CANADA
Department of Northern Affairs and National Resources
FORESTRY BRANCH

CONTROLLED BURNING EXPERIMENTS ON JACK PINE SITES

by
Z. Chrosciewicz

Forest Research Division
Technical Note No. 72
1959

Published under the authority of
The Honourable Alvin Hamilton, P.C., M.P.,
Minister of Northern Affairs and National Resources
Ottawa, 1959

Cat. No. R47-68

THE QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1959

TABLE OF CONTENTS

68622-0—2

ACKNOWLEDGEMENTS

The author wishes to thank many members of the Executive and Technical Staff of the KVP Company Limited in Espanola, Ontario, for their fine co-operation and splendid contribution to the development and trial of controlled burning as a method of regenerating jack pine after cutting.

Mr. B. F. Avery on behalf of the Company authorized the experiments, and Messrs. A. H. Burke, D. W. Gray, A. G. H. Stewart, L. F. Lounder, F. Dunne, D. D. Avery, W. J. Charlesworth and F. T. Shreeve were especially helpful in both planning and organization of the actual field work. Mr. B. Land was in charge of the fire protection crews at the time of burning.

Dr. J. L. Farrar and Mr. J. R. T. Andrews, both formerly with the Forestry Branch, worked on the project. Dr. Farrar co-operated with the Company during the first burning experiment in 1949. Mr. Andrews participated in all other experiments until 1956, and much of the information for this report was obtained from unpublished progress reports which he prepared.

The author also wishes to thank the Dominion Meteorological Service of the Department of Transport for providing specialized daily weather forecasts during the experiments, and the Ontario Department of Lands and Forests for issuing fire permits. Their co-operation was essential in all the work undertaken.

Controlled Burning Experiments on Jack Pine Sites

(Project H-108)

by

Z. Chrosciewicz[1]

INTRODUCTION

Between 1949 and 1956, several trials of controlled burning were carried out on the KVP Company Limits west and northwest of Sudbury, Ontario. The purpose of these trials was to develop methods of regenerating jack pine (*Pinus banksiana* Lamb.) by the use of fire. The experiments included: burning slash; burning an open stand; burning slash and subsequent seeding; burning individual seed trees; and burning slash with seed trees.

REVIEW OF LITERATURE

Silvicultural Characteristics of Jack Pine

In many areas throughout Northern Ontario, jack pine is considered to be one of the most important commercial tree species. It is mainly used for the production of sulphate pulp, poles, posts, railway ties, mining timber and lumber.

In Ontario, jack pine grows either in pure stands, or in various associations with trembling aspen (*Populus tremuloides* Michx.), white birch (*Betula papyrifera* Marsh.), black spruce (*Picea mariana* (Mill.) BSP.), white spruce (*Picea glauca* (Moench.) Voss), balsam fir (*Abies balsamea* (L.) Mill.), red pine (*Pinus resinosa* Ait.), and white pine (*Pinus strobus* L.). It is usually found on dry outwash sands, on rocky hills and ledges, on eskers and kames, on river flats, and on moist sands near swamps (16). According to Bedell and MacLean (2), the natural distribution of species is often altered by forest fires and, therefore, jack pine may occur on a wide range of sites from dry sand dunes to moist upland tills.

From a silvicultural point of view, jack pine has many good qualities. It is most abundant on dry sandy soils, grows to a large extent in pure stands with a fairly high volume per acre, produces merchantable material at an early age, and in dense stands develops long clean boles with little taper. Eyre and LeBarron (9) expressed their opinion that jack pine is more important on the poorer soils than elsewhere, because it utilizes sites that otherwise might not yield valuable products.

Jack pine maintains itself and spreads mainly through the occurrence of forest fires. Watson (21) points out that a moderately intense fire has the following beneficial effects: it removes the duff from the soil surface; kills back competing vegetation; helps to open cones on standing trees; and drives away or kills seed-eating rodents and insects.

Jack pine does not reproduce itself readily after cutting. According to Cameron (3), the cones open only under the stimulus of high temperature, because of a gummy resin that seals the scales. Cones may be opened by a forest fire if they are still on the trees, or by heat from the sun if on slash scattered over the ground following logging operations. Eyre and LeBarron (9) state that, under normal field conditions, jack pine germination varies with the character

[1] Forestry Officer, Forestry Branch, Ontario District Office, Ottawa.

68622-0—2½

of the forest floor. Mineral soil is a good medium for germination; burned humus is often suitable, but undisturbed humus is poor. From the foregoing it is evident that an adequate seed supply on a favourable seedbed is the main requirement in regenerating jack pine after cutting.

Sexsmith (15) reported that several areas in Northern Ontario have been successfully regenerated by lopping and scattering cone-bearing branches on exposed mineral soil. Satisfactory regeneration has also been obtained in some areas by broadcast seeding following ground scarification. However, the most important factor limiting the application of these treatments on a large scale is their relatively high cost. For this reason, controlled burning techniques should be thoroughly tried, first to determine if they have practical application, and then to discern their limitations. Like all silvicultural treatments, controlled burning will be applicable only on certain sites and under certain conditions, and will of necessity be combined with a variety of other techniques in fulfilling the requirements for securing regeneration on any given area.

