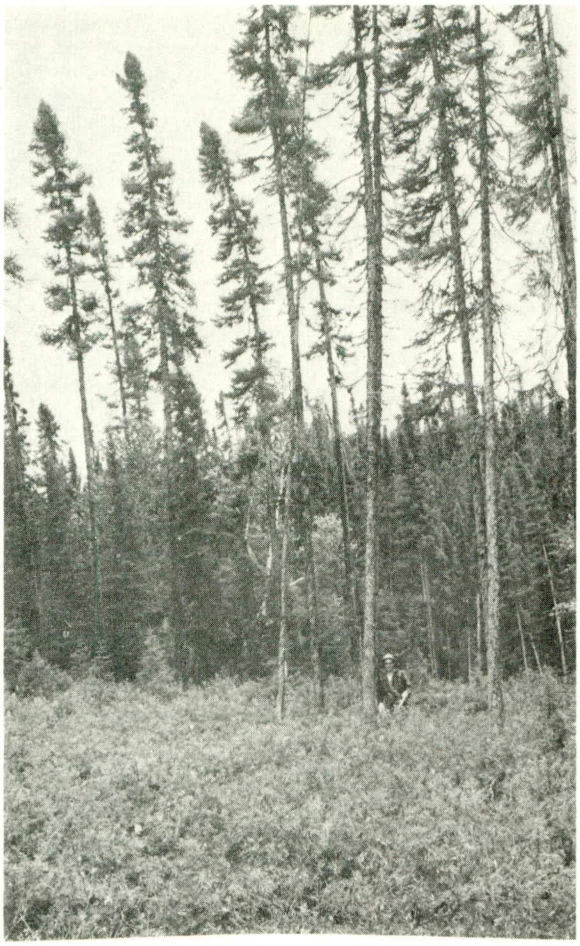


PHOTO 3: Strip cut with dense Kalmia-Ledum shrubs

PHOTO 4: Elliptical cut with heavy slash accumulation

This strip cutting program consisted of:

a) 3 replications of 4-chain wide cuts; 18.8 acres

b) 5 replications of 2-chain wide cuts; 10.0 acres

c) 2 replications of 2-chain wide cuts; 2.0 acres.

The latter 2 replications were East-West oriented whereas all other strips were North-South. By having different orientation, studies can be made of the variations in the microenvironment, i.e. duration of direct sunlight, maximum and minimum temperatures, evaporation, relative humidity, etc.

A total of 30.8 acres were logged during August and September of 1969. The total volume cut in 1969, including roads and landings, was 459 cunits. Complete details of the 1968/69 cutting experiments are outlined in table 1. The 1968/69 cutting program has been primarily carried out on some of the most representative forest types of the Research Forest. The four types covered by the logging program were:

1. bt $\frac{\text{KP.ts-s}}{\text{E-G}}$ (30 acres)

2. bt $\frac{\text{KP.ts-s-SP.a}}{\text{E-G-H}}$ (17 acres)

3. tg $\frac{\text{AP}}{\text{D}}$ (10 acres)

4. wd $\frac{\text{KP.s-SP.c}}{\text{G-I}}$ (7 acres)

The symbols are those used by Jurdant and Frisque (1970).

The following table gives their meaning:

bt	:	ground moraine
tg	:	shallow till over gneissic bedrock
wd	:	water worked drift complex
KP.ts	:	black spruce-Kalmia
KP.s	:	black spruce-Kalmia-Sphagnum
SP.a	:	black spruce-Sphagnum-Alnus
SP.c	:	black spruce-Sphagnum-Chamaedaphne
AP	:	black spruce-balsam fir
D,E	:	well drained
G	:	imperfectly drained, no seepage
H	:	imperfectly drained, seepage
I	:	poorly drained, seepage.

Figure 1 shows the location of the experimental cuts. The two first numbers indicate the year when the cuts were carried out. In 1970, the cutting experiments will be continued into the northeast sector of Lake Epave which is the youngest part of the forest, i.e. around 100 years old. There will be 2,4 and 6-chain wide strips. Naturally, successful execution of this work is dependent on the cooperation extended to the experimental cutting program by Consolidated-Bathurst Limited.

