The effects of plant hormones, rooting media, and intermittent mist on the rooting and transplanting of herbaceous, evergreen, and hardwood cuttings
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A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Horticulture
Montana State University

Abstract:
Experiments were designed to determine the responses of herbaceous, evergreen, and hardwood cuttings to various treatments including different concentrations of indolebutyric acid, various rooting media, and presence or absence of intermittent mist. Experiments were also designed to determine the response of herbaceous cuttings to various combinations of soil and transplanting treatments.

Based on the rooting percentage or root quality or both, the results of the experiments indicated that herbaceous and hardwood cuttings rooted well when treated with low to intermediate concentrations of IBA. Chrysanthemum cuttings rooted best with 1,000 ppm IBA, carnation with 2,OOO ppm" IBA, and German ivy with all concentrations tested. Potentilla, cara-gana, and sand cherry all rooted best when treated with 2,OOO ppm IBA.

Evergreen cuttings rooted best when treated with high concentrations of IBA. Pfitzer junipers rooted best when treated with 8,000 ppm IBA.

Species adaptability to media did not follow the same pattern as hormone response. In addition it did not seem as important. However, in most cases certain media aided in rooting to some degree. Carnation and sand cherry rooted best in 100% perlite. Pfitzer juniper rooted best in a 75% perlite and 25% peat medium. A 50% perlite and 50% peat medium proved to be best for potentilla. Chrysanthemums rooted best in a 50% sand and 50% peat medium as did caragana.

Intermittent mist treatments benefitted Camation, juniper, and potentilla rooting. However, Chrysanthemum, Caragana, and sand cherry cuttings rooted better under non-mist.

Transplants of cuttings resulting from the cutting experiments had nearly 100$ survival under all treatments tested. The only exception was sand cherry which proved difficult to transplant under all conditions.

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INTRODUCTION

Many plants are reproduced under natural conditions by asexual means. Asexual or vegetative propagation of plants is that form of plant propagation in which the new individual possesses exactly the same characteristics as the parent plant from which it was taken.

The early history of asexual propagation was essentially the history of grafting. It was not until the 17th century that detailed information on the propagation of plants by means of layers and cuttings was available. Probably no other single operation in asexual propagation is more important than cuttage, because the average nurseryman depends very largely upon this type of propagation. Cuttage may be described as a method of propagating plants by the use of detached vegetative plant parts which, when placed under conditions favorable for regeneration, will develop into a complete plant.

The main advantages of propagation by cuttage are the relative simplicity of the operations, the low unit cost of production, and the ease with which plants will reestablish themselves. Therefore, this method of propagation is highly practical and economically important. It is used extensively to propagate ornamental plants, including deciduous types, broad-leaved evergreens and coniferous forms. Fruits such as grapes and figs have been propagated in this manner since ancient times.

This thesis is a report of research on several factors and techniques affecting rooting of cuttings which have been developed in recent years, including rooting media, hormones, and intermittent mist, and some important factors affecting transplanting of rooted cuttings.

Experiments were made on the effect of indolebutyric acid on rooting of herbaceous, evergreen, and hardwood cuttings; the effect of rooting media on root formation and root quality; and the effect of intermittent mist on root formation. They were designed to determine the response of herbaceous, evergreen, and hardwood cuttings to different concentrations of indolebutyric acid, varying proportions of perlite, peat, and sand in the propagation medium, and the presence or absence of intermittent mist over the propagating bench.

Experiments were also made on the effect of various soil and transplanting treatments on rooted herbaceous evergreen and hardwood cuttings which resulted from the cutting experiments.

The author wishes these preliminary results to be a reference for nurserymen and people who are interested in propagation work, but more research work needs to be done in this field.

LITERATURE REVIEW

The history of propagation by cuttings can be traced to the 17th century. In the ensuing years, many techniques and methods have been evolved. In recent years, much information has been developed concerning internal and external factors affecting rooting of cuttings. Internal factors affecting rooting of cuttings include the amount of stored food in cuttings, the age and maturity of tissue, the formation of callus and adventitious roots and the presence of leaves and buds on cuttings. The external factors include rooting media, chemical and hormone treatments, light, temperature, mechanical treatment and mist spray.

Internal or Physiological Factors:

Internal or physiological factors represent conditions within a cutting, which may influence its ability to form roots and to develop into a plant.

It has been shown repeatedly that available carbohydrate and nitrogen markedly affect the rooting of cuttings. Cuttings with a high starch content formed better roots than those with low starch contents (88). Cuttings from plants that have a carbohydrate accumulation in excess of inorganic nitrogen, are more likely to root properly (1).

Both maturity of the tissues and age of cuttings (juvenility) affect the readiness of cuttings to root. Many early papers indicated that cuttings of a suitable degree of maturity (1, 22, 54, 79, 91) from a juvenile plant will root more readily than cuttings from older plants.

Juvenility, first described by Goebel as a physiological condition, may be characterized not only by morphological characteristics, such as lack of pubescence, thinness of leaves, leaf shape modification and thorniness, but also by the inability of the plant or plant parts to initiate flower buds (25). The seat of juvenility or that portion of plant where the juvenile influence remains longest and exerts its greatest influence is at or just below ground level and probably extends well into the lateral roots (52). Juvenile wood can be induced to form on many plants by cutting back and disbudding greenhouse forced stock (22, 66, 83).

Root primodia are sometimes present within stems of normally growing plants and require only favorable conditions to grow out as roots. Although root primodia are not ordinarily present in stems of most plants, they may be induced to form on cuttings placed under favorable conditions for a period of time. Plant hormones aid in hastening the formation of roots on cuttings (71).

Through an anatomical study of adventitious root development in stems, it was concluded that roots originate in cambium and phloem and project through the callus or through cortex and epidermis. This suggests that if some means could be provided to dissolve the cuticular and epidermal layers and the pericyclic fibers, rooting percentage might be improved (48).

Callus formation at the basal end of the cutting was at one time considered to be a vital factor in the rooting of hardwood cuttings. Callus formation may be of benefit in sealing the ends of the cuttings and preventing decay. In some cases, callused cuttings also respond more readily to chemicals used to aid in root formation than those not callused (87). More recently it has been accepted that callus formation does not play an important part in root formation. Rather, callus formation and root development are processes not directly interdependent, and are favored by different environmental factors: callusing by a very moist, heavy medium, and root formation by a light well aerated medium (43).

The presence of leaves on cuttings provides a favorable influence on the rooting of herbaceous, semi-hardwood and evergreen cuttings. Leaves and buds form a substance which promotes root formation in cuttings. Growing leaves are reported to promote cell division in the cambium (63). Root formation on Hibiscus cuttings depends upon both auxin and the presence of leaves. In auxin treated cuttings, the number of roots formed increases with the number of leaves left on the cuttings (53). The amount of leaf area allowed to remain on a cutting partly determines the extent and amount of root production (7).

External or Environmental Factors:

The rooting and growth of cuttings depends upon certain external or environmental factors which represent treatments that are applied just before the cuttings are set in the bed, or the conditions to which the cuttings are subjected in the bed.

Many papers present studies on the effect of various media for rooting cuttings (4, 10, 27, 35, 40, 72, 82, 87). Vermiculite, perlite, and other products have been and are being tested with a view of improving plant propagation methods.

It has been the concensus of opinion with plant propagators that No. 7 silica sand is the best grade to use as a rooting medium (49).

The acid reaction of peat is considered beneficial (46) or necessary for some cuttings (34).

Vermiculite is used widely as a medium for rooting cuttings. The No. 2 grade has proven to be most satisfactory for most ornamental deciduous shrubs (51). In this medium cuttings produce a desirable fibrous branched type of roots (27, 72). Vermiculite is valuable in the rapid rooting of soft cuttings such as chrysanthemum, carnation, dahlias, etc., (87).

Many mixtures have been used as media for propagation. Cuttings of some plants which root poorly in sand often root satisfactorily in mixtures of equal volumes of sand and peat (10, 12, 35). A mixture of equal parts of peat and sawdust was satisfactory for rooting of rabbiteye blueberry. A mixture which contained 1 part of peat, 1 part of sand, and 1 part of sawdust also proved satisfactory (4).

In general, any medium which holds moisture and supplies air is satisfactory. However, different media cause variations in root quality (40). Of 43 kinds of plants propagated by stem cuttings, 30 produced finer and more flexible roots in peat moss than in sand due to the reduced aeration and increased moisture (45).

Many chemicals have been used in efforts to induce root formation in plant species difficult to propagate or to improve rooting quality (2, 8, 13, 41, 62, 71, 80, 90). Sugars, nitrates, zinc, boron, manganese, iron, phosphorus, acetic acid, potassium permanganates, and carbon monoxide have been reported effective but results of experiments have been so variable that the advisability of using them appears very slight (8, 13, 41, 43, 90). However, hormone treatment has proved effective.

The importance of hormones in the rooting of cuttings was clearly established in 1935 when indoleacetic acid in lanolin paste was first used successfully to stimulate the rooting of lemon, lantana, and acalypha cuttings by Cooper (15). Since then many plants have been tested to ascertain the effectiveness of hormones in inducing or improving root formation (2, 5, 26, 27, 28, 53, 55, 56, 62, 63, 73, 80). Also, many other similarly active chemical compounds have been discovered; indole-butyric, indolepropionic and naphthaleneacetic acids, napthaleneacetamide, 2, 4-dichlorophenoxyacetic acid, 2, 4, 5-trichlorophenoxyacetic acid and trichlorophenoxypropionic acid all induce root formation but their activity varies considerably (2, 39, 62, 67, 71, 73, 80).