Controlled Burning in North America

In 1926, Chapman (4) recommended periodic use of controlled burning in managing long-leaf pine (*Pinus palustris* Mill.) throughout its natural range in the Southeastern United States. From that time until 1939, controlled burning was advocated in at least 26 publications. In 1939 an article by Wahlenberg, Greene and Reed (20) marked the first official recognition by the United States Forest Service that fire had a place in forest management.

Burning is now being used in the management of long-leaf pine (6); loblolly pine (*Pinus taeda* L.), (5, 8); short-leaf pine (*Pinus echinata* Mill.), (12, 13); pitch pine (*Pinus rigida* Mill.), (12, 13); sand pine (*Pinus clausa* Engelm. Vasey), (7); ponderosa pine (*Pinus ponderosa* Laws.), (19, 22); and a few other species. The main purposes of burning in the United States are to reduce fire hazard, to establish reproduction, to encourage seedling survival, and to prevent changes in species composition.

Burning has long been used in various parts of Canada but only to reduce fire hazard. In some provinces it has been compulsory under certain circumstances to burn slash after logging. Regulations to this effect have been modified in most cases to allow discretion on the part of the government officers charged with managing Crown timber.

Williams (23), in a study of fire hazard resulting from jack pine slash in the Sandilands Forest Reserve in Manitoba, found that "if logging slash is piled and burned, the fire hazard will be approximately one-third of that in slash left unburned and will be comparable to the hazard in the uncut forest". On the other hand, "if slash is left unburned, the fire hazard can be expected to remain relatively high, regardless of treatment, for at least ten years after the cut". These statements stress the importance of slash disposal as a measure in forest protection. In addition to the reduction of fire hazard, slash disposal by burning is the best known method of cleaning up an area prior to planting.

Effects of Burning on Soil Fertility

Although there have been many studies of effects of burning on forest soils, no conclusive evidence has been presented to show that burning is deleterious. Vlamis, Biswell and Schultz (19) bring this point out in their description of work done on the effect of burning on soil fertility in second-growth ponderosa pine. They cite 28 authors, and find no complete agreement on any aspect of the effects of fire on soil nutrients with the exception of increased nitrification.

They state that, "differences in type and amount of vegetation, intensity of burn, intensity and frequency of rainfall, other climatic factors, and the nature of the soil, may add up to give results which may vary with the circumstances".

According to Lutz and Chandler (14), in localities where almost pure organic soil is accumulated either on rocks or on a very thin layer of loose mineral material, the effects of fire may be extremely disastrous. The organic soil may be completely burned and any mineral soil washed away by rains. Devastation of this kind is most likely to occur on rocky hilltops, or on relatively steep slopes with sandy and gravelly material.

Since jack pine maintains itself mostly through the occurrence of forest fires, it appears that infrequent burning does not cause serious degradation of good and average jack pine sites in so far as this species is concerned. Lutz and Chandler (14) report that some foresters even favour burning of certain mor types of humus where nitrification will not occur from exposure to direct solar radiation.

Süchting (17) states that burning not only eliminates the unwanted "humus" but also fertilizes the soil with large quantities of potash, phosphorus and calcium, the most valuable constituents of ash. Sushkina (18) goes one step further. Dealing with nitrifying processes which take place in forest soils after various disturbances, he gives the following conclusions with regard to burning:

1. "Fire always has a stimulating effect upon nitrifying processes in forest soils. After burning, nitrification begins in soils where it has not been observed heretofore, and greatly increases where it has been going on before the burning.

2. "A moderate burning of the soil has a more favourable effect on its nitrifying capacity than an intense burning.

3. "The experiments undertaken prove that the effect of the burning upon the soils lasts during a period of five years.

4. "The capacity to nitrification reaches its maximum in the autumn.

5. "A running fire evidently will have a more favourable effect upon nitrification than the burning of forest debris gathered in piles".

Hesselman (11) explains still further the process of nitrification following burning. In his work published in 1937, he points out that fire releases volatile nitrogen from that portion of the humus which is burned, and consequently this nitrogen is lost to the soil. The effect of fire on raw humus in stands of the Vaccinium-Type, he concludes, is characterized by the reduction in acidity and by a change in the process of nitrogen mobilization. After burning, the remaining humus becomes loose, and then as a rule more or less intense nitrification sets in. Lutz and Chandler (14) further point out that "in northern forests having mor types of humus layer the total amount of nitrogen may be reduced as a result of fires, but the available amount appears to be increased".

From the foregoing it is evident that infrequent burning on better quality sites does not have detrimental effects on soil fertility. On the contrary, some fires may even temporarily stimulate nitrification and thus benefit the soil.

THE EXPERIMENTS

The first experiment with controlled burning by the KVP Company was undertaken in 1949 near Ramsay, Ontario, in co-operation with the Federal Forestry Branch and the Pulp and Paper Research Institute of Canada (10). Other experiments followed. These were carried out in co-operation with the Forestry Branch in the West Branch Spanish River Management Unit of the KVP Company north of Espanola, Ontario.

In general, the Company took full responsibility for providing men and equipment, and for supervision and direction of fire protection measures, while the Forestry Branch was responsible for the design of the experiments, collection of data, and interpretation of results. However, some of these latter functions were shared, and ideas and techniques worked out together to a point of mutual satisfaction.

Liaison with the Ontario Department of Lands and Forests was maintained by the Company, who obtained burning permits and kept the Department informed about the date and place of each fire.

Burning Slash

Location: North of Ramsay, Ontario, at mileage 7 on the Jerome Road.

