to obtain a satisfactory stand By a satisfactory stand I mean at least a 80% or 90% take

Field results are not conclusive, although after being planted out for one year there was no noticeable top growth but the root system showed considerable increase, thereby giving a good foundation for future development of the plant

I hope I have been able to offer information that will be of some benefit to all, because there is nothing more rewarding than starting out with an experiment and through trial and error come up with satisfactory results I wish to thank you all for the attention given and I am looking forward to answering any questions you may have during the discussion period

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MODERATOR HALWARD. We have time for a few brief questions.

MR. WALTER GRAMPP: Have you tried anything other than 2 per cent IBA?

MR. RAVESTEIN Yes

MR. SAUR: Do you think you get more root growth by having a long cutting than you would from a shorter cutting?

MR. RAVESTEIN. Definitely The bigger your cutting, the better rooting you have I don't believe in small cuttings.

MODERATOR HALWARD· That will be all the questions on hardwood cuttings. I believe Mr. Cumming has slides that he brought with him, and we have had some requests to show these slides. We will work them in now, before our last speaker of the morning.

Editor's Note: Mr W A. Cumming showed and discussed a number of colored slides which brought out particular features of his foregoing talk.

MODERATOR HALWARD. We are right on schedule, fortunately, and the last speaker of the morning is Mr. Hans Nienstaedt, Lake States Forest Experiment Station, Rhinelander, Wisconsin. He received his education at the Royal College of Agriculture at Copenhagen and at Yale University I present Hans Nienstaedt who will talk on "Fall Grafting of Spruce and Other Conifers."

Mr. Nienstaedt then presented his address on "Fall Grafting of Spruce and Other Conifers." (Applause)

FALL GRAFTING OF SPRUCE AND OTHER CONIFERS

HANS NIENSTAEDT
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We in forestry are novices in the field of propagation, while you have been at the game for centuries. We have had to look at the experience gained in horticulture for the fundamentals to use in the propagation of our plant material. However, since our work schedule, our plant material, and our objectives often differ from yours, our approach to problems have sometimes followed new directions and have

resulted in some modifications of techniques. One such modification, fall grafting of conifers, is the subject of my talk

Mark Holst of the Petawawa Forest Experiment Station in Ontario was, I believe, the first tree breeder on this side of the Atlantic to suggest fall grafting. His initial results and the earlier results reported by Stefansson (4) in Sweden were not very successful and prompted me to try to develop a more satisfactory technique. In the following, I shall discuss the results of my experiments and newer successful experiments by Mark Holst with spruce, I will also mention some additional information on pine.

EXPERIMENTAL APPROACH

The assumption was that grafting success primarily is a function of the speed and effectiveness of union formation and that these in turn depend on the amount of cambial activity of the root stock and scion at the time of grafting and immediately thereafter. Therefore, the experiments attempted to control this activity through photoperiodic treatments and chilling.

With most trees long photoperiods of 16 hours or more extend the growth period while short photoperiods of about 13 hours or less result in the early cessation of growth. White spruce and Norway spruce are typical in this respect as indicated by earlier experiments in which cambial activity was maintained at least until late September on long-day but stopped very soon after the plants had been exposed to short-day conditions.

The root stocks used in the experiment were 2-year-old seedlings of white and Norway spruces. The stocks were unusually large, the largest seedlings in a group of several hundred thousand Normally we would use 2-1 or 2-2 transplants. The plants were potted in the spring of 1956 in 4-inch pots in a 50-50 mixture of leaf mold and a light sandy loam, and were set in the field under partial shade.

Rootstock treatments were begun on June 27, when the plants were moved to a lightproof shed. The treatments were.

L (for long day) 20-hour photoperiods 6/27 to 9/11. Active at time of grafting.

F (for field conditions) Remained in field until September 11. Dormant at time of grafting Chilling required for resumptoin of growth

C (for chilling) 13-hour photoperiods 6/27 - 7/12; chilling at 41°F. 7/12 - 9/11. Dormant at time of grafting, ready to resume growth.

S (for short day) 13-hour photoperiods 6/27 - 9/11. Dormant at time of grafting. Chilling required for resumption of growth.

The extended photoperiod beyond 13 hours was of low intensity from 25-watt incandescent light bulbs. Throughout the treatments the stock plants were carefully watered to maintain them in the best possible growing condition.

