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GREENHOUSE GRAFTING OF SPRUCE AND HARD PINE

at the

Petawawa Forest Experiment Station
Chalk River, Ontario

BY

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Project P-60

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INTRODUCTION

Vegetative propagation has been used for many years by horticulturists to produce a great many varieties of fruit trees, shrubs and ornamentals. It was not until 1936 when Dr. C. Syrach Larsen outlined the use of vegetative propagation in tree-breeding that any large-scale tree-breeding program was found to be practicable. Without the aid of various vegetative propagation techniques the tree-breeders would have been forced to use the slow techniques of pure-line breeding, but by using the technique of vegetative propagation it is now possible: (1) to facilitate future breeding work by establishing in one place a collection of plus trees which would otherwise be widely scattered and often inaccessible; (2) to duplicate any one plus tree in as many plants as required; and (3) under uniform conditions of soil and climate to rate the plus trees for their relative qualities.

Two methods of vegetative propagation are of main interest in tree-breeding work. They are cuttings and grafting.

Seedlings and saplings may frequently be propagated by cuttings, but cuttings from trees that have reached the flowering stage do not usually root in numbers sufficient to justify the expense. With the exception of some cottonwoods and willows, old trees must be propagated vegetatively by means of grafting. Selected plus trees of spruce and pine are usually mature or overmature. Mastery of the grafting techniques is therefore of primary importance in any tree-breeding program.

ROOTSTOCKS

For grafting, the scions should be fresh and healthy. Rootstocks should be the best available. It is not always possible to secure healthy scions, but it should be possible to produce a sturdy and healthy rootstock of the desired size and shape.

Choice of Rootstock Species

European experience has shown that most spruces can be grafted on Norway spruce (*Picea abies* (L.) Karst.) and that two-needled pine should be grafted on two-needled pine. Only a few experiments with interspecific grafting have been made at the Petawawa Forest Experiment Station, but some observations arise from them.

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Spruce: Only Norway spruce and white spruce (*Picea glauca* (Moench) Voss) have been used as rootstocks, and the following species have been successfully grafted on both: Norway spruce, white spruce, red spruce (*Picea rubens* Sarg.), Colorado blue spruce (*Picea pungens* Engelm.), Serbian spruce (*Picea omorica* (Pancic) Purkyne), Oriental spruce (*Picea orientalis* (L.) Link), *Picea Kojamai* Shiras, *Picea asperata* Mast., and various sitka × white spruce hybrids. There have been no differences in take or development of these species attributable to the different species of rootstock employed. One attempt has been made to graft black spruce (*Picea mariana* (Mill.) BSP.) on Norway spruce. This attempt failed, probably due to causes other than incompatibility between scion and rootstock.

Of the two species of spruce rootstocks (white and Norway) used in routine grafting, the one preferred depends on the timing of grafting and subsequent handling of the grafted plants (*see* Grafting Schedule, page 9).

Hard Pine: Scots pine (*Pinus sylvestris* L.) and red pine (*Pinus resinosa* Ait.) are used almost exclusively as rootstocks for hard pine grafting. On either species of rootstock the following species can be grafted satisfactorily: Scots pine, red pine, all varieties of *Pinus nigra* (Arnold), and Japanese red pine (*Pinus densiflora* Sieb. and Zucc.). It is likely that most pines of the group Lariciones can be grafted on these rootstocks.

A number of jack pine (*Pinus banksiana* Lamb.), lodgepole pine (*Pinus contorta* var. *latifolia* S. Wats.) and Virginia pine (*Pinus virginiana* Mill.), all of the group Insignes, have been grafted on Scots pine rootstocks with normal survival or per cent "take". Growth of these grafts, however, has not been entirely satisfactory. It is still too early to judge whether Scots pine is a satisfactory rootstock for these species. If not, jack pine would be preferred.

Seedlings Suitable as Rootstocks

Skilful handling, care, and heavy grading of seedlings are required to produce top-quality rootstocks. It is best to use locally-raised transplants for potting, because seedlings that have been shipped in from the larger nurseries, especially spruce, may take heat in shipping and therefore are usually not as satisfactory. The freshly-dug local seedlings are graded to provide healthy, single-stemmed, straight plants which have internodes long enough to provide for the graft cut.

Often only half the plants of any ordinary lot of seedlings are suitable as rootstocks. This should be kept in mind when rootstocks are ordered from local or outside nurseries. The heavy grading will ensure that a high percentage of the grafts take.

Spruce: 2/2 spruce transplants are potted in 5-inch pots. These rather sturdy rootstocks are excellent for thick scions but not for the thin scions collected from mature or overmature trees. It is probable that sturdy 2/0 or 3/0 seedlings would be better for grafting of thin scions as these seedlings have long internodes and slender stems, which provide for a long narrow grafting cut. These non-transplanted seedlings can be potted in $3\frac{1}{2}$-inch pots, thereby saving space in the greenhouse.

The rootstocks are potted either in early spring or in August, and plunged in a shaded frame. They should be left in the frame for at least one full growing season, before being used for grafting. Thus spring-potted rootstocks can be grafted in the autumn of the same year (September), or during the first winter. Rootstocks potted in the autumn can be grafted the following autumn at the earliest.

Potted rootstocks should be used after they have been in the pots for one growing season. They may be left in the pot for two growing seasons and still provide satisfactory grafting stock, but this should be avoided if possible. After three growing seasons they are pot-bound and should not be used for grafting.

Hard Pine: The pine rootstocks most in demand are sturdy plants, as pine scions are usually rather thick. Heavily graded 2/1 transplants are potted in 4-inch pots and treated similarly to the spruce described above. It is often desirable to have especially sturdy rootstocks for grafting species with thick branches such as red pine and Austrian pine. These large rootstocks are produced by potting 2/2 transplants in 5 or 6-inch pots and allowing them to grow a further one or two growing seasons before grafting.

Preparation of Potting Soil

The correct preparation of the potting soil is important in attaining healthy rootstocks and subsequently grafting success.

The nursery soil at the Petawawa Forest Experiment Station is classified as a very fine silty sand, and is free from stones. The soil is easily cultivated, and from this standpoint, especially adapted for conifer propagation, although it is not fertile enough for a potting soil, not even for pine. Application of artificial fertilizers might improve the colour of stagnating plants potted in this soil, but would not produce plants of satisfactory health. The stoney soil found in the old gardens around the Station area does not grow satisfactory plants either. Therefore a mixture is used for spruce consisting of three parts of loamy meadow soil (with crumb structure), one part rich forest soil (mull type), one part compost, and one part peatmoss. For pine the three parts of loamy meadow soil are replaced with three parts of sandy nursery soil. Both spruce and pine rootstocks potted with these mixtures are superior in colour and vigour to those potted in the nursery soil or those in the old garden soil. The generally poor results of greenhouse grafting in 1952 are attributed mainly to the use of poor soil in potting (Table I).

