CANADA
Department of Northern Affairs and National Resources
FORESTRY BRANCH

PHENOLOGY OF ROOTSTOCKS AND GRAFTS
in a
Timing Experiment with Autumn and Winter Grafting of Norway and White Spruce

By
M. J. Holst

Forest Research Division
Technical Note No. 48
1956

79981—1

Published under the authority of
The Minister of Northern Affairs and National Resources
Ottawa, 1956

CONTENTS

79981—2

Phenology of Rootstocks and Grafts in a Timing Experiment with Autumn and Winter Grafting of Norway and White Spruce

Project P-60

BY

M. J. HOLST[1]

INTRODUCTION

Greenhouse grafting of spruce during the autumn and winter is a standard practice in most tree-breeding programs. The techniques and timing employed are those used by horticulturists. The disadvantage of such methods is that grafting is confined to two short periods, August-September and February-March.[2]

These periods are too short to permit full advantage being taken of the opportunities for collecting scions in the late autumn and early winter. But how can the grafting season be extended to allow continuous grafting from early autumn to late winter? Only two methods are possible: (1) either keep the late autumn grafts in the greenhouse over winter, or (2) place rootstocks in the greenhouse before freeze-up and utilize their slight cambial activity for grafting.

Several problems must be investigated before these methods can become standard practice. Therefore a small experiment was set up to arrive at answers to the following questions: Is it better to give early autumn grafts a normal chilling by placing them in the cold frame and over-wintering them out-of-doors, or is it better to keep them non-chilled in the greenhouse over winter? When should the rootstocks for late autumn and winter grafting be taken into the greenhouse, and when are they ready for grafting? What combination of chilled and non-chilled scions and rootstocks gives the best take and the best growth of the scion? What species are suitable as non-chilled rootstocks?

Most of these questions can be answered by studying the phenology of rootstocks and scions and combining these observations with data for survival (per cent "take"), colour, and interspecific differences.

MATERIALS AND METHODS

Norway spruce (*Picea abies* (L.) Karst.) and white spruce (*Picea glauca* (Moench) Voss.) rootstocks were taken into the greenhouse on September 1, October 1, December 1, and January 16, and were thus given various periods of chilling.

The rootstocks taken in during the early autumn (September 1 and October 1) were grafted the same day they were taken in; half of these grafts were set

[1] Forest Geneticist, Petawawa Forest Experiment Station, Chalk River, Ontario.

[2] Autumn grafting of spruce in August-September is done with rootstocks taken into the greenhouse shortly before grafting. After four to six weeks in closed air the grafts are hardened-off preparatory to planting-out in open cold frames in October. Winter grafting is done with rootstocks lifted from the frames in mid-January or later. These rootstocks can be grafted from the middle of February, or later as required, usually to the middle of March.

79981—2½

out in cold frames on November 21 to get normal winter chilling, while the other half were retained in the greenhouse over winter for comparison with other non-chilled rootstocks.

The rootstocks taken into the greenhouse in late autumn (December 1) and early winter (January 16) were all grafted on February 1.

Over the whole experiment Norway spruce scions were grafted on white spruce rootstocks and white spruce scions were grafted on Norway spruce rootstocks to determine what effect scions and rootstocks had on each other.

The following treatments were given to rootstocks and scions:

(1) White spruce rootstocks taken into the greenhouse on September 1, 1953, and grafted with four clones of Norway spruce on the same day. The finished grafts were set out in cold frames on November 21, 1953, for over-wintering out-of-doors.

(2) Grafted as in (1) but kept in the greenhouse over winter.

(3) White spruce rootstocks taken into the greenhouse October 1, 1953, and grafted with four clones of Norway spruce on February 1, 1954.

(4) White spruce rootstocks taken into the greenhouse on December 1, 1953, and grafted with four clones of Norway spruce on February 1, 1954.

(5) White spruce rootstocks taken into the greenhouse on January 16, and grafted with four clones of Norway spruce on February 1, 1954.

(6) Norway spruce rootstocks taken into the greenhouse on September 1, 1953, and grafted with white spruce on the same day. The finished grafts were set out in cold frames on November 21, 1953, for over-wintering out-of-doors.

(7) Norway spruce rootstocks taken into the greenhouse on October 1, 1953, and grafted with white spruce on the same day. The finished grafts were set out in cold frames on November 21, 1953, for over-wintering out-of-doors.

(8) Grafted as in (6) but kept in the greenhouse over winter.

(9) Grafted as in (7) but kept in the greenhouse over winter.

(10) Norway spruce rootstocks taken into the greenhouse on December 1, 1953, and grafted with four clones of white spruce on February 1, 1954. (None of these clones are the same as in treatments 6 to 9.)

(11) Norway spruce rootstocks taken into the greenhouse on January 16, 1954, and grafted with four clones of white spruce February 1, 1954. (Same clones as in treatment 10.)

These treatments are summarized in Table I.

Scions and rootstocks were rated for their phenological behaviour in the period January 15 to March 15. Notes were taken every two weeks in this period. Each scion and rootstock was rated for the following "stages":

(1)—buds closed and firm,

(2)—buds swelling,

(3)—needles visible,

(4)—shoot elongation.

Notes were made on the phenology, foliage colour, and health of both scions and rootstocks. Survival (or "take") was counted in August, 1954, and the first season's shoot-growth was measured in September, 1954.

