

Propagation and Improvement of Horticultural Plants

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FOREWORD

Plant improvement offers an interesting and often profitable field for the amateur or plant fancier, and Oregon men and women have made many contributions in the form of new types and varieties. Oregon plant breeders have added much to the world's wealth of ornamental and fruit plants as well as to the staple crops such as grains and grasses. The Bing and the Lambert cherries are products of Oregon plant breeding. The pansy, the iris, and the delphinium owe much of their present perfection to Oregonians, who also have done much to improve filberts, prunes, pears, small fruits, and other plants. Through the efforts of fanciers, many native Oregon plants have been improved and introduced into cultivation.

There is nothing particularly difficult or mysterious in the technique of plant improvement. As Darwin said, it is natural for plants to vary or differ from each other, and small deviations from type, such as differences in vigor, disease resistance, and size and color of bloom, may be the basis of new varieties. Man can often aid nature in bringing about variation through the use of *hybridization* or *crossing*. This makes possible the combining of the characteristics of two or more groups of plants, and may supply vigor, which is often of prime importance.

As a second tool, man may employ *selection*. Many of the finest plant varieties owe their existence to selection alone. The individual grower who is on the alert and who observes plants with the aim of finding differences between them often finds and selects out of a plant population individuals that become varieties of superior merit.

HENRY HARTMAN,
Professor of Horticulture.

SUMMARY

1. Plant propagation by seed is nature's way of continuing the species. It is dependent on a previous fertilization of mother by pollen parent, the resulting seedling having characteristics of one or both parents. Many plants, such as fruit, ornamental, and forest trees, exhibit variations in their seedlings. In some cases, this is not enough to make any material difference, but in others the difference is too great for commercial purposes. Many of our finest horticultural plants have originated from seedlings; but in order to perpetuate these selected variations, it is necessary to use other or vegetative methods of propagation.

2. The Talisman rose, Koster's Blue spruce, the cutleaf Japanese maple, the Delicious apple, and others are preserved by such methods as cuttage and graftage. These methods of propagation also account for the marked uniformity of type, and, at least in part, for the greater cost in comparison with the seedling method. The same is true with different varieties of strawberries, lilies, filberts, gladioli, dahlia, chrysanthemums, and many other sorts of choice plants that are propagated by layerage, cuttage, separation, or division.

3. By studying the ways in which plants reproduce in nature and also through extensive experimental work and long experience with many species, it has been learned that most plants can be successfully propagated by vegetative methods. Some plants such as the potato, fig, pineapple, banana, seedless grape, and seedless orange have all but ceased to reproduce viable seed, due to the fact that even in the natural condition they have propagated vegetatively for a long time. Then, too, the uncertainty of germination of seeds of many plants such as holly, hawthorn, rose, and others, usually requires that

SUMMARY—*Continued*

vegetative propagation be used. In order to obtain stronger, more uniform nursery plants or more productive mature ones, or plants that thrive, or are more resistant to adverse conditions, they are often budded or grafted on roots of seedling stock of species other than their own.

4. All of these points, and many more, have been learned by experience accumulated through many centuries. The amateur is not in a position to obtain good results at first, but plant propagation does offer a means of pleasure and recreation. With experience one learns much that is profitable. For commercial purposes, it is apparent that in most instances one should obtain his plants from nurserymen who have learned the methods and requirements for specific plants and who have successfully practiced them. Some, too, have specialized with much success along certain lines and can produce plants that are especially satisfactory.

5. The search for better varieties and strains is being carried on by government, state, and private agencies and individuals through plant breeding and selection. It is by these methods of plant improvement that the pleasure and profit of plant propagation is enhanced.

Illustration on cover—

Rooted blackberry root cutting and new shoot.

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By W. P. DURUZ

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PART I—PROPAGATION

INTRODUCTION

ALMOST everyone who is interested in agriculture, especially in horticulture, has a general interest in plant propagation and how it may be applied either for pleasure or profit. Plant propagation deals with methods for quantity production of plants having certain desirable qualities. It includes growing of plants from seed as well as from vegetative parts, such as cuttings, layers, bulbs, tubers, buds, and scions.

Plant propagation is both an art and a science. The art has been known to plantsmen for thousands of years, for from ancient writings we have records of methods similar in many details to those that are practiced today. Theophrastus, the Greek philosopher, writing about 300 B. C. in his "Enquiry into Plants," Book II, states:

"The ways in which trees and plants in general originate are these: growth from seed, from a root, from a piece torn off, from a branch or twig, from the trunk itself; or again from small pieces into which the wood is cut up. Of these methods growth from seed or root would seem most natural; wherefore they are found even in wild kinds, while the remaining methods depend on human skill or at least on human choice. . . . And, while all the trees which are propagated thus or by some kind of slip seem to be alike in their fruits to the original tree, those raised from the fruit, where this method of growing is also possible, are nearly all inferior, while some quite lose the character of their kind, as vine, apple, fig, pomegranate, pear."

Usually, however, those who practiced plant propagation kept the actual procedure and details shrouded in mystery. The majority of people were kept in ignorance of the facts, and the impression was given that there was something supernatural

about the process. Thus the secrets of the trade were in the minds and hands of a few. Some erroneous ideas and notions of the ancients have been handed down from generation to generation, and even to this day many of these ideas based on misinformation and superstition still persist in the minds of the uninformed.

The art of plant propagation was practiced by the earliest gardeners, the forerunners of present-day nurserymen. Nurserymen now commercially produce well-grown plants propagated by the same methods that have been followed for ages, with some improvements. The study of botany and other sciences, however, has aided in discovering some of the underlying reasons for the responses of plants to the manipulations of man. Discovery of cells and their functions led to an understanding of the processes going on in plants, and we now begin to understand the long-practiced art of plant propagation.

GENERAL METHODS

In nature most plants reproduce from seed. All plants, if unmolested, pass through a regular cycle of activity, the length of this cycle varying from one to several, or in a few cases even hundreds of years.^{*} Annual plants, for example, grow and produce seed in one year. Biennials require two years for production of seed, while perennials live from year to year, bearing seed nearly every year after they have become mature. In the case of perennials, however, there is an important difference in that they produce buds, which are condensed stems. While the trees themselves may die, the buds or twigs bearing buds are capable of unlimited growth. Thus, a tree may live for many years, and although it is slowly approaching the end of its life, the little twigs out on the ends of the branches, each with a bud at its tip, could be cut off, and, by planting in sand or other medium, caused to form roots and produce a new tree to start the cycle again. This process could be kept up indefinitely—a form of perpetual regeneration.

There are many different methods of propagating plants, from: (1) seeds and (2) buds. These methods are the results of observation in nature and experience gained and added to from time to time. Plant propagation is the result of studying plants and their behavior and of actual experience in manipulating them for the purpose of increasing their number.

SEEDAGE

Propagation by seed is nature's method for increasing most species of plants. The seed, derived from the fertilized and

mature ovule of a flower, generally has a tough outer seed coat, which varies in thickness. Within is an embryo and stored concentrated plant food to be used later by the sprouting seedling until it is able to manufacture its own food materials. Many seeds have appendages that aid in their dissemination and propagation. Seeds vary in size from the smallest microscopic orchid seed to the largest coconut.

Seeds require water, oxygen, and temperature; must be viable; able to absorb water and oxygen; and, in some cases, must have had the proper rest period. Many seeds require preparatory treatment before planting, to obtain the highest percentage of germination. A few require rather long periods of after-ripening before they will germinate, while others are short-lived and should be sown immediately after harvesting the fruit (Table 1, page 14). Still others require light or, in some cases, nutrients such as potassium nitrate before they will germinate. Some seeds, such as lettuce and cucumbers, should preferably be a year old before being planted, for the best crops. Port Orford cedar seed more than a year old germinates better than one-year-old seed. Seeds of a few varieties, such as citrus, may even germinate in the fruit while it is maturing, while on the other hand, it has been stated that seeds of lotus have been found several hundred years old, still capable of germination.

Seed preparation. Many seeds require special treatment before they will germinate satisfactorily. Very hard-coated seeds, if allowed to become too dry, must be cracked or softened before the embryo can grow. Some seeds naturally require a longer period or a lower temperature for proper maturing than others.

In nature, seeds are covered by leaves and other debris that keep them moist until they are ready to germinate. This condition has suggested the practice known as *stratification*, which is the operation of storing seeds in different materials, such as moist sand or peat moss, or keeping the seeds cool, usually in burlap bags on ice, or in cold storage for a period of time, until they are planted. Freezing in ice cubes or chilling in a refrigerator will assist in better germination of certain seeds.* The soaking of seeds in

* F. C. Reimer has found that Mazzard cherry seed requires cold storage temperatures of 35° to 36° F. for not less than 4½ months in moist sand.

Pear seed should be placed in equal parts moist sand in cold storage for three months. Before stratifying, the seed is disinfected with Semesan, one ounce to three gallons of water for five minutes, or one pound in fifty gallons of water. The seeds are then placed in sand and kept moist in cold storage at 34° to 36° F.

