3 Romberg, L D 1942 Use of nurse seedlings in propagating the pecan from stem cuttings *Proc Amer Soc Hort Sci* 40 298-300
4 Wheat, J G 1964 Rooting of cuttings from mature Douglas fir *For Sci* 10 319-320

VOICE: At what stage do you cut off the rootstock?

JOE WHEAT: When I investigate the grafts in the fall — October and November. If the inarch is rooted, then I remove it; I don't bother to cut it. I just take them and tear them apart. It is removed then because it will have its own foliage by then and will have an active root system started. I would almost prefer to let the inarches go 12 months because I feel that there are some that were starting to root that I would not have lost if I had left them a little longer. I have to jump ahead a little bit because I want to get them out of the lath-house before winter and back into the greenhouse.

VOICE: Could you use two or three inarches on one root-stock?

JOE WHEAT: You could on some of the huskier ones. Actually I use two. I find I have better results with ordinary cuttings, or with these inarches, by using a sterile medium, something like clean masonry sand or vermiculite, rather than soil. They will root directly in soil but there is a larger initial loss, just as with ordinary cuttings, because of the pathogen problem in unsterilized, normal soil.

MODERATOR DOUGLASS: The next speaker, unfortunately, is absent today. Dr. Oscar Sziklai is in Europe attending the International Union of Forestry Research Organization. However, Dr. Phillip Haddock, University of British Columbia, has kindly agreed to give Dr. Sziklai's presentation on grafting techniques in forestry. Dr. Sziklai is associate professor at the University of British Columbia, teaching forest genetics.

GRAFTING TECHNIQUES IN FORESTRY

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Apomixis is a general term used for all types of asexual reproduction that replace or substitute for sexual methods. Agamospermy includes all types of apomictic reproduction in which embryos and seeds are formed by asexual means. In the case of vegetative reproduction, the propagules are not produced from seed but as a result of cell multiplication by mitotic division. Most plants have the capacity to reproduce vegetatively from roots, stems, branches and leaves; and even in a few cases, the propagules occur within the inflorescence as is the case in vivipary.

Layering, rooting and grafting, as different means of vegetative propagation, have been widely used in horticulture from ancient times. Rooting is the most widely used method of asexual reproduction in forestry practice. Rooting by stem cuttings, mainly in the genera *Populus, Salix* and *Platanus* is a well developed practice in intensive forest management. Layering is of a more limited application and is used mainly in experimental studies when other means of vegetative propagation are not successful.

The importance of grafting in forestry practice originated from a recent development of forest genetics and forest improvement. Selection of desirable phenotypes of certain species in the forests necessitated the propagation of the "plus trees" into a more accessible environment than those in which the plus trees were standing. "Clone banks" and later "seed orchards" were established. Homogeneous sites were selected to provide a basis for objective evaluation of phenology and growth characteristics of clones. These "clone banks" and "seed orchards" were also more ideally suited for carrying out controlled pollinations than the ortets from which the scions were collected.

Dr. Syrach Larsen's pioneering work on grafting Scandinavian forest trees in the middle 1930's was the beginning of the realization of the importance of grafting in forestry. This trend was further intensified by work in Sweden, in the Southeastern pine region and in the Douglas fir region of North America. Grafting is now widely used in forestry practices mainly for the following purposes (Wright, 1962): — to facilitate controlled pollination, to hasten cone production in selected breeding programs, to produce species hybrids, to determine total genetic variance, to preserve superior germ plasm, and to provide genetically uniform material.

The following three basic types of grafting are recognized (Mergen, 1954) depending on the genetical constitution of the scion and the rootstock:

(a) autoplastic grafting: scion and rootstock are of the same genotype.
(b) homoplastic grafting: scion and rootstock belong to the same species but differ genotypically.
(c) heteroplastic grafting: scion and rootstock differ genetically and belong to a different species, genus, or even family.

Of the above-mentioned three types, homoplastic grafting is the most widely practised in forestry, while the other two types — autoplastic and heteroplastic — have a more limited application, mainly in research work. Interestingly enough, Dr. Klaehn's survey on grafting methods on forest trees conducted in 1962 (Stairs, 1964) gave an amount of 800 interspecific and approximately 160 intergeneric and interfamily heteroplastic graftings.