Size of Treated Area: 5 acres.

Original Stand: 58-year-old jack pine with a small admixture of trembling aspen; volume 30 cords per acre.

Site: Gently rolling, dry sandy terrace; almost normal ecoclimate.

Logging: Clear cut in autumn 1948; 8-foot logs piled along 12-foot-wide strip roads spaced 1 chain from centre to centre; slash windrowed between strip roads; wood hauled on snow.

Experimental Design: After cutting, the area was divided into four sections, and each section was assigned a different treatment. The treatments were:

Section	Treatment
1A	Burning slash in windrows
1B	Burning slash in windrows followed by broadcast seeding
2A	Burning scattered slash
2B	Burning scattered slash followed by broadcast seeding

Where required, slash scattering was carried out shortly before burning.

Date of Burn and Weather: May 10, 1949. Clear; temperature 60°F.; north wind at 12 m.p.h.; slash fire hazard 9[2].

Conditions of Fuels: The duff layer was 1.5 inches thick. Only the slash and the surface litter were dry before burning.

Fire Protection: Suitable precautions were taken to ensure that the fire did not spread to adjacent areas. A clean 6-foot-wide fire line was bulldozed around the area. The protection crew consisted of 12 men and one supervisor. Equipment included two motor pumps, enough hose to surround the area, pack pumps, hand tools, and two fire torches. A bulldozer was kept ready for use if needed in emergency.

Procedure of Burning: Back-firing commenced at 3 p.m., the windward side was ignited one hour later, and by 6 p.m. all intense burning had ceased. There was no difficulty in controlling the fire. The burn was patrolled during the night, and by noon on the next day the fire was completely extinguished.

Observations after Fire: The burn failed to create a favourable seedbed. More than 90 per cent of the surface litter and most of the slash were consumed, but the lower inch of duff remained intact owing to its high moisture content. It was estimated that over 90 per cent of the seed in the slash was destroyed.

[2] All fire indices presented in this report were determined from the "Forest Fire Danger Tables" (1).

The only cones remaining were on branches that projected some distance from substantial amounts of fuel. Seed extracted from these cones was tested for germination. Even in the best sample, germination was reduced to 30 per cent from the normal value of 80 per cent. Other samples showed a viability of around 5 per cent.

Seeding: Following the burn, sections 1B and 2B were broadcast seeded at the rate of about 5 ozs. of seed per acre. The seed was 80 per cent viable.

Regeneration: A regeneration survey was carried out in the autumn of 1952 with the following results.

By treatments, the stocking[3] of jack pine seedlings was as follows:

Treatment	Stocking (%)
Burning slash in windrows	7
Burning slash in windrows followed by broadcast seeding	16
Burning scattered slash	6
Burning scattered slash followed by broadcast seeding	23

From comparison of stocking figures it is evident that burned slash was a poor source of seed supply. Broadcast seeding following the fire produced somewhat better results.

Practically all seedlings were found on patches of mineral soil exposed during the logging operations, and the fire brought about little improvement in seedbed conditions. It is doubtful if distribution of slash prior to burning had any influence on experimental results. Although some increase in regeneration was associated with broadcast seeding following burning, the treatment was not particularly effective because the seedbed was still generally unfavourable.

Burning an Open Stand

Location: North of Espanola, Ontario, at mileage 28 on the West Branch Road.

Size of Treated Area: 4 acres.

Original Stand: 27-year-old jack pine of an orchard-like type; trees about 25 feet tall with limby crowns bearing a good crop of cones.

Site: Very dry, sandy and cobbly terrace; warm and dry ecoclimate.

Treatment: Burning only.

Date of Burn and Weather: May 30, 1949. Clear; temperature 75°F.; west wind at 5 m.p.h.; no fire indices have been recorded.

Condition of Fuels: The forest floor was characterized by an abundance of surface cobbles and by less than one inch of duff which barely filled the gaps between them. This relatively thin layer of duff and the ground vegetation, consisting mainly of blueberry (*Vaccinium* sp.), were the only fuels covering the mineral soil. Owing to its loose structure, and to favourable weather, the duff was dry before burning.

Fire Protection: A 10-foot-wide fire line was bulldozed around the area. The protection crew consisted of 12 men and 2 supervisors. Two motor pumps were set up on the river bank, and the area surrounded by hoses. Other equipment included pack pumps, hand tools, two fire torches, and a bulldozer.

[3] All stocking figures used in this report refer to milacre quadrats which were stocked by one or more jack pine seedlings.

Procedure of Burning: The whole area was burned between 3 p.m. and 6 p.m. by both back- and head-fires. Burning was under control at all time. The area was watched during the night and the following day.

Observations after Fire: Since the duff was dry before burning, the fire consumed all surface litter except a very thin layer of humus thus creating a favourable seedbed. The effects of the fire were not restricted to the forest floor and standing trees were severely damaged. Most needles were either scorched or burned, and the cones opened shortly after, resulting in a good seedfall.

Regeneration: Sampling for regeneration two years after the fire showed that the area was more than 60 per cent stocked. The seedlings were healthy and just pushing their tops through the blueberry ground cover. The area was inspected again in the spring of 1954, and was still about 60 per cent stocked.

The relatively good regeneration in this area may be attributed first, to the improved seedbed, and second, to the adequate seed supply.

Burning Slash and Broadcast Seeding

Location: North of Espanola, Ontario, 0.5 mile northeast of Camp 3 across the West Branch Spanish River.