FIGURE 1

LOCATION OF THE 1968-69 EXPERIMENTAL CUTS

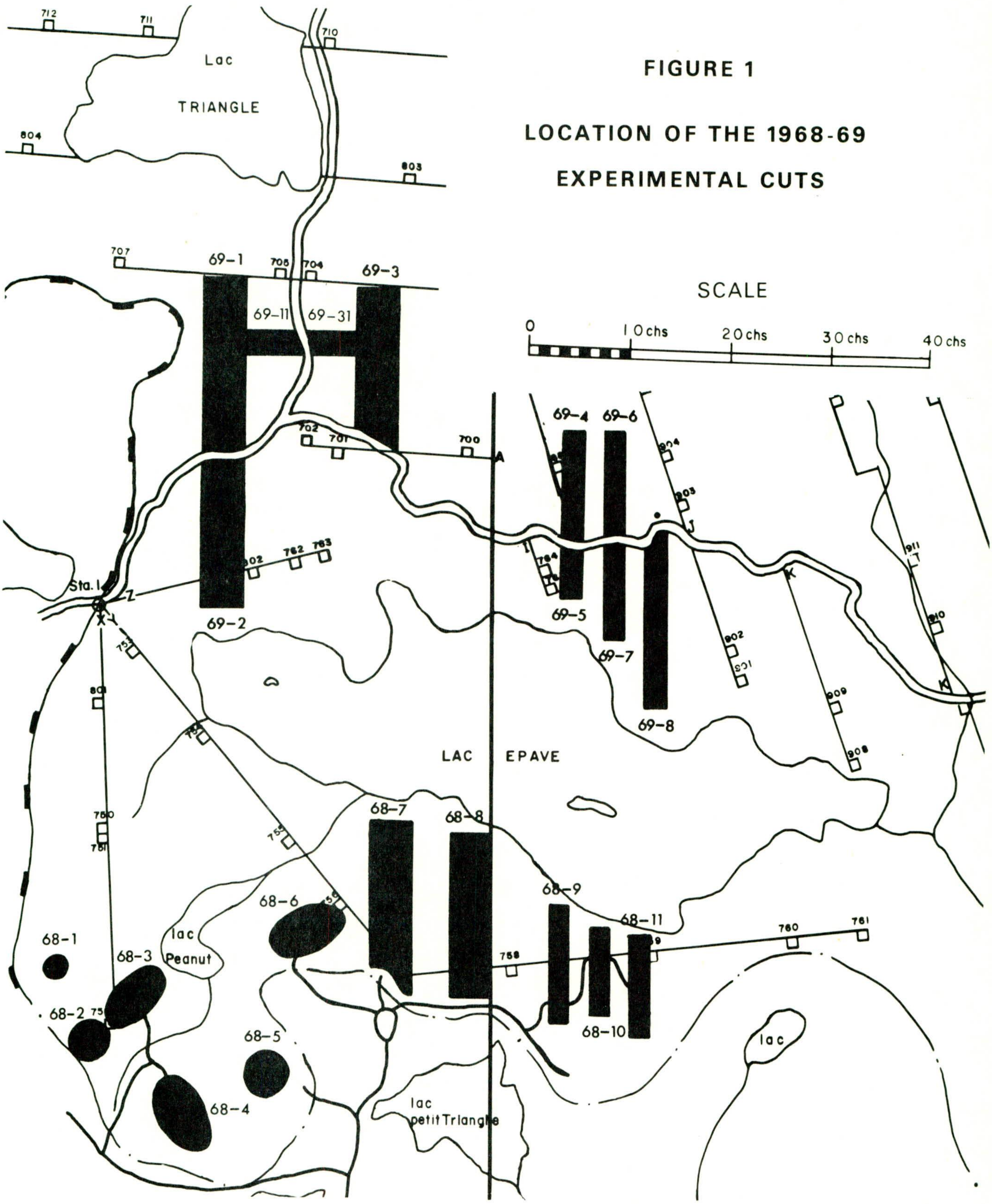


Table 1 Characteristics of the 1968/69 experimental cuttings

Code No.	Type of cut	Width x Length (chains)	Area (acres)
68-1	circular	diam. : 4	1.25
68-2	circular	diam. : 4	1.25
68-3	elliptic	4 x 8	2.5
68-4	elliptic	4 x 8	2.5
68-5	circular	diam. : 4	1.25
68-6	elliptic	4 x 8	2.5
68-7	strip	4 x 19	7.5
68-8	strip	4 x 20	8.0
68-9	strip	2 x 15	3.0
68-10	strip	2 x 10	2.0
68-11	strip	2 x 10	2.0
Total			33.75
69-1	strip	4 x 17	6.8
69-2	strip	4 x 15	6.0
69-3	strip	4 x 15	6.0
69-4	strip	2 x 10	2.0
69-5	strip	2 x 5	1.0
69-6	strip	2 x 10	2.0
69-7	strip	2 x 10	2.0
69-8	strip	2 x 15	3.0
69-11	strip	2 x 5	1.0
69-31	strip	2 x 5	1.0
Total			30.8

b) Scarification

Following the strip and group clear cutting outlined in the previous section, studies have been initiated to compare black spruce regeneration on the cutovers both with and without seedbed treatment.

Portions of the 1968 cutting experiments were scarified the following year using the shark-fin barrel-tractor pad combination. The areas scarified were as follows: 68-10 (1.0 acres), 68-8 (2.0 acres) and 68-6 (2.5 acres)(Figure 1). Plans also called for scarifying one of the circular cuttings (68-5) but, owing to access problems, the equipment could not be transported for treatment of that area. Production rate for scarification was 1.1 acre / hour.

With very deep humus and moss layers on these sites, it is not surprising that scarification did not prepare a very suitable mineral soil seedbed for black spruce regeneration especially when a little slope is encountered. A detailed evaluation of seedbed type created will be prepared.

c) Controlled burning

It is doubtful that controlled burning on these cutovers will have any appreciable effect on the deep organic mantle typical of these sites. However, fire, in the absence of mechanical or chemical tools, may well reduce the amount of slash on the experimental cuttings. Following controlled burning, supplementary scarification to provide mineral soil seedbeds for black spruce will be much easier to execute, and perhaps may be more effective because of the reduction in logging slash. The necessary agreement of Consolidated-Bathurst Ltd. and the cooperation of the Laurentian Forest Protective Association were obtained. A first attempt to burn was made in the spring of 1969 but the climatic conditions at this period did not permit a successful burn. A second attempt was made in the spring of 1970. However, the Company required that the burning should take place only in May when sufficient snow was still on the ground. This requirement reduced the probability of having a fire heavy enough to burn the large accumulation of slash and mosses, and thus to reach the mineral soil.

d) Regeneration survey

In the experimental cuts with or without scarification and/or controlled burning, the natural regeneration is surveyed by the milacre method. Figures 2 to 5 illustrate the experimental design chosen for this survey. The milacre samples are permanently identified by two numbered aluminium pickets put at opposite corners of the milacre. Surveys are made every three years and the number of seedlings per species is noted together with a brief description of the seedbed conditions following the method used by Webber _et al._ (1968).