The scions were collected September 10. They were all from the current year's growth, were cut about 3 inches long, and were taken in the lower crown of approximately 30-year-old white spruce trees. The plants were grafted on September 11-14, 1956, using the veneer graft

with the graft union placed 3 to 6 inches above the soil line, but below the crown of the seedlings. The grafts were waxed with Trowbridge's grafting wax and placed on the open bench The greenhouse was not readily controlled; temperature was set at a 65-68° minimum, but often reached into the high 80's on warm sunny days with corresponding relative humidities as low as 30 per cent.

After grafting, the plants were again exposed to different environments of photoperiod and chilling, which were expected to influence the growth activity of the scion and rootstock and therefore the formation of the union. These treatments were.

l (for long day) 20-hour photoperiods.
cn (for chilling and normal daylight) 13-hour photoperiods 9/12 - 10/31; chilling at 41°F. 10/31 - 4/1; then normal greenhouse conditions.
cs (for chilling and short day) 13-hour photoperiods 10/15 - 10/31; chilling at 41°F. 10/31 - ½; then short day in greenhouse.
cl (for chilling and long day) as **cs** except long day in greenhouse.
s (for short day) Unaltered short day in the greenhouse.

The rootstock was first cut back on October 31, when the leader and a few of the first side branches were removed Not until the scions had completed one season's growth were the stocks completely cut back.

EXPERIMENTAL RESULTS

Survival. The result of the experiment clearly indicates that grafting of white spruce in September is feasible; 76.5 percent of the original 340 grafts survived on July 29, 1957, almost 11 months after grafting. In 22 of the treatment combinations (comprising 220 of the original grafts) survival was 80 per cent or better. Very similar results have been reported by Holst **et al** (2) in Canada; they have obtained average survival percentages ranging from 72 to 95 per cent in grafts of white spruce scions on Norway spruce rootstocks and of Norway spruce scions on white spruce stock.

Only in 4 of the 34[1] treatment combinations was survival much influenced by the treatments, and then only when white spruce was involved. In treatments **L-s** the sudden change from long– to short-day undoubtedly is a considerable shock to the plant and affects union formation; in **cn** the plants were not exposed to light (as they were in the other chilling treatments) and the white spruce rootstocks lost all their needles shortly after they were moved back to the greenhouse. This undoubtedly accounts for the low survival

The rootstock behaved as expected in response to the treatments before grafting. At the time of grafting, some were active (**L**), some were dormant (**F**), and remained dormant and some were dormant but resumed growth shortly after they were grafted (**C**). However, since survival showed no characteristic response pattern depending on treatments, (with only the few exceptions already mentioned) the conclusions must be that rootstock activity during the first 6 weeks of grafting had little or no effect on survival. Continued dormancy, on the other hand, is not desirable. This is not clearly evident in the data on survival after

[1]The 4 rootstock and 5 graft treatments for 2 species suggest a total of 40 treatment combinations However, no **cn, cs,** or **cl** graft treatments were applied to rootstocks given the short-day (**s**) treatment

1 year (3); however, the majority of the grafts that were not chilled and failed to break dormancy during the first year eventually died. Holst et al (2) also recommend chilling after grafting to obtain the highest possible survival.

Growth The dormant scions will only resume growth if they are exposed to cold or long-day conditions. Of the chilled grafts surviving (treatments **cs, cn,** and **cl**), 96 per cent had grown at the end of the experiment. Seventy-three per cent of the nonchilled grafts on long-day (treatment **l**) had shown activity, but only 4 per cent put out new shoots on short-day (treatment **s**)

The plants on long-day which had no chilling showed the first signs of flushing in the middle of March, 6 months after grafting, while the chilled plants began to show signs of activity 3 weeks after they were removed from the chilling conditions to the greenhouse.

Not only is chilling required for the maximum number of the plants to become active, it is essential if maximum growth is to be obtained Chilled grafts growing on long-day (treatment **cl**) had an average leader growth of 6 60 centimeters (2 6 inches)—almost twice the amount (3 62 centimeters or 1 4 inches) obtained with nonchilled scions on long-day (treatment **l**). Chilled scions on short-day (treatment **cs**) grew 5 46 centimeters (2 1 inches) or 17 per cent less than chilled scions under long-day (treatment **cl**).

Choice of Roostock: Mark Holst recommends that only Norway spruce be used for grafting during the late fall since white spruce suffers greatly by being kept in the warm greenhouse over winter without chilling; the following summer growth is reduced and the foliage has a poor color.