Size of Treated Area: 17 acres.

Original Stand: 50-year-old jack pine with a volume of 30 cords per acre.

Site: Gently rolling dry, sandy and cobbly terrace; almost normal ecoclimate.

Logging: Clear cut in autumn 1946; 8-foot logs piled along 12-foot-wide strip roads spaced one chain from centre to centre; slash windrowed between strip roads; wood hauled on snow.

Experimental Design: The cut-over area was divided into four blocks, each to be seeded with a different amount of seed per acre after the windrowed slash had been burned.

Date of Burn and Weather: October 15, 1953. Clear; temperature 70°F.; west-northwest wind at 5 m.p.h.; slash fire hazard 15.

Conditions of Fuels: The duff layer was 1.5 inches thick. Approximately one inch of duff and the slash were dry before burning.

Fire Protection: A 10-foot-wide fire line was bulldozed around the area, and another through its middle dividing it into two almost equal sections. The protection crew consisted of 9 men and 3 supervisors. One motor pump was set up on the river bank, and hoses laid along the fire lines. Other equipment included pack pumps, hand tools, two fire torches, and a bulldozer.

Procedure of Burning: The fire was started at 2:45 p.m., and each section was burned in a separate operation. Each was back-fired until one-third had been burned, and then a head-fire was started, so that both fires met in the middle. By 6:50 p.m., the whole area was burned over without any complications. On the next day, all spot fires in the burned area were completely extinguished.

Observations after Fire: On the average about 0.5 inch of duff remained unburned because of higher moisture content close to the mineral soil, and the resultant seedbed was of medium quality. The fire consumed all but the largest pieces of slash.

Seeding: On May 17, 1954, the area was broadcast seeded, and the intensity of seeding by blocks was as follows:

Block	Seed per Acre (Ozs.)	Seed Viability (%)
A	6	87
B	10	87
C	12	87
D	32	50

Regeneration: A regeneration survey was carried out in the autumn of 1956, with the following results:

Block	Stocking (%)
A	25
B	50
C	55
D	20

These results are indicative of poor to moderate success. In general, stocking improves as intensity of seeding increases, and the best stocking resulted from using 12 ozs. of highly viable seed per acre. An anomalous situation occurs where 32 ozs. of seed were sown as only 20 per cent stocking is associated with this treatment. Although the seed was only 50 per cent viable, this does not account for the situation and no explanation for it is offered.

Seedlings were mostly located where patches of mineral soil were exposed during logging operations and where logs in an advanced state of decay were completely consumed by the fire. Although 12 ozs. of highly viable seed were required to secure an acceptable amount of regeneration, it is evident that if the fire had been more successful in preparing a suitable seedbed, satisfactory results might have been achieved with less seed per acre.

Burning Individual Seed Trees

Location: North of Espanola, Ontario, 4 miles north of Camp 9 along the West Branch Road.

Experimental Design: According to the original design, individual seed trees were to be burned following ground scarification. It was believed that this method would involve very little risk from fire, and could be used safely in regenerating some cut-over areas to jack pine. However, work to date has been mainly concerned with development of a suitable burning technique, and therefore, no ground scarification accompanied the various trials.

Initial Trials: In October 1954, three trees were burned. To get fuel to the crowns a man climbed each tree with climbing irons, taking with him a rope and pulley. After securing himself, he pulled up a pressure flame thrower and sprayed kerosene over the branches and down the trunk. He also laid paper along the branches and soaked it with fuel. The fuel on the trunk of each tree was ignited and the flame spread up the crowns. Although some difficulty was encountered in igniting the crowns because the needles had a high moisture content, enough heat was generated to dry out the tops and they eventually burned like torches.

Following burning, the trees were felled and examined. Most cones had opened within 24 hours, and the greatest degree of success was obtained in the upper quarter of the crowns where about 80 per cent of the cones were open.

Further Trials with Special Equipment: During the winter of 1954-55, special equipment was designed for individual tree burning. It consisted of a sectional aluminum-magnesium pole to which a flame thrower nozzle was attached. Kerosene was forced to the top of the pole through a rubber hose by pressure in the flame thrower tank, and ignited by means of an electric element on the nozzle. This element was connected by wires to a car battery on the ground with a switch to allow ignition while the pole was vertical. The equipment was hoisted with a long forked stick until it stood vertical beside the tree. The tree was then sprayed with kerosene and ignited.

Trials of this equipment were undertaken in 1955, and they did not prove successful. It was found that the pole was not sufficiently rigid if it were extended more than 40 feet and it was impossible to apply enough kerosene to the upper portion of the crowns to obtain a satisfactory burn.

Burning Slash with Seed Trees

Location: North of Espanola, Ontario, 4 miles north of Camp 9 along the West Branch Road.

Size of Treated Area: 49 acres.

Original Stand: 85-year-old jack pine with a volume of 37 cords per acre; trees about 60 feet tall.

Site: Dry to fresh sandy terrace with a shallow cap of sandy loam mainly in the B horizons; warm and dry ecoclimate.

Logging: Seed trees marked along the edges of one-chain-wide cutting strips at right angles to haul roads; other timber cut in summer 1954; 8-foot logs piled down the centre lines of cutting strips; slash windrowed on their edges; wood bundle-yarded to haul roads in early autumn.