When the seeds are taken out they are soaked again in Semesan and in water for two days to keep them moist and to start slight germination before planting.

water, the use of acids and other chemicals, and mechanical treatment, such as polishing, cracking, or scratching, are some of the methods used to obtain quicker germination of some seeds that do not germinate readily with normal treatment.* Most of our garden annuals require no seed treatment, but many of the ornamental shrubs and trees and fruit trees do require seed treatment either because the seed coats are hard or because they require after-ripening, a condition in the development of seeds that goes on at low temperatures (35° to 40° F.). Such seeds as rose, cotoneaster, apple, pear, peach, plum, cherry, and hawthorn require such treatment for varying lengths of time.†

Seed testing. Seed samples vary in their purity, trueness to name, presence of foreign matter and weed seeds, and viability. Information is continually being sought by amateur and practical seed growers relative to these matters. Seed testing aids in avoiding mistakes and possible loss. The United States Department of Agriculture and the different states have laboratories for the testing of the purity and germination of seeds. At Oregon State College there is a seed laboratory that furnishes to farmers not to exceed six free analyses a year. Seedsmen are interested in obtaining such an analysis because it provides a basis for sale; and prospective purchasers are interested because it supplies assurance of the quality of the seed for field, lawn, garden, or greenhouse. An analysis prevents possible seeding of undesirable mixtures, including noxious weeds, and assures that only good seed of high quality is planted.‡

Damping-off. Serious loss is often occasioned by a common disease of germinating seed and young seedlings known as damping-off. This is caused by fungi that inhabit the soil and attack the seeds or seedlings, particularly when there is excessive wetness in the seedbed. Certain soil and seed treatments have been found to give excellent control, regardless of moisture. These treatments include coating the seeds with chemicals, such as copper oxide or organic mercury compounds, and sterilization of

* George Waldo states that red raspberry seeds soaked four hours in water followed by two hours in concentrated sulphuric acid germinate more perfectly than untreated seeds.

† Further information on the rest period in seeds is given in the 1938 Proceedings of the American Society for Horticultural Science, pp. 652-659, Vol. 36.

‡ *Rules and Recommendations for Testing Seeds*, Circular 480, U. S. Department of Agriculture, 1938.

See *Standards of Germination of Vegetable Seeds*, Oregon State Department of Agriculture, 1937.

the soil by heat and chemicals, which kill or retard the fungi so that they can no longer attack seeds or seedlings. Attention to light, ventilation, and cleanliness in the seedbed are precautionary measures against damping-off that have proved successful.*

Sowing of seed. Seed may be sown indoors or out, depending on circumstances. The sowing of seed indoors requires suitable shallow pans or boxes in which to sow; a supply of rooting medium suitable for the particular type of seed; provision for ventilation; and very little fluctuation of temperature (Figure 1). Some plants are started indoors and transplanted outdoors,

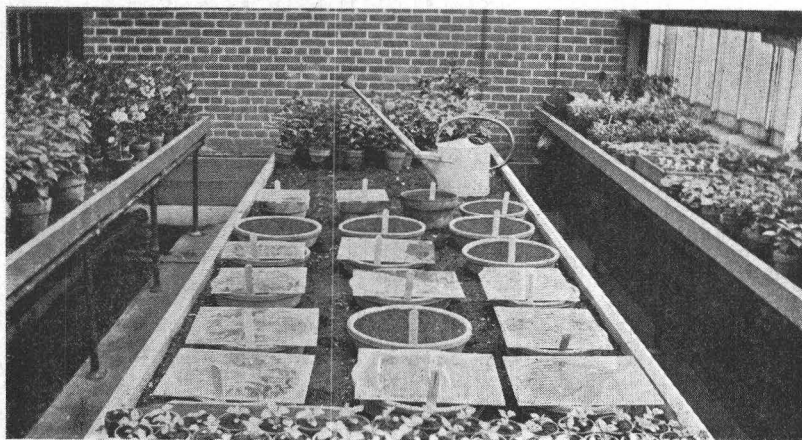


Figure 1. Germinating fine seeds. Note seed pans with glass covers to retain moisture during germination, later to be removed.

while others are planted outdoors where they are to grow. A few kinds are started in individual containers or plant bands made of thin veneer or paper and, when the seedlings are large enough, the containers are planted with as little disturbance to the plants as possible. The containers soon decompose and allow the roots to spread into the surrounding soil.

The best period for outdoor sowing for many seeds is from the middle of February to the first of May. This gives a germination period of several weeks, depending on the nature of the seed, after which the seedlings have the advantage of the longer daily periods of sunlight beginning in April. This is the season of most

* See *Combating Damping-off*, New York Agricultural Experiment Station Bulletin 683.

rapid growth. The later the seeds are sown, the less time there is for the seedlings to become established and to make vigorous, sturdy plants the same season. If possible, the soil in the bed or border, where the seeds are to be sown outdoors, should be worked thoroughly the previous autumn. It would be advisable to add some well-decomposed organic matter, unless the soil is of a heavy clay type, in which case it should be lightened by adding sand. The best all-purpose soil is a light loam, in as fine a condition as possible, and with good drainage. When only a few kinds of seed are to be sown, the seedbeds are best made about four feet wide and as long as desired, with a path about 18 inches wide between them. The surface soil of the seedbed should be smoothed either by rolling with a light roller or packing with a hand tamp. In the case of small seeds, thin broadcast sowing is perhaps the best method, but with larger seeds, sowing in rows may be found more economical and more labor-saving when it comes to weeding, thinning, transplanting, and similar operations. Depth of

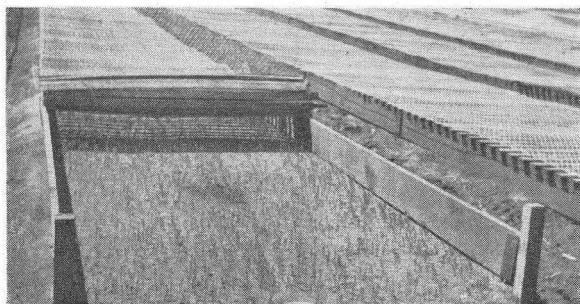


Figure 2. Seedlings in the outdoor seedbed sometimes require shading, as well as protection from birds, by use of small-mesh chicken wire.

covering the seed varies with the size of seed, but in general it should be three to four times the diameter or thickness of the seed. After sowing the seed, it may be covered lightly with fine soil or sand and pressed in by rolling or tamping, leaving the surface smooth as before. Precautionary measures may be necessary to protect the seeds and seedlings from drying out due to strong sun or wind, and also from birds, mice, and frost. Some commercial and forest nursery seeds are coated with chemicals, including copper oxite or organic mercury compounds to prevent rotting, or are treated with poison to decrease bird and rodent activity. A cover of burlap, lath, canvas, or muslin lessens evaporation and damage from birds and animals (Figure 2).

Once the seedlings are up an inch or more, the covering may be removed. A covering to give half shade, such as lath, ever-

green branches, or light muslin, may be kept over the beds part of the time to prevent sun scorch and drying out. In some nurseries lath houses are used. Some seedlings are transplanted the first season while others remain two years in the seedbed. The seedlings are lined out in another bed or field, in rows a few inches to a foot or more apart depending on the kind of plant.

Special seeding measures are sometimes necessary depending on the size, kind of seed, and other factors. Following are some directions that may be useful:

Very fine seeds, such as azalea, begonia, petunia, and rhododendron, require special attention as to sowing and watering. A soil mixture of equal parts of sifted loam or leafmold and sand, preferably sterilized, in either

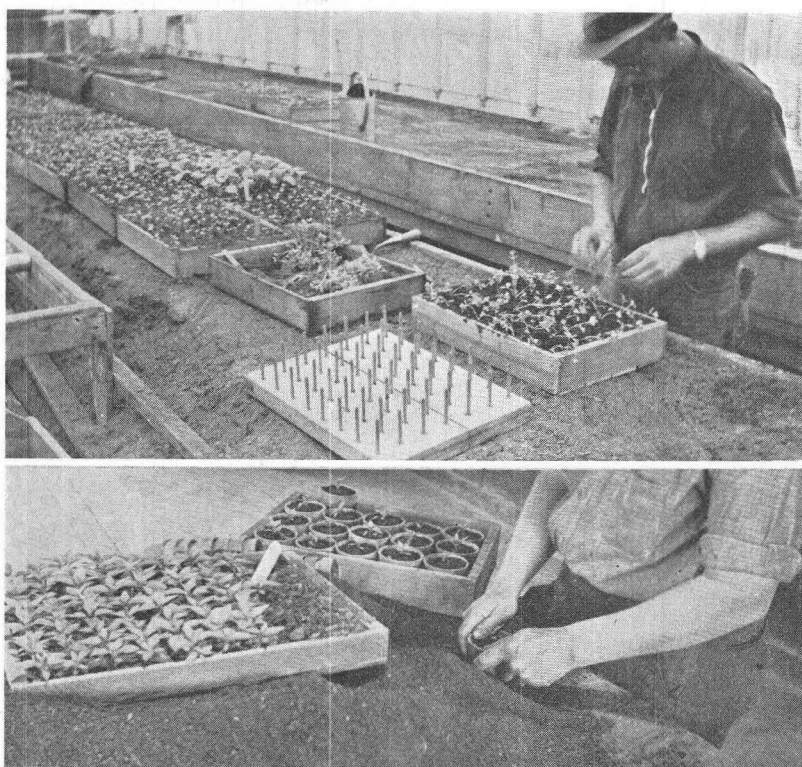


Figure 3. *Above:* Flats showing seedlings before and after being pricked out and spotted. Note spotting board with spikes for marking positions of plants. *Below:* Potting off seedlings, which have been grown in flats. These are pricked out and potted in a mixture of compost, leafmold, and sand, which has been thoroughly mixed and screened.

shallow pots or pans is used. The seed is thinly broadcast, and covered very lightly with finely sifted compost and sand, previously moistened. After sowing, the container should be placed in a pan of water up to its rim for a few minutes, or watered with a very fine spray. The top of the container should be covered with a pane of glass or with wet cloth or newspaper to retain the soil moisture. As soon as the young seedlings appear, they should be given light and air, but should not be overexposed. The seedlings will probably require shading during intense sunlight. When the first true leaves appear following the seed leaves, the seedlings are ready for pricking out or lifting, using a pot label to pry up under the roots. They are shifted to flats or sometimes to individual pots containing the same soil mixture. Transplanting at this stage is to avoid damping-off and to make larger plants.

This transplanting is often called "spotting" since a marker or spotting board arranged with spikes, dibbles, or holes two or three inches apart, is used to mark the places in the flats where the seedlings will be planted (Figure 3). They are grown in the greenhouse a while longer and then in coldframes (Figure 4) or in a lath house. After all danger of frost is past, they may be planted out in beds or rows.

