PROPAGATION OF THE PARKLAND ROSE SERIES BY LEAF-BUD CUTTINGS

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by

Lynn Marie Collicutt

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of

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LYNN MARIE COLLICUTT

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LIST OF ABBREVIATIONS

IAA - indole-3-acetic acid

IBA - indole-3-butyric acid

NAA - naphthalene acetic acid

RCBD - randomized complete block design

LIST OF DEFINITIONS

Plant Propagation: the art and science of reproducing a plant using only a fraction of the selected plant for regeneration.

Vegetative Propagation: the perpetuation of a selected plant by parts other than the sexual organs, except apomixis.

Softwood Stem Cutting: a portion of new stem growth which usually consists of more than one leaf and the associated axillary buds, and may regenerate a plant.

Leaf-Bud Cuttings: a type of softwood stem cutting which consists of a short piece of stem, one leaf and the axillary bud.

Adventitious Roots: roots derived from the tissue of any organ other than a root.

Callus: an irregular mass of parenchyma cells sometimes associated with adventitious rooting of cuttings, or wounding of plant tissues.

ABSTRACT

Collicutt, Lynn Marie, M.Sc., The University of Manitoba, October, 1981. Propagation of the Parkland Rose Series by Leaf-Bud Cuttings. Major Professor; David E. Vanstone.

Leaf-bud cuttings appeared to be a suitable method of propagation for the Parkland Roses. Cuttings taken during May, June and July rooted better than cuttings made in August. Indole-3-butyric acid (IBA) had a greater root promoting activity than did indole-3-acetic acid or naphthalene acetic acid. The number, total length, and fresh weights of roots per rooted cutting appeared to increase at higher IBA concentrations. The number and length of branch roots and also the average length per root was not affected by IBA concentration. Subsequent growth of the cuttings, as measured by plant height and fresh weight, was not affected by varying levels of IBA applied to the cuttings before rooting. Only slight differences were found between cuttings rooted in perlite, peat moss, turface, shale, sand, and all 1:1 mixtures of these. Cuttings rooted in the propagation bed, British Columbia/Canadian Forestry Service Styroblock 8 rooting containers, Hillson Spencer-Lemaire rooting containers and peat pots, then planted into frames or pots were comparable at the end of the growing season.

INTRODUCTION

Roses are important as flowering plants in the florist trade. The majority of these plants are miniature or floribunda roses. Miniature roses are less than 46 cm high with diminutive stems, foliage and blooms. Floribunda roses are usually low growing and bear large clusters of small flowers supported on short stems. 'Morden Cardinette', a cultivar of the Parkland Rose Series, is intermediate in size between the miniature and floribunda types.

The Parkland Rose Series was developed by Agriculture Canada through a breeding program which incorporated characteristics of both a native rose, Rosa arkansana Porter, and various cultivated roses (Marshall, 1974). Two important traits transferred to 'Morden Cardinette' from R. arkansana were the degree of winter hardiness, and the rootability of stem cuttings. 'Morden Cardinette' is an everblooming rose which bears cardinal red flowers comparable to those of floribunda roses in size and number (Figure 1a).

'Morden Cardinette' has unique features which render it suitable as a flowering potted plant. When purchased as a flowering potted plant it can be enjoyed indoors for several weeks and then planted outdoors into the garden where it will survive winters in Manitoba without protection. It is suitable for local production because of its winter hardiness. 'Morden Cardinette' is accepted by the florist growers because of its intermediate plant size, excellent flower quality and flower initiation on the current season's growth.

Roses are usually propagated commercially by budding or grafting onto a rootstock. However, some researchers have documented the feasibility of rose production using stem cuttings (Jensen, 1975; Marshall, 1974; Moe, 1973; Marston et al., 1969). The technique of grafting involves uniting two pieces of living plant tissue together in such a manner that they will function as one plant. Budding entails the insertion of a bud onto a rootstock such that the bud will form the top of the plant and the rootstock, the root. Propagation by cuttings is performed by removing a section of stem from a plant and inserting it into a rooting medium.

Growing roses on their own roots eliminates the problem of rootstock suckers which often grow and compete with the budded or grafted cultivar. This occurrence is especially common in cold climates as the budded or grafted cultivar is frequently weakened or partially killed by low temperatures. In addition, incompatibility problems do not arise when propagating plants by cuttings.

'Morden Cardinette' can be propagated from softwood stem cuttings as evidenced by the fact that rootability was a breeding selection criterion. Amounts of stem material available for cuttings are limited due to the dwarfness of the plant. Leaf-bud cuttings have rooted satisfactorily and appear to be suitable for propagation of 'Morden Cardinette' (Figure 1b).

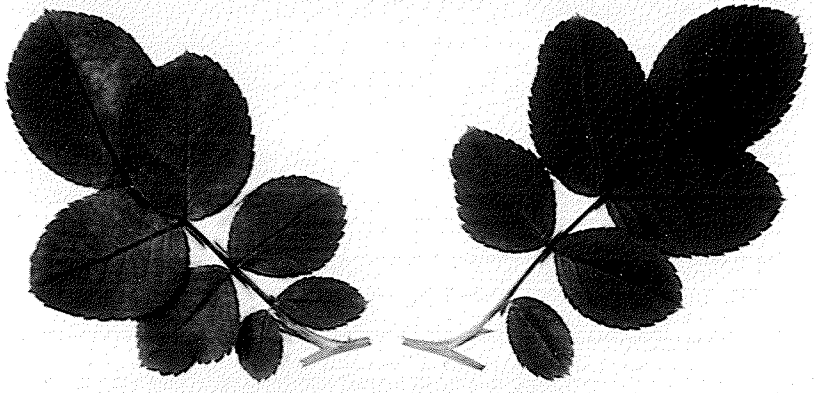
Propagation, transplanting and initial growth are the first steps in a production sequence upon which all other steps depend. The purpose of the research reported in this thesis, therefore, was to examine the effects of rooting media, types and concentrations of exogenous growth regulators, and seasonal effects on adventitious rooting, to relate

rooting to subsequent plant growth and to investigate the suitability of using containers to decrease transplant shock.

Figure 1a. Potted flowering plant of 'Morden Cardinette'.

Figure 1b. Leaf-bud cuttings used in all experiments.

Figure 1c. Root scale rating, left to right, 1-5. Right hand scale is centimeters, originating from the site of rooting.

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LITERATURE REVIEW

Anatomical and Morphological Features

The genus Rosa L. consists of woody dicotyledonous plants, some of which will form adventitious roots from stem cuttings. The adventitious roots of roses arise from the secondary phloem close to the cambium (Stangler, 1956), the parenchyma of secondary phloem either within or between vascular bundles (Carlson, 1933), or from the cambium (Orlov, 1977). Callus formation and root initiation often occur simultaneously due to their dependence upon similar internal and environmental conditions. Even though adventitious rooting may seem dependent on callus formation, the two events are independent in most cases (Hartmann and Kester, 1975).

Working with Rosa spp., Orlov (1977) noted morphological changes in the zone of root formation. Callus developed at the cut surface of easily-rooted cultivars and formed longitudinal rows of swellings 1-3 cm in length. The bark then split and young roots emerged in vertical rows. Cuttings of less readily rooted roses exhibited root emergence either as single roots or basal rows of roots. Adventitious roots emerged at right angles to the vertical axis of the stem (Mahlstede and Watson, 1952; Carlson, 1933) and were white, succulent and brittle (Brutsch et al., 1977; Cameron and Thompson, 1969). Orlov (1977) observed that when many roots emerged, the growth of each was slow. Branch roots developed when the original roots were several centimeters long (Orlov, 1977; Cameron and Thompson, 1969).

Rooting Media

Media used for propagating cuttings require several chemical and physical properties to function successfully. Important properties include good drainage, aeration and water holding capacity, neutral pH and sufficient density to hold cuttings in place (Hartmann and Kester, 1975). The proper gaseous composition of the atmosphere around the base of the cutting is important for good rooting (Evans, 1952). Matkin (1965) stated that the free porosity of the media used in mist propagation should be greater than 20%. Reisch (1967) observed that the basal portion of the stem rotted when aeration and drainage were sub-optimal. Evans (1952), working with Theobroma cacao L., noted that optimum gas composition at the base of cuttings resulted in prolific rooting in 13-15 days compared to 4-5 weeks, or no rooting, when this factor was unfavorable.

The literature does not distinguish any particular medium to yield the highest rooting percentages. The medium which optimizes root production varies with the plant species and watering practices (Evans, 1952). A major difference between cuttings rooted in different media appears to be the type of root system produced. Both Laurie and Stillings (1949), working with the rose cultivars 'Better Times' and 'Golden Rapture', and Shisa and Hazu (1957), working with R. multiflora Thunb. ex. J. Murr., noted that cuttings rooted in sand produced brittle, thick and unbranched roots. Roots of cuttings cultured in perlite were brittle, fleshy and easily fractured when cuttings were removed (Flemer, 1965). Reisch (1967) observed that fine, fibrous and well-branched root systems were produced by cuttings rooted in peat moss or peat moss mixtures.

Some of the media used for the propagation of softwood stem cuttings are soilless components such as perlite, peat moss and sand (Hartmann

and Kester, 1975). Perlite is a silicaceous mineral of volcanic origin, each particle containing numerous air bubbles (Cook and Dunsby, 1978). This medium is sterile and inert (Hartmann and Kester, 1975).

Peat moss is formed from the partially decomposed vegetation of very wet areas. Its composition varies widely depending on the origin, content and state of decomposition (Lucas et al., 1971; Patek, 1965). Peat moss has a good water-holding capacity but poor aeration and high acidity (Hartmann and Kester, 1975; Bluhm, 1978). Sand or perlite mixed with peat moss is a suitable propagating medium (Hitchcock, 1928). Hitchcock (1928) noted browning of the basal cut surface and lower one-fourth of Prunus L. spp. and Syringa vulgaris L. cuttings rooted in peat moss, presumably due to water logging or high acidity.

Quartz sand is composed of weathered quartz rock and is the heaviest of all rooting media. Sand particles range from 0.05 to 2.0 mm in diameter, contain no mineral nutrients, have no buffering capacity and are well drained (Hartmann and Kester, 1975).

Seasonal Effects

Many experimenters have observed a seasonal effect on rooting of stem cuttings (Williams and Bilderback, 1980; Smith and Chiu, 1980; Klahr and Still, 1979; Nanda et al., 1971; Osterby, 1970; Eriksen, 1968). Researchers have investigated the seasonal effects on adventitious rooting by examining the photoperiodic, endogenous starch and internal auxin changes.

Photoperiodism is the phenomenon whereby the relative length of daily light and darkness influences the development of plants and animals (Kelley, 1965). Results of experiments using various plant species have

shown rooting of stem cuttings to be better under long-day (LD) than under short-day (SD) conditions (Whalley and Cockshull, 1972; Kelley, 1965; Piringer, 1961). Waxman (1959) found high concentrations of growth promoters in plants under LD regimes and high levels of growth inhibitors in plants under SD regimes. However, LD conditions have also depressed rooting (Snyder, 1955) or had no effect on rooting (Barba and Pokorny, 1975). Baker and Link (1963) observed that the rooting response to day length was species dependent. Photoperiodic conditions under which the stockplant was grown had varying effects on rooting of cuttings (Kelley, 1965; Moshkov and Kocherzhenko, 1939).

The rooting response was correlated positively with the seasonal changes of endogenous starch and auxin levels in cuttings of Populus nigra L., Bryophyllum tubiflorum and Hibiscus rosa-sinensis L. (Nanda et al., 1971; Nanda and Anand, 1970; Bala et al., 1970). Bala et al. (1970) and Nanda and Anand (1970) postulated that auxin exerted an influence on rooting by increasing the activity of hydrolyzing enzymes, which increased the mobilization of starch available for root initiation and development. Other researchers have reported an increased breakdown of starch to sugar caused by auxins in the leaves, stems and roots (Borthwick et al., 1937; Beal and Whiting, 1945). However, Brandon (1939) found no correlation between starch content and rooting of various Rosa spp. Correlations of rooting and IAA content of Salix atrocinerea Brot. cuttings showed that root response was not controlled by an optimum hormone content (Vieitez and Pena, 1968).

Growth Regulators

It is a common practice during the propagation of cuttings to apply

exogenous growth regulators to promote rooting. Auxins have the greatest effect on adventitious root formation (Hartmann and Kester, 1975) and are used widely on a commercial scale.

The first reports of root promotive effects by auxin began in the 1930's when Went (1935) and Thimann and Went (1934) stimulated adventitious root formation on stem cuttings using plant extracts. When these extracts were tested, the active ingredient was indole-3-acetic acid. Not long after, researchers demonstrated the ability of synthetically produced indoleacetic acid (IAA), indolebutyric acid (IBA) and naphthalene acetic acid (NAA) to promote adventitious root formation (Thimann and Poutasse, 1941; Thimann, 1935; Zimmerman and Wilcoxon, 1935). Since these early accounts, numerous reports have been published citing adventitious root promotion of many species by auxins (Davies and Joiner, 1980; Myers and Still, 1979; Smith and Thorpe, 1975; Hess, 1962; Laurie and Stillings, 1949). These studies have resulted in suggested hormone types and concentrations for optimal adventitious root production by stem cuttings of specific species and cultivars. The effects of auxins on stem cuttings of Rosa spp. and cultivars have also been studied (Jensen, 1975; Eriksen, 1968; Moe, 1973; Tognoni et al., 1973; Bhujbal and Kale, 1973; Osterby, 1970; Marston et al., 1969; Laurie and Stillings, 1949; Kirkpatrick, 1940).

Tincker (1938) and Hartmann and Kester (1975) observed three main effects of applied auxins to stem cuttings, namely the acceleration of rooting, an increased number of roots developed, and a higher percentage and uniformity of rooted cuttings. An acceleration of the rooting process, resulting in a decrease of time to rooting, is very important in cases when cuttings have limited reserves. A delay of this regenerative

process absorbs a more substantial part of the energy generating substances in rootless cuttings and leads to a more unbalanced state (Orlov, 1977). Auxins will not promote root initiation if the cutting fails to root without auxin (Hartmann and Kester, 1975). Although treatment of cuttings with root promoting substances has been effective in improving propagation of plants, the ultimate size and vigor of treated plants has not always been superior to untreated plants (Kirkpatrick, 1940; Chadwick and Kiplinger, 1938).

The role of auxins in root initiation appears to be accepted as essential but the relationship to other factors required for adventitious rooting remains unclear. These other factors include carbohydrate content and the presence of root promoters and inhibitors. It appears that, although there is not a direct correlation between starch content and adventitious rooting in every case, a relationship is found often enough to indicate that this energy source is somehow involved in the rooting process (Robinson and Schwabe, 1977; Okoro and Grace, 1976; Molnar and LaCroix, 1972; Brandon, 1939; Carlson, 1933). Van Overbeek and Gregory (1945) demonstrated the presence of root promoters or cofactors. More recently, researchers have observed the presence of substances which act to promote adventitious rooting when in combination with IAA (Gorter, 1969; Hess, 1967; Hess, 1965; Kawase, 1964; Zenk and Muller, 1963).

Although many exogenous growth regulators exhibit auxin activity, only IBA and NAA are commonly used for the promotion of adventitious roots. It has been observed that IAA is quickly decomposed by sunlight, IBA is partially light stable and NAA appears to be entirely light stable. Indoleacetic acid is destroyed by the IAA oxidizing enzyme while IBA and NAA are resistant. Indolebutyric acid is perhaps the best choice as it

is non-phytotoxic over a wide range of concentrations and is effective in promoting rooting of many plant species (Hartmann and Kester, 1975). Naphthalene acetic acid is usually not as useful as IBA because it inhibits bud break and growth (Gorter, 1961).

The growth regulators which optimize adventitious rooting vary between species and cultivars (Klahr and Still, 1979; Bhujbal and Kale, 1973; Tincker, 1938). Scheiber (1973) noted that an equal percentage of rooted cuttings of Ulmus americana L. resulted from either IAA or IBA applications, but that IBA promoted a greater number of roots than did IAA. However, he found shorter root lengths and lower dry weights of roots from IBA than IAA treatments. Indolebutyric acid was more effective than NAA in promoting rooting of Platanus L. cuttings (Myers and Still, 1979). In some cases, mixtures of IBA and NAA have been more effective in promoting rooting than either hormone alone (Hitchcock and Zimmerman, 1932).

Kirkpatrick (1940) recommended that IBA was the most effective hormone for induction of adventitious roots of rose stem cuttings. Moe (1973) reported that IBA strongly stimulated the formation and growth of adventitious roots of Rosa x 'Garnette' cuttings and that when compared to IAA and NAA, the rooting response was greater. The formation of callus at the base was somewhat inhibited by the IBA treatment. Other studies have shown that the rooting of rose cuttings was better with IBA than IAA (Tognoni et al., 1973).

An optimal concentration of IBA for maximum adventitious rooting exists for each species and cultivar of roses. Moe (1979), evaluating the effect of 500, 1,000 and 2,000 ppm IBA on root promotion of Rosa x 'Garnette' cuttings, observed the greatest response at 2,000 ppm. A

1,000 to 2,000 ppm IBA treatment was recommended for rose cuttings by Kirkpatrick (1940). Bhujbal and Kale (1973) found that the percentage of rooted cuttings of R. x borboniana Desp. was maximized at 1,000 ppm of IBA. Eriksen (1968) stated that no significant increase in the percentage of rooted cuttings of Polyantha and Hybrid Tea roses occurred upon the application of IBA. The main advantage of IBA was an acceleration of rooting. He observed that 500 ppm of IBA was the optimum for acceleration of rooting without inhibitory effects on the bud growth. Jensen (1975), working with Rosa x 'Dr. Verhage', reported that IBA concentrations above 2,000 ppm had little effect on the number of cuttings which rooted, but that the number of roots per rooted cutting increased with increasing IBA concentrations. R. moschata J. Herrm. cuttings had the greatest number of main roots per cutting for the 1,500 ppm IBA treatment, whereas 1,000 ppm of IBA induced the highest number of roots for R. x borboniana cuttings (Bhujbal and Kale, 1973). Bhujbal and Kale (1973) also noted that the greatest number of secondary roots per cutting of R. moschata was with 1,500 ppm IBA.