TABLE I.—SURVIVAL OF WINTER GREENHOUSE GRAFTS OF SPRUCE AND PINE, 1952-54

Potting soil	Year	Species	Number grafted	Per cent survival	
				May	Oct.
Poor	1952	Spruce	761	61	13
		Pine	628	88	22
Good	1953	Spruce	904	92	80
		Pine	375	96	91
Good	1954	Spruce	997	.....	85
		Pine	1,084	.....	94

Handling of Rootstocks prior to Grafting

Freshly-potted rootstocks are placed in the cold frame and covered with snow fence (wired wooden slats) for partial shade. The snow fence is removed after six to eight weeks when the root systems are well established. The plants are watered regularly and weeded when necessary. The basal part of the rootstocks is trimmed of small branchlets to make them clear for grafting in the spring.

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Before freeze-up the rootstocks intended for lifting in January and February are placed in a specially constructed glass-covered frame with electric heating coils laid down in the soil. These heating coils make it possible to thaw loose the pots at any time during the winter. The glass covers are removed to allow the rootstocks to be covered with snow, which is important in preventing the plants from being desiccated during the winter. When the rootstocks are required in the greenhouse the glass covers are again placed on the frame, the power switched on, and in a week to ten days the plants can be lifted and transferred to the greenhouse.

Other potted rootstocks are placed on a layer of straw which allows them to be lifted during the winter. This method is convenient when there is a heavy snowfall at the beginning of the season.

SCIONS

A general rule when collecting scions is to carefully select the most suitable material, bearing in mind the requirements (which may vary with species) for a good scion, such as length, diameter, the preference for the current year's growth, straightness, vigour and, above all, the existence of at least one bud that will produce a vegetative shoot. Few living trees are so old that branches cannot be found on them which may be successfully propagated by careful grafting.

Collection of Scions

Most of the scions collected for grafting are cut from branches of mature and overmature trees. The choice of suitable branches from such trees is limited, and great care must be taken with each tree to select the branches that will provide good scions. The scions should always be cut longer than necessary in order that the propagator may have some extra length when preparing them for grafting.

White spruce: In the top of a mature white spruce it is usually not possible to find current shoots of sufficient length (3 to 5 inches) and quality to form a good scion. The weather-beaten branch ends of old crowns have a short annual shootgrowth and are usually much divided with short branchlets at every node, (Figure I). If the branches are thick enough the propagator can usually cut suitable scions by trimming away small branchlets and grafting back on three- to six-year-old wood. However, such scions are regarded as poor material and will usually give a low take in grafting. The branches in the upper part of the crown have often only one end bud, and if this bud happens to be a flower bud it may take many years before the grafted scion develops a vegetative bud. Grafts produced from such scions are usually last as it is difficult to trim the rootstock in harmony with the weak scion.

On mature white spruces the best scions can usually be cut from the lower and more shaded and protected parts of the crowns. It is often possible to find branches with current shoots that when cut back on two- or three-year-old wood will provide a scion of reasonable quality.

The quality of scions collected from mature trees is generally low compared with those collected from middle-aged trees in good growth or from saplings. From middle-aged trees it is usually possible to find current shoots of sufficient length and thickness to form good scions. Branches from the uppermost part of the crown are preferred, because they eventually give grafts of more upright and better form than do scions collected from the lower branches. It has also been found that the take of scions collected from the upper part of open-grown middle-aged trees is higher than for scions collected from the lower branches.

TABLE II. SURVIVAL OF GRAFTS TAKEN FROM THE UPPER AND LOWER PART OF THE CROWN OF OPEN-GROWN MIDDLE-AGED TREES

	Scions collected from upper part of crown.	Scions collected from lower part of crown.
	%	%
Norway spruce	82	75
Red pine	96	80

In practice branch ends are cut much longer than the length of a scion. For mature trees whole branch ends up to 18 inches long are collected and bundled, and the scions later selected and trimmed by the propagator in the greenhouse shortly before grafting. For middle-aged trees, branch ends of two to three times the length of the scion (about 10 to 12 inches) are collected.

Red pine: Collection of scions from mature red pine presents only a small problem. Usually the current terminal shoots from the top-most branches of first order are long enough, but they are often too thick to make a perfect match with rather small potted rootstocks used in the greenhouse. The terminal shoots of second order are somewhat thinner and thus better suited for greenhouse grafting.

Suppressed branchlets with none or few side shoots, such as those found in the lower part of the crown, can also be grafted but not with as high a percentage of take (Table II). These branchlets are grafted on 4- to 6-year-old wood and therefore require more care in grafting. The grafts produced with such scions will not grow as vigorously and will demand more skill in handling during the first few years than grafts produced from the current year's shoots from the tops of the trees.

Flower buds are no obstacle in pine grafting as they are in spruce grafting. The male flowers are formed from the dwarf branch buds which otherwise would develop into needle fascicles, and the female flowers develop from the lateral buds below the terminal bud. In both, the terminal bud will produce a vegetative shoot, and this is required for the satisfactory development of the graft.

The scions should be cut five to six inches long, about one-quarter inch thick and preferably of the current year's growth.

Jack pine: Jack pine are rather thin. The best scions can usually be cut from the current year's growth of first order branches and preferably in the top of the tree. Suppressed branches in the lower part of the crown are usually too thin and spindly to produce a satisfactory scion.

Shipping and Storage of Scions

Very often scions or branches must be in storage or shipment for some time prior to grafting. It can be seen from Table III that the freshness of the scions is of primary importance for successful grafting, and that the locally collected scions cut the day before grafting and stored in a cool cellar over-night show a higher rate of survival than material collected elsewhere.

Scions collected during the winter (preferably in February) when the trees are dormant should be packed firmly but not tightly in small bundles in a

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TABLE III.—SURVIVAL OF AUTUMN-GRAFTED WHITE SPRUCE PRODUCED WITH LOCALLY COLLECTED AND SHIPPED SCIONS

Treatment of scions prior to grafting	Number grafted (Autumn 1953)	Per cent survival (June 1954)
Scions collected from old trees. En route 6 to 10 days before grafting	455	42
Scions collected from local old trees and grafted the day after collection	40	68
Scions collected from local young trees and grafted the day after collection	100	80

mixture of peatmoss or sawdust and ice, wrapped in a sheet of polythene film, placed in a box labelled "KEEP COOL" and "PERISHABLE", and shipped by the coolest and fastest possible route, express or air mail as the case may be, to the place where they are to be grafted. Winter-cut spruce scions do not stand up as well in transit as do pine scions. The main consideration is to keep the parcel cool in shipping so that the scions will not take heat.