> "As to the success of grafting, the main skill is to join the inward part of the scion to the sappy part of the stock, closely but not too forcibly; that being the best

and most infallible way by which most of the quick and juicy parts are mutually united, especially towards the bottom." (Evelyn, 1663).

This old, but not outdated statement, emphasized the importance of cambial union of scion and rootstock, as one of the cardinal requirements for successful grafting. Fulfilling this requirement, numerous grafting methods have been developed.

Garner (1958) listed 46 different methods (Fig. 1, 2, 3). Nienstaedt *et al.* (1958) mentioned only 13 of them applied in forestry practice. (Table 1).

Table 1 The main divisions of grafting methods and the number used in forestry

Type of Grafting	Number	
	Listed by Garner	*Used in forestry*
Approach grafting		
a) True approach grafting	5	2
b) Inarching	2	1
c) Bridging	1	1
Detached Scion Grafting		
a) Bud grafting	9	2
b) Inlay grafting	4	1
c) Apical grafting	12	2
d) Side grafting	8	3
e) Bench grafting	5	1
Total	46	13

The characteristic feature of approach grafting is that the two plants brought together retain parts above and below the union. After union formation, the stem portion of the rootstock above the grafting point and the root part of the scion below the grafting are cut off. The spliced approach graft has limited application in forestry, on birches and other species difficult to graft.

Seed production could be obtained on detached branches, as demonstrated by Johnsson (1951) in *Salicaceae, Betulaceae,* and *Ulmaceae* families, using bottle grafting. Mirov (1940) successfully used inarching on white pines, southern and northern hard pines and on spruces, while Graves (1948) recommended it for hardwoods. Nienstaedt and Graves (1955) also used inarching to bypass diseased stem portions of chestnut. Diller (1958) for the same reason, worked with bridging.

Bridge grafting is selected mainly for species such as white pines and southern hard pines that are difficult to graft.

Detached scion grafting is less cumbersome than approach grafting, consequently a large number of different techniques are currently practised. Nienstaedt *et al.* (1958) listed nine different methods of these used in forestry.

Shield budding is practised mainly on hardwoods, but it is also used on white pines and northern hard pines. In patch budding, part of the rootstock is replaced by the same size of single bud, removed from the scion. Success is most likely if both scion and rootstock are the same age. The technique is used in hardwood, northern and southern hard pines.

Among the different apical grafting methods, the spliced graft and the wedge or cleft graft are techniques frequently employed in forestry. The ease of making cut surfaces on the rootstock and on the scion, and the excellent knitting in splice grafting, would lend the method to wider application than exists at present, but because of the difficulty of tying, the weak union, and the equal diameters needed of rootstock and scion, this method is not applied frequently in forestry. It is used mainly in the grafting of hardwoods, but northern hard pines, and recently Douglas fir in British Columbia, also have been grafted by this method.

The wedge or cleft graft is a preferred method of grafting in forestry. The ease of application and the good knitting result in the wide use of this method among hardwoods, pines and Douglas fir. Orr-Ewing and Prideaux (1959) recommend using veneer crown graft, a modified version of wedge graft, for Douglas fir when the rootstock and scion are not equal in diameter.

The side cleft graft, veneer side graft, and side tongue grafts are the three mainly used side grafting methods in forestry (Nienstaedt *et al.* 1958). White pine is grafted by all three grafting methods. Only side cleft and veneer side grafts are used in the case of southern hard pines. Northern hard pines are grafted with veneer side and side tongue grafts, while veneer side graft is used in the case of spruces.

Bench grafting applies to any grafting processes performed on bare rootstock and scion regardless of the technique used. Without proper environmental conditions the bench graft, when it is completed on the stem portion of the rootstock, is seldom successful. On the other hand, if the grafting involves roots, the survival may be quite high. One method of x-cutting or root approach graft described by Jackson and Zak (1949) was used successfully in *little-leaf* disease study of shortleaf pine.

During the previous part of my presentation I briefly described the different grafting methods practised in forestry. Unfortunately, it is difficult to attach to these grafting methods a frequency number which should express how often they are used in practice. But as a rough estimation on how frequently the different grafting methods are used in forestry, I would like to refer to Table 2, which is based on Klaehn's survey on interspecific heteroplastic grafting.