The experimental design is installed in the field at the beginning of the field season following the cutting or silvicultural treatments, i.e. scarification and/or controlled burning. Identical procedures are followed in all the cutting experiments or silvicultural treatments.

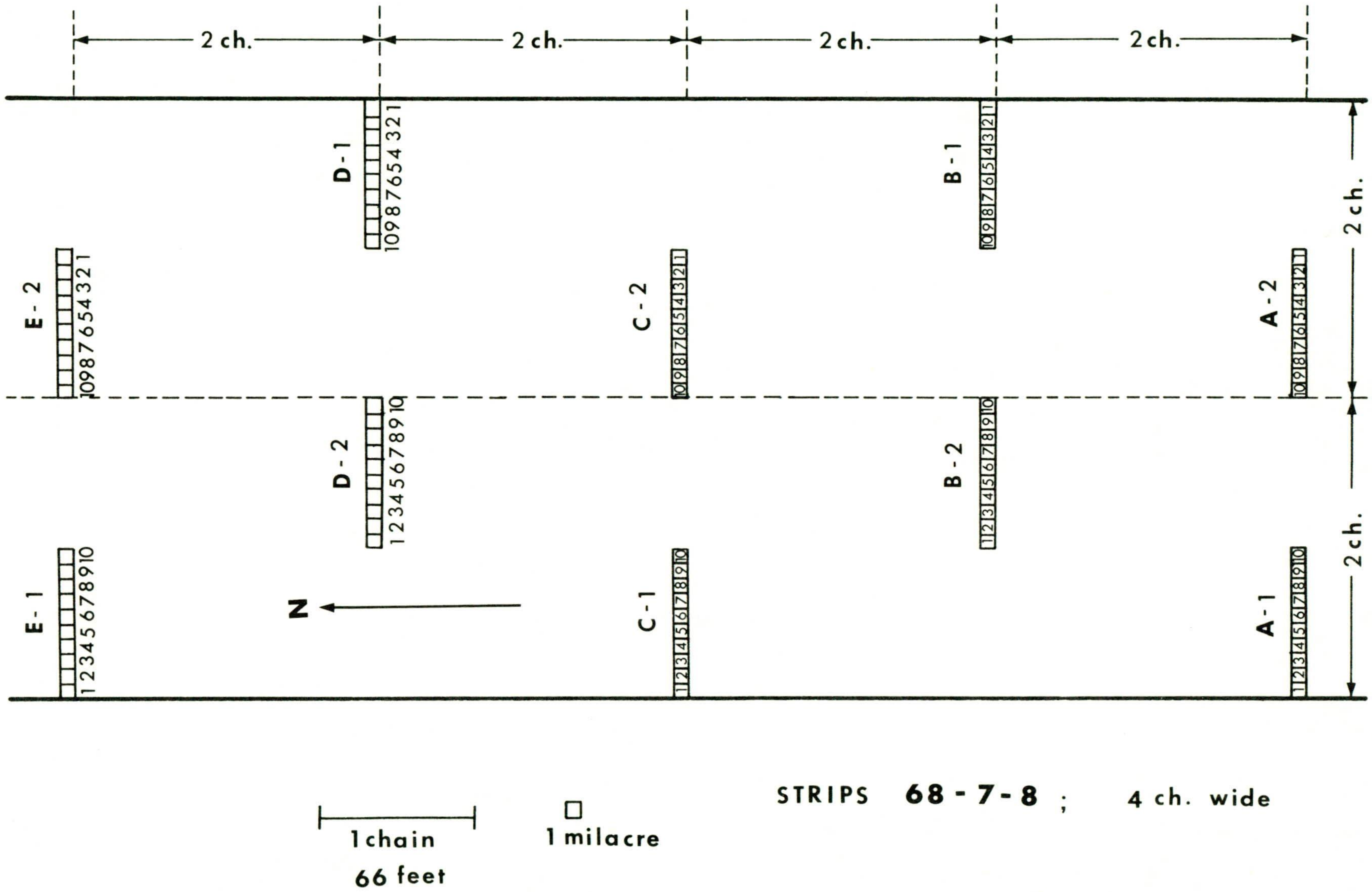
Figure 2. Regeneration survey, experimental design in the 4 chain-wide strip cuts.

Figure 3. Regeneration survey, experimental design in the 2 chain-wide strip cuts.

Figure 4. Regeneration survey, experimental design in the elliptical patch cuts.

