# ROOTING RESPONSE TO DWARF APPLE CUTTINGS
# UNDER MIST AND ITS EFFECTS ON
# FIRST YEAR TREE GROWTH


By

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# INTRODUCTION

In recent years there has been considerable interest in dwarf apple trees for both home and commercial use. The dwarf or semi-dwarf trees have several advantages over normal sized trees. To the home gardener the small trees would fit better into the surroundings and allow more trees to be planted. The commercial grower's interest is primarily in the reduction of costs in the pruning, spraying, and harvesting operations.

Dwarf fruit trees are propagated by grafting a variety on a dwarfing rootstock or using a dwarfing interstem piece between the root and the top. There is evidence that the degree of dwarfness will vary with different stocks and the manner in which they are used.

To produce dwarf trees, it is necessary to multiply clonal grafts of the dwarfing stocks. The usual method is by mound layering, however, only a limited number of individuals can be reproduced from a single plant by this method. Although cuttings should be the best method of reproducing stocks, it has not given satisfactory results since the percentage of rooting has been very low.

In this study results are reported on the rooting of softwood cuttings of dwarf apple stocks under mist system and the influence of dwarf stocks on tree growth for the first year after grafting.

## REVIEW OF LITERATURE

### Propagation of Dwarf Apple Stocks

One of the major problems in propagating dwarf apple trees is the multiplication of the rootstocks. It has been difficult to root cuttings of the different apple stocks. In recent years, the use of mist has been an important advancement in propagating difficult-to-root species. Although numerous instances have been reported of the rooting of softwood cuttings, the techniques have not been fully developed in relation to commercial use.

The theory of mist propagation according to Hess (26) is to maintain a high humidity around the leaves of the cuttings in order to reduce the rate of respiration and transpiration. Mist, not only increases the humidity of the air, it also lowers the leaf temperature and decreases the rate of consumption of stored foods. Under high light intensity sugars are produced by the process of photosynthesis in leaves. They are, in turn, used in all the functions of the plant, including the formation of roots.

Hartmann (21) working on rooting of softwood cuttings of plum, peach, apple, walnut and olive pointed out that difficulty often arose in maintaining a sufficiently high humidity to reduce transpiration to keep the cuttings alive until roots formed. The mist technique seemed to be the best method yet devised to overcome this difficulty. Hess and Snyder (27) reported that cuttings under intermittent mist root more quickly with less leaching than cuttings under constant mist. Also cuttings might be hardened off when the intermittent mist system is used so that the loss of the cuttings from mist beds to open benches or open field planting is greatly reduced. Since less water is used in the intermittent mist operation, the drainage problem is practically eliminated. Continuous mist may cause the temperature to be too low at night for root development to take place. Thus, the intermittent mist system seems to be more practical for the purpose of propagation. Hartmann and Whisler (22) suggested that the best practice for most plants was to apply the mist intermittently during the daylight hours. The "on" and "off" intervals should be spaced so as to allow the mist to wet the leaves thoroughly, but to reduce the water used to the absolute minimum.

It appears that there is a certain range of temperature at which apple cuttings may root best, but the optimum temperature may vary with varieties. In 1935, Nightingale (37) reported that in both apple and peach the maximum yield of new roots and shoots occurred when the sand temperature was 65 degrees F. If the temperature was increased, there was a decrease in root development as well as in aerial organs. He also indicated that temperature had a very marked influence on the ability of the roots to reduce nitrate to nitrite, ammonium, and amino acids. This process of reduction and synthesis may always be accompanied by the oxidation of carbohydrates or their derivatives. Nelson and Tukey (36) found that root growth in EM VII, EM XVI and seedling rootstocks increased as the temperature was raised from 44 degrees F. to 77 degrees F. They assumed that the increase of the root temperature from 44 degrees F. to 77 degrees F. increased root cell maturation, as indicated by differentiation of primary tissues, vascular cambial activity and subsequent deposition of secondary tissues. On the other hand, the greatest root growth in EM I, EM II and EM IX was found at a temperature of 55 degrees F. Too high a temperature also was noted to increase browning and sloughing of the cortex of the roots.

Growth promoting substances have long been known to stimulate root development. They may induce the elongation and division of plant cells. Nelson (35) propagated Malus understocks from leaf bud cuttings and reported that hormones were beneficial, but toxicity occurred if they were used in too strong a concentration. Indolebutyric acid (IBA) 3000 ppm seemed to be the maximum concentration needed for rooting of Malus cuttings. Hartmann and Whisler (22) found that the indolebutyric acid was almost indispensable in obtaining satisfactory rooting for most plants even under mist. Hitchcock and Zimmerman (28) noted that indolebutyric acid was more effective than naphthalene acetic acid or indoleacetic acid on most species. They also pointed out that treating dry cuttings with powder was relatively ineffective on most species. Effective results were obtained by wetting the cuttings with 50 to 95 per cent ethyl alcohol. The presence of a solvent on the treated surface of the stem increases solubility of the crystalline rooting substance into the plant.

The formation of roots on cuttings is related to the manufacture and utilization of carbohydrates such as sugars and a root-producing substance, namely, rhizocaline, in leaves. Hess (26) found that a moderately high light intensity increased the manufacture of sugars in leaves. He also suggested that the cuttings should be taken early in the spring while the wood is very active. Nelson (35) concluded that the physiological age of the parent plant was of utmost importance, and very poor success was obtained with older material.

Many different media have been used as rooting materials and results have varied with the methods and types of cuttings used. According to the experiments of Mahlstede (32), a mixture of styrofoam, sand and peat was as successful as sand.

## Influence of Dwarf Stocks

For many years, the stock and scion relationship has been the subject of considerable investigation both in America and England, but it has been particularly active since the end of the World War I in 1918. The effect of the stock on tree growth is a relatively complex factor. The internal structure affecting the efficiency of conduction of water and nutrients, and congeniality between scion and stock influence the tree growth.

It was reported (6) (8) (58) that the internal structure of EM IX and other dwarf stocks have remarkably smaller vessels and more wood ray tissue in comparison with the more vigorous varieties. There is a close correlation between vigor and the bark to wood ratio. Mosse (34) found that the bark-wood ratio of scion shoots on dwarfing rootstocks had a greater bark percentage than shoots of the same variety on vigorous rootstocks and also a high proportion of bark in the roots. Fillmore (17) examined the stock of EM IX and EM XVI and indicated that a dwarf apple stock always contained a comparatively small core of wood and a comparatively thick rind or ring of bark. Dwarfness also causes early fruiting of the scion.

Furr (18) reported that the flow of water in the xylem of the apple trees was greatest in those which had the largest vessels. In using water culture for apple trees, Pearse (39) found that trees on EM XII rootstock absorbed more water per unit of leaf area during the growing season than those on EM IX. Warne and Raby (63) made the general statement that the graft union with Malling rootstock No. IX caused an additional resistance to the flow of water in the trees. It might be pointed out, however, that certain growth characteristics of trees on EM IX stock, namely the presence of small leaves and short internodes and early cessation of seasonal shoot growth, were characteritstics which might be associated with a slight internal deficit of water in these plants. As reported by Rao and Berry (42), starch accumulated in EM IX stock prior to the cessation of growth in the scion. Also, the water content of the EM IX stock and the scion thereon was appreciably less than that in the EM XII. Beakbane and Thompson (9) indicated that dwarfing rootstocks with higher bark to wood ratio and a high proportion of wood ray tissue have a larger volume of cells capable of storing carbohydrates. At the same time the absorption and passage of mineral salts in solution through the small vessels in the wood of the dwarfing rootstocks might be slower than through the large vessels of the vigorous rootstock (39) (2) which would tend to restrict shoot growth. The total amount of potassium and nitrogen absorbed was directly proportional to the growth made. After a careful observation of dwarf and standard understocks in Washington, Overholser, Overly, Schultz and Allmandinger (38) reported that the root spread appeared to be directly and closely proportional to the degree of dwarfing or vigor of the top, and that the Malling understocks differed in their ability to obtain mineral nutrients from the soil.

In comparing various dwarf stocks Hatton (24) found that EM. VIII and EM IX had the poorest anchorage. Since the Malling IX rootstock is shallow rooted and easily broken, the development of a dwarf tree by the double-grafting method should be a better method. Furthermore, such a method would be an economical use of dwarfing material since it requires only a short stem piece rather than an entire rootstock for dwarfing.

The intermediate stem piece serves as a passageway for water and nutrients between the top and root and influences the growth of each. The normal root system did not change as reported by Baker (4) in his study of the behavior of grafted trees as compared to trees on dwarf roots. The intermediate stem piece was as effective in dwarfing as the dwarf rootstock used. Tukey and Brase (54) found that there was a relationship between the length of the intermediate stem piece and the dwarfness of double-worked trees. Furr (18) noted that the long segements decreased the water flow the most. If the length was reduced to one-half, the rate of flow was more than doubled. Hatton (23) reported that Grubb found that a two foot intermediate stem piece intensified the dwarfing over a three inch stem piece when the same variety was used. However, the influence of the intermediate stem piece could not always be directly correlated with the vigor of the tree.

In recent years much work has been done in regard to the relation between uncongeniality and dwarfing, but no one has indicated that the influence of EM VII, EM IX and Clark on the top growth of the scion was due to uncongeniality. In the grafted trees the differences in the normal size of cambium cells, tree growth, and periods of vegetation may be considered to induce partial uncongeniality. Bradford and Sitton (12), working on defective graft unions in apples and pears found that the uncongenial grafts were principally due to the failure of maintaining cambium contact and that the xylem and phloem tissue generally became discontinuous. Chang (14) using mechanical and chemical tests reported that incompatible combinations were due to some forms of obstruction at the union as indicated by (1) a slower flow of dyes through the union, (2) a much higher resistance to the flow of water, and (3) a heavy deposit of starch above the union in November. He also found that various stocks and scions have different periods of cambial activity, periods of callus growth and regions of callus differentiation, and the rate of growth. In 1951 Herrero (25) stated that the symptoms of incompatibility were decreased in growth, poor leaves and early defoliation, premature degeneration of the phloem, and the abnormal distribution of starch. Blair (10), double working Bramley seedling on EM IX and then on French Crab, found that there was a swelling of the tissue of both scion and stem piece at the union. Furthermore, it was comparatively easy to break the tree across at the union and when so broken it was found that the xylem tissue had never really knit together. Bradford and Sitton (12) considered that the discontinuity in the phloem was largely responsible for dwarfing. Webber (64) indicated that in some cases interruption in the uniting of the tissues led to accumulation of carbohydrates above the union. Amos, Hoblyn, Garner and Witt (1) studied the incompatibility of stock and scion between EM VIII and EM IX and reported that they were the healthy dwarf types. Uncongeniality is not the universal cause for dwarfing.

