THE PROPAGATION OF *MALUS* SPECIES

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Fruit trees, and apples in particular, are usually composed of two genetically distinct parts the root-system developed from the rootstock, and the stem or branch system, grafted upon the rootstock, both functioning together as a single living organic unit On the other hand most other economic plants are produced either from cuttings or from seeds, and consequently their root and shoot systems are of the same genetic origin and constitution Apple rootstocks may be raised either from seeds, in which case the stocks are of miscellaneous genetic origin, or they may be raised by a vegetative method such as stooling in which case the stocks are uniform in their genetic composition. In practice there is a range of the vegetatively raised rootstocks each with its own special characteristics.

The choice of a rootstock is governed by the aims of the tree propagator. In the early development of the apple industry in Continental Europe. The British Isles and in North America, fruit growers sought trees of vigor and longevity. Until recently seedlings have been regarded as the most suitable understocks for such requirements, but certain of the vegetatively propagated rootstocks are now shown to possess vigor. For our present purpose it is sufficient to realize that the seedling rootstocks are generally regarded as "vigorous" but that they are of non-uniform genetic origin; while on the other hand certain vegetatively raiesd rootstocks are also vigorous, but of uniform genetic origin. Some vegetatively raised rootstocks produce trees of medium vigor and still others are associated with extreme dwarfing and precocity. In practice, therefore, the propagator may choose a vegetative rootstock that will give him a tree with the desired degree of vigor and precocity.

It will be realized at once that the apple tree presents a number of complex problems. What, in fact, is the nature of the so-called rootstock influence? Does it depend upon the ability of a root-system to absorb substances from the soil or upon the ability of the stem to transmit these substances or upon some combination of both? The literature on the subject has now assumed considerable proportions; in fact, it is so large that a general review is out of the question. From the data on rootstock and scion relationships presently available, it seems that no one plant part dominates the entire tree. The rootstock may influence the scion at one time, the intermediate stempiece at another, and the top scion at still another, all indications of the complexity of rootstock and scion relationships Actually, it could hardly be otherwise since both scion and rootstock are so very dependent upon each other for the means of subsistence. There is evidence to suggest that in some cases it may be the "nature of the union" as when EM IX gives it characteristic dwarfing and precocious effect. Fundamentally, however, the nature of the union depends not only upon the co-ordination of the many stem tissue functions but also upon the sheer mechanical problem of obtaining xylem and phloem continuity in tissues which may or may not have the same cell size, shape and structure. Furthermore, the normal periodicity in tissue development

and the whole problem of translocation are involved. It is apparent that a great deal of research in the field of applied plant physiology is necessary before the fundamental aspects of the rootstock and scion effects are clearly understood.

Seedling Rootstocks: As stated earlier propagators have generally used seedlings as understocks for apples. The main objections to the seedling rootstocks in widespread use are their vigor and mixed genetic origin, for most apple trees on seedling roots are large and somewhat variable in tree performance. Nevertheless, seedling rootstocks have certain desirable features. They are relatively cheap, they are less likely to become virus infected, and they have a wider range of compatibility. Even that fault of too great vigor can be partly overcome if the propagator uses seedling rootstocks that are known to produce smaller trees. For example, at Ottawa, McIntosh trees propagated on *Malus baccata robusta* and Antonovka seedlings are about the same size after 18 years as those propagated on EM I and EM II. In other words, *M. baccata* and Antonovka seedling rootstocks produce hardy semi-standard trees. These are selected parental combinations which greatly improve the uniformity and general performance of the seedling understocks. Further, at one of our Experimental Farms a seed block planting of Antonovka and Beautiful Arcade, another hardy variety, has proved very successful. In the Great Plains region some nurserymen prefer Columbia seedlings. Here again the source of seed could be improved by a seed block of Columbia and Bedford, another hardy crab. Seed selection for rootstock production is probably more expensive than extracting seed from cider presses. However, at Ottawa the procedure has been very effectively handled by grinding the apples in an ordinary turnip pulper and extracting the seed from the pulp in a long sluice containing a number of baffles. By this technique very little seed is lost providing the water flow is not too great. With gentle agitation the pulp and abortive seeds are carried over the baffles and the good seed settles in the sluice. Where seedling rootstocks are preferred more attention should be given to the seed source.