RESULTS

Some of the results related to per cent take have already been published (2). This report presents details of the growth rhythm of rootstocks and scions. The first part is a comparison of chilled and non-chilled autumn grafts. The second part deals with the phenology of non-chilled and partly-chilled rootstocks grafted with non-chilled and chilled scions.

TABLE I.—TREATMENT OF ROOTSTOCKS AND SCIONS

Scions and Rootstocks	Treatment Number	Date Rootstock Taken into Greenhouse	Date Grafted	Over-wintering of Autumn Grafts	Treatment of Winter-grafted Rootstocks
Norway spruce scions grafted on white spruce rootstocks	1	Sept. 1	Sept. 1	outdoors Nov. 21	—
	2	Sept. 1	Sept. 1	greenhouse	—
	3	Oct. 1	Feb. 1	—	non-chilled
	4	Dec. 1	Feb. 1	—	slightly chilled
	5	Jan. 16	Feb. 1	—	chilled
White spruce scions grafted on Norway spruce rootstocks	6	Sept. 1	Sept. 1	outdoors Nov. 21	—
	7	Oct. 1	Oct. 1	outdoors Nov. 21	—
	8	Sept. 1	Sept. 1	greenhouse	—
	9	Oct. 1	Oct. 1	greenhouse	—
	10	Dec. 1	Feb. 1	—	slightly chilled
	11	Jan. 16	Feb. 1	—	chilled

Comparison of Chilled and Non-chilled Autumn Grafts

Table II shows that survival per cent and shoot-growth of rootstocks and scions is better for chilled than for non-chilled autumn grafts.

Shoots on chilled scions and rootstocks of Norway spruce grew respectively 80 per cent and 85 per cent more than non-chilled material; shoots on chilled scions and rootstocks of white spruce grew 37 per cent and 61 per cent more than comparable non-chilled material. Thus non-chilled Norway spruce showed greater percentage reduction of shoot-growth than did white spruce. This might lead to the belief that the non-chilled Norway spruce were more unhealthy than the non-chilled white spruce, but this was not so. It was the white spruces that suffered most by lack of chilling, as was indicated by the pronounced foliage discolouration (Table III). Probably the reason was that the Norway spruce shoot-growth may have been more retarded in an early stage, but that in a later stage of growth Norway spruce better endured the change in physiological balance brought about by lack of chilling, than did white spruce.

Table II also shows that early autumn grafting (September 1) gave higher per cent survival and better shoot-growth than late autumn grafting (October 1). The superiority is apparent for both chilled and non-chilled grafts.

Phenology of Chilled and Non-chilled Rootstocks

The standard procedure is to graft chilled rootstocks as soon as they show strong white root tips. These appear about a week before the rootstocks show signs of budswelling.

Non-chilled rootstocks behave differently and show only slight cambial activity and root-growth during late autumn and winter, and root-growth is not followed by budswelling and shoot-elongation. They must therefore be regarded as being in some kind of prolonged autumn condition and should be grafted according to their cambial activity (as for early autumn grafts).

TABLE II.—SURVIVAL AND SHOOT-GROWTH OF CHILLED AND NON-CHILLED AUTUMN GRAFTS

Material	Date Grafted	Survival of Grafts (per cent)		Shoot-growth (centimetres)			
				Scions		Rootstocks	
		Chilled	Non-chilled	Chilled	Non-chilled	Chilled	Non-chilled
Norway spruce scions grafted on white spruce rootstocks	Sept. 1	95	80	7·2	4·0	6·6	4·1
White spruce scions grafted on Norway spruce rootstocks	Sept. 1	92	88	7·8	5·7	6·3	3·4
White spruce scions grafted on Norway spruce rootstocks	Oct. 1	72	72	5·6	4·6	5·9	3·4

Non-chilled rootstocks are physiologically unstable. Although they are graftable during autumn and winter, their unstable physiological balance influences not only their own growth rhythm, but also that of the scion. Therefore the phenology of the rootstocks is investigated first, and later the question to what extent the growth rhythm of the rootstocks influences the growth rhythm of the scions.

The phenological behaviour of the white spruce and Norway spruce rootstocks taken into the greenhouse September 1, October 1, December 1, and January 16, and kept there over winter is shown in Figure 1.

The rootstocks (both white and Norway spruce) taken into the greenhouse on December 1 were the first to show signs of new growth. The white spruce had reached stage 2 (budswelling) (*see* p. 4) as early as January 1 while the Norway spruce reached this stage on February 7. The white spruce also reached stage 4 (shoot elongation) about a month earlier than did the Norway spruce.

White spruce rootstocks taken in on December 1 and January 16 had reached stage 4 (shoot elongation) on February 21 and March 1 respectively; similarly treated Norway spruce rootstocks reached the same stage on March 15.

The rootstocks of both species taken in on October 1 were a little later than those taken in on January 16.

The rootstocks taken in on September 1 were all late in starting shoot-growth. Although the Norway spruce seemed to follow a delayed but normal growth pattern and all reached stage 4 (shoot elongation) on March 15, the white spruce followed a rather irregular pattern and 10 per cent had not commenced growth on March 15.

It appears then that white spruce commenced shoot-growth more quickly after the two periods of partial chilling than did Norway spruce, and both spruces commenced growth more quickly after long chilling than after short chilling. Furthermore, the rootstocks placed in the greenhouse on September 1 are more irregular in commencing growth than any of the other treatments.