Indolebutyric acid (IBA) and naphthaleneacetic acid (NAA) and its derivative naphthaleneacetamide (NAd) are the materials in most common use for rooting of cuttings. The potassium salts of IBA and NAA appear equally effective and have the advantage of being readily soluble in water. The indole compounds usually produce a more fibrous root system than the naphthalene compound. Also, IBA does not inhibit the growth of terminal buds as much as NAA (71). A mixture of IBA and NAA is more effective on both IBA and NAA sensitive cuttings (38).

Numerous methods of applying the plant hormone to cuttings have been used. At the present time three methods of application have come into widespread practical use; the hormone powder method (2, 37, 71), the concentrated solution dip-method (2, 16, 28, 37) and the dilute solution soaking method (2, 5, 26, 59, 71).

Weak solutions of hormones coupled with prolonged soaking were widely used in early work. The effective concentrations range from 10 ppm to 100 ppm. Duration of treatment ranges from a few hours to 24 hours (2, 5, 26). It was shown that the chief disadvantage of the method was that the long period of treatment allowed for variations in external conditions which influenced the hormone effect (59).

The concentrated solution dip-method was first proposed by Hitchcock and Zimmerman. The concentrations tested were from 1,000 ppm to 20,000 ppm (37). Others indicate that IBA at 4,000 to 10,000 ppm will induce rooting on most kinds of cuttings (2).

Rooting powder containing approximately 500 to 2,000 ppm IBA, NAA or naphthalene-acetamide is effective in stimulating root formation of the more easily rooted cuttings. Concentration from 10,000 to 20,000 ppm is required to root more difficult cuttings (2).

Stoutemyer concluded that three concentrations of IBA, NAA or NAd rooting powder were effective in rooting three groups of plants; 1,000 ppm for easy-to-root plants; 4,000 ppm for intermediate groups and 10,000 to 20,000 ppm for difficult-to-root plants (71).

The concentrated hormone solution dip-method and the hormone powder method are used most commonly and are the most convenient methods to use (16, 28).

Control of temperature is very important in the rooting of cuttings. Steady and even bottom heat in a bench is beneficial in rooting hardwood cuttings and for winter propagation work (87). The cutting bench should be maintained around 65° to 70° F. (about 6 to 10° F. warmer than the surrounding air) to give satisfactory results with many plant species (1, 87). However, Swingle found that the optimum rooting temperature for apple cuttings was between 75 to 85° F. (76).

The light effect on cuttings is mainly an indirect factor. Light is essential for photosynthesis to produce food which is necessary for producing roots. A number of papers reported the effect of light on rooting (23, 50, 61, 68, 69, 70). Cuttings rooted faster and more abundantly in June than when days were shorter (50).

Mechanical treatments of various kinds have been used to stimulate root formation (17). But the most important mechanical consideration has proven to be the location of the basal cut. A basal cut 1/2 inch below the bottom node was superior for 41 of the 86 common shrubs tested as compared with 17 which rooted best with a cut at the node. In 23 cases, the position of the cut was unimportant. In some cases, the position of the basal cut influenced the number of roots and in other cases it influenced the time of rooting (9, 11, 13).

The type of wood at the base has an important influence on the rooting of cuttings of some plants. In general, cuts made at the base of the current season's growth aided rooting. Mallet cuttings made to include a small portion of last season's wood generally rooted poorly (36). The use of a small portion of 2-year old wood at the base of a cutting did not appear to help the rooting of coniferous cuttings (89).

Wounds at the base of cuttings often cause better root formation. They increase the area in which roots may form; roots often develop along the margins of the wound. It is not clearly understood why wounds stimulate rooting. Some people suggest that a wound hormone is produced which aids in healing the mutilated tissue, while others theorize that wounding stimulates cambium cells into active division to seal up the wound (1, 87). Some people think it is due to the increase of water adsorption (17).

Wounding is of particular value on conifers, which are propagated from stem cuttings. In a series of tests on Juniperus Pfitzerana, Juniperus stricta, and Thuja orientalis pyramidalis wounding increased the percentage of rooting more than any other treatment (87).

The use of mist for rooting cuttings was introduced by Raines (57, 58), Gardner (24), and Fisher (20, 21). That these reports appeared so nearly at the same time suggests that the concept of mist propagation was developed simultaneously by these people. Interest in this field was aroused, but rapid progress did not occur until the early 1950's when various research stations and commercial firms studied propagation factors, developed equipment, and applied their results to the practical field.

The environmental factor most difficult to control is water which is important in all physiological processes. Mist propagation involves the use of apparatus which disperses fine droplets or particles of water in such a manner that the surfaces of leaves and stems are covered with a thin film of water. Water evaporates from the surface film to the atmosphere but little or no water is lost from the leaf tissue. In this way, mist helps to maintain the turgidity of the cuttings (64).

Mist lowers leaf temperatures thereby reducing food utilization. However, cuttings are able to manufacture larger amount of foods since they can be exposed to full light intensity without wilting. Thus, a large amount of reserve foods, which are utilized in the rooting process, accumulate in the cuttings. Therefore, the rooting potential of cuttings under mist are much greater than cuttings under other methods (32).

Mist apparatus are of two basic types: the over-head system and the in-bed system. In-bed system has three advantages: no water dripping occurs, no support is necessary for the feeder lines and a larger number of cuttings can be placed in the propagation bed. Nozzles used in mist operations are of three types: oil burner nozzles, self-cleaning nozzles and deflection nozzles (64).

Most of the early work on mist was concerned with the use of continuous mist during daylight hours only or on a 24-hour per day basis (20, 24, 57, 58, 84, 85, 86). More recently the use of intermittent mist has been advocated (18, 29, 30, 31, 32, 33, 44, 47, 64, 74, 75, 77, 78).

Comparing the constant mist system with the intermittent mist system, Hess found that the temperature of the medium under constant mist was reduced due to the excessive amount of mist to a point where the rooting response was actually inhibited. The temperature of the medium under "electronic leaf" controlled intermittent mist was always near or above the optimum because only enough mist was applied to maintain a film of water on the foliage of cuttings. There was no excess mist leading to low medium temperature (32).

Methods of operating an intermittent mist system are hand controls (42), timer mechanisms (31), solar control mechanisms (64), humidistats

(77) and electronic leaf (32, 64, 78). Of these methods, the "electronic leaf" was the most effective mechanism for controlling mist. Because it is weather sensitive, it affords automatic protection on a 24-hour basis, it requires a minimum of water but affords maximum protection. It is relatively easily constructed at a reasonable price (64).

Suitable well drained rooting medium (20, 21, 57, 75, 84, 85, 86, 87), hormone treatment (29, 30, 42, 47) and time of collecting cuttings (24, 84) are the important factors affecting successful rooting under mist propagation.

Among the narrow leaf evergreens, the Pfitzer juniper represents plants in which mist is of marked benefit to rooting in regard to rooting percentage and root quality. Thuja occidentalis elegantissima is also noticeably benefited by the mist (64).

In a large commercial test involving some 50,000 azaleas of most common varieties and 25,000 magnolias, the azaleas rooted 100 per cent. All the standard varieties of the magnolias rooted with such rapidity that the more easily rooted varieties were potted in four weeks and the more difficult ones in six (87).

Many ornamental trees and shrubs rooted freely and quickly under mist from very soft cuttings. Carnations, chrysanthemum and dahlia cuttings all rooted 100 per cent under mist conditions within three weeks of insertion (42). Peach, several clones of mahaleb cherries and EM VII apple root stock rooted satisfactorily under mist propagation (74).

Mist propagation in open frames (81) or under lath house (65) are promising and economical methods for commercial propagation of cuttings during the summer months.

Cuttings under mist produce long unbranched succulent roots, which later branch; at the later stage a cutting of this type is easier to transplant (6).

Cuttings under mist, regardless of whether they are rooted under glass or in open beds can not withstand an abrupt shift from the mist. It was suggested that cuttings be potted and returned to the mist bench. The potted plants are then hardened by gradually decreasing the period of mist. A simpler method is to leave the rooted cuttings in the bench under mist until maximum rooting has been obtained. The cuttings are then hardened by a gradual decrease in the mist periods until they are capable of withstanding the more severe conditions of the greenhouse or outside planting (14, 64). It was also reported that by using shading both softwood and evergreen cuttings were transplanted successfully from the mist bed (19, 60).

MATERIALS AND METHODS

All the experiments reported herein were conducted in the Horticultural greenhouse at Montana State College during the period November 1956 to April 1957. A temperature of approximately 65° F. was maintained in the propagation bench. The mean daily temperature was 60° F.

A. Rooting of Cuttings

(1) Plant Materials -

Three types of cuttings, herbaceous, evergreen and hardwood, were used. The plant species were chrysanthemum (Chrysanthemum morifolium), carnation (Dianthus caryophyllus), German ivy (Senecio mikanioides), Pfitzer juniper, (Juniperus chinensis pfitzeriana), caragana or Siberian pea shrub (Caragana arborescens), potentilla or bush cinquefoil (Potentilla fruticosa), sand cherry (Prunus besseyi) and McIntosh apple (Malus spp.). These will be referred to as chrysanthemum, carnation, German ivy, Pfitzer juniper, caragana, potentilla, sand cherry, and Malus.