Fine seeds, such as many flower and vegetable seeds, including pansy and tomato, require light covering when sown. They are sown thinly in flats in rows or broadcast, covered not more than a quarter of an inch, sprinkled, and never permitted to become dry. As the seedlings become large enough they are spotted in flats two or three inches apart, or sometimes in individual containers; later are moved into coldframes, and finally to the field or garden when all danger of frost is past.

Hard-coated seeds, including apple, hawthorn, peach, pear, walnut, and others, should first be cleaned so as to remove the fleshy pulp surrounding them. If not, the pulp may ferment and cause a lower germination. The seeds in this class are stratified or soaked before planting. Some are planted in the nursery as early in the fall as possible, while others are stratified and

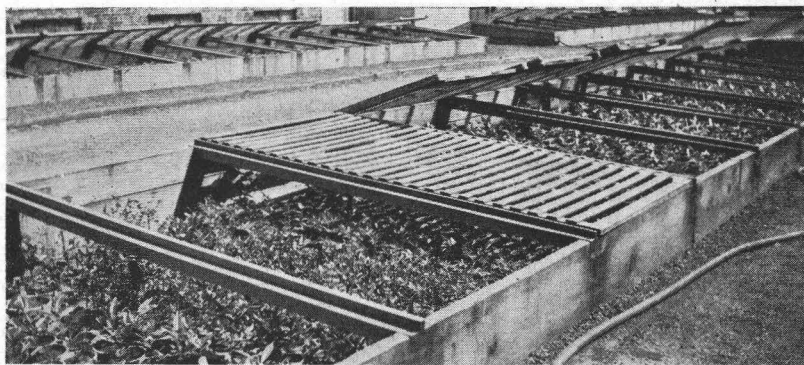


Figure 4. Coldframes showing glass and lath for covering on cold nights or bright days as required.

planted in the spring. These are planted deeper than the small seeds, varying from one-fourth to two inches deep, depending on the size of the seed. The larger the seed the deeper it should be covered.

Winged seeds, such as birch, beech, elm, maple, and most of the conifers, should have their wings removed and be cleaned before stratifying or sowing. The early-ripening kinds should be sown at once, the later-ripening kinds not until spring, in an outdoor seedbed, and covered lightly with moist soil. Moisture may be maintained by covering the seedbed with burlap or similar material. When the seedlings come up the cover should be removed gradually, by mounting on overhead supports for continued protection (Figure 2).

Seedling growers. The business of growing seedlings is itself a specialized industry (Figure 5). Certain nurserymen confine their attention to the growing of seedlings, selling them to other



Figure 5. Nursery crew planting elm seedlings. Individual holes, large enough to accommodate the root systems, are dug along the row.

nurserymen who continue the propagation process by budding or grafting to the desired varieties. Seedlings are desired, and certain kinds often preferred, for root-stock purposes because as a rule they are hardier, more vigorous,

and often produce better results than plants on their own roots. Many of the fruits and ornamentals, such as birch, elm, flowering cherry, maple, rhododendron, and rose, are best when grown and produced on seedling stock of a particular species. (Extension Bulletin 528, page 28.)

Improvement by seedlings. It is generally known that seedlings of fruit plants do not come true to parent. Such fruits, if produced, are known as "common" fruits, "seedlings," or "wildlings" and are generally inferior. Occasionally, however, there is one of outstanding merit that may be selected and thus become a variety. Plant breeders grow thousands of seedlings in the search for better varieties, although only a very small percentage are selected for further testing and finally given a variety name.* (See Part II.)

* See *Yearbook of Agriculture*, U. S. Department of Agriculture, 1937, for full discussion of plant improvement.

Table 1. PROPAGATION OF SOME TREES AND SHRUBS FROM SEED

Name of plant	Type of seed	Best storage	Treatment	Best temperature for after-ripening	Days for after-ripening	Usual method of propagation	Time of ripening	Remarks
<i>Betula</i> (Birch)	Fine, thin	Moist	Sow as soon as ripe, or after-ripen	33°-50° F.	60-75	Seed	Late summer	Viability rapidly lost if stored dry.
<i>Crataegus</i> (Hawthorn)	Hard-coated	Moist	After-ripen and sow in spring	33°-50° F.	1-2 yrs.	Seed	Fall	Remove seed coat with acid; this reduces after-ripening period from 2 years to 1 year.
<i>Juglans</i> (Walnut, Butternut)	Nut	Moist	Stratify at once and sow in spring	-----	-----	Seed; grafting	Fall	Do not allow to dry completely.
<i>Malus</i> (Apple, Crabapple)	Tough coat	Moist or dry	After-ripen and sow in spring	33°-50° F.	60-85	Seed; budding; grafting	Fall	Stores well for 2½ years and still retains viability. The apple requires 2 to 3 weeks longer than the crabapple for after-ripening.
<i>Picea pungens</i> (Colorado Spruce)	Winged	Dry	After-ripen and sow in spring	-----	-----	Cuttings	Fall	Pick as soon as plump; otherwise, cone opens and seed drops. Can be stored 2 to 4 years. Sow in early spring.
<i>Rhododendron</i>	Fine	Moist	After-ripen	-----	-----	Cuttings	-----	Sow in peat moss or acid soil. Should not dry out.

CUTTAGE

Plants are the only complex organisms that can be reproduced from severed parts. This method of propagating plants is known as cuttage. Plants cut into a number of pieces can be influenced to start new individuals capable of carrying on and perpetuating the exact characters of the parent. No matter how old a plant may be, if a young vegetative shoot can be found, this often may be used to reproduce another plant identically like the parent.



Figure 6. Cuttings prepared for the cutting bed. All but a few of the topmost leaves are removed and sometimes these have the surface reduced by being cut in half or less.

A cutting is the gardener's term for a piece of stem, root, or leaf that is cut off and planted (Figure 6). Cuttings may be taken from stems, roots, and occasionally leaves. They may be classified according to the part from which taken, as stem, root, or leaf cuttings; also as to the age of wood taken: (1) soft, that is current season's growth, often called "slips"; (2) semihard, or partly mature wood; or (3) hard, or fully mature wood. If the cutting has a portion of an older stem attached, it is a mallet; if only a sliver of old wood is attached, it is a heel cutting. A simple

cutting is one taken from a straight portion of the stem other than the tip, while a tip cutting is from the terminal end.*

Rooting medium. Cuttings may be encouraged to root by giving them the required conditions of oxygen, moisture, and temperature, preferably bottom heat of 60° F. with tops 5 to 10 degrees cooler. There are now on the market electrical heating elements that can be laid in the bottom of the propagating bench and the electrical current controlled by means of a thermostat so that any desired temperature can be maintained in the propagating medium. The use of a propagating bench inside a greenhouse is termed under *double-glass*, and is often advantageous in maintaining high humidity and controlled temperature (Figure 7).

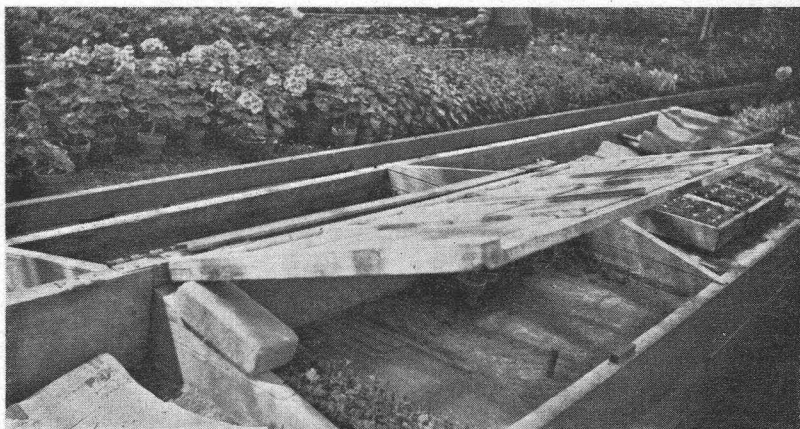


Figure 7. Propagating bench showing double glass (sash over a bench in a greenhouse).

The usual medium for rooting cuttings is clean, coarse sand. Experiments have shown, however, that a mixture of peat moss and sand in equal parts is better for some species, especially those that require an acid reaction, such as azaleas, rhododendron,

* Robert L. Brown, senior in pomology, conducted experiments in 1934 with Christmas holly (*Ilex aquifolium*) to determine the best type of cuttings, also what period during the year gives the highest percentage of strong growth.

The method used was with cuttings from selected trees, taking different types (tip, mallet, heel, simple) and with varying number of leaves per cutting, also varying the location of the basal cut. Cuttings were placed in a rooting medium of one-half peat moss and one-half clean washed river sand, under double glass with bottom heat, at approximately 22° C. The glass was kept tightly closed so as to keep the humidity inside, which is necessary for holly cuttings. The cuttings were placed February 2 and results taken May 14.

The results showed that tip cuttings were better than the mallet, heel, or simple types of cuttings.

and huckleberries.* Such a mixture has a high water-holding capacity and therefore may be susceptible to overwatering. Too much water is probably the most common cause of failure in the rooting of cuttings. At first, the cuttings should be thoroughly watered; later waterings should be light and applied with a fine spray nozzle to maintain the humidity. Also, it has been found that sterilized media are better in certain instances.†

Stem cuttings. Many of our ornamentals are conveniently propagated by means of cuttings (Figure 8). Hardwood or dormant simple cuttings, four to six inches long, are made from a straight portion of the previous season's growth, taken in the fall or early winter, with the basal cut just below a bud. These are used for propagating many plants, including the following: deutzia, forsythia, fig, hydrangea, privet, rose, and many other deciduous ornamentals and fruits, such as quince, currant, and red raspberry. Semihard tip cuttings are preferred for coniferous plants and are best taken with a heel during the fall or early winter (October to December). Broad-leaved evergreens, including azalea, boxwood, laurel, and rhododendron, may be taken in the fall or early winter, although late summer is probably better for some of these, particularly rhododendron. Coniferous evergreen cuttings, including yew, juniper, redwood, and others, may be taken in the winter or spring and usually require a rela-

* Henry C. Williamson, Jr., graduate student in pomology in 1932, working on the propagation of the Pacific Coast evergreen huckleberry (*Vaccinium ovatum*) and using one-year-old hardwood cuttings, concluded that best results were obtained in the coldframe in contrast to an electric hotbed in the greenhouse. Cuttings taken in November and placed in the greenhouse showed more rapid growth, which seemed to exhaust their vitality, while similar cuttings under coldframe conditions showed slow top growth at first, allowing a better chance for subsequent rooting.