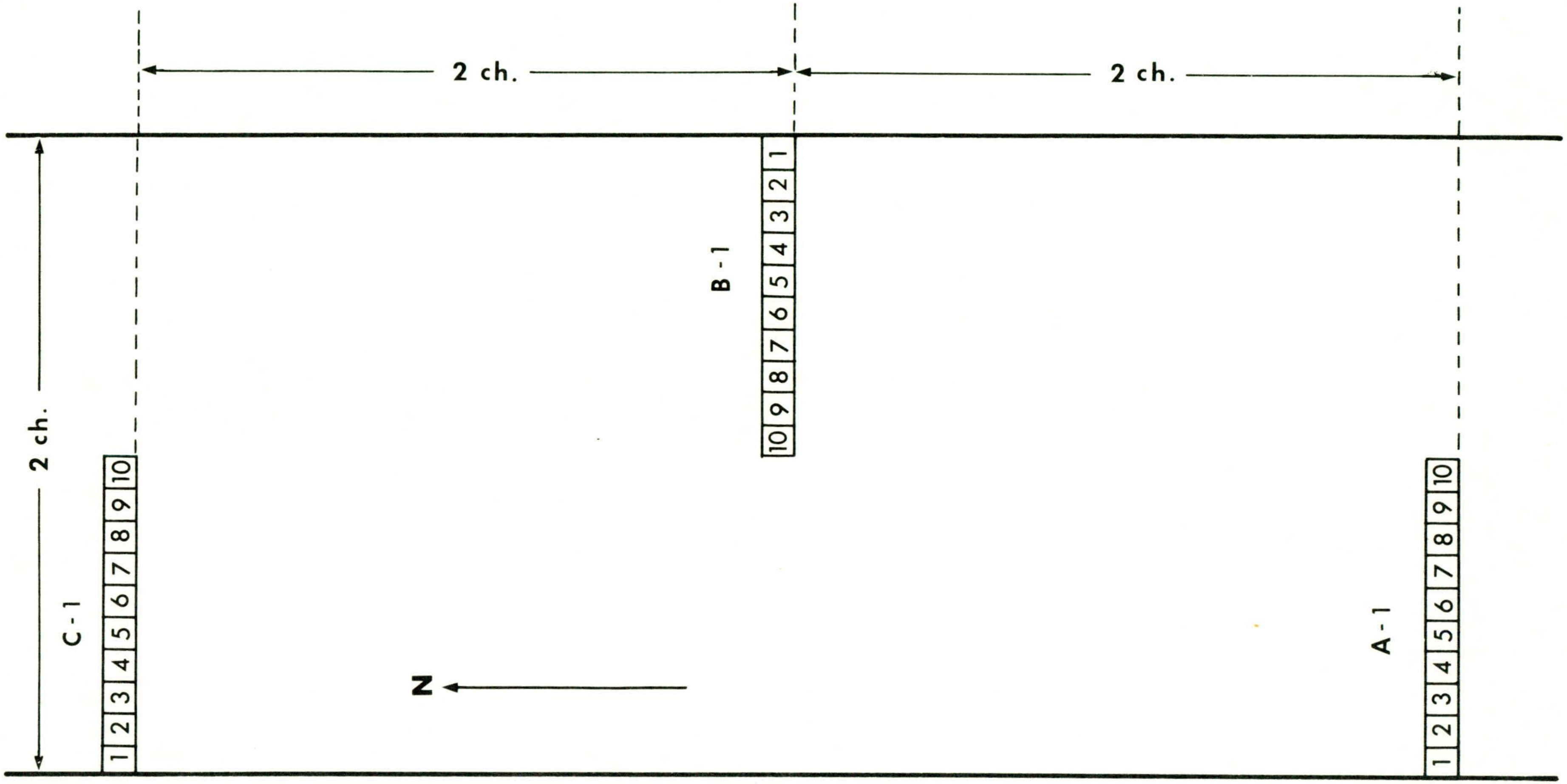
Figure 5. Regeneration survey, experimental design in the circular patch cuts.

