HETEROPLASTIC GRAFTING IN THE GENERA ACER, FRAXINUS, PICEA AND ABIES

John A. Pitcher

State University College of Forestry
at Syracuse University
Syracuse, New York

The College of Forestry at Syracuse is in the process of establishing an arboretum of grafted specimens of available species and genera capable of surviving under the climate of the Northeast. This arboretum has several objectives:

(1) To provide an area where many different species are available at any time;
(2) To produce a large gene pool, for further genetic studies;
(3) To serve as a gene-storage plantation for valuable material such as apparently resistant clones;
(4) As an area where a hybridization program involving many different combinations could be conveniently carried out.

The arboretum program has been underway at Syracuse since 1956, under the direction of Dr. Friedrich Klaehn, and many valuable species have been collected, grafted, and are now growing in the arboretum. In addition to the four genera under discussions, Pinus, Larix, Pseudotsuga, Betula, Prunus, Ulmus, Populus, and Quercus species are well represented. Future plans call for the inclusion of several more genera, including Liriodendron and Fagus.

In connection with this program, a study was initiated to determine the grafting compatibility of the several species collected for inclusion in the arboretum. It would be valuable to have this information available before undertaking a larger grafting program such as that involved in the establishment of seed orchards for interspecific hybridization and arboretums for the preservation of valuable phenotypes. This paper is the first year's results of a part of this study in compatibility.

Materials and Methods

The four genera selected for the study were Acer (maple), Fraxinus (ash), Picea (spruce), and Abies (fir), giving a representation of both hardwoods and softwoods. Forty-two species were involved in the study, including the controls. Thirty-eight heteroplastic combinations were attempted and 664 grafts made (table 1).

Because grafting is a technique involving art as well as science all the grafting was carried out by the author, to eliminate as much as possible the variation due to personal technique and to keep the technique constant across clones and between genera.

Grafting was divided into two phases; a greenhouse grafting program using the College greenhouse and a field grafting program using stocks set out at the College Experiment Station.

Potted rootstocks were brought into the greenhouse from outside in late December and arranged in blocks by genera and numbered. Random numbers were assigned the clones to be grafted to eliminate chance position effect.

Temperature in the greenhouse compartment was lowered to 40° F, (5°C) and slowly increased to 65°F. (18°C) over a period of six weeks to force the rootstocks into growth. Photoperiod was increased to approximately 14 hours by the use of artificial light.

Acer saccharum rootstocks were 2-3; Fraxinus americana, Picea abies and Abies balsamea rootstocks were 2-2. All the rootstocks were in good condition and apparently healthy. With the exception of Acer all the stocks were more or less uniform in size within the genus. Some of the Acer rootstocks had been used previously and the unsuccessful grafts removed. These rootstocks were still suitable for regrafting and therefore were used as the supply was limited.

Scion material -was collected from Highland and Durand-Eastman Parks in Rochester, New York, where there is a large collection of identified exotics. Three collection trips were made and scions collected from the same tree each time. The first two collection trips, to gather material for the greenhouse grafting phase, were made on January 27 and February 18, 1959. The scion material was placed in polyethylene bags, packed with snow, tagged, and brought at once to the college where it was stored outside the greenhouse at temperatures below freezing.

Greenhouse grafting-Grafting was started on February 3, 1959, and carried out over a period of nearly seven weeks. As the rootstocks reached the point of development where the buds were just opening, they were grafted. A side-veneer graft was used in all cases, wrapped with rubber grafting strips and sealed with warm grafting wax. For a discussion of grafting techniques, refer to Hartmann and Rester (1959).

Table 1 summarizes the results of the greenhouse grafting program.

Field grafting.--The second phase of the study was carried out at the College Experiment Station. The area is designed specifically for field grafting purposes and consists of several species of trees set out in rows. Because this study has a secondary purpose, i.e., that of producing an arboretum, the clones were assigned by random blocks within the rows rather than by individual numbers. Since the area was fairly uniform, the rows to be used were not border rows and the study did not lend itself to statistical analysis, it was felt that this method could be applied.

A third collection trip was made to Rochester on April 16 to secure fresh scion material for grafting in the field. Grafting was carried out from April 18 to 24, inclusive, and also on May 2 when the ash stocks were grafted. All rootstocks were 2-3 at the time of grafting.