Eriksen (1968) reported a negative correlation between the applied concentration of IBA and the percent bud break of Rosa spp. No significant differences between IBA treatments were found for the average number and total length of shoots and the percentage survival of rooted rose cuttings after potting (Bhujbal and Kale, 1973). Moe (1973) also noted that increased concentrations of IBA decreased the percentage of bud break. Bud break of other species has also been inhibited by applied growth regulators (Tincker, 1938).

Indole-3-butyric acid can be applied as a concentrated liquid dip or as a powder formulation. Rooting was less uniform when cuttings were

dipped into a powder preparation than into a liquid dip (Hartmann and Kester, 1975; Hatcher and Garner, 1951). Hermann (1968), working with Pyrus communis L. cv. Williams, observed that the percentage of rooted cuttings were equal for both powder and quick-dip IBA treatments. Cuttings from the powder treatment rooted earlier and produced more roots per rooted cutting than did those of the quick-dip treatments. Roots of the cuttings treated with powder were slender and emerged up the stem, whereas the roots from the quick-dip treatment were thick and initiated only at the base of the cutting.

Container Use

A container is any receptable filled with soil or other media, in which plants are rooted or grown (Spomer, 1980). The individual container concept allows the rooting medium to be transplanted with the rooted cuttings to the field or to another container for growing. This is accomplished while maintaing the integrity of the root system (Whitcomb, 1978; Tinus, 1976).

Although investigated in the 1930's (Strachan, 1974), the use of containers in plant production has gained general acceptance only in the last 15 years (Reese, 1974), mainly in response to problems encountered in reforestation (Tinus, 1978). The root system of a containerized plant is shaped and pruned without leaving wounds, as is the case with bare-root plants (Tinus, 1976). The container provides protection to the roots during transport and handling (Kinghorn, 1974; Tinus, 1976). In addition, the use of containers allow for the standardization of production timing, rooting medium, spacing irrigation, nutrition and, if a greenhouse is used, temperature, humidity, photoperiod, light intensity and carbon dioxide (Tinus, 1976; 1975).

The major biological advantage of containers is the reduction of 'transplant shock' (Lavender and Cleary, 1974). Transplant shock is the delay of growth resulting from transplanting, specifically from direct injury to the roots (Spomer, 1980). Cuttings transplanted from containers maintained the integrity of the root system which resulted in higher survival rates, faster establishment and better growth than bare-root plants (Whitcomb, 1978; Lavender and Cleary, 1974; Shreve, 1974; Tinus, 1974). Other researchers have not observed superior plants resulting from container compared to bare-root treatments (Buchanan, 1974; Johnson, 1974).

There are several disadvantages associated with using containers for cutting propagation. Day and Skoupy (1971) observed a rapid outward movement of water from the container soil to the surrounding soil within a few days of transplanting. They stated that the container was a poor support package. Spomer (1980) also noted a lack of water retention by the transplanted container plug. Other disadvantages include higher money, labor and technological requirements for containerized than bare-root plants (Stein, 1974).

There are many kinds of containers, all of which may be broadly classified into two basic types. There are those, such as peat pots which are retained at planting, and others which are removed, leaving only a soil plug.

The removable containers are typified by the British Columbia/ Canadian Forestry Service (BC/CFS) Styroblocks and the Spencer-Lemaire Rootrainers. These containers define the shape of the root and protect the root, but they necessitate the removal of root plugs at planting (Kinghorn, 1970). Roots are channelled to a central bottom hole by means of vertical ribs in the container. Emerging roots are air pruned by

supporting the units clear of the ground, and growth of lateral roots is promoted. These vertical ribs also direct root growth downward and avoid the spiralling of roots. The underlying principle of the container plug system requires that plants be grown in the containers long enough for the roots to develop a firm, but unbound, root plug to permit efficient removal and outplanting with the rooting medium held intact (Van Erden, 1974).

The basic unit of the Spencer-Lemaire Rootrainer, another removable container, is a folding book planter. It is a vacuum formed plastic sheet containing both halves of the container. When folded, rectangular cavities are formed which have holes in the bottom. The folding sheets fit into trays with open bottoms to accommodate air pruning of the roots. Various sizes of cavities ranging from 16 cc to 290 cc are used, depending on the crop species and management sequence (Ferdinand et al., 1974).

The BC/CFS Styroblock was developed by the Pacific Forest Research Center of the Canadian Forestry Service and introduced in 1970 (Sjoberg, 1974; Kinghorn, 1970). The Styroblock containers are a rigid styrofoam block containing cavities available in sizes from 16 cc to 130 cc. These cavities are tapered and the ribbed sides train roots downwards to a bottom hole (Sjoberg, 1974).

MATERIALS AND METHODS

General Procedures

IBA Preparations and Application

Liquid IBA solutions were prepared by dissolving reagent grade IBA in ethanol then diluting with distilled water to 50% ethanol. Liquid solutions of IBA were applied as a quick dip (Hartmann and Kester, 1975) to the basal 3-5 mm of each cutting during experiments performed in 1979.

Powdered IBA formulations used in 1980, were prepared by adding talc to reagent grade IBA. The strongest concentration was prepared first, then diluted to the desired concentration by the addition of talc. The desired concentrations were prepared at the beginning of the season and stored in opaque bottles in the refrigerator. Fresh samples were drawn from these bottles at each date as needed. The cuttings were dipped into distilled water then into the appropriate IBA concentration and were tapped to remove excess powder. Most of the powder remained on the base and lowest 1 mm of stem, although some powder adhered up to 3 mm.

Stock Plants

The stock plants were grown in the greenhouse in a shale:peat:soil medium (4:2:1 volume) contained in clay pots, and watered as needed. The plants were fertilized in 1979 as described later, and in 1980 as 1 tablespoon (7-9 gms) of commercially formulated 20-20-20 per gallon of water (4.5 liters) watered on twice weekly. No artificial light or heat was applied throughout the growing season. The stock plants were sprayed

for pests as required and disbudded every 2-3 weeks. Cuttings were made from one-year old stock plants in 1979 for Experiments 1, 2, 3 and 4. Two-year old stock plants were used in 1980 as a source of cuttings for Experiments 3, 5, 6 and 7.

Preparation of Cuttings

Cuttings were taken approximately 1 week after disbudding. A firm stem and swollen bud were desired but this combination was not always possible. Very immature cuttings wilted easily so the woodiness of the stem took priority over bud maturity as to when the cuttings were made. Terminal cuttings were discarded as the axillary buds were usually floral. Cuttings, consisting of a stem section 1 cm above and below the node, the leaf and associated axillary bud, were taken from the youngest two to four nodes of the stem. Cuttings from each node were separated into statistical blocks and also, when possible, cuttings were blocked based on bud maturity and leaf size. Cuts were made at right angles to the stem using secateurs. Cuttings of the selection J1 and the cultivar 'Morden Cardinette' averaged three to five leaflets per leaf. The cultivar 'Cuthbert Grant' had seven, and occasionally three leaflets per leaf and were frequently larger than the other two roses. After the cuttings were taken, root hormone was applied to the base and the cuttings were inserted to a depth of 2 cm into preformed holes in the rooting medium. The cuttings were lightly watered after their insertion and then placed in the propagation house. To avoid water loss, the cuttings were taken in small bunches and hand misted as needed, prior to their placement in the propagation house.

No artificial heat or light was used throughout the experiments, except for some heat in the greenhouse at the beginning and end of the

growing season.

Rooting Environment

All cuttings were rooted under intermittent mist in a quonset-style greenhouse covered with 6 mil polyethylene. Ventilation throughout the house was achieved by a fan which drew air through a ventilating tube connected to an intake vent. The propagation beds, oriented east and west, were misted using Flora-Mist fogger nozzles (Reed F., Kofford Co., Walnut Creek) set 80 cm above the beds and spaced 120 cm apart.

A carbon electrode sensor (Aquamonitor, New York) which timed mist applications according to the environmental conditions, was utilized in 1979. It was replaced in 1980 by a conventional time clock system. The duration of each misting was 10 to 15 seconds; the interval between misting was manually adjusted to 7½, 10, 15, 20 or 30 minutes, depending on prevailing weather conditions. Mist was not applied at night, except during hot periods when one application of mist was made during the night.

Fertilization and Pest Control

The cuttings were fertilized beginning 2 weeks after their insertion. Cuttings and plants were fertilized weekly using 1 tablespoon (7-9 gms) of a commercial formulation of 20-20-20 per gallon of water (4.5 liters). Approximately 200 ml were applied per plant. In 1980, 1/2 tablespoon of fertilizer was used twice weekly. Benlate was applied as a 100 ppm solution watered on or as a 200 ppm solution sprayed on weekly to prevent fungal diseases.

Pesticides were applied as required: aldicarb (Temik), dienoclor (Pentac) and dicofol (Kelthane) were used to control spider mites; aldicarb (Temik), malathion and endosulfan (Thiodan) were used to control aphids;

dinocarp (Karathane) and morestan were used to control powdery mildew; benomyl (Benlate) and captan were used to control blackspot.

1979 Root Scale

A root scale ranging from 1 to 5 was developed in 1979 to evaluate root production of cuttings. Pictures were taken as a visual guide (Figure 1c).

Root Scale:

1 - no roots

2 - a few short roots

3 - 3 main roots with branches

or 2 main roots but well branched

or greater than 3 roots but not branched

4 - 4-5 main roots with branches

or 3 main roots but well branched

5 - greater than 5 main roots with branches

Fresh and Dry Weight Procedures

Flower buds and stalks and the original leaf of the cuttings were removed. Dust adhering to the leaves was wiped off before weighing. The soil was gently knocked off the root mass then the roots were washed free of soil. Roots were severed from the top either at the point of callus development (1979) or at the node of the stem (1980). When fresh weights were recorded replicates were weighed during the same time of day to remove variability due to differential water uptake. The roots were dried for 12-16 hours and the tops for 42 hours at 85^{o}C then

weighed to determine dry weights.

Media, Root Scale and Container Experiments

Experiment 1: The Effect of Rooting Media

Cuttings of 'Morden Cardinette' were prepared August 3, 1979 by dipping them into a 2,500 ppm IBA liquid solution and then inserting them into the following media: perlite, peat moss, turface, sand, shale and all 1:1 (volume) mixtures of these media. Shale obtained from a local source was screened to a particle size of 1.7 to 1.8 mm, which was the approximate size of the turface particles. The sharp sand was screened to a particle size of 3 mm. The peat moss was shredded by hand and large pieces were discarded. The media were placed into 15 cm plastic pots. Seven cuttings per pot per medium were replicated four times. The pots were set under intermittent mist in a RCBD and were moved once during the rooting period to minimize any gradient effects.

Rooting was evaluated after 3½ weeks using the previously defined root scale. General observations were noted on the types of root systems produced and the ease of handling the various media. Overall rooting-values were calculated as described by Klahr and Still (1979).

All media were analyzed by the Manitoba Provincial Soil Testing Laboratory for particle density, bulk density, total porosity, water at saturation (percent weight and volume basis), water at field capacity (percent weight and volume basis) and porosity at field capacity. These values were compared to root scale ratings to determine if relationships existed between these properties and adventitious root production.

Experiment 2: The Relation of Root Scale Rating to Plant Growth

Cuttings, from the media experiment, which had rooted to a value of 2 or more on the root scale were potted into 12.5 cm plastic pots using a shale:peat moss:soil medium (4:2:1 volume). Five plants of each treatment, replicated five times in a RCBD were placed in the greenhouse on August 28, 1979. Dry weights of tops and roots were recorded 5 weeks later.

Experiment 3: Container Study

1979. Cuttings of 'Morden Cardinette', 'Cuthbert Grant' and the selection J1 were taken on June 7 (date 1), July 4 (date 2) and August 31 (date 3). Cuttings on the first two dates were dipped into a 2,500 ppm IBA solution. All cuttings were then inserted in the rooting medium (perlite:sand, 1:1 volume) and rooted either directly in the propagation bed, or in BC/CFS Styroblock 20 containers (Beaver Plastics Ltd., Edmonton) or in Hillson Rootrainers (Spencer-Lemaire Industries, Edmonton). All cuttings were rooted under intermittent mist and randomized as a split-plot design at each date, with the containers as main-plot and the cultivars as sub-plot. Four replicates ere used requiring 32 cuttings per treatments.

Cuttings from date 1 and date 3 were evaluated for adventitious rooting after 4 weeks using the root scale. Cuttings taken at date 2 were tested for survival and growth in the greenhouse, after potting into 12.5 cm plastic pots using a shale:peat moss:soil medium (4:2:1 volume). Cuttings rooted in the propagation bed were potted once they had rooted to a root scale rating of 3. Once rooted, approximately 3 weeks

after insertion, cuttings in the BC/CFS Styroblock 20 containers and the Hillson Rootrainers were taken to the greenhouse for a hardening-off period of 1 week and then planted. Height and leaflet number were recorded approximately once per week. Dry weights of tops and roots were recorded 10½ weeks after potting according to the procedure previously described.

1980. Cuttings of 'Morden Cardinette' were taken May 3, dipped into a 2,500 ppm IBA-talc powder and rooted. Cuttings were randomized in blocks to remove the effects of nodal position and bud maturity. The containers evaluated were: 20.5 cm pots representing the propagation bed, 8 cm peat pots, BC/CFS Styroblock 8 and Styroblock 20 containers, and Tinus and Hillson Rootrainers. Each container held five cuttings to be transplanted to the frame and five cuttings to be potted. A peat moss: perlite medium (1:1 volume) was used in all containers for rooting, and for both rooting and growing cuttings in the Styroblock 20 and Tinus containers.

All cuttings were transplanted 9 weeks after their insertion, except for cuttings rooted in the Tinus and Styroblock 20 containers. Cuttings were left to grow throughout the season in the Tinus and Styroblock 20 containers on account of the relatively large size of these containers. These two treatments were included to demonstrate the feasibility of using these containers for propagation and growth of plants and thus offer an alternate production scheme. Another treatment was added in which the cuttings were transplanted from the propagation bed to 8 cm peat pots 3 weeks after insertion grown and then planted in the frames.

The rooted cuttings were transplanted into 15 cm plastic pots using a sand:soil:perlite medium (1:1:1 volume) and also into outdoor frames.

Due to a low percentage of rooting, the Hillson container, propagation bed and Styroblock 8 treatments in block 1, the Styroblock 8 treatment in block 4 and the Hillson container and peat pot treatments in block 5 were eliminated. Plots within the frame and pot treatments were randomly distributed. The Styroblock 20 and Tinus containers were located within the blocks of potted plants but were placed at the edge of each block. All containers were set on black polyethylene to avoid roots growing into the ground.

The cuttings were fertilized by weekly waterings with a solution of 20-20-20 fertilizer, prepared as previously described, beginning 2 weeks after insertion until the cuttings were planted in the frame or potted. Analysis of the soil in the frame by the Manitoba Provincial Soil Testing Laboratory showed adequate fertility levels so no fertilizer was added. Plants in the pots, Styroblock 20 and Tinus received 530 mg of 20-20-20 applied as a 5 ml aliquot per plant once a week for the first 2 weeks after potting, 312 mg of 34-0-0 as a 5 ml aliquot for the next 5 weeks and the 20-20-20 application for the last 3 weeks. These fertilizer applications were made on the basis of soil and tissue analysis which were taken after rooting and at mid-season. Analyses were also performed at the end of the experiment. Fully expanded new leaves were picked and carefully wiped off for the tissue analysis. Leaves of several plants in each treatment were used to give a representative picture of fertility levels.

Temperatures of the medium in pots, the frame, and Styroblock 20 and Tinus containers were recorded twice weekly to show any differences between the containers.

Heights were measured mid-season and at the end of the experiment

(19 weeks after insertion of the cutting). Fresh weight of the tops and roots were also taken.

Rooting Hormone Study

Experiment 4: Preliminary Study

Cuttings of 'Morden Cardinette' were taken July 26, 1979 and treated with 2.5 ppm or 2,500 ppm IBA. Six cuttings per treatment were replicated four times in a RCBD. The cuttings were inserted in a perlite:sharp sand medium (1:1 volume), then set under intermittent mist. Two and one-half weeks later the cuttings were removed from the rooting medium, root scale ratings were taken, and the number and length of roots were measured for each rooted cutting.

Root Hormone Type

Cuttings of 'Morden Cardinette', taken July 23 and August 26, 1980 were dipped into 0, 1,000, 7,000 or 20,000 ppm IAA, NAA or IBA powder formulations. The cuttings were inserted into 10 cm plastic pots containing a peat:perlite medium (1:1 volume). Each pot contained four cuttings and represented one treatment. The four replicates of each treatment were placed under intermittent mist in a RCBD. Lengths and numbers of roots and branches, and root fresh weight and dry weight were measured 4 weeks later.

Experiment 6: Comparison of IBA Preparations and Commercial Formulations

Cuttings of 'Morden Cardinette' were taken June 28 and August 26, 1980 and dipped into the commercial IBA formulation of Stim Root 1, 2, 3 (1,000; 4,000; 8,000 ppm IBA respectively, Plant Products Co. Ltd., Bramalea) and Seradix 1 (1,000 ppm IBA, May and Baker Ltd., Dagenham).

The corresponding concentrations of IBA at 1,000, 4,000 and 8,000 ppm IBA, prepared as previously described, were applied for comparative purposes. Cuttings were inserted, four to a pot, in pots containing a peat moss:perlite medium (1:1 volume) and positioned under intermittent mist in a RCBD. Roots and branches were counted and measured after 4 weeks and dry weights of roots were recorded.

Experiment 7: The Effects of IBA Concentration on Rooting and Plant Growth

Rooting and Growth Measurements. The effects of IBA concentration on adventitious rooting and also on subsequent plant growth were treated as separate experiments, but the methodology and timing of rooting the cuttings were identical. One cultivar, 'Morden Cardinette' and one selection, J1, were chosen. A RCBD was used at each of the four dates. Four cuttings were used per treatment and replicated six times.

Cuttings were taken May 13 (date 1), June 7 (date 2), July 17 (date 3), and August 19 (date 4, 'Morden Cardinette' only), 1980. Concentrations of IBA tested were: 0, 1,000, 2,000, 2,500, 3,000, 7,000 and 10,000 ppm. Treatments applied to cuttings of 'Morden Cardinette' are summarized in Table 1. Dates 1 to 4 corresponded to 4, 5, 6 and 7 months, respectively, after growth of the stockplants began in February.