Foliage Discolouration

White spruce seemed also in other respects to suffer more from lack of chilling than did Norway spruce. An attempt was made to judge the general health, both of rootstocks and scions, on the basis of the various degrees of discolouration of the foliage.

In the spring of 1954 it was already apparent that the white spruce kept in the greenhouse over winter had started to turn yellow while the Norway spruce treated in the same way had retained much more of their lush green colour. In the autumn of 1954 all treatments were again rated for discolouration. The discolouration of the foliage of the white spruce material kept in the greenhouse over winter had now attained a dull nut-brown tone, and only the small whitish and firm buds gave hope for a somewhat normal development in the 1955 growing season. Similarly treated Norway spruce appeared quite healthy. The grading is shown in Table III.

TABLE III.—FOLIAGE COLOUR OF NORWAY AND WHITE SPRUCE ROOTSTOCKS

Treatment of Rootstocks	Norway Spruce	White Spruce
Chilled all winter, set out Nov. 21, 1953.	treatments 6 and 7, normal lush green colour, normal bud formation.	treatment 1, deep blue-green colour, normal bud formation.
Partly chilled, taken into greenhouse January 16, 1954.	treatment 11, normal lush green colour, normal bud formation.	treatment 5, yellowish-green colour, normal bud formation.
Taken into greenhouse December 1, 1953.	treatment 10, slight discolouration, normal bud formation.	treatment 4, strong discolouration, many plants yellowish-brown. Only small buds.
Taken into greenhouse October 1, 1953.	treatment 9, slight discolouration, normal bud formation.	treatment 3, strong discolouration, many plants almost nut-brown with small buds.
Taken into greenhouse September 1, 1953.	treatment 8, slight discolouration, normal bud formation.	treatment 2, strong discolouration, nearly all plants dull brown and with small buds.

Also the per cent take was influenced by the general health of the rootstocks. The healthy looking non-chilled Norway spruce rootstocks gave a higher take when grafted than did the sickly looking non-chilled white spruce rootstocks.

Phenology of Non-chilled Scions and Rootstocks

The bud-rest periods of non-chilled scions are comparable only for autumn-grafted material.

Figure 2 shows that the Norway spruce scions on March 15 were in the same stage of development as were similarly treated Norway spruce rootstocks on February 21. As the Norway spruce scions were grafted on white spruce rootstocks, it appears that the white spruce rootstocks delayed flushing of the Norway spruce scions by about three weeks. A similar delay did not occur with the white spruce scions grafted on to Norway spruce rootstocks, because the white spruce scions on February 15 had reached the same stage of development as similarly treated white spruce rootstocks.

Also the species differences in commencement of growth showed up in these autumn-grafted non-chilled scions; the white spruce scions commenced growth about one month earlier than comparable autumn-grafted Norway spruce scions. (Figure 8.)

Phenology of Chilled Scions Grafted on Chilled and Non-chilled Rootstocks

Rootstocks differed in development according to the dates they were taken into the greenhouse. This difference—and the species difference—influenced the growth rhythm of the winter-grafted scions. (Figure 2.)

The chilled white spruce scions grafted on February 1 started growth about two weeks earlier than the Norway spruce scions grafted on the same date. There is also an indication that there was a few days difference in development of the scions due to the rootstocks; the rootstocks taken in on December 1 gave the fastest growth of the scions, while the rootstocks taken in on October 1 gave a somewhat slower development of the scions. The rootstocks taken in on January 16 gave the slowest. However, these differences are small compared to the inter-specific differences.

Finally there is the problem of how much the growth rhythm of the rootstocks influenced the growth of the scion. The shoot growth of rootstocks and scions is shown in Figure 3. When these data are re-arranged and compared with the phenological data, several interesting features of the interactions between rootstock and scions are brought to light.

Table IV shows that shoot-growth of scions was inversely proportional to shoot-growth of rootstocks. The later the rootstock commenced growth, the shorter was the shoot-growth of the rootstock and the longer was the shoot-growth of the scion.

That chilled scions grafted on late-starting non-chilled rootstocks showed superior growth may be explained as follows. The scion was ready for shoot-growth because its chilling requirements had been met. Shoot-growth of the non-chilled rootstock was delayed, but there was ample cambial activity and root-growth. The rootstocks were therefore in a graftable stage, but only the shoot-growth of the chilled scion could benefit from the cambial activity of the rootstock. The chilled scion was the only "outlet" for the assimilates of the rootstock and was therefore "forced" to produce a longer shoot. Had the scion been in "competition" with the advanced shoot-growth of a chilled rootstock, it would have been only one of many "outlets" and therefore not "forced" to produce. A similar pattern of shoot-growth has been found for white pine (1) and for Scots pine (2).

DISCUSSION

The apparent differences between white spruce and Norway spruce are that white spruce suffers pronounced discolouration from lack of chilling, but needs only a short period of chilling to commence growth, and quickly responds to an increase in temperature. Norway spruce does not suffer from lack of chilling, needs a longer period of chilling to commence growth, and responds only slowly to an increase in temperature. The results suggest that there are fundamental differences between the responses of the two species. These differences might be best understood by considering white spruce as being a species adapted to a continental climate, that is, adapted to sudden and lasting but not necessarily very big changes in temperature. White spruce could therefore commence growth quickly on a slight increase in temperatures. Norway

spruce should be considered an oceanic spruce (from Western Europe) adapted to relatively mild winters and unstable spring weather. The Norway spruce rootstocks did not suffer from lack of chilling as they were accustomed to mild winters, and start of growth was delayed because of an adaptation to unstable spring weather. Growth is not started before the temperature has been high enough for a long period of time to ensure that frost damage is no longer possible.