Experimental Design: An area of about 107 acres, divided into 12 treatment sections, was set aside for this experiment. On nine sections, reserved seed trees numbered 6, 8, 10 or 12 per acre and the windrows of slash were to be burned. Two of the remaining three sections were laid aside as controls, and one was intended for planting. Because of unsuitable weather, burning to date has been restricted to four sections, listed as follows:

Section	Approximate Area in Acres	Seed Trees per Acre
B1	13	6
D1	1	10
A1	25	6
A2	10	12

Date of Burn and Weather: (All weather readings were taken at 12:30 p.m. E.S.T.)

	Sections			
	B1 (first attempt)	B1 (second attempt)	D1	A1, A2
Date of burn	June 2/55	June 7/56	June 3/55	June 11/56
Sky condition	Clear	Clear	Cloudy	Clear
Temperature	77°F.	80°F.	69°F.	81°F.
Relative humidity	30%	29%	55%	36%
Wind direction	SE	SW	SE	SW
Wind velocity	3 m.p.h.	10 m.p.h.	5 m.p.h.	3 m.p.h.
Slash fire hazard	16	15	16	11

It will be noted from the foregoing table that two fires were required to burn section B1. The 1955 fire covered only 0.5 acre and the remaining 12.5 acres were burned in 1956.

Condition of Fuels: The duff layer was about 2 inches thick on all sections. Slash and the surface litter were dry before burning, but even at the extreme fire hazard of 16, the lower portion of duff remained moist.

Fire Protection: Each section chosen for broadcast burning was separated from other sections by fireguards such as roads, creeks, lakes, or 24-foot-wide bulldozed lines. The number of men employed in controlling fires on the individual sections varied as follows:

Section	Number of Men	Number of Supervisors
B1 (first attempt)	25	6
B1 (second attempt)	27	3
D1	10	3
A1, A2	12	3

Similar equipment was used on all fires. It consisted of two motor pumps, water hoses, pack pumps, hand tools, two fire torches, and a bulldozer. As a rule, the motor pumps were set up and the hoses laid out in advance of burning. However, when sections A1 and A2 were burned, the fire hazard was not extreme and the pumps and hoses were merely kept in a truck parked nearby.

Procedure of Burning: Since different techniques were used for both starting and controlling the various fires, each burn is described separately.

Section B1 (first attempt): By 2:25 p.m., all men and equipment were in assigned positions and a back-fire was started in the northwest corner of the section. The flames built up very quickly in dry slash. As the wind shifted its direction, the fire was extinguished because there was a danger that sparks would ignite either slash or timber beyond the section. The whole operation took approximately 30 minutes, and only 0.5 acre was burned.

Section B1 (second attempt): At 2 p.m. the fire was started in the northwest corner of the section along the edge of the 1955 burn. Two men equipped with torches proceeded to ignite the slash around the perimeter of the section. When they reached about 6 chains south of the starting point, a head-fire was ignited at right angles, cutting off about one-third of the section. The head- and back-fires met and burned out in 35 minutes. At 2:48 p.m. the torch men started to ignite the edges of the remaining portion of the section, but after about 15 minutes this procedure was discontinued, because several spot fires were discovered in another section, apparently resulting from a change in wind direction. These were quickly extinguished with hand tools and a bulldozer, and by 4:30 p.m., the remaining portion of section B1 was burned by a gradual spread of edge fires.

Section D1: Burning commenced at 2:25 p.m. with a back-fire in the north corner of the section. From this point the ignition of slash was carried out progressively along the northwest and northeast sides to almost halfway down the section, and then a head-fire was set in the centre. At 4:05 p.m., the southeast side of the section was ignited. Soon the two head-fires gained momentum and in about 15 minutes the fire had completely burned out.

Sections A1 and A2: Two men operating torches began ignition at the northeast corner of the area at 5:35 p.m. They proceeded around the perimeter in opposite directions at a speed of 25 chains per hour and completed the operation in $1\frac{1}{2}$ hours. The fire burned towards the centre of the area at a moderate and

steady rate of about 4 chains per hour. On the average, flames were 5 feet high. With practically no effort on the part of the protection crew the whole area (sections A1 and A2) was burned over by 8:30 p.m. Since 0.46 inch of rain fell shortly after the fire, very little mop-up action was required.

All sections, except A1 and A2, were patrolled during the night following burning to make sure that no danger existed from smouldering stumps and logs. Most of these were completely extinguished, or put under proper control, by noon of the following day.

Observations after Fire: Both in 1955 and in 1956, burning failed to create favourable seedbeds, regardless of the type of fire. As the duff was too moist to burn completely, the lower 1.0 inch to 1.5 inches remained intact. The flames consumed all slash up to one inch in diameter, and the stems of seed trees were charred to a height of 20 to 40 feet from the ground. Some cones on the seed trees opened immediately, and others opened during the following days. The number of opened cones varied with the intensity of fire. Within four months almost all cones had opened on the seed trees in areas burned by a head-fire, whereas perimeter- and back-fires caused only 40 to 50 per cent of the cones to open.

Regeneration: All burned sections were sampled for regeneration in the autumn of 1957. By sections, the following stocking figures were obtained:

Section	Stocking (%)
B1	17
D1	10
A1	13
A2	10

This table shows that burning slash in the presence of seed trees did not produce satisfactory jack pine regeneration. Although the total stocking was generally low on all sections, only part of it could be attributed to the burn alone, because many seedlings were found growing on small patches of mineral soil exposed during logging operations rather than by the fire. If these seedlings were eliminated from the tally, the total stocking for the area would only be two per cent.