The cuttings were prepared as previously described then inserted into a peat moss:perlite medium (1:1 volume), which was contained in 15 cm plastic pots, and rooted under intermittent mist as described earlier.

No supplementary heat or artificial light was used during the rooting of cuttings. Light intensity, photoperiod, and air and medium temperatures were measured and monthly averages calculated. Indirect lighting from adjacent greenhouse benches extended the photoperiod for

Table 1. Treatments applied to cuttings of 'Morden Cardinette' in experiment 7.

Treatment	Date 1 May 13		Date 2 June 17		Date 3 July 17		Date 4 August 19	
	Roots	Plants	Roots	Plants	Roots	Plants	Roots	Plants
Water	NA°	NA	A	A	A	NA	A	A
Captan	NA	NA	NA	NA	A	NA	A	A
0*	A	A	A	A	A	A	A	A
1,000	A	A	A	A	A	A	A	A
2,000	A	A	A	A	A	A	A	A
2,500	A	A	A	A	A	A	NA	NA
3,000	A	A	A	A	A	A	A	A
Captan + 3,000	NA	NA	NA	NA	A	NA	NA	NA
7,000	A	A	A	A	A	A	A	A
10,000	A	A	A	A	A	A	A	A
15,000	NA	NA	NA	NA	NA	NA	A	A

*All concentrations are ppm IBA. 0 ppm was talc.
°NA = treatment not applied; A = treatment applied.

greenhouse grown plants at date 4. Supplemental heat in the greenhouse was applied when temperatures warranted. Light intensity was measured at plant height both inside the quonset house and outside with a LI-COR Quantum sensor (Lamda Instruments Corp., Lincoln). Temperatures were measured with a Y51 Model 42 SL Tele-thermometer (Yellow Springs Instrument Co., Yellow Springs).

Cuttings which were analyzed for root development were removed from the rooting medium 3 weeks after insertion, carefully washed and

blotted dry, then measured and weighed. Number and length of roots and branches, fresh and dry weight (dry weight - only dates 1 and 2) and callus scale were measured for surviving cuttings. Root fresh weight included only roots and branches. It was not determined if roots arose from the callus or stem and roots were cut off at the point of emergence. It was reasoned that if the fresh weight included the stem or callus an inaccurate conclusion could be drawn, as some cuttings produced large amounts of callus but few roots, while others yielded little callus but many roots. Branches, at least 5 mm in length, and all roots were counted and measured. Some cases arose where two roots appeared fused; these were counted as one root and their occurrence noted. The callus was rated visually on a 1-5 scale:

1 - no to little callus

2 - callus present but not completely around stem

3 - callus completely around stem

4 - callus completely around stem and also produced in internode

5 - very prolific callus, often splitting the epidermis of the internode and completely covering the stem base

Cuttings which were analyzed for subsequent top growth were potted 24 days after insertion. A mid-season and final height was measured, and plant survival and bud break noted. Eleven weeks after the cuttings were inserted, fresh and dry weights were recorded (dry weights - only date 1 and date 2).

Morphological Features

Cuttings of 'Morden Cardinette' were taken and their bases dipped into 0, 2,000, 7,000 and 10,000 ppm IBA talc. The cuttings were inserted in a peat moss:perlite medium (1:1 volume) contained in 10 cm plastic pots.

The pots and cuttings were placed in the quonset-propagating house under intermittent mist. Four cuttings of each hormone level were removed 0, 2, 5, 7, 9, 12, 16 and 21 days after insertion and external root morphology noted.

RESULTS AND DISCUSSION

Media, Root Scale and Container Experiments

Experiment 1: The Effect of Rooting Media

The root production of 'Morden Cardinette' cuttings, as measured by rooting-values, did not differ greatly between the media tested with the exception of perlite, which did not appear to be a suitable medium. As perlite is used for cutting propagation (Hartmann and Kester, 1975), further trials should be performed to distinguish whether perlite is not satisfactory for rooting cuttings of 'Morden Cardinette', or if these results just did not reflect the normal rooting response (Table 2). Any variations which did occur were difficult to interpret and probably not of great significance because the Duncan's multiple range test showed many overlapping groups. These findings agreed with some of the results in the literature. Reisch (1967) stated that much of the literature indicated few differences existing between rooting media. When sand, peat moss and other media were tested, using seven plant species, no effects of rooting media on rooting were noted (O'Rourke and Dedolph, 1965). However, other reports exist in which optimal media were cited for specific species (Carra, 1956; Evans, 1952). Roses are not usually propagated by cuttings, therefore few references exist which include recommendations for the best medium in which to root rose cuttings.

The major differences observed were the various types of roots produced in each medium. Cuttings rooted in peat moss produced very fine, well-branched root systems. Long (1932), working with 42 different plant

Table 2. Rooting-values and root scale ratings of 'Morden Cardinette' leaf-bud cuttings rooted in 15 media.

Rooting medium	Rooting-value per 7 cuttings[z]	Mean root scale rating per cutting[y]
Perlite:Peat	28.5 a[x]	4.1 a
Sand:Peat	27.5 a	3.9 ab
Shale	27.0 ab	3.8 abc
Sand:Turface	26.2 abc	3.5 abc
Sand:Shale	26.0 abcd	3.7 abc
Turface:Peat	25.8 abcd	3.7 abc
Shale:Perlite	25.8 abcd	3.7 abc
Sand	25.5 abcd	3.5 abc
Shale:Peat	24.8 abcd	3.4 bc
Turface:Perlite	24.8 abcd	3.5 abc
Turface:Shale	24.5 abcd	3.6 abc
Peat moss	22.8 bcd	3.2 c
Sand:Perlite	22.3 cd	3.2 c
Turface	21.8 d	3.2 c
Perlite	16.3 e	2.5 d

[z]Values are means of 4 replicates. Rooting values: 0 - low, 35 - high.

[y]Values are means of 28 cuttings. Root scale: 0 - low, 5 - high.

[x]Values within columns followed by the same letter do not differ significantly by Duncan's multiple range test, 5% level.

types and Chadwick (1949), using evergreen species, also noted this occurrence. Roots were fleshy, brittle and unbranched when cuttings were rooted in perlite or sand, in accordance with observations of Shiza and Hazu (1957), and Laurie and Stillings (1949). The root systems of cuttings rooted in turface resembled those which had been rooted in sand or perlite, probably because of the similar texture and particle size of the media. Mixtures of the media yielded cuttings with root systems intermediate to those already described.

Rooting-values and root scale ratings were plotted against particle density, bulk density, percent total porosity, percent porosity at field capacity; water at saturation (percent weight and volume basis), and water at field capacity (percent weight and volume basis). No relationships appeared to exist between rooting and any property measured, so correlations were not calculated. Physical properties of the media are presented in Table 9.

Single degree of freedom contrasts were used to compare the five media unmixed to their 1:1 mixtures (Table 3). There were no differences between sand and the sand mixtures, or between shale and the mixtures of shale. Cuttings rooted in turface, perlite or peat moss produced fewer roots than cuttings rooted in the mixtures of each. This may have been due to the perlite and turface drying out near the surface and the water-holding capacities increasing with additions of peat moss and sand. Hare (1975) noted that the bases of woody cuttings sometimes dried out when rooted in perlite, even under intermittent mist. Peat moss alone may have been too water logged to provide good aeration for rooting cuttings of 'Morden Cardinette' as mixtures with turface, perlite or sand tended to increase rooting. Dickey *et al*. (1978) stated that peat moss used alone

did not provide good aeration. Some rotting of the roots appeared to have occurred in peat moss, and the addition of perlite, sand or turface may have alleviated this problem by decreasing the water retention of the medium. Moe (1975) and Dickey et al. (1978) found that sand or perlite mixed with the peat moss resulted in a suitable propagation medium.

It was assumed then, that the rooting of cuttings of 'Morden Cardinette' was essentially similar in all the media tested with the exception of perlite. Therefore, relative weights and ease of handling were also considered when choosing an optimal medium (Table 10). Sand, turface, shale, sand:turface, sand:shale, and turface:shale were heavy media and were consequently difficult to carry if held in containers. Shale and shale mixtures became sticky in consistency as the small particles were wetted. Also, the shale was obtained locally and, therefore could not be recommended as a standard medium to use. Turface was difficult to obtain in 1980 and was not recommended on this basis, although turface:peat moss and turface:perlite appeared to be acceptable rooting media. The mixtures of sand:perlite, sand:peat moss, and perlite:peat moss were apparently the best choices for rooting media. It must be noted, however, that sand could be used if propagation benches were utilized so that the sand need not be carried. It was difficult, however, to remove the cuttings due to compaction of the sand. Cuttings of 'Morden Cardinette' rooted slightly better in perlite:peat moss and sand: peat moss than in sand:perlite. Of the remaining two media, the perlite: peat moss mixture was easier to handle and lighter in weight than the sand:peat moss mixture. Also, many researchers have used this rooting medium with good results (Moe, 1973; Gray, 1967; Robinson, 1967; Hocking and Thomas, 1979). However, in 1980, it became apparent that the

Table 3. Comparison of 5 rooting media: unmixed and in all 1:1 mixtures of each medium.

Medium	Rooting-values per 7 cuttings	
	Unmixed[z]	Mixtures[y]
Sand	25.5 a[x]	25.5 a
Shale	27.0 a	25.2 a
Turface	21.8 b	23.8 a
Peat moss	22.8 b	26.6 a
Perlite	16.2 b	25.3 a

[z]Values represent means of 4 replicates.
[y]Values represent means of 16 values.
[x]Values within rows followed by the same letters do not differ, 5% level.

pH value of the perlite:peat moss medium was usually 4.7 even under intermittent mist and, although not a problem in this experiment, the acidity of the medium could affect rooting in some cases. Under some conditions, the perlite:peat moss medium did not appear to drain well enough and water-logging occurred. After the cuttings were fertilized, algae tended to grow on the peat moss to a greater extent than other media.

It appeared then that the type of rooting media did not greatly affect rooting of 'Morden Cardinette' cuttings except to influence the type of root system which developed.

Experiment 2: The Relation of Root Scale Rating to Plant Growth

In 1979, adventitious root production of the cuttings was evaluated on the basis of a root scale rating. It was questioned whether the root system of the cutting was related to growth of the resultant plant, as

ultimately the plant was the object of propagation and the important factor in the plant production. If there was no effect of the root system development of the cutting on the subsequent plant, then the validity of studying methods to increase rooting could be queried.

One week after potting, cuttings with higher initial root scale ratings appeared to have greater numbers of bud breaking and increased height per cutting than did cuttings with lower initial root scale ratings (Table 4). These results indirectly complied with those of Jensen (1975). He found that increasing concentrations of IBA resulted in a greater number of buds breaking and felt that this was due to the IBA increasing the number of roots. He suggested that possibly there was a greater ability to provide water and nutrients to the bud if more roots were present. All cuttings of 'Morden Cardinette' were treated with identical concentrations of IBA at a level which was later determined not to have any effect on the time of bud break, therefore increased initial growth appeared to be due to a more extensive root system.

It appeared that a well-developed root system provided only an initial advantage to plant growth and that this advantage decreased as the plant grew. There were no differences between the initial root scale ratings when the number of plants surviving after 5 weeks was determined (Table 4). Significant positive linear trends existed between plant dry weights and root scale ratings, indicating that dry weights of roots, shoots, and total plants tended to increase at higher root scale ratings (Figure 2; Table 4). However, large differences occurred only between root scales 2, 3, 4 compared to scale 5, indicating that only relatively large root systems produced substantially greater top growth. It should be pointed out that the media source was not noted, therefore it was

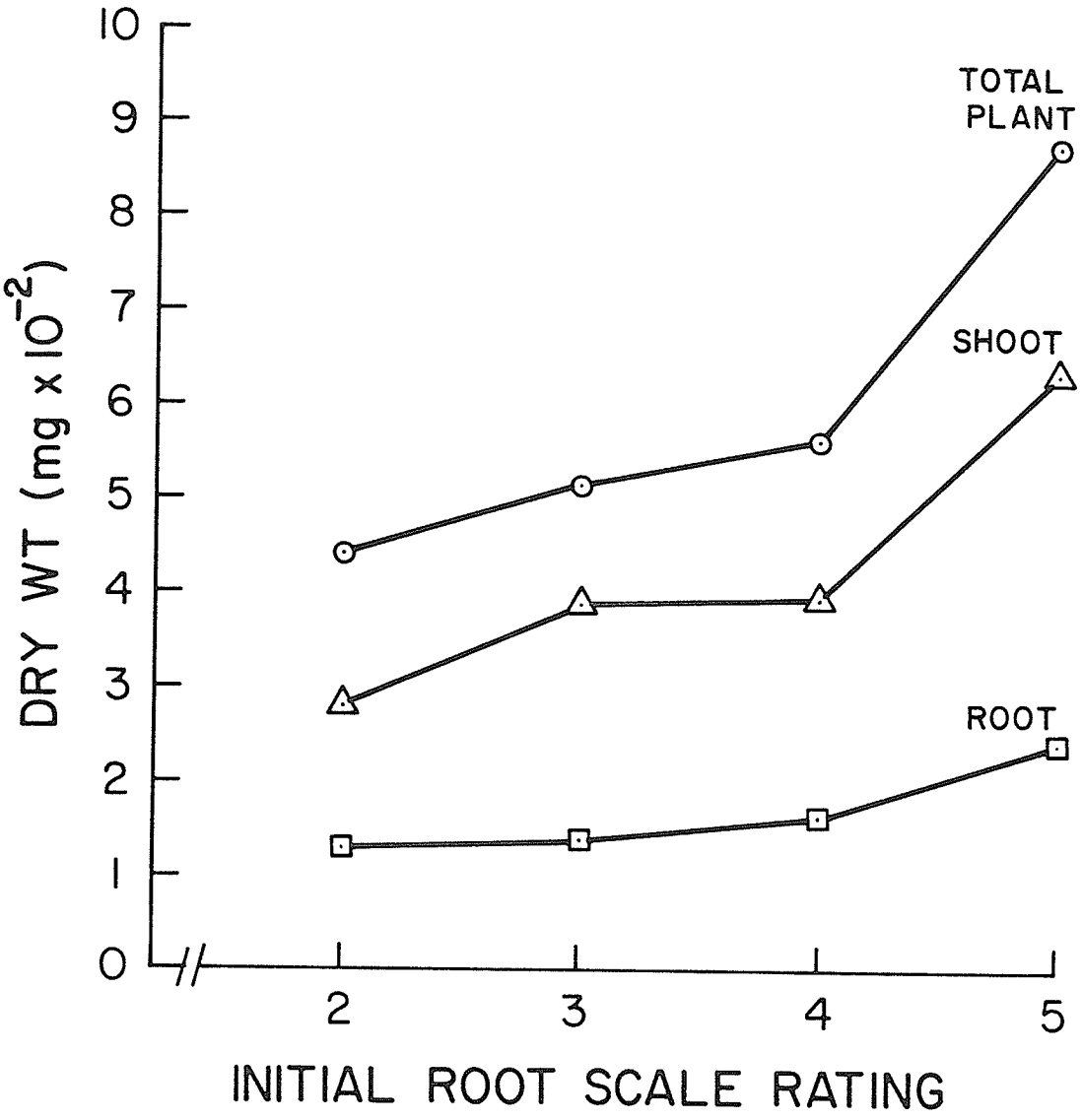


Figure 2. The relation of initial root scale rating to root, shoot and total plant dry weights 5 weeks after potting.

impossible to know if the rooting media influenced dry weight accumulation in the roots. For example, cuttings rooted in perlite were short and unbranched. This type of root system would have been rated scale 2

Table 4. Growth measurements of 'Morden Cardinette' cuttings relative to initial root scale ratings.[z]

Root scale	Growth parameters[y]					
	1 week		5 weeks			
	Mean ht (mm)	No. growing of 20 cuttings	No. surviving of 20 cuttings	Mean dry wt (mg)		
				Top	Root	Plant
2	15.6 a	7	17	271 a[w]	134 a	405 a
3	35.8 b	13	19	388 a	136 a	524 a
4	41.9 bc	17	19	398 a	167 a	565 a
5	44.2 c	20	20	631 b	245 b	876 b
Linear	**[x]	-	-	**	**	**
Quadratic	NS	-	-	NS	*	NS

[z]Values are means of number of cuttings growing or surviving.

[y]Measurements were taken 1 and 5 weeks after potting.

[x]Non-significant (NS), significant at 5% (*), 1% (**) level.

[w]Means within columns followed by the same letter do not differ significantly by Duncan's multiple range test, 5% level.

but because of its thickness, may have had a high dry matter weight. Roots of cuttings rooted in peat moss or shale were well branched and quite long, but were of small diameters so may have had lower dry weights. However, the roots had developed 5 weeks before dry weights were recorded so the differences may have been eliminated. Also, later results tended to support the findings of this experiment so it was doubtful whether the original rooting media had any large effects on subsequent growth of the cutting (Tables 21 and 22). The results of this experiment were only preliminary and therefore conclusions were limited. However, because there was a possibility that the initial root system did not greatly affect the resulting plant growth, this hypothesis was studied further

in experiment 7.

Experiment 3: Container Study

Consequences of using containers in the propagation of some Parkland roses were studied in 1979 and 1980. Experiments in 1979 were performed to ascertain any effects on rooting and subsequent plant growth in the greenhouse. A study in 1980 was carried out to evaluate if plant growth was enhanced when cuttings were rooted in containers then transplanted outdoors into frames or pots.

Results obtained in 1979 (Tables 5, 11, 12, 13, 14; Figure 3) did not show any marked advantage in the use of containers to increase rooting, survival, or growth of 'Morden Cardinette' cuttings and were concurrent with the findings of Buchanan (1974) and Johnson (1974). As seen in Table 5, rooting was greater in experiment 2, than experiment 1, probably due to the hormone rates used: 2.5 ppm IBA was applied in experiment 1, whereas a 2,500 ppm concentration was used in experiment 2. The application of IBA in experiment 7 resulted in increased rooting, thus supporting this reasoning (Table 19). Rooting of cuttings in the propagation bed and Styroblock containers appeared better than the Hillson containers in experiment 1 but no differences occurred in experiment 2. The results for experiment 2 were probably more indicative of the normal situation because the differences in experiment 1 were not great and there did not appear to be large observable differences when the rooting was evaluated. It was impossible to compare these results to other reports in the literature as there were no studies specifically designed to investigate rooting in containers.