Although the tests showed distinct differences in the chilling requirements of the two species, (basically similar to those reported by Holst (l), there was no clear-cut effect of rootstock species on either survival or growth of the scions except in the unchilled scions on long-day (treatment l), and here white spruce rather than Norway spruce gave the best results. Thus, only 56 per cent of the surviving grafts on Norway spruce rootstocks showed active growth while 89 per cent grew when white spruce rootstocks were used.

Scheduling Fall Grafting of Spruce: Only well-established rootstocks potted the previous spring should be used. No special treatment of the plants is necessary aside from regular care to keep them in the very best condition.

The fact that rootstock activity apparently has very little effect on graft survival indicates that it should be possible to extend grafting over a considerable period during the fall It is not surprising, therefore, that Holst has reported successful grafting from August through the month of November He did report some decrease in survival as the season progressed.

After grafting, about 6 weeks are needed in the greenhouse to allow some degree of union formation. Thereafter, some provision must be made for chilling the plants to insure normal flushing. Where the grafts have been made early in the fall and in mild climates, this can be done in cold frames outside. Where the conditions are too severe

to permit direct removal to the cold frames, indoor cold-storage facilities can be used. The schedule I have used in that case can be summarized as follows: Grafting approximately by September 15, followed by 4 weeks at long-day (20-hour photoperiod), then 2 weeks of short-day, and finally chilling The plants can either be left in cold storage or they can be taken out after about 8 weeks (perhaps shorter) and returned to the greenhouse, where they will break dormancy in about 3 weeks. By repeating this cycle, it is actually possible to have the plants complete one period of growth in the course of the winter and be ready for renewed growth by late May Present experiments indicate that the chilling period may be cut to between 4 and 6 weeks, which should permit at least two flushes of growth during the winter season.

GRAFTING OTHER SPRUCE SPECIES

Holst has made a great many grafts of Norway spruce with a high survival percentage. Besides white spruce we have grafted nine species with suvival percentages as listed below.

Species	*Percent survival after one year*
Picea koraiensis	72
P. abies acrocona	63
P bicolor	16
P. orientalis	28
P. jezoensis V. 11	73
P. jezoensis V. 10	50
P. montigena	25
P. omorika V 17	80
P. omorika V. 16	10
P. koyamai	16
P. asperata	Final survival not determined

White spruce rootstocks were used for all these grafts. The scions used for the grafts of *P. bicolor* and *orientalis* had been in the mail for several days before they were grafted; this very likely accounts for the low survival The low survival of the *P montigena* grafts probably was due to the low vigor of the scions which came from a suppressed tree of low vigor. The low survival of *P. koyamai* is as yet unexplained; more grafts will be needed to show whether this species actually is poorly adapted for fall grafting.

GRAFTING OF OTHER CONIFERS

To my knowledge, the work which has been done with other conifers such as the pines is very limited.

Dr. C. Heimburger of the Southern Research Station at Maple, Ontario, had "very encouraging"[2] results with field grafting of white pine from the middle of September until the middle of October. Veneer grafts are used on the side of this or last year's leader of trees 2 to 4 feet tall. They are tied with a rubber band (not budding strips) and

[2]Personal communication on file at the Northern Institute of Forest Genetics, Rhinelander, Wisconsin

covered with friction tape. The graft is enclosed in a plastic bag which in turn is protected with a kraft paper bag. The bags are supported by the cut stub of the leader above the graft. They will partly disintegrate during the winter and can be removed in one operation the following spring

The method is suited for grafting in already-established plantations, but does not give the type of tree desirable for landscaping. However, the results are encouraging, and modified techniques suitable for horticulture undoubtedly can be designed.

Holst at Petawawa has found the grafting of red pine *Pinus resinosa*, and Scotch pine, *Pinus sylvestris* more difficult than the grafting of spruces He emphasizes two factors in particular: (1) Grafting in late fall in November and early December gives better results than grafting in October, (2) The grafts should be over-wintered in the greenhouse For example, in one experiment 150 grafts were made on October 8 and placed in the greenhouse on the open bench, 20 survived. The same year, 112 grafts were made December 3 and kept in closed air in the greenhouse until February 28, 85 (76 8 percent) survived. In another experiment (2) red pine was grafted on Scotch pine in the middle of October. Half of the grafts were set out in cold frames to be chilled on November 21, the rest were kept in the greenhouse The following June, 42 per cent of the chilled and 69 per cent of the non-chilled grafts survived.

