CANADA
Department of Northern Affairs and National Resources
FORESTRY BRANCH

SEEDING AND PLANTING RED AND WHITE PINE

by
W. M. Stiell

Forest Research Division
Technical Note No. 80
1959

73603-3—1

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

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

Cat. No. R47-80

TABLE OF CONTENTS

73603-3—2

PREFACE

This report was prepared as one part of a comprehensive study of the red and white pine cover types of the Great Lakes—St. Lawrence Forest Region, carried out by the Federal Forestry Branch. The investigation sought to consolidate information available in the literature, previously unpublished work of the Forestry Branch, and the results of field studies undertaken especially for this project. Following publication of individual papers dealing with specific fields of the investigation, the material will be brought together in somewhat condensed form in a single bulletin.

Acknowledgements for information, technical data, and access to certain records and maps are due the Reforestation Branch of the Timber Division, Ontario Department of Lands and Forests. Particular mention should be made of the following field personnel: the Superintendents and staffs of the Angus Tree Seed Plant, and the Kemptville, Midhurst, Orono, and St. Williams Nurseries; and the Zone Foresters of the Pembroke, North Bay, and Kemptville Districts. Much of the information dealing with reforestation in Ontario was obtained solely from interviews with the above personnel, and is therefore not supported by references to published material.

Seeding and Planting Red and White Pine

by

W. M. Stiell[1]

INTRODUCTION

Red and white pine[2] have been extensively planted in Eastern Canada and in the northeastern and Lake States. They have shown themselves well suited to light dry soils, with white pine planted on the wider range of sites—from sands to loams (9). Afforestation of abandoned farmlands has been particularly successful with these species.

Between 1905 and 1953 the Division of Reforestation, Ontario Department of Lands and Forests, distributed 81.3 million red pine seedlings, and 30.1 million white pine seedlings, for planting in the province[3]. In recent years the proportion of red pine to white pine planted in Ontario has been about 4 or 5 to 1, but the present trend is towards more equal production, and an output of about 9.5 million seedlings of each species is planned for 1960. Other regions where red and white pine have been planted on a large scale include the Lake States—498 million red pine and 106.2 million white pine planted by public agencies up to 1944 (29); New York—235.3 million red pine and 172.3 million white pine shipped from State nurseries 1909-1955 (7); Ohio—6.3 million red pine and 2.7 million white pine distributed by State nurseries 1904-38 (26); and Pennsylvania—red and white pine, together with Scots pine, were the main species planted up to 1940 (19).

The high reputation of white pine as a lumber-producing species made it an early choice for planting. Later, owing to its vulnerability to injury by the white pine blister rust and white pine weevil, it fell into disrepute as a popular plantation species. More recently it has been found that in some areas satisfactory stands of white pine can be developed by special control and planting measures (13, 17), or by alternate row mixtures with red pine followed by suitable thinning procedures.

Much more success has been attained with red pine, which has been the most widely planted species in southern Ontario. Introduction of the European pine shoot moth, however, has caused serious damage, and pure plantations of red pine are unlikely to be successful within the range of this insect unless satisfactory control methods are developed.

SEED PRODUCTION AND TREATMENT

Species Characteristics

The minimum commercial seed-bearing age for red pine is 25 years and for white pine is 15 to 20 years, but the optimum for both species is 50 to 150 years (6). Good cone crops may occur every 3 to 7 years for red pine, and every 3 to 5 years for white pine (6), but seed years at 5 to 8 years and 2 to 3 years respectively are of more common occurrence in Ontario. A light crop of seed is borne by both species in most intervening years.

[1] Forestry Officer, Forestry Branch, Forest Research Division, Ottawa.

[2] See Appendix for list of scientific names.

[3] Compiled from records of Reforestation Branch, Ontario Dept. Lands and Forests.

73603-3—2½

Red pine cones ripen September-October, when they turn a deep purple with red-brown scale tips; their specific gravity is then 0.80 to 0.94 (6). They are considered ready to pick when they will float in kerosene (2), or S.A.E. No. 20 oil (12). September 10 is the earliest date in Ontario. Cones should be collected within 30 days of ripening, since the seed is dispersed from the autumn to the following summer.

Ripe white pine cones are yellowish-green with brown-tipped scales; they have a specific gravity of 0.92 to 0.97 and will float in linseed oil (6). Ripening occurs in August to September, or August 25 at the earliest in Ontario. Cones should be collected within 20 days. Seed dispersal is normally complete by October (6).

For both species there is about one week's variation in ripening dates throughout Ontario. Ripening is usually, but not always, later farther north; early frosts, which hasten the process, normally occur first in the northern districts. Cones open quickly when frosty nights succeed warm days.

Cone Collection

In order to produce planting stock with the best inherent qualities, cones should be collected from undamaged trees showing good form and growth rate, rather than merely from the most convenient specimens or those with the most abundant crops. Desirable features in red pine have been described as straight stem, good natural pruning, moderate crown width, reasonably thin branches at an angle near 90 degrees to the axis of the main stem, and resistance to the European pine shoot moth, Saratoga spittlebug, and red-headed pine sawfly (32). Superior characteristics of white pine are straight stem, slender leader, at least moderate self-pruning, moderate crown width, branch angle close to 90 degrees, and resistance to blister rust and the white pine weevil (32).

Unless provenance tests have indicated that particular geographic sources produce superior strains, it is advisable to plant in any area only stock derived from seed collected locally or within the influence of the same prevailing climate. In Ontario, cones are collected within definite zones whose limits are based on effective temperature and moisture, which in turn control forest succession. In practice, the boundaries have been modified slightly to conform with county lines and topographical features, allowing easy recognition in the field. Seven zones are presently recognized in central and southern Ontario (see map). Seed from the different zones is kept separate throughout extraction, refining, and in the nurseries, so that planting stock with the correct provenance is available for any zone.