How are these results related to the general theories on rest? The experimental set-up and the control of temperatures have not been such that far-reaching conclusions on the general rest problem in woody plants can be made. The experiment indicates how necessary is a period of rest (chilling) for normal growth and development, but the observations also give a clue to how deeply the rest is induced.

The plants kept in continuous heat were not without growth activity. Both root-growth and cambial activity (slight) were apparent, which indicates that root-growth and cambial activity are mainly controlled by temperature. These are not new findings. Ladefoged (3), for instance, found that root-growth was mainly controlled by soil temperature and everybody has seen the effects of sun scald, where the sun heats up local parts of the cambium and initiates cambial activity.

Only shoot-growth was retarded in the experimental plants, and as only shoot-growth was measured in the experiment, the following discussion refers only to the bud-rest problem.

The results shown in Figure 1 have been slightly re-arranged in Table V. It can be seen that plants kept in continuous heat have a longer bud-rest period than have chilled plants; and the chilled plants have the shorter bud-rest period the longer they are chilled.

TABLE IV.—SHOOT-LENGTH AND START OF SHOOT-GROWTH OF WHITE AND NORWAY SPRUCE SCIONS AND ROOTSTOCKS

	Rootstocks taken into the greenhouse on			
	October 1 1953	January 16 1954	December 1 1953	September 1 1953
Average shoot-length of white spruce rootstocks (centimetres)	3·2	3·4	3·5	—
Average shoot-length of Norway spruce scions grafted on February 1, 1954 (centimetres)	6·4	5·6	4·9	—
About half the rootstocks in stage 2 (budswelling)	February 15	February 1	January 1	after February 15, very irregular
Average shoot-length of Norway spruce rootstocks (centimetres)	—	3·4	3·6	—
Average shoot-length of white spruce scions grafted on February 1, 1954 (centimetres)	—	5·2	4·8	—
About half the rootstocks in stage 2 (budswelling)	February 22	February 20	February 7	February 20

The bud rest of the two spruces is apparently induced during the summer and is well fixed for non-chilled material regardless of, or perhaps even because of, the high temperatures in the greenhouse (the experiment does not indicate which).

TABLE V.—INCIDENCE OF BUD REST

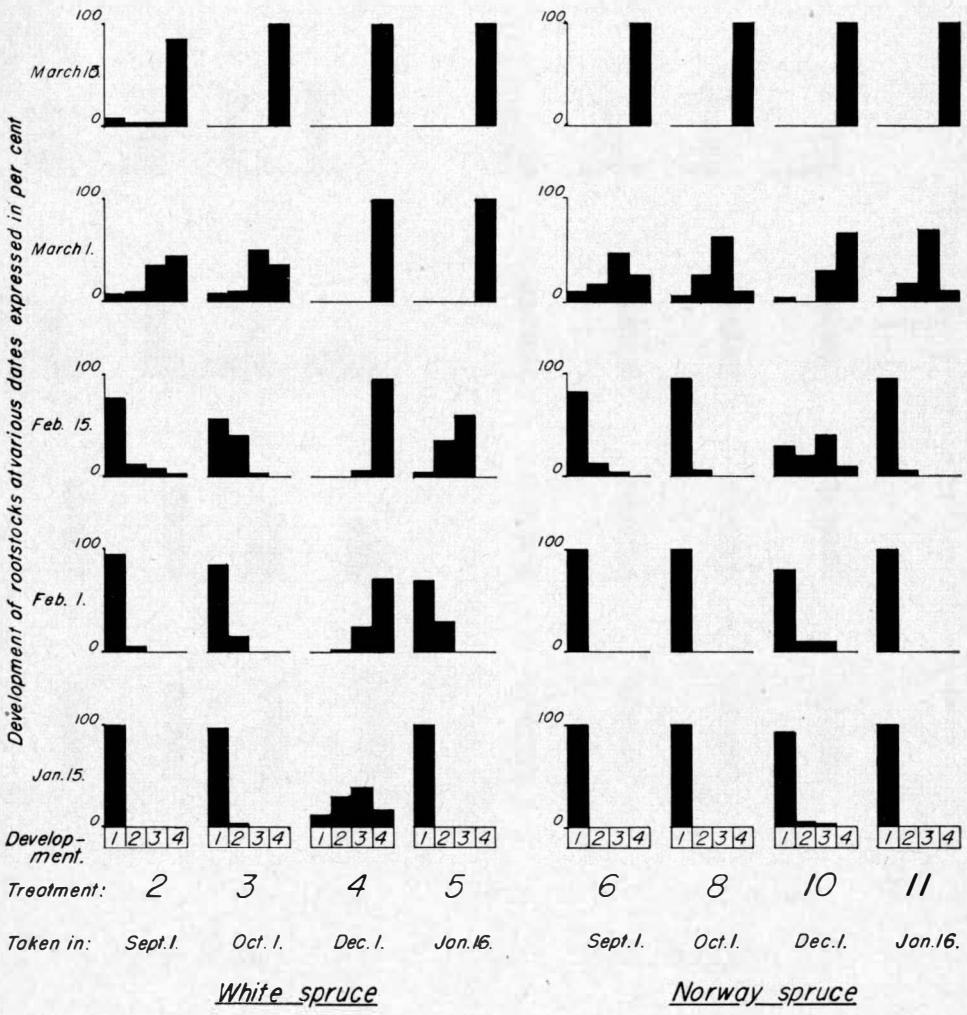
Rootstocks taken into greenhouse on	Months needed to reach stage 4 (shoot elongation)	
	White spruce	Norway spruce
September	7	6½
October 1	5½	5¼
December 1	2½	3½
January 16	1½	2

The nature of the bud-rest period is such that, in its early stage, it can be broken only by chilling, and the longer the plants are chilled in this early stage, the more readily is the rest broken.