The cuttings were about five or six inches in length and were trimmed to just below a bottom node. They were divided into lots as nearly equal in vigor as possible. The caragana, potentilla and sand cherry cuttings were given a 108 day callusing treatment (November 12, 1956 to March 2, 1957) and Malus a 28 day treatment (February 4, 1957 to March 2, 1957). The callusing treatment consisted of burying the cuttings in damp peat maintained at a temperature of approximately 40° F. Hormone treatments were applied after callusing.

(2) Rooting Media -

Four rooting media were used: 100% perlite, 75% perlite and 25% peat, 50% perlite and 50% peat, and 50% sand and 50% peat.

Perlite is a synthetic rooting medium consisting of 95% aluminum silicate plus traces of calcium, iron, magnesium, sodium, potassium and minor element salts. It is neutral in reaction. In its manufacture, it is expanded about eight times in volume resulting in a great increase in water holding capacity and aeration. Canadian peat and clean washed bank-run sand were used in making the mixtures.

(3) Intermittent Mist -

The automatic mist system used was of an "In-bed" type with Type A-6 "Humido-mist" nozzle (self-cleaning) in which the mist was controlled by an "electronic leaf". The electronic leaf consisted of a small rectangle of plastic about one inch long and 1/2 inch wide, two carbon electrodes inserted in the plastic 3/4 inch apart. A wire led from each electrode to the Thyraton tube control unit. When a film of water was on the leaf, an electric current passed between the electrodes and the control mechanism kept the solenoid valve closed. When the film of water evaporated the "leaf current" circuit was interrupted and the control mechanism opened the solenoid valve to start the mist. The "on" period for the mist varied from a minimum of three seconds to a maximum of about twenty seconds. The "off" period depended on the rate of evaporation of the water film. The electronic leaf was located about 6 inches above bench level in the center of the bench.

(4) Hormone -

Indolebutyric acid (IBA) was selected as it was the most commonly used rooting hormone. It was used in powder form for herbaceous cuttings and in concentrated solution form for evergreen and hardwood cuttings.

The hormone powder was made by dissolving 400 mg. of IBA in about 50 c.c. of 95% ethyl alcohol. This solution was stirred into

100 grams of talc to form a paste which was allowed to stand until the alcohol evaporated. All lumps were eliminated by stirring and crushing to form a uniform 4,000 ppm IBA powder. Fifty grams of 2,000 ppm IBA rooting powder was made by mixing 25 grams of the 4,000 ppm IBA powder with 25 grams of talc. Fifty grams of 1,000 ppm IBA rooting powder was made by mixing 12.5 grams of IBA 4,000 ppm rooting powder with 37.5 grams of talc.

The concentrated hormone solution was made by dissolving 400 mg. of IBA in 50 ml. of 50% ethyl alcohol to form an 8,000 ppm IBA solution. Twenty-five ml of 8,000 ppm IBA solution was diluted with 25 ml of 50% ethyl alcohol to form a 4,000 ppm IBA rooting solution. Twenty-five ml of 4,000 ppm IBA solution was diluted with 25 ml 50% ethyl alcohol to form a 2,000 ppm IBA rooting solution.

(5) Methods -

The experimental design for all three experiments was a factorial arrangement of treatments in randomized plots. As it was impossible to randomize mist treatments, half of the bench received intermittent mist and half received no mist. Four media were randomized in each half of the bench. Plant species were randomized in each medium in rows. Each row consisted of 24 cuttings of a single species extending the full width of the bench. Four hormone treatments were randomized in each row in plots of 6 cuttings each.

<u>Experiment 1</u>: Chrysanthemum, carnation and German ivy cuttings were treated with 1,000 ppm, 2,000 ppm, and 4,000 ppm indolebutyric acid

(IBA) powder by dipping the basal end (1/2 to 1 inch) of the cuttings in tap water, shaking off the excess and dipping in the hormone powder. All excess powder was removed by gently shaking the cuttings which were then inserted into the media. Treatments were made on November 24 to 26, 1956. Rooting records were taken on December 16 and 17, 1956.

Experiment 2: Pfitzer juniper cuttings were treated with 2,000 ppm, 4,000 ppm, and 8,000 ppm of IBA solution by dipping the basal inch of the cuttings in the rooting solution for 3 seconds. The treated cuttings were then inserted in the rooting media. Treatments were made on November 27, 1956. Rooting records were taken on February 27, 1957.

Experiment 3: Caragana, potentilla and sand cherry cuttings were subjected to a 108 day callusing treatment and Malus cuttings to a 28 day treatment by storing them in damp peat in a plastic sack at a temperature of about 40° F. The callused cuttings were treated with 2,000 ppm, 4,000 ppm and 8,000 ppm of IBA solution by dipping the basal inch of the cuttings in the hormone solution. The treated cuttings were then inserted into the rooting media. Treatments were made on March 2, 1957. Rooting records were taken on April 12, 1957.

B. Transplanting rooted cuttings

(1) Plant materials -

Rooted cuttings of chrysanthemum, carnation, German ivy, Pfitzer juniper, caragana, potentilla, and sand cherry which resulted from the cutting experiments were selected for transplanting. Selection was based upon root development with the best ones being selected from each experiment. The cuttings which rooted under intermittent mist were kept separate from those which rooted under non-mist conditions. In order to minimize the carry over effect of hormone treatments the numbers of cuttings treated with various concentrations of IBA were selected as equal as possible. However, no attempt was made to equalize the number of cuttings rooted in each medium in these experiments.

(2) Soil treatments -

Two soil treatments were used: a greenhouse potting mixture and the same potting mixture to which skim milk was added. The potting mixture contained 50% Huffine silt loam soil, 25% sand and 25% well rotted manure. The potting mixture plus skim milk was the same potting mixture as above plus skim milk powder at the rate of 1/2 ounce per flat. The flats used were 20.5" x 12.0" x 3.5". Flats were used for all species except Pfitzer juniper which was transplanted into six inch standard pots.

(3) Transplanting treatments -

Flats containing cuttings rooted under intermittent mist were placed under one of two conditions immediately following transplanting. One of the conditions was an immediate transferal to non-mist conditions. The other condition was a hardening process in which the flats were placed in intermittent mist which was decreased by 2 hours a day until non-mist conditions were obtained. All flats containing cuttings rooted under non-mist conditions were placed only under non-mist conditions.

(4) Methods -

The design of this experiment varied for different species as the availability of rooted cuttings varied. Chrysanthemum, carnation and German ivy were the only species which produced sufficient numbers of rooted cuttings on which to conduct all the phases of the experiment.

Seventy-two cuttings of chrysanthemum were divided into 24 lots of 3 each. Sixteen of the lots had been rooted under intermittent mist and 8 under non-mist conditions. Eight of the lots of cuttings rooted under intermittent mist and 4 of the lots of cuttings under non-mist were transplanted into flats containing a greenhouse potting mixture. The remaining lots of cuttings were transplanted into flats containing the potting mixture plus skim milk.

Seventy-two rooted cuttings of carnation and 72 rooted cuttings of German ivy were divided into lots in the same way. Then they were transplanted into the flats containing the rooted chrysanthemum cuttings following the same plan of selection. Thus, each flat contained rooted cuttings which had received as near identical pre-transplanting treatments as possible.

The flats were divided into three lots of 8 flats each. Two lots contained the cuttings which had rooted under intermittent mist and the third lot contained cuttings which had rooted under non-mist.

Each lot consisted of four flats filled with the potting mixture and four filled with the potting mixture plus skim milk. One of the lots containing cuttings rooted under intermittent mist was put through a hardening process. The remaining two lots were placed directly under non-mist condition.

The herbaceous cuttings were transplanted into flats on December 17, 1956 and the results were observed on March 27, 1957.

Forty rooted cuttings of Pfitzer juniper were divided into 12 lots of cuttings, 8 of the lots contained 4 cuttings each and 4 of the lots contained 2 cuttings each. All cuttings had rooted under intermittent mist conditions. One half of the lots were transplanted into pots containing greenhouse potting mixture soil. The other half of the lots were transplanted into pots containing the potting mixture soil plus skim milk.

The pots were then divided into two lots of 6 pots each. Each lot consisted of three pots filled with the potting mixture soil and three pots filled with the potting mixture soil plus skim milk. One of the lots was put through a hardening process and the other lot was placed directly under non-mist conditions.

The juniper cuttings were transplanted into pots on February 28, 1957 and the results were observed on June 10, 1957.

Twenty-four rooted cuttings of potentilla were divided into 12 lots of 2 cuttings each. Six of the lots had been rooted under intermittent mist and 6 under non-mist conditions. Three of the lots of cuttings rooted under intermittent mist and 3 of the lots of cuttings rooted under non-mist were transplanted into flats containing a greenhouse potting mixture soil. The remaining lots of cuttings were transplanted into flats containing the potting mixture soil plus skim milk.

Twenty-four rooted cuttings of caragana and 24 rooted cuttings of sand cherry were divided into lots in the same way as potentilla. Then they were transplanted into the flats containing the rooted potentilla cuttings following the same plan of selection as potentilla. Thus, each flat contained rooted cuttings which had received as near identical pre-transplanting treatments as possible. All flats were placed directly under non-mist conditions.