Another successful method of transporting scions in winter is to place the scions in boxes in a mixture of peatmoss and snow. In this way scions have been successfully grafted after being a month in transit.

When the scions arrive at the Station they are stored in a snowbank until required. They are then taken into a cool cellar for defrosting and final trimming before being grafted in the greenhouse during February and March.

Winter-cut scions can be packed in a mixture of snow and sawdust and stored in a deep-freeze storage room at 0°F. This method is seldom used for scions intended for winter greenhouse grafting, but it is an excellent storage method for winter-cut scions to be used for propagation out of doors in the spring or early summer.

Scions collected during September, October and November should be handled very carefully in packing and shipping. It should be remembered that autumn-cut scions still have active tissue and are therefore more difficult to handle than winter-cut scions. When packed they readily take heat; they must not be frozen and they cannot stand prolonged shipping.

Autumn-cut scions have been successfully shipped by packing in peatmoss around a block of ice in a large wooden box. This method keeps the scions crisp and cool during shipment, which should not be prolonged; a week to ten days is the upper limit in hot autumn weather.

The earlier in the autumn the scions are cut the more quickly they spoil. Scions collected in August and September should be grafted as soon as possible after they have been cut. Those cut in October and November can endure longer shipping without being severely damaged.

When the scions arrive at the tree-breeding station the bundles are checked and loosened, and the material repacked and stored in a cold-storage room just above freezing point until grafting can be done. When any amount of long-distance shipment is required, it is preferable to cut and ship scions during the winter.

GRAFTING SCHEDULE

Rootstocks commence growth and reach the graftable stage according to the treatment they are given prior to grafting. This growth rhythm must be taken into consideration when planning the grafting schedule and in the subsequent handling of the grafted plants. However, as the growth rhythm is different for spruce and pine, and can be modified considerably according to the time the rootstocks are taken into the greenhouse, the grafting schedule is quite flexible.

Autumn Grafting

It is the slight cambial activity of both rootstock and scion that makes it possible to graft in the autumn. The temperature during this period is usually low, but favourable for callus formation which is the main evidence of growth activity. Neither rootstock nor scion start shoot-elongation. By the time growth is stopped by the winter frost the grafts are sufficiently established to endure the winter. The mastery of the autumn-grafting technique is an important contribution to a flexible grafting program, as scions can be collected in the autumn when extensive seed-collecting trips are made.

Spruce: The spruces have been grafted successfully in August, September, October and November. As the grafts need a six-week period to form sufficient callus to carry them through the winter, only the grafts made during August and September may be removed from the greenhouse and placed in cold frames in the middle of November. The grafts made during October and November must be over-wintered in the greenhouse. Only Norway spruce rootstocks should be used for late autumn grafting, as there appears to be a pronounced difference in chilling requirements of the Norway and white spruce rootstocks. White spruce suffer greatly by being kept in the warm greenhouse over winter, and the following summer they show a marked discolouration of foliage and reduced growth, while Norway spruce retain their healthy appearance.

It can be seen from Table IV that chilled autumn grafts—besides being of better health as mentioned above—have superior per cent survival than the grafts kept in the greenhouse over winter. It is also noticeable that early autumn grafting is superior to late autumn grafting regardless of whether the grafts are chilled or non-chilled.

TABLE IV.—SURVIVAL OF CHILLED AND NON-CHILLED GRAFTS OF SPRUCE

Species	Date grafted	Chilled*	Non-chilled**
		%	%
Norway spruce grafted on white spruce	Sept. 1	95	80
White spruce grafted on Norway spruce	Sept. 1	92	88
White spruce grafted on Norway spruce	Oct. 1	72	72

* Chilled grafts placed in cold frames November 15.
** Non-chilled grafts kept in greenhouse over winter.

Hard pine: Autumn-grafting of hard pines has been limited to small lots of red pine scions collected during seed collection trips in the first week of October and grafted a week later on Scots pine rootstocks. Half of these grafts were set out in cold frames on November 21, 1953, and the other half were retained in the greenhouse over winter. Forty-two per cent of the chilled and 69 per cent of the non-chilled grafts had survived when counted in June, 1954. It is apparently beneficial to over-winter such late-autumn red pine in the warm greenhouse. It is yet to be discovered whether early autumn (August-September) grafting with subsequent chilling can be done with satisfactory survival.

Winter Grafting

There are several methods of filling the greenhouse with rootstocks and they are all important for the winter grafting schedule. The phenological behaviour is quite different for rootstocks which have been placed in the greenhouse in early autumn, late autumn, and in the middle of the winter. By juggling the timing it is possible to have graftable rootstocks in the greenhouse from the end of December to the beginning of the out-door grafting season in May. However, it is usually desirable to have the winter grafting completed before March 15, in order to have time to prepare for the busy spring season.

Spruce: Spruce rootstocks are grafted best when the roots show abundant new growth or when the buds are swelling. Non-chilled white spruce rootstocks placed in the greenhouse during the autumn suffer from lack of chilling as indicated by their unsatisfactory growth and discolouration, and are of doubtful value for winter grafting. Non-chilled Norway spruce rootstocks do not suffer so much from lack of chilling and are therefore better suited to be kept in the greenhouse over winter. In the spring following grafting the non-chilled white spruce begin to turn yellow while similarly-treated Norway spruce retain more of their lush green colour. It is shown in Table V that Norway spruce rootstocks give a higher survival than do white spruce.

TABLE V.—SURVIVAL OF CHILLED SPRUCE SCIONS GRAFTED FEBRUARY 15 ON CHILLED AND NON-CHILLED ROOTSTOCKS

	Rootstocks taken into the greenhouse		
	October 1	December 1	January 15
	%	%	%
Norway spruce grafted on white spruce	95	85	83
White spruce grafted on Norway spruce		100	100

Of similarly treated (non-chilled and partly chilled) rootstocks, white spruce commence growth about one week earlier than Norway spruce (Table VI). The dates were February 15 and February 20 respectively in 1954. However, the slightly chilled rootstocks placed in the greenhouse on December 1 behaved quite differently. Of these, the white spruce commenced growth on January 1 and the Norway spruce reached the same stage on February 7 (or a month later).