These results are in agreement with Vegis (4) who showed that the rest period could be prolonged considerably by high temperature storage of *Stratiotes aloides*. Apparently, the buds of plants kept in high temperature are in some kind of voluntary rest, or autonome rest, while the chilled plants gradually have changed from the autonome rest to a rest enforced on them by the low temperature of the environment. The latter can easily be broken by raising the temperature, while raising the temperature does not break the autonome rest.

SUMMARY

Chilled and non-chilled white spruce and Norway spruce rootstocks were rated for their phenological behaviour. It was found that rootstocks placed in cold frames in November and thus receiving normal winter chilling were superior to non-chilled rootstocks with regard to health, shoot-length and survival of grafted scions. White spruce suffered more from lack of chilling than did Norway spruce. Foliage of non-chilled white spruce discoloured to a dull yellowish-brown colour, while non-chilled Norway spruce appeared quite healthy. Although white spruce suffered most from lack of chilling, it commenced growth more quickly than did Norway spruce after two different chilling periods. Both spruces commenced shoot-growth more quickly after long chilling than after short chilling. Chilled scions grafted on non-chilled rootstocks showed better growth than those grafted on chilled rootstocks. Non-chilled plants had continuous root-growth and cambial activity but retarded shoot-growth. The difference in growth rhythm of the two spruces is discussed and explained by the continental origin of the white spruce and the oceanic origin of the Norway spruce.



Stages of development: 1 Buds closed
2 Buds swelling
3 Needles visible
4 Shoot elongation

FIGURE 1.—Phenological behaviour of white and Norway spruce rootstocks taken into the greenhouse September 1, October 1, December 1, and January 16.

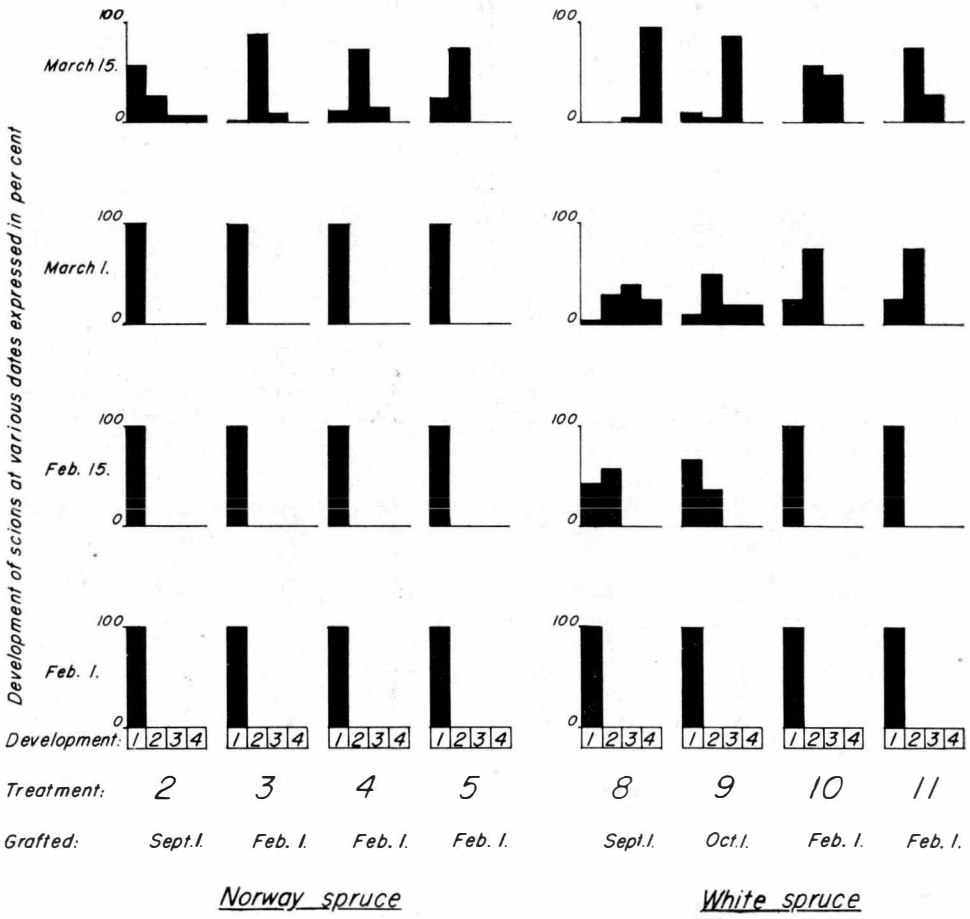


FIGURE 2.—Phenological behaviour of Norway spruce and white spruce scions grafted at various dates on respective white spruce and Norway spruce rootstocks which were taken into the greenhouse September 1, October 1, December 1, and January 16.