Rootability and growth of the three clones differed. Cuttings of J1 had the poorest rooting at both dates, cuttings of 'Morden Cardinette'

and 'Cuthbert Grant' rooted equally well in experiment 1, and cuttings of 'Cuthbert Grant' rooted better than cuttings of 'Morden Cardinette' in experiment 2 (Table 5). Differences in rooting between cultivars of roses have been noted previously (Orlov, 1977; Brandon, 1939). Overall, it appeared that plants of J1 were less vigorous than plants of 'Morden Cardinette' or 'Cuthbert Grant'. This may have been a contributing factor

Table 5. Root scale ratings for cuttings of rose clones rooted in different containers in 2 experiments.[z]

Rooting container and rose clone	Root scale rating per cutting[y]	
	Exp. 1	Exp. 2
Rooting container (means of all rose clones)		
Propagation bed	2.5 a[x]	3.4 a
Styroblock	2.1 b	3.3 a
Hillson	1.7 c	3.1 a
Rose clone (means of all rooting containers)		
Cuthbert Grant	2.4 a	4.1 a
Morden Cardinette	2.4 a	3.4 b
J1	1.6 b	2.3 c

Interactions between container and clone were not significant, 5% level.

[z]Values are means of 90-96 cuttings rooted for 4 weeks.
[y]Rating: 1 - few roots; 5 - many roots.
[x]Values within containers and clones of each experiment followed by the same letter do not differ by Duncan's multiple range test, 5% level.

to differences in rooting. 'Cuthbert Grant' cuttings were larger than those of 'Morden Cardinette', usually having seven leaflets and a larger

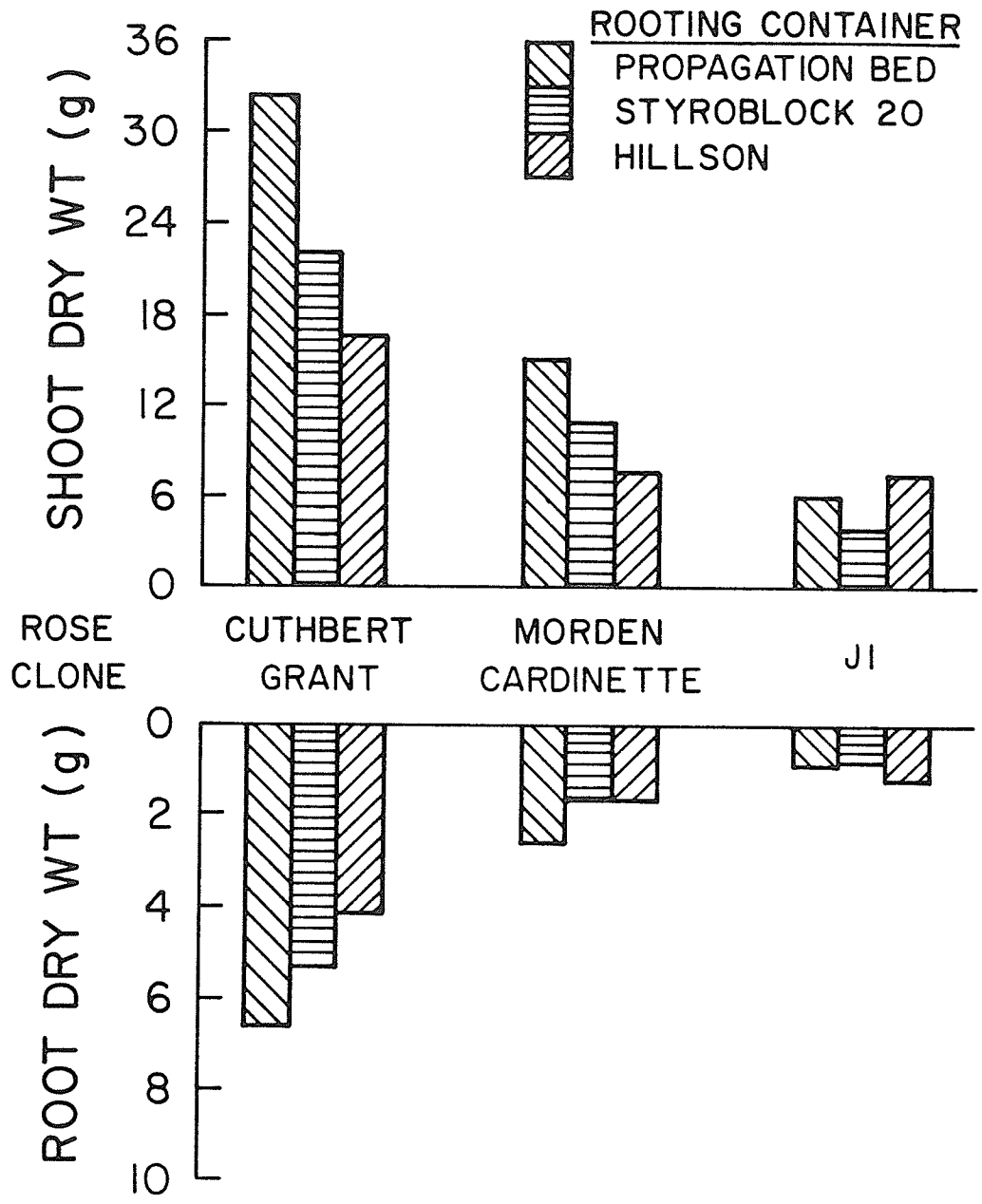


Figure 3. Shoot and root dry weights of three rose clones rooted in three containers, potted then grown 14 weeks.

stem diameter than the five leaflet leaf of 'Morden Cardinette'. Morsink and Smith (1974) hypothesized that larger cuttings of Tilia americana L. may have contained more carbohydrates than smaller cuttings and therefore had more reserves for increased root production. 'Cuthbert Grant' cuttings developed more top and root growth than did cuttings of 'Morden Cardinette' or J1 when the cuttings were potted and grown 10½ weeks (Figure 3; Tables 11, 12, 13, 14). Again, this was probably due to the more vigorous growth and the larger cuttings of 'Cuthbert Grant' compared to the other two clones. 'Morden Cardinette' cuttings had greater root dry weights and appeared to develop into larger plants than cuttings of J1. Cuttings of J1 consistently had a lesser number of leaflets and shorter heights per cutting than did the other two cultivars at each date of measurement (Tables 11, 12). Cuttings of 'Cuthbert Grant' developed more leaflets than did cuttings of 'Morden Cardinette', however, the differences were not significant. 'Cuthbert Grant' cuttings were taller than 'Morden Cardinette' cuttings at 3, 5 and 6 weeks after potting. Most likely, 'Cuthbert Grant' is a more vigorous cultivar than 'Morden Cardinette'.

Growth of cuttings rooted in the propagation bed then potted, appeared to be greater than cuttings which were rooted in containers. There were no differences between the shoot dry weights of J1 plants rooted in the three rooting treatments (Figure 3; Table 13). Johnson (1974) also did not find differences resulting from a comparison of containerized and bare-root plants. Cuttings of 'Morden Cardinette' rooted in the propagation bed had greater shoot dry weights than cuttings rooted in the Hillson or Styroblock containers. Shoot dry weights of 'Cuthbert Grant' cuttings rooted in the propagation bed were greater than cuttings rooted in the Styroblock container. Similarly, dry weights of the Styroblock treatment

were higher than those of the Hillson treatment. The number of leaflets and shoot heights per cutting appeared to be greatest for cuttings which were rooted in the propagation bed (Tables 11, 12). There were essentially no differences between cuttings rooted in the Hillson or Styroblock 20 containers. The apparent superiority of the propagation bed treatment existed early in the growing season and continued through the summer. Root dry weights of cuttings of all three clones rooted in the propagation bed were greater than the other two rooting containers (Table 14). These results did not agree with those of other investigators who reported either greater growth of containerized than bare-root plants (Whitcomb, 1978; Tinus, 1974) or no differences (Buchanan, 1974; Johnson, 1974). Cuttings of the three clones rooted in the propagation bed were potted when they were rooted to a root scale 3, then placed in the greenhouse. Once rooted, cuttings in the Hillson and Styroblock containers were moved to the greenhouse for a week then potted. If containers are employed in propagation, the rooting medium used should be able to retain the integrity of the root system once roots have developed. The sand:perlite mixture did not have this quality, consequently the root plug of the cuttings rooted in Hillson and Styroblock containers fell apart upon transplanting. As cuttings in these two containers had developed more roots by the time of transplanting, the number of roots damaged was probably greater than cuttings rooted in the propagation bed. The advantage of using containers is to enable the formation of a root plug which maintains an intact root system during planting. As discussed, the root plug fell apart and the comparison essentially became one of the growth of cuttings planted with an intermediate sized root system compared to cuttings planted with well-developed root systems. At this time, there had been little development

of photosynthetic tissue so the cuttings were probably relying on stored carbohydrates. Perhaps a greater setback in growth was incurred by cuttings rooted in the containers compared to those of the propagation bed because of this greater root damage. Watering or fertilizing the cuttings in the containers was difficult. The Hillson containers had openings along each side of the cells, thus allowing water to flow out instead of downwards to the roots. Both the Hillson and Styroblock containers had a limited area at the top of each cell to hold water, increasing the likelihood of insufficient water reaching all roots. These two problems probably accounted for the apparent superiority of plants resulting from cuttings rooted in the propagation bed. Also, the full potential of the containers was perhaps not realized because the rooted cuttings were not transplanted into a stressful environment where an intact root system could be increasingly advantageous.

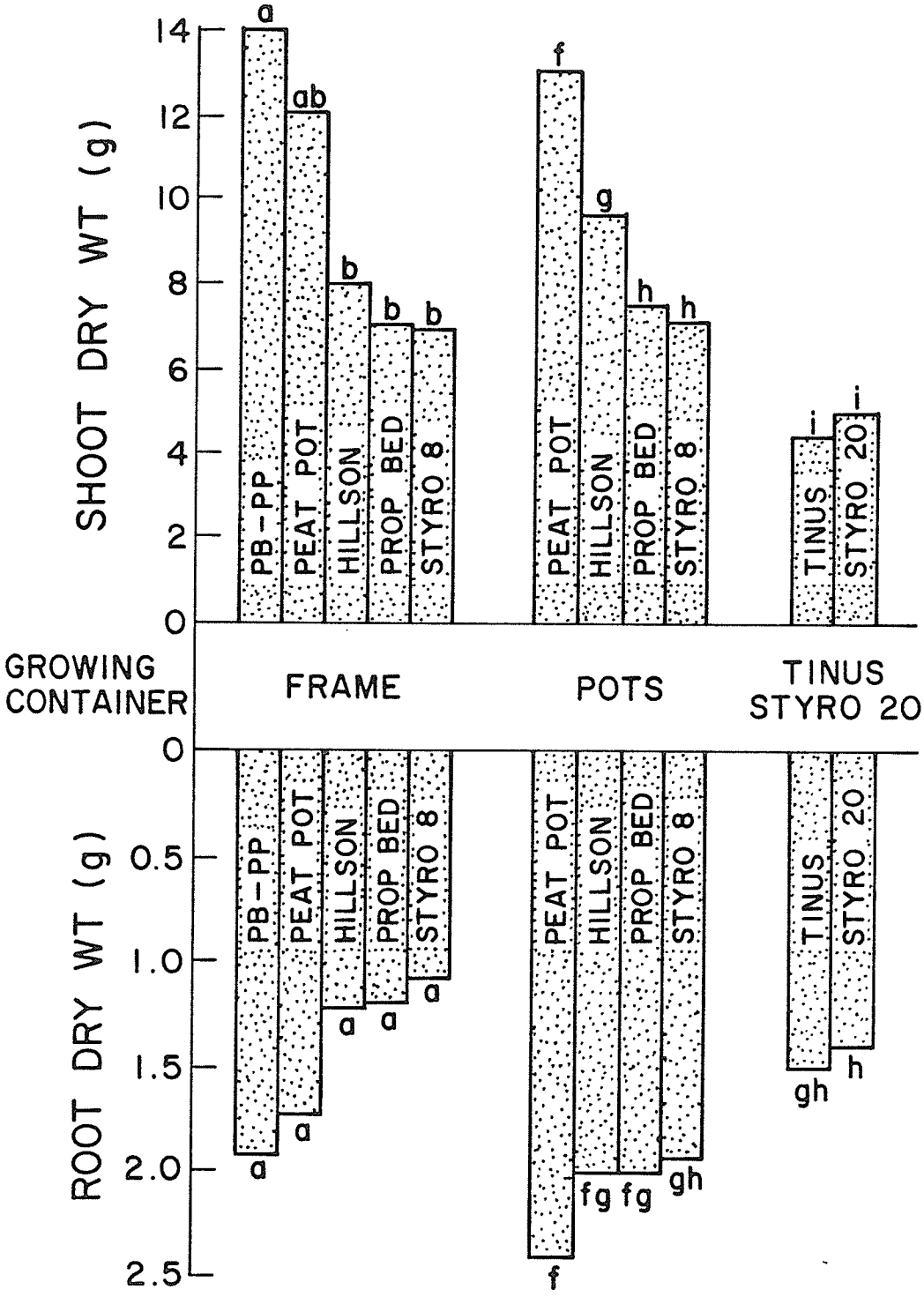
The study was expanded in 1980 to test the effects of transplanting rooted cuttings outside. It was hoped that this experiment would better test any differences between the cuttings rooted in containers and those in the propagation bed. Both pots and frames were employed to compare two methods of growing 'Morden Cardinette' plants. These two treatments were compared using only the rooted cuttings from the peat pot, Hillson, Styroblock 8 and propagation bed rooting treatments. Plants grown in pots did not differ from those grown in the frame, except for fresh and dry weights of roots (Figure 4; Table 15). This difference occurred because the roots of potted plants were fleshier, more brittle and completely contained in the pots, whereas the roots of the plants grown in the frame were woodier, less compact and less branched. It was doubtful whether all of the root system of the frame plants was recovered, making

Figure 4. Shoot and root dry weights of 'Morden Cardinette' cuttings rooted in containers and grown in frames or pots, Styroblock 20 and Tinus containers.

Bars marked with the same letter do not differ significantly by Duncan's multiple range test, 5% level.

a-b, frame ; f-i, pots

Prop Bed = Propagation Bed
Styro 8 = Styroblock 8
Styro 20 = Styroblock 20
PB-PP = Propagation Bed transplanted to Peat Pot


SHOOT DRY WT (g)
14
12
10
8
6
4
2
0
a
ab
b
b
b
f
g
h
h
PB-PP
PEAT POT
HILLSON
PROP BED
STYRO 8
PEAT POT
HILLSON
PROP BED
STYRO 8
TINUS
STYRO 20
GROWING CONTAINER
FRAME
POTS
TINUS STYRO 20
0
ROOT DRY WT (g)
0.5
1.0
1.5
2.0
2.5
a
a
a
a
a
f
fg
fg
gh
gh
h
PB-PP
PEAT POT
HILLSON
PROP BED
STYRO 8
PEAT POT
HILLSON
PROP BED
STYRO 8
TINUS
STYRO 20

it possible to confidently assign only qualitative differences between roots of plants from pots and frames. Other measures did not differ significantly between plants grown in the frame or in pots. Plants from frames appeared to be slightly taller although this difference was not significant. Soil and tissue analyses were determined after rooting, at mid-season, and at the end of the experiment. There was presumably no nutritional limitations on either group as fertility was adequately maintained. Soil temperatures varied between pots and frames but there was not a consistent trend which may have affected growth (Table 16). Air temperatures of the two locations were equal (Table 18).

The weights of plant roots grown either in pots or frames did not differ between the rooting containers (Table 15; Figure 4). This was interesting as more root damage could have been expected for cuttings of the propagation bed treatment. Perhaps, more growth of secondary roots was promoted if apical tips were damaged. Horsley (1971) found a proliferation of lateral roots when the root tip was removed. The increase in secondary root growth possibly could have compensated for the roots lost in transplanting and perhaps explained the lack of differences between root systems. The perlite:peat moss medium adhered to the roots, therefore even cuttings rooted in the propagation bed maintained a fairly intact root system during transplanting. It was possible then that little root damage actually occurred. Also, the cuttings were irrigated in the frame and watered in the pots so stresses were not imposed on the plants and the photosynthesis of the shoot was probably not limited. Perhaps then, there was sufficient photosynthate transported to the root so as not to limit growth.

There were no interactions between plants of the rooting containers

and growing treatments, however, comparisons among plants rooted in different containers were analyzed separately within pot and frame treatments because not all rooting treatments existed within both growing methods (Figure 4; Table 15). The Tinus and Styroblock 20 treatments were included only with the potted plants, while the propagation bed to peat pot treatment existed only with the frame plants. Differences among plants were determined using Duncan's multiple range test (5% level).

Root fresh weights of the cuttings grown in pots or Styroblock 20 and Tinus containers did not differ among the rooting containers. Dry weights of roots only differed slightly, the weights being greater for plants rooted in the peat pots, propagation bed and Hillson containers compared to plants rooted in the Styroblock 8, Styroblock 20 and Tinus containers, although these differences were not pronounced. Plants rooted and grown in the Styroblock 20 and Tinus containers had lower shoot weights than did the other treatments. They were equal in height to plants rooted in the Styroblock 8, but were smaller than the peat pot, Hillson or propagation bed rooting treatments. This result was probably due to a restricted area for root growth and an inadequate growing medium. These containers were difficult to water and fertilize due to the small area at the top of the container. Based on results of this experiment, cuttings of 'Morden Cardinette' could be rooted and grown in Styroblock 20 or Tinus containers, which would eliminate transplanting, but would demand more management and result in slightly smaller plants than the other methods tested.