Only one scion was placed on each of the coniferous stocks and a side-veneer graft was used. On the maples and ashes two scions were used; one as a side-veneer graft and the other as a bottle-graft. The graft was wrapped with rubber grafting strips and painted with an asphalt emulsion. The completed graft, including part of the rootstock, was covered by a polyethylene bag (18"x6"x3") to increase humidity and prevent dessication. This, in turn, was covered by a large kraft paper bag to provide shade and reduce the temperature inside the plastic bag. In early June all the grafts were checked and the bags, both polyethylene and kraft, were removed in the case of maple and ash, or a split was made on the north side of the bags in the case of fir and spruce. At the end of June the bags were removed from the fir grafts and in late July they were removed from the spruce grafts.

Table 1.--Summary of greenhouse and field graftings

Scion species[1]	Greenhouse graftings: Attempted	Greenhouse graftings: Successful	Field graftings: Attempted	Field graftings: Successful
	Number	Percent	Number	Percent
Acer				
macrophyllum	11	0	8	0
saccharum monumentale	8	25	8	0
platanoides columnare	10	0	8	12
campestre	9	0	8	0
monspessulanum	11	27	8	25
Miyabei	9	0	8	0
griseum	11	0	8	0
Mono	9	0	8	0
nigrum	10	10	8	12
grandidentatum	9	22	8	0
cissifolium	11	0	8	0
leucoderme	11	0	8	0
cappadocicum	9	0	8	0
rubrum	9	0	-	-
spicatum	-	-	8	25
nikoense	10	0	8	0
saccharum (control)	9	0	8	25
	156	5	128	6
Fraxinus				
chinensis acuminata	20	25	12	75
quadrangulata	15	0	12	0
Ornus	20	35	12	50
biltmoreana	16	25	12	75
americana (control)	22	0	24	92
	93	17	72	64
Picea				
asperata	10	70	9	44
Glehnii	10	90	9	22
Maximowiczii	10	30	9	0
polita	10	100	9	22
Omorika	10	50	9	0
bicolor	10	70	9	67
jezoensis hondoensis	10	100	9	11
Schrenkiana	10	0	9	0
Koyamai	10	90	9	22
mariana Doumetii	10	10	9	44
Abies (control)	10	80	9	44
	110	63	99	25
Abies				
concolor	6	100	5	100
Nordmanniana	6	100	5	100
recurvata	6	17	5	100
cephalonica	6	83	5	100
sachalinensis	6	100	5	80
homolepis	6	67	5	20
lasiocarpa	6	100	5	40
Veitchii	6	100	5	80
balsamea (control)	6	100	5	100
	54	85	45	80

[1] Botanical names according to Rehder, 1956.

A count of the survival was made on August 6 and the results are shown in Table 1.

Results

Abies.--Of the four genera under consideration, *Abies* was by far the easiest to graft, yielded the highest percent take, formed the best union, and did it sooner than any of the other genera. It was also the first to break dormancy in both the greenhouse and the field and required the least care. The rootstocks were cut back completely on most of the greenhouse stock after three months.

In the greenhouse Abies recurvata did poorly and only one broke dormancy. The other eight species did well, with only A. cephalonica and A. homolepis not showing 100 percent take (table 1).

The conditions for the fulfillment of the requirements of dormancy for most forest tree species are largely unknown, However, the ecotypic variation in time of bud-bursting is known for certain species and could provide a plausible explanation for the apparent inability of A. recurvata to leaf out and form a union, for in the field this species was excellent--producing 100 percent take. The difference in time between the greenhouse grafting and the field grafting was nine weeks in this case.

The possibility of a mechanical dormancy due to the highly resinous nature of Abies buds was dismissed when treatments with alcohol solutions or cutting the tips of the buds, a technique which has been used quite successfully by Dr. Ljunger (1955), Ekebo, Sweden, on oak and beech grafts, failed to produce any increase in bud bursting.

Length of time in storage could be a factor in the case of A. *recurvata*, but it seems unlikely as it was grafted two weeks after collection while four other Abies species were grafted four weeks after collection and three of them took100 percent while the fourth, A. homolepis, was 67 percent successful.

In the field Abies did nearly as well as in the greenhouse, but A. homolepis and A. lasiocarpa were not as successful (table 1).