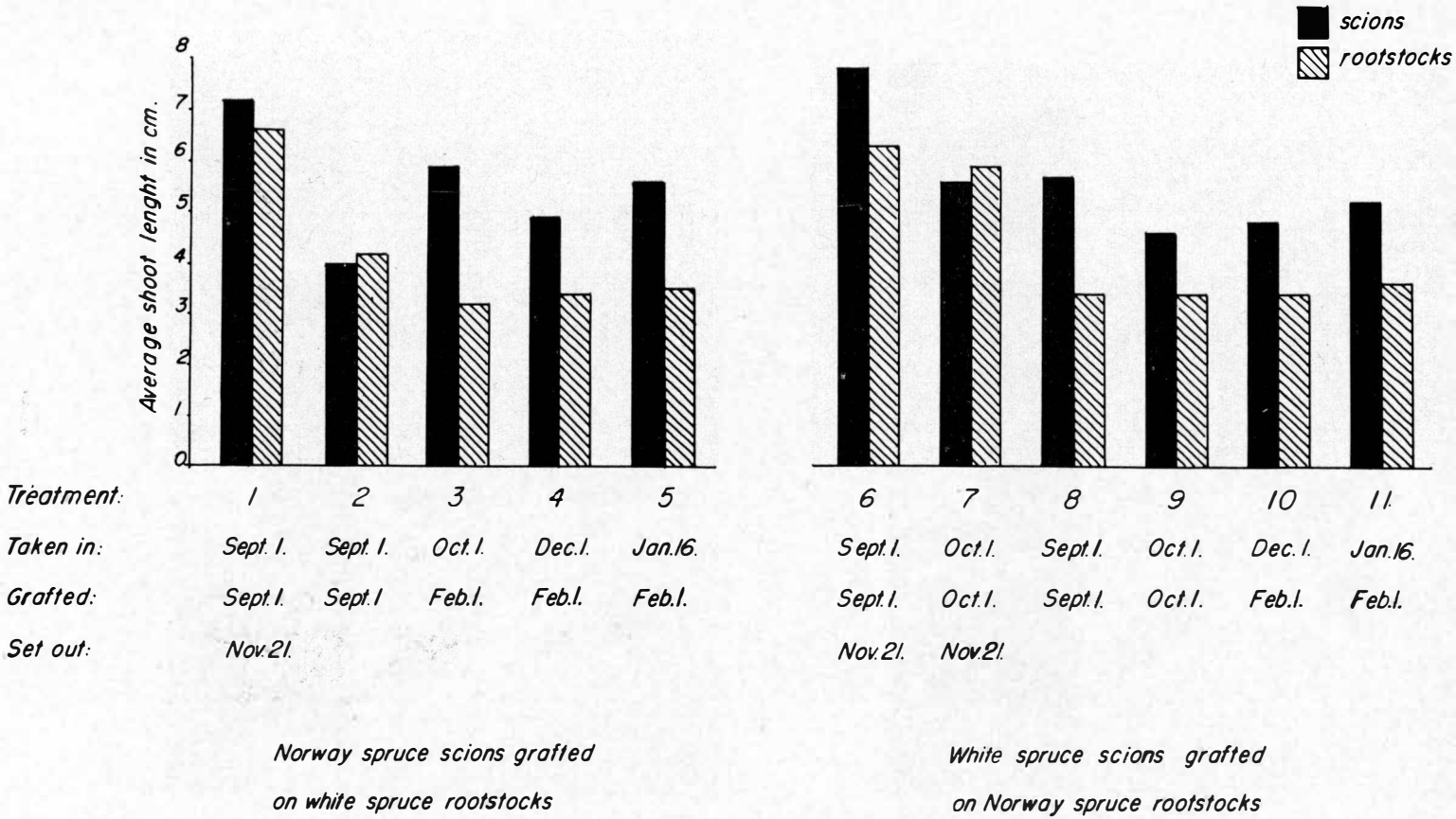


FIGURE 3.—Average shoot-length of rootstocks and scions as measured in the autumn of 1954.

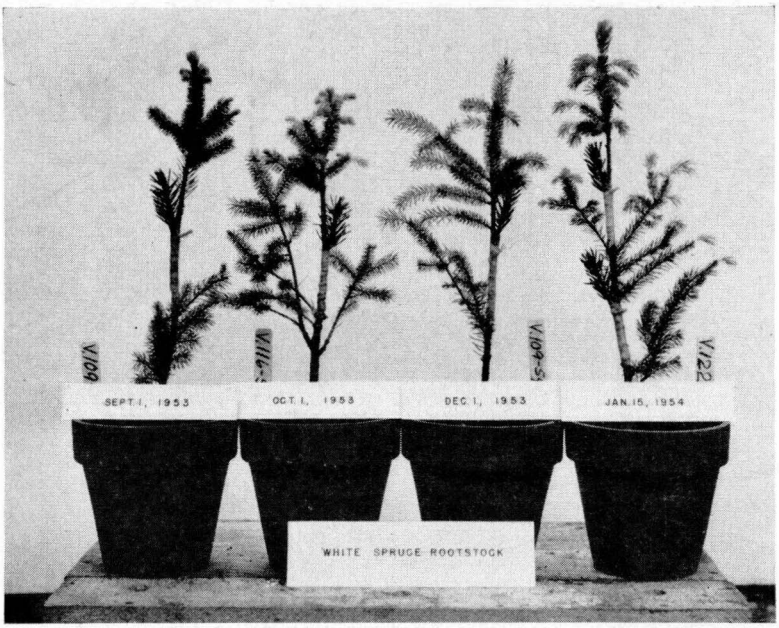


FIGURE 4.—Development on February 17, 1954, of grafted white spruce rootstocks. The dates shown in the pictures are the dates the rootstocks were taken into the greenhouse. From left are seen treatments 2, 3, 4, and 5. Note the very advanced growth of the white spruce rootstocks taken into the greenhouse on December 1, 1953. Compare this figure with Figure 7 and notice that none of the Norway spruce rootstocks are in the shoot-elongation stage.