Collection usually requires tree-climbing, and employs such aids as ladders, and various hooks for pulling down branches and detaching cones. Measurements are made in the field to one-eighth of a bushel. In Ontario, 1.5 bushels and 5 bushels are considered normal yields per adult tree for red and white pine respectively. One bushel contains 1,300 to 1,800 closed red pine cones, or 500 to 700 closed white pine cones (6).

Trucks are used where possible for rapid delivery of cones to the extraction plant. If there is much delay in shipment, the cones must first be air-dried to prevent overheating and moulding. They should be spread out 8 to 10 inches deep and turned over daily for two weeks. Without treatment, red pine cones will usually overheat within a week, and white pine cones even sooner.

Extraction and Cleaning

At the Tree Seed Plant of the Ontario Department of Lands and Forests at Angus, cones are placed on trays in a drying shed for not less than three weeks to reduce moisture content from about 40 per cent to 25 per cent, and to harden

resin which would interfere with later processes if still in an adhesive state. Kiln drying is needed to complete opening, although some cones in each lot open sufficiently in the sheds. At Angus also, it has been found that kiln-dried seed usually germinate more quickly than those which have been air-dried only. Two types of kiln are used.

In the hot air kiln, trays of cones are loaded on to cars, and run into a drying room where fans blow hot air from a furnace across them. Red pine cones are removed periodically and sprinkled with water, but white pine cones do not need this treatment. The relative humidity of the drying room is kept below 35 per cent and should be 6 to 8 per cent when the seed is released from the cones. Red pine are held at 140°F. for 48 hours, and white pine at 120°F. for 24 hours.

In a kiln providing heat developed from infra-red rays, red pine cones are placed on conveyors which pass slowly beneath the lamps. The temperature is 170°F., and the time required is about 4 hours. The cones are soaked in water half-way through the process. White pine cones are too resinous to be treated by this method.

Other reported extraction practices for red pine are 24 to 72 hours in a convection kiln at a temperature of 130° to 140°F. (6); 5 hours in a forced draft kiln at 170°F. and 21 per cent relative humidity (6); 9 hours in a forced hot-air kiln at 130°F. and 15 per cent relative humidity (39); 7 hours in an internal-fan extractory at 150°F. and 18 per cent relative humidity (39). Alternative recommendations for extracting white pine seed are by convection kiln at 110° to 120°F. (6); 8 hours in a forced draft kiln at 140°F. and 40 per cent relative humidity (6); 12 hours in a forced hot-air kiln at 120°F. and 37 per cent relative humidity (39); 4 to 5 hours in an internal-fan extractory at 140°F. and 41 per cent relative humidity (39).

Refining

After extraction, the seed and cones are separated by screens. An important treatment in the refining process detaches the seed-wings. At Angus, brush-type machines have been found to damage a proportion of the seed, retarding germination. A converted cement mixer is now used, containing one cup of water to each half bushel of seed. Subsequently the mixture of seeds and wings is dried on trays at low temperatures. Further treatments separate out seed-wings and other impurities, and at Angus the cleaned seed are dried to 5 to 6 per cent moisture content for storage.

The yield of cleaned seed is reported as follows:

	Red Pine	*White Pine*
Per bushel of cones.....	9 to 12 ounces (6) 7 to 8 ounces (39)	5 to 28 ounces (6) 15 ounces (39)
Per 100 pounds of fresh cones....	1 to 2 pounds (6)	2 pounds (6)
Per pound of seed—low.....	30,000 seed (6)	20,000 seed (6)
—average.....	52,000 seed (6) 55,000 seed (39)	27,000 seed (6) 27,000 seed (39)
—high.....	71,000 seed (6)	53,000 seed (6)

Storage

Red pine seed stored in sealed containers will retain viability 3 to 5 years at "ordinary" temperatures, or for 10 or more years at 32° to 50°F. (6). One lot of seed stored for 19 years gave 94 per cent germination (10). At Angus, where storage is at 36° to 38°F., red pine seed are expected to remain viable at least 8 to 10 years, or a maximum of 15 years.

White pine seed stored in sealed containers at 32° to 41°F. retain viability for 8 or more years (6). At Angus, the white pine seed stored at 36° to 38°F. remain viable at least 4 to 6 years, or a maximum of 10 to 12 years.

Storage practices at Angus agree closely with those recommended elsewhere for red and white pine (11, 18, 28, 39).

Germination

Red pine seed ordinarily germinate satisfactorily without pre-treatment. White pine seed exhibit embryo dormancy which can be broken by stratifying at 50°F. in moist acid peat or sand for 30 days (6). For germination tests at Angus, dormancy of white pine seed is broken by storing them on wet filter paper under a bell-jar at 36° to 38°F. for 30 days.

At Angus, two kinds of viability test are made for each seed lot at the time of storage, and also prior to shipping if the seed have been stored for more than two years. Two 100-seed samples are tested by each method. Red pine should germinate at 75°F. in 8 to 9 days by the Jacobsen test and in 15 days in the sand test, and should give over 90 per cent germination by both methods; white pine should give 75 to 80 per cent. Both species show regular germination within a seed lot. Sand test germination of 85 per cent for red pine and 64 per cent for white pine have been reported in the Lake States (39). In New York State, average 30-day germination of 87 per cent for red pine and 73 per cent for white pine was obtained with the Jacobsen test (18). Other germination data are as follows (6):

	Red Pine	White Pine
Germinative energy*	25 to 75% in 7 to 25 days	7 to 90% in 12 to 39 days
Germinative capacity**—low	9%	0%
—average	75%	64%
—high	100%	96%

* The per cent of seed germinated at the time the trend of germination reaches its peak.