## METHOD AND MATERIAL

A study was conducted at the Department of Horticulture, Oklahoma Agricultural and Mechanical College, from December, 1955, to February, 1957, to attempt a better technique to use in the propagation of dwarf apple stocks and their effects on the first year of top growth.

### PROPAGATION OF DWARF APPLE STOCKS

#### Softwood Stem Cuttings

The experiments on softwood stem cuttings were set up on May 29, July 2, July 13, August 31, and September 22. They were collected from the new shoot growth on two-year-old trees of EM VII, EM IX and Clark growing at the College Nursery. The cuttings were taken early in the morning, placed in moist peat and held in a refrigerator at 40 degrees F. to maintain freshness and turgidity until used. During the day the cuttings were prepared approximately three inches long and inserted in the different media and structures. The cuttings received the following treatments: (1) wounding -- (a) severe by removing a thin slice one half inch in length from the base on two sides, (b) medium by removing a thin slice on one side of the base, and (c) no additional wounding; and (2) hormone -- (a) dipping the basal end of cuttings in indolebutyric acid 3000 ppm[a], (b) indolebutyric acid 8000 ppm[b], and (c) untreated cuttings. Three media

---
[a]Hormodin No. 2
[b]Hormodin No. 3

were included in each propagation structure, i.e., (a) sand, (b) a mixture of equal parts of sand and peat, and (c) a mixture of equal parts of sand and perlite. The perlite is a glassy volcanic lava being expanded artificially by heating.

The experiments were conducted in three propagation structures. They were (a) the greenhouse, (b) an out-of-doors polyethylene structure, and (c) the water air cooled greenhouse which was designated as the cool house. The out-of-doors structure was constructed between two greenhouse ranges. The bed was 4 feet 3 inches wide by 11 feet 3 inches long. Drain tile and coarse gravel was used below the bed for drainage. The roof, being an even span, was covered with 4 mil (0.004 inch thickness) poleythylene film.

Mist application was installed above the bench in the greenhouse and above the bed in the polyethylene house. "Monarch Number 3.00" nozzles were spaced at 30-inch intervals. Two lines were used with one line placed on each side of the bench. The nozzles were staggered from one side to the other for better distribution of the mist. In the greenhouse the lines were placed 4 feet above the bench, while in the polyethylene house the lines were placed one foot above the bed.

Since the temperatures were high during the summer months, the greenhouse was partially shaded with lime to reduce light intensity and the polyethylene house was shaded with plastic saran cloth which reduced the light 52 per cent.

The mist system was controlled by a solenoid valve. The intermittent mist was operated first by an electronic leaf, but after unsuccessful operation, it was changed and operated by an electric timer. The time of misting was from 7 a.m. to 7 p.m. with misting for 7 seconds out of each minute. On July 5, the mist period was changed to 14 seconds out of each minute. Then, on August 30, the time of misting was changed to operate from 6 a.m. to 10 p.m. with misting for 25 seconds out of each minute.

In the cool house the cuttings were placed in flats containing the various media. Camouflage netting was placed above the cuttings to reduce light intensity. The cuttings were hand watered 2 to 3 times daily.

During the experiment, air and sand temperature were recorded by thermographs.

## Leaf Bud Cuttings

The material for leaf bud cuttings was collected from the trees of EM VII, EM IX and Clark at the College Nursery and inserted in sand in the greenhouse and the polyethylene house. The cuttings were processed and placed under mist in the same manner as for the softwood stem cuttings. The experiments were carried out on May 29, June 18 and July 26. The leaf bud cuttings were made into two types, the mallet and the heel cuttings. The former consists of a leaf with a segment of the stem and the axillary bud and the latter consists of a leaf with a small sliver of the stem and the axillary bud.

## Layering

Ten plants of two-year-old trees of each EM VII, EM IX and Clark with branched shoots were mounded with six inches of soil at the College Nursery on April 10, 1956. These trees were irrigated throughout the the growing season. The mounded shoots were examined on December 30, 1956 to determine the number of rooted plants produced.

## PROPAGATION AND GROWTH OF DWARF APPLE TREES

### Rootstocks Compared with Intermediate Stem Pieces

For the purpose of measuring the effects of dwarf apple stocks on top growth, single-worked and double-worked trees were made by means of splice grafting. Scions of Summer Champion and Starking were grafted on EM VII, EM IX and standard seedling roots. In double-working, 3 inch stem pieces of EM VII, EM IX and Clark were grafted between standard seedling roots and Starking or Summer Champion. Since stocks were obtained at different times, the work of grafting started on December 23, 1955, and was finished on March 19, 1956. All the grafts were kept in moist peat at a temperature around 50 degrees. F. for a period of more than two weeks. After callus tissue had formed at the unions, the grafts were planted in the field on April 3, 1956, in a randomized design, 3 trees in each plot with 6 replications. The stem diameter and the length of new growth were measured on December 11, 1956.

### Various Lengths of Intermediate Stem Pieces

Intermediate stem pieces of 3, 6, 9 and 12 inch lengths of EM VII, EM IX and Clark were splice-grafted between standard seedling roots and Starking or Summer Champion scions.

Grafts were made of each length of stem piece and variety. They were callused and planted in the field in a randomized design with 3 trees per plot and four replications. Measurement of stem diameter and shoot growth was made on December 11, 1956.

# EXPERIMENTAL RESULTS

## PROPAGATION OF DWARF APPLE STOCKS

### Softwood Stem Cuttings

The purpose of this experiment was to determine a desirable technique for multiplication of dwarf apple stocks by softwood cuttings. Several treatments were carried out on cuttings during the period of propagation under intermittent mist, and the results were recorded as follows:

### Hormone Treatment

The IBA 3000 ppm treatment gave the highest percentage of rooting of the stem cuttings. The root system was heavier as compared to the untreated or the IBA 8000 ppm treated cuttings. Cuttings placed in the polyethylene house on May 29 died in the dry spots between nozzles due to the lack of water. Thereafter, all the cuttings were inserted within the area where the mist was evenly applied. Data for the hormone treatments are shown in tables I to VIII.

### Wound Treatment

The wounding at the basal end of stem cuttings improved rooting. The best results were obtained where cuttings were wounded on two sides and treated with IBA 3000 ppm. Wounding on one side was better than no wounding.

Severe wounding of EM III and EM IX cuttings which were placed in the greenhouse resulted in 73.3% rooting. The cuttings in the polyethylene house did not root as well as in the greenhouse because most of them were lost due to the high temperatures of the sand. The cuttings which were made on September 22, rooted relatively slow in sand. Results are shown in tables V to VIII.

TABLE I

The Number of Softwood Stem Cuttings Which Rooted in the Greenhouse under Intermittent Mist.
Date: May 29-July 14.
(25 Cuttings per Treatment)

| Variety and Treatment | Degree of Rooting | | | | % Rooted |
|---|---|---|---|---|---|
| | Heavy | Medium | Light | Callused | |
| EM VII | | | | | |
| IBA 3000 ppm | 6 | 3 | 7 | 9 | 64 |
| Untreated | 5 | 3 | 3 | 13 | 44 |
| Clark | | | | | |
| IBA 3000 ppm | | 2 | 3 | 18 | 20 |
| Untreated | | | 2 | 23 | 8 |
| EM IX | | | | | |
| IBA 3000 ppm | | 6 | 8 | 11 | 56 |
| Untreated | | 3 | 5 | 16 | 32 |

Temperatures During First Two Weeks of the Experiment in the Greenhouse.
Date: May 29-June 11

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 95.0° F | 118.0° F | 99.0° F |
| Minimum | 59.0° F | 73.0° F | 72.0° F |
| Mean | 74.7° F | 84.0° F | 83.0° F |

TABLE II

The Number of Softwood Stem Cuttings Which Rooted in the Polyethylene House under Intermittent Mist.
Date: May 29-July 14.
(25 Cuttings per Treatment)

| Variety and Treatment | Degree of Rooting | | | | % Rooted |
|---|---|---|---|---|---|
| | Heavy | Medium | Light | Callused | |
| EM VII | | | | | |
| IBA 3000 ppm | 2 | 3 | 3 | 12 | 32 |
| Untreated | | 3 | 2 | 14 | 20 |
| Clark | | | | | |
| IBA 3000 ppm | | 1 | 4 | 12 | 20 |
| Untreated | | 2 | 1 | 12 | 12 |
| EM IX | | | | | |
| IBA 3000 ppm | 1 | 4 | 2 | 14 | 28 |
| Untreated | | 3 | 4 | 10 | 28 |

Temperatures During First Two Weeks of the Experiment in the Polyethylene House
Date: May 29-June 11

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 95.0° F | 110.0° F | 100.0° F |
| Minimum | 59.0° F | 64.0° F | 68.0° F |
| Mean | 74.4° F | 81.1° F | 83.5° F |

TABLE III

The Number of Softwood Stem Cuttings Which Rooted in the Greenhouse under Intermittent Mist.
Date: July 2-Sept. 8

| Variety and Treatment | No. Cutting | Degree of Rooting: Heavy | Medium | Light | Callused | % Rooted |
|---|---|---|---|---|---|---|
| EM VII | | | | | | |
| IBA 3000 ppm | 28 | 7 | 3 | 3 | 5 | 46.4 |
| Untreated | 28 | 6 | 2 | 2 | 9 | 25.7 |
| Clark | | | | | | |
| IBA 3000 ppm | 19 | 4 | 2 | 1 | 10 | 36.8 |
| Untreated | 19 | 2 | | 3 | 12 | 26.3 |
| EM IX | | | | | | |
| IBA 3000 ppm | 28 | 3 | | 7 | 18 | 35.7 |
| Untreated | 28 | | 1 | 3 | 23 | 14.3 |

Temperatures During First Two Weeks of the Experiment in the Greenhouse.
Date: July 2-July 15.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 106.0° F | 120.0° F | 97.0° F |
| Minimum | 60.0° F | 73.0° F | 70.0° F |
| Mean | 81.9° F | 87.5° F | 82.5° F |