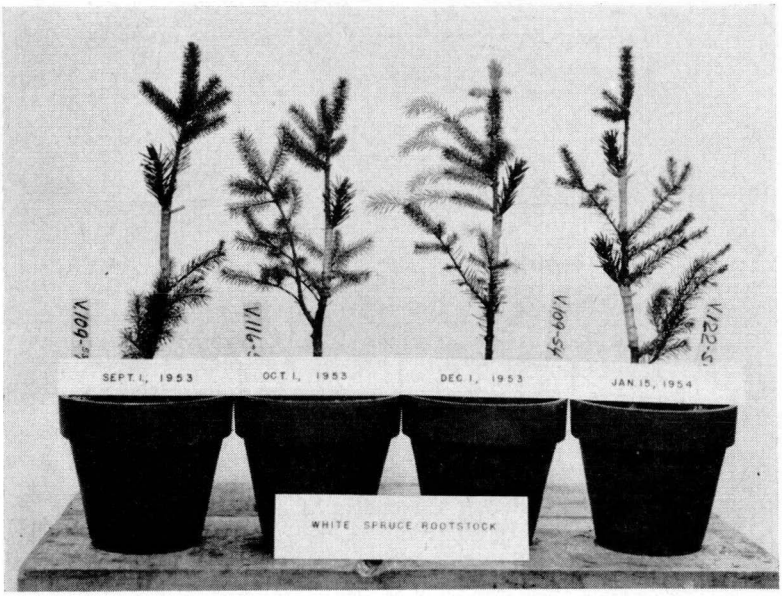


FIGURE 5.—Development on March 5, 1954, of grafted white spruce rootstocks. Same plants as in Figure 4. All rootstocks are now in the shoot-elongation stage. Notice that the Norway spruce scion grafted on September 1 (treatment 2) has not started to grow. Compare this figure with Figure 8 showing white spruce scions grafted on Norway spruce rootstock and notice that the white spruce scions grafted on September 1 and October 1 are in an advanced stage of growth while the growth of the Norway spruce rootstocks is much more retarded.

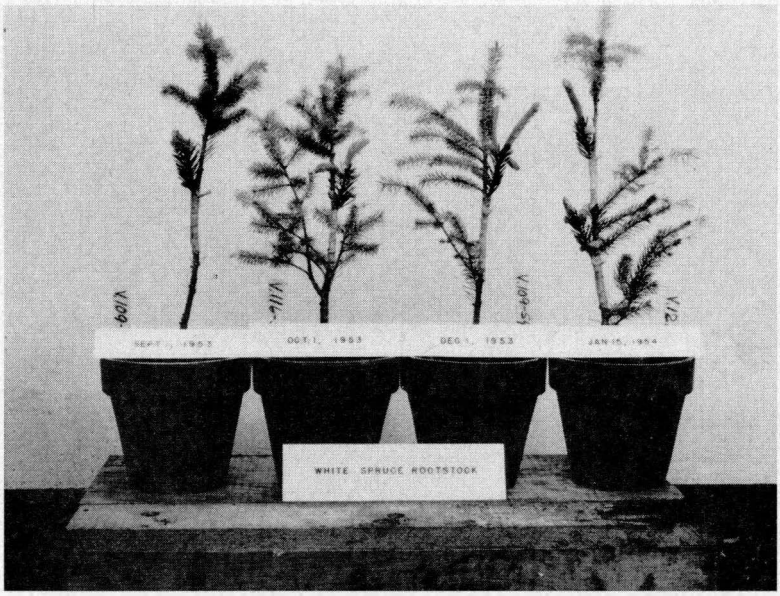


FIGURE 6.—Development on April 6, 1954, of grafted white spruce rootstocks. Same plants as in Figure 4. Notice that the non-chilled Norway spruce scion grafted on September 1 is very slow in commencing growth.