TABLE VI.—GRAFTING DATES FOR SPRUCE ROOTSTOCKS TAKEN INTO THE GREENHOUSE DURING AUTUMN AND WINTER*

	Rootstocks taken into greenhouse			
	Sept. 1	Oct. 1	Dec. 1	Jan. 15
White spruce grafting dates	Feb. 15 (not uniform)	Feb. 15	Jan. 1	Feb. 15
Norway spruce grafting dates	Feb. 20	Feb. 22	Feb. 7	Feb. 20

* Based on the date on which half the plants have swelling buds.

It is known that rootstocks placed in the greenhouse during the autumn can be grafted successfully at least from August to November.

The following schedule has been a useful guide for co-ordinating the date the spruce rootstocks should be placed in the greenhouse with the date of grafting.

Time for placing rootstocks in greenhouse	Rootstocks ready for grafting
Norway spruce—October * White spruce—December 1	End of December and beginning of January.
Norway spruce—October * Norway spruce—December 1	Beginning of February.
Norway spruce—October* White spruce—January 15 Norway spruce—January 15	Middle and end of February.
Norway spruce—February 15** White spruce—February 15**	March.

* May be grafted any time from October to February inclusive.
** Rootstocks are forced more easily towards the end of winter.

Hard pine: Chilled red pine and Scots pine rootstocks should not be grafted too early. It is better to wait until the new growth is in the first stage of shoot-elongation. The standard method for forcing red pine and Scots pine rootstocks is to place them in the greenhouse in the early part of winter. About six weeks in the greenhouse is needed to bring the rootstocks into a stage suitable for grafting. Those taken in on January 15 will be ready about March 1.

Red pine and Scots pine could be kept in the greenhouse over winter and thus provide rootstocks for grafting from November to March inclusive. These non-chilled rootstocks have a lush deep green colour and almost continuous root and cambial activity. The commencement of shoot growth is much later with these than it is with the chilled rootstocks taken into the greenhouse in the middle of January, and the subsequent shoot-elongation is somewhat retarded.

Non-chilled hard pine rootstocks have been grafted in November and February-March with good success. On the few grafts made with chilled scions in February-March, it has been observed that the chilled scions grafted on non-chilled rootstocks have stronger shoot growth than similar scions grafted on chilled rootstocks. This has also been found in C. C. Heimburger's grafting experiments with white pine at Maple, Ontario.

GRAFTING TECHNIQUE

The two grafting techniques used when grafting conifers on small rootstocks are the "side graft" method (also called the "veneer graft" method) and the "pocket graft" method.

Prior to grafting, the scions are prepared by trimming the needles from the lower section of the scion, and are cut to length, allowing the propagator "leeway" for the grafting cut. The spruce needles should be cut with a sharp knife from below to within one to two inches from the end bud (Figures 1 and 17). Pine needles can be trimmed off the scion by pulling with the grain, and only the outer inch is left untrimmed. The scions are then placed in a moist cloth and are ready for grafting. The place where the rootstock is to be cut is given a similar trimming, and cleaned with a cloth.

The Side Graft Method

The side graft method is shown in Figures 3 to 11 for spruce, and in Figure 12 for pine. The diameter of the scion should be just a little smaller than that of the rootstock. The propagator tries to match scion and rootstock in this way for

each graft. Usually the scion is grafted low on the rootstock, just above soil level. However, the scions are sometimes too thin for the available rootstocks and are grafted high on the rootstocks as shown in Figure 11 (left).

When the propagator has selected his scion and rootstock, and given them a final trimming, he cuts the scion diagonally on one side with a three-inch-long cut. He then turns it over and makes a short cut to remove the soft flap of bark left at the base. He checks the length of his cut surface, makes a similar incision on the rootstock, cuts off the bark slip near the bottom of the incision to provide a shoulder for the base of the scion, checks the fit, places the scion, ties firmly with raffia, and waxes. If this procedure has been done correctly the exposed cambium on the rootstock matches exactly with that of the scion. More often than not the experienced propagator makes the cuts without correction. However, if the match is not perfect he reconsiders his cuts and makes a second try usually by making a new cut on the scion. If the incision on the rootstock is too deep and the exposed surface too wide, he makes sure the cambia match at least on the one side, which is more important than placing the scion on the middle of the incision and thus getting a poor fit on both sides.

The Pocket Graft Method

The pocket graft is shown in Figure 2. It is an excellent method for exceptionally thin scions such as those collected from overmature white spruce (Figure 1, C and D). Thin scions will give only a low take if grafted with the side graft method, but the pocket graft method is especially designed to overcome the difference in diameter of scion and rootstock, and gives a survival that is close to that of the side grafting method.

Scions and rootstocks are trimmed as mentioned above for side-grafting. The scion is then given two long cuts to produce the desired wedge shape, with a sharp edge along the one side. A thin unbroken strip of cambium should be found along the sharp edge. On very thin scions these two cuts barely remove the outer bark. The incision in the rootstock is then made with a square-pointed grafting knife. The cut is made from the bottom and it is important to hold the knife in the position shown in Figure 2, stage 1, to secure a good "bottom" for the pocket and an unbroken living strip of cambium on the bark flap. The horizontal cut is made at the top and the incision carefully opened from the top down. The wedge-shaped scion is then placed in the pocket and checked for position. It is important that the position be exactly as shown in Figure 2, stage 3, that is, with matching cambia. The graft is tied with raffia and waxed.

CARE OF GRAFTS

Considering the time and effort that have been spent on the grafted plants, it would be unpractical not to take the utmost care that as many of the grafts as possible are "carried through". Handling of the grafts takes as much time and effort as the work that has been done to the grafts up to this stage. It is true that the busy spring season has a tendency to divert attention to other fields of work, but it is wise to assign a man to the job of seeing that the grafts get the attention and treatment they need.

When the grafts are finished the potted plants are placed in a tub of water to get a thorough watering (Figure 13). They are then plunged in moist peat on the open benches and are left untouched for about six weeks. The development

during this period and later is shown in Figures 14, 15 and 16. An attempt is made to keep the temperature at approximately 60°F. by liming the greenhouse glass and opening the air vents when necessary during the day. Air humidity is kept high by frequent watering of the the floor and grafts are watered when necessary.