Comparisons of the remaining rooting treatments showed that no differences occurred among the number of cuttings surviving from each rooting treatment (Table 15). The results of shoot weights appeared to

support a hypothesis of decreasing transplant shock, and increasing survival and growth when containers are used. Whitcomb (1978) and Tinus (1974) also found results concurrent with this hypothesis. The cuttings rooted in peat pots had the highest shoot weights compared to the other treatments. Conceivably, the cuttings rooted in peat pots may have undergone the least amount of transplant shock because the container was planted with the rooted cutting. Cuttings rooted in Hillson Rootrainers, a container removed before planting showed greater shoot weights than cuttings rooted in the propagation bed. Cuttings rooted in the Styroblock 8, another container which is removed before planting, also had lower shoot weights than cuttings rooted in the comparable Hillson containers. This latter difference was most likely due to root damage upon the removal of cuttings from the Styroblock 8 containers. The Hillson container opens like a book, enabling the cutting to be removed without damage, while the Styroblock 8 is a solid styrofoam block with holes punched in it. An object had to be inserted through the bottom hole and the cutting pulled to remove it, sometimes fracturing the root plug and damaging the root system. Differences of heights were not as pronounced as were shoot weights (Table 15). Heights of the shoots taken at mid-season were higher for cuttings rooted in the peat pots and Hillson containers, than the propagation bed and Styroblock 8 treatments which, in themselves, did not differ significantly. By the end of the season these differences decreased, as shoot heights did not differ between the peat pot, Hillson and propagation bed treatments, which were all greater than the Styroblock 8 treatment. Growth may have been delayed in cuttings of this latter treatment if root loss and damage had occurred. If the root area was decreased, the ability to supply the shoot with water and nutrients may have also

decreased. Since the cuttings were transplanted 7 weeks after their insertion, shoot growth had already begun. If the amount of shoot material produced was in balance with the root system, a decrease of the root area may have resulted in a decreased ability to supply water and nutrients and conceivably could have limited growth.

Comparisons of plant growth of cuttings rooted in various containers and transplanted to the frame, also showed few predominate differences (Figure 4; Table 15). Cuttings rooted in the propagation bed then transplanted to peat pots before planting in the frame had the highest shoot weights. The apparent superiority of this treatment may have been due to a near optimal rooting and planting procedure. The cuttings were transplanted to peat pots when they had rooted 3 weeks and had developed enough roots to uptake water and nutrients, yet not too many roots as to hinder transplanting and result in root damage. The cuttings were grown another 3 weeks, during which time the root system was probably further developed, and also the cuttings may have benefited from being grown in a soil medium compared to the other treatments, which were maintained in the perlite: peat moss medium until transplanted outdoors. Shoot weights of the other rooting treatments did not differ significantly. There was slightly more gradation of differences in heights than in shoot weights, although there was still considerable overlap of differences as determined by Duncan's multiple range test (5% level). Differences among the heights were more pronounced at the end of the season compared to the mid-season. Heights of cuttings which had been rooted in the peat pots, or rooted in the propagation bed then transplanted to peat pots, seemed higher than cuttings which were rooted in the propagation bed or Styroblock 8 containers. Heights of cuttings rooted in the Hillson container appeared intermediate

between the peat pot treatments and Styroblock 8 containers.

It must be stressed that any differences which existed were not large and further experimentation would have to occur before any definite conclusions could be formed. Measurements were determined after only one season's growth, therefore a possibility exists that perhaps differences would only be exhibited during later growth as Owston and Seidel (1978) observed. Also, the advantages of container use may lie in transplanting rooted cuttings into unfavourable environments. Much of the research which documents decreased transplant shock using containers has arisen from forestry plantings where containerized plants are planted into very stressful environments. This is usually not the case with nursery plantings. Differences have been found between containerized and bare-root plants (Tinus, 1976), but not consistently enough to make generalizations, and certainly many conditions of forestry experiments are not equal to those used for the production of 'Morden Cardinette'. Therefore, there may not be sufficient biological advantages to the use of containers to outweigh the added expense. The answer would be seen more clearly after field trials had been performed.

Root Hormone Study

Experiment 4: Preliminary

Cuttings of 'Morden Cardinette' had greater root production when treated with 2,500 ppm than with 2.5 ppm IBA (Table 6). Total root length per cutting was 5.5 times longer, root number was 3 times higher, and the root scale rating was 1.7 times greater for cuttings of the 2,500 ppm treatment compared to the 2.5 ppm application. Other researchers also found increased rooting of rose cuttings when exogenous growth

Table 6. Rooting parameters of 'Morden Cardinette' cuttings 2½ weeks after applications of IBA.[z]

IBA concentration (ppm)	Rooting parameters per cutting[y]		
	Length (cm)	Number	Scale[x]
2.5	8.45	5.0	2.0
2,500	48.03	14.7	3.5

[z]Values are means of 24 cuttings.

[y]Means within columns differ by the student's t test, 5% level.

[x]Scale: 1 - low, 5 - high.

regulators were applied (Orlov, 1977; Jensen, 1975; Moe, 1973; Osterby, 1970; Eriksen, 1968; Bhujbal and Kale, 1963; Kirkpatrick, 1940).

Experiment 5: Root Hormone Type

The results of experiment 5 are presented in Table 7. There was no significant interaction between hormone type and concentration for each variable measured. Significant positive linear trends were associated with increasing hormone concentrations for root number, fresh weight, and total length per cutting. There was no effect of exogenously applied hormone on the average length per root, the number and length of branch roots, or the number of cuttings rooted. It appeared, therefore that increasing concentrations of IBA, NAA and IAA applied to cuttings of 'Morden Cardinette' resulted in increased number of roots, total root length and fresh weight of roots per cutting. These results agreed with those of other researchers who found that rooting parameters were increased when higher concentrations of exogenous growth regulators were applied to

softwood cuttings (Moe, 1973; Bhujbal and Kale, 1973; Kirkpatrick, 1940). Applications of IBA promoted rooting to a greater degree than did IAA or

Table 7. Rooting of 'Morden Cardinette' cuttings 4 weeks after applications of IBA, IAA or NAA.[z]

Auxin type and concentration	No. rooted of 48 cuttings	Mean root growth			
		Fresh wt (mg)	No.	Length (cm)	
				Per cutting	Per root
Auxin type (mean of all concentrations)					
IBA	39	218 a[y]	11.2 a	21.01 a	1.82 a
IAA	33	138 ab	5.9 b	10.65 b	1.67 a
NAA	34	97 b	4.9 b	7.41 b	1.42 a
Auxin concentration (mean of all auxin types)					
1,000	46	82	4.2	5.91	1.44
7,000	33	141	6.9	12.00	1.68
20,000	37	232	10.9	21.20	1.80
Linear	-	**[x]	**	**	NS
Quadratic	-	NS	NS	NS	NS
Interaction of hormone type and concentration was not significant at 5% level.					

[z]Values are means of no. of rooted cuttings.

[y]Means within columns followed by the same letter do not differ significantly by Duncan's multiple range test, 5% level.

[x]Non-significant (NS), significant at 5% level (**).

NAA treatments. Other researchers have also observed that IBA stimulated rooting of softwood rose cuttings more than IAA or NAA (Moe, 1973; Bhujbal and Kale, 1973; Tognoni et al., 1964; Kirkpatrick, 1940). Indolebutyric acid was found to be more effective due to its greater stability and lower mobility in the plant compared to IAA (Audus, 1953). Indoleacetic acid is not usually an effective auxin to apply exogenously due to its rapid breakdown by the IAA oxidizing enzyme system (Weaver, 1972). The rooting response to NAA was less than to IBA and it appeared that

this result was obtained for roses (Moe, 1973) as well as for other species (Myers and Still, 1979; Sen and Bose, 1964). It was not known why the NAA treatment did not promote rooting to a greater extent than IAA. Perhaps the internal metabolism was such that no additional root promotion occurred with NAA than with IAA. Alternatively, the NAA stock mixture could have been contaminated at some point, decreasing its activity.

This experiment was repeated August 26 but no rooting response occurred. This was most likely due to the time of taking cuttings, which corresponded to the same timing after the stockplants had begun growth, as a period of decreased rooting in experiment 7 (Table 19). The same factors were probably causal agents of the reduced rooting and lack of response for the second experiment of this study. This is discussed in experiment 7.

Experiment 6: Comparison of IBA Preparations and Commercial Formulations

Orthogonal contrasts were calculated to compare the commercial formulations with the corresponding concentrations of IBA preparations used in the root hormone study. In addition, all treatments were compared to the 0 ppm control (talc) using Dunnett's procedure.

The fresh and dry weights of the roots per cutting, taken over all three concentrations were significantly greater for the prepared IBA than the Stim Root applications (Table 8). No differences occurred between cuttings treated with the Stim Root or IBA preparation when the root number and length were determined.

Cuttings treated with the 1,000 ppm IBA-talc preparation had greater fresh and dry weights of roots than those treated with Seradix 1 or Stim Root 1. Although not significant, values for length and number of roots showed the same trend as fresh and dry weights. Root dry weights

Table 8. Comparison of rooting promoted by commercial formulations and corresponding IBA-talc preparations.[z]

IBA formulation	Root parameters			
	Fresh wt (mg)	Dry wt (mg)	Length (cm)	No.
1,000 ppm				
IBA-talc	632 a[y]	51 a	40.27 a	7.8 a
Stim Root 1	309 b	24 b	22.98 a	6.5 a
Seradix 1	232 b	19 b	15.34 a	5.5 a
4,000 ppm				
IBA-talc	639 a	47 a	50.75 a	10.0 a
Stim Root 2	375 a	27 b	34.38 a	8.5 a
8,000 ppm				
IBA-talc	856 a*	59 a*	68.82 a*	12.2 a*[x]
Stim Root 3	612 a	49 a	49.94 a	9.6 a
0 ppm	432	33	57.88	7.9

Main interaction of IBA-talc and Stim Root was significant for fresh weight and dry weight at 1% level.

[z]Values are means of 12-16 cuttings rooted for 4 weeks.

[y]Means within each concentration level followed by the same letter do not differ significantly, 5% level.

[x]Means differ from 0 ppm by Dunnett's procedure, 5% level (*).

of cuttings treated with 4,000 or 8,000 ppm IBA were greater than cuttings treated with Stim Root 2 and 3, respectively. Fresh weights, root lengths and number of roots did not differ significantly at the 4,000 and 8,000 ppm levels, although the values for the IBA-talc treatment were higher than the corresponding Stim Root treatments.

When all treatments were compared to the control (talc), using Dunnett's procedure, only the 8,000 ppm IBA-talc treatment differed from the others (Table 8). Generally, the same distribution of means was observed for dry weight, number of roots, and length of roots. When trends were examined, it was noted that mean values for the 1,000, 4,000, 8,000 ppm IBA and Stim Root 3 treatments were usually greater than 0 ppm, while the mean values for Stim Root 1 and 2 and Seradix 1 were less than those for 0 ppm.

It appeared then that perhaps the Seradix and Stim Root preparations had lost auxin activity because rooting of cuttings which had been treated with these commercial preparations did not differ from those treated with only talc. The optimum IBA concentration for root production by cuttings of 'Morden Cardinette' was later determined to be 7,000 ppm (Table 19). If these results were indicative of the rooting response of 'Morden Cardinette' cuttings to exogenously applied IBA, then the 8,000 ppm level should have had the greatest response with rooting decreasing at 4,000 and decreasing again at 1,000 ppm. The 8,000 IBA-talc preparation increased rooting compared to the 0 ppm application, whereas the corresponding Stim Root 3 treatment did not, again indicating that the activity of the Stim Root 3 preparation might have decreased. The commercial preparation may have been contaminated at some point or their concentrations improperly prepared. Hartmann and Kester (1975) pointed out that contamination of IBA preparations by moisture, fungi or bacteria could decrease effectiveness. Marston et al. (1969) found that applications of Seradix 1, 2 and 3 promoted rooting of rose cuttings more than the control, thus further supporting the argument that a loss of root promoting activity must have occurred in the commercial formulations.

It was more difficult to explain why rooting at 1,000 and 4,000 ppm IBA was not significantly higher than rooting at 0 ppm. Perhaps increases of IBA did not greatly affect rooting of 'Morden Cardinette' cuttings unless higher levels were applied. This would explain why, while some increase in rooting was noted from 0 to 4,000 ppm IBA, these differences were not significant.

This experiment was repeated to confirm the results found from the first investigation. However, no significant differences were found between treatments, most likely because cuttings were taken in August. Cuttings which were taken during August in experiment 7 had little rooting response to IBA treatments (Fig. 7).

Experiment 7: The Effects of IBA Concentration on Rooting and Plant Growth

Rooting and Growth Measurements. Fresh and dry weights of both roots and shoots were highly correlated in a preliminary experiment, indicating a possibility of measuring only fresh weights. In this experiment, dry weights and fresh weights of roots of cuttings were highly correlated at dates 1, 2 and 3 (r^2 = 0.958, 0.948, 0.951) as seen in Figure 5. As fresh weights increased, dry weights likewise increased, therefore only fresh weights were measured at date 4 and only fresh weights are presented graphically. The reader is directed to the regression equation:

$$DW(mg) = 2.85 + 7.61\ [FW(g)],$$

should dry weight values be desired.

Fresh and dry weights of roots and shoots of the plants were also highly correlated at dates 1 and 2 (Shoots: r^2 = 0.847, 0.970; Roots: r^2 = 0.817, 0.817) as seen in Figure 6. Dry weight values for dates 3 and 4 can be calculated by the following equations:

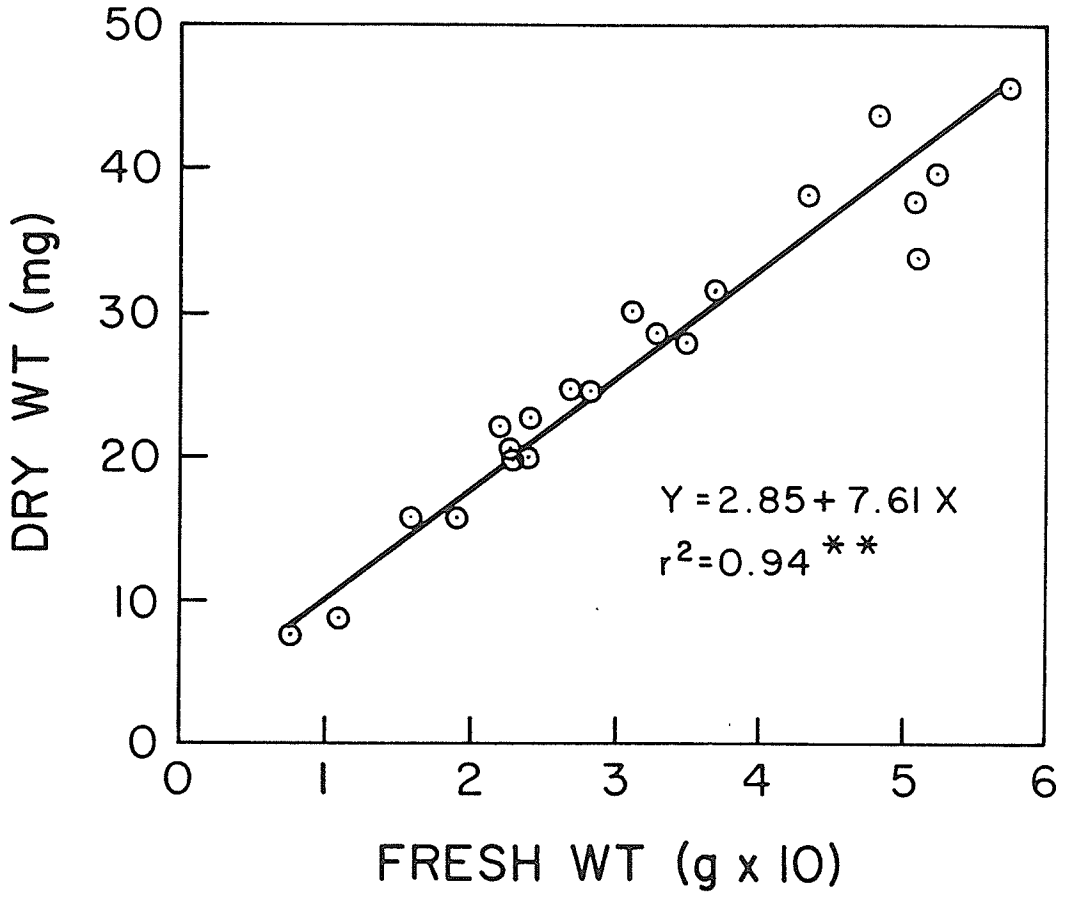


Figure 5. Correlation of fresh weight and dry weight of roots of 'Morden Cardinette' cuttings, 3 weeks after insertion. Each point is the mean of 24 cuttings. r^2 is significant at 1% level (**).

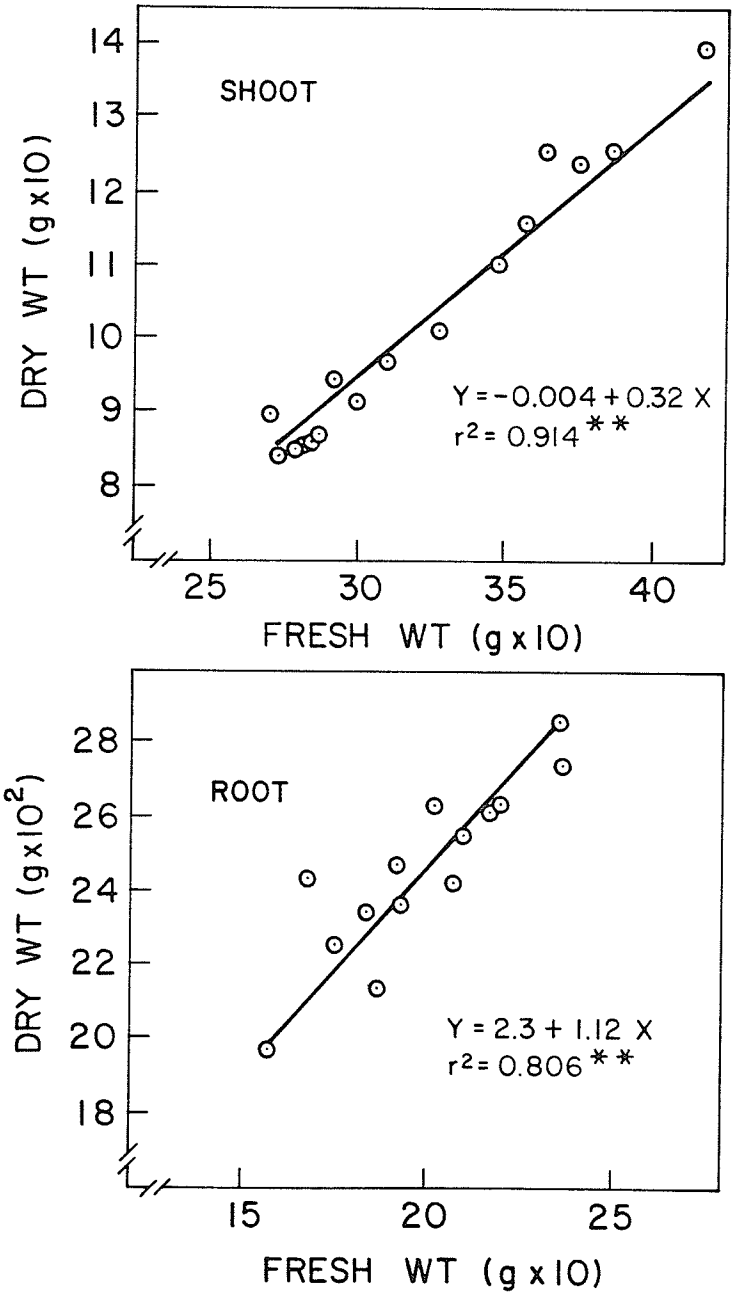


Figure 6. Correlation of shoot and root fresh weights and dry weights of 'Morden Cardinette' cuttings 8 weeks after potting. Each point is the mean of 24 plants, r^2 is significant at 1% level (**).