It would not be right to discuss apple seedlings without mentioning Apomixis. Apomixis is the production of seed without fertilization. It is a definite hindrance to the plant breeder but may prove to be useful to the propagator. Since apomictic seedlings are usually genetically identical with the mother plant they are essentially a clone. Apomictic seedlings of *Malus sikkimensis, toringoides, M. Sargenti, M. platycarpa, M. Sieboldii* and *M hupehensis* are presently being tested as dwarfing rootstocks. Sax at the Arnold Arboretum, Harvard University, Brase at the N.Y. State Agricultural Experimental Station, Geneva, N.Y., and Clarke at the Pennsylvania State University are conducting these tests. Brase (1) has found that *M. sikkimensis* seedlings are dwarfing and precocious. and that they are quite promising as understocks. With *M. toringoides* seedlings he has found that ten commercial varieties tested are not only fully compatible but also that they fruit at an early age. Clarke (2) in his investigations of apomictic seedlings observed that those of *M. Sargenti, M. Siebaldii* and *M. pehensis* were incompatible with the red and sports of Stayman Winesap, Rome Beauty and York Imperial.

The workers at the Long Ashton Research Station in England are also interested in apomixis. Since apomictic seedlings arise from somatic

tissue, the spread of virus from the parent tree could be a problem. Nevertheless only extensive investigations can determine the full rootstock value of apomictic apple seedlings.

Vegetative Rootstocks· Although most of the apple trees on the North American Continent are on seedling rootstocks, interest brought about mainly through orchardists' demands for smaller than standard trees as one means of reducing a sharply rising cost of management.

One of the main factors in favor of clonal rootstocks is that they produce a known degree of vigor and precocity in the scion variety. For example, the most widely known vegetative rootstocks are the East Malling series where individual rootstocks are classified from dwarf to very vigorous Examples of some of the better known understocks of this collection are EM IX, very dwarf, EM VII semi-dwarf, EM I and EM II moderately vigorous and EM XII and XVI very vigorous.

When I was in Germany recently, I found that the EM XI is being used extensively. This is another example of the vigorous understock. The reason it is used in Germany is that it is the hardiest of the EM series. It is the only EM rootstock that is satisfactory in particular parts of Germany, particularly southern Germany.

Although clonal rootstock can produce orchard trees of the desired size and productivity, a number of factors must be considered in such rootstock production. Possibly the most important factor is the cost of propagation. Stooling, the recommended propagation method for these clonal stocks, as it is practiced in England, is a time-consuming, laborious task. At Ottawa, certain mechanical short cuts have been incorporated and these can be most easily presented by giving a resume of our annual procedure.

Stooling: To establish a stool bed, young rooted shoots of the rootstock desired are planted in rows seven feet apart and two feet apart in the rows. Well rooted shoots which are on the large size for budding are preferred. After spring planting the young trees are pruned. About one-third of their growth is removed and the trees are allowed to grow for one season. Early the following spring the plants are cut back to approximately two inches above ground level. From below these cut surfaces adventitious buds initiate numerous shoots and thus a crown is established. The soil should be a good loam preferably on the light side but with an ample amount of organic matter, thus assuring a friable soil fairly retentive of moisture. If the area can be served by irrigation so much the better. When the youngest shoots are approximately six inches high the plants receive their first mounding of approximately four inches. The soil should be slightly moist at mounding, and the tender young tips of the shoots should not be covered, a precaution that prevents loss from decay. Additional moundings are made as growth progresses until there is a nine to twelve inch mound above the crown. Mounding can be accomplished with the aid of a hiller which consists of a pair of twenty-four-inch discs mounted on a sturdy plank and attached to the hydraulic lift at the rear of a tractor. The mechanical method of mounding must be supplemented by some hand labor. The mounds are left undisturbed through the late summer and fall to allow rooting. The following spring the earth is removed down to the level of the original crown. A digging