Soil mixtures of different types also were tested; sand-peat moss and sand-leafmold mixtures produced better rooting than sand-leafmold-soil combinations. Loose-textured soils with acid reaction seemed best for rooting the huckleberry.

† Oliver A. Batcheller, senior in pomology in 1935, experimented with rooting media in propagating holly, rose, grape, daphne, camellia, and rhododendron cuttings.

The media were placed in flats, some of which were sterilized in a steam autoclave at 230° C. under 105 pounds pressure for 45 minutes. All the flats were placed in an electric hotbed in which the average temperature was maintained at 70° F.

Results showed that sterilized media gave highest percentages of rootings; also the roots in sterile media were larger and more branched than in unsterilized media.

Silt-free medium sand proved to be the best all-round rooting medium with the following plants: holly, grape, rose, daphne, rhododendron.

Sterilized sand proved to be better than unsterilized sand.

The media containing 25 per cent peat moss produced a higher percentage of rooted plants than did the media containing 50 per cent peat moss.

Holly cuttings should not be too long, and should be buried deeply in the soil.

All cuttings should be kept well watered and should have the medium packed tightly about them.

Bottom heat is beneficial in bringing about rapid rooting of cuttings.

tively long period for rooting, although some are surprisingly rapid in rooting; arbor vitae, cryptomeria, and the big tree, *Sequoia gigantea*, being examples.

Softwood cuttings, often called slips, are used to propagate many indoor and greenhouse plants, as well as others growing outdoors, during the growing season (June to September). These

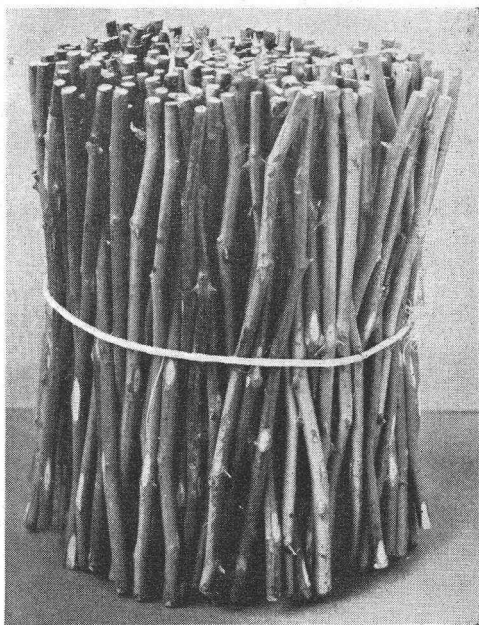


Figure 8. Bundle of 100 *Rosa multiflora* cuttings, made in large quantities simply by sawing the canes into the desired lengths. All but the upper two buds have been removed to avoid suckering when growth starts. These are usually planted in the spring, without callusing, and the following summer budded to the desired variety.

cuttings should be taken from succulent, turgid, recent growth (Figure 6). The lower leaves and part of the remaining upper leaves should be cut away to reduce chances of wilting. The cuttings must be handled quickly and always under moist conditions. They should be placed in the cutting medium without delay, sprinkled frequently, and kept shaded from bright light until they are rooted. Softwood cuttings will produce roots quicker than the other types, usually in two or three weeks' time.

Origin of roots.

Species vary greatly in the facility with which they form roots and in the places where roots arise. While most species form roots more readily at the nodes, many, it is known, will root as readily between the nodes. As a rule, roots arise more quickly in all species near the base of the cutting (Figure 9). The reason that a cutting is more likely to succeed if the basal cut is near a node is that there is greater cambial activity in that region and more food is stored there.

Region of cut. Many plants root just as well whether the cut is made below or above the node. A few seem to root best

when cut is made above the node. As a general rule with many of the common shrubs, a basal cut one-half inch below the node has proved superior to a cut at the node. No one position, however, is superior for all species or varieties.

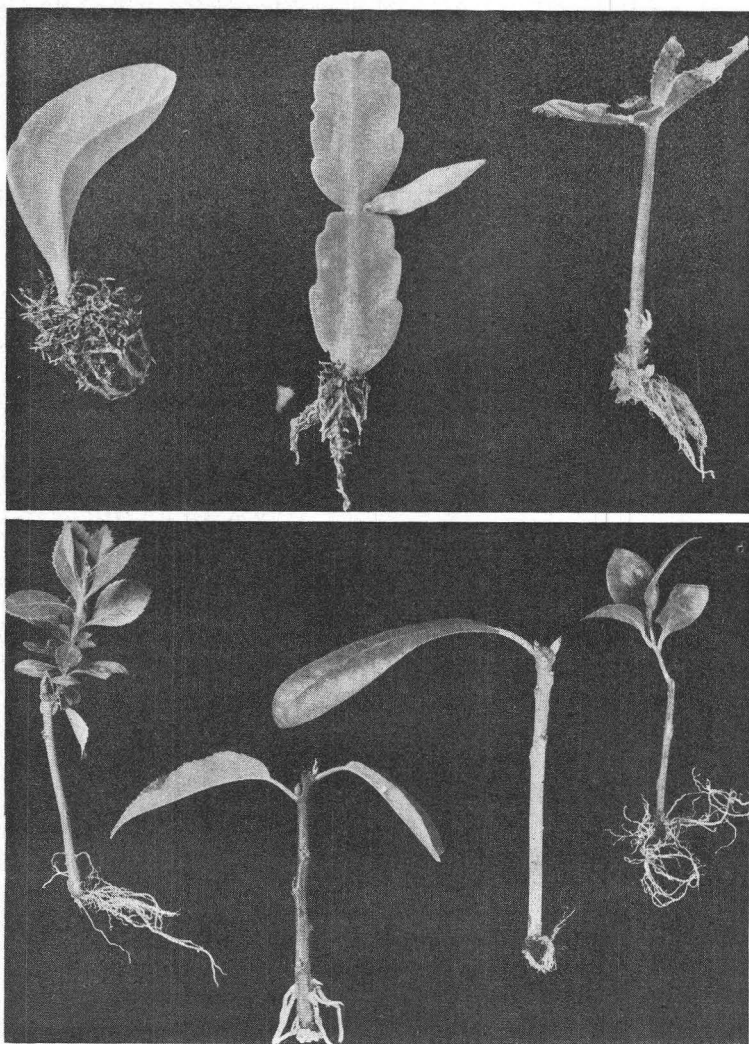


Figure 9. *Above:* Rooted leaf cuttings of peperomia, Christmas cactus, Rex begonia. *Below:* Rooted broad-leaf evergreen cuttings of euonymus, Portugese laurel, rhododendron, camellia.

Treating cuttings. It has been known for some time that dipping the butt ends of cuttings in certain solutions would aid in inducing their rooting. Such solutions have usually contained chemicals that in some unknown way resulted in a greater stimulation of root growth. Recently it has been learned that certain synthetic root-growth-promoting substances, including indolebutyric, indoleacetic, and other acids, familiarly called hormones, have resulted in quicker and stronger rooting of certain species. There are now on the market substances in liquid, paste, and powder forms for the treating of cuttings to induce better rooting.* Directions for their use accompany the respective kinds and should be closely followed (Figure 10).

Advantages of treating cuttings with growth-promoting substances are that roots may develop more quickly and over a larger area on the cuttings. A greater number of cuttings can be depended upon to root. There is a saving of time in getting rooted cuttings established and growing in a new location, as compared with untreated cuttings. There are some possible disadvantages, also, in that there is the extra cost and additional time required for the treating of cuttings, the cuttings may be brought on too rapidly and ahead of season for some kinds, and there may be resultant weaknesses in the treated cuttings due to overstimulation in certain cases. At present, however, the advantages seem

* L. O. Schaad, graduate student in pomology in 1939, working with growth-producing substances, or hormones, found that dahlia, carnation, gooseberry, currant, and grape all produced quicker and better rootings when treated.

The root-promoting substances, indoleacetic and indolebutyric acids, were tested to find their effectiveness in shortening the time and increasing the rooting of cuttings. It was found that results were best with indolebutyric acid.

In the results of all tests, it was found that growth-promoting substances applied carefully and correctly increased and hastened rooting of cuttings. They were of particular value in the propagation of carnations, grape varieties, and Irish yew (*Taxus baccata*). Good results were also obtained from Abelia (*Abelia chinensis*), rhododendron leaf cuttings, and currant and gooseberry varieties. In all trials of 15 different plants, the best treatment was superior to the untreated cuttings. The time saved was as much as 2 or 3 weeks, with the amount of rooting considerably increased.