The hardwood cuttings were transplanted into flats on April 12, 1957 and the results were observed on June 11, 1957.

EXPERIMENTAL RESULTS

A. Rooting of cuttings

Experiment 1. The results of rooting herbaceous cuttings of chrysanthemum, carnation, and German ivy are summarized in Tables 1, 2, and 4, and illustrated in Figure 1. The analysis of variance is summarized in Table 3. The analysis of variance shows that the effect of different concentrations of hormone (IBA) treatments, plant species and their first order interaction were all highly significant. There was no significant difference between intermittent mist and non-mist treatments nor any among the four media.

Table 1. Number[a] of herbaceous cuttings rooted under different concentrations of indolebutyric acid (IBA), mist, and non-mist, and different kinds of media.

		Hormone concentration									
		Check		1,000 ppm IBA		2,000 ppm IBA		4,000 ppm IBA		Total	
Species	Media[b]	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist
Chrysanthemum	A	4	6	4	6	5	6	5	1	18	19
	B	5	6	6	6	6	4	4	5	21	21
	C	6	6	6	6	6	5	6	4	24	21
	D	5	6	5	6	5	6	3	6	18	24
Total		20	24	21	24	22	21	18	16	81	85
Carnation	A	4	4	5	6	6	6	6	4	21	20
	B	4	1	6	6	6	5	5	5	21	17
	C	5	0	5	6	6	6	6	5	22	17
	D	3	0	6	1	5	6	5	6	19	13
Total		16	5	22	19	23	23	22	20	83	67
German ivy	A	5	5	6	6	5	6	5	6	21	23
	B	6	4	6	6	6	6	6	6	24	22
	C	6	6	6	6	6	6	6	5	24	23
	D	6	6	6	6	6	6	6	6	24	24
Total		23	21	24	24	23	24	23	23	93	92

a Six cuttings per treatment.

b Media were as follows: A. 100% perlite
B. 75% perlite and 25% peat
C. 50% perlite and 50% peat
D. 50% sand and 50% peat.

Table 2. Quality of root system[a] of herbaceous cuttings rooted under different concentration of indolebutyric acid (IBA), mist, and non-mist, and different kinds of media.

		Hormone concentration									
		Check		1,000 ppm IBA		2,000 ppm IBA		4,000 ppm IBA		Average	
Species	Media[b]	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist
Chrysanthemum	A	1	3	2	4	3	4	4	2	2.5	3.25
	B	2	3	3	4	4	2	1	3	2.5	3.0
	C	2	3	4	4	4	4	2	2	3.0	3.25
	D	2	1	4	4	4	3	1	2	2.75	2.5
Average		1.75	2.5	3.25	4.0	3.75	3.25	2.0	2.25	2.68	3.0
Carnation	A	1	1	2	3	4	4	3	2	2.5	2.5
	B	1	1	3	3	4	3	2	2	2.5	2.25
	C	1	0	2	3	4	4	3	4	2.5	2.75
	D	1	0	4	2	2	4	3	3	2.5	2.25
Average		1.0	0.5	2.75	2.75	3.5	3.75	2.75	2.75	2.5	2.44
German ivy	A	1	1	4	3	3	4	2	2	2.5	2.5
	B	1	1	3	3	2	2	4	4	2.5	2.5
	C	1	1	4	4	2	3	3	2	2.5	2.5
	D	1	2	2	3	3	4	4	1	2.5	2.5
Average		1.0	1.25	3.25	3.25	2.5	3.25	3.25	2.25	2.5	2.5

a Root quality expressed as average of six cuttings per treatment, with 0 representing no rooting, with 1 representing poor roots, with 2 representing fair roots, with 3 representing good roots, and with 4 representing excellent roots.

b Media were as follows: A. 100% perlite
B. 75% perlite and 25% peat
C. 50% perlite and 50% peat
D. 50% sand and 50% peat.

Table 3. Analysis of variance based on number of rooted cuttings of chrysanthemum, carnation, and German ivy under different concentrations of indolebutyric acid (IBA), mist, and non-mist, and different kinds of media.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Mist vs. Non-Mist (M)	1	1.5004	1.5004	1.48
Media (Me)	3	2.5833	.8611	.85
Hormone treatment (T)	3	18.7500	6.2500	6.15**
Plant species (P)	2	20.2708	10.1354	9.97**
M Me	3	3.5829	1.1943	1.17
M T	3	2.5829	.8610	.85
M P	2	6.0621	3.0310	2.98
Me T	9	6.5000	.7222	.71
Me P	6	9.7292	1.6215	1.59
T P	6	38.3125	6.3854	6.28**
Higher order Int. (error)	57	57.9592	1.0168	
Total	95	167.8333		

* Significant to the 5% level.
** Significant to the 1% level.

Table 4. Rooting percentage of herbaceous cuttings[a] under different concentrations of indolebutyric acid (IBA), mist and non-mist, and different kinds of media.

		Hormone concentration									
		Check		1,000 ppm IBA		2,000 ppm IBA		4,000 ppm IBA		Average	
Species	Media[b]	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist
Chrysanthemum	A	67	100	67	100	83	100	83	17	75	79.25
	B	83	100	100	100	100	67	67	83	87.5	87.5
	C	100	100	100	100	100	83	100	67	100.0	87.5
	D	83	100	83	100	83	100	50	100	74.8	100.0
Average		83.3	100	87.5	100	91.5	87.5	75.0	66.8	84.3	88.5
Carnation	A	67	67	83	100	100	100	100	67	87.5	83.5
	B	67	17	100	100	100	83	83	83	87.5	70.8
	C	83	0	83	100	100	100	100	83	91.5	70.8
	D	50	0	83	17	83	100	83	100	74.8	54.3
Average		66.8	42.0	87.3	79.3	95.8	95.8	91.5	83.3	85.3	69.9
German ivy	A	83	83	100	100	83	100	83	100	87.3	95.8
	B	100	67	100	100	100	100	100	100	100.0	91.8
	C	100	100	100	100	100	100	100	83	100.0	95.8
	D	100	100	100	100	100	100	100	100	100.0	100.0
Average		95.8	87.5	100	100	95.8	100	95.8	95.8	96.8	95.9

a Six cuttings per treatment

b Media were as follows:
A. 100% perlite
B. 75% perlite and 25% peat
C. 50% perlite and 50% peat
D. 50% sand and 50% peat.

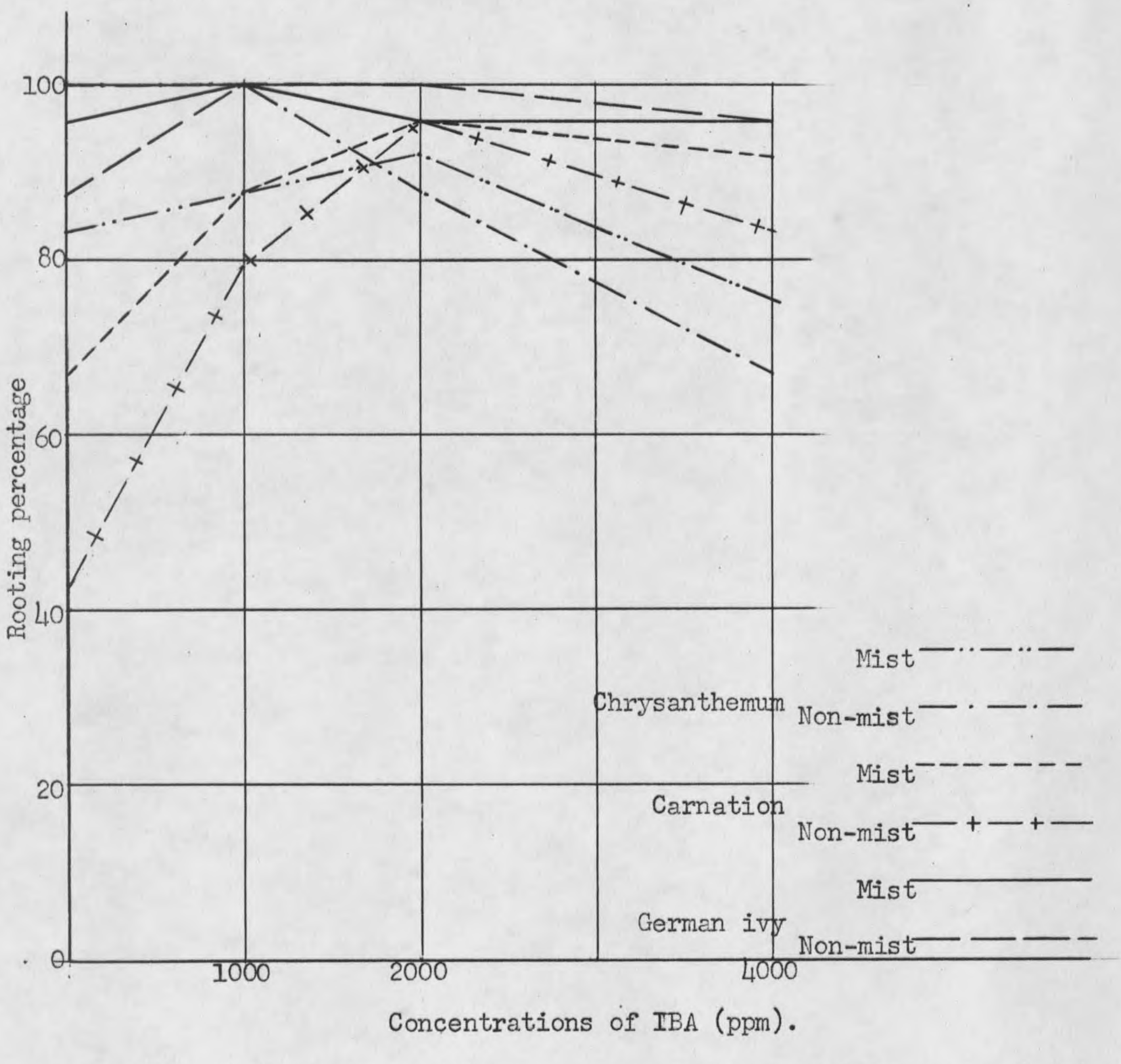

Figure 1. The effects of different concentrations of hormone treatments on the rooting of herbaceous cuttings.[a]

[a] Rooting percentage base on 24 cuttings, six each from four media.