fork is the best implement for with a fork there is less chance of cutting or breaking off the young tender roots. All the shoots should be removed from the crown, when taking the rooted shoots from the crown a sharp pair of hand pruners should be used. The shoots should be detached as close to the original crown as possible leaving a stub of one-quarter to one-half inch. After the shoots have been removed the crowns are left uncovered while new adventitious shoots are formed from the stubs. Twelve to sixteen well rooted shoots to the crown are considered the maximum production under ideal conditions.

Adaptability. Unfortunately for us on the North American Continent the Malling rootstocks are of European origin. These rootstocks have been known for centuries in Europe under various names. Through the years they have become mixed and it was only through the efforts of Hatton at the East Malling Research Station, England, who rogued and typed these rootstocks that we have the present series. The fact that these rootstocks originated in a climate where moderate winters and relatively cool summer soil temperatures prevail, creates a problem here in North America. For many of our apple growing regions the Malling stocks are not hardy. In these areas complete killing may not occur but the performance and longevity of apple trees on these rootstocks are severely reduced because of the accumulated injury to the root system. At Ottawa, EM IX and EM I rootstocks have been more susceptible to winter injury than the other rootstocks of this series tested Furthermore, the performance of the East Malling clones, has been unsatisfactory in southerly apple growing regions where high soil temperatures exist. Recently through controlled experimentation Nelson and Tukey (7) at Michigan State University have shown that media temperatures affect the performance of these stocks and that they prefer a cool media temperature during the growing season In an endeavour to overcome these problems a rootstock selection program has been carried out for a number of years at Ottawa.

Seed of hardy apple species is brought in to Ottawa through the courtesy of the international seed exchange. The plants grown from these seeds are subjected to a stooling test. Preliminary selection is on rooting ability, and subsequent selections are on hardiness, vigor, and compatibility. It is hoped that this work will provide a series of hardy rootstocks that range in vigor from dwarf to vigorous. *Malus robusta* No. 5 is a rootstock resulting from this project. It is a rootstock which roots readily by the stooling method, is moderately vigorous and is compatible with most varieties Approximately 100 other selections of Malus species are being tested.

Incompatibility: Some serious cases of incompatibility have occurred with clonal stocks. Such have resulted in the complete failure of the stock-scion combination. This is much less likely to occur with the heterogenous seedling stocks. Nevertheless, if the rootstock-scion combination is extremely important the "Nicolin" system of shield budding can overcome such incompatibility. By the "Nicolin" method a small sliver of wood of a compatible variety is placed between the two incompatible varieties. Short intermediate stempieces can also be employed to overcome this trouble.

Viruses have become a very serious problem in clonal rootstocks, and the propagation method itself is conducive to a rapid spread of the dis-

ease. In Europe, all the East Malling clonal apple rootstocks have been found to carry virus of one form or another. This situation is very disturbing since the varieties budded on these rootstocks become virus infected also and unless heat therapy proves effective in inactivating the viruses, the use of these clonal stocks may have to be curtailed.

Double-Working: So far, the varieties used as vegetative rootstocks are those that root readily when subjected to stooling. As mentioned, the well-known clonal rootstocks produce certain definite effects. Therefore, different intermediates can produce a great range of these "rootstock effects," and since reciprocal graft unions do not behave in the same way, the range can be increased enormously. Now the EM IX rootstock is dwarfing and precocious, but it is not hardy. In a climate unsuitable for EM IX, the orchardist could use an intermediate stempiece that would give him the desired size, precocity and hardiness.