Picea.--Certain Picea species apparently have a deep dormancy. Scions of spruce grafts made in early February in the greenhouse did not show signs of breaking dormancy until at least sixty days had elapsed and then they were sporadic with certain clones showing a variation of fourteen days up to seven weeks. The spruce grafts did not show any apparent effects from being grafted on the rootstocks for so long a period without visible signs of growth and once the new shoots began to elongate they proved to be healthy and the union was firm and well-healed. Some buds did not break at all and there was no new growth for the current season, yet the needles were green and the buds, when broken off, were green and moist inside. This condition was especially true in P. polita where very few new shoots exist, yet the unions were strong and well-knit.

P. Schrenkiana was the only spruce that did not graft at all. This is probably not a case of incompatibility as other grafts of this species on Norway spruce stocks exist. Other species which did poorly were P. Maximowiczii and P. mariana Doumetii. In the field all the P. Omorika grafts died but in the greenhouse there was 50 percent take.

Fraxinus.--Ash was about the reverse of spruce for it grafted poorly in the greenhouse but was excellent in the field. This reversal is likely due to the deep dormancy of Fraxinus species and also to the length of storage of the scions before they could be grafted on the slow developing rootstocks in the greenhouse. In the field, ash was also the last species to break dormancy.

In the greenhouse the stocks had to be grafted as they broke dormancy. Because of the random design employed, only one or two grafts of any one species were done on any one day. This prolonged the period of grafting and may have affected the results and given the low percent take obtained, Only three species proved any success in the greenhouse, the other two hardly developed at all (table 1). Low humidity in the greenhouse, due to a conflict with other interests, may have caused some of the mortality. Many grafts, recorded as dead, actually burst their buds and leafed out for a time only to shrivel and die a few weeks later. Those that are still alive are, for the most part, in poor condition and quite weakened.

In the field ash was quite successful, with the exception of F. quad rangulata. Discounting this species the over-all take was 77 percent. F. quadrangulata was the only ash species that did not graft at all. No record of this combination has bee found or reported so far. The combination of F. americana*quadrangulata[1] could well be studied further as it now seems to be compatible on the basis of what evidence is available.

Acer.--Grafting in the genus Acer was discouraging. Of 267 attempted heteroplastic graftings, encompassing sixteen species within six sections, only fourteen grafts survived but they represent four of the sections of Acer. The poor survival, in both the greenhouse and in the field, indicates that the physiological, morphological and anatomical differences that exist between the various species and sugar maple stocks are so gross as to give only rare survivals. Technique may have been at fault here but others have tried various techniques without much better success. It seems that as long as the technique was consistent, the differences would still exist, though perhaps not to so great a degree.

As with ash, certain of the maple species leafed out and appeared to be growing successfully, only to shrivel and die in a few weeks.

Discussion

Conditions in the field were particularly severe with respect to te mperature and humidity. Although the polyethylene bags served their purpose in maintaining high humidities it was extremely difficult to keep the temperate down to normal levels. The kraft paper bags weakened in the rain, separating along the seams, exposed the plastic bags to direct sunlight on

[1] The symbol * denotes a graft with the stock species always preceding the *symbol and the scion species following it.

clear days. Although no temperature measurements were made inside the bags, measurements under polyethylene sheets covering seedbeds have been made on sunny days and ranges up to 135° F. (57.2° C.) recorded (Engelken, 1959). Al though life may continue at high temperature, growth ceases because photosynthesis cannot keep up with the catabolic processes (Went, 1953). Growth is necessary for the formation of the union. These high temperatures seem to be the main cause for the failure of the spruce in the field. Many root -stocks as well as scions were killed.

Two types of grafts were used on the hardwoods in the field. A side-veneer and a bottle graft were used on each of the Acer stocks and one-half of the Fraxinus stocks were bottle grafted. Both methods were successful but the bottle grafting had an advantage in that it could supply the scion with water while the union was forming.

The fact that intersectional grafts were successful refutes the statement by Bailey and Bailey (1941) that using a stock and scion of different taxonomic units is usually difficult, if not impossible. They further noted that, generally, the grafting of different sections of the Acer genus is impossible.

Gourley and Howlett (1941) have summarized the problem of grafting of different taxonomic units. They stated that while no grafting is really im possible, the more widely divergent the stocks and scions are, the poorer will be the survival.