Table 1 summarizes the number of cuttings rooted. Table 2 summarizes the characters of the roots developed. Table 4 summarizes the per cent of cuttings that rooted and Figure 1 graphically illustrates the per cent of cuttings rooted for all three plant species.

<u>Chrysanthemum</u> - Under intermittent mist chrysanthemum cuttings treated with 1,000 ppm and 2,000 ppm IBA rooted better than the check. Under non-mist conditions, all the cuttings in the check and those treated with IBA at 1,000 ppm rooted. Those treated with 2,000 ppm IBA rooted almost as well. However, under both intermittent mist and non-mist rooting was poor at 4,000 ppm IBA.

The root quality of cuttings treated with 1,000 ppm and 2,000 ppm IBA compared with the check was markedly superior, under both intermittent mist and non-mist. At 4,000 ppm root quality was poor.

Four thousand ppm IBA treatments appeared to be too high to induce rooting in chrysanthemum. Both per cent of cutting rooted and quality of roots were low, indicating possible toxic effects from the hormone treatments.

The 50% perlite and 50% peat mixture seemed to be the best medium for rooting chrysanthemum cuttings under intermittent mist treatments, while 50% sand and 50% peat seemed best for non-mist treatments. As this experiment was not replicated no mathematical significance could be determined. However, a difference of 20-25% between the poorest and best media seems reasonably beyond the experimental error usually attributed to biological growth.

<u>Carnation</u> - All cuttings of carnation treated with IBA were better

than any of the cuttings in the check plots under either intermittent mist or non-mist. In addition, the root quality was markedly superior in all IBA treatments. Cuttings rooted better under intermittent mist than non-mist with or without IBA treatments, although there was no effect upon root quality. The best treatment under either intermittent mist or non-mist was obtained with the 2,000 ppm IBA treatment.

The 50% perlite and 50% peat mixture seems best for rooting of carnation cuttings under intermittent mist, while 100% perlite seemed best for non-mist treatments. Once again mathematical significance could not be computed but the difference present seems to be beyond a reasonable amount of experimental error.

German Ivy - Cuttings of German ivy rooted very well under all conditions. However the root quality was greatly improved under both intermittent mist and non-mist by the IBA treatments.

There were no differences among the four media used for rooting German ivy cuttings under either intermittent mist or non-mist or with IBA treatments.

Experiment 2. The results of rooting evergreen cuttings of Pfitzer juniper are summarized in Tables 5, 6, and 8 and illustrated in Figure 2. The analysis of variance is summarized in Table 7. The analysis of variance shows that the effects of intermittent mist and non-mist, different concentrations of hormone (IBA) treatments and their first order interactions were all significant. There was no significant difference among the four media.

Table 5. Number[a] of Pfitzer juniper cuttings rooted under different concentrations of indolebutyric acid (IBA), mist and non-mist, and different kinds of media.

		Hormone concentration									
		Check		2,000 ppm IBA		4,000 ppm IBA		8,000 ppm IBA		Total	
Species	Media[b]	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist
Pfitzer juniper	A	0	0	4	1	0	0	3	0	7	1
	B	0	0	6	0	6	0	5	0	17	0
	C	0	0	4	0	1	0	4	0	9	0
	D	2	0	3	0	1	0	4	0	10	0
Total		2	0	17	1	8	0	16	0	43	1

[a] Six cuttings per treatment.

[b] Media were as follows:
A. 100% perlite
B. 75% perlite and 25% peat
C. 50% perlite and 50% peat
D. 50% sand and 50% peat.

Table 6. Average number[a] of roots per rooted Pfitzer juniper cuttings which rooted under different concentrations of indolebutyric acid (IBA), mist and non-mist, and different kinds of media.

		Hormone concentration									
		Check		2,000 ppm IBA		4,000 ppm IBA		8,000 ppm IBA		Average[a]	
Species	Media[b]	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist
Pfitzer juniper	A	-	-	8	3	-	-	19	-	12.7	3
	B	-	-	9	-	10	-	23	-	13.4	-
	C	-	-	16	-	10	-	23	-	18.4	-
	D	1.5	-	8	-	11	-	9.5	-	9.1	-
Average[a]		1.5	-	10.2	-	10.1	-	18.8	-	13.5	3

a Average number of roots based upon total number of roots developed and the number of cuttings rooted as indicated in Table 5.

b Media were as follows: A. 100% perlite
B. 75% perlite and 25% peat
C. 50% perlite and 50% peat
D. 50% sand and 50% peat.

Table 7. Analysis of variance based on number of rooted cuttings of Pfitzer juniper under different concentrations of indolebutyric acid (IBA), mist and non-mist, and different kinds of media.

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F
Mist vs. clear (M)	1	55.1250	55.1250	59.24**
Media (Me)	3	6.25	2.0833	2.24
Treatment (I)	3	20.50	6.8333	7.34**
M Me	3	8.125	2.7083	2.91
M T	3	17.3750	5.7917	6.22*
Me T	9	9.7500	1.0833	1.16
M Me T (error)	9	8.3750	.9306	
Total	31	125.50		

* Significant to the 5% level
** Significant to the 1% level

Table 8. Rooting percentage of Pfitzer juniper[a] under different concentrations of indolebutyric acid (IBA), mist and non-mist, and different kinds of media.

		Hormone concentration									
		Check		2,000 ppm IBA		4,000 ppm IBA		8,000 ppm IBA		Average	
Species	Media[b]	Mist	Non-mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist
Pfitzer juniper	A	0	0	67	17	0	0	50	0	29.3	4.3
	B	0	0	100	0	100	0	83	0	70.8	0
	C	0	0	67	0	17	0	67	0	37.8	0
	D	33	0	50	0	17	0	67	0	41.8	0
Average		8.3	0	71.0	4.3	33.5	0	66.8	0	44.9	1.08

a Six cuttings per treatment.

b Media were as follows: A. 100% perlite
B. 75% perlite and 25% peat
C. 50% perlite and 50% peat
D. 50% sand and 50% peat.