We are trying, for example, the variety Robin crab, which is used extensively on the Great Plains This variety when inserted between a vigorous scion variety will give a tree of small size and will overcome the hardiness problem present when short intermediates of EM rootstocks are used.

Where hardiness is important in the trunk and crotches of the tree even longer intermediate stempieces are used. The possibility of building a tree with a hardy framework to solve the problem of winter hardiness in the colder regions has received considerable attention at Ottawa. Some sixty stem builders have been and are in the process of being evaluated These stem builders must be hardy; they must be compatible with the rootstock and the scion variety, they must be mechanically strong, and finally, they must produce the desired vigor and shape of tree. Propagators have preferred Hibernal because it is easy to topwork and is compatible with most varieties, but Hibernal has not proved mechanically strong when the trees come into bearing. The stem builder constitutes the main framework of the tree, that is, the trunk and some four to six scaffold limbs worked over to the scion variety approximately twelve inches from the trunk. Budding is the most economical method of working over the scaffold limbs. Top-working at distances greater than twelve inches may cause considerable later twisting and breaking of the limbs. On the other hand, if the buds or grafts are inserted too close to the trunk, continued trunk growth soon envelops the unions and the purpose of top-working or hardy tree building is defeated.

Cuttingss The demand for apple trees fluctuates and for this reason stool beds are too constant and since cuttings can be varied to meet the requirements this method of propagation is eagerly sought. Although some successes have been attained experimentally much is still to be learned before fruit trees can be propagated commercially by hardwood and softwood stem cuttings.

The problems of propagating apple rootstock varieties by hardwood stem cuttings have long been understood and have engaged the attention of many investigators at the East Malling Research Station, England, notably Garner and Hatcher (4). The early research was concerned primarily with the cutting in its nursery environment. Later the effects of growth regulating chemicals were investigated intensively. Now the in-

teractions of these factors coupled with those present in the transitional development of the plant are being studied

Growth Stages of Fruit Trees: The fact that plant life and fruit trees in particular undergo, like animals, metamorphosis in their development is not generally appreciated. Unlike an animal, where metamorphosis affects the whole body, fruit trees retain the different phases throughout their life. These phases are of a physiological nature and although the fundamental causes are not fully understood, their external features are quite definite and are generally referred to as the juvenile. transitional, mature and senile phases. These stages of development are of profound importance to those engaged in fruit tree research, particularly the plant propagator and fruit breeder. As early as 1900, Goebel (6) observed the ready-rooting of very young seedlings and established the term juvenility to describe the physiological condition Fritzsche (3), Gardner (5), Olden (8) and Passecker (9) present results illustrating lack of rooting from the mature forms and good rooting from the juvenile forms. Wherever I went in Germany this fall, I found that the fruit breeders and propagators were very much concerned about growth stages in fruit trees. I feel that we in this country have overlooked this matter and should give it more attention

The hardy rootstock, *M. robusta 5*, was developed at Ottawa from one finally-selected seedling raised from seed obtained in 1927 from Russia through the courtesy of the Arnold Arboretum. A stoolbed was established, and it was noted that the young shoots were, and are, rough, thorny and twiggy, all characteristics of what is termed "juvenile" growth. As the *M. robusta 5* trees developed, later shoot-growth lacked the spring and twiggy character. Moreover, when buds were taken from this later shoot-growth and budded in the nursery the resulting trees produced smooth, spineless growth in contrast to the cut-back *M. robusta 5* developing from adventitious buds. These latter produced thorny growth.

Since working with smoother and spinless growth is easier and more pleasant, it was decided to establish a second stoolbed of the smooth type. The buddings for this second stoolbed were layered in 1948. The *M. robusta 5* trees from which the buds were obtained had been planted in 1938, approximately 10 years after germination of the seed. Therefore, bud source for the second stool bed was about 18 years from seed germination.