Shoots: DW (g) = -0.004 + 0.32 [FW (g)].

Roots : DW (g) = 2.3 + 1.12 [FW (g)].

Observed and predicted values were plotted to ensure that the relationships existed over the whole line. It was assumed that the slope was the same for slightly smaller plants as cuttings taken at dates 3 and 4 resulted in smaller plants than those taken at dates 1 and 2. The slopes of the lines for roots of cuttings and the roots of plants probably differed because the roots of the plants were washed prior to weighing and adhering water perhaps accounted for a larger part of the fresh weight than for roots of the cuttings. Also, more peat moss may have been associated with roots of the plants than of the cuttings.

Cultivar. Rooting of cuttings of 'Morden Cardinette' and J1 was compared at dates 1, 2 and 3 for the number of roots, total main root length and fresh weight of roots (Figures 7-10; Tables 19, 20). Cuttings of 'Morden Cardinette' developed more roots, longer total root length, and greater fresh weight of roots per cutting than did cuttings of J1. Differences in rooting and in rooting response to auxin concentrations between rose cultivars and species have been noted previously (Orlov, 1977; Bhujbal and Kale, 1973; Tognoni et al., 1973; Laurie and Stillings, 1949; Brandon, 1939), thus results obtained in this study are in agreement with the literature. Hartmann and Kester (1975) stated that even cuttings of closely related clones may differ widely in their rootability. It was difficult to state the actual cause of these differences as ultimately what was required was an explanation of the rooting phenomenon and factors responsible for inhibiting root formation. Explanations in the literature to date have involved the absence or low levels of rooting cofactors or synergists (Haissig, 1974; Hess, 1965; Kawase, 1965), the

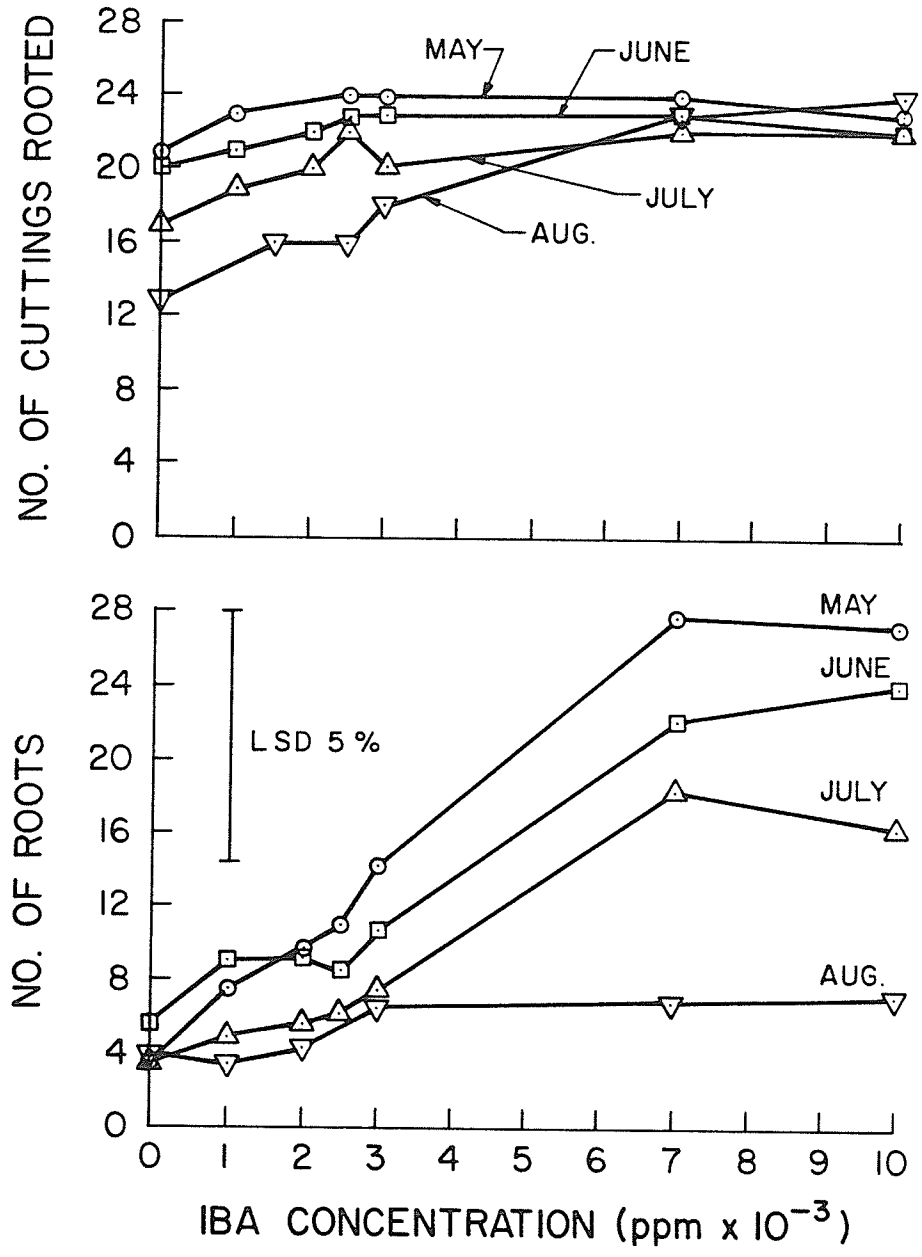


Figure 7. The number of cuttings rooted of 24 cuttings and the number of roots per cutting of 'Morden Cardinette' 3 weeks after IBA applications.

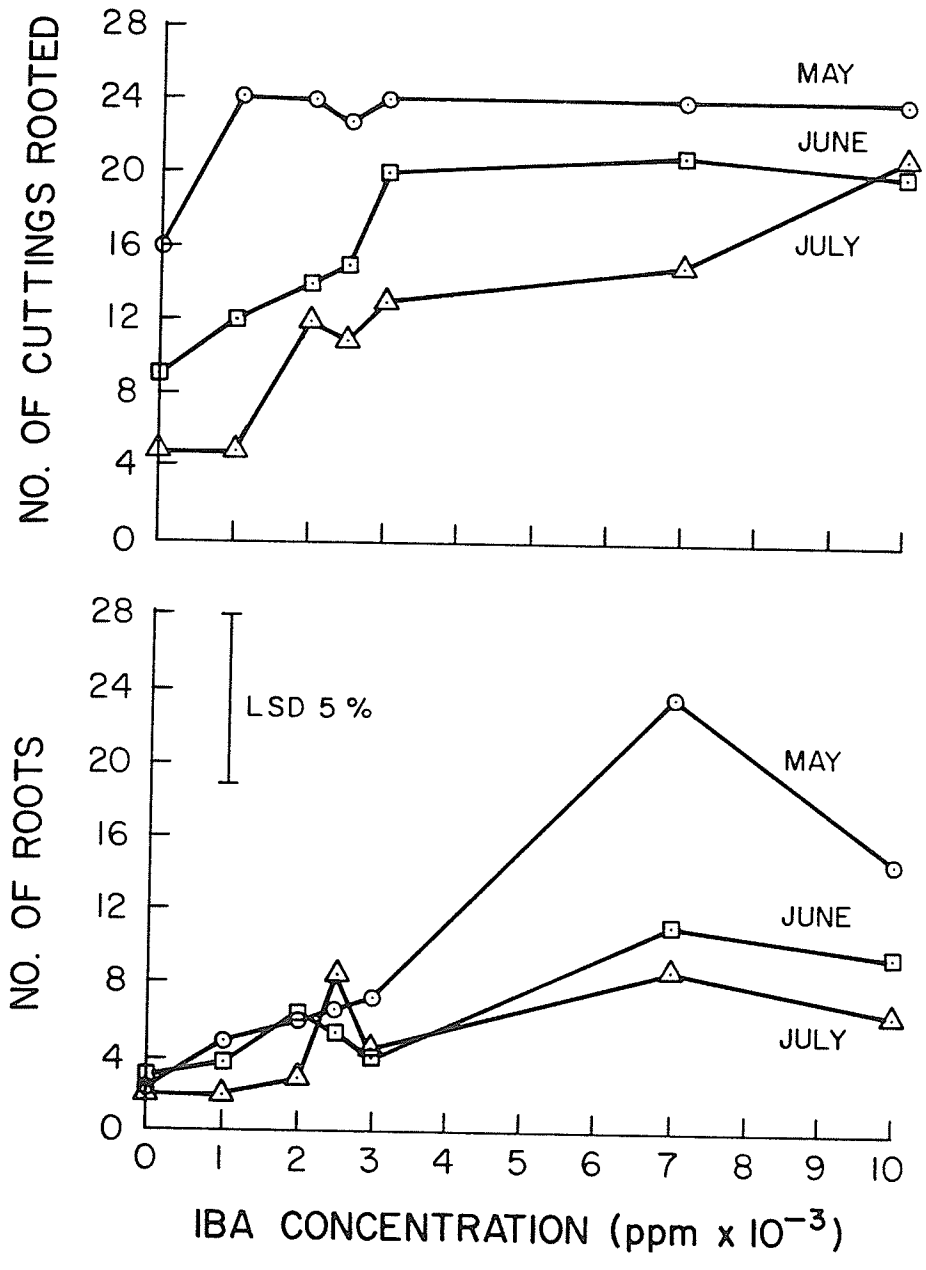


Figure 8. The number of cuttings rooted of 24 cuttings and number of roots per cutting of J1 3 weeks after IBA applications.

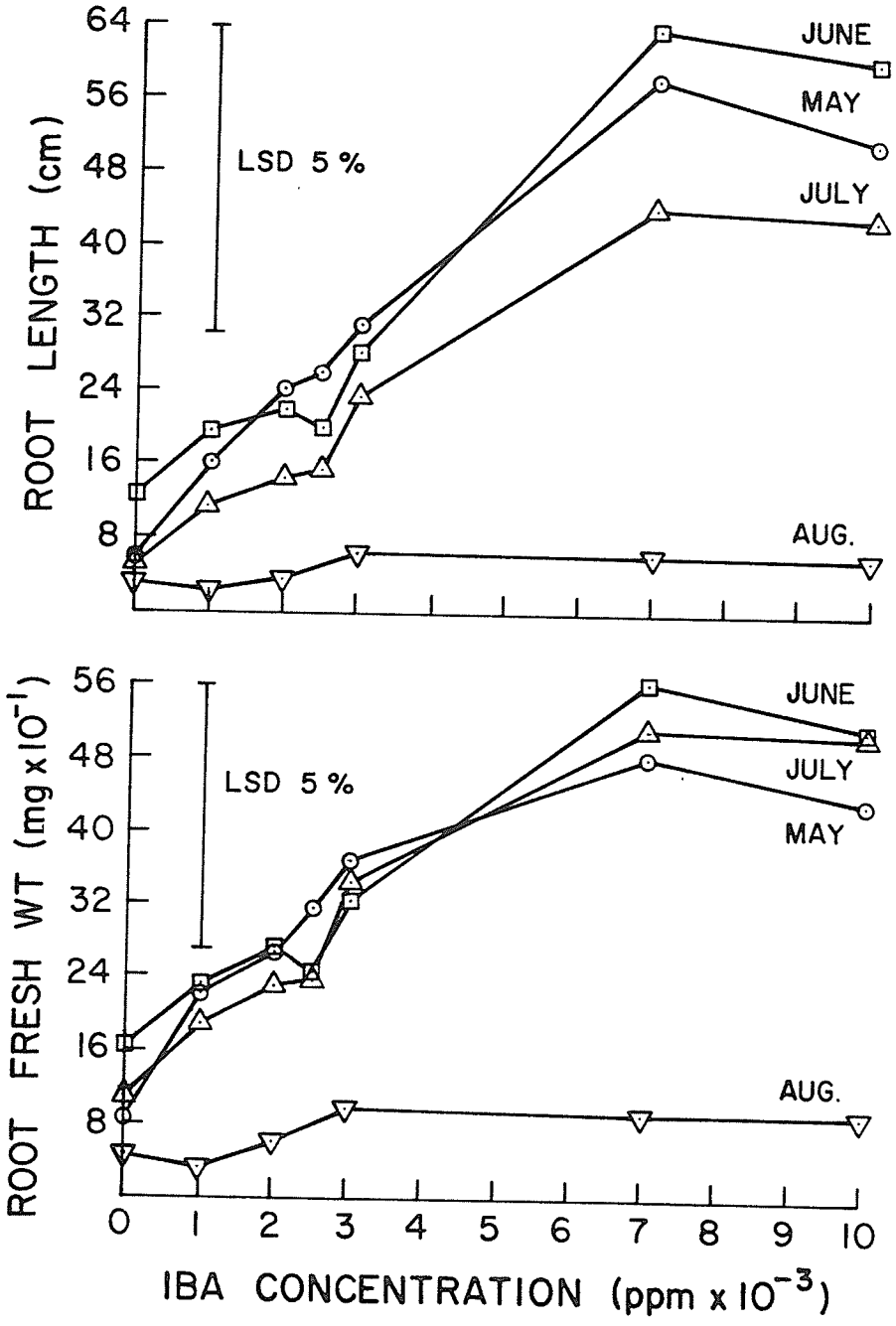


Figure 9. Total root length and fresh weight of roots per cutting of 'Morden Cardinette' 3 weeks after IBA applications.

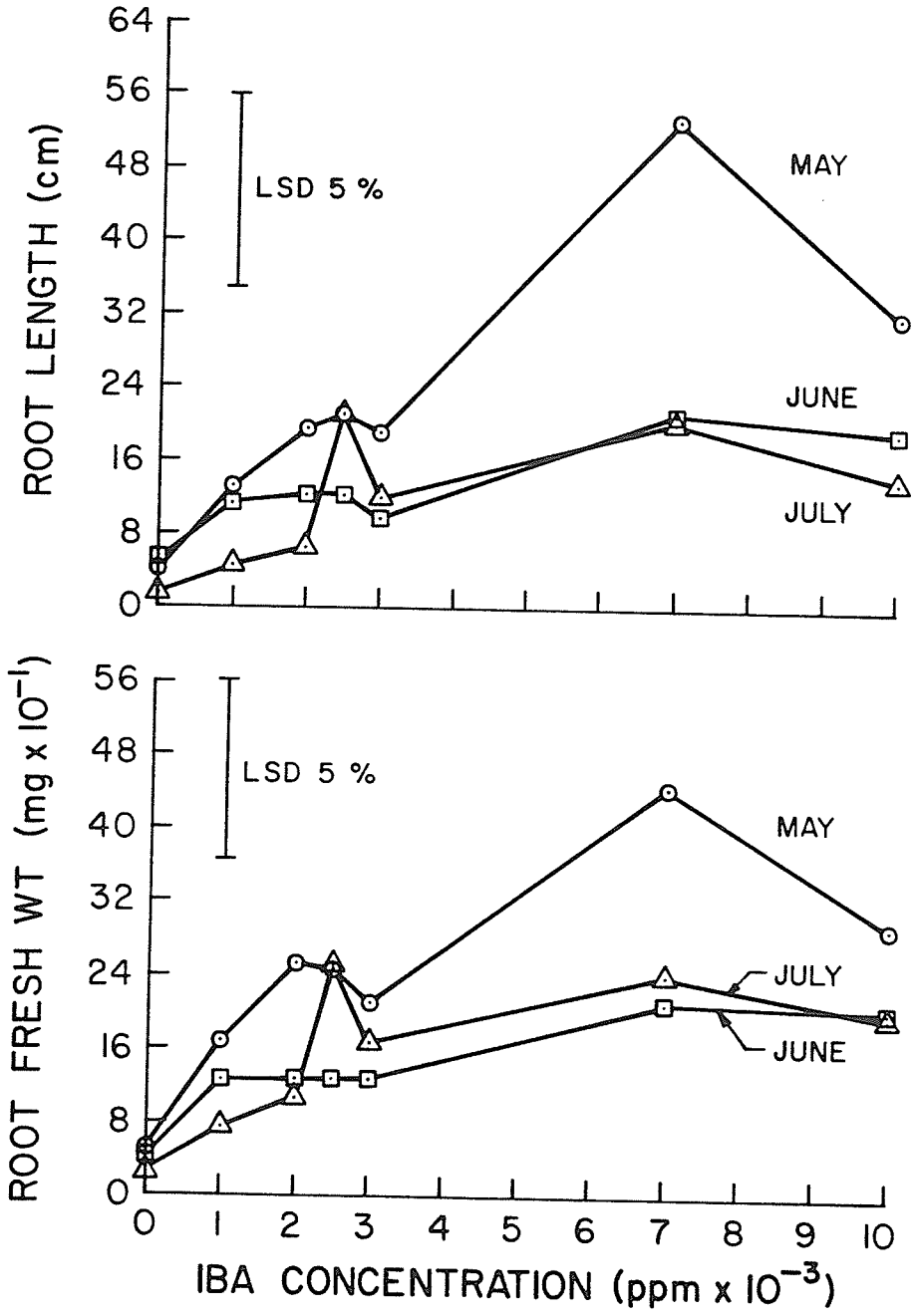


Figure 10. Total root length and fresh weight of roots per cutting of J1 3 weeks after IBA applications.

the presence of rooting inhibitors (Zenk and Muller, 1963), or internal IAA, carbohydrate, nitrogen or phenolic levels (Tognoni et al., 1973; Hess, 1965). Tognoni et al. (1973) pointed out that root formation was dependent upon many complex biochemical processes which were influenced by numerous factors. Accordingly, an inadequate level of a required compound or the failure of a reaction would inhibit or slow the rate of rooting. It was evident that the elucidation of the causal variable or variables was beyond the scope of this study. Increased rooting of cuttings of both 'Morden Cardinette' and J1 occurred when IBA was applied thus it was possible that both roses had relatively low levels of endogenous IAA. Still, cuttings of J1 did not root as well as those of 'Morden Cardinette', and as an optimum concentration appeared to have been reached, it seemed that another factor limited rooting of J1 cuttings.