TABLE IV

The Number of Softwood Stem Cuttings Which Rooted in the Polyethylene House under Intermittent Mist.
Date: July 2-Sept. 8

| Variety and Treatment | No. Cutting | Degree of Rooting Heavy | Medium | Light | Callused | % Rooted |
|---|---|---|---|---|---|---|
| EM VII | | | | | | |
| IBA 3000 ppm | 28 | 4 | 1 | 3 | 18 | 28.6 |
| Untreated | 28 | 2 | 5 | 2 | 14 | 32.1 |
| Clark | | | | | | |
| IBA 3000 ppm | 19 | | 2 | 1 | 7 | 15.8 |
| Untreated | 19 | | 1 | 1 | 9 | 10.5 |
| EM IX | | | | | | |
| IBA 3000 ppm | 28 | 1 | 4 | 2 | 16 | 25.0 |
| Untreated | 28 | | 3 | 2 | 19 | 17.9 |

Temperatures During First Two Weeks of the Experiment in the Polyethylene House.
Date: July 2-July 15

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 106.0° F | 110.0° F | 104.0° F |
| Minimum | 60.0° F | 64.0° F | 75.0° F |
| Mean | 81.9° F | 84.7° F | 88.7° F |

TABLE V

The Number of Softwood Stem Cuttings Which Rooted in the Greenhouse under Intermittent Mist.
Date: July 13-Oct. 6.
(15 Cuttings per Treatment)

| Variety and Treatment | Degree of Rooting | | | | % |
|---|---|---|---|---|---|
| | Heavy | Medium | Light | Callused | Rooted |
| EM VII | | | | | |
| IBA 3000 ppm | | 3 | 4 | 6 | 46.7 |
| IBA 3000 ppm 1W[a] | 3 | 3 | | 8 | 40.0 |
| IBA 3000 ppm 2W[b] | 5 | 2 | 4 | 4 | 73.3 |
| IBA 8000 ppm | | 3 | 1 | 8 | 26.7 |
| Clark | | | | | |
| IBA 3000 ppm | 1 | 1 | | 10 | 13.3 |
| IBA 3000 ppm 1W[a] | 3 | 1 | 1 | 10 | 33.3 |
| IBA 3000 ppm 2W[b] | 5 | | 3 | 6 | 53.3 |
| IBA 8000 ppm | 1 | | 1 | 9 | 13.3 |
| EM IX | | | | | |
| IBA 3000 ppm | 2 | 1 | | 11 | 20.0 |
| IBA 3000 ppm 1W[a] | 4 | 4 | 3 | 3 | 73.3 |
| IBA 3000 ppm 2W[b] | 4 | 4 | 3 | 4 | 73.3 |
| IBA 8000 ppm | 3 | 1 | | 7 | 26.7 |

[a] One wound.
[b] Two wounds.

Temperatures During First Two Weeks of the Experiment in the Greenhouse.
Date: July 13-July 26.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 106.0° F | 121.0° F | 96.0° F |
| Minimum | 60.0° F | 71.0° F | 68.0° F |
| Mean | 84.2° F | 84.5° F | 80.7° F |

TABLE VI

The Number of Softwood Stem Cuttings Which Rooted in the Polyethylene House under Intermittent Mist.
Date: July 13-Oct. 6
(15 Cuttings per Treatment)

| Variety and Treatment | Degree of Rooting Heavy | Medium | Light | Callused | % Rooted |
|---|---|---|---|---|---|
| EM VII | | | | | |
| IBA 3000 ppm | | 5 | 2 | 5 | 46.7 |
| IBA 3000 ppm 1W[a] | | 4 | 2 | 6 | 40.0 |
| IBA 3000 ppm 2W[b] | | 1 | 2 | 8 | 20.0 |
| IBA 8000 ppm | | 4 | 2 | 5 | 40.0 |
| Clark | | | | | |
| IBA 3000 ppm | | | | 8 | 0.0 |
| IBA 3000 ppm 1W[a] | | 1 | | 10 | 6.7 |
| IBA 3000 ppm 2W[b] | | | | 9 | 0.0 |
| IBA 8000 ppm | | 1 | | 7 | 6.7 |
| EM IX | | | | | |
| IBA 3000 ppm | | 1 | | 12 | 6.7 |
| IBA 3000 ppm 1W[a] | | 2 | | 8 | 13.3 |
| IBA 3000 ppm 2W[b] | 3 | 1 | 1 | 10 | 33.3 |
| IBA 8000 ppm | | | | 7 | 0.0 |

[a] One Wound.
[b] Two Wounds.

Temperatures During First Two Weeks of the Experiment in the Polyethylene House.
Date: July 13-July 26.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 106.0° F | 110.0° F | 103.0° F |
| Minimum | 60.0° F | 66.0° F | 76.0° F |
| Mean | 84.2° F | 83.5° F | 88.5° F |

TABLE VII

The Number of Softwood Stem Cuttings Which Rooted in the Greenhouse under Intermittent Mist.
Date: Sept. 22-Nov. 8.
(15 Cuttings per Treatment)

| Variety and Treatment | Degree of Rooting: Heavy | Medium | Light | Callused | % Rooted |
|---|---|---|---|---|---|
| EM VII | | | | | |
| Untreated | 1 | 1 | | 4 | 13.3 |
| IBA 3000 ppm | | 2 | 2 | 5 | 26.7 |
| IBA 3000 ppm 1W[a] | | 1 | 2 | 8 | 20.0 |
| IBA 3000 ppm 2W[b] | 1 | 1 | 1 | 4 | 20.0 |
| IBA 8000 ppm | | | 1 | 7 | 6.7 |
| Clark | | | | | |
| Untreated | | 1 | | 6 | 6.7 |
| IBA 3000 ppm | | | 2 | 8 | 13.3 |
| IBA 3000 ppm 1W[a] | 1 | | 1 | 4 | 13.3 |
| IBA 3000 ppm 2W[b] | | 1 | 2 | 5 | 20.0 |
| IBA 8000 ppm | | 1 | | 5 | 6.7 |
| EM IX | | | | | |
| Untreated | | | 1 | 6 | 6.7 |
| IBA 3000 ppm | | | 1 | 6 | 6.7 |
| IBA 3000 ppm 1W[a] | | | 1 | 5 | 6.7 |
| IBA 3000 ppm 2W[b] | 1 | 1 | 1 | 7 | 20.0 |
| IBA 8000 ppm | | | | 8 | 0.0 |

[a] One Wound.
[b] Two Wounds.

Temperatures During First Two Weeks of the Experiment in the Greenhouse.
Date: Sept. 22-Oct. 5.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 100.0° F | 94.0° F | 83.0° F |
| Minimum | 70.4° F | 56.0° F | 53.0° F |
| Mean | 71.9° F | 74.7° F | 68.6° F |

TABLE VIII

The Number of Softwood Stem Cuttings Which Rooted in the Polyethylene House under Intermittent Mist.
Date: Sept. 22-Nov. 8.
(15 Cuttings per Treatment)

| Variety and Treatment | Degree of Rooting: Heavy | Medium | Light | Callused | % Rooted |
|---|---|---|---|---|---|
| EM VII | | | | | |
| Untreated | | 1 | 2 | 4 | 20.0 |
| IBA 3000 ppm | | 1 | 1 | 4 | 13.3 |
| IBA 3000 ppm, 1W[a] | | 2 | | 5 | 13.3 |
| IBA 3000 ppm, 2W[b] | | 2 | 2 | 8 | 26.7 |
| IBA 8000 ppm | | | 2 | 5 | 13.3 |
| Clark | | | | | |
| Untreated | | | | 7 | 0.0 |
| IBA 3000 ppm | | 2 | | 8 | 13.3 |
| IBA 3000 ppm, 1W[a] | | 1 | 3 | 6 | 26.7 |
| IBA 3000 ppm, 2W[b] | | 1 | 2 | 8 | 20.0 |
| IBA 8000 ppm | | 1 | 1 | 7 | 13.3 |
| EM IX | | | | | |
| Untreated | | | 1 | 7 | 6.7 |
| IBA 3000 ppm | | | 1 | 6 | 6.7 |
| IBA 3000 ppm 1W[a] | | | 3 | 9 | 20.0 |
| IBA 3000 ppm 2W[b] | | 1 | 4 | 5 | 33.3 |
| IBA 8000 ppm | | | | 4 | 0.0 |

[a] One Wound.
[b] Two Wounds.

Temperatures During First Two Weeks of the Experiment in the Polyethylene House.
Date: Sept. 22-Oct. 5.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 100.0° F | 100.0° F | 93.0° F |
| Minimum | 70.4° F | 51.0° F | 64.0° F |
| Mean | 71.9° F | 71.5° F | 77.1° F |

## Media

Cuttings treated with IBA 3000 ppm were tested in different media, namely, sand, a mixture of equal amounts of sand and perlite, and a mixture of equal amounts of sand and peat. The best results were obtained from cuttings of the three different stocks in the mixture of sand and peat regardless the structures in which the cuttings were rooted. The mixture of sand and perlite also gave a better response to rooting of cuttings than those in sand alone. The results are shown in tables IX, X and XI. Figures 1 to 3 show that the root growth of cuttings was correlated with the rooting media.

## Structures

Moisture and temperature, which usually vary within the various structures, are two very important factors influencing the root formation of cuttings. In the greenhouse and the polyethylene house, similar mist systems were used. In all the experiments the softwood stem cuttings consistently rooted better in the greenhouse than in either the polyethylene house or the cool house, although some of the percentages of survival were quite low. Data on the rooting of cuttings in the various structures are shown in table XII. The root systems of EM VII, EM IX and Clark in the three structures are shown in Figure 4.