In general, burning failed to improve the seedbed conditions. Regeneration occurred mostly on mineral soil which had been exposed by logging, and stocking could not be correlated with the number of seed trees per acre. However, since many cones on the seed trees had opened after burning, it was believed that enough seed had been released to produce both better stocking and more uniform distribution of seedlings if the seedbed conditions had been favourable.

DISCUSSION AND CONCLUSIONS

It is too early yet to form any definite opinion as to whether or not controlled burning will be successful in regenerating jack pine after cutting. Conclusive evidence on this point will not be available until all possibilities of burning are thoroughly explored by actual trials, and the results tested with multiple replications of treatments. Although the experiments to date proved to be deficient in providing such evidence, they yielded a considerable amount of basic information on many aspects of controlled burning.

Seedbed Preparation

The quality of seedbed is one of the key factors in regenerating jack pine by the use of fire. This was clearly demonstrated by the experiments. On a good seedbed such as mineral soil, or soil covered only by ash mixed with traces of humus, good regeneration will usually occur providing that the area is adequately seeded. On medium quality seedbeds, with approximately 0.5 inch of partially burned duff, considerably more seed per acre will be required than on mineral soil if an adequate amount of reproduction is to be obtained. Poor seedbeds, on the other hand, with more than 0.5 inch of undisturbed duff, will always produce insufficient regeneration regardless of the intensity of seeding.

If fires are to be used in the preparation of jack pine seedbeds, the duff must be very dry. When duff is an inch or more in depth, prolonged periods of drought must occur before this condition is brought about. These are usually restricted to the summer months, but if the duff is shallow, relatively short dry periods, which sometimes occur in spring and in autumn, may be sufficient to create moisture relationships that will allow adequate burning. The experiments described in this report have been confined to spring and autumn, and as they have not met with success when thick duff was encountered it is suggested that additional experiments should be undertaken in midsummer to determine whether satisfactory seedbeds can be prepared by burning at that time.

Seed Supply

In areas treated by controlled burning, jack pine seed may be furnished by seed trees, or it may be introduced by direct seeding. Formerly it was believed that sufficient seed would be released from slash by burning, but these experiments have shown otherwise. If seeds in slash are not burned, their viability is so reduced by the heat in the burning slash that they are of little use.

Although most of these experiments have not been particularly successful because of difficulty in preparing satisfactory seedbeds, they do indicate that slash fires provide sufficient heat to open cones on seed trees. The experiments have shown that the proportion of opened cones on seed trees varies with the intensity of the slash fire. A good head-fire may result in the opening of almost all cones, whereas back-fires are usually about half as successful. There is still some doubt as to the number of seed trees per acre required to furnish adequate seed if good seedbeds are present. These experiments, although inconclusive in this respect, indicate that ten large and mature trees may be sufficient.

Good seedbeds have been successfully regenerated by means of broadcast seeding, and it may be that spot seeding is a suitable alternative. When seeding is to be undertaken, it should be carried out in early spring so as to give the young seedlings a better chance of establishment and survival. Desirable intensity of seeding is still open to question but it seems that from 4 to 8 ozs. per acre of seed may be sufficient if the seedbed is good but about 16 ozs. per acre are most likely to be required when the seedbed is of medium quality.

Indirect seeding by means of scattering cone-bearing slash has been successful in parts of Ontario when seedbeds were prepared by mechanical scarification. This procedure would be impractical with controlled burning as the cone-laden slash in the treated area is destroyed.

Weather

Wind speed and direction are two of the most important factors affecting the safety of burning. Wind speed at approximately six feet above ground level should be less than 5 m.p.h. Its direction should be constant and away from any uncut timber which may be adjacent to the area to be burned. Suitable

wind speeds are usually encountered if winds of less than 15 m.p.h. are predicted, as such predictions refer to an elevation 33 feet above the ground where wind speeds are much higher than those near the surface. Since fire may be extremely hazardous if strong winds or unsuitable wind directions develop during burning operations, special weather forecasts should be obtained for the specific locality in which burning is contemplated. Such forecasts are particularly useful in planning of fire protection measures with regard to expected weather at the time of burning.

Likelihood of encountering hazardous winds is less if fires are begun after 3 p.m. Daily wind speeds are usually near their maximums about 2 p.m. and they decrease towards evening. As a consequence, evening fires burn more slowly than afternoon fires and they are normally less difficult and less costly to control.

Local weather data should always be obtained as they are required to ascertain fire indices from "Forest Fire Danger Tables" (1), which enable the selection of a day for burning when fires of sufficient intensities are likely to be obtained. In the experiments described in this report, days for burning were selected on the basis of slash fire hazard. It is suggested that in any future experiment of this kind the day of burning should be determined with respect to indices based on the moisture content of duff, as duff will have to be destroyed if the purpose of the experiment is to be achieved.

Fire Protection Measures

One of the principal requirements for effective control of fires is a bulldozed fire line surrounding a treatment area on all sides. The line should have straight edges, completely exposed mineral soil, and no accumulation of heavy slash close to it. Moreover, experience indicates that it is easier to control a fire on a square area than on a strip. This provision should be kept in mind, especially when a large area is subdivided into sections to be burned separately.