REGENERATION SURVEY



STRIPS **68-7-8** ; 4 ch. wide

REGENERATION SURVEY



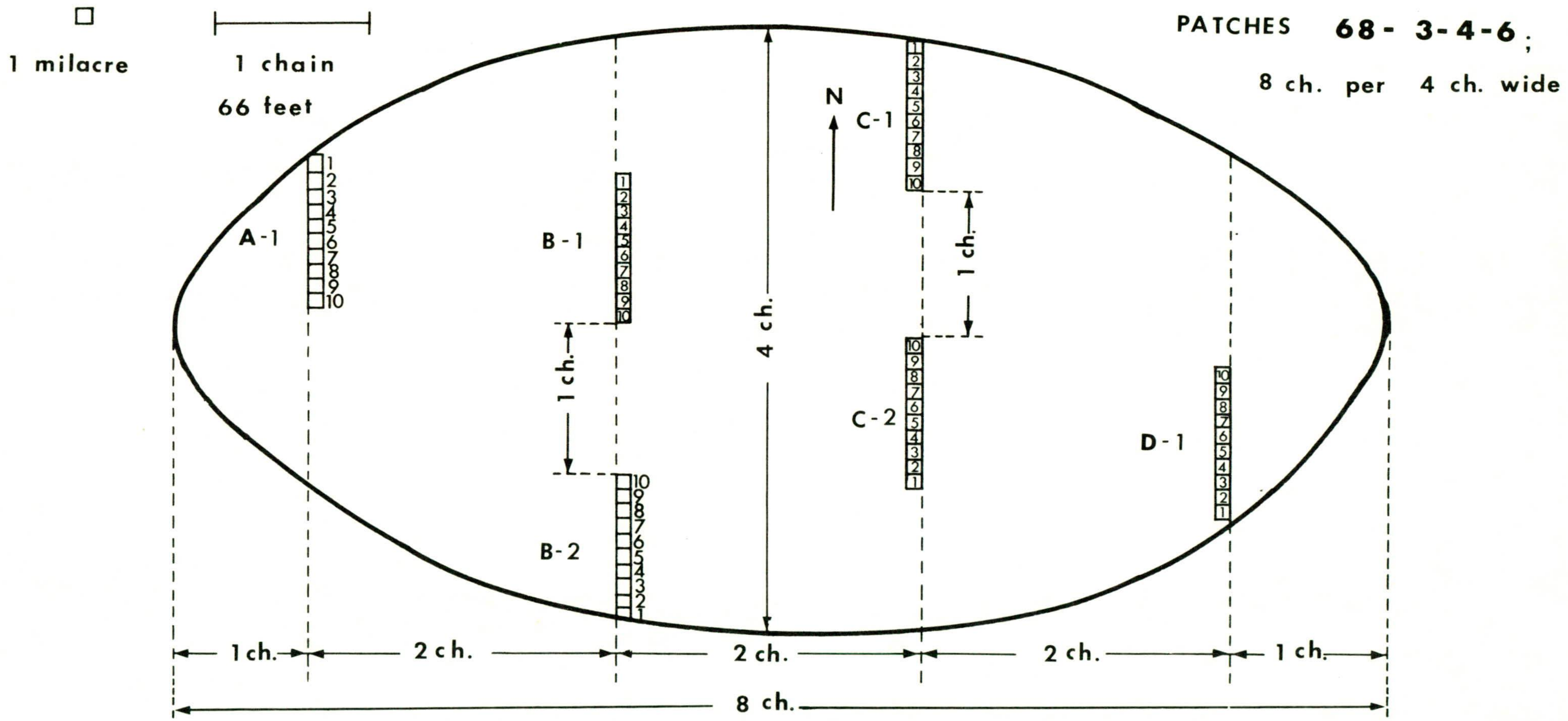
1 chain

66 feet

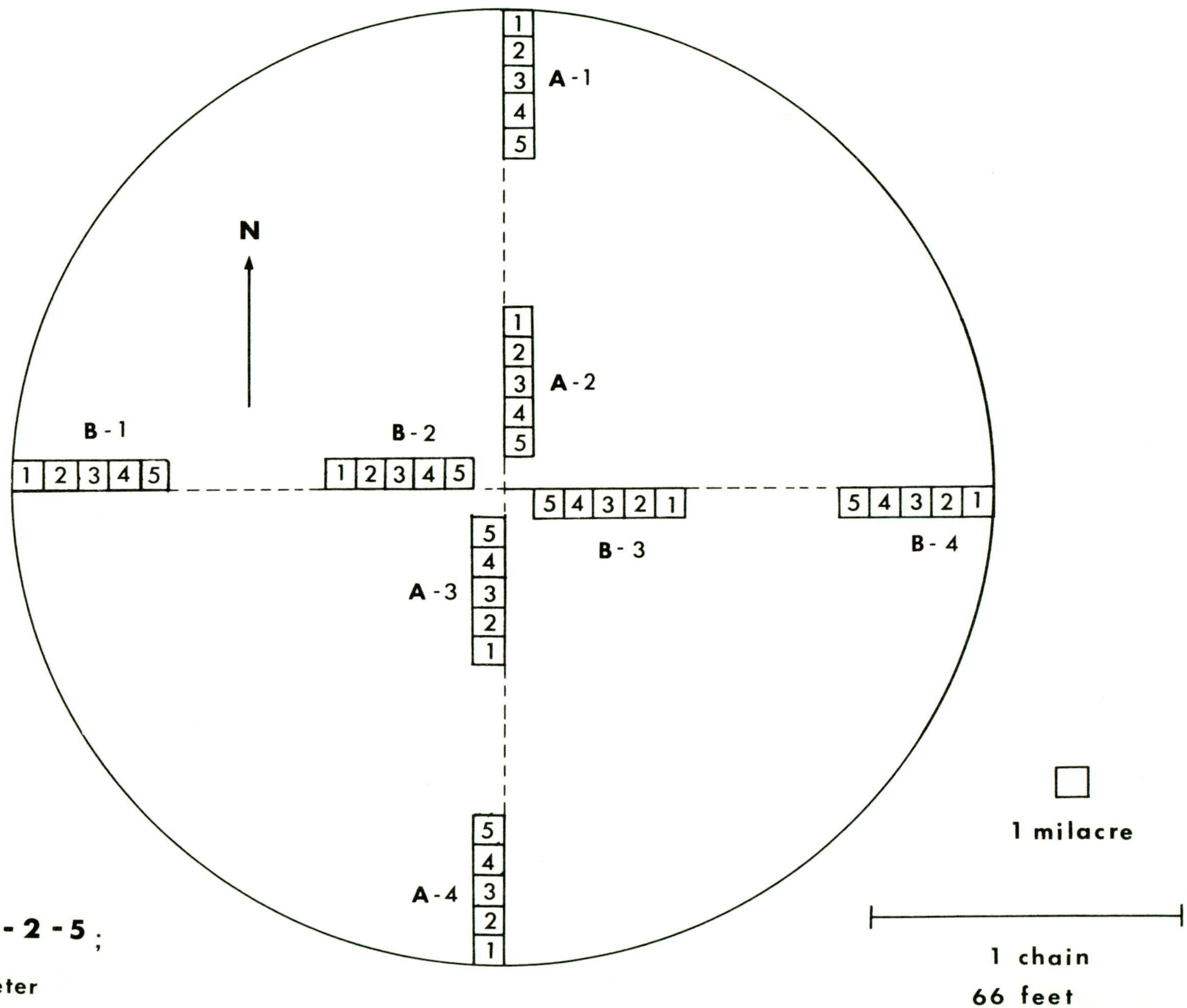
1 milacre

STRIPS **68-9-10-11** ; 2 ch. wide

REGENERATION SURVEY



REGENERATION SURVEY



PATCHES **68-2-5**;

4 ch. diameter

2. Seed production and dispersal

a) Seed production

Seed production studies have been in progress at the Research Forest since 1965. Results for the first three years have been described by Frisque and Arnott (1969). The study encompasses nine fifth-acre square plots established in three major ecological types of the Research Forest. Each plot contains 16 seed-traps layed out in virgin stands in a systematic half-chain square grid. Each trap has a catching area of one square foot. There are four collection dates, one in spring and one in June, July, August. At each collection date, the seeds are counted and the percentage of filled seeds determined.