The grafts studied in this paper are still in their first growing season. It is therefore too early to make any concrete statements on compatibility as many grafts may yet succumb. Some of the earlier grafts of Acer in the arboretum program died when the rootstock was pruned back completely, suggesting the synthesis of an essential component by the leaves of the stock but not by the leaves of the scion.

This study points up that much more knowledge could be gained in the area of heteroplastic grafting, particularly with the genus Acer.

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DISCUSSION

NIENSTAEDT. Dick, I would like you to explain to us in more detail how you intend to use the tissue culture technique as a tool for determining resistance to the chestnut blight fungus.

JAYNES. As indicated it seems to be a very promising technique. We have no adequate tests for determining blight resistance of trees in the juvenile stage. Even in older maturing trees there is some question of the level of resistance. By using tissue cultures, cambial tissue of trees with different genetic backgrounds can be grown under specified standard conditions. The blight fungus might then be introduced into these test tube cultures. Providing a differential reaction resulted that could be correlated to the genotype of the host tissue used, we would have a wonderful system for further analysis of disease resistance. It would allow us to develop a technique for determining adult resistance of a tree while it is still in the juvenile state. And since one is working with material grown in the laboratory, under much more constant conditions than occur under natural conditions, further analytical work on the chemistry of disease resistance becomes an easier task.

CALLAHAM. Don't you have any suitable inoculation tests for use on mature trees? Cant you inoculate by transfer of fungus mat or something like that?

JAYNES. We can inoculate the juvenile trees, but blight resistance seems to be a characteristic of all juvenile trees. If a mature tree is inoculated and it does not get the blight then you can say with some assurance that it is resistant. But if the trees are in the juvenile stage, whatever the juvenile stage is, you can inoculate them from now until Dooms Day and some won't get the blight. Yet leave them, and next year they may be blighted from spores that blow in.

RENDLE. The speaker referred to desirable wood characteristics in chestnut. Could he enlarge on what he considers to be desirable characteristics?

JAYNES. I am speaking in very broad, general terms when I speak of the desir able characters of chestnut. One of the most important is rot resistance. Of course one of the bad traits is the checking which it would be nice to try to overcome in our hybrids.

SATOO. Dr. Chandler, do cuttings from laterals grow upright or remain lateral?

CHANDLER. We have quite a few of these lateral cuttings in the nursery and they are not making erect trees like the terminal cuttings do. For this reason we have been delayed in our field planting of clonal material since we will use only terminal cuttings. Tetraploids obtained by soaking seeds in aqueous solutions of colchicine also have this prostrate habit of growth.

GABRIEL. I have a question for Gerhold. Did you make the statement that long day-length and low temperature minimized yellowing?

GERHOLD. Yes, by use of additional light after normal day-length is over, discoloration was prevented. This treatment started in August and was continued until December and during this period there was no measurable discoloration.

GABRIEL. On the same latitude but on different elevations would you have a tendency under natural conditions to have the same coloration as your latitude changes? You have the same day-length, but you have different temperatures.

GERHOLD. I think that question could be answered in two ways., one is that it has been stated that the natural variability of Scotch pine in its native range is such that at higher elevation the trees are more prone to discolor. This is something that has developed probably over a long period of time through natural selection. If you have plantations of the same seed source at different elevations, I would expect that there would be a difference, but I am just guessing here.

GABRIEL. The selection agents acting at different elevations; would it be day-length and temperature alone, or are there some others?

SIMONDS. We find that on different aspects, when you have a plantation that goes around a hill, trees on the side away from the wind will stay green longer than trees on the southwest where we get our prevailing winds, particularly the cold fall winds. Same stock, same plantation but just a difference in aspect and protection from the wind. I'd like the make this other comment if any of you are interested in Christmas tree breeding. It was brought out last night in a couple of pictures that the branching angle and straightness of the stem are two other factors of very great interest to Christmas tree growers. Another factor would be slowness of growth so that you have a minimum of shearing; and shorter needles seem to show up better. Some of the strains from Europe have very long, stiff needles which are not too desirable for Christmas trees.

GERHOLD. There is this agent for selection but I don't know what the agent would be. I don't know of any indication that there is any direct selection for needle color but because of this close correlation with the winter climate I would guess that there might be some connection between these two factors, and possibly it is an indirect selection for needle color.

GABRIEL. Why don't you permit your men to sell your discolored trees as golden hybrids.