The use of a well-trained crew greatly increases the safety of burning operations, and at the same time costs are reduced because fewer men are needed.

The fire-fighting equipment should be carefully checked in advance of burning. This practice has already proved to be a worthwhile precaution supplementing the normal annual check.

Placement of equipment before burning reduces hazards and speeds up the work. The decision of where to place the pumps and how to lay out the hose lines will depend upon accessibility to the nearest source of water. In any case, the laying out of hose should be such as to ensure an adequate supply of water to any part of the area.

Before burning, the slash on the outside of the fire line should be thoroughly sprayed with water, and men posted along the line to deal with any emergency which may arise. Normally, the main fire burns out by itself, and the only action required from the protection crew during the first day is extinguishing isolated stump and log fires along the edges of the burned area.

Suppression of fire does not usually end on the day of burning, however. Stumps, roots, and partially decomposed logs may smoulder for several days. As potential sources of fire, they should be extinguished as soon as possible. The best time for this work is the first morning after the main fire. Every smouldering spot should be uncovered and then soaked with water. Although hand tools are best for uncovering spot fires, a bulldozer may be of considerable

help in places where burning stumps are covered by mounds of earth. As a rule, this operation should be finished by noon on the first day following the fire. If this is not done by noon, high winds can carry sparks to some of the neighbouring areas, thus starting new fires. After the fire is extinguished, the area should be patrolled for a few days to make sure that the fire is fully out.

Efficient communication with the nearest camp or head office is essential in any burning operation. This may be maintained either by radio or telephone. The latter method was used by the KVP Company.

The experiments to date indicate that burning may be carried out efficiently and without any complications. To make burning relatively safe, the whole operation must be properly planned with respect to weather, method of ignition, and required protection. Favourable weather appears to be more important than any other factor.

Burning Techniques

The method of controlled burning will vary with any change in the purpose of burning, time of burning, fire hazard, weather, or size of the area. If fire is merely intended to dispose of slash after clear cutting, perhaps the safest time for burning would be in early spring, a few days after the snow has melted. When the slash is sufficiently dry, and there is no high wind, each pile or windrow should be ignited separately as the burning progresses. This type of fire may be easily controlled, and it can be carried out at a low cost. If fire is to be used in seedbed preparation, an entirely different approach is required. It should be kept in mind that duff must be dry if mineral soil is to be exposed. The technique of setting and then controlling a fire, especially when hazard is high, may vary with local conditions. Two of them are described in the following paragraphs.

When the operation takes place in the afternoon, the safest way to start burning is against the wind with a back-fire. This may be accomplished by igniting slash along the edges on the lee side of the area. After the fire has burned about 3 chains in the windward direction, a head-fire may be started across the area a few chains ahead of the back-fire. Later when the two fires have merged, burning may be completed by one more head-fire, or by several successive head-fires depending on the size of the area.

During calm weather, or when wind velocity is very low, which usually occurs in the evening, an entirely different method of burning can be used. This method consists of a progressive ignition of slash along the edge of the area. The procedure is very simple. First, the ignition is carried out on the lee side of the area, then on the two adjoining sides proceeding always against the wind, and finally on the windward side. Apart from this procedure, no other steps are required as the edge fires will burn by themselves toward the centre of the area.

Costs

The costs of experimental burning on the KVP Company Limits were inconsistent, ranging from $4 to $20 per acre. In general, afternoon fires are more costly than evening fires. Because conditions are usually much more hazardous in the afternoon, burning must be restricted to small areas and larger fire protection crews are required to deal with any emergency. Although it is impossible to draw any firm conclusions about costs of silvicultural treatments from experimental work alone, particularly when development of techniques is given primary emphasis, there is some indication that controlled burning may be less expensive than other treatments designed to secure jack pine regeneration.

SUMMARY

To develop methods of regenerating jack pine by the use of fire, several trials of controlled burning were carried out on the KVP Company Limits between 1949 and 1956. Experiments included burning slash, burning an open stand, burning slash and subsequent seeding, burning individual seed trees, and burning slash with seed trees.

Briefly, results revealed that:

1. On mineral soil, or where the soil is covered by ash mixed with traces of humus, good regeneration will usually occur even if the area is seeded with a relatively small amount of seed per acre. A medium quality seedbed, on the other hand, with 0.5 inch of partially burned duff, will require considerably more seed per acre if acceptable regeneration is to be secured. Since poor results may always be expected on a poor seedbed, no seeding should be carried out in areas where the layer of undisturbed duff is thicker than 0.5 inch.
2. In general, the quality of burns improves with increasing dryness of duff. If prolonged droughty weather precedes a burn, a fire may destroy the duff thus creating a favourable seedbed for germination. Since the occurrence of such conditions is likely to be infrequent in both spring and autumn, the chances of successful burning in either one of these seasons are relatively small.
3. Burning could not be regarded as a dependable means of releasing seed from cones in slash because the fire either destroys the seed, or drastically reduces its viability.
4. The success of opening cones on seed trees by means of slash fires depends largely upon the intensity of the fire. A good head-fire may open all the cones on seed trees or twice as many cones as an average back-fire.
5. When properly planned, controlled burning may be carried out efficiently and without complications. Suitable weather and adequate fire protection are the main requirements for safe burning.