Plants of 'Morden Cardinette' and J1 were compared 8 weeks after potting. The survival of J1 plants grown from cuttings decreased markedly from date 1 to date 2 to date 3 (4, 5, 6 months after stock plants began growth); in fact no plants of J1 grown from date 3 survived. Plants of 'Morden Cardinette' showed only a slight decrease in plant survival from date 1 to date 3. It was not surprising that the two roses differed in growth and survival rates as it is well known that cultivars within species often differ (Brandon, 1939; Orlov, 1977). As seen in Figures 13, 14 (Tables 21, 22), shoot fresh weights of 'Morden Cardinette' and J1 did not differ significantly, however, dry weights of 'Morden Cardinette' plants were greater than those of J1. Plants of 'Morden Cardinette' appeared to have greater shoot growth than plants of J1 as heights of the shoots, taken at mid-season and at the end of the experiment, were greater for plants of 'Morden Cardinette' (Figures 11, 12; Tables 21, 22). Only the

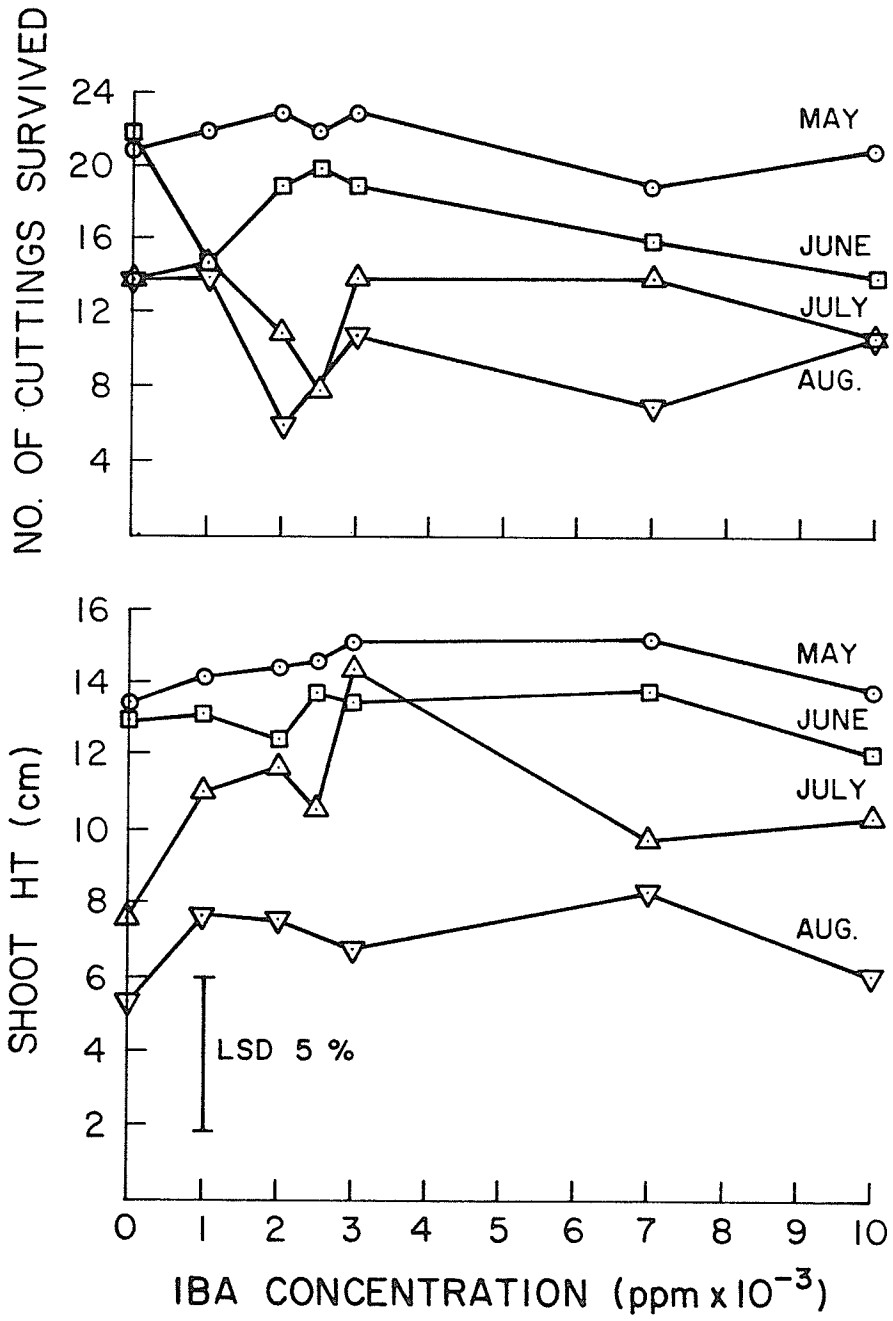


Figure 11. The number of cuttings surviving of 24 cuttings and shoot height per cutting of 'Morden Cardinette' 11 weeks after IBA applications.

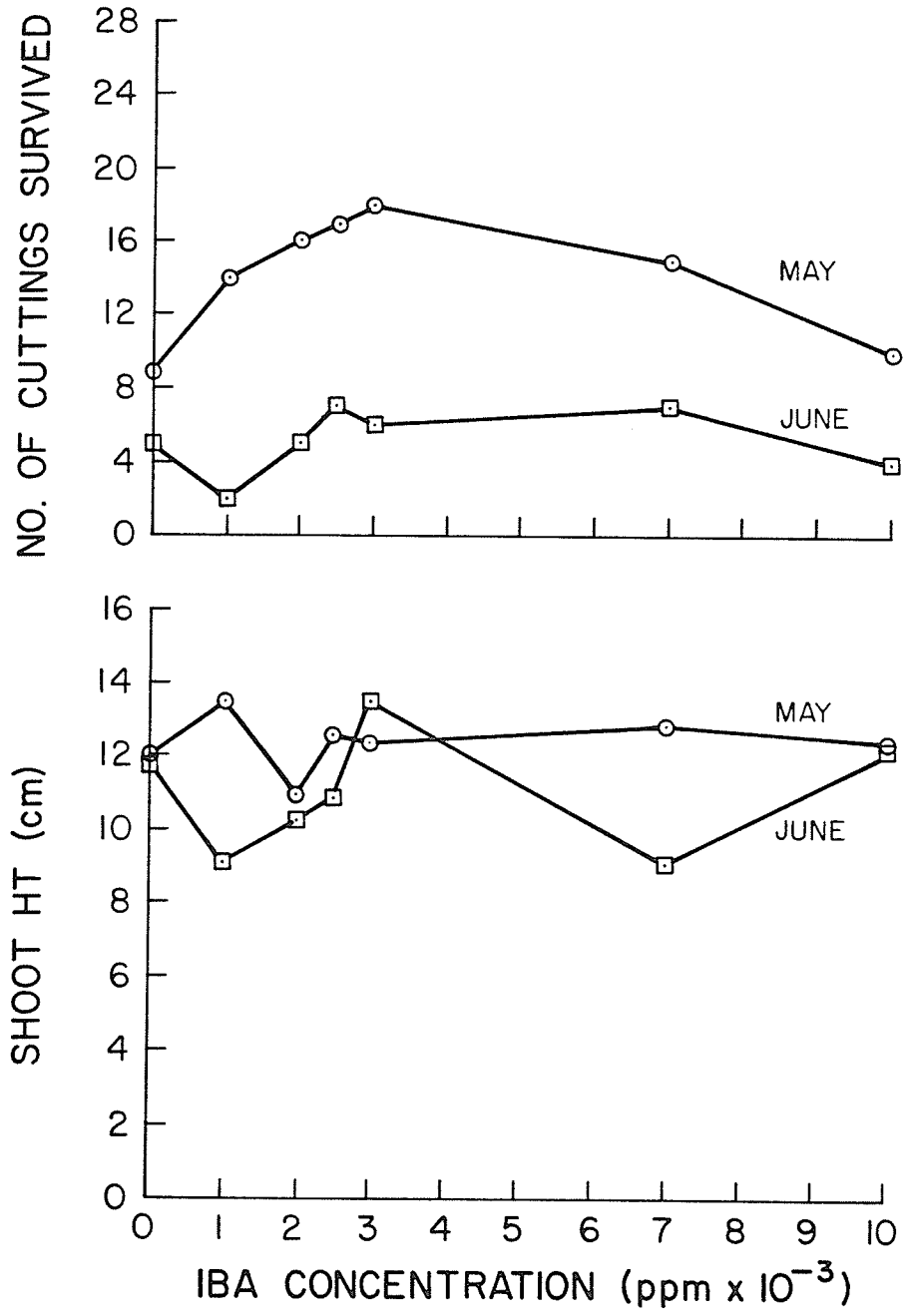


Figure 12. The number of cuttings surviving of 24 cuttings and shoot height per cutting of J1 11 weeks after IBA applications.

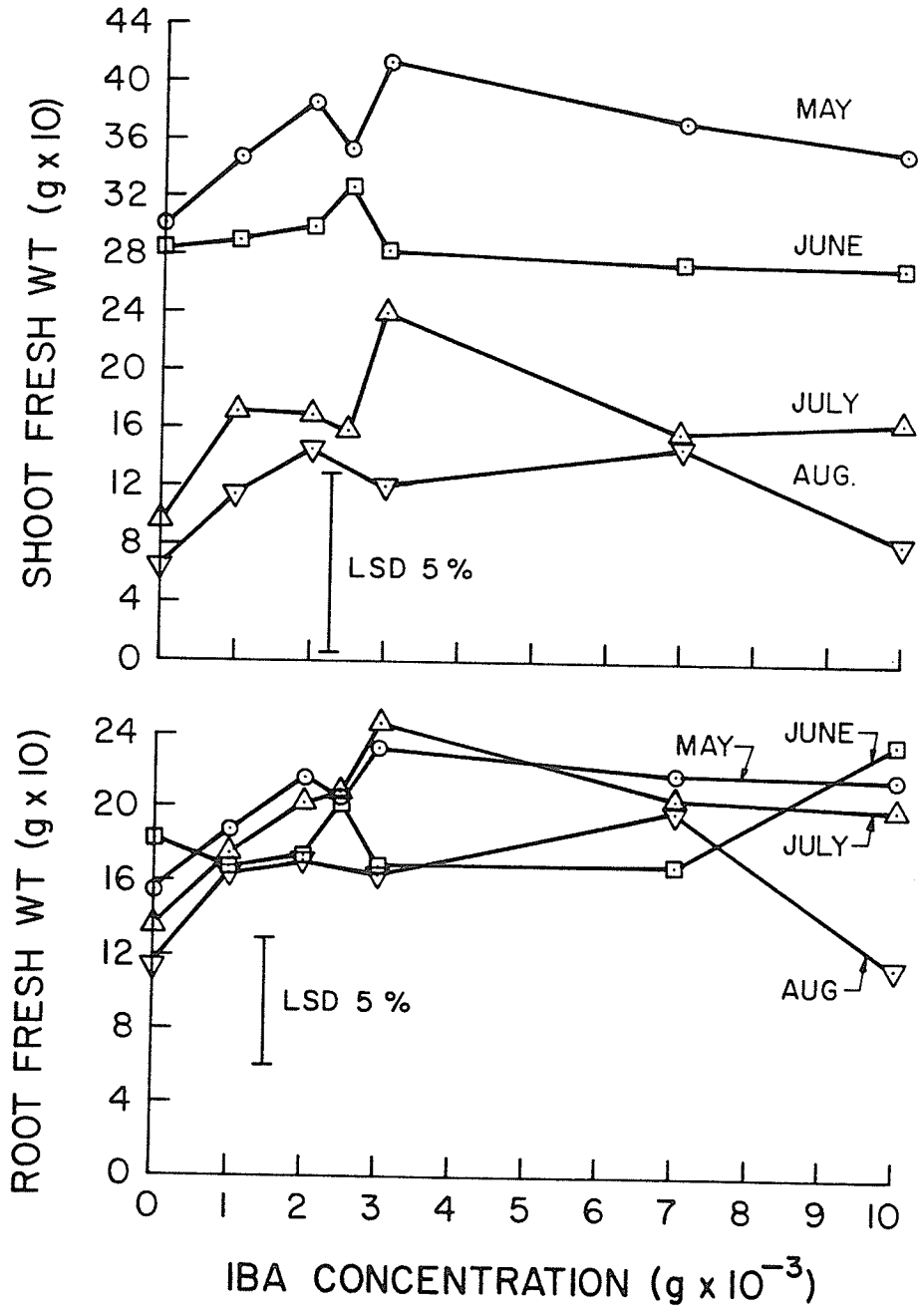


Figure 13. Shoot and root fresh weights per cutting of 'Morden Cardinette' 11 weeks after IBA applications.

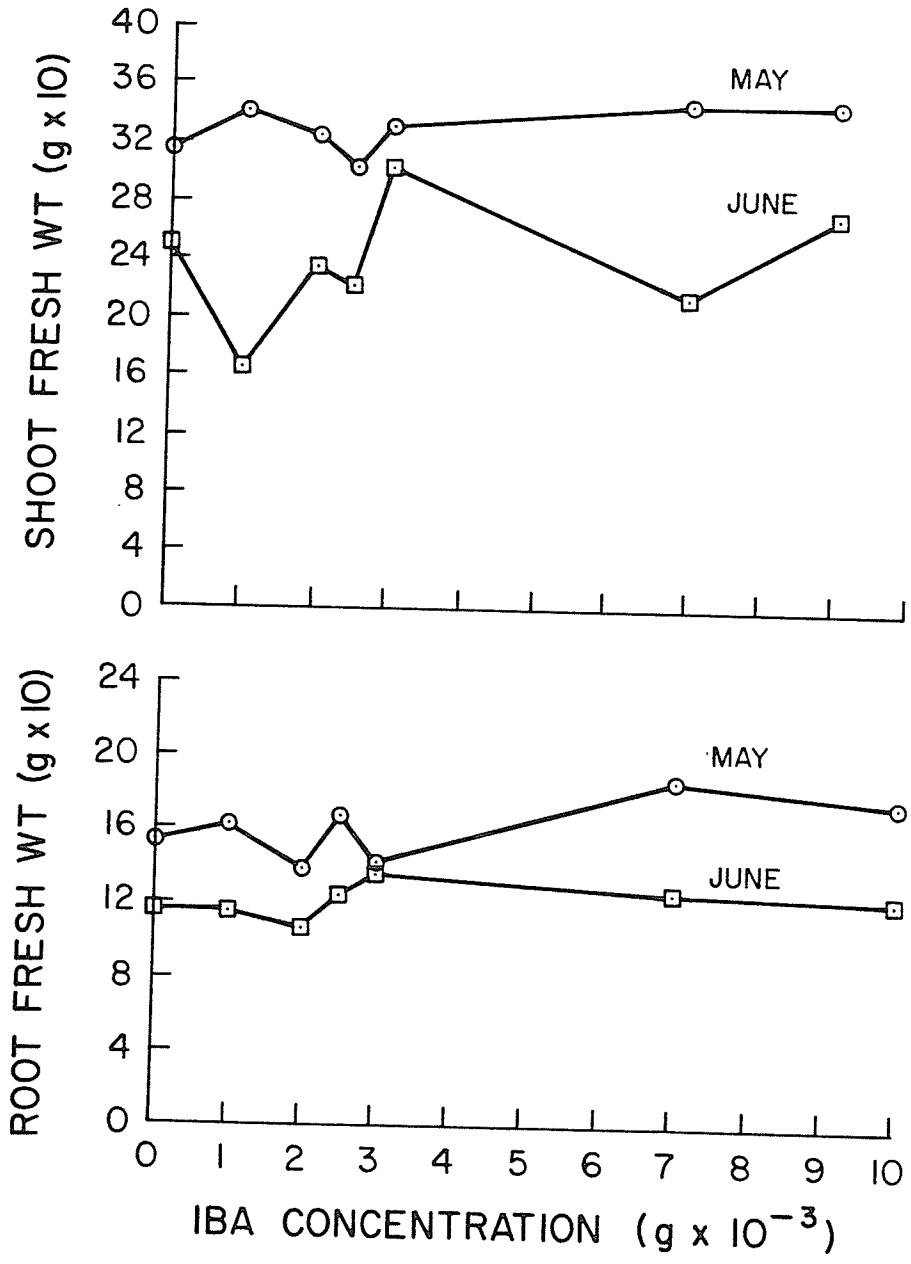


Figure 14. Shoot and root fresh weights per cutting of J1 11 weeks after IBA applications.

heights measured at the end of the season are shown in Figures 11 and 12 because mid-season heights reflected these trends. Root weights of 'Morden Cardinette' plants were greater than those of J1 (Figures 13, 14; Tables 21, 22). 'Morden Cardinette' appeared to be a more vigorous cultivar than J1 as shown by the results of the growth measurements. Stock plants of 'Morden Cardinette' also appeared to be more vigorous compared to plants of J1 and J1 has been observed to lack vigor on many previous occasions (personal communication; Marshall, 1980).

Concentration. The number of cuttings of J1 which rooted at dates 1, 2 and 3 increased with the application of IBA, as determined by the chi-square test of independence (Figure 12; Table 20). The application of IBA to cuttings of 'Morden Cardinette' increased the number of rooted cuttings at dates 1, 2 or 3 compared to the 0 ppm treatment, but did not increase the number of rooted cuttings at date 4, compared to the talc control (Figure 11; Table 19). Varied effects of applications of IBA on the percent of cuttings rooted have been reported. Application of indolebutyric acid have increased (Jensen, 1975; Tognoni et al., 1973; Kirkpatrick, 1940) or shown no effect (Bhujbal and Kale, 1973; Eriksen, 1968) on the number of cuttings rooted of rose species or cultivars.