** The per cent of seed actually germinating, regardless of time.

NURSERY PRACTICE

The following account describes the usual Ontario nursery practices for red and white pine. Sandy soil is used for seedbeds. After the stock has been lifted, the beds are sown to field crops which are ploughed down for summer fallowing, and sometimes followed by a second crop. Manure and chemical fertilizers may be added to maintain fertility. One or two years are allowed in field crops before a bed is used again for seedlings or transplants. Seedbeds are 30 feet long and contain 100 to 120 square feet. They may be laid out with the long axis in an east-west direction to facilitate shading, but usually direction is not considered important.

The seed is sown in late October or early November, to avoid autumn germination. Sowing rates aim at densities of 75 to 160 seedlings per square foot, depending on the nursery. The seed is sown broadcast, covered with sand about one-eighth of an inch deep, and mulched with clean straw, pine needles, or sphagnum moss. In one nursery, however, the general procedure differs in that seedbeds are not formed, and the seed is sown by drill on level ground, after cultivating and rolling (8).

Time of germination varies with the weather, but usually occurs about the middle of May for both species. The mulch is removed as soon as germination

begins. This is a critical stage when the seedlings can easily dry out, especially in bright or windy weather. Lath screens which give 55 to 71 per cent shade are erected immediately, and the beds are watered until germination is complete.

Red pine is subject to damping-off within 2 to 3 weeks of germination, and the danger remains until the lateral roots begin to form—5 to 6 weeks from germination. Warm and humid conditions favour the disease, so the seedlings are not watered during this period unless the weather is very dry. Damping-off has been most serious in one nursery where the soil has a high lime content. The chief pathogens are *Fusarium* and *Rhizoctonia*. As a preventive measure, a thin layer of sterile sand (subsoil well removed from the organic layers) is placed on the beds before sowing, and the seed is covered with the same material. On the whole, control measures have not been successful.

When the danger of damping-off is past, the seedlings are watered throughout the summer and autumn. The beds are weeded by hand, since chemical weed-killers usually injure the seedlings. The shades are not removed until winter. In the second year similar procedures are followed, although some nurseries do not replace the shades. Much less weeding is required in this year.

Both species are transplanted and usually shipped as 2-2 stock. Most transplanting is carried out in the spring. Seedling roots are loosened by a lifter—a steel blade of variable design which is dragged at 7 to 8 inches beneath the soil surface. The seedlings are then lifted by hand and transplanted by machine at intervals of 2.5 inches in rows 7 to 9 inches apart. Production is about 15,000 seedlings per man-day. On sloping ground, transplanting is done by hand, using Yale boards, at the rate of about 5,000 seedlings per man-day. Transplants are watered immediately after autumn or late spring transplanting. In most nurseries they receive some watering during the summer also, but less than seedlings. Transplants are weeded in both years. Chemical weedkillers are used, but some hand weeding is needed also. Transplants are not shaded.

Most shipping is done in the spring, and lifting is accomplished in the same way as when transplanting. Trees considered unsuitable for planting are culled during lifting operations. No grading is attempted. Lifted trees are heeled in to await shipment.

Bundles of 25 trees are placed root to root in crates, cartons, or bales, and the roots are packed in sphagnum moss which has been soaked for two days. The containers are kept well moistened until shipped by express. Alternatively, large orders which will arrive at the planting site within 12 hours may be bulk-loaded. By this method the bundles are packed root to root with moss in the body of a truck, watered, and covered with a tarpaulin.

There would be considerable advantage if planting stock were available for shipment in the spring before plants could ordinarily be lifted from nursery beds, and stock has been stored successfully over winter with this object. Also, stock required for northern areas could be kept dormant by cold storage until the planting sites were workable. Storage in crates or piles at 30° to 40°F. and 90 per cent relative humidity was found satisfactory, and a simple insulated building was recommended for the purpose (4).

In New York State nurseries, the following practices for red pine are reported (10). For seedbeds, good drainage is essential. Alkaline nursery soils encourage damping-off. Red pine seed is sown either in the spring or autumn. Autumn sowing usually gives larger 2-year seedlings, but with lower density, for the same amount of seed sown. Poor storage, or extraction injuries, give poor spring germination after autumn sowing. If the spring is unusually cold, poor and slow

germination results. One pound of red pine seed containing 52,000 viable seed usually produces about 11,000 seedlings. Seed is sown to produce 50 seedlings per square foot, which are given 30 to 40 per cent shade during the first year. Root-pruning is not practiced, and seedbed density is used to control the ratio of top to root development. The stock is shipped as 2-0 or 3-0 seedlings.

In the Lake States (39) light sandy soils with good drainage are preferred for conifer nurseries, and the following fertility standards have been found satisfactory for red and white pine:

	Red Pine	White Pine
Reaction (pH)	5.4	5.4
Base exchange capacity (milliequivalents per 100 gm. soil)	8.0	10.0
Total nitrogen (per cent)	0.12	0.14
Available nitrogen (pounds per acre)	30	35
Available phosphorus (P_2O_5) (pounds per acre)	50	80
Available potassium (K_2O) (pounds per acre)	150	200
Replaceable calcium (milliequivalents per 100 gm. soil)	3.0	5.0
Replaceable magnesium (milliequivalents per 100 gm. soil)	1.0	1.5