   When making decisions on burning, special consideration must be given to wind speed. No fire should be started either in the early part of the day, or when wind speed exceeds 5 m.p.h. Since wind speed usually reaches a maximum at about 2 p.m. and then decreases toward evening, the best time to start a fire is in late afternoon, or early evening. Because of the importance of favourable winds, weather forecasts and observations of local weather are essential in controlled burning.

   As for fire protection, the requirements may be listed as follows: bulldozed fire lines, nearby source of water, efficient communication with head office, adequate number of trained men, proper distribution of pretested equipment, suitable method of burning, and complete suppression of fire by noon of the following day.
6. The cost of burning tends to vary with both the size of burned area and the type of fire. In general, the lowest costs per acre are obtained when fairly large areas are burned in the evening.
7. It is still too early to form definite conclusions as to whether or not controlled burning will be a suitable means of regenerating jack pine after cutting. Sufficient evidence on this point will not be available until further study is made of the use of fire under various conditions, particularly when the duff is dry.

REFERENCES

(1) Beall, H. W. 1948. Forest fire danger tables. Canada, Dom. For. Serv., For. Res. Note 12.

(2) Bedell, G. H. D. and D. W. MacLean. 1952. Nipigon growth and yield survey. Canada, Dept. Resources and Development, Forestry Branch, Silv. Res. Note 101.

(3) Cameron, H. 1953. Wilting point of the bonding material in lodgepole pine and jack pine cones. Canada, Dept. Resources and Development, Forestry Branch, Silv. Leaf. No. 86.

(4) Chapman, H. H. 1926. Factors determining natural reproduction of longleaf pine on cut-over lands in La Salle Parish, Louisiana. Yale Univ., School of Forestry, Bull. 16.

(5) Chapman, H. H. 1942. Management of loblolly pine in the pine hardwood region in Arkansas and Louisiana, west of the Mississippi River. Yale Univ., School of Forestry, Bull. No. 49.

(6) Chapman, H. H. 1948. The initial and early stages of research on natural reforestation of longleaf pine. J. For. 46-7: 505-510.

(7) Cooper, R. W. 1953. Prescribed burning to regenerate sand pine. S.E. For. Exp. Stn. Res. Note No. 22.

(8) Elliott, F. A. and K. B. Pomeray. 1948. Artificial regeneration of loblolly pine. J. For. 46-4: 296-298.

(9) Eyre, F. H. and R. K. LeBarron. 1944. Management of jack pine in the Lake States. U.S. Dept. Agr. Tech. Bull. 863.

(10) Farrar, J. L., D. W. Gray and D. Avery. 1954. Jack pine regeneration. Pulp and Paper Mag. of Canada. 55-12: 136-146.

(11) Hesselman, H. 1937. Om humustäckets beroende av beståndets ålder och sammansättning i den nordiska granskogen av blåbärsrik Vaccinium—typ och dess inverkan på skogens föryngring och tillvaxt. (Über die Abhängigkeit der Humusdecke von Alter und Zusammensetzung der Bestände im nordischen Fichtenwald von blaubeerreichem Vaccinium—Typ und über die Einwirkung der Humusdecke auf die Verjüngung und das Wachstum des Waldes.) (German summary, pp. 669-715.) Meddl. f. Statens Skogsförsöksanstalt, 30: 529-716.

(12) Little, S. 1953. Prescribed burning as a tool of forest management in the northeastern states. J. For. 51-7: 496.

(13) Little, S. and E. B. Moore. 1950. Effect of prescribed burns and shelterwood cutting on reproduction of shortleaf and pitch pines. N.E. For. Exp. Stn. Paper No. 35.

(14) Lutz, H. J. and R. F. Chandler. 1949. Forest Soils. John Wiley and Sons Inc., New York.

(15) Sexsmith, E. R. 1955. The forestry program of the Longlac Pulp and Paper Company Ltd. P. and P. Mag. of Canada 56(4): 108.

(16) Society of American Foresters. 1954. Forest cover types of North America (exclusive Mexico). Report of the Committee on forest types. Washington, D.C.

(17) Süchting, H. 1929. Die Bekämpfung des Humus der Waldböden. Zeitschr. f. Forst— u. Jagdwesen, 61: 349-363.

(18) Sushkina, N. N. 1933. Nitrifikatsia v lessnykh pochvakh v zavissimosti ot sostava nasjdenia, rubki i ognevo i ochistki lessosek. (Nitrification of forest soils with reference to the competition of the stands, cutting and fire.) Izv. Akad. Naouk S.S.S.R., pp. 111-159 (Translation No. 56, 1934—U.S. For. Serv. Div. of Silvics).

(19) Vlamis, J., H. H. Biswell and A. M. Schultz. 1955. Effects of prescribed burning on soil fertility in second growth ponderosa pine. J. For. 53-12: 905-909.

(20) Wahlenberg, W. G., S. W. Greene and H. R. Reed. 1939. Effects of fire and cattle grazing on longleaf pine lands as studies at McNeill, Mississippi. U.S. Dept. Agr. Tech. Bull. No. 683.

(21) Watson, R. 1937. Jack pine in Michigan. U.S. For. Serv. Reg. 9.

(22) Weaver, H. 1955. Fire as an enemy, friend and tool in forest management. J. For. 53-7: 499-504.

(23) Williams, D. E. 1955. Fire hazard resulting from jack pine slash. Canada, Dept. Northern Affairs and National Resources, Forestry Branch, For. Res. Div. Tech. Note 22.