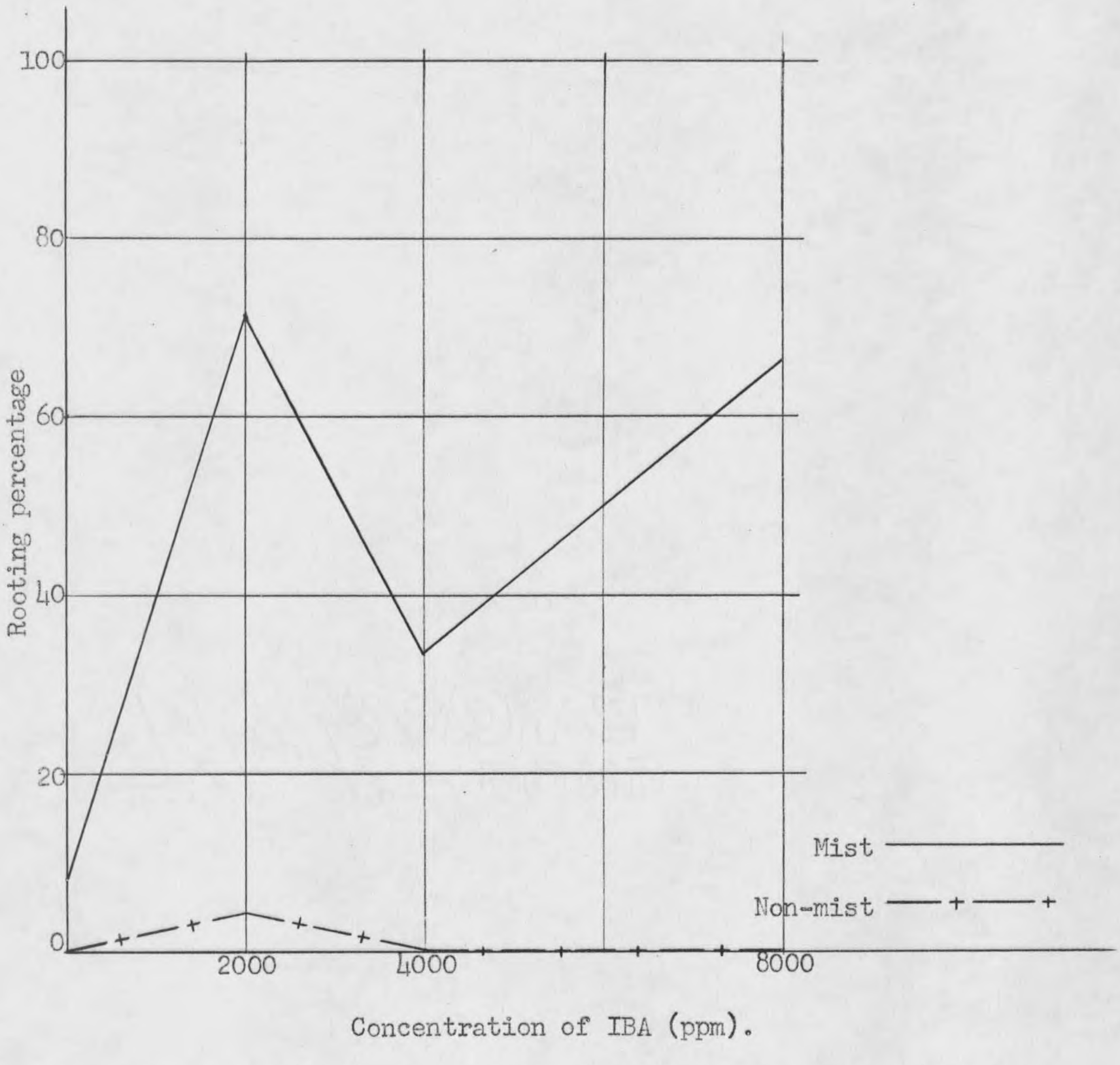

Figure 2. The effects of different concentrations of hormone treatments on rooting Pfitzer juniper cuttings.[a]

[a] Rooting percentage based on 24 cuttings, six each from four media.

Table 5 summarizes the number of cuttings rooted. Table 6 summarizes the average number of roots per cuttings. Table 8 summarizes the rooting percentage of the cuttings and Figure 2 graphically illustrates the per cent of rooting for Pfitzer juniper cuttings.

There is a significant difference between propagating junipers under intermittent mist and non-mist conditions. The cuttings almost completely failed to root under the non-mist condition although the cuttings had been treated with 2,000 ppm, 4,000 ppm, or 8,000 ppm IBA.

In general, the cuttings treated with 8,000 ppm indolebutyric acid (IBA) produced the greatest number of roots per cutting, but the cuttings treated with 2,000 ppm IBA had a slightly higher rooting percentage. The cuttings treated with 4,000 ppm IBA rooted at a low percentage for which no explanation can be given except that it may be due to the small sample size causing a large experimental error. However, the number of roots developed on the cuttings which did root equalled the number on the cuttings treated with 2,000 ppm (IBA).

The analysis of variance indicated that there is no significant difference among media for rooting junipers. But from the data presented in Table 8 it may be observed that the cuttings rooted best in 75% perlite and 25% peat.

<u>Experiment 3</u>. The results of rooting hardwood cuttings are summarized in Tables 9 and 11 and illustrated in Figure 3. The analysis of variance is summarized in Table 10. The analysis of variance shows that the effects of different concentrations of hormone (IBA) treatments and

Table 9. Number[a] of hardwood cuttings rooted under different concentrations of indolebutyric acid (IBA), mist and non-mist, and different kinds of media as expressed by fractions.

		Hormone concentrations									
		Check		2,000 ppm IBA		4,000 ppm IBA		8,000 ppm IBA		Total	
Species	Media[b]	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist
Potentilla	A	3/6	2/6[d]	4/5	3/6	2/5	0/5	0/6	0/6	9/22	5/23
	B	2/6[c]	0/6	2/5	2/6	4/4	0/5	0/6	0/6	8/21	2/23
	C	4/6	2/6	4/5	3/6	3/5	4/5	3/6	3/6	14/22	12/23
	D	4/6	4/6[c]	5/5	1/6[d]	0/5	0/5	1/6	0/6	10/22	5/23
Total		13/24	8/24	15/20	9/24	9/19	4/20	4/24	3/24	41/87	24/92
Caragana	A	1/6	3/6	0/6	0/6	1/6	1/6	0/6	0/6	2/24	4/24
	B	2/6[c]	2/6[c]	2/6	4/6	2/6	0/6	0/6	0/6	6/24	6/24
	C	2/6[d]	2/6[d]	0/6	2/6[c]	1/6	1/6	0/6	0/6	3/24	5/24
	D	3/6[d]	3/6	0/6	2/6	1/6	4/6	2/6[d]	0/6	6/24	9/24
Total		8/24	10/24	2/24	8/24	5/24	6/24	2/24	0/24	17/96	24/96
Sand cherry	A	3/5[d]	3/5[d]	2/6	4/6	1/6	1/6	0/6	0/6	6/23	8/23
	B	2/4[d]	2/4[c]	0/6	0/6	0/6	2/6	0/6	0/5	2/22	4/21
	C	1/4[c]	2/5[d]	1/6	5/6	0/6	1/6[c]	0/6	0/5	2/22	8/22
	D	1/4	2/5[d]	0/6	0/6	0/6	0/6	0/6	0/5	0/22	2/22
Total		7/17	9/19	3/24	9/24	1/24	4/24	0/24	0/21	10/89	22/88

Malus failed to root under all treatments.

a Number expressed as number of rooted cuttings/number treatments. Six cuttings used per treatment except where 5 or 4 were used due to shortage of material.

b Media were as follows: A. 100% perlite; B. 75% perlite and 25% peat; C. 50% perlite and 50% peat; D. 50% sand and 50% peat.

c Indicate cuttings rooted poorly.

d Indicate cuttings barely rooted.

Table 10. Analysis of variance based on number of rooted cuttings of potentilla, caragana, sand cherry and malus under different concentrations of indolebutyric acid (IBA), mist and non-mist, and different kinds of media.

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	F
Mist vs non-mist (M)	1	.0313	.0313	.03
Rooting media (Me)	3	4.3438	1.4479	1.56
Hormone Treatments (T)	3	37.2813	12.4271	13.39**
Plant species (P)	3	67.7813	22.5938	24.35**
M Me	3	1.5937	.5312	.57
M T	3	1.4062	.4687	.51
M P	3	15.0312	5.0104	5.40**
Me T	9	6.8437	.7604	.82
Me P	9	29.3437	3.2604	3.51**
T P	9	18.4062	2.0451	2.20*
Higher order int. (error)	81	75.1564	.9279	
Total	127	257.2188		

* Significant to the 5% level.

** Significant to the 1% level.

Table 11. Rooting percentage[a] of hardwood cuttings under different concentrations of indolebutyric acid (IBA), mist and non-mist, and different kinds of media.

		Hormone concentrations									
		Check		2,000 ppm IBA		4,000 ppm IBA		8,000 ppm IBA		Average	
Species	Media	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist	Mist	Non-Mist
Potentilla	A	50	33[d]	80	50	40	0	0	0	42.5	20.8
	B	33[c]	0	40	33	100	0	0	0	43.3	8.3
	C	67	33	80	50	60	80	50	50	64.3	53.3
	D	67	67[c]	100	17[d]	0	0	17	0	46.0	21.0
Average		54.3	33.2	75.0	37.5	50.0	20.0	16.8	12.5	49.0	25.8
Caragana	A	17	50	0	0	17	17	0	0	8.5	16.8
	B	33[c]	33[c]	33	67	33	0	0	0	24.8	25.0
	C	33[d]	33[d]	0	33[c]	17	17	0	0	12.5	20.8
	D	50[d]	50	0	33	17	67	33[d]	0	25.0	37.5
Average		33.0	41.3	8.3	33.2	21.0	25.3	8.3	0	17.7	25.0
Sand cherry	A	60[d]	60[d]	33	67	17	17	0	0	27.5	36.0
	B	50[d]	50[c]	0	0	0	33	0	0	12.5	20.8
	C	25[c]	40[d]	17	83	0	17[c]	0	0	10.5	35.0
	D	0	50[d]	0	0	0	0	0	0	0	12.5
Average		33.7	50.0	12.5	37.5	4.3	16.8	0	0	12.6	26.1

Malus failed to root under all treatments.

a Rooting percentage based on six cuttings except where 5 or 4 cuttings were used due to shortage of materials as indicated in Table 9.

b Media were as follows: A. 100% perlite; B. 75% perlite and 25% peat; C. 50% perlite and 50% peat; D. 50% sand and 50% peat.

c Indicate cuttings rooted poorly.

d Indicate cuttings barely rooted.