Because it is difficult to maintain a very high relative humidity in the greenhouse, the importance of the relative humidity was investigated by comparing the survival of spruce grafts which were kept for a period of six weeks after grafting in the following conditions: (1) in closed air in a propagation box; (2) in polythene bags; (3) in a plunge pit; and (4) open on the table (Figure 18). The results shown in Table VII indicate that there is no significant difference between the treatments. It appears that grafted scions die for other reasons than the difference between the 100 per cent humidity created in "closed air" and approximately 70 per cent relative humidity in the greenhouse. The reason is perhaps that the relative humidity in the greenhouse for a short period (one-quarter to one-half hour) after each watering rises to 100 per cent, even though it soon returns to the 70 per cent level.

TABLE VII.—SURVIVAL OF RED SPRUCE GRAFTS PLACED IN CLOSED AIR FOR SIX WEEKS AFTER GRAFTING AND OPEN IN THE GREENHOUSE

Treatment	Number grafted	Per cent survival
Plunge box—closed	156	68
Polythene bag protection	76	68
Plunge pit—closed	156	72
Table—open	79	70

At the time of grafting, rootstocks are cut back to reduce the rate of callus formation and diameter growth. If this is not done the scion might be "walled off" by callus or strangled by the raffia.

However, the rootstocks are not cut back completely the first year because it is desirable to retain a sturdy stem to support the weak scion. This is simply a matter of mechanical support, as the scion is better protected from breakage due to ice and snow when it is tied to the stem of the rootstock than when it is tied to a stake. The stem of the rootstock is retained for this purpose for one to two years depending on the development of the scion. The sturdier the scion the more quickly is the rootstock reduced.

At the end of April or beginning of May the raffia is cut (and replaced where needed) to prevent strangulation, and the plants are hardened-off by reducing the temperature and providing greater aeration in the greenhouse.

The grafts are taken out of the greenhouse at the beginning of June, the root balls are gently "broken down", and the grafts planted in rich till soil. Although the spruces must be planted in shaded cold frames, the pines can be planted out without shade as long as they are carefully watered.

All summer the plants are watered regularly. The shade is removed from the spruces in August, the scions tied to the rootstocks, and the rootstocks tied to stakes. The grafts are then well prepared to withstand winter exposure to ice and snow.

As soon as the snow is off the ground the following spring the rootstocks are cut back. Depending on the development of the scions, the rootstocks are cut back completely, or only reduced to provide a support for the scion the following winter.

It will usually take three to four years of cultivation before the grafts are ready to be transplanted to the field. The year before transplanting they are root-pruned to secure a bushy root-system.

SUMMARY

The grafting techniques used for greenhouse grafting of spruce and hard pine at Petawawa Forest Experiment Station are described. Details are given for the preparation of rootstocks; collection, shipping and storage of scions; grafting schedules for autumn and winter grafting; and the handling of the grafts until they are ready for transplanting to plantations.

Examples of White Spruce Scions.

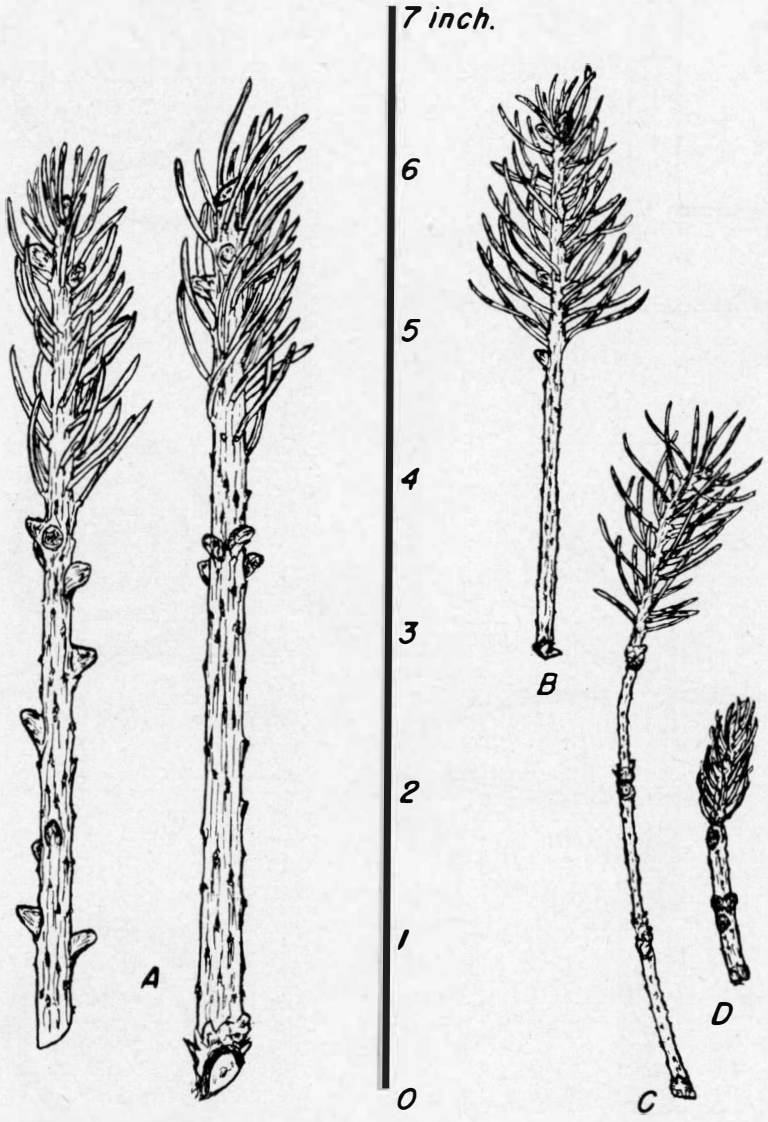

FIGURE 1.—Types of white spruce scion used for grafting. (A)—About 12-inch-long current shoot collected from the upper crown of a young tree. The branch is cut in half to provide two excellent sturdy scions. (B)—About 4-inch-long current shoot cut from the lower part of the crown of a middle-aged tree. This type of scion gives lower "take" than the scions collected from the top of the tree (Table II). (C)—Scion collected from the lower part of the crown of an overmature tree and trimmed for branchlets and needles. The "grafting cut" must be made on 3- and 4-year-old wood, and the scion is so thin that it can be grafted only by the pocket graft method. (D)—Scion collected from the top of a mature tree and trimmed for branchlets and needles. This type of scion is a little sturdier than the scions collected from lower branches.