Indolebutyric acid treatments: Plant	Milligrams per 100 cubic centimeters	Recommended length of treatment
Carnation—Harvest White	3	4-6 hours
Abelia (<i>Abelia chinensis</i>)	3	24 hours
Concord grape (<i>V. vinifera</i>)	8	24 hours
Niagara grape (<i>V. vinifera</i> and <i>V. labrusca</i> hybrid)	5	24 hours
Zinfandel grape (<i>V. vinifera</i>)	3	24 hours
Irish yew (<i>Taxus baccata</i>)	10	24 hours
Gooseberries—Oregon Champion, N. Y. 1253	3	16 hours
Currants—Pomona, Viking, White Versailles	5	16 hours

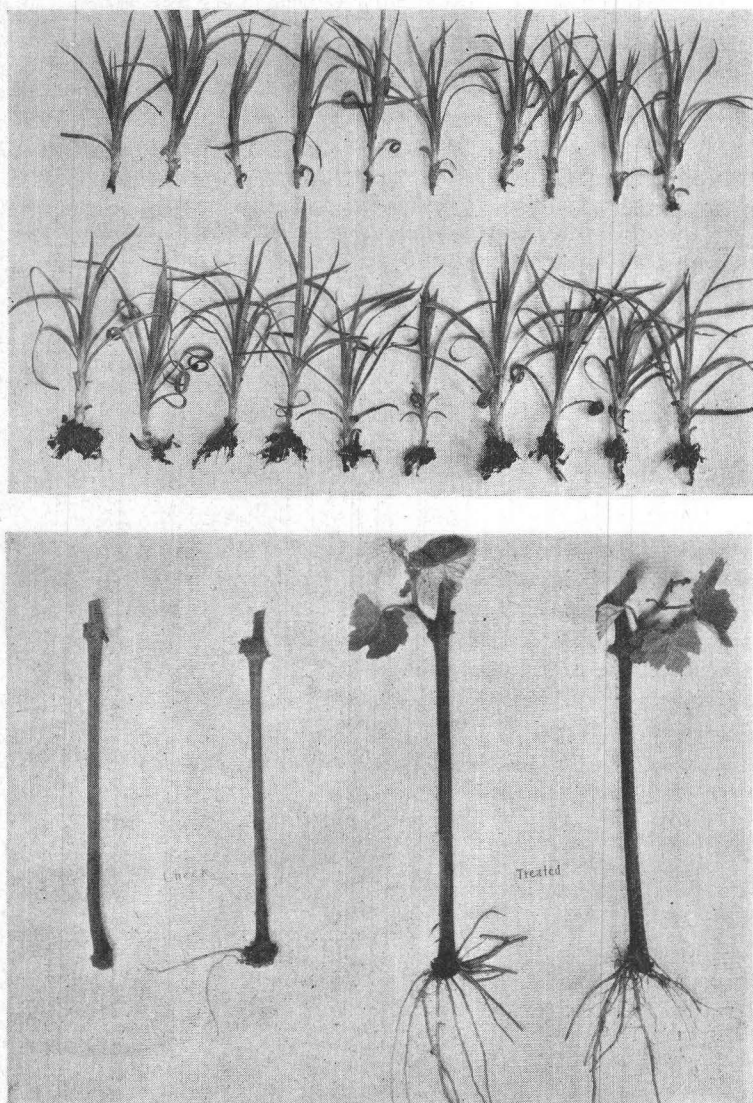


Figure 10. *Above: Top*, Harvest White carnation—Check after 31 days. *Bottom*, Harvest White carnation treated with indolebutyric acid, 3 mg. for 6 hours. After 31 days. *Below: Left*, Concord grape—Check after 42 days. *Right*, Concord grape treated with indoleacetic acid, 5 mg. for 16 hours. After 42 days. (L. O. Schaad)

to outweigh the disadvantages that follow treatment of cuttings with root-stimulating materials.*

Callus formation. The production of callus, which is a mass of rather spongy, whitish cells that accumulates especially on the basal end, often precedes or accompanies the rooting of the cuttings. It has been believed by some persons that roots originate from the callus (Figure 11). Experiments, however, have shown

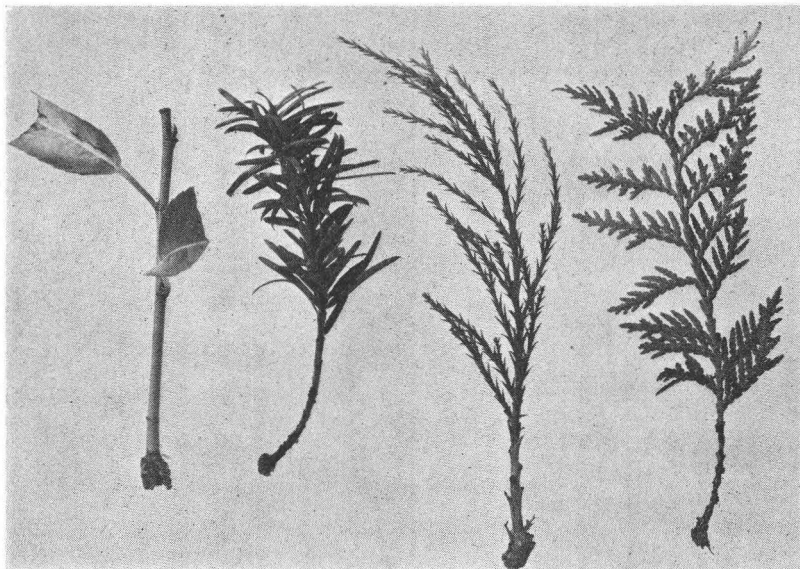


Figure 11. Calloused cuttings (Portugese laurel, Irish yew, *Sequoia gigantea*, *Arbor vitae*).

that the formation of callus and rooting are two distinct processes: callus formation is favored by high moisture, while root formation is favored by aeration. The best callusing and rooting medium, therefore, should be well aerated and, at the same time, moist. Roots may grow through the callus but they always start from inside the cutting itself.

Callusing may be induced by bottom heat. Keeping the butt end of a cutting warmer than the top will allow callus to form before the buds start. This may be accomplished by planting the cuttings top end up in electrically heated hotbeds. Frequently sand callusing-pits located on the sunny side of a building are used, in which cuttings are placed butt ends up, covered at least

* Further information relative to the effect of synthetic growth substances on plants is given in the 1938 Proceedings of the American Society for Horticultural Science, pp. 796-822, Vol. 36.

two inches, and kept moist at all times. The top ends covered by the soil are kept cool and dormant while the sun warms the butt ends of the cuttings, causing them to form callus. Callusing by these methods is practiced with good results for slow-rooting cuttings or those that have quick-starting buds. Many cuttings will callus satisfactorily by merely burying, either top ends up, or horizontally, in sand boxes or sand pits that are relatively cool and moist. It may be stated, however, that some propagators do not desire callus to form, because when planting in the nursery row, the callus may be injured and the cuttings weakened. Cuttings should be planted before an abundance of callus or new roots form, if they are to be planted by merely sticking them into the nursery soil, otherwise they should be dibbled in, or individual holes should be dug to receive them so as not to injure the callus or break off small roots.

Polarity. It is an interesting fact that pieces of a stem will form roots at the lower end and shoots at the opposite end. No matter into how many pieces a stem may be cut, this habit of growth persists. The phenomenon is known as polarity. In a few species, stem cuttings may be inverted and caused to take root at the opposite end, but such growth is generally weak and plants seldom live long. Root cuttings do not exhibit this marked polarity, and roots emerge from almost any place on the cutting.

Rest period. For those plants that do not otherwise root well it has been suggested that to plant cuttings taken in the fall while they are in the rest period will cause rooting. The reason for this seems to be that certain plants have a short rest period. Food or growth-promoting material is used for the first root growth, but if the tops are not in rest the material will be used for shoot growth. It is obvious, therefore, that cuttings of many varieties should be planted while they are still in the rest period; otherwise the buds will break and new leaves will start and consume all of the stored nutrients in the cutting so that none will be available for root formation.

Process of rooting. The following phases occur in the rooting of cuttings:

1. Healing of cut surface
 - a. Cork formation
 - b. Callus formation
2. Swelling of buds and appearance of new leaves and shoots

3. Appearance of new roots
4. Elongation of shoots and roots and establishment of the new plant on its own roots

The following phenomena may be noted:

1. Shoots upon shoots, from adventitious or true buds
2. Shoots upon roots
3. Roots upon stems
4. Roots upon roots
5. Shoots and roots upon leaves
6. Adventitious buds and shoots from seed

Root cuttings. Root cuttings or pieces of roots are used to propagate some plants. These are used particularly with species that have a tendency to sucker or send up sprouts from the roots. Among the plants that show these tendencies, either with or without cutting, are Japanese quince, red raspberry (*Frontispiece*), blackberry, and others. Some of these are commercially propagated by cutting the roots into pieces two or three inches long and planting in the spring in a sand box or in the nursery.

Leaf cuttings. Leaf cuttings are used to propagate a few plants. The Rex begonia and certain other begonias, peperomia, and gloxinia, together with the kalanchoe and bryophyllum, chiefly ones with thick, fleshy leaves, under proper conditions may be made to produce roots and stems. In the case of bryophyllum and kalanchoe, the whole leaf is used flat on moist sand

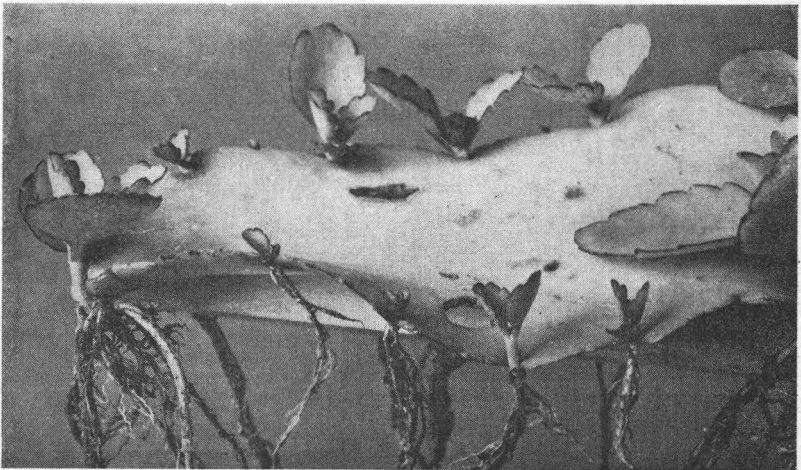


Figure 12. Bryophyllum leaf with new plants forming at the notches of the old leaf.

with the petiole planted in the same (Figure 12). It will form roots and buds at the notches. In others the leaves may be used whole or cut into pieces, each piece including a part of the petiole, being set in moist sand. A modification of a leaf cutting is a leaf-bud cutting, which is a leaf cut off with a heel or portion of stem attached, having a bud in the axil of the leaf petiole.