When the plants are brought out on the open bench, the stock should only be trimmed, not until a couple of months later should it be completely cut back.

SUMMARY

Experiments at the Northern Institute of Forest Genetics and in Canada indicate that grafting of spruce during the fall months, September to December, is feasible. To obtain maximum survival and growth, the grafts must be chilled During the early fall and in milder climates this can be done in cold frames outside; otherwise cold storage at about 40° F for about 8 weeks is quite satisfactory. A detailed grafting schedule for spruce is discussed.

Fall field grafting of white pine is satisfactory, and techniques now in use in Canada probably could be modified to fit the needs of horticulture.

Red pine and Scotch pine apparently give the best results if grafted in the late fall, ie., November and early December. They should be over-wintered in closed air in the greenhouse to insure maximum survival.

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MR. JAMES WELLS· Mr. Nienstaedt, I am sure everybody else in the room, together with myself, is busy trying to adapt what you have said to the economical production of spruce.

I have a hypothetical question. If we all rushed home and grafted some spruce we can presume that the union should be complete in, say, six to eight weeks. On a short day and normal conditions in the greenhouse, this brings us to about the middle or end of January. Now, if we put them outside under cool conditions, which would normally exist at that time, do you think that we would get better development of the scion? Do you follow me?

* * * * *

MR NIENSTAEDT· Let me just get this straight You have your plant on a short day without any chilling in the greenhouse Then your question is, "Should you move them out to get normal development the following spring, or should you not?"

You would definitely have to chill them if you wanted normal development next spring. As in all cases here, except two plants in 96 I had not chilled and kept on a short day, they never developed a shoot until the following July.

MR. WELLS: But the development of the apical shoot is of prime importance in the development of a symmetrical tree, and one of the arguments for fall grafting, which the Dutch pursue Following this procedure the development of the apical part in the spring is normal, whereas if you graft at the end of February and March, you do not get the normal development of the apical part. Therefore, I thought that if we were to set back our grafting time to say next week, we would enable the plants to unite, and then they could be chilled prior to spring when we would get normal growth.

MR NIENSTAEDT· That is right. Maybe I didn't get your schedule quite right. Did you say grafting on September 15?

MR WELLS No, I said grafting on December 15

MR. NIENSTAEDT: Oh, by December 15 you probably would have had enough chilling, I would think, to get normal development.

MR. RICHARD H. FILLMORE (Durham, N.C): Did I understand that long day, at least in part, will substitute for chilling and bring about normal resumption of growth of the plant part?

MR. NIENSTAEDT. The general response that you get if you use the long'day is that it does compensate in part for the lack of chilling. However, again to repeat, whereas 96 per cent of the plants that had been chilled came through, only 72 per cent of the scions on long day and no chilling came through

DR. CHARLES HESS On your plants that received only partial chilling, do you find that the lateral buds tend to break?

MR. NIENSTAEDT: I would say yes You do get, with partial chilling, very irregular bud development. In addition, you get the same kind of irregular response on the rootstock on long day without chilling

DR. CHARLES HESS. The reason I brought this up is because with our pink dogwood we found the last bud to break under deficient chilling requirements was the terminal. This may substantiate the point you brought up, Jim, that poor development of the terminal bud on the spruces by late grafting would be due to improper chilling

One important thing I think you brought out, however, is that when your scions have already received sufficient chilling, when they were taken in February, they could carry on normally. In other words, they won't require any further chilling. Or do they have to receive this chilling after grafting?

MR. NIENSTAEDT. I don't think it makes much difference. In terms of physiology, it shouldn't. But I think perhaps interference with the scion at the time of grafting in February is sufficient to interefere with normal development of the bud Apparently I got less interference by doing it in the fall and then chilling. That apparently is the type of response you have.

MEMBER· We know very little about spruce, of course, in the South, but I wonder if the chillings after the union is made would apply to juniper grafts. We seem to get good union and when I think they are on their way we lose them

MR. NIENSTAEDT: I must admit ignorance on the question. I do not know how juniper responds. You can't make a general statement about these things because sometimes they do not need chilling and sometimes they do not respond So I wouldn't want to commit myself.

MODERATOR HALWARD: Thank you, Hans. May I also thank the other speakers this morning for their detailed preparation, their fine delivery and the cooperation they have given the Moderator

PRESIDENT STEAVENSON Ray, you did a fine job. You are exactly on the minute.

We all stand adjourned until one-thirty o'clock.

The meeting recessed at twelve o'clock