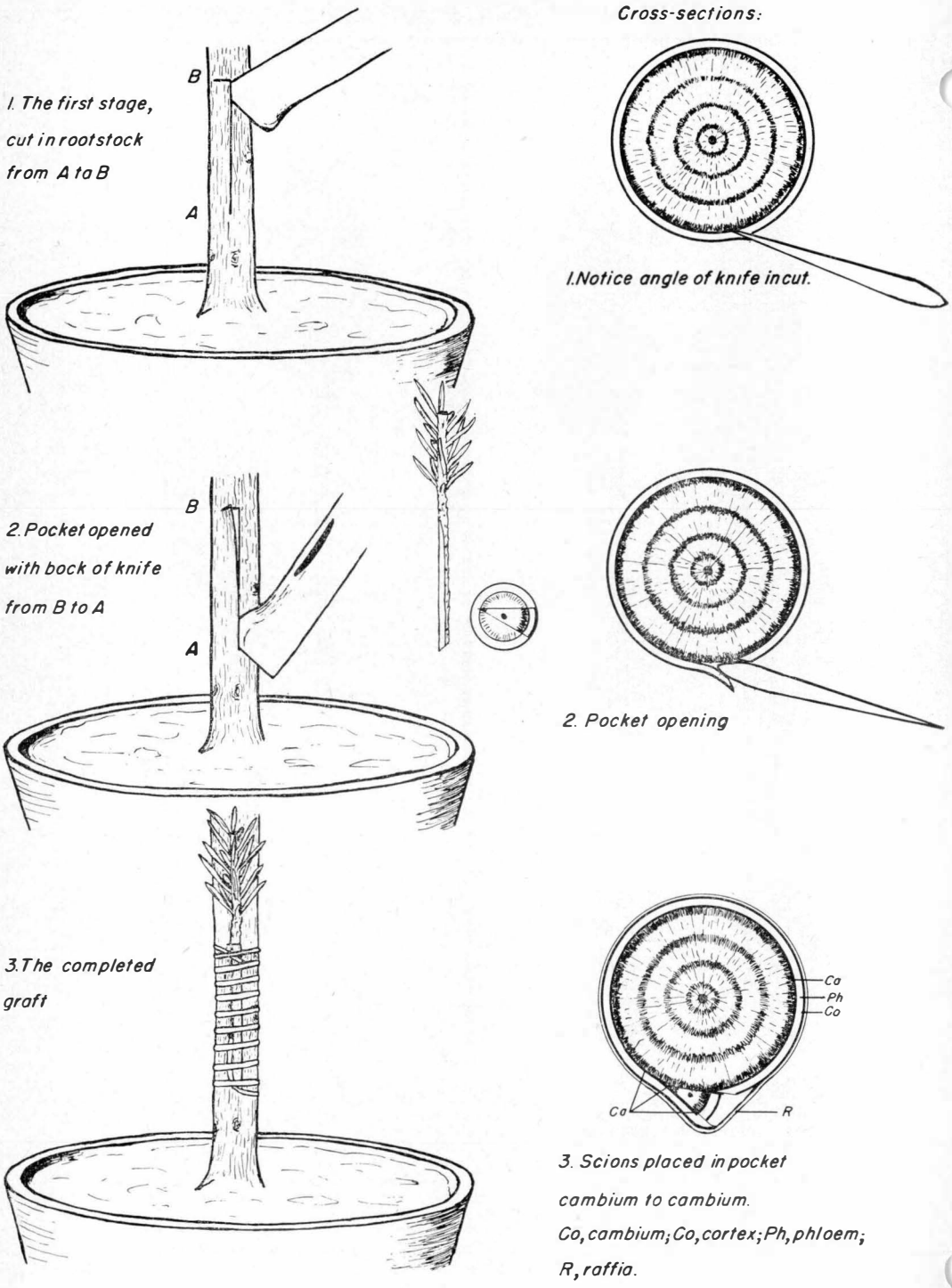

FIGURE 2.—The pocket graft method. (*See* text for explanation.)

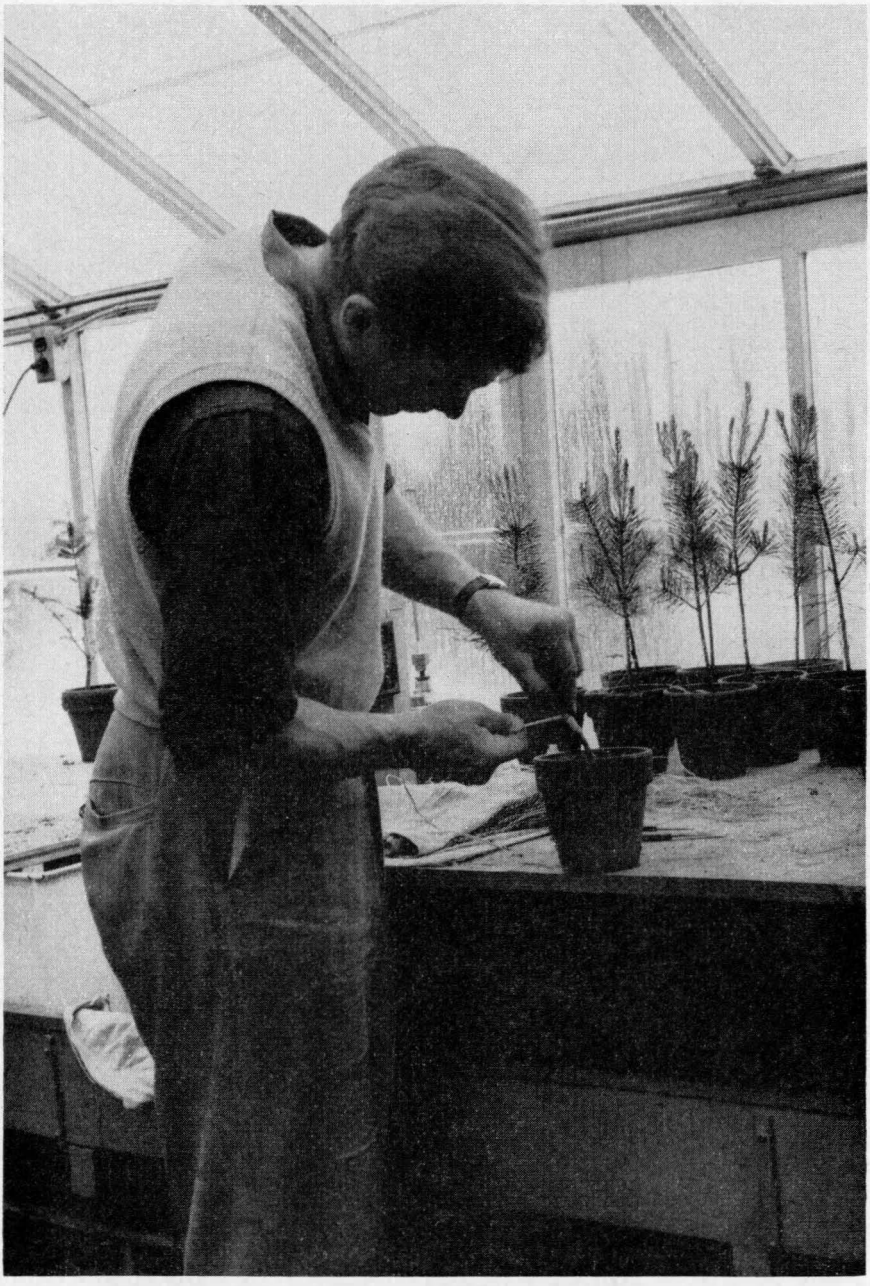

FIGURE 3.—The propagator at work in the greenhouse. Notice that he is using two knives, one for trimming the rootstock, and one for grafting. The scions to be grafted are under a wet cloth on the table.