Table 2. Frequencies of the basic type of grafting methods in the case of interspecific grafting; based on Stairs (1964) report

Genus	Basic type of graftings (after Klaehn[1])									Total
	1	2	3	4	5	6	7	8	9	
Gymnosperms										
Abies	53	25	—	3	—	5	—	—	—	86
Cupressus	—	—	—	—	—	1	—	—	—	1
Larix	28	14	—	1	—	3	—	—	—	46
Picea	33	16	—	1	—	4	6	—	—	60
Pinus	77	36	—	29	—	96	1	2	—	241
Pseudotsuga	2	2	—	—	—	—	—	—	—	4
Total	193	93	—	34	—	109	7	2	—	438
Per cent	44.1	21.2	—	7.8	—	24.9	1.6	0.4	—	100.0
Angiosperms										
Acer	8	—	—	14	2	—	5	—	3	32
Alnus	11	—	—	4	—	—	5	—	—	20
Betula	1	—	—	—	—	—	5	—	—	6
Caragana	—	—	—	—	4	—	—	—	—	4
Crataegus	—	—	—	—	—	—	—	—	1	1
Castanea	1	—	2	—	4	1	11	—	—	19
Eucalyptus	—	—	—	—	—	4	—	—	—	4
Fraxinus	6	1	—	4	2	1	1	—	2	17
Juglans	—	—	1	—	—	1	1	—	1	4
Liquidambar	2	—	—	—	—	—	—	—	—	2
Populus	6	1	1	7	39	6	3	—	—	63
Prunus	3	—	—	—	—	—	1	—	7	11
Quercus	—	5	—	—	—	76	—	—	10	91
Salix	—	—	—	—	2	—	—	—	—	2
Sorbus	—	—	—	—	—	—	—	—	47	47
Tilia	4	—	—	—	—	—	—	—	21	25
Ulmus	5	—	—	6	1	1	1	—	—	14
Total	47	7	4	35	54	90	33	—	92	362
Per Cent	13.0	1.9	1.1	9.7	14.9	24.9	9.1	—	25.4	100.0

[1]Basic type of graftings (after Klaehn).

1 — side graft
2 — veneer graft
3 — T-graft
4 — bottle or approach graft
5 — whip graft (splice graft)
6 — cleft graft
7 — triangle graft (inlay graft)
8 — succulent graft
9 — budding

Bridge (approach) grafting (4) is used in 7.8% of the cases in Gymnosperms and 9.7% in Angiosperms, playing only a limited role in both groups compared to the detached scion grafting methods.

Bud grafting (9) was reported only in Angiosperms with a frequency of 25.4%. Inlay grafting (7) is used more frequently in Angiosperms (9.1%) than in Gymnosperms (1.6%). Apical grafting (5) and (6) is the most frequently applied method in Angiosperms with 38.9% while in the Gymnosperms it is used with 24.9%. Side graftings (1), (2) and (3) take up the largest percentage (66.3%) in Gymnosperms but only 16% in Angiosperms.

The techniques listed above, as used in grafting of forest trees, form only one of the steps required to obtain successful grafts. Certainly, the importance of providing uniform contact between the cambia of rootstock and scion is not disputed at all and the grafting methods listed here serve the purpose effectively. But there are other aspects of grafting which are also important: — selection of rootstock, collection and storage of scionwood, time of grafting, rootstock-scion relationships at the time of contact layer and callus formation, and the time of callus differentiation.

For successful grafting, besides the more desirable techniques, the last-mentioned points should be considered. Although information on them is sketchy at this time in relation to forest trees, we hope that research projects currently under way on this topic will soon provide the answers.

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MODERATOR DOUGLASS: Our next speaker is Dr. Donald L. Copes, Associate Plant Geneticist, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon. Dr. Copes has worked during the past three years primarily on grafting incompatibility in Douglas fir. This mysterious and aggravating factor has been a major bottleneck to foresters and researchers in establishing seed orchards, clone "banks", breeding archives, and other forestry endeavors which involve grafting. Some of the finest Douglas fir clones thus far discovered simply won't live with their rootstocks. Discovering the reasons for the incompatibility, and hopefully finding some solutions, has been handed over to Dr. Copes.