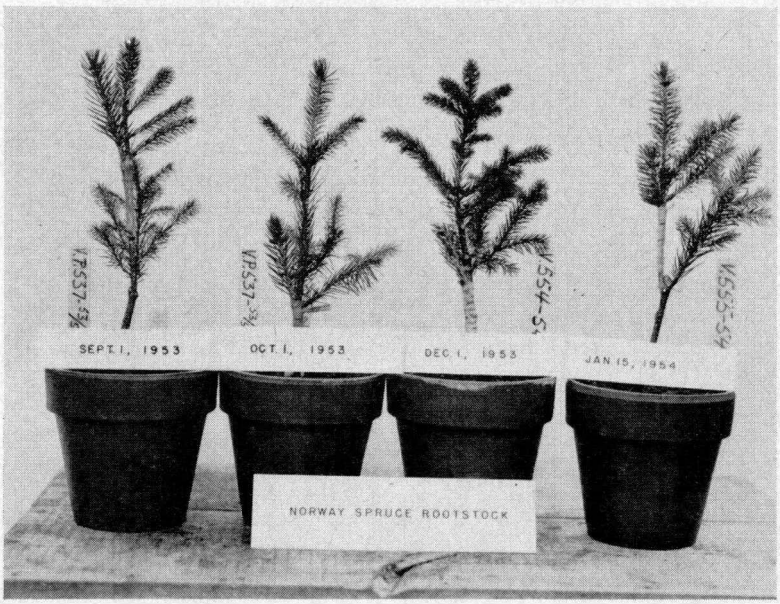


FIGURE 7.—Development on February 17, 1954, of grafted Norway spruce rootstocks. The dates shown are the dates the rootstocks were taken into the greenhouse. From left are seen treatments 8, 9, 10, and 11. None of the rootstocks are in the shoot-elongation stage.

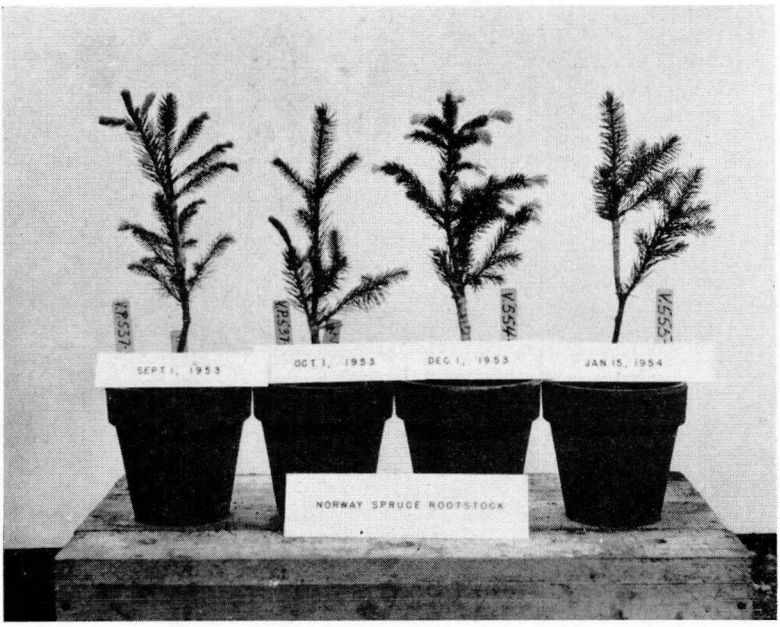


FIGURE 8.—Development on March 15, 1954, of grafted Norway spruce rootstocks. Same plants as in Figure 7. Notice that the rootstock taken in on December 1 is the most advanced. The white spruce scions grafted on September 1 and October 1 are more advanced than any of the Norway spruce rootstocks.

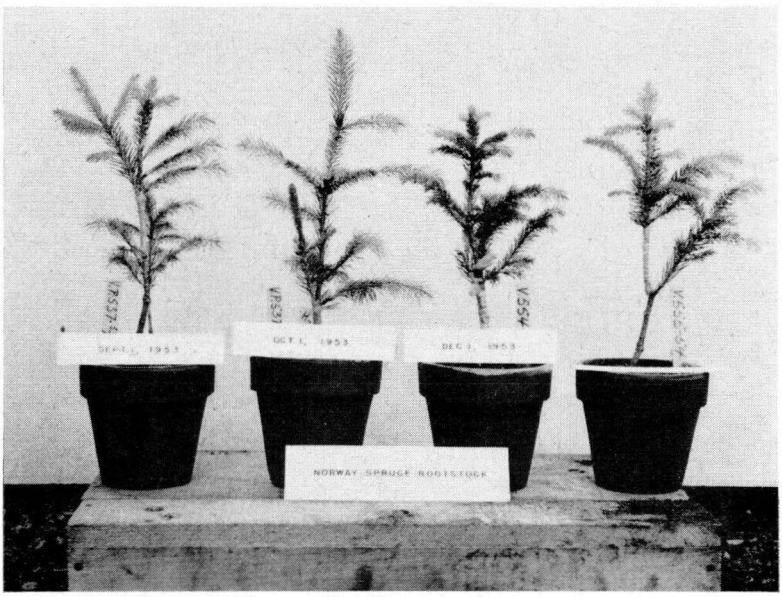


FIGURE 9.—Development on April 6, 1954, of grafted Norway spruce rootstocks. Same plants as in Figure 7. Notice that the white spruce scion grafted on September 1 is more advanced than that grafted on October 1.

REFERENCES

1. HEIMBURGER. C. C. 1952. Personal communication.

2. HOLST, M. J., J. A. SANTON and C. W. YEATMAN. Greenhouse grafting of spruce and hard pine at the Petawawa Forest Experiment Station, Canada. Dept. of Northern Affairs and National Resources, Forestry Branch, For. Res. Div., Tech. Note No. 33.

3. LADEFOGED, K. 1939. Untersuchungen uber die Periodizitat im Ausbrusch und Langenwachstum der Wurzeln bei einigen unserer gewöhnlichsten Waldbaume. The Danish Forest Experiment Station 16: 1-256.

4. VEGIS, A. 1949. Durch hohe Temperaturen bedingter wiedereintritt des Ruhezustandes bei den Winterknospen. Svensk Botanisk Tidskrift, 43(2-3): 671-714.

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1957