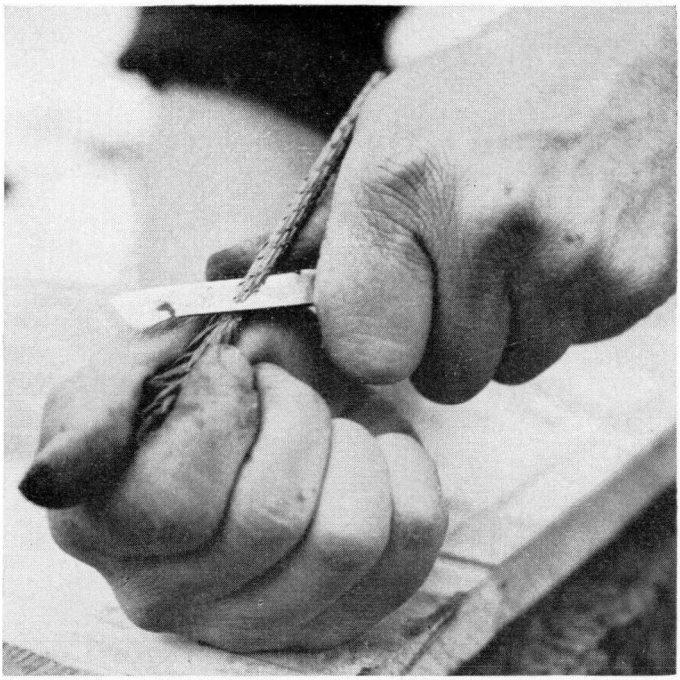

FIGURE 4.—Making the long cut on a scion intended for a side graft. The propagator is supporting the scion with his thumb, which enables him to make a straight cut.

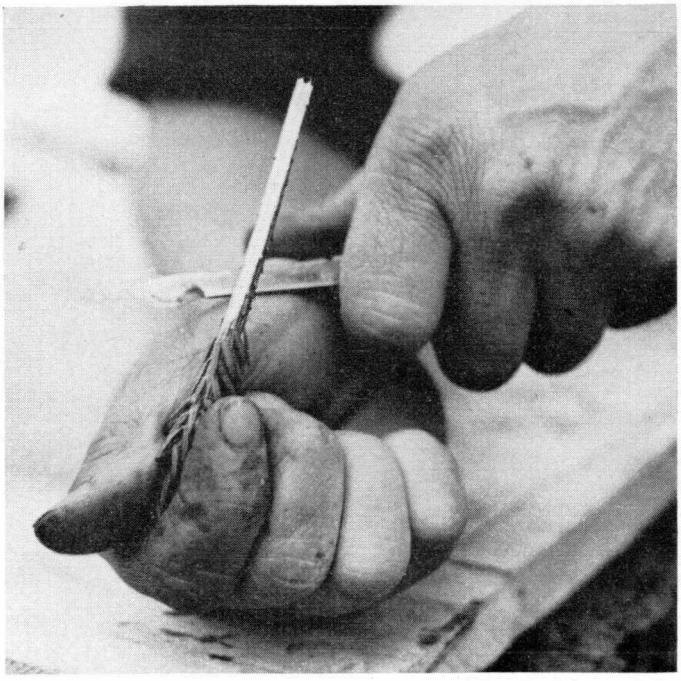

FIGURE 5.—The long cut is made and the soft bark flap at the base of the scion is removed with a short cut.

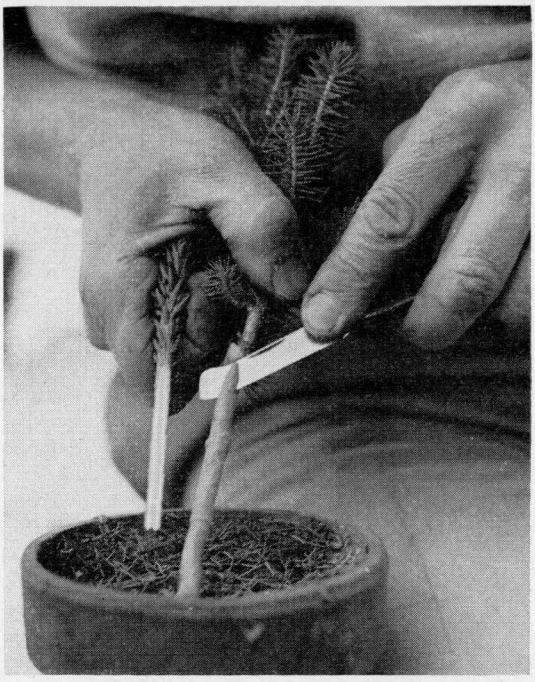

FIGURE 6.—The incision in the rootstock is made. The propagator holds the prepared scion at the side to gauge the depth and length of the cut required. The loosened flap of bark is cut near the bottom of the incision to provide a shoulder for the scion.

FIGURE 7.—Scion and rootstock are checked for fit. The cambium of the exposed cut on the scion should exactly match that on the rootstock.

FIGURE 8.—Scion tied firmly but not too tightly with raffia.

FIGURE 9.—The grafted plant is tilted over to be waxed. The propagator turns the plant and makes certain that the cuts are completely covered with wax.

FIGURE 10.—The finished graft with moisture-proof coat of wax. The wax seal prevents irrigation water from seeping in between scion and rootstock.