SIMONDS. That has been done, actually they have been sold as golden Scotch. We can overcome the yellowing with flocking and actually the trees that are more open grown and less desirable for normal Christmas trees are the ones that are best for flocking. Flocking is the process where they use two spray guns; one sprays an adhesive and the other blows on the material known as flocking. It is short pieces of fiber, usually nylon. They may be most any rayon or any fiber of different colors.

CALLAHAM. The Engler experiment that you talked about in Europe gave the first indication of this elevational variation in foliage winter coloring. This was a plantation experiment where seeds from different elevational sources were planted at the different elevational sources. The results demonstrated the heritability of winter coloration. One of the selective forces that was suggested was the higher direct insulation which occurs at high elevations which could very well account for the kind of phenomena that you found.

CONNOLA. I'd like to ask what time of year you did your fertilizing? Was any of it in the fall?

GERHOLD. We did some fertilizing. Fertilizers were applied in water solu tion directly to the needles in the fall after discoloration was under way. However, the experiments I referred to were in the nature of foliar analyses of the needles in which the elements were analysed and in the same needle samples the pigments were analyzed and then correlations were attempted, unsuccessfully, I might add. The fertilizer experiments resulted in no improvement to the needle color and this goes along with a lot of other fertilizer experiments that have been conducted to try to improve the needle color. The only cases in which improvement has been made are those in which there has been some nutrient deficient in the soil. But this is a different phenomenon. It is visible also in the summer time whereas the color change I speak of is seasonal; it becomes visible to the eye perhaps in September or October.

ADAMS. We appreciate the fact that the attempt to get the green color in Scotch pine is for the purpose of raising Christmas trees. Of course., up here in Vermont we hope you don't succeed too well because we want to sell our balsam and spruce. But you might be interested in a situation I had last Christmas. We sell some greens to florists and to wreath makers and in one case we cut them a little early, before Thanksgiving. They turned yellow in storage and the florist objected seriously, so we cut some more. Then I went to see him and sold him on the idea of this yellow color on the Scotch pine and how beautiful this would be in mixture with other species. So the idea occurred to me at that time that we accept this yellowing in Scotch pine; try a merchandising process, recognize the fact that they are going to yellow, and sell yellow trees.

GERHOLD. The United States grades that have been set up do not object to the yellow color of Scotch pine. They only object to unnatural coloration and since this phenomenon is a natural process it does not violate any of the grade rules.

I have a question for Dave Cook, I've never seen a plantation of tamarack. Do these exist and if so how do they compare with some of the exotics?

COOK. On the best upland sites, tamarack will grow in height perhaps 80 percent as fast as the average of Europeans; in diameter, they will be only about 50 percent. They are tall, slim, thin-crowned trees, don't carry the weight of foliage that it takes to grow a good tree. Perhaps there is something genetic about it because the tremendous outbreak of the larch sawfly in the 1880's just about cleaned the population. We don't know whether it took all the good genotypes out of it or not.

LARSSON. I've a question for Mr. Cook concerning the plus trees of larch he mentioned. No matter how nice a tree looks it still has to be utilized, and I was wondering if there have been some studies on the wood qualities of these hybrids and exotics. I would think that would be an important item to include in your plus tree record.

COOK. I deliberately stayed away from any mention of that because this is a little bit out of my field. Dr. Chandler has some material now at the College of Forestry in an attempt to determine whether the big trees and the little trees in the same stand have different wood characteristics, We do know that the technical characteristics of the Dunkeld hybrid larch are perfectly satisfactory but whether they are superior or not, we don't know. And I haven't bored into any of my own giants and I don't think anyone else has. A giant is not something one sacrifices.

LARSSON. I have one more question. This is just a suggestion we are toy ing with at present with a different species. Since you can get various degrees of pluses in high quality trees, we thought of giving them numerical values so that a tree of 80 would be of certain qualities different from a tree of 90; each quality would have a number with some signif icance. It would have to be worked out with a group of foresters to find out just what evaluation to put on each quality of the tree you are trying to evaluate. I was wondering if you had considered that.

COOK. We have thought about it, but I believe that comes in the next stage. After we get a roster of a couple of hundred plus larches, then it will be time to go in and reduce that number perhaps to 40 or 50 super select and then we will need a numerical evaluation. I would be reluctant to try one now.