First results show that the total seed production is about 2,000,000 seeds per acre, per year, for the best sites namely the black spruce - Hypnum type well drained on kame moraine and the black spruce - Kalmia type well drained on ground moraine and 700,000 seeds for the poor sites,namely the black spruce - Sphagnum - Chamaedaphne type poorly drained without seepage in bogs and the black spruce - Kalmia- Sphagnum type imperfectly drained without seepage on water worked drift complex. The amount of empty seeds is great (more than 50%) and this is probably due to a failure in the physiological process and not as a consequence of insect attack. After three years of results, it appears that the ecological type had a determinant influence on the seed production and amount of filled seeds. The drainage class of the stand seems to be an important factor, as would be expected owing to its relation to growth and vigor. However, these conclusions are tentative and will require confirmation by further study.

Since 1969, seed-trapping experiments have also begun on the experimental cuts. The objective of these trials is to determine seed dispersion and distribution in relation to the type and size of the cuts.

Those experiments will continue with increased sampling density and with strip cuts of different orientation.

b) Seed dispersal

A test has been carried out at Nicauba to determine the maximum dispersion of black spruce seeds when released from a fifty foot-high tower in various wind velocities. But the results are of little value owing to the difficulty of obtaining a precise evaluation of the falling distance of the seeds. Furthermore, tests have showed that the falling distance varies greatly with the presence or absence of the seed-wing and with the weight of the seedlot.

A better evaluation of the seed dispersal will be obtained from the seed-trapping design laid out at regular intervals in the experimental cuts.

To obtain an idea of the local weight of black spruce seeds, five trees were sampled. The seeds were cleaned, counted, weighed and the percentage of filled seeds determined.

The mean for the 5 samples indicates a percentage of filled seeds of 55%, this value is higher than the average for Nicauba. The number of filled and cleaned seeds is 532,254 per pound.

B. SHORT-TERM PROJECTS

1. Ecology of black spruce regeneration

The ecology is the study and description of the relationship between a living body and its environment, that involves both the physical environment (soil and climate) and the community in which the body is living.

The community and the soils have been described in Part I of this report (Jurdant and Frisque, 1970), the meteorological environment however, remains to be characterized.

Forest meteorology may be approached from three different points of view which consist of three different but complementary steps (Reifsnyder, 1967). The first step is principally descriptive and considers the atmosphere within the forest by investigating meteorological phenomena. It provides the background information for a more analytical study of the latter two. The second step investigates the effect of meteorology on the phenology of the forest.

The third is the study by silvicultural treatments of the effects which the forest has on meteorological phenomena.

To obtain local data more representative of the forest conditions than those of the available meteorological station, five meteorological stations have been established in five forest stands having different degrees of densities ranging from open cutover to full canopy. Furthermore, weekly meteorological observations are also taken in the experimental cuts of the Research Forest and in adjacent burned-over areas.

At each meteorological station, daily readings are taken at 8.00 a.m., which consist of:

- maximum and minimum temperatures in a Stevenson shelter and near the ground,
- current temperature of the ground at depths of 4, 8 and 12 inches,
- relative humidity of the air,
- daily evaporation with Wright and Piche evaporimeters,
- daily rainfall,
- daily global radiation with Bellani spherical pyranometers.

The main station, which serves as a reference, is located in an open, well-exposed area. In addition to the usual observations, it records the length of the bright sunshine, with a Campbell- Stokes recorder, the wind speed and direction, plus the daily maximum solar temperature.

Observations have been taken for three years and are summarized in tables and graphs. Following a longer period of time, these observations will give more precise data on the local environment. Climatic averages, extremes and periods during which they can occur in different stand densities can thus be taken into account in the experiments.

Preparation of the heat and water budgets of the forest are planned. Both are extremely important in regeneration and growth studies. For example, even on a cloudy day, twice as much energy is used in evaporation as used in heating the air (Reifsnyder, 1967) and if the water capacity of the seedbeds is not known, it will be difficult to successfully predict their regeneration potential.

Thus, the meteorological observations are a basic and essential phase for providing background information to all research work in the area. It should be remembered that "insofar as there still is a climate near the ground, it is raised from the solid surface and relocated at the crown level. In place of the ground, which now lies within the forest depths, de-activated, the crown surface becomes the outer, active surface" (Geiger, 1957). For this reason the available meteorological stations, laid out in open field, are not satisfactory. Hence, the need of local observations.

As light plays a major role in the microclimatic environment because of its influence on the other climatic factors and because it is the factor which the forester can mostly easily control or modify through silvicultural practices, a study is presently centered on this aspect. The goals are:

1. to analyse the importance of light intensity in the bioclimatic environment and its action on the other microclimatic factors in the boreal forest,
2. to determine the action of light in the different processes of germination and regeneration in black spruce,
3. to obtain more information on mean radiant temperature (Reifsnyder and Lull, 1965) at ground level for different seedbeds.

As this part of the study was only initiated in 1968, it is too early to draw conclusions for the work in progress. However, a first trial was made in 1969 in order to test an experimental design. Black spruce seeds were sown every 15 days throughout the growing season on scalped seedbeds and in two different environments; one in an open area, the other in a fully stocked stand. Germination was superior in the fully stocked stand, i.e. with less light but with a higher relative humidity and lower temperature extremes than in the open area. Of 140 seeds sown between early June and the end of August, 55 seeds germinated in the fully stocked stand against 16 in the open area. Best germination occurred in June. This experiment will continue using a greater variety of degrees of stand opening and with more seeds. The results should indicate the stand density associated with optimum microenvironmental conditions for natural regeneration. The results should also indicate the time at which seedling-growth is slowed down by the light competition of the stand.

2. <u>Phenological characteristics of black spruce</u>

a) Young trees

Phenological observations are being made on the three main species encountered in the Research Forest, i.e. black spruce, balsam fir and jack pine. Measurements are taken on ten trees per species, all ten trees having a similar mean age. In 1969, the age of the black spruce, balsam fir and jack pine sample trees was 15, 14 and 12 years, respectively.