Transplanting rooted cuttings. The time required for rooting of different cuttings varies a great deal. Softwood cuttings usually root quickly, requiring from a few days to two weeks. Hardwood deciduous cuttings and the broad-leaf evergreens require eight to ten weeks and conifers from two to fifteen months. A rooted cutting is called a rooting. When roots have been produced in sufficient quantity and are about half an inch long, the rootings should be transplanted into a more nutrient medium, consisting of one-third compost, one-third leafmold, and one-third sand. Transplanting should not be delayed too long, for the rootings may become weak and spindling. Small-sized flower pots are preferred for starting small rootings and medium and large pots for the corresponding sizes of rootings. Containers made of veneer or paper may likewise be used.

Table 2. PLANTS THAT GROW FROM CUTTINGS

1. Hardwood stem cuttings		
Barberry	Honeysuckle	Pyracantha
Cotoneaster	Hydrangea	Quince
Currant	Lilac	Rose
Dogwood	Mock Orange	Spirea
Fig	Olive	Tamarix
Forsythia	Pomegranate	Viburnum
Grape	Poplar	Willow
Gooseberry	Privet	
2. Semihardwood stem cuttings		
Arbor vitae	Hibiscus	Rose
Boxwood	Holly	Wisteria
Camellia	Myrtle	Yew
Cryptomeria	Photinia	
3. Softwood stem cuttings		
Abelia	Gardenia	Petunia
Ageratum	Geranium	Poinsettia
Carnation	Heliotrope	Rose
Coleus	Hydrangea	Salvia
Fuchsia	Lantana	Snapdragon
		Stevia
4. Leaf cuttings		
Begonia	Kalanchoe	Sansevieria
Bryophyllum	Peperomia	(division for variegated type)
5. Root cuttings		
Apple (Daucin)	Blackberry	Red raspberry
6. Leaf-bud cuttings (highly specialized)		
Black raspberry	Rhododendron	

LAYERAGE

The operation of rooting plants while still attached to the plant is called layerage. It may happen naturally, as in the case of runner plants on strawberries, and tip layers on trailing black-

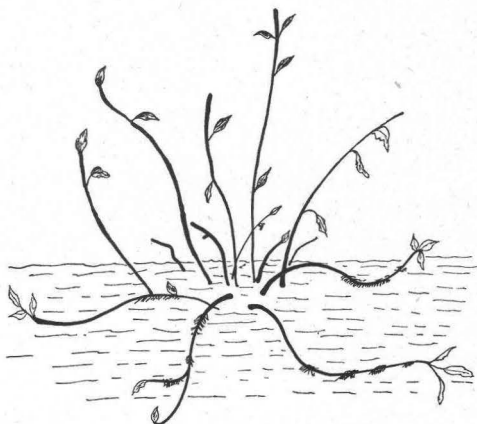


Figure 13. Common layering. Shoots laying close to the ground, when covered with soil, root and produce new plants.

berries, dewberries, and blackcap raspberries. Grape vines, Virginia creeper, and honeysuckle, for example, take root at the nodes and produce new individuals if partly covered. Likewise, filberts, gooseberries, and rubber plants when given special aid by the propagator can be rooted, using different types, such as tip, mound, or air layerage, in which cases the stems

are covered with soil or similar material into which roots grow. After roots form, the parts may be severed from the mother plant and transplanted as new individuals (Figures 13 and 14.)

SEPARATION

The method of propagating plants from their *naturally* detachable parts is known as separation. Certain plants are so constituted that they can be easily broken into smaller units, such as bulbels from mother bulbs and cormels from mother corms (Figure 15). Bulblets are small bulbs produced above ground in the axils of the leaves of certain lilies, or even in the tops among the flowering parts of some plants, such as the onion. These parts, if planted, will produce new plants, the larger ones producing flowers the first year while the smaller ones, if given careful attention, will produce flowers the first or second year after planting. Some of these, if given special treatment, will produce masses of smaller individuals, such as in the case of hyacinth bulbs, which if slashed or scooped at the base will form a mass of bulbels under the mother bulb. The outer scales of some of the lily bulbs, if separated and planted, often produce bulbels and new plants in a few months (Figure 16).

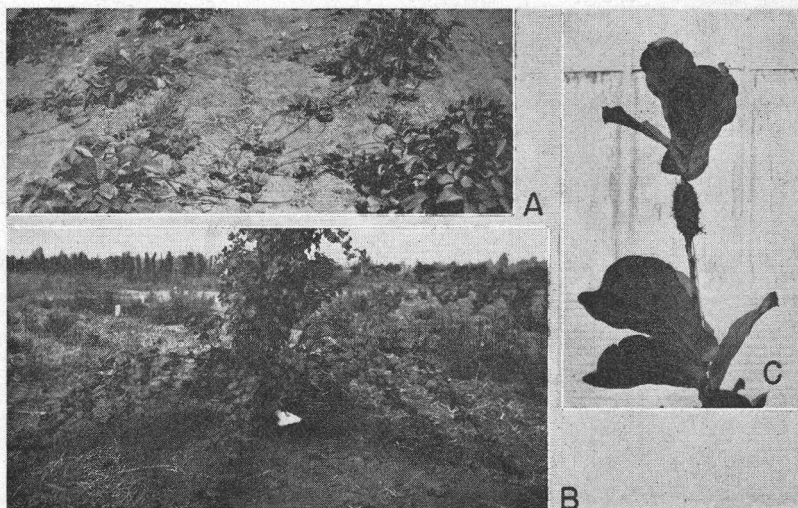


Figure 14. A. Strawberry plants showing runners and daughter plants. B. Trailing blackberry showing some canes bending to the ground and rooting at the tips. C. Air layerage of *Ficus pandurata*. The stem is slit diagonally upward four or five nodes below the top of the plant. The slit is held partly open with a small peg. A ball of moist sphagnum moss is bound around the cut and kept moist until roots grow out. The new plant is cut off below the ball of roots and potted.

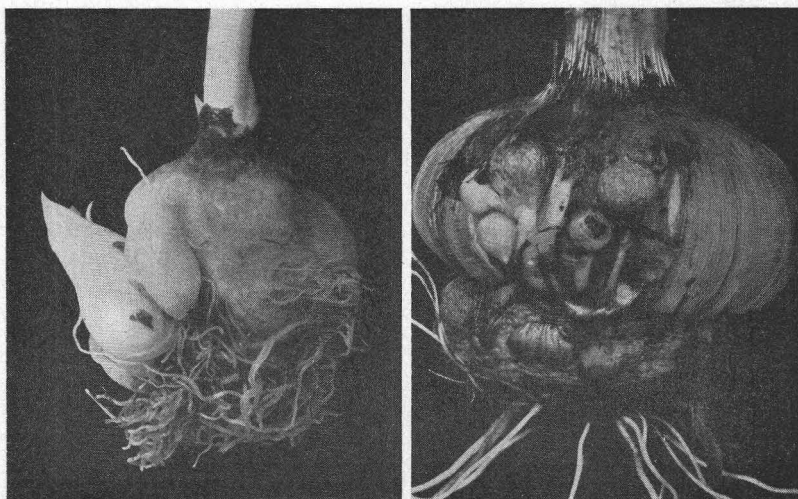


Figure 15. Left: Tulip, showing mother and daughter bulbs. Right: Gladiolus showing old (below) and new corm (above) with cormels growing on the side.



Figure 16. Scales of lily showing bulbels and new plants forming at the base of the old bulb scale.

DIVISION

Division is a common method of increasing many plants by means of parts that are broken or cut away from the parent. With herbaceous perennials, like dahlia, lily of the valley, violet, chrysanthemum, hollyhock, rhubarb, and asparagus, when the roots are lifted from the ground the center clump may be cut or divided into several pieces, each of which may be transplanted to form individual specimens. With some plants that have fewer buds on the center clump, as in the case of the peony, dahlia, and canna, more care must be taken to insure that at least one bud is present on each divided portion. In addition to being a source of new plants, an occasional division is beneficial to many perennials, but too frequent division may tend to weaken the mother plant.

SUCKERS are shoots that come up around the base of a plant, or several feet away. They arise from roots or underground stems, often being increased by injury to these parts from cultivation tools. Familiar examples are the blackberry, red raspberry, and filbert. Well-rooted suckers may be dug in the early spring and transplanted to propagate the variety.

OFFSHOOTS AND OFFSETS are small plants that are produced on the stem or around the base of some plants, including anthericum and "hen and chickens," respectively. These plantlets may be

broken away and, by planting in sand or a light soil, each will produce a good root system and a new individual.

CROWNS are rooted buds, produced by some species on underground stems late in the summer. Crowns of plants, such as asparagus, are dug in the late fall or early winter and stored dry at low temperature until planting time in the spring. Lily of the valley crowns or "pips" are imported annually by florists and kept in cold storage until planted.