Autumn sowing, by drill, is generally practised, giving larger first-year seedlings than result from spring sowing. Sowing aims at densities of 50 seedlings per square foot if the stock is to be field-planted direct from the seedbed at age 2-0, or 40 seedlings per square foot for planting at age 3-0; a density of 65 seedlings per square foot is used if the stock is to be transplanted. Sufficient irrigation to keep the surface inch of soil moist is necessary during germination and for about the following two months. Once the succulent stage is passed, it is satisfactory to maintain the available soil moisture of the top 8 inches at 4 to 8 per cent for red pine and 5 to 10 per cent for white pine; one watering every 7 to 10 days is usually enough for transplants. Half-shade may be required in the first season, for white pine only. Weeds are generally removed from first-year seedbeds by hand and by treating with mineral spirits; safe dosages of mineral spirits containing 10 to 12 per cent of aromatic hydrocarbons are:

	Red Pine	White Pine
4 to 6 weeks old (U.S. gallons per acre)	50	40
6 weeks to 1 year old (U.S. gallons per acre)	60	60
1+ year old (U.S. gallons per acre)	75	75

Damping-off is a problem in some nurseries, and a variety of effective treatments has been reported. In root-pruning trials, the treated root systems were compact, denser, and more fibrous. Seedlings transplanted for one or two years give better balanced plants than those merely root-pruned without transplanting. Both seedlings and transplants are produced for field planting, with the older stock preferred for the more difficult sites. Transplanting is usually carried out in the spring; mechanical lifters are commonly used, and the seedlings are transplanted with machines at $2\frac{1}{4}$ by $7\frac{1}{4}$ inches, or by hand at $2\frac{1}{4}$ by 6 inches. Prior to shipping, trees are dug or lifted mechanically, culled, and their roots often trimmed to 8 inches; they are packed in bundles, bales, or crates with sphagnum moss or shingle tow. Packed stock awaiting shipment, or lifted seedlings awaiting transplanting, are sometimes stored at 34° to 40°F. and can be held in this way without loss of survival up to 5 weeks.

PLANTING

Site Preparation

Some site preparation is usually required to facilitate planting and to reduce shrubby or herbaceous competition to the young stock. Light overhead cover, which admits 50 to 60 per cent of full sunlight at ground level, may have a protective value during the first summer after planting, resulting in increased survival (1, 30). However, brush, immature growth, or residual trees from a former stand can seriously suppress red pine in a short time. In most cases underplanting with this species should be avoided, unless the implications of future release can be accepted, or the overstorey is expected to be short lived, e.g. aspen on dry, coarse sands. Overhead cover may be less serious for the more tolerant white pine, and if not too dense may be of value in controlling weevil attacks. In some parts of Ontario, where weevilling is severe, white pine is planted only beneath an overstorey.

In the Lake States a disk-plough has been used successfully to prepare sites with heavy brush cover (30), and a pusher plough mounted in front of a tractor (pulling a planting machine) has effectively cleared away brush, slash, and debris ahead of the planter (31). In Ontario it is customary to fit the species to the existing ecological unit, i.e. the cover is more often underplanted with a tolerant species rather than cleared prior to planting. However, sites supporting poor quality aspen have been planted with heavy machines drawn by bulldozers. Much of the aspen is knocked down, but sometimes recovers or suckers freely. This method is therefore unsuitable for planting red pine, except on very dry sites where the aspen is open, does not grow tall, and has little tendency to sucker.

Furrows, running along the contour where the ground is steep, provide the most satisfactory preparation on sites supporting only a low cover. Their main purpose is to reduce competition for soil moisture until the stock is well established. Furrows should not be used on low-lying sites or the heavier soils, or on areas liable to develop into blow sands. Generally, they should not be used for autumn planting, e.g. on areas liable to blow clear of snow. On very steep slopes, or where rocks, stumps, or heavy cover make ploughing impracticable, furrows can be replaced by scalps (5, 16, 30).

Season

Early spring, as soon as the land can be worked and before the buds begin to open, is usually the preferred planting season. Autumn planting is only successful when the soil is moist well below the root systems of the young trees. Stock planted in the autumn is frequently heaved out of the ground, or suffers considerably from exposure where there is no snow cover and the soil is wet or heavy (5, 16).

In the Lake States, survival has generally been greater with spring planting, particularly on heavier soils; even on light soils there have been heavy losses from excess transpiration in autumn planting (30).

Class of Stock

In the Lake States, it has been found that transplant stock normally gives better survival and better initial growth than seedlings (30), and the difference is usually much greater on adverse sites (33). Transplants are much more expensive to produce than seedlings, but under many conditions the results justify extra costs. Transplants are generally better suited to machine planting (30). It has been noted that in Ontario red and white pine seedlings are transplanted, usually for two years. One nursery stated that 2-2 stock requires only about 10 per cent culling, as compared to 40 per cent for 2-1 stock. However, the use of seedling stock is being tested.

On the other hand, it is the practice of New York State nurseries to produce only 2-0 and 3-0 red pine seedlings for field planting (10). At the Pack Forest, root-pruned red and white pine seedlings have proved equal or superior to transplants, and this performance has been attributed to better developed root systems which have not been deformed by transplanting (13). In the Lake States, 3-0 white pine suitable for spring planting is produced at densities of 40 to 45 seedlings per square foot, but lower densities are required for good survival with autumn planting (39); in one experiment 3-0 white pine seedlings which had been grown at a nursery density of 26 per square foot gave a stock and field survival comparable to 2-1 transplants (38). For red pine, 3-0 seedlings are considered satisfactory for spring planting if grown at 40 to 50 per square foot, but 2-1 stock is generally superior for autumn planting (39). In a Lake States experiment, 3-0 red and white pine seedlings which had been root-pruned at the beginning of the third year gave survival in excess of 73 per cent; this was not so good as for 2-1 stock, but production costs were more than two and one half times as great for the transplants (3). Elsewhere it has been found that production time for white pine stock suitable for field planting can be shortened materially by lessened seedbed density (27).