Since 1968, the dates of opening of the terminal buds have been noted for each species, together with weekly measurements of the length of the terminal shoot. The total height of the trees at the beginning and at the end of the growing season is also recorded.

These results should be interpreted in relation to the meteorological data observed at the sampling location. The results for the two first years indicate that jack pine begin growth first, followed by balsam fir and finally black spruce. Cessation of terminal shoot growth occurs in the same sequence. The main height growth period is approximately the same for the three species (7 weeks). For the period of the study, annual height growth data are 13 inches for jack pine, 9 inches for black spruce and 5 inches for balsam fir.

b) Mature trees

Twenty black spruce, having a mean age of 50 years in 1969, were selected for measurement. Once again, the date of bud opening has been noted followed by weekly measurements of the terminal or main shoot length. The results will eventually be related with meteorological observations. Over the two-year period of measurement, individual variation between trees was quite high (from 2 to 8 inches of annual height growth). This experiment will end in 1970 and the three years results will be summarized in a short report.

3. <u>Layerings and their importance in stand development</u>

Nicauba was one of two areas selected in an investigation to assess the importance of layering in the reproduction of black spruce stands (Stanek, 1968). Factors studied were the growth of trees of layer and seed origin, their respective roles in restocking logged areas and their contribution to volume production of black spruce stands. The results of the study, as they appear in the author's abstract, are as follows:

"Black spruce of layer or seed origin develops into merchantable trees with similar growth in height, diameter and volume. Layerings tend to have a poorer stem form than seedlings especially under adverse growing conditions. However, stem form of old layering trees is considerably better. The proportion of layerings and seedlings is influenced by stand history. Black spruce stands undisturbed for a long time consist largely of layerings. After fire, scarification, or exposure of mineral soil, stands regenerate mainly from seedlings. Stocking of black spruce is satisfactory where advanced growth has been preserved after cutting, whether it is of layer or of seed origin".

4. Artificial regeneration

As the natural regeneration, without silvicultural treatments, is spotty at best, and since the combined effects of logging and fire remove all seed sources and create poor seedbeds, artificial regeneration is also tested and surveyed in the Nicauba Research Forest.

Extensive burned cutovers exist 2 miles south of the Research Forest and on these areas scarification and direct seeding were initiated to determine how, where and when artificial seeding of cutover and burned forest is successful. The work involves the testing of soil scarifiers on a variety of terrains and vegetation types. Following scarification, artificial seeding of black spruce and jack pine has been carried out using treated and untreated seed. A complete report of this work is given by Arnott, 1970.

In addition, the tubeling (3 inches styrene tube) regeneration method is also assessed (Arnott, 1969) with some small scale seedspotting trials. Furthermore, the germination and survival of black spruce is studied on different moss seedbeds.

CONCLUSIONS

In recent years, there has been considerable changes in logging operations in the black spruce forest of northern Quebec and the use of heavy equipment is now the rule rather than the exception. There is evidence (Hatcher, 1964) that black spruce is not regenerating naturally in many areas where formerly natural regeneration could be expected.

In northern areas, such as the Nicauba Research Forest, which are situated far from the company mills, it is felt that artificial regeneration methods, such as planting, will not be practiced for quite some time. Thus, there is a need to determine the quantity and the quality of the regeneration related to the microenvironment and the type of seedbed which develops as a result of silvicultural treatments.

The cooperation of Consolidated Bathurst Limited and the Laurentian Forest Protective Association are ensured, and the Research Forest is recognized as such by all concerned.

Some tentative conclusions may be drawn from the research completed to date. These conclusions may be stated as follows:

(1) To conduct research in silviculture and regeneration, which are long-term projects, it is necessary to obtain an agreement with a forest company in order to have a part of land well

defined and reserved for research for a long period, and to have cooperation in provision of manpower and equipment to carry out the silvicultural treatments.

(2) Before beginning any kind of silvicultural research it is necessary to have an ecological map with a scale precise enough for the research purposes. This map should give the forest types, landform types and ecological types. In this way, the quality and representativity of the sites can be determined before the beginning of the study thus avoiding a loss of time and energy in studying non-representative areas or in treating potentially non-producing sites.

(3) The patch cutting method appears difficult to carry out with the present day harvesting methods. However, the patch cutting method can create a more favourable microclimate for regeneration than the strip cutting method, or the usual large scale company cuts.

(4) Black spruce seed production varies greatly with ecological sites, from 2,000,000 seeds per acre per year in the best well drained sites to 700,000 seeds, in the worst poorly drained sites. The amount of empty seeds is considerable and usually around 50%.

The number of black spruce seeds per pound, at Nicauba, is high, around 532,000.

The best way to evaluate the dispersal of black spruce in their natural environment seems to be the seed-trapping method with seed-traps laid out at regular intervals.

The percentage of error, by releasing the seeds from a tower, is high owing to the weight and to the condition of the seed-wings of the seed-lot used in the experiment.

(5) There is a need to establish local meteorological stations in order to obtain microclimatic data more representative of the forest conditions than those usually read in open field.

(6) The height-growth period is short at the latitude of the research forest. The main shoot growth occurs during 7 weeks. On the other hand, the annual height growth between trees varies from 2 to 8 inches for 50-year- old local black spruce.

(7) The layerings show a similar growth in height, diameter and volume than trees of seed origin (Stanek, 1968).