TABLE IX

The Number of Softwood Stem Cuttings Which Rooted in the Greenhouse under Intermittent Mist.
Date: Aug. 31-Nov. 8.
(15 Cuttings per Treatment)

| Variety and Medium | Degree of Rooting Heavy | Medium | Light | Callused | % Rooted |
|---|---|---|---|---|---|
| EM VII | | | | | |
| Sand | | | 3 | 12 | 20.0 |
| Sand and Perlite | | 2 | 1 | 12 | 20.0 |
| Sand and Peat | 1 | 3 | 3 | 8 | 46.7 |
| Clark | | | | | |
| Sand | 2 | | 5 | 8 | 46.7 |
| Sand and Perlite | 3 | 2 | 3 | 7 | 53.3 |
| Sand and Peat | 4 | 4 | | 6 | 53.3 |
| EM IX | | | | | |
| Sand | 2 | 1 | 2 | 6 | 33.3 |
| Sand and Perlite | 4 | 1 | 2 | 6 | 46.7 |
| Sand and Peat | 7 | | 2 | 6 | 60.0 |

Temperatures During First Two Weeks of the Experiment in the Greenhouse.
Date: Aug. 31-Sept. 13.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 104.0° F | 108.0° F | 87.0° F |
| Minimum | 44.0° F | 60.0° F | 56.0° F |
| Mean | 75.7° F | 76.8° F | 71.7° F |

TABLE X

The Number of Softwood Stem Cuttings Which Rooted in the Polyethylene House under Intermittent Mist.
Date: Aug. 31-Nov. 8.
(15 Cuttings per Treatment)

| Variety and Medium | Degree of Rooting: Heavy | Medium | Light | Callused | % Rooted |
|---|---|---|---|---|---|
| EM VII | | | | | |
| Sand | | | | | 0.0 |
| Sand and Perlite | | 2 | 1 | 8 | 20.0 |
| Sand and Peat | 3 | 1 | 2 | 9 | 40.0 |
| Clark | | | | | |
| Sand | | | | | 0.0 |
| Sand and Perlite | 1 | 1 | 2 | 4 | 26.7 |
| Sand and Peat | 2 | 1 | 2 | 12 | 33.3 |
| EM IX | | | | | |
| Sand | | | | | 0.0 |
| Sand and Perlite | | 2 | 1 | 8 | 20.0 |
| Sand and Peat | 1 | 4 | | 8 | 33.3 |

Temperatures During First Two Weeks of the Experiment in Polyethylene House.
Date: Aug. 31-Sept. 13.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 104.0° F | 113.0° F | 102.0° F |
| Minimum | 44.0° F | 52.0° F | 65.0° F |
| Mean | 75.7° F | 76.2° F | 81.0° F |

Intermittent mist was off on Sept. 14, 1956.

TABLE XI

The Number of Softwood Stem Cuttings Which Rooted in the Cool House by Hand Watering.
Date: Aug. 31-Nov. 8
(15 Cuttings per Treatment)

| Variety and Medium | Degree of Rooting Heavy | Medium | Light | Callused | % Rooted |
|---|---|---|---|---|---|
| EM VII | | | | | |
| Sand | 1 | 2 | 1 | 5 | 26.7 |
| Sand and Perlite | | 1 | 2 | 7 | 20.0 |
| Sand and Peat | 2 | 2 | 1 | 7 | 33.3 |
| Clark | | | | | |
| Sand | | | | 6 | 0.0 |
| Sand and Perlite | | 1 | | 8 | 6.7 |
| Sand and Peat | | 1 | 2 | 9 | 20.0 |
| EM IX | | | | | |
| Sand | | 1 | 1 | 4 | 13.3 |
| Sand and Perlite | | 1 | | 5 | 6.7 |
| Sand and Peat | 2 | 1 | 1 | 8 | 26.7 |

Temperatures During First Two Weeks of the Experiment in Cool House.
Date: Aug. 31-Sept. 13.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 104.0° F | 94.0° F | ---- |
| Minimum | 44.0° F | 51.0° F | ---- |
| Mean | 75.7° F | 72.9° F | ---- |

TABLE XII

The Number of Softwood Stem Cuttings Treated with IBA 3000 ppm in Different Structures
Date: Sept. 22-Nov. 8.
(15 Cuttings per Treatment)

| Variety and Structure | Degree of Rooting | | | | % |
|---|---|---|---|---|---|
| | Heavy | Medium | Light | Callused | Rooted |
| EM VII | | | | | |
| Greenhouse | 4 | 2 | 1 | 8 | 46.7 |
| Polyethylene House | 3 | 2 | 1 | 9 | 40.0 |
| Cool House | 2 | 1 | 1 | 11 | 26.7 |
| Clark | | | | | |
| Greenhouse | 5 | 1 | 1 | 8 | 46.7 |
| Polyethylene House | 3 | | 3 | 9 | 40.0 |
| Cool House | | 2 | 1 | 10 | 20.0 |
| EM IX | | | | | |
| Greenhouse | 4 | 2 | 1 | 8 | 46.7 |
| Polyethylene House | 2 | 3 | 3 | 7 | 53.3 |
| Cool House | | 2 | 2 | 11 | 26.7 |

Temperatures During First Two Weeks of the Experiment in Different Structures.
Date: Sept. 22-Oct. 5.

| Structure | Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|---|
| Greenhouse | Maximum | 100.0° F | 94.0° F | 83.0° F |
| | Minimum | 70.4° F | 56.0° F | 53.0° F |
| | Mean | 71.9° F | 74.7° F | 68.6° F |
| Polyethylene House | Maximum | 100.0° F | 100.0° F | 93.0° F |
| | Minimum | 70.4° F | 51.0° F | 64.0° F |
| | Mean | 71.9° F | 71.5° F | 77.1° F |
| Cool House | Maximum | 100.0° F | 88.5° F | ------ |
| | Minimum | 70.4° F | 48.0° F | ------ |
| | Mean | 71.9° F | 64.1° F | ------ |

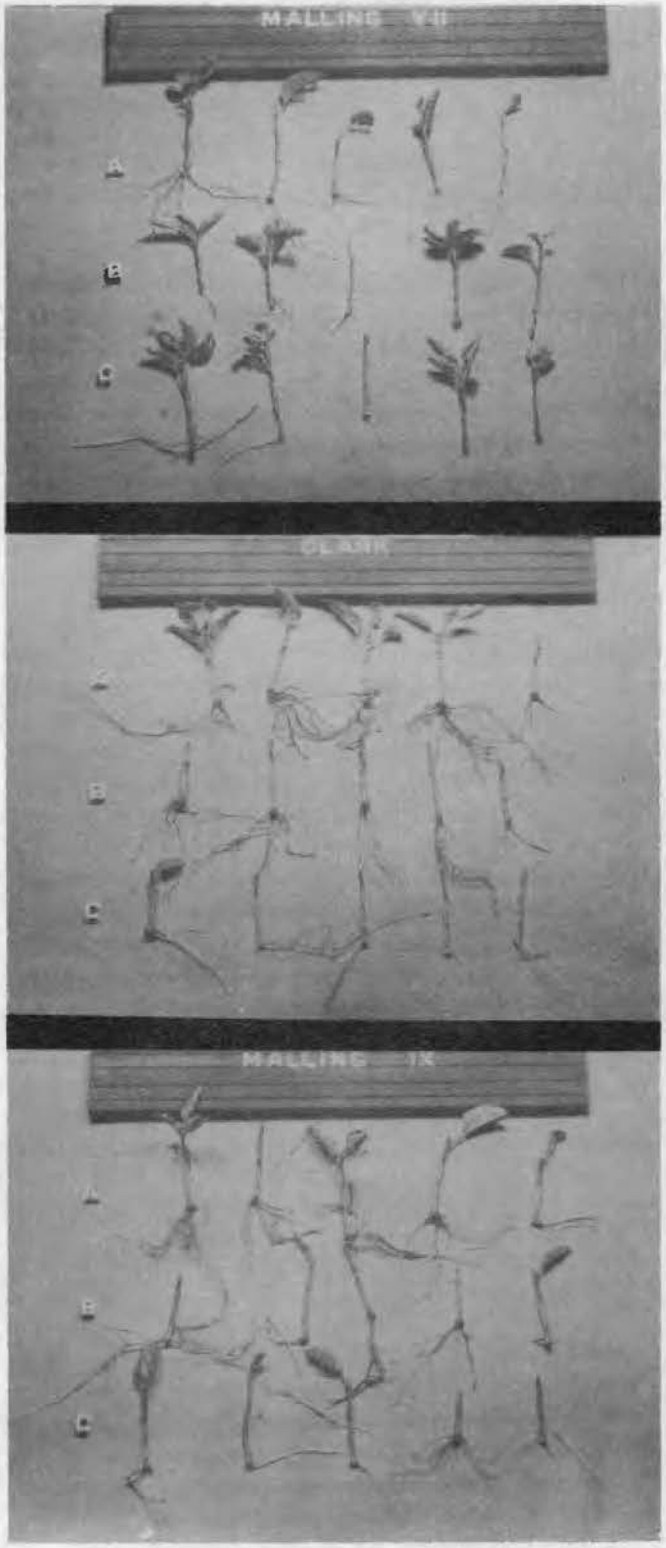



Figure 1. Typical Root Growth of Softwood Stem Cuttings in Different Media at the Greenhouse.