In fact, a well-balanced plant is required, and this has been described as one having a fibrous, compact, well-developed root system, and a comparatively short top without excessive foliage area (40). These features are more often found in transplants, but seedlings which have been grown at a suitable density in the seedbed or which have been root-pruned may meet the desired specifications. Seedlings grown at the high densities which usually presuppose transplanting, but which are lifted as 2-0 or 3-0 stock for field planting, are unlikely to give good results.

Field Storage

Stock may be stored at the planting site in the shipping containers for short periods, provided it is well shaded and the roots are kept moist. For lengthy storage, heeling-in is necessary. Storage with the roots in water for prolonged periods, especially if the water is stagnant, is probably detrimental to the stock.

Circle-piling for periods up to two weeks is commonly practised in Ontario. By this method, the bundles of seedlings are placed in a circle on the ground with the roots inwards and making an inner circle about one foot across. Successive layers of seedlings are added, moving the roots a little closer to the centre with each layer until they are touching. The result is a flat-topped pile about three feet tall. The roots of each layer are covered with damp moss. The piles should be shaded. Seedlings are removed from the top as required. It was claimed that stock stored in this manner does not overheat, since the foliage is well aerated. By this method, stock can be stored, removed, and watered very rapidly, and the roots are not subject to mechanical injury.

Planting Method

On suitable sites machine planting is the quickest and cheapest method, and some machines accomplish planting and site preparation in one operation (16, 30). In the Lake States the expected average for machine planting is between 6,600 and 10,500 trees per day (30). In Ontario, production under reasonable conditions is about 8,000 trees per day, with 4,000 to 5,000 considered the economic minimum (16). Small, irregularly shaped areas cannot be planted economically with machines. Most machines are unsuited to steep slopes, heavy or rocky soils, or sites with heavy brush or numerous stumps (30). On sidehills, machines are liable to overturn or to dislodge the operator. On stony soils, spacing becomes erratic as the coulter is forced out of the ground. Brush or other obstacles can

jam or damage the machine. However, the recent development of types which will plough a furrow or not, as required, or which can be levelled hydraulically on sidehills (16), should increase the scope of machine planting.

There are various hand planting methods most of which have numerous refinements. Wedge-planting has been recommended in Ontario, in this instance referring to the following method: a wedge of soil is removed with a shovel, leaving a hole with one vertical and one sloping side; the roots of the tree are spread out against the vertical side, and the wedge of soil is replaced and tamped down (5). The T-slit method may be used where there is a sod cover, and hole-planting is satisfactory where roots or stones make the other two methods impracticable (5). Ordinary slit-planting is cheap and rapid, but often gives poor results; it should be used only for small seedling stock, on light soils, and by careful planters (5, 30).

Spacing

Ice and snow damage, root resinosis, and poor humus decomposition in red pine plantations in New York State have been attributed to early closure and stagnation following close planting—apparently 6 by 6 feet or less (44). In Ontario, an average spacing of 8 by 8 feet has been recommended for red pine (16). It is then possible to defer thinning until a salable product can be removed. On adverse sites, closer spacings are advisable to allow for expected mortality (5). A spacing study at the Petawawa Forest Experiment Station indicated that to achieve the greatest volume growth commensurate with vigorous crowns and large diameters, red pine on moderate and good sites should be grown at about 7 by 7 feet for the first 20 years, and then given a commercial thinning (37).

The standard spacings adopted by the United States Forest Service in the Lake States for red and white pine are 6 by 8 feet on good to medium sites, and 6 by 6 feet on medium to poor sites (30).

Closer spacings have been proposed for white pine, as a means of limiting crook following weevil attacks, and of producing more unweevilled trees per acre. In Ontario it has been suggested that on open areas white pine should be planted in alternate rows with red pine, with the rows 6 feet apart, the red pine 8 feet apart in their rows, and the white pine 6 feet apart in theirs. At the Pack Forest a spacing of about 4 by 4 feet or 3 by 6 feet has given the best white pine plantations, and the extra costs were believed to be justified (13). An experimental white pine plantation established at 2 by 2 feet at the Petawawa Forest Experiment Station contained more than enough undamaged stems to form an acceptable stand by the time the trees were more than 17 feet tall; however, diameter growth was so slow that a pre-commercial thinning was necessary to prevent a very lengthy rotation (36).

Composition

In any given mixture the relative growth rates of the species vary considerably with the site. It is therefore difficult to generalize on stand development.

As a rule, alternate rows is the best arrangement for two species, since it ensures equal competition from two sides and erect stems for the slower growing species (16). However, early thinnings are usually essential to maintain the desired composition because of differences in growth rate which may occur between the two species.

In mixtures of red and white pine, the initially faster growing red pine often suppress the white pine to some extent. In certain plantations in Michigan this type of development was considered to have the same effect as a thinning (35). In New York State it has been found that the white pine will overtake and

surpass the red pine at the age of 40 to 50 years (17). However, in Ohio and Indiana, white pine was reported to make the faster height growth even after the first 10 years, in red pine-white pine mixtures planted on old fields (15). In Ontario, it has been suggested that these species should be planted in alternate rows and thinned between 20 and 30 years of age to stimulate growth of the white pine (5). In such a mixture, the red pine develops greater diameters than in pure stands, and a relatively small number of well-formed white pine may be brought through. Thinnings are most important to the success of stands with this composition; if treatment is delayed, the white pine can be badly suppressed on light soils. This mixture is more likely to be successful on the moister sites.