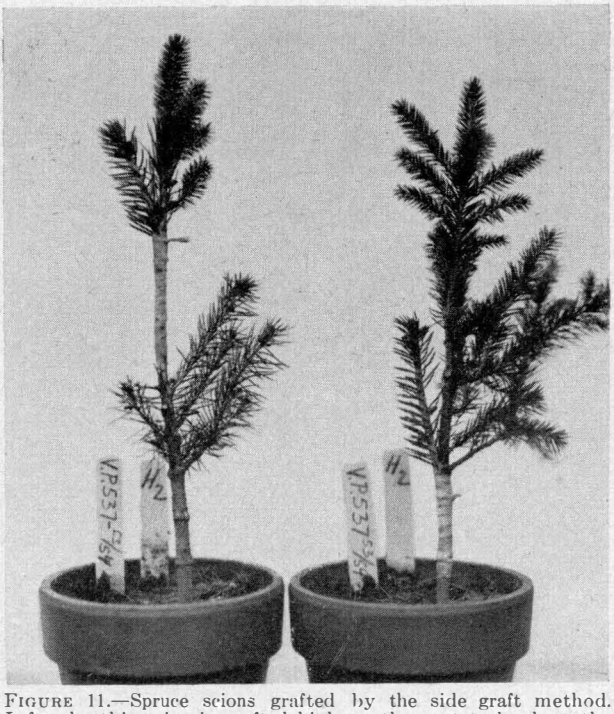

FIGURE 11.—Spruce scions grafted by the side graft method. Left—the thin scion is grafted high on the rootstock where the propagator found the best match for the scion. Right—the sturdy scion grafted just above soil level.

FIGURE 12.—Red pine scion grafted onto a Scots pine rootstock by the side graft method. Notice that a big rootstock of large diameter is needed for the rather sturdy red pine scion.

FIGURE 13.—Newly-made pine grafts placed in a tub of water to soak. When grafts are watered in this way they can be placed in "closed air" for a period of six weeks without additional watering.

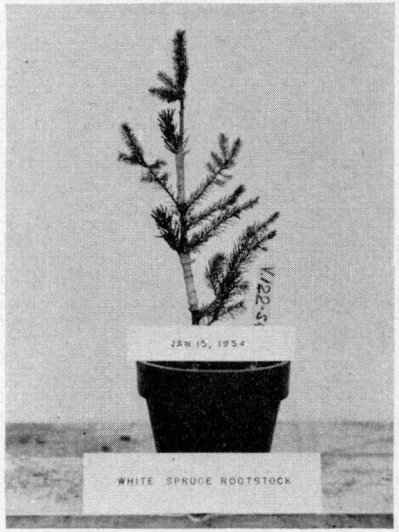

FIGURE 14.—Norway spruce scions grafted February 15 on white spruce rootstock taken into the greenhouse January 15. The picture was taken two days after grafting (February 17). The scions had dormant buds, while the buds of the rootstock were swelling, the correct stage for the grafting of spruce rootstocks.

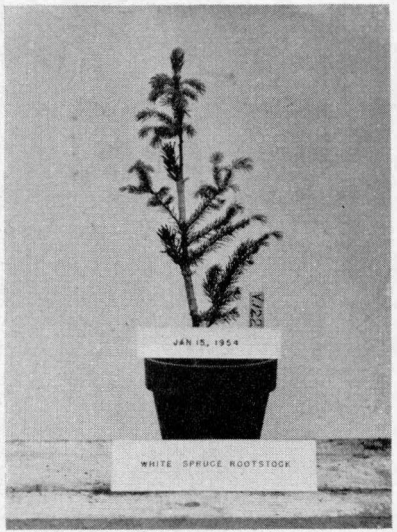

FIGURE 15.—Same graft as shown in Figure 14, photographed March 5. The rootstock had soft hanging elongating shoots, and the scions had begun to show swelling buds.

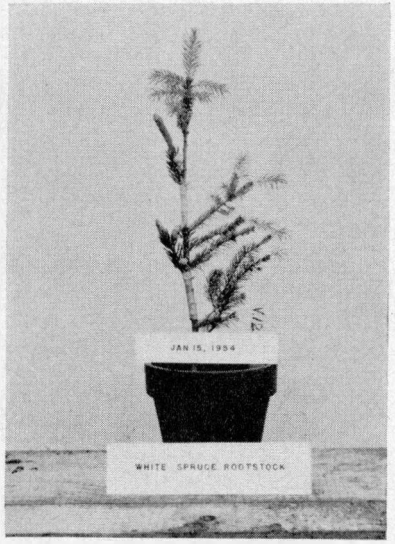

FIGURE 16.—Same as shown in Figure 14, photographed April 6. The rootstock had stiff new shoots and the scions had just begun shoot-elongation

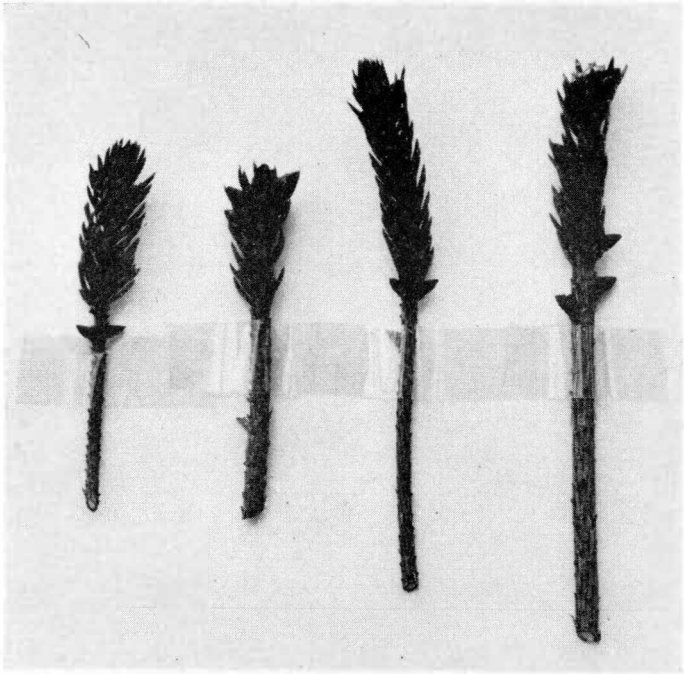

FIGURE 17.—Norway spruce scions trimmed for needles and ready for grafting.

FIGURE 18.—Interior of the greenhouse. On the side bench on the left are the plunge boxes designed to keep the grafts in closed air. Right front is the plunge pit where it is possible to keep a somewhat lower and more even temperature than in the open greenhouse. Benches for open propagation are found on the middle table and the right side bench. Extra shelves are put up in the greenhouse to provide extra space. Only grafts, preferably pine, that are more than six weeks old are placed on the shelves, as the pots are quite exposed. It is necessary to water these pots abundantly each day.