A. Cuttings in Sand and Peat.
B. Cuttings in Sand and Perlite.
C. Cuttings in Sand.

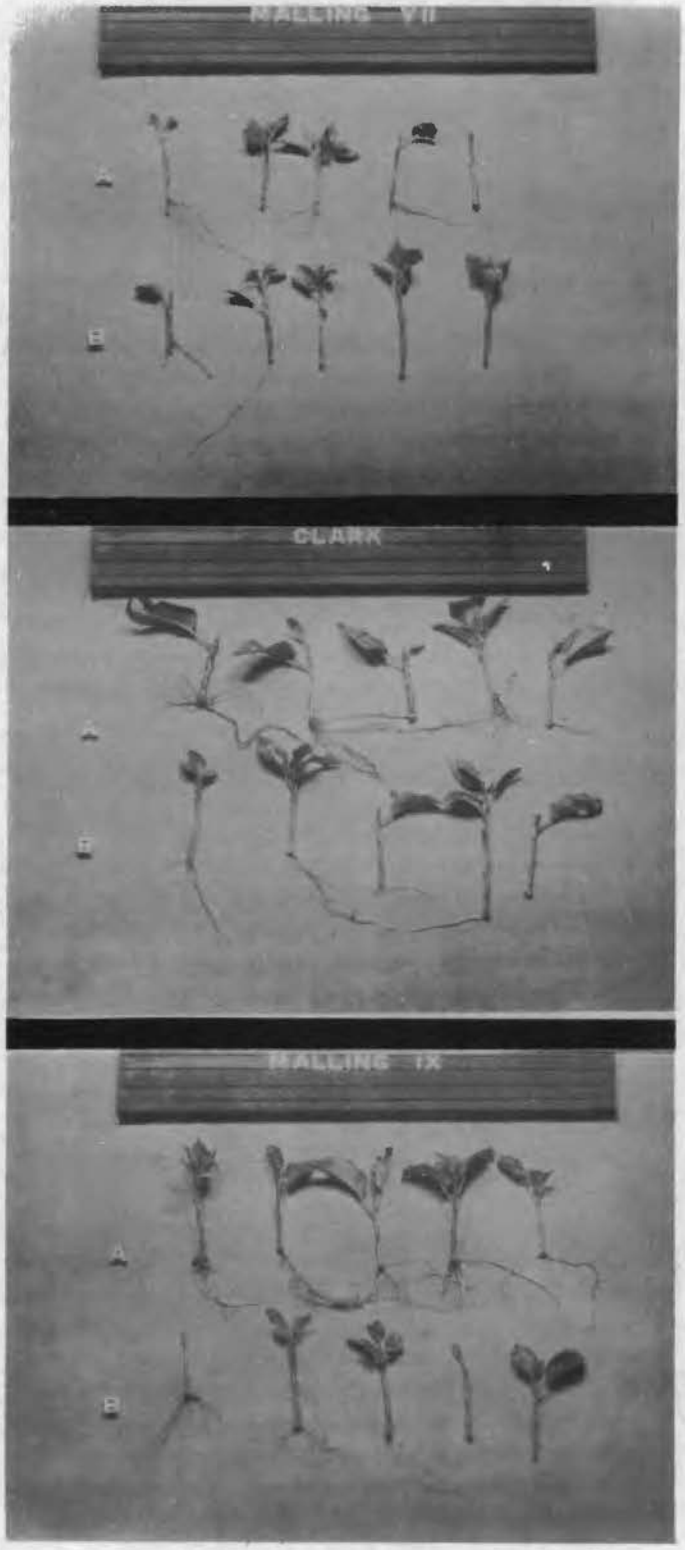



Figure 2. Typical Root Growth of Softwood Stem Cuttings in Different Media at the Polyethylene House.

A. Cuttings in Sand and Peat.
B. Cuttings in Sand and Perlite.

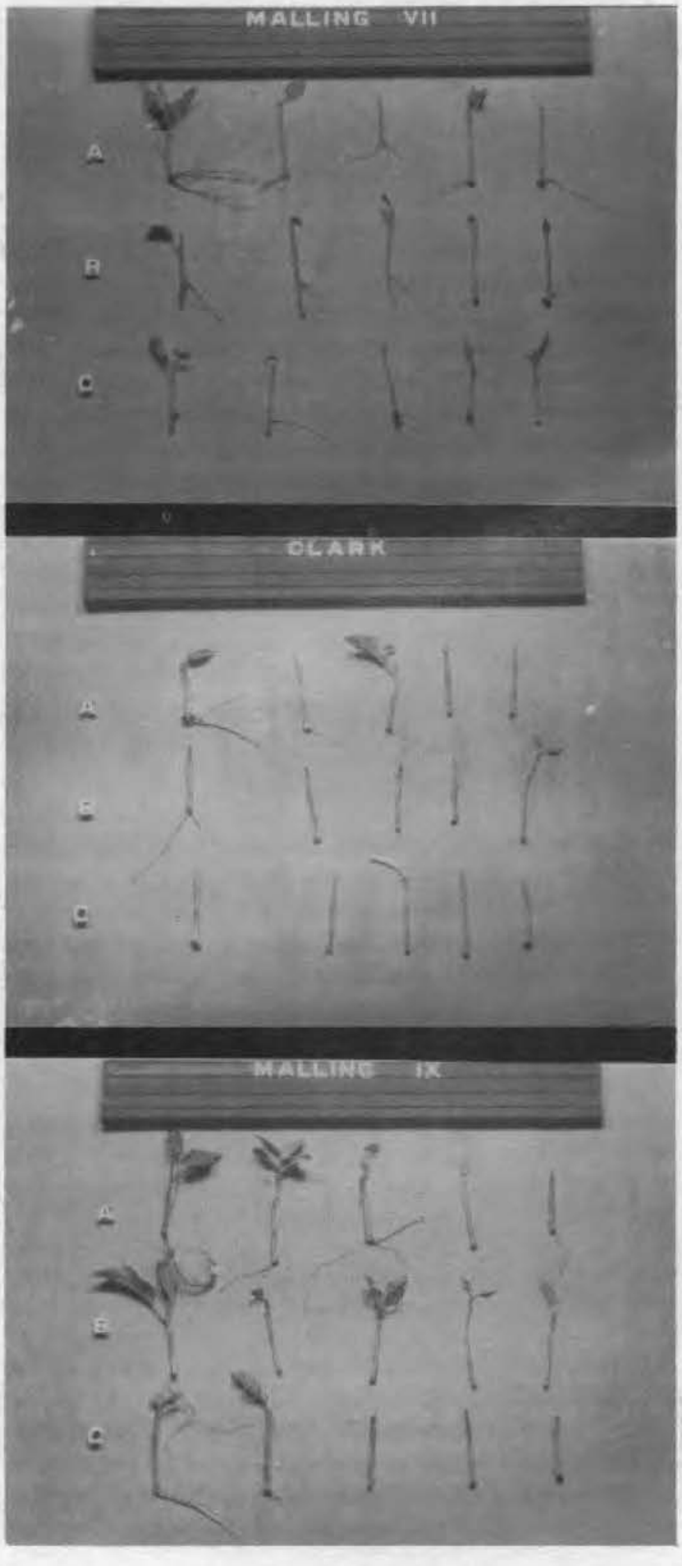



Figure 3. Typical Growth of Softwood Stem Cuttings in Different Media at the Cool House.

A. Cuttings in Sand and Peat.
B. Cuttings in Sand and Perlite.
C. Cuttings in Sand.

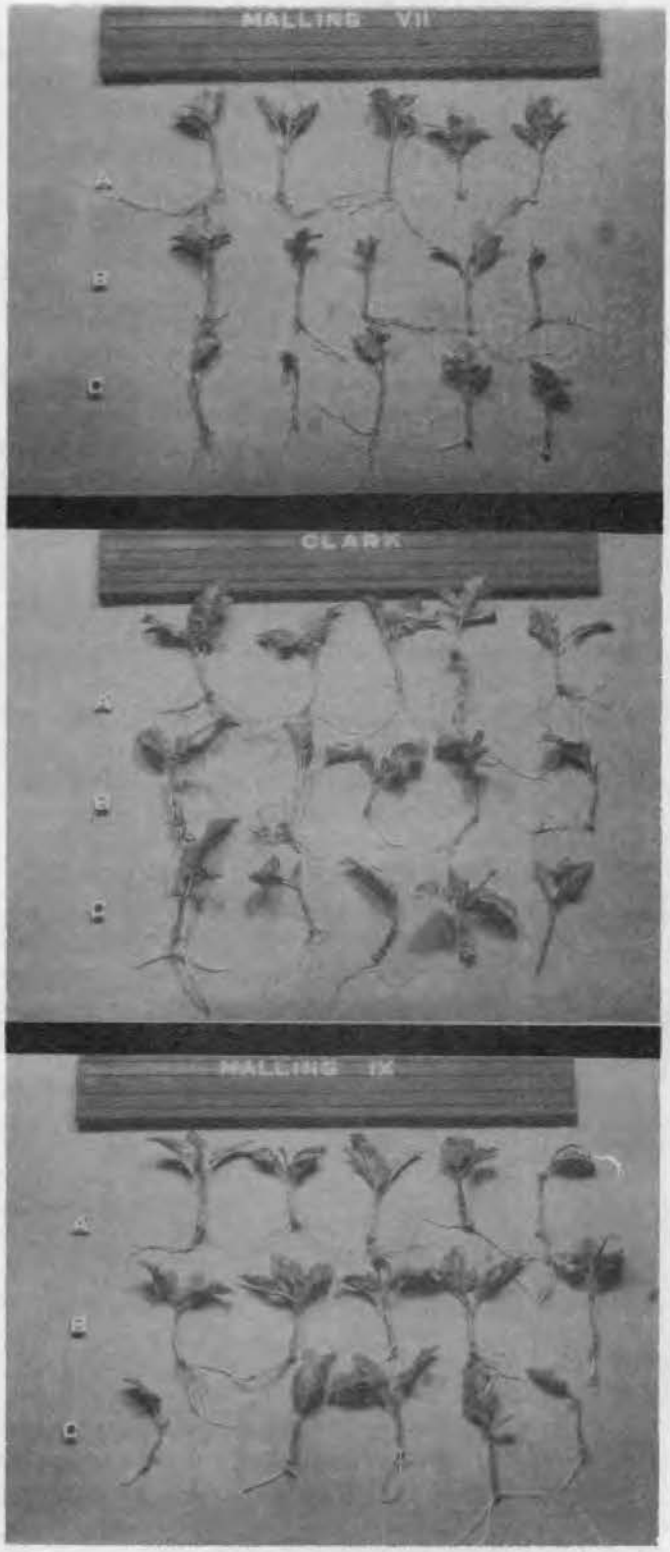



Figure 4. Typical Root Growth of Softwood Stem Cuttings in Sand and Peat at Different Structures.

A. Cuttings grown at greenhouse.
B. Cuttings grown at polyethylene house.
C. Cuttings grown at cool house.

## Dwarf Stocks

There was some variation in rooting among the three different stocks used, but EM VII was the most consistent and rooted the best. Clark was the most difficult stock to root in sand. On the other hand, the Clark rooted best in a mixture of equal amounts of sand and peat under intermittent mist.

## LEAF BUD CUTTINGS

The mallet leaf bud cuttings treated with IBA 3000 ppm gave the best percentage of rooting in the greenhouse and the polyethylene house. EM VII gave the best results of rooting, while EM IX gave the lowest percentage of rooting. The greenhouse served as a more desirable structure for the propagation of leaf bud cuttings under mist than the polyethylene house which had too high a sand temperature during the summer season. However, the experiment was handicapped by the fact that all the cuttings lost their leaves and eventually, even those cuttings which had already rooted, died. The leaves of the leaf bud cuttings inserted on July 26 rapidly turned yellow and died due to the extremely high temperatures. The results are shown in tables XIII, XIV, XV, and XVI.