Red and jack pine may be planted in alternate rows, at 8 by 8 feet; on the drier sites, the jack pine will make the faster growth but can be thinned out between 20 and 30 years of age. The same arrangement of red pine and European larch, or red pine and red oak, has been successful (5). Red pine and white spruce seldom develop uniformly in mixtures with one another.

White pine may be planted in alternate rows with European larch, red oak, or with white spruce on the heavier soils (5). Some type of overhead cover is necessary to protect white pine from weevil attacks. A promising approach appears to be underplanting aspen stands, and controlling the density of the overstorey to obtain sufficient shade to prevent weevilling without suppressing and killing the pine (24). The aspen is not readily removed, however. Other fast-growing intolerants, such as jack or Scots pine, have been suggested as nurse crops (17). In Ontario it has been found that these two species need to be watched carefully if suppression of the white pine on light soils is to be prevented. Scots pine underplanted with white pine should later be removed in a single operation, since all but very light thinnings will result in the establishment of Scots pine reproduction which will take over the site from the white pine.

DIRECT SEEDING

Direct seeding of red and white pine has often been attempted as a cheaper method of reforestation than planting. Varying results have been attained, but at present success cannot be ensured. Following direct seeding trials with pines, including red and white pine, in Ohio and Illinois, it was concluded that while less expensive than planting, hand seeding methods were still too expensive and subject to failure, often resulting in dense clumps of spindly, poorly-formed trees, unless thinned; mechanical methods were also subject to erratic results, but were very cheap and might be useful under special conditions when (a) an extensive reforestation programme requires covering a large area in a short time, or (b) sufficient planting stock is lacking but seed is available or can be collected economically, or (c) manpower and money are scarce but seed is plentiful (25).

The main factors limiting success of direct seeding are insolation, herbaceous competition, drought in the germination period, and high rodent populations. For Ontario, the best seeding chance has been described as an area of light soil, with adequate moisture, that has been burnt over 1 to 5 years before, and where little competition is yet established (21).

In seed-spotting, site preparation is important, and ploughed furrows, or scalps to mineral soil, are effective. Where rodents are numerous, the sites should be prepared well in advance of seeding, or the seed spots should be screened; the latter measure may be sufficient to bring the cost of the operation above that of planting (34). However, successful seed-spotting of red pine has sometimes been achieved in Ontario without screens (21).

At the Petawawa Forest Experiment Station, it was found that a severe burn or the removal of litter to mineral soil were satisfactory methods of preparing the site for seeding white pine under a mature white pine stand (22). Seed-

spotting of red and white pine under a mixed hardwood stand was unsuccessful owing to severe competition from other species (14). Poor results were also obtained from seed-spotting in a cut-over jack pine stand, since the red and white pine apparently required some shelter to survive on such a dry site (23). Elsewhere in Ontario it has been found that success of seeding seems to decrease towards the north, where the soil is colder and heavier (21). In New Brunswick, seed-spotting of red pine on an area which had been cut and burned was successful where the seeds were sown on spots cleared to mineral soil, and then lightly covered; poor results were obtained where the seeds were sown on small mounds of mineral soil. The soil was a well-drained clayey loam (42).

Rodent losses are less with spring sowing, but autumn sowing gives prompter germination of white pine in the following spring (34). In Wisconsin, red pine sown at 0.6 pound of seed per acre in the autumn and 0.63 pound of seed per acre in the spring gave 1,125 and 1,187 seedlings per acre respectively. White pine (believed to be of low viability) sown at 0.65 pound of seed per acre gave 109 seedlings per acre (41).

The Brohm hand probe, developed by the Ontario Department of Lands and Forests, appears to have promise. Advantages claimed for this seeding device are certainty of placing the seed in a favourable spot, prevention of waste by delivering only one seed at a time, and better protection from rodents (20).

Aerial broadcast seeding is uneconomic unless the area to be seeded is large, but in such cases there may be difficulties in obtaining sufficient seed for the operation (21). The following success in aerial broadcast seeding of white pine was achieved in Maine (43). The area had been burnt over in October, and was seeded the following February. Seed mixed with sawdust was broadcast at the rate of 4,000 and 8,000 seed per acre; the area was covered with two feet of snow, and more snow fell immediately after the operation. The best results were obtained on moderately burnt areas, where 2,475 seedlings per acre and 1,325 per acre for the 8,000 and 4,000 sowing densities respectively, were found by the following August. Little success was achieved on severe burns where deficient moisture and high soil surface temperature were believed to be limiting factors. In this operation, rapidity of seed distribution and favourable cost were held to be the main advantages.

REFERENCES

(1) Anon. 1939. Beneficial effect of partial shade on field survival. U.S. Forest Serv., Lake States Forest Experiment Station, Technical Note No. 144.

(2) ———— 1941. Testing cone ripeness. U.S. Forest Serv., Lake States Forest Experiment Station, Technical Note No. 176.

(3) ———— 1942. Root pruning—a labour saver. U.S. Forest Serv., Lake States Forest Experiment Station, Technical Note No. 190.

(4) ———— 1946. Storage of tree planting stock over winter. Ontario Dept. of Lands and Forests, Technical Circular No. 111.

(5) ———— 1947. Forest tree planting. Ontario Department of Lands and Forests, Division of Reforestation, Bull. No. R1, Rev.

(6) ———— 1948. Woody plant seed manual. U.S. Dept. of Agriculture, Misc. Publication No. 654.

(7) ———— 1957. Forty-sixth annual report—for the year 1956. Conservation Dept., State of New York.

(8) Cressman, E. M. 1954. Thunder Bay nursery management. Pulp and Paper Magazine of Canada 55(11):153-156.

(9) Eggeling, M. E. 1952. Municipal forest administration in Ontario. The Empire Forestry Review 31(4):318-324.