GRAFTAGE

Growing plants on the roots or stocks of other plants is an interesting and important phase of plant propagation. This process is known as graftage and comprises the operation of inserting a part of one plant into or upon another for the purpose of uniting them. Graftage includes both *grafting* proper and *budding*. The former involves the union of a twig or scion having one or more buds, while the latter involves the use of a single bud. The chief purpose of graftage is to perpetuate a variety that does not reproduce itself from seed, or that cannot be established easily from cuttings, layers, or some other more economical method. Grafting or budding onto the stock of another plant frequently produces a more vigorous or more productive top. One may desire to use a root system that is particularly resistant to a certain insect or disease, or adaptable to a certain soil condition. For dwarfing purposes, moreover, a stock may be chosen to make a scion grow less vigorously, as for example, pear on quince produces a dwarf pear tree. Finally, for repairing an injury, bridge grafting or inarching may be employed. (See Extension Bulletin 528, Grafting and Budding.)

Theoretically, plants that are closely related botanically are capable of being grafted. There is no sure guide, however, as to which plants will intergraft successfully. Generally different species of the same genus can be grafted upon each other, but it may not be profitable to do so. Pears may be grafted on apples, but it is problematical whether they will succeed because of a short-lived union. On the other hand, it is sometimes found that plants belonging to distinct genera unite readily as, for instance, the grafting of pear on quince or pear on hawthorn. It is safe to state that the apple will not grow upon the oak, the orange, the peach, or any other distinctly unrelated plant. The final proof can be determined, however, only by finding how long the scion will live and grow satisfactorily.

Grafting. The time for most outdoor grafting is in the spring when the cambium cells become active. This is indicated by a swelling of the buds on the stock. The scions, however, should



Figure 17. Side-graft of *Chamaecyparis wissleri* (right) on Port Orford cedar seedling.

be taken in advance of this time and kept dormant in a cool place or in cold storage and not permitted to become dry. The actual operation of grafting is most successful in the spring or early winter. If many trees are to be grafted, winter grafting may be more practicable. Walnuts, however, should be grafted in the late spring when the stock is beginning to put forth new shoot growth. Grafting wax should be used to cover the graft union to prevent drying of the cut surfaces.

Some forms of grafting are done indoors, using stocks that have been grown in pots and forced a little in the greenhouse, and scions that have been freshly taken from plants outdoors. Such grafting is very special and requires the use of a grafting case and bottom heat so that moisture and temperature may be controlled. Certain conifers, maples, and rhododendrons may be grafted in this manner during the early winter (Figure 17).

Budding. The form of graftage known as budding is done usually in the late summer. Some spring budding of ornamentals, such as flowering cherries, is being done in Oregon with a high degree of success (Figure 18). In the latter method, dormant buds of the previous season's growth are kept in cold storage until March or April. The great majority of budding, however, is in the summer, generally late July, August, and early September, using mature buds of current season's growth. The buds unite during the fall but do not grow until the following spring, at which time the old tops are cut off. Tying is with string,

raffia, or rubber budding strips. The latter stretch and do not require cutting two or three weeks after budding, to prevent



Figure 18. Nursery showing apple and weeping flowering cherry stock. Note flowering cherry budded high on Mazzard stock.

girdling, as do the others. Waxing or covering of buds is not generally practiced.

GROWING THE NEW PLANTS

After the young plants have become established in the propagating bed, they will require transplanting for further development. This is often done in a plot of ground called a nursery, which is devoted to the rearing of many kinds of plants, more especially the hardy and woody plants. In general, the nursery site should be chosen with regard to desirable soil, such as a good garden loam that is well drained, that can be easily worked, especially early in the spring, that is retentive of moisture, and that can be irrigated. It should not be unduly exposed to wind, and it should not be in a low place subject to frost injury. The soil should be light, especially for seedlings of deciduous plants. For evergreen plants it may be a heavier soil. The soil reaction may be adjusted by applications of lime to make it more alkaline, or by the addition of aluminum sulphate, ammonium sulphate, or peat moss to make it more acid. The nursery soil should be prepared in advance by plowing, disking, and leveling, and possibly piped for an irrigation system. A diagram should be prepared for planting the stock to provide systematic arrangement

CHART SHOWING METHODS FOR PROPAGATING COMMON FRUITS

Fruit	Budding	Grafting	Cuttings	Layers	Suckers and offsets
Almonds	*	1	3	3	3
Apples	1	*	2	2	3
Apricots	*	1	3	3	3
Avocados	*	1	3	3	3
Bananas	3	3	3	3	*
Blackberries, trailing	3	3	2	*	1
Blackberries, upright	3	3	1	3	*
Black raspberries	3	3	2	*	3
Cherries	*	1	3	3	3
Cranberries	3	3	*	1	2
Currants	3	3	*	3	3
Dates	3	3	3	3	*
Figs	2	2	*	1	1
Filberts	2	1	3	*	2
Gooseberries	3	3	1	*	3
Grapes	2	1	*	2	3
Huckleberries	3	3	*	1	2
Kumquats	*	1	2	3	3
Lemons	*	1	2	3	3
Limes	*	1	2	3	3
Loquats	*	1	2	2	3
Mandarins	*	1	2	3	3
Mangos	*	1	2	3	3
Mulberries	1	1	*	3	3
Olives	2	2	*	3	3
Oranges	*	1	2	3	3
Peaches	*	2	3	3	3
Pears	*	*	3	3	3
Pecans	*	1	3	3	3
Persimmons	*	1	2	3	3
Pineapples	3	3	1	3	*
Plums	*	1	3	3	3
Pomegranates	2	2	*	1	1
Pomelos (grapefruit)	*	1	2	3	3
Prunes	*	1	3	3	3
Quinces	1	1	*	2	3
Red raspberries	3	3	1	3	*
Strawberries	3	3	3	*	1
Walnuts	2	*	3	3	3

* The usual method
 1 May be used
 2 Occasionally used
 3 Not practicable

of beds, rows, walks, roadways, and avenues, to carry on the nursery operations, and for record keeping purposes.

Starting the nursery. Many of our horticultural plants are started in the nursery from seeds or cuttings. Seedlings are many times more vigorous, more hardy, and generally longer-lived than those produced by vegetative methods and are often desired for resistance to particular diseases, insect pests, or adverse soil conditions. For best results one should obtain seeds as near his requirements as possible, gathering from mature fruit so he can be sure that they are the right kind. Seeds should be properly cleaned, stored, or stratified, if necessary, before planting. Planting should be done in the early spring (March to April) in order to get the plants up as soon as possible and to have the maximum growth by the middle of the summer. Some of the nursery stock may be dug and sold as seedlings or rooted cuttings, while other

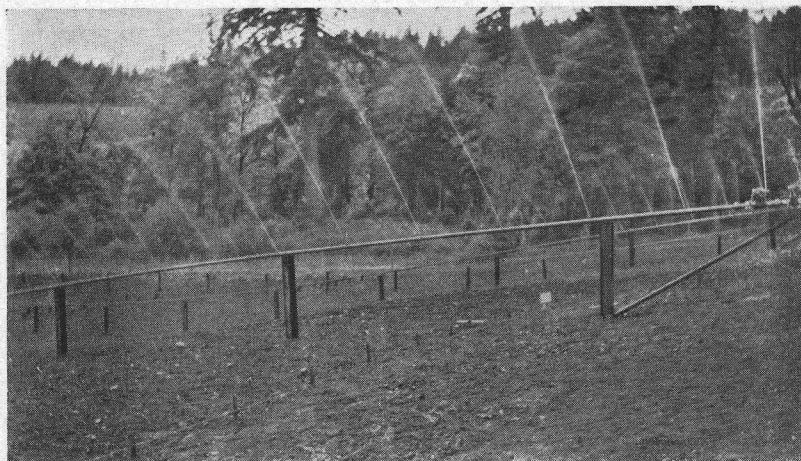


Figure 19. Irrigation by overhead sprinkling is becoming more extensively used in seedling nurseries

kinds may be left in place for nursery budding or grafting. Young plants growing in the nursery will need careful attention, including irrigation (Figure 19), cultivation, and possibly shading, spraying, dusting, fertilizing, mulching, and pruning. Plants that are to be budded during the season will need preliminary preparation, which consists of trimming the lower parts of the seedlings where the buds are to be inserted.

Nursery schedule. Some plants can be grown rapidly enough to be budded the first season while others cannot be budded or

grafted until the second or third season. Peach seedlings, for example, are generally budded in August or early September of the first season, while cherry, myrobalan plum, pear, and apple are budded the second summer that they are in the nursery. Black walnut seedlings are generally two years old when grafted, although sometimes when the seedlings are a year old and about one inch in diameter they may be grafted just above the surface of the soil. Some nurserymen, however, prefer to graft a foot or two above the soil and still others graft four and five feet, using the scaffold branches.

For plants propagated by cuttings, the same general procedure holds true. The new shoot from the cutting is budded during the first season. When the bud grows the old top is cut off. In the case of the rose, the shoot from the new bud as it starts to grow is cut back an inch or two above the stock to cause branching of the new top and to give a No. 1 rose bush, which requires three good branches or canes when it is dug.

Digging and transplanting. Plants should be dug from a nursery only when they are mature and preferably in a dormant condition. They may be dug with as much of the root system as practicable, either with bare roots or with an accompanying ball of soil (Figure 20). The ball is bound around the root system with burlap or heavy paper, or sometimes encased in wooden or metal containers. At all times the root system is prevented



Figure 20. Nursery sales yard, showing groups of conifers, and of ornamental and shade-tree nursery stock.

from drying out, by watering and packing in moist material and wrapping to prevent loss of moisture. If possible, the plants should be planted immediately in the new location; otherwise they should be heeled-in, that is, planted with the roots in moist soil, sawdust, or similar material and preferably in a shady place.

On planting in the new location, a sufficiently large hole should be dug to accommodate the root system and to allow the setting of the plant at about the same height or slightly deeper than it stood in the nursery. Moist fine top soil should be well packed around the roots. The plants should then be watered well to settle the soil and to encourage new root growth.

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PART II—IMPROVEMENT OF HORTICULTURAL PLANTS

The improvement of plants is the ultimate goal of many persons interested in the propagation of plants. The mere multiplication and continuation of the same characteristics would not cause much advancement for horticulture. New varieties and strains, however, may be produced by the same organs that are used for propagation; namely, the seeds and the buds.