TABLE XIII

The Number of Leaf Bud Cuttings Which Rooted in the Greenhouse under Intermittent Mist.
Date: May 29-July 14.
(25 Cuttings per Treatment)

| Variety and Treatment | No. Rooted | No. Callused | % Rooted |
|---|---|---|---|
| EM VII | | | |
| Mallet, IBA 3000 ppm | 18 | 6 | 72 |
| Heel, IBA 3000 ppm | 12 | 9 | 48 |
| Heel | 7 | 7 | 28 |
| Clark | | | |
| Mallet, IBA 3000 ppm | 9 | 4 | 36 |
| Heel, IBA 3000 ppm | 6 | 5 | 24 |
| Heel | 4 | 8 | 16 |
| EM IX | | | |
| Mallet, IBA 3000 ppm | 3 | 5 | 12 |
| Heel, IBA 3000 ppm | 2 | 4 | 8 |
| Heel | 2 | 3 | 8 |

Temperatures During First Two Weeks of the Experiment in the Greenhouse.
Date: May 29-June 11.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 95.0° F | 118.0° F | 99.0° F |
| Minimum | 59.0° F | 73.0° F | 72.0° F |
| Mean | 74.7° F | 84.1° F | 83.0° F |

TABLE XIV

The Number of Leaf Bud Cuttings Which Rooted in the Polyethylene House under Intermittent Mist.
Date: May 29-July 14.
(25 Cuttings per Treatment)

| Variety and Treatment | No. Rooted | No. Callused | % Rooted |
|---|---|---|---|
| EM VII | | | |
| Mallet, IBA 3000 ppm | 5 | 12 | 20 |
| Heel, IBA 3000 ppm | 11 | 11 | 44 |
| Heel | 11 | 6 | 44 |
| Clark | | | |
| Mallet, IBA 3000 ppm | 9 | 7 | 36 |
| Heel, IBA 3000 ppm | 8 | 10 | 32 |
| Heel | 5 | 8 | 20 |
| EM IX | | | |
| Mallet, IBA 3000 ppm | 2 | 11 | 8 |
| Heel, IBA 3000 ppm | 2 | 13 | 8 |
| Heel | 3 | 9 | 12 |

Temperatures During First Two Weeks of the Experiment in the Polyethylene House.
Date: May 29-June 11.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 95.0° F | 100.0° F | 100.0° F |
| Minimum | 59.0° F | 64.0° F | 68.0° F |
| Mean | 74.7° F | 81.1° F | 83.5° F |

TABLE XV

The Number of Leaf Bud Cuttings which Rooted in the Greenhouse under Intermittent Mist.
Date: June 18-July 22.
(25 Cuttings per Treatment)

| Variety and Treatment | No. Rooted | No. Callused | % Rooted |
|---|---|---|---|
| EM VII | | | |
| Mallet, IBA 3000 ppm | 6 | 17 | 24 |
| Heel, IBA 3000 ppm | 5 | 14 | 20 |
| Heel | 2 | 11 | 8 |
| Clark | | | |
| Mallet, IBA 3000 ppm | 3 | 12 | 12 |
| Heel, IBA 3000 ppm | 4 | 10 | 16 |
| Heel | 1 | 7 | 4 |
| EM IX | | | |
| Mallet, IBA 3000 ppm | 3 | 6 | 12 |
| Heel, IBA 3000 ppm | 2 | 5 | 8 |
| Heel | 3 | 4 | 12 |

Temperatures During First Two Weeks of the Experiment in the Greenhouse.
Date: June 18-July 1.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 102.0° F | 120.0° F | 98.0° F |
| Minimum | 62.0° F | 74.0° F | 72.0° F |
| Mean | 81.2° F | 90.9° F | 83.3° F |

TABLE XVI

The Number of Leaf Bud Cuttings Which Rooted in the Polyethylene House under Intermittent Mist.
Date: June 18-July 22.
(25 Cuttings per Treatment)

| Variety and Treatment | No. Rooted | No. Callused | % Rooted |
|---|---|---|---|
| EM VII | | | |
| Mallet, IBA 3000 ppm | 4 | 11 | 16 |
| Heel, IBA 3000 ppm | 3 | 5 | 12 |
| Heel | 3 | 5 | 12 |
| Clark | | | |
| Mallet, IBA 3000 ppm | 3 | 4 | 12 |
| Heel, IBA 3000 ppm | 2 | 8 | 8 |
| Heel | | 5 | 0 |
| EM IX | | | |
| Mallet, IBA 3000 ppm | 2 | 4 | 8 |
| Heel, IBA 3000 ppm | | 1 | 0 |
| Heel | | 1 | 0 |

Temperatures During First Two Weeks of the Experiment in the Polyethylene House.
Date: June 18-July 1.

| Range | Outdoor Air | Inside Air | Sand |
|---|---|---|---|
| Maximum | 102.0° F | 110.0° F | 105.0° F |
| Minimum | 62.0° F | 67.0° F | 78.0° F |
| Mean | 81.2° F | 87.7° F | 88.6° F |

## LAYERING

East Malling VII, EM IX and Clark were multiplied by means of mound layerage. Eight months after the layers were made, they were examined for root development. The best results were obtained from EM VII, although only 4.3 plants were produced per layer. Detailed data are shown in table XVII.

TABLE XVII

The Number of Rooted Shoots Produced by Layerage in the Nursery.
(10 Stools of Each Variety)
Date: April 4-Dec. 30.

| Variety | No. of Shoots Rooted | | | Total No. of Shoots Rooted |
|---|---|---|---|---|
| | Heavy | Moderate | Poor | |
| EM VII | 19 | 15 | 9 | 43 |
| Clark | 19 | 3 | 4 | 26 |
| EM IX | 25 | 6 | 1 | 32 |

## PROPAGATION AND GROWTH OF DWARF APPLE TREES

### Rootstocks Compared with Intermediate Stem Pieces

In this experiment, single grafted trees on EM VII and EM IX roots produced less growth than those on standard rootstocks. Clark, used as the intermediate stem piece, produced less growth as compared with that of EM VII and EM IX. There seemed to be a difference between the dwarfing effects of rootstocks and intermediate stem pieces of different dwarf stocks used. The 3-inch stem piece of EM VII gave more dwarf influence on tree growth than the rootstock of the same variety. On the other hand, the result was just reverse with EM IX.

The best percentage of survival was obtained with the varieties grafted on standard rootstock while the lower percentage of survival was obtained with varieties grafted on the dwarfing stocks. Growth measurements for the first year and per cent survival are shown in tables XVIII and XIX and figure 5.

In comparing the root system, trees with the least amount of top growth had the smallest root system. The trees on standard roots had the heaviest root system and the largest top growth. The EM VII trees consisting either of intermediate stem piece or rootstock had medium sized roots. The trees on EM IX and Clark produced the smallest roots.

### Various Lengths of Intermediate Stem Pieces

By using standard rootstocks, Starking and Summer Champion were grafted on intermediate stem pieces of EM VII, EM IX and Clark in lengths of 3, 6, 9 and 12 inches. The amount of new shoot growth during the first year was measured and shown in tables XX and XXI, and figure 6. The first year's growth indicated that to a certain extent, the dwarfing was associated with the length of intermediate stem pieces used. In most instances, the 9-inch intermediate stem pieces gave the most restriction on top growth, while the 3-inch intermediate stem pieces gave the least dwarfing effect. The data obtained for Clark were inadequate because the percentage of survival was low. The observation of root systems of grafted trees indicated that the EM VII used as an intermediate stem piece had heavier root systems than trees on EM IX or Clark. In other words, the growth of roots coincided to the vigor of the grafted trees.

The Starking trees produced more top growth than the Summer Champion. During the early part of the growing season, Summer Champion exceeded Starking in growth, but since Starking continued to grow late in the season, it surpassed Summer Champion in total growth.

TABLE XVIII

Dwarfing Effects of Rootstocks and Intermediate Stem Pieces on First Year Growth of Starking Apple.

| Rootstock | Intermediate | Length of New Growth in Inches | Diameter of New Growth in Inches | % Survival |
|---|---|---|---|---|
| Standard | ——— | 46.42 | 0.41 | 88.9 |
| Standard | EM VII | 33.30 | 0.31 | 61.1 |
| EM VII | ——— | 41.43 | 0.37 | 44.4 |
| Standard | EM IX | 38.54 | 0.33 | 88.9 |
| EM IX | ——— | 34.50 | 0.32 | 33.3 |
| Standard | Clark | 32.61 | 0.29 | 66.6 |

TABLE XIX

Dwarfing Effects of Rootstocks and Intermediate Stem Pieces on First Year Growth of Summer Champion Apple.

| Rootstocks | Intermediate | Length of New Growth in Inches | Diameter of New Growth in Inches | % Survival |
|---|---|---|---|---|
| Standard | ——— | 39.82 | 0.33 | 83.0 |
| Standard | EM VII | 30.42 | 0.29 | 77.8 |
| EM VII | ——— | 34.35 | 0.28 | 27.8 |
| Standard | EM IX | 35.20 | 0.30 | 77.8 |
| EM IX | ——— | ——— | ——— | 0.0 |
| Standard | Clark | 24.00 | 0.24 | 22.2 |

Figure 5. Dwarfing Effects of Rootstocks and Intermediate Stem Pieces on First Year Tree Growth