(10) Eliason, E. J. 1949. Seed sources and nursery practice of red pine. *In* Red Pine in New York: papers presented at the winter meeting of the N.Y. Section, S.A.F.:2-6.

(11) ———— 1958. Tree seed handling in New York. U.S. Forest Serv., Tree Planters' Notes, No. 32:21-24.

(12) ———— and J. Hill. 1954. Specific gravity as a test for cone ripeness with red pine. U.S. Forest Serv., Tree Planters' Notes, No. 17:1-4.

(13) Foster, C. H., and B. P. Kirkland. 1949. The Charles Lathrop Pack demonstration forest, Warrensburg, N.Y. Results of twenty years of intensive forest management. Charles Lathrop Pack Forestry Foundation, Washington, D.C.

(14) Fraser, J. W. 1952. Seed-spotting conifers under a mixed hardwood stand. Canada, Department Resources and Development, Forestry Branch, Silvicultural Leaflet No. 67.

(15) Gaiser, R. N., and R. W. Merz. 1953. Growth of planted red and white pine in Ohio and Indiana. U.S. Forest Serv., Central States Forest Experiment Station, Technical Paper No. 138.

(16) Grinnell, W. Ross. 1953. Reforestation: Planning and reporting for planting and seeding for forest establishment. Sec. 4 of the Municipal Forest Management Plan with Consideration given to Crown Land Planting. Ontario Department of Lands and Forests, Division of Reforestation. Mimeo.

(17) Heiberg, S. O. 1953. White pine research. New York Forester 10(2):1-4.

(18) Heit, C. E., and E. J. Eliason. 1940. Coniferous tree seed testing and factors affecting germination and seed quality. New York State Agriculture Experiment Station, Technical Bulletin No. 255.

(19) Hetzel, J. E. 1941. Forest plantations in northwestern Pennsylvania. U.S. Forest Serv., Allegheny Forest Experiment Station. Occasional Paper No. 3.

(20) Leslie, A. P. 1951. A new aid to reforestation. Pulp and Paper Magazine of Canada 52(6):122-123.

(21) ———— 1953. Direct seeding as a means of reforestation. Pulp and Paper Magazine of Canada 54(5):180-188.

(22) Logan, K. T. 1951. Effect of seedbed treatment on white pine regeneration. Canada, Department Resources and Development, Forestry Branch, Silvicultural Leaflet No. 54.

(23) ———— 1951. Seed-spotting in a cut-over jack pine stand. Canada, Department of Resources and Development, Forestry Branch, Silvicultural Leaflet No. 57.

(24) ———— and J. L. Farrar. 1953. An attempt to grow white pine under an aspen stand. Canada, Department Resources and Development, Forestry Branch, Silvicultural Leaflet No. 77.

(25) Minckler, L. S., and A. G. Chapman. 1954. Direct seeding of pines in the central hardwoods region. U.S. Forest Serv., Central States Forest Experiment Station, Tech. Paper No. 140.

(26) Paton, R. R., E. Secrest, and H. A. Ezri. 1944. Ohio forest plantings. Ohio Agricultural Experimental Station, Bulletin No. 647.

(27) Reineke, L. H. 1942. Effect of stocking and seed on nursery development of eastern white pine seedlings. J. For. 40:577-578.

(28) Roe, E. I. 1948. Viability of white pine seed after 10 years of storage. J. For. 46:900-902.

(29) Rudolf, P.O. 1946. Tree species planted in the Lake States. U.S. Forest Serv., Lake States Forest Experiment Station, Tech. Note No. 265.

(30) ———— 1950. Forest plantations in the Lake States. U.S. Department of Agriculture, Technical Bulletin No. 1010.

(31) ———— 1953. Plows precede a tree planting machine. U.S. Forest Serv., Tree Planters' Notes, No. 14:10.

(32) ———— 1956. Guide for selecting superior forest trees and stands in the Lake States. U.S. Forest Serv., Lake States Forest Experiment Station, Station Paper No. 40.

(33) ———— and S. R. Gevorkiantz. 1935. Seedlings or transplants? J. For. 33:979-984.

(34) Shirley, H. L. 1937. Direct seeding in the Lake States. J. For. 35:379-387.

(35) Skog, R. E. 1951. Growth of mixed red and white pine plantations in the upper peninsula. Michigan Agricultural Experiment Station, Quarterly Bulletin 34:30-34.

(36) Stiell, W. M. 1955. The Petawawa plantations. Canada, Department Northern Affairs and National Resources, Forestry Branch, Forest Research Division, Technical Note No. 21.

(37) ———— and A. Bickerstaff. 1959. Spacing as a factor in the development of red pine plantations. Canada, Department Northern Affairs and National Resources, Forestry Branch, Forest Research Division, Mimeo. 59-2.

(38) Stoeckeler, J. H. Can nurserymen produce white pine seedling stock comparable to transplants? U.S. Forest Serv., Lake States Forest Experiment Station, Technical Note No. 339.

(39) ———— and G. W. Jones. 1957. Forest nursery practice in the Lake States. U.S. Department of Agriculture, Handbook No. 110.