(8) The interim results of the direct seeding in non-reproducing burns and cutovers after scarification demonstrate the superiority of jack pine over black spruce. Black spruce seeding has been a failure. In direct seeding, season of sowing is an important factor and it appears that spring seeding is superior to fall seeding. In terms of seeding survival, seed treatments with the Arasan-Endrin rodent and bird repellent has had a beneficial effect in practically all treatments.

(9) It is yet too early to draw conclusions from the plastic tubeling experiment. But it seems that the dimensions and behaviour of the tubelings in the soil after planting require further studies.

PAPERS DIRECTLY RELATED TO THE NICAUBA RESEARCH FOREST

Arnott, J.T., 1968. Germination and survival of black spruce on certain moss seedbeds. Can. Dept. For. and R. Develop., For. Br., Inf. Rept. Q-X-4, 8 p.

Arnott, J.T., 1969. The application of Silvisar 510 by the spaced-cut injection method on some hardwood and coniferous species in Quebec. Can. Dept. Fish. and For., For. Br., Inf. Rept. Q-X-9, 6 p.

Arnott, J.T., 1969. A study of container planting in Quebec (Project Q-12: Tubelings). Can. Dept. Fish. and For., For. Br., Int. Rept. Q-11, 6 p.

Arnott, J.T., 1970. Scarification and direct seeding in non-reproducing burns and cutovers in the boreal forest region of Quebec. Can. Dept. Fish. and For., Can. For. Serv., Int. Rept. Q-17, 26 p.

Frisque, G.J., 1968. Stand history of the Nicauba Research Forest. Can. Dept. Fish. and For., For. Br., Mimeogr. Quebec Region, 13 p.

Frisque, G.J. and J.T. Arnott, 1969. Three years of trapping black spruce seed in the boreal forest of Quebec. Can. Dept. Fish. and For., Can. For. Serv., Inf. Rept. Q-X-13, 21 p.

Frisque, G.J., 1969. Volumes tables of the Nicauba Research Forest. Can. Dept. Fish. and For., Mimeogr. Quebec Region, 7 p.

Frisque, G.J. and J.T. Arnott, 1970. The Nicauba Research Forest. A research area for black spruce in Quebec. Part II: Research Program Objectives. Can. Dept. Fish. and For., Can. For. Serv., Inf. Rept. Q-X-19, 36 p.

Hatcher, R.J., 1964. Regeneration stocking in black spruce cutover and burned stands in Quebec. Can. Dept. For., Mimeogr. Rept. 64-Q-28, 8 p.

Hatcher, R.J. and M.L.G. Jurdant, 1965. Chibougamau Research Forest, Quebec. Can. Dept. For., For. Res. Br., Mimeogr. Rept. 65-Q-5, 14 p.

Jurdant, M.L. and G.J. Frisque, 1970. The Nicauba Research Forest. A research area for black spruce in Quebec. Part I: Forest Land Survey. Can. Dept. Fish. and For., Can. For. Serv., Inf. Rept. Q-X-18, 150 p.

MacArthur, J.D., 1969. Quebec black spruce research forest highlighted by industry cooperation. Pulp and Paper Mag. of Canada, 70 (23): 41-43.

Stanek, W., 1968. Development of black spruce layers in Quebec and Ontario. Forestry Chron., 44(2): 25-28.

REFERENCES

Arnott, J.T., 1969. A study of container planting in Quebec (Project Q-12: Tubelings). Can. Dept. Fish. and For., For. Br., Int. Rept. Q-11, 6 p.

Arnott, J.T., 1970. Scarification and direct seeding in non-reproducing burns and cutovers in the boreal forest region of Quebec. Can. Dept. Fish. and For., Can. For. Serv., Int. Rept. Q-17, 26 p.

Frisque, G.J. and J.T. Arnott, 1969. Three years of trapping black spruce seed in the boreal forest of Quebec. Can. Dept. Fish. and For., Can. For. Serv., Inf. Rept. Q-X-13, 21 p.

Geiger, R., 1957. Das Klima der Bodennahen Luftschicht. (The climate near the ground). Rev. Ed. 2, Transl. by M.N. Stewart and al., Cambridge Mass., Harvard Univ. Press., 494 p.

Hatcher, R.J., 1964. Regeneration stocking in black spruce cutover and burned stands in Quebec. Can. Dept. For., Mimeogr. Rept. 64-Q-28, 8 p.

Heinselman, M.L., 1957. Silvical characteristics of black spruce. U.S.D.A., Lake States For. Expt. Sta., Paper No.45, 30 p.

Heinselman, M.L., 1959. Natural regeneration of swamp black spruce in Minnesota under various cutting systems. U.S.D.A., Prod. Res. Rept. No.32, 22 p.

Jurdant, M.L. and G.J. Frisque, 1970. The Nicauba Research Forest. A research area for black spruce in Quebec. Part I. Forest Land Survey. Can. Dept. Fish. and For., Can. For. Serv., Inf. Rept. Q-X-18, 150 p.

Reifsnyder, W.E. and H.W. Lull, 1965. Radiant energy in relation to forests. U.S.D.A., For. Serv., Tech. Bull. 1344, 111 p.

Reifsnyder, W.E., 1967. Forest meteorology: the forest energy balance. Int. Rev. For. Res. (2): 127-179.

Stanek, W., 1968. Development of black spruce layers in Quebec and Ontario. Forestry Chron., 44 (2): 25-28.

Vincent, A.B., 1965. Black spruce, a review of its silvics, ecology and silviculture. Can. Dept. For., Public. No. 1100, 79 p.

Webber, B., J.T. Arnott, G.F. Weetman and G.C.R. Croome, 1968. Advance growth destruction, slash coverage and ground conditions in logging operations in eastern Canada. Pulp and Paper Res. Inst. of Canada, Woodlands Rept. WR-8, 109 p.