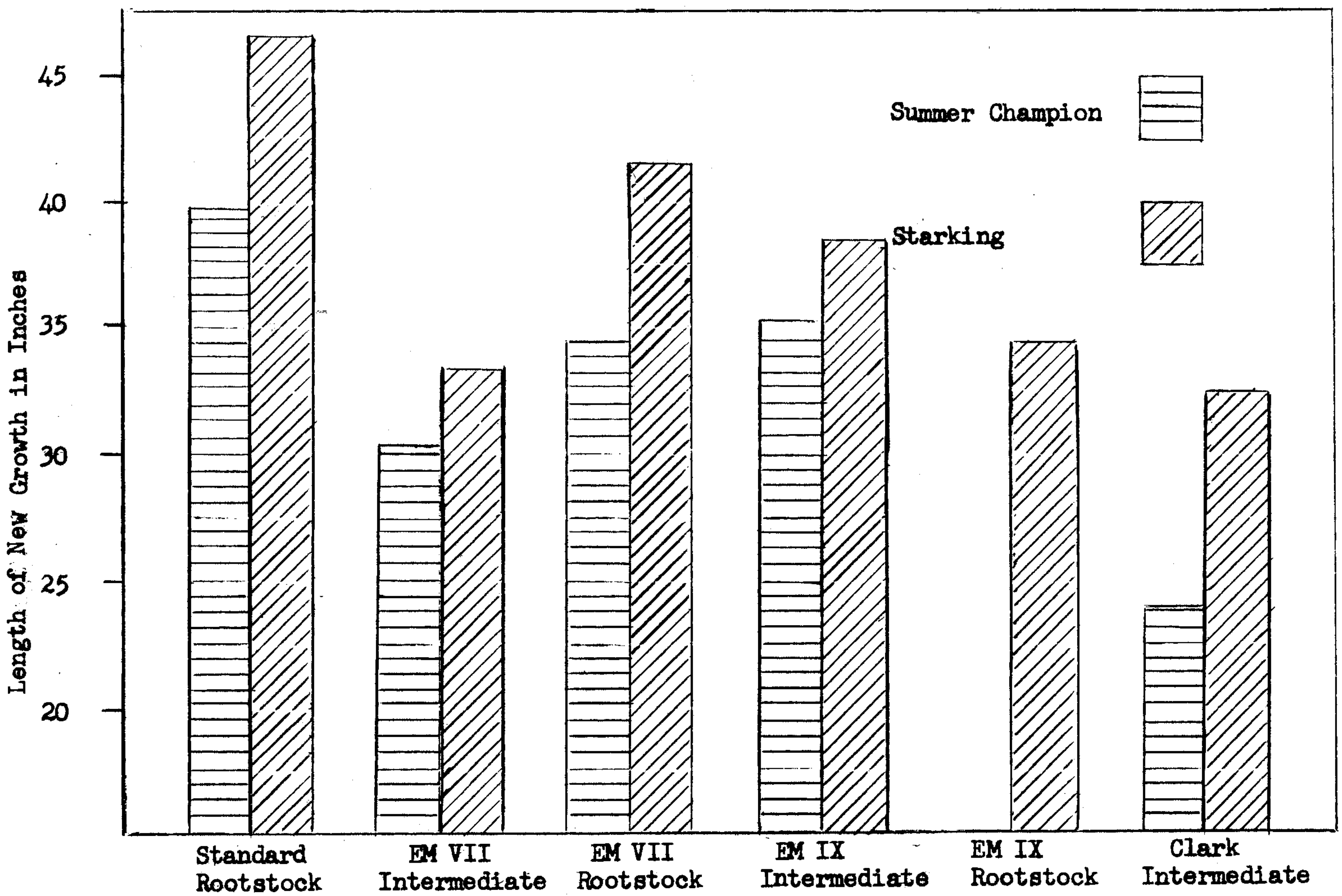


TABLE XX

Dwarfing Effects of Various Lengths of Intermediate Stem Pieces on First Year Growth of Starking Apple.

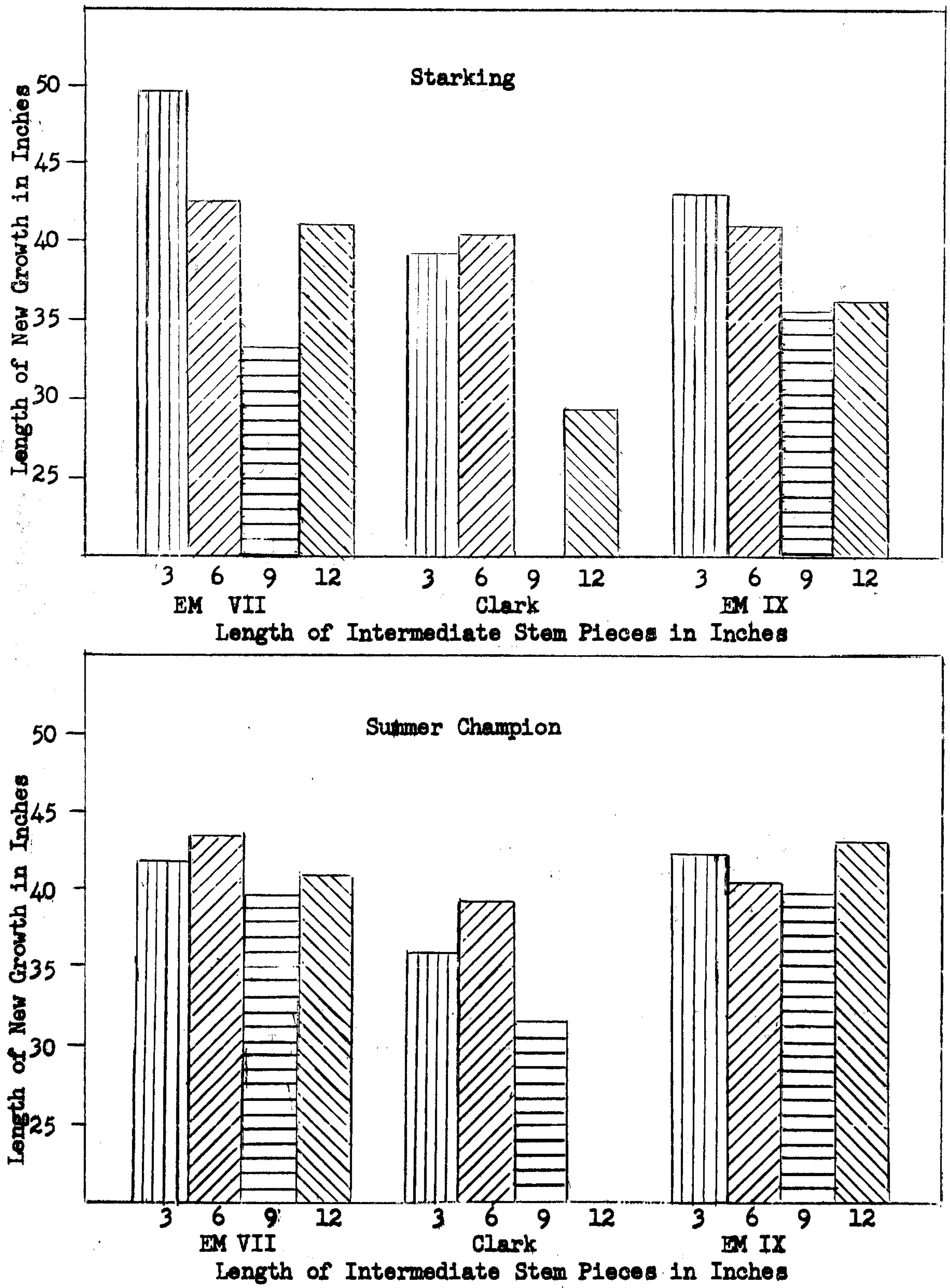
| Variety | Length of Intermediate Stem Piece (inches) | Length of New Growth in Inches | Diameter of New Growth in Inches | % Survival |
|---|---|---|---|---|
| | 3 | 49.75 | 0.42 | 41.7 |
| EM VII | 6 | 42.50 | 0.38 | 50.0 |
| | 9 | 33.44 | 0.28 | 100.0 |
| | 12 | 41.40 | 0.37 | 100.0 |
| | 3 | 39.17 | 0.31 | 50.0 |
| Clark | 6 | 40.33 | 0.32 | 25.0 |
| | 9 | ----- | ---- | 0.0 |
| | 12 | 29.32 | 0.32 | 41.7 |
| | 3 | 42.79 | 0.34 | 100.0 |
| EM IX | 6 | 41.44 | 0.32 | 100.0 |
| | 9 | 35.28 | 0.30 | 100.0 |
| | 12 | 36.10 | 0.31 | 100.0 |

TABLE XXI

Dwarfing Effects of Various Lengths of Intermediate Stem Pieces on First Year Growth of Summer Champion Apple.

| Variety | Length of Intermediate Stem Piece (inches) | Length of New Growth in Inches | Diameter of New Growth in Inches | % Survival |
|---|---|---|---|---|
| | 3 | 41.70 | 0.33 | 91.7 |
| EM VII | 6 | 43.27 | 0.35 | 91.7 |
| | 9 | 39.54 | 0.34 | 100.0 |
| | 12 | 40.83 | 0.35 | 100.0 |
| | 3 | 36.00 | 0.28 | 8.3 |
| Clark | 6 | 39.00 | 0.33 | 25.0 |
| | 9 | 31.74 | 0.28 | 25.0 |
| | 12 | ----- | ---- | 0.0 |
| | 3 | 42.20 | 0.34 | 100.0 |
| EM IX | 6 | 40.47 | 0.33 | 91.7 |
| | 9 | 39.82 | 0.34 | 100.0 |
| | 12 | 42.81 | 0.36 | 100.0 |

Figure 6. Dwarfing Effects of Various Lengths of Intermediate Stem Pieces on First Year Tree Growth.



# DISCUSSION AND CONCLUSION

## PROPAGATION OF DWARF STOCKS

### Hormone Treatment

Internal factors influencing root formation in cuttings which have been investigated by several workers, are primarily the nutrient content and the plant hormones. Some synthetic chemicals have been found to be very effective in the stimulation of roots on cuttings. Indolebutyric acid, one of these substances, plays a role in the stimulation of cell division and cell elongation, and has the same effect as rhizocaline in the initiation of roots.

Throughout the experiments reported here, softwood stem cuttings treated with IBA at 3000 ppm produced a heavy root system and gave the highest percentage survival. Tests with IBA at 8000 ppm were not as effective. It is assumed that IBA 3000 ppm is sufficient concentration for rooting of apple cuttings, but the IBA 8000 ppm seemed to be too concentrated, thus producing a toxic effect. The leaf bud cuttings gave the best rooting response when they were treated with IBA 3000 ppm.

### Wound Treatment

Wound treatments of various kinds have long been used to stimulate root formation in plant propagation. The roots formed on plants can be classified as (1) wound roots, which form just prior to their emergence, arise usually in the cambium; and (2) morphological roots, which arise in certain definite places, are determined by the presence of performing root primodia. The wound roots appear in the immediate vicinity of the wound area or basal cut of cuttings.

The type of roots produced from stem cuttings of the material used in the experiments reported here was largely the wound type roots. It appeared that when the basal ends of the cuttings were sliced on both sides, a greater amount of water was taken up by the plant from the medium and the accumulation of the hormone in the basal area caused roots to develop. Whether this hormone was liberated by the injured cells or produced in the leaves or growing tips has not been determined.

The mallet leaf bud cuttings rooted better than the heel cuttings. Since the mallet cuttings contained more woody tissue as compared to the sliver of the heel cuttings, the carbohydrate content in it was greater. These additional carbohydrates would influence a higher percentage of rooting.