George Lindley in his book, "A Guide to the Orchard and Fruit Garden," published in England in 1846, states:

"All our fruits, without exception, have been so much ameliorated by one circumstance or another, that they no longer bear any resemblance in respect of quality to their original. What resemblance can now be traced between the delicious Beurré pears, whose flesh is so succulent, rich and melting, and that hard, stony, astringent fruit, which even birds and animals refuse to eat? Yet these are undoubted cases of improvement resulting from time and skill patiently and constantly in action. But it would be of little service to mankind that the quality of any fruit should be improved unless we found some efficient and certain mode of multiplying individuals when obtained. Hence, there are two great considerations to which it is, above all things, necessary that the attention of the cultivator should be directed, viz. Amelioration and Propagation."

"*Amelioration* consists either in acquiring new and improved varieties of fruit, or in increasing their good qualities when acquired. Cultivators increase this disposition chiefly in two ways; either by constantly selecting the finest existing varieties for seed, or by intermixing the pollen and stigma of two varieties for the purpose of securing something of an intermediate nature. The power of obtaining cross-bred varieties at pleasure has only existed since the discovery of sexes in plants; but as it exerts a most extensive influence over alterations in the vegetable kingdom, it may be considered the most important controlling power that we possess.

"The power of procuring intermediate varieties by intermixture of the pollen and stigma of two different parents is, however, that which most deserves consideration. We all know that hybrid plants are constantly produced in every garden and that improvements of the most remarkable kinds are yearly occurring in consequence."

Seedlings. The great majority of varieties have originated from seed. If both parents are unknown, the resultant offspring is called a "chance seedling." If only one parent is known the resultant offspring is said to be a seedling of a certain variety (example: seedling of Marshall strawberry). Both parents may be known from a controlled cross, in which case the resultant offspring is said to be a cross (example: Marshall x Ettersburg 121). This process is termed hybridizing and is being carried on by plant breeders in many sections of the country, with all sorts

of plants, with the view of obtaining new and desired types (Figure 21).

Bud mutations. A comparatively small number of varieties originate as bud mutations, also called sports, strains, and variants. These originate unexpectedly as the result of some abnormal disturbance in the cell division of the vegetative tissues. Variations in color, form, size, season, form of plant, or leaf may appear. The

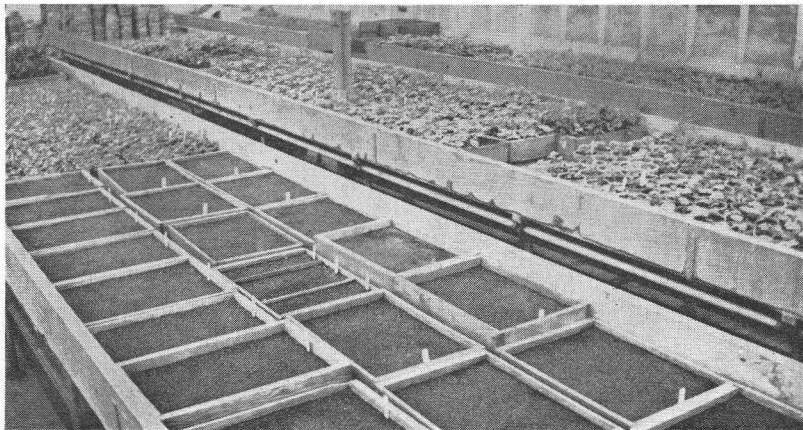


Figure 21. Greenhouse bench with flats of seed and potted seedlings. Seedling raspberry plants from known crosses in the foreground.

character may be an intensification of one already present in the parent or it may be an entirely new one that has been concealed somewhere in the parent tissue. The various color strains, the weeping and dwarf forms of ornamentals, the early-blooming or late-ripening strains of certain fruit varieties are examples.

Not all changes in plants are of this character. Some may be variations due to environmental factors. If a new characteristic appears it must be tested to ascertain whether it will reproduce vegetatively. If it does, it is a true bud mutation and can be so designated.

Bud selections. Some species exhibit more instability than others. Frequent red color strains are found with apples, some varieties producing many more than others. Not all such mutations are superior, however. There is always the equal possibility of degenerate types or strains appearing. It is also true that, once a mutation has appeared it is not certain that it will remain constant. It, too, may produce a mutation and revert to a kind

different from either its parent or itself. One should be in search of new developments of this kind, for the purpose of selection toward improvement and for the purpose of eliminating undesirable types.



Figure 22. Plant experimenter, Professor F. C. Reimer, who has worked for many years to attain uniform blight resistant pear stock and varieties, produced from seeds of known parents.

Hybridization. Definitely new types can be originated by the combination of two parent plants. The development of varieties by crossing is generally a long-time enterprise (Figure 22). The procedure involves the technique of emasculating the flower of the female parent, applying the male pollen under controlled conditions, saving the fruit and seeds, growing, testing, and selecting the seedlings for desired characteristics. Thousands may be grown to produce only one worthwhile selection. After several years of testing under different conditions, the selection may be found worthy and be given a variety name (example: Marshall x Ettersburg 121 produced OAC No. 12, which was named Corvallis strawberry after about ten years of testing).

Seedless Fruits. If fertilization of the ovule of the flower has not been completed, the fruit usually does not mature. With some kinds, however, including the seedless orange, fig, grape, persimmon, pineapple, banana, tomato, English cucumber, and more rarely watermelon and pepper, fruits and even seeds may develop without fertilization, or even without the stimulus that sometimes comes from pollination. Such fruits may develop fully but of course the seeds may be aborted. There are cases in

which these occurrences are natural, as in the case of Washington Navel orange, which produces no pollen and requires no pollination to set and mature its seedless fruits.

There are instances where the application of chemicals, and hormones, brushed on the stigma or ovaries or sprayed on the flowers has influenced seedless fruits. Such fruits are termed *parthenocarpic* fruits, since the growth of the carpels and other parts of the flower continues without fertilization. Not all seedless fruits, however, develop without fertilization. Some are seedless because the embryos break down after fertilization has taken place. Climatic conditions, such as freezing or frost, may also be the cause of seedless fruits, in the case of apples and pears, for instance.

Propagation of seedless fruits of necessity must be by vegetative means, such as cuttage, graftage, layerage, separation, or division.

Polyembryonic seeds. Some seeds, including avocado, citrus, mango, and others, develop several embryos and more than one seedling from a single seed. This phenomenon is called polyembryony or apogamy, meaning without marriage. The embryos are developed adventitiously or accidentally, only one being a true embryo of the fertilized ovule. The sexual embryo becomes aborted or eliminated, in a high percentage of certain species that have been studied. The seedlings are really vegetative reproductions of the female parent. It is impossible to distinguish the sexually produced or hybrid embryo from those that arise from the apogamic or adventitious type. This means that a great many more seedlings must be grown to a stage where they can be distinguished than is the case with plants possessing only normal or sexual embryos and seedlings.

Seedlessness and parthenocarpic development of fruit are considered varietal features to be selected in developing new varieties or strains. They cannot be produced normally by cultural measures.

Clonal propagation. When a variety has been found worthy of propagation, it is continued by vegetative methods. A selected strawberry seedling would be propagated by runners, a peach seedling by budding, and so on. Each group from the same parent is called a clon (clone). Strictly speaking, all varieties, that are propagated vegetatively are clons, such as Jonathan apple or Elberta peach.

Plant patents. Since the plant patent act of May, 1930, it has been possible to obtain for the originator of a new variety, a patent that assures him the right to propagate it for seventeen years. Patents under this law are limited to plants propagated by vegetative means, excluding bulbs and tubers. There are now recorded more than three hundred plant patents that have been originated in several species. The originator must file application, together with a description of the new discovery, which, if found worthy by specialists of the United States Department of Agriculture, is patented. According to law the patentee has exclusive rights to use and sell the discovery throughout this country. This law provides protection also for the names of horticultural varieties that have been given by the originators.

Such a law is needed to protect the use, not only of the varieties, but of their correct names and to list such names in legal records where they may be used in rendering court decisions on the misuse or substitution of variety names. It has been truly stated that "the variety is the cornerstone of horticulture." It seems that the name of a variety, therefore, should remain unchanged after it has once been given as a contribution to horticulture.

Plant introductions. There are several agencies, including Federal, state, and private institutions, corporations, and individuals engaged in originating, propagating, and distributing new varieties of plants. The United States Department of Agriculture, Bureau of Plant Industry, through its different offices, discovers, introduces, and distributes new varieties of horticultural plants, as do certain other institutions where such work is being conducted. Many of these are patented or certified varieties that are highly desirable as being the latest improvements of the horticultural world.

Plant certification. A plan of plant certification for strawberry and raspberry plants has been designed by O. T. McWhorter and S. M. Zeller and adopted by the Oregon State College Extension Service. Under the terms of this plan growers of high-grade planting stock are offered a means of protection and prospective purchasers are provided assurance that the plants are selected or are from certified stock. Any grower may voluntarily make application through his county agent by April 15 each year, accompanying his application with one-half of the fee based on acreage. Inspections are made by the College during the blooming period and fruiting period and again in the fall

before the plants are dug. All low-yielding, diseased, or abnormal plants are rogued out; all fields showing more than five per cent virus or other serious diseases are rejected. If not found acceptable in every way the certification is refused and an adjusted fee is returned to the applicant. Before final certification the applicant pays the remainder of his fee and his plants are then tagged by the College. This plan has been in operation since 1932 and in 1938-1939 provided more than a million plants of strawberry and raspberry planting stock true to name, vigorous, with well-developed roots, and with a minimum of serious diseases or insects. It has been an important aid to improvement of plants through selection (Figure 23).



Figure 23. Harvesting improved Corvallis strawberries on the Experimental Farm. Oregon State College.

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