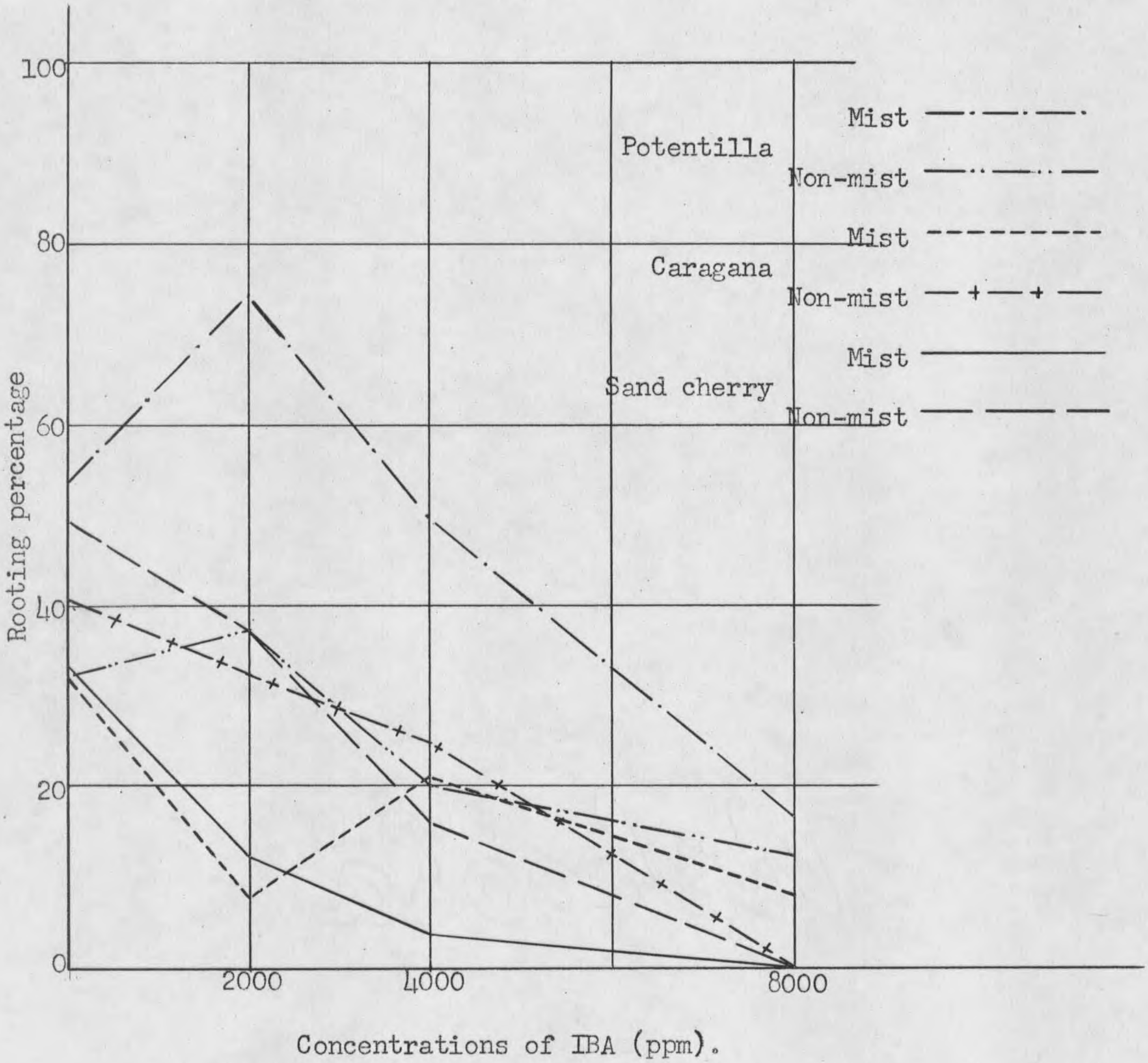

Figure 3. The effects of different concentrations of hormone treatments on the rooting of hardwood cuttings.[a]

[a] Rooting percentage based on six cuttings except where 5 or 4 cuttings were used due to shortage of materials as indicated in Table 9.

plant species were highly significant. In addition, the first order interaction between hormone treatments and plant species was significant. The first order interaction between plant species and mist treatment was highly significant as was the first order interaction between plant species and media.

Table 9 summarizes the number of cuttings rooted expressed by fraction to indicate the variation in sample size. Table 10 summarizes the rooting percentage of cuttings and indicated the plots which rooted poorly. Figure 3 graphically illustrates the rooting percentage at different concentrations of hormone treatments.

Potentilla - Both mist and suitable hormone treatments were beneficial in rooting potentilla cuttings. Intermittent mist appeared to increase rooting to a considerable extent over non-mist conditions. Every treatment under intermittent mist except the 8,000 ppm IBA exhibited a superior rooting percentage over the non-mist treatments regardless of hormone treatments. Under both intermittent mist and non-mist conditions, the cuttings treated with 2,000 ppm IBA rooted better than other concentrations of hormone treatments. The drop in rooting percentage at 4,000 ppm IBA and to a greater extent at 8,000 ppm indicates that these concentrations might have some toxic effects on the rooting of potentilla.

The cuttings rooted best in the medium containing 50% perlite and 50% peat under either intermittent mist or non-mist conditions.

Caragana and sand cherry - Caragana and sand cherry reacted similarly to all treatments. Rooting was not benefitted by either intermittent mist or hormone treatments. The cuttings under non-mist conditions rooted slightly or somewhat better than the cuttings under intermittent mist but the rooting percentages were all below 50%.

The rooting percentages of cuttings in all checks were as good as or better than those of any of the hormone treated cuttings. However, the cuttings in the checks were poorly rooted. The only treatment which compared favorably in rooting percentage with the checks was the 2,000 ppm IBA treatments under non-mist conditions. In most cases, the hormone treatments helped to develop better root systems, except for the 8,000 ppm IBA treatments which suppressed rooting.

The caragana cuttings rooted best in the medium containing 50% sand and 50% peat under both intermittent mist and non-mist conditions.

The sand cherry cuttings rooted better in 100% perlite under both intermittent mist and non-mist conditions.

Malus - Malus cuttings failed to root in all treatments.

B. Transplanting rooted cuttings

All plant species tested had nearly 100% survivals under the conditions of this experiment as indicated by the data summarized in Tables 12, 13 and 14. The exception was sand cherry which survived poorly in all cases. The results show that there were no differences between soil treatments and none among transplanting treatments under the conditions of these experiments.

Table 12. Number of rooted herbaceous cuttings surviving different transplanting and soil treatments.

Plant Species	Transplant[a] treatment	Soil[b] treatment	Number plants[c] surviving
	A	P M	12
		P M + M	12
Chrysanthemum	B	P M	12
		P M + M	12
	C	P M	12
		P M +	12
	A	P M	11
		P M + M	12
Carnation	B	P M	12
		P M + M	12
	C	P M	12
		P M + M	12
	A	P M	11
		P M + M	12
German ivy	B	P M	12
		P M + M	12
	C	P M	12
		P M + M	12

a Transplant treatments:
- A: Cuttings rooted under mist put through a hardening process after transplanting.
- B: Cuttings rooted under mist placed under non-mist conditions directly.
- C: Cuttings rooted under non-mist returned to non-mist after transplanting.

b Soil treatments:
- PM: Potting mixture consisting of 50% silt loam, 25% sand and 25% manure.
- PM + M: Potting mixture consisting of above mixture plus skim milk powder at the rate of 1/2 ounce per flat.

c Total number surviving of 12 rooted cuttings transplanted.

Table 13. Number of rooted Pfitzer juniper cuttings surviving different transplanting and soil treatments.

Plant species	Transplant[a] treatment	Soil[b] treatment	Number plants[c] surviving
Pfitzer juniper	A	PM	10
		PM + M	10
	B	PM	10
		PM + M	8

a Transplant treatments:
- A: Cuttings rooted under mist put through a hardening process after transplanting.
- B: Cuttings rooted under mist placed under non-mist conditions directly.

b Soil treatments:
- PM Potting mixture consisting of 50% silt loam, 25% sand and 25% manure.
- PM + M: Potting mixture consisting of above mixture plus skim milk powder at the rate of 1/2 ounce per flat.

c Total number surviving of 10 rooted cuttings transplanted.

Table 14. Number of rooted hardwood cuttings surviving different transplanting and soil treatments.

Plant species	Transplant treatment[a]	Soil treatment[b]	Number plants surviving[c]
Potentilla	A	PM	6
		PM + M	6
	B	PM	6
		PM + M	6
Caragana	A	PM	6
		PM + M	4
	B	PM	5
		PM + M	5
Sand cherry	A	PM	1
		PM + M	1
	B	PM	1
		PM + M	3

a Transplant treatments:
- A: Cuttings rooted under mist placed under non-mist conditions directly.
- B: Cuttings rooted under non-mist returned to non-mist after transplanting.

b Soil treatments:
- PM: Potting mixture consisting of 50% silt loam, 25% sand and 25% manure.
- PM + M: Potting mixture consisting of above mixture plus skim milk powder at the rate of 1/2 ounce per flat.

c. Total number surviving of 6 rooted cuttings transplanted.

DISCUSSION AND CONCLUSIONS

Several factors were studied for their effect on initiation of rooting of cuttings. Of these the most effective factors were hormone (IBA) and mist treatments with relatively minor benefits obtained from different media. The interaction between these factors was also important in successful rooting.

Plant hormones helped to increase the rooting percentages of carnation, juniper and potentilla, had little or no effect on German ivy and chrysanthemum and slightly depressed the rooting of sand cherry and caragana. Malus had no response to hormone treatments or other treatments in this experiment as all cuttings failed to root. The optimum concentration of hormone for initiation of rooting varied among plant species. If the concentration of hormones was too high, the hormone treatment suppressed rooting and caused other toxic symptoms such as the inhibition of buds and shoots etc. In these experiments the 4,000 ppm IBA treatment appeared to reduce the rooting of chrysanthemum and the 8,000 ppm IBA treatment suppressed potentilla, caragana and sand cherry rooting. In general, the younger and least differentiated cells, tissues, or parts of plants are the most likely to respond to plant hormones. In addition, growth hormones have not been nearly as successful with hardwood cuttings as with herbaceous cuttings. Higher concentrations of hormones are needed for hardwood cuttings. This may be due to the presence of leaves on herbaceous cuttings which produce both food and hormones which favor rooting. The absence of leaves which produce hormones also explains why hardwood cuttings can stand a higher concentration of hormone treatment than herbaceous cuttings before exhibiting toxic symptoms.