The limitations of propagation by means of leaf bud cuttings lie essentially within the ease and speed with which rooting can occur before deterioration of the leaf in the rooting medium, and in the ability of the axillary bud to make a satisfactory start in producing the new plant. Under high temperatures during summer months, the rate of evaporation was so great that the leaf had more difficulty in maintaining itself and the abscission layer was formed.

## Media Treatment

Aeration and retention of moisture are two important requirements of the rooting medium. Clean, sharp sand is used universally more often than other materials. The addition of peat to the mixture improved its water-holding capacity while maintaining aeration. Under intermittent mist, the mixture consisting of equal parts of sand and peat increased the amount of water held in the medium and gave the best rooting. Acid peat is composed largely of partly decomposed organic material being light and granular with a high water-holding capacity and good aeration. The acid reaction of the peat is considered to be beneficial or even necessary to prevent decomposition by bacteria. The addition of perlite also improved the rooting but was not as effective as peat. Since perlite is a glassy volcanic lava being expanded artificially by heating, it contains no organic material. Perlite is very light in weight and will float in water; therefore, it was somewhat difficult to handle in flats when the cuttings were watered by hand.

## Intermittent Mist and Temperature

The humidity and temperature were considered as two of the most important factors affecting the root formation of cuttings in the structures.

Intermittent mist was applied in both the greenhouse and polyethylene house. Some difficulties were experienced with the control equipment. The electronic leaf is an excellent device to control intermittent mist, but the minerals in the water produced a deposit and prevented its proper function. The timer worked satisfactory for intermittent operation, but the amount of water could not be regulated according to the need of the plants. The rate of evaporation varied from day to day due to the variation in temperature, light intensity and wind. At the beginning of the experiment, the time of misting was set from 7 a. m. to 7 p. m. with misting for 7 seconds out of each minute. Later, as the temperature increased, the water supply was found insufficient to keep the leaves of the cuttings turgid, and the mist period was increased to 14 seconds out of each minute. Finally, this appeared to be insufficient and the time of operation was increased to operate from 6 a. m. to 10 p. m. with misting for 25 seconds out of each minute.

Recently, Curtis May developed a new control for intermittent mist. The unit operates on the evaporation and the absorption of water from a porous clay globe. It may solve the problem of regulating the application of water. However, this equipment was not used in the tests reported.

Polyethylene makes an excellent covering to maintain high humidity. It has a high resistance to the passage of moisture and low resistance to the passage of carbon dioxide and oxygen. It was easy to maintain high humidity in the polyethylene house because the structure was low and small.

The temperature of the medium used was another important factor in the rooting of the cuttings. The experiments were conducted during the summer months when the temperature was often above 100 degrees F. The maximum air temperature in the green house was usually higher than that in the polyethylene house. This was probably due to the difference in ventilation. The maximum temperature in the sand was higher in the polyethylene house than in the greenhouse. The polyethylene house being tight allowed for more rapid warming. In the summer months the maximum sand temperature in the polyethylene house was above 100 degrees F while in the greenhouse the sand temperature remained 10 degrees lower. The humidity, however, was easier to maintain in the polyethylene house. The low percentage of rooting of softwood stem cuttings and leaf bud cuttings in the polyethylene house was due to the high temperature of the sand.

In the cool house the maximum temperature was 94 degrees F with a mean air temperature ranging from 60 to 73 degrees F. This temperature was most desirable for root formation, but since the cuttings were watered by hand, the water supply was not sufficient to meet the need of the cuttings. The percentage of rooting of cuttings was lower in the cool house as compared to other structures.

From the data recorded, it may be concluded that the cuttings in the greenhouse under intermittent mist rooted the best. It seems, however, that more desirable results could have been obtained if mist application could have been improved and lower temperatures maintained. During the period of the experiments, the dropping leaves occurred in most cuttings in all the structures. The difference between the intake and the evaporation of water from the cuttings before root formation, and the extremely high temperatures might be considered as the causes for improper leaf function and the formation of the abscission layer.

Softwood stem cuttings, in most instances, should be the most desirable material for the propagation of plants. It is the most active growing part of the plant and is easy to obtain during the growing season.

Leaf bud cuttings, to a certain extent, may have the same advantages as softwood stem cuttings; however, they have proportionately greater evaporation area as compared to the absorption area. Thus, the loss of water from their leaves was greater than what could be obtained from the rooting media during the high temperatures. This was evident in the leaf bud cuttings by the yellowing and shedding of leaves.

In conclusion, the best results for the rooting stem cuttings should be by heavy wounding, treating with IBA 3000 ppm, inserting a mixture of equal parts of sand and peat, and placing them under intermittent mist. The greenhouse would be the best structure for rooting cuttings.

### Layering

Layering is a simple method used generally for the propagation of dwarf apple stocks. The mound layering resulted in a limited number of new plants ranging from 1.6 to 4.3 per mounded plant. Data in this experiment also indicated that there might be a correlation between the percentage of shoots rooting and the vigor of the varieties. EM VII was the most vigorous and produced the most plants.

## PROPAGATION AND GROWTH OF APPLE TREES

### Rootstocks Compared with Intermediate Stem Pieces

Dwarf apple rootstocks, controlled by genetical factors, are characterized by smaller conductive tissues and smaller root systems. The rate of water movement and metabolites are influenced by the number and size of vessels and tracheids that make up the conducting tissues of the dwarfing stocks. The efficiency of absorption by roots and the speed of translocation of water and nutrients at the union may exert additional influences on the amount of growth made as well as the vigor of the trees.

From one year's growth on the trees, the EM IX rootstocks caused more dwarfing than intermediate stem pieces, while on the other hand, EM VII, as an intermediate stem piece, had a greater dwarfing influence than the root. The root system of EM IX stock was the smallest and thus probably less efficient in absorbing water and nutrients than the roots of the other stocks tested. Since tree growth is mainly dependent upon the supply of water and minerals from the soil, the dwarfing influence of EM IX roots would be more pronounced than that caused by the intermediate stem pieces and the unions. The root system of EM VII were found to be heavier than that of EM IX and it was apparent that more water and minerals were being absorbed by the EM VII roots. This also resulted in reduced dwarfing caused by the roots as compared to the intermediate stem pieces. Trees with Clark as the intermediate stem piece made the least top growth. Also, a low percentage of survival was obtained. This may be attributed to a degree of incompatibility.

Starking trees produced more top growth than Summer Champion during the first year. There was a difference in the growing period and the rate of growth made by each variety. Trees grafted on standard root-stocks were found to be more vigorous in both the amount of top growth and root growth made. From the observations made, it was apparent that the influence on the trees' growth was not only due to the dwarf stocks or the dwarf intermediate stem pieces, but, also, to the union between scion and dwarf stock.

EM VII and EM IX produced a more brittle type root system which could be broken with ease. This weakness can be overcome by the use of the dwarf stock as an intermediate stem piece.

## Various Lengths of Intermediate Stem Pieces

Propagating dwarf apple trees with an intermediate stem piece simplifies the problem of multiplication of dwarfing stock. The intermediate stem piece directly influenced the top growth. It was evident that the longer stem pieces produced the most dwarfing effect because the resistance of the translocation of water and nutrients was in direct proportion to the length of the intermediate stem piece. In this experiment the nine-inch intermediate stem piece had the most dwarfing effect. The trees on twelve-inch intermediate stem pieces gave slightly more growth, but the difference was not significant. The maximum limitation influenced by the length of intermediate stem pieces may be due to mechanical or physical factors. However, this question needs to be solved and explained by further experiments.

Clark stock used as intermediate stem pieces produced the greatest dwarfing effect on Summer Champion and Starking varieties, but the percentage of survival was low. The poor growth could be attributed to incompatibility. The roots of the trees with Clark and EM IX as intermediate stem pieces were smaller than those with the EM VII stem pieces. In most cases, the trees with EM VII had more top growth than others. It was evident that the degree of restriction of the downward movement of carbohydrates varied with the dwarf stocks used as intermediate stem pieces which would in turn affect the growth of roots. A larger root system would absorb more water and minerals and resulted in more top growth. Also, a reciprocal effect existed between the top and the root. It is concluded from observations made that the dwarfing influence was correlated with the length of the intermediate stem pieces used.

# SUMMARY

Leaf bud stem cuttings were made of EM VII, EM IX and Clark and rooted under mist technique.

The greenhouse, generally speaking, gave the best response to the rooting of cuttings due to the lower temperatures of the media used. The cool house had a more desirable temperature for rooting, but since intermittent mist was not used, the percentage of rooting was low.

IBA 3000 ppm gave the best percentage and heaviest roots.

Heavy wounding of cuttings was found to be beneficial in promoting root formation of softwood stem cuttings. Mallet leaf cuttings resulted in a higher percentage of rooting as compared to heel cuttings.

A mixture of equal amounts of sand and peat improved the water holding capacity of the medium and gave the best rooting. Perlite mixed with sand was better than sand alone.

The yellowing and shedding of the leaves from the leaf bud cuttings and stem cuttings influenced the rooting and survival of the plants.

Softwood stem cuttings under intermittent mist were found to be more desirable than other methods tested, although techniques need to be improved in future studies.

Apple stocks were found to exert certain influences on top growth. During the first year, Clark and EM IX produced the least top growth.

The difference in top growth among different dwarf stocks used as intermediate stem pieces was not great for the first year. Clark was the least compatible of the stocks used.

The nine-inch length of intermediate stem pieces gave the most dwarfing on top growth while the three-inch stem pieces produced the least dwarfing effect. The root system was found to have a positive correlation with the vigor of the trees.

## Suggestions for Future Study

1. An experiment for the propagation of apple stocks by either softwood stem cuttings or leaf bud cuttings should be started in early April when the wood of the apple trees is in an actively growing state.
2. Develop an automatic control for mist application based on evaporation. A timer will or will not supply enough water throughout the day.
3. Cuttings should be tested with 50% - 90% ethyl alcohol treatments before dipping them into hormone powder to improve the efficiency of the hormone treatment.
4. Chemical sprays on foliage should be investigated to determine if they will prevent formation of abscission layer and dropping of leaves.
5. The number of trees for each replication should be increased to eliminate the variation caused by soil fertility and moisture supply. Reduce the number of treatments and increase the number of trees per replication.
6. Microscopic examination of the anatomical structure of trees and radioactive isotope tests to determine translocation and distribution of nutrients in plant tissue should be carried out to study the cause of the dwarfing effect of stock on top growth.

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