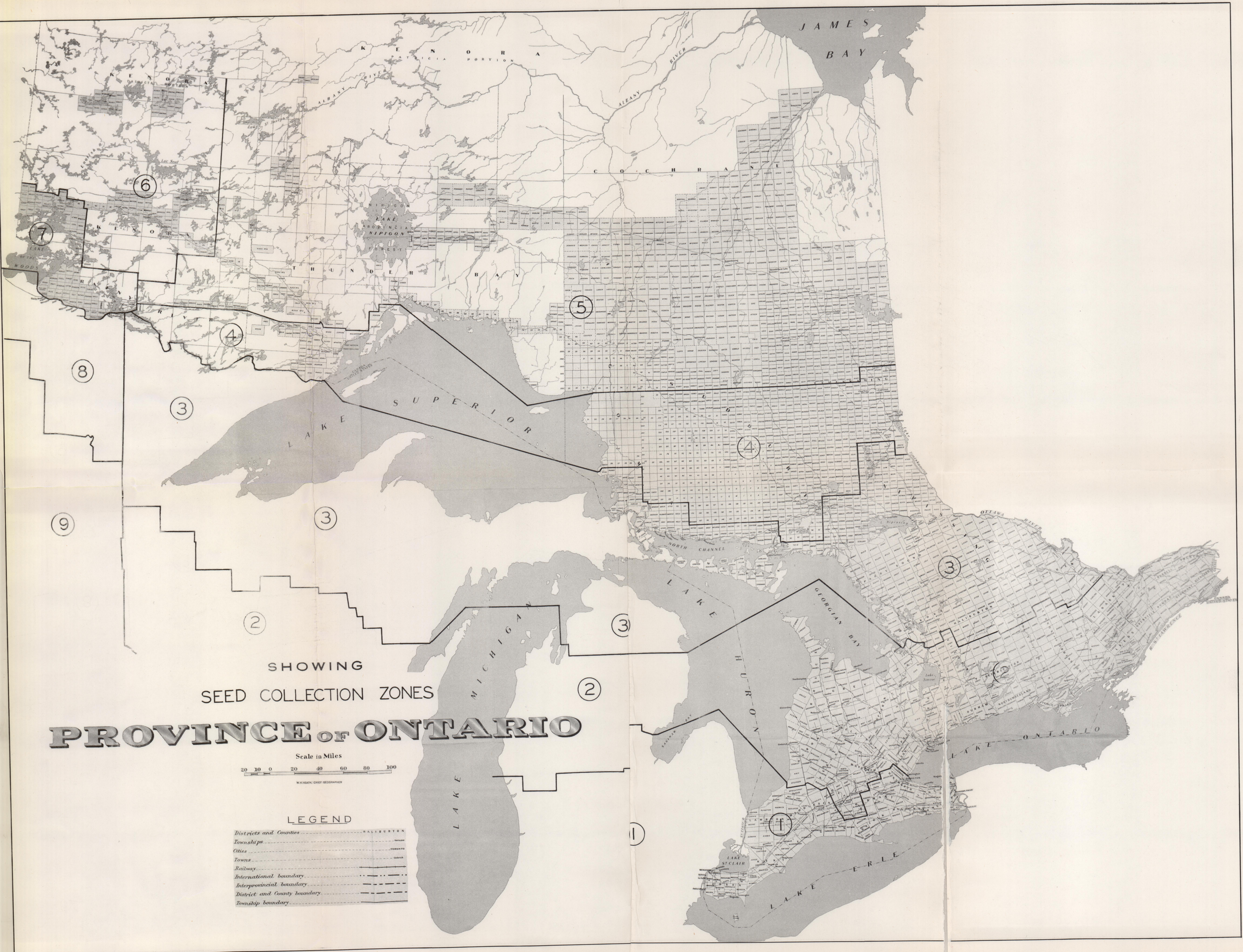
(40) ———— and G. A. Linstran. 1950. Reforestation research findings in northern Wisconsin and upper Michigan. U.S. Forest Serv., Lake States Forest Experiment Station, Station Paper No. 23.

(41) ———— and A. W. Sump. 1940. Successful direct seeding of northern conifers on shallow-water-table areas. J. For. 38:572-577.

(42) Thomson, C. C. 1949. Direct seeding with red pine in central New Brunswick. Canada, Department Mines and Resources, Dominion Forest Service, Silvicultural Leaflet No. 35.

(43) Westveld, M. 1949. Airplane seeding—a new venture in reforestation. Unasylva 3:95-99.

(44) Woodford, A. J. 1949. Management of pure red pine plantations. *In* Red Pine in New York: papers presented at the winter meeting of the N. Y. Section, S.A.F.:13-15.


SHOWING
SEED COLLECTION ZONES
PROVINCE OF ONTARIO
Scale in Miles
20 10 0 20 40 60 80 100
LEGEND
Districts and Counties
Townships
Cities
Towns
Railway
International boundary
Interprovincial boundary
District and County boundary
Township boundary
JAMES BAY
KENORA
PATRICIA PORTION
COCHRANE
THUNDER BAY
RAINY RIVER
LAKE NIPIGON
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
NORTH CHANNEL
LAKE ONTARIO
LAKE ERIE
LAKE ST. CLAIR
HALIBURTON
OTTAWA RIVER
ALBANY RIVER
1
2
3
4
5
6
7
8
9

APPENDIX

	Common Name	*Scientific Name*
1.	Aspen	*Populus tremuloides* Michx. and *Populus grandidentata* Michx.
	Larch, European	*Larix decidua* Mill.
	Oak, red	*Quercus rubra* L.
	Pine, jack	*Pinus banksiana* Lamb.
	Pine, red	*Pinus resinosa* Ait.
	Pine, Scots	*Pinus sylvestris* L.
	Pine, white	*Pinus strobus* L.
	Spruce, white	*Picea glauca* (Moench) Voss
2.	Rust, white pine blister	*Cronartium ribicola* Fisch.
3.	Moth, European pine shoot	*Rhyacionia buoliana* Schiff.
	Sawfly, red-headed pine	*Neodiprion lecontei* Fitch
	Spittlebug, Saratoga	*Aphrophora saratogensis* Fitch
	Weevil, white pine	*Pissodes strobi* Peck