The second stool bed is providing material of varying thorniness, but the tendency is to smoothness and the absence of spines. However, rooting in the second stool bed is much less prolific and when used as a stem builder further growth appears to be slower and more open than when the thorny type is used, differences both physiological and morphological. The less prolific rooting in and slower growth of the second stool bed may nullify the easier working with such material. Additional morphological differences are the fewer but larger leaves on shoots in the second stool bed and the statistically significant difference in areas of bark between cross-sections of lateral roots of the same age from the two lines. On the other hand, cytological examinations show no differences in chromosome number ($2n = 34$), shape or size. Further, investigations underway on this rootstock include experiments designed to show wheth-

er the second stool bed is a "transitional" or "mature" growth stage of *M. robusta 5* and, if so, the effect on earliness of fruiting.

In other propagation studies with *M. robusta 5* it has been observed that the source of propagation material is of prime importance. The number of leaf-bud and soft tip cuttings forming roots was far greater when they were taken from the original stool bed than when gathered from 18-year-old stock trees or from 2-year-old nursery trees that had been budded from these stock trees. Apparently the severe annual pruning of the stool bed retards physiological development of the plants, thus retaining certain characteristics for rooting associated with juvenility.

In rootstocks studies of the past thirty years at Ottawa, attempts have been made to propagate vegetatively such hardy cultivated varieties as Anis, Antonovka, Charlamoff, Hibernal, and Virginia Crab. One-year whips of these varieties that had been propagated on a hardy rootstock were layered. None rooted well and all were considered of no value as vegetative rootstocks. Seedlings of a number of these hardy cultivated varieties were cut back hard and stooled. Several rooted quite well and are now being subjected to stooling, incompatibility and hardiness trials. This again illustrates that young apple seedlings of an apple variety in the juvenile phase root much more readily than do shoots from the mature phase of the same variety. We feel that the time has come when we should retain all our new introductions in the juvenile phase so that they may be propagated vegetatively. I was surprised to find that some of the German plant breeders maintained juvenile clones of all of their new selections. These are being propagated by hardwood cuttings, thereby reducing the cost of production.

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MODERATOR BLAIR: I am now going to call on Dr. S. H. Nelson to give you the results of his work this past season in propagating apple from leaf-bud cuttings.

Dr. Nelson is a plant propagator employed by the Canadian Department of Agriculture. I don't know of any other similar position in the entire Dominion Service. He was appointed a few years ago to work exclusively on the problems pertaining to the propagation of fruit and ornamental materials. We consider this matter of propagation to be of equal importance to other phases of our horticultural work. Dr. Nelson took his undergraduate work at Ontario Agricultural College and, as a graduate student at Michigan State University, worked with Dr. H. B. Tukey. Therefore he has quite an appreciation of propagation work and experiments which are in progress in the United States. Dr. Nelson!

DR. NELSON: I think it is needless for me to say that I am very happy to be here today. It is a pleasure and an honor to have the opportunity to describe to you my recent work with leaf-bud cuttings.

Dr. Nelson presented his paper, entitled: "Malus Understock from Leaf-bud Cuttings." (Applause).

MALUS UNDERSTOCK FROM LEAF-BUD CUTTINGS

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As Mr. Blair has pointed out in his survey, there are two or three broad types of rootstocks that can be used as understocks for apples. With due respect to seedlings and apomictics, we will leave these and concern ourselves only with clonal rootstocks, for the purpose of this paper.

Let us reiterate a little further. It has been brought out that stool bed maintenance is costly and laborious, and even with mechanical aids the production of clonal rootstocks is expensive. Furthermore, with stool beds a rather fixed amount is produced each year and the flexibility required to fit the unstable requirement for apple trees is lacking. Some more flexible method is desired, and cuttings naturally appear to fit this problem.

At Ottawa, random attempts have been made over the years to root harwood cuttings, but with little success. Climatic factors certainly play an important role since we cannot line out cuttings in the field, as is being done in Europe. Another factor, however, may have been the mature physiological condition of the wood, referred to by Mr. Blair.