It appeared that chrysanthemum cuttings rooted best when treated with 1,000 ppm IBA and carnation cuttings rooted best when treated with 2,000 ppm IBA. However, it is probable that the optimum concentration for carnations was close to 3,000 ppm. In further experiments this concentration should be tested. German ivy rooted well with all concentrations tested. The rooting percentage of the check was also quite high. It is possible that the treatment of IBA at less than 1,000 ppm would be of value for improving root quality. The 2,000 ppm IBA treatment was beneficial in rooting potentilla. The 2,000 ppm IBA treatment improved the root quality of caragana and sand cherry although no increase in rooting percentage was observed. A lower than 2,000 ppm IBA treatment may be sufficient for rooting these plants. Pfitzer juniper cuttings treated with 8,000 ppm IBA rooted best in regard to both root number per cutting and rooting percentage. Cuttings treated with 2,000 ppm IBA had a slightly higher rooting percentage but the number of roots per cutting were slightly lower. The cuttings treated with 4,000 ppm IBA rooted at a low percentage in most media but the data from Table 8 indicates that the cuttings treated with 4,000 ppm IBA rooted 100% in the 75% perlite and 25% peat mixture. It appeared that the media and hormone interaction was quite important in rooting Pfitzer juniper. The optimum concentration for rooting Pfitzer juniper could be between 4,000 ppm and 8,000 ppm. The reason that cuttings treated with 4,000 ppm IBA rooted at a low percentage may be that the small sample size caused a large experimental error.

In most cases, hormone treatments accelerated rate of rooting and increased the percentage of rooting. The quality of root systems produced with hormone treatments is generally superior to that of untreated cuttings.

Mist propagation is being adopted as an important method for propagating herbaceous softwood and leafy cuttings. In the author's experiments intermittent mist helped to increase the rooting of carnation and also markedly benefited the rooting of juniper cuttings. Juniper cuttings under non-mist completely failed to root.

The chrysanthemum cuttings did not root as well under intermittent mist as under non-mist. This might be due to the excessive supply of water as supplied by intermittent mist which increases the spread of diseases and cause the rotting of cuttings. Chrysanthemum apparently is easy to root without intermittent mist. There was no difference between intermittent mist and non-mist treatments for rooting German ivy.

Sand cherry and caragana were not benefited by intermittent mist at all. Under non-mist conditions they rooted slightly better than under intermittent mist. It is possible that hardwood cuttings without leaves do not need to be maintained under mist. Moreover, the mist spray might cause a negative effect because it may increase the spread of fungi and other diseases. For instance some of the cuttings showed end rot under mist conditions. On the other hand potentilla rooted better under mist.

This might be because of their new shoots and leaves which grew rapidly during the rooting period. Intermittent mist probably helped to prevent the new shoots and leaves from drying out.

Although intermittent mist helped to increase the rooting percentage it was apparent that mist had no effect on root quality.

Hormone treatments accompanied by intermittent mist occasionally gave better results than either treatment alone. Although hormone treatments helped to initiate adventitious roots, the other cofactors were equally important. For example, in rooting juniper, the cuttings treated with different concentrations of hormone (IBA) failed to root unless accompanied with intermittent mist. In rooting carnation and potentilla cuttings with and without hormone treatments intermittent mist obviously helped to increase rooting percentage.

There was no significant difference among four media for rooting German ivy. Chrysanthemum cuttings rooted better in 50% perlite and 50% peat under intermittent mist and in 50% sand and 50% peat under non-mist. The carnation cuttings rooted best in 50% perlite and 50% peat under intermittent mist and in 100% perlite under non-mist. The potentilla cuttings rooted better in 50% perlite and 50% peat, caragana cuttings rooted better in 50% sand and 50% peat, sand cherry cuttings rooted better in 100% perlite, and juniper cuttings rooted better in 75% perlite and 25% peat. These results may be due to the different water holding capacities and aeration exhibited by the different media mixtures. The herbaceous cuttings were easy to root and therefore, they exhibited no preference among media.

In hardwood cuttings Hartmann suggested that the callusing period follow the hormone treatments. The initiation of adventitious roots is stimulated by hormone treatments and the callusing period allows time for the development of these root initials to the point where they are ready to emerge from the cutting at the time of planting (27).

In the author's experiments, hardwood cuttings were treated with hormones after the callusing period and before inserting into the bench. Therefore, the hormone treatments may not have been as beneficial as they might have been if Hartmann's suggestion had been followed.

Blair suggested that the malus cuttings should be taken from a parent plant still maintaining juvenile characteristics. Cuttings made from juvenile plants root quite readily whereas cuttings taken from an adult type root poorly. The author used the adult type of cuttings and this might have been one of the reasons for the complete failure of the malus cuttings (3).

According to Wells' discussion wounding is quite an important factor in propagating Pfitzer juniper. Rooting generally follows much more rapidly and vigorously after wounding than is normally the case (87). In this experiment no attention was paid to special wounding treatments. The bases of the cuttings were only cut to form an inclined surface thereby increasing the rooting area. With proper hormone treatment and intermittent mist the Pfitzer juniper cuttings gave a fairly high rooting percentage. If in addition the cuttings had been wounded even higher rooting percentages may have occurred. Further experiments should consider the wounding effect.

Experimentation indicated that there was no difficulty encountered in transplanting herbaceous cuttings without a hardening process. In transplanting caragana, potentilla and Pfitzer juniper, the results were good without hardening but sand cherry was difficult to establish and a hardening process may have helped to increase the number of surviving plants. However, in this experiment, due to the lack of rooted cuttings, the hardening process was not studied in the transplanting of hardwood cuttings.

According to Lynn and Hartmann, and Congdon, a satisfactory method for transplanting is to gradually increase the off-periods of the mist and decrease the on-periods until the rooted cuttings will survive without mist. Shade should be provided during this period to prevent sun burn (14, 47).

The results of this experiment may vary from the works of Lynn and Hartmann, and Congdon, because the rooted cuttings were carefully selected and only the best rooted ones were used for transplanting. Cuttings with good root systems are able to withstand an abrupt shift from mist without a hardening process. In addition, the herbaceous cuttings were left in the cuttings bench for 22 days so the root system was well developed. This might be why herbaceous cuttings transplanted so successfully from mist conditions directly to non-mist conditions. The commercial propagator usually transplants the cuttings as soon as they root.

In this experiment, the difference between the growing and rooting habits of various types of cuttings caused difficulties in comparing data based on limited observations. However, this was a preliminary experiment and more research needs to be done on individual plant species.

Too much was attempted in this series of experiments. Difficulties were encountered by combining all the growing factors. It was very hard to analyze and to see their interaction because the biological aspects are especially complicated.

In the experiments, the media effects were very slight. Thus, further experiments should pay more attention to the hormone and mist effects as they were more important.

In general, mist favored rooting of herbaceous and softwood cuttings, but not hardwood cuttings. In addition to causing negative effects on hardwood cuttings mist needlessly increases the cost of commercial propagation.

Plant species used in further experiments should be selected carefully. Chrysanthemum and German ivy should not be used in further experiments as they root easily under all conditions. Malus and sand cherry should be tested in further experiments. The time for doing the experiment is quite important. An all year round experiment might be needed for finding the optimum time of rooting.

The sample size of these experiments was very small and may have influenced the reliability of the results. In further experiments greater sample size and greater replication should be used.

SUMMARY

IBA at 1,000 ppm increased rooting of chrysanthemum cuttings and caused better development of root systems. Rooting was best under non-mist conditions. Under non-mist the 50% peat and 50% sand medium caused best rooting and under intermittent mist the 50% perlite and 50% peat medium caused best rooting.

Carnation cuttings produced the best rooting percentage and root quality under intermittent mist and when treated with 2,000 ppm IBA. Under both intermittent mist and non-mist conditions they rooted best in the 100% perlite medium.

German ivy rooted readily under all conditions. However, root quality was slightly improved by IBA treatments. Intermittent mist did not improve rooting nor did any of the media.

Pfitzer juniper treated with 8,000 ppm IBA and under intermittent mist produced the greatest number of roots per cutting with a fairly high rooting percentage. They rooted somewhat better in the 75% perlite and 25% peat medium.

Potentilla cuttings rooted best when treated with 2,000 ppm IBA, intermittent mist, and in the 50% perlite and 50% peat medium.

Root systems of caragana and sand cherry cuttings were improved by the 2,000 ppm IBA treatments but rooting percentages were not affected. Non-mist was better than intermittent mist for rooting. Caragana rooted best in the 50% sand and 50% peat medium and sand cherry rooted best in 100% perlite.

Malus cuttings failed to root under all conditions.

All plant species tested had nearly 100% survival under all combinations of three transplanting treatments and two soil treatments. The exception was sand cherry which survived poorly in all cases.

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