Regression analysis was used to determine the rooting response of J1 and 'MordenCCardinette' cuttings to increasing IBA concentrations. Logrithmic, square root, and reciprocal transformations were calculated, but did not improve the analysis. No definite relation was found between the variance and the mean. Chong (personal communication, 1980) also noted that transformations of this type of data did not have any beneficial effects. Linear, cubic and quadratic regression models were determined separately and in combination to account for the rooting responses.

Although some variables had slightly higher r^2 values with different regression models, variation in most variables due to IBA concentration was accounted for to the greatest degree by concentration and the square of concentration. It must be stated from the outset of this discussion that all regression coefficients were low, in the order of 0.2 to 0.3, and that variability associated with the rooting of cuttings was very high.

The number, total length and average length of branches of cuttings of 'Morden Cardinette' and J1 were not affected by, or related to the IBA concentrations at dates 1, 2 and 3 (Tables 19, 20). Cuttings of 'Morden Cardinette' did not develop any branches at date 4. This is discussed under date effects. These results were not in agreement with observations by Bhujbal and Kale (1973) who noted that secondary root production by different Rosa spp. was optimized by certain concentrations and hormone mixtures. However, cultivar and species differences occurred and could, therefore, be the basis of differences between their study and the present investigation. It was difficult to compare these results with the findings of other researchers as branches, or secondary roots, were not measured in many experiments.

The average total and average main root length per root of cuttings of both clones was also not affected by increasing IBA concentrations (Tables 19, 20). These results conflicted with those of Orlov (1977) who, working with Rosa spp., noted that the average root length decreased as the number of roots increased. However, Mercedes-Flores and Kester (1966) found that increasing IBA levels resulted in increasing average root lengths of Prunus amygdalus cuttings, while Moe (1973) also observed this response for cuttings of Rosa x 'Garnette'. Part of this

apparent contradiction may have been due to the concentrations used in each experiment. High auxin levels have inhibited root elongation, but lower levels stimulated root elongation (as reviewed in Torrey, 1956). As the fresh weight per root also did not differ between IBA concentrations, it appeared that the individual roots produced by cuttings of both clones were not affected by IBA concentration. There was a lack of literature to consult regarding measurements on individual roots because studies such as this one have their benefit in elucidating, more exactly, the rooting response but such experiments are laborious and time consuming. Root scale ratings require less time but also yield less information.

The r^2 values and response curves for dry weights of roots obtained over the IBA concentrations were almost identical to those of the fresh weights. The same situation was found for total main root length and total root length. Consequently, results will only be discussed for the fresh weights and total main root lengths for each clone.

As seen in Figures 7-10 (Tables 19-22), the number, fresh weight, and total main length of roots of both J1 and 'Morden Cardinette' at dates 1, 2 and 3 generally increased as IBA concentrations increased. The regression model for the number of roots produced by cuttings of J1 was significant at date 1 ($r^2 = 0.265$), and date 3 ($r^2 = 0.392$) but not at date 2 ($r^2 = 0.114$). Regression coefficients for 'Morden Cardinette' cuttings taken at dates 1, 2, 3 and 4 were 0.245, 0.327, 0.159 and 0.079, respectively, all values were significant. It is evident, as previously stated, that the amount of variation accounted for by increasing concentration was not very great. However, there was a trend of increasing number of roots produced as the IBA concentration increased. These results were in accordance with results of other researchers working with

roses (Jensen, 1975; Moe, 1973; Tognoni et al., 1973; Kirkpatrick, 1940). However, cuttings of 'Morden Cardinette' which were taken at date 4 seemed to develop increased number of roots as the IBA concentration increased to 3,000 ppm then did not respond to further increases of IBA. This observation is discussed further under the effect of dates. The 7,000 ppm IBA concentration maximized the number of roots per rooted cutting at dates 1, 2 and 3, although a slight increase, probably due to variation, occurred at 10,000 ppm at date 2. The 7,000 ppm level was higher than any concentration listed in other reports. Jensen (1975), Moe (1973) and Kirkpatrick (1940) all found the maximum number of roots developed at 2,000 ppm IBA. However, this concentration was also the highest applied in the experiments, therefore the concentration which optimized root number of the rose species tested, could have been higher than 2,000 ppm. Marston et al. (1969) applied Seradix 1, 2 and 3 for cuttings of hybrid tea and floribunda roses. Cuttings treated with Seradix 2 (4,000 ppm) had the greatest number of cuttings rooted, however, cuttings treated with Seradix 3 (8,000 ppm) had the longest roots. These were the only researchers who applied such high concentrations of IBA and whose results in part surrounded the observation that rooting of 'Morden Cardinette' was greatest at about 7,000 ppm.

The total length of the primary roots per cutting of 'Morden Cardinette' and J1 increased as IBA concentrations increased at dates 1, 2 and 3 (Figures 9, 10; Tables 19, 20). Again at date 4 root length increased to 3,000 ppm IBA, then remained constant. Regression coefficients for J1 were 0.316 (**), 0.054 (NS), and 0.383 (**) at dates 1, 2 and 3. The regression coefficients obtained for cuttings of 'Morden Cardinette' at dates 1, 2, 3 and 4 were 0.260 (**), 0.333 (**), 0.149 (**) and 0.067 (**),

respectively. The relationship of total main root length and IBA concentration at date 4 was essentially non-existant even though statistically significant. If the average length per root was constant at all IBA concentrations and the number of roots increased as IBA levels increased, it was logical to expect total main root length to increase as IBA concentrations increased. Baston (1933) also found total root lengths to increase as IBA levels increased.

Likewise, if fresh weight per root remained constant and the number of roots increased, fresh weight would also increase as IBA concentrations increased. This was the case (Figures 9, 10; Tables 19, 20). Rooting response of cuttings of J1 was associated with r^2 values of 0.206 (**), 0.033 (NS) and 0.293 (**) at dates 1, 2 and 3. Regression coefficients for 'Morden Cardinette' cuttings were 0.154 (**), 0.339 (**), 0.175 (**) and 0.068 (**) at dates 1, 2, 3 and 4. The reason for the lack of significance of the regression model for rooting of J1 cuttings at date 2 was not known.

It appeared that the number of roots produced by cuttings of 'Morden Cardinette' was positively correlated with the callus rating (Table 19). Again, however, the r^2 values were low: 0.22, 0.34 and 0.17 at dates 1, 2 and 3. These findings were not in accordance with Moe (1973) who noted that high IBA concentrations seemed to inhibit callus formation. However, Hartmann and Kester (1975) stated that, although the formation of callus and roots was independent, the two often occurred simultaneously, due to their dependence upon similar internal and environmental conditions.

Indolebutyric acid concentrations had less influence on subsequent growth than rooting of the cuttings. The percent survival of J1 cuttings appeared to increase when IBA was applied at date 1, but since this response

only occurred once it was impossible to deduce a general response (Figure 12; Table 22). The level of IBA applied to 'Morden Cardinette' cuttings did not affect plant survival after potting (Figure 11; Table 21). As seen in Figure 13, it appeared that there was a slight increase of root fresh weight as IBA concentrations rose from 0 ppm to 3,000 ppm at dates 1 and 3, however, it was impossible to state this conclusively as the regression model was non-significant at dates 2 and 4. Also, the r^2 values were very low, meaning that changes in IBA concentrations accounted for very little of the variation in fresh weights of roots. The y-intercepts were approximately equal to the means at each date and the slopes were near 0, indicating that the regression lines were probably almost horizontal. It seemed then, that the change in IBA levels applied to the cuttings at the time of rooting had no effect on the fresh weight of the root system of the potted plant after 8 weeks of growth.

The regression coefficients associated with fresh weights of the shoots were also very low (Figures 13, 14; Tables 21, 22). As was the case with root fresh weights, the intercepts at each date approximately equalled the means for each date. The slopes of the regression lines were less than 0.04, indicating that the lines were probably horizontal and that increases of IBA applied to the cuttings did not result in greater growth of 'Morden Cardinette' cuttings after potting. This hypothesis was supported by the fact that plant height also appeared not to be affected by IBA concentration (Figure 11; Table 21).

These results agreed with those found by some other researchers. Bhujbal and Kale (1973), working with species of Rosa, did not find any differences between IBA levels with respect to the mean number of shoots and survival percentages of rooted cuttings after potting. The

size and vigor of treated plants ultimately did not differ from untreated plants of various species (Chadwick and Kiplinger, 1938).

The application of IBA did not influence the time of bud break at lower concentrations but appeared to slightly inhibit bud break at 7,000 and 10,000 ppm (Tables 21, 22). Jensen (1975), Moe (1973) and Eriksen (1968) observed that increased levels of IBA tended to decrease the number of buds which grew. However, they observed effects at 1,000 to 2,000 ppm, levels which did not evoke any response in this experiment. Moe (1973) also included results which indicated greater bud growth as IBA levels increased, but unfortunately did not comment on these. Kirkpatrick (1940) noted that rose cuttings with 25 or more roots were delayed in top growth. Chadwick and Kiplinger (1938) stated that growth regulators used in excessive concentrations for the species may inhibit bud development. It was entirely possible, therefore, that IBA concentrations used in this experiment were non-toxic to 'Morden Cardinette' and J1, and did not greatly inhibit bud break. The optimal concentration for adventitious root production is usually just below the toxic point. An effective concentration for root promotion is characterized by swelling and callusing of the basal portion of the stem and profuse root production just above the base of the cuttings (Hartmann and Kester, 1975). This type of root development occurred in this experiment, indicating that the toxic level was perhaps very close to 7,000 ppm. As there were no concentration levels between 3,000 and 7,000 ppm, it was not known whether the 7,000 ppm was the optimum or if it was located on the decreasing portion of the response curve. If this latter situation was the case, then the 7,000 ppm level could have been slightly toxic, explaining the slight inhibition of bud break.

The number and length of roots per cutting did not differ between the water and talc (0 ppm IBA) treatments, however, the fresh weight of roots was greater for the talc treatments. It appeared that talc may have slightly promoted rooting of 'Morden Cardinette' cuttings although this difference was not very large. Other researchers have observed promotion of adventitious rooting by talc (Hartmann and Kester, 1975). There was no effect on the growth of the cuttings after potting. Captan did not have any effect on the rooting or survival of 'Morden Cardinette' cuttings. Growth and survival after potting were not affected by applications of Captan or Captan plus IBA to cuttings. These observations disagreed with reports in the literature but, as some results showed beneficial effects (Snyder, 1966; Grigsby, 1965) while others showed unsatisfactory responses (Hocking and Thomas, 1979), no response as in this study was quite realistic.

Date. Differences in rooting occurred between cuttings of 'Morden Cardinette' and J1 taken at different dates throughout the summer which corresponded to various times after the stock plants began growth in February. This observation agreed with many accounts in the literature (Klahr and Still, 1979; Waxman, 1965; Eriksen, 1968; Kirkpatrick, 1940). As seen in Figures 7-10 (Tables 19, 20), rooting of 'Morden Cardinette' and J1 cuttings decreased as the growing season progressed. Mercedes-Flores and Kester (1966) and Smith and Wareing (1972) also noted poorer rooting of Prunus and Populus cuttings towards the end of the summer.

The number of cuttings of J1 which rooted at dates 1, 2 and 3 differed by the chi-square test of independence; rooting decreased progressively at each date (Figure 8; Table 20). The number of roots, total and average main root lengths, total and average root lengths (branch

lengths included) and fresh and dry weights of roots per cutting were greater at date 1 than date 2 or 3, the latter two dates not differing significantly (Figures 8, 10; Table 20). The fresh weight per root appeared to be maximized at date 1. The branch length and number did not follow any discernible trends and accordingly the values were not analyzed. Rooting of J1 cuttings appeared to be maximized when taken in May (date 1) compared to June (date 2) or July (date 3).

All measures of rooting of 'Morden Cardinette' cuttings differed between the four dates (Figures 7, 9; Table 19). As seen in Figure 7, the number of cuttings rooted decreased as the season progressed. Other researchers have also noted better rooting of rose cuttings in early summer. Eriksen (1968) found 80% rooting of cuttings taken June 9 and 44% rooting when cuttings were made July 21. Cuttings of R. multiflora rooted well in June and July, although no figures were listed (Brandon, 1939). The number and length of branches per rooted cutting was slightly greater at date 2, than at dates 1 or 3, although the time of taking cuttings did not appear to have a pronounced effect on the production of root branches, except at date 4, when branches were not produced. This lack of branches at date 4 may have been due to the poor rooting of cuttings and the short root lengths. This reasoning was supported by the observations of Orlov (1977) and Cameron and Thomson (1969) who noted that adventitious roots of Rosa spp. and Pinus radiata grew to several centimeters in length before branch roots developed. The total length per root, which included both main and branch roots, the main length per root and the fresh weight of roots per cutting were greater for cuttings taken at dates 1, 2 and 3 compared to date 4, but did not differ between dates 1, 2 and 3. The fresh weight per root was greatest at date 3, equal at date 1 compared to

date 2 and lowest at date 4. The number of roots per cutting taken at dates 1, 2 and 3 were greater than cuttings taken at date 4. Lengths of main roots per cutting did not differ at dates 1, 2 and 3, but were shorter at date 4. The total root length per rooted cutting reflected the response of the main root length and was, therefore, not presented in the figures. Overall then, it appeared that rooting of cuttings taken at dates 1, 2 and 3 did not differ widely, although there was a trend of decreasing rooting as the season progressed. Rooting of cuttings taken at date 4 was reduced compared to rooting of cuttings from dates 1 to 3.

The interaction of date and IBA concentration was significant for rooting of 'Morden Cardinette' cuttings and was due mainly to the 7,000 and 10,000 ppm treatments at date 4. The rooting of cuttings at dates 1, 2 and 3 followed the same shaped response curves for increasing IBA concentrations. Rooting at dates 1, 2 and 3 generally increased to 7,000 ppm then levelled off or decreased at 10,000 ppm, whereas cuttings taken at date 4 increased rooting with increasing hormone concentrations to 3,000 ppm. There was no additional rooting response to 7,000, 10,000 and 15,000 ppm IBA. It appeared that some factor, or factors, limited rooting as the season progressed especially between dates 3 and 4. During this time, it appeared that an internal change occurred which prevented increased rooting response as IBA levels increased.

Temperatures decreased slightly in August and September in the propagation house (Table 16). Light intensities did not show any pronounced changes over the experiment (Table 17). The temperature and light measures taken were not detailed enough to provide more than a general trend and it was impossible to state conclusively whether or not temperature or light

intensity were causal variables of the seasonal fluctuation in rooting. However, it did not appear that light intensity or temperature influenced rooting to any great degree.

The length of photoperiod has been found to influence rooting (Kelley, 1965), usually increasing it under long day (LD) and decreasing it under short day (SD) photoperiods (Whalley and Cockshull, 1972; Piringer, 1961; Nitsch, 1957). During this experiment the total monthly hours of light in May, June, July, August, September and October were 447, 489, 493, 448, 380 and 334, respectively (Table 17). The decrease from July to August indicated the period when shorter daylengths began. The pronounced decrease in rooting of 'Morden Cardinette' cuttings occurred when cuttings were taken during August indicating a possible photoperiodic influence.

A preliminary trial was performed during September, 1980, using cuttings of 'Morden Cardinette' and 'Cuthbert Grant' to evaluate rooting under natural and extended photoperiods. Cuttings were rooted in the propagation bed under natural daylength and in an unheated greenhouse where fluorescent lights were turned on from 11:00 p.m. to 1:00 a.m. The lights served to create long-day conditions without greatly increasing photosynthesis. A root scale rating of 1 to 10 was used and rooting indices were calculated. Cuttings under natural daylength (short-day conditions) rooted to a rooting index of 153 for 'Morden Cardinette' and 128 for 'Cuthbert Grant'. Rooting indices of cuttings rooted under long-day conditions were 71 and 53, respectively. The differences between LD and SD cuttings for each cultivar indicated that long days might well have had a beneficial effect on the degree of rooting, though not on the number of cuttings rooted. Moe (1973) also found that rooting of R. x 'Garnette' was promoted during short-day conditions if supplemental

light was supplied. The results outlined so far in this discussion have supported the possibility that the decrease in rooting at date 4 was due to a photoperiodic response but does not constitute a basis for conclusive explanations.

The onset of dormancy in woody plants sensitive to photoperiod lengths appears to be induced by short days as reviewed by Wareing (1956). In 1946, Chouard showed that dormancy was induced in a species of Rosa by short daylengths. Vietez and Pena (1968), working with Salix atrocinera, noted that cuttings which were rooted in September produced few roots of short lengths. They found that this phase of rooting coincided with the fall and the start of winter dormancy. Cuttings of Populus nigra also rooted poorly in the period which coincided with the onset of winter dormancy (Nanda and Anand, 1970). There was no information available to predict the critical daylength when induction of dormancy could have begun in 'Morden Cardinette'. It was, therefore, only possible to suggest that decreasing photoperiods may have initiated internal changes which affected rooting. However, there were no external signs of dormancy such as senescing leaves when the cuttings were taken in August.

In many experiments cited in the literature, outdoor stock plants were used, so seasonal and growth interactions were impossible to separate. Stock plants of 'Morden Cardinette' and J1 were removed from cold storage in February and placed in the greenhouse, therefore growth began earlier than plants outside. Any discussion of seasonal changes in rooting was complicated by the fact that the interaction of photoperiod and growth stage of the indoor stock plants may have resulted in varied internal states compared to plants outdoors.

Progressive decreases in internal auxin levels through the season

have been measured and correlated with decreased rooting (Nanda and Anand, 1970; as reviewed in Wareing, 1956). Nanda and Anand (1970) observed that vigorous rooting occurred when cuttings were taken during the beginning of growth when auxin levels were high. Cuttings of 'Morden Cardinette' were taken from the first flush of growth of the stock plants at date 1 and, as these cuttings appeared to root the best of all dates, the results agreed with those of Nanda and Anand (1970). Carrying this hypothesis further, supposing auxin was limiting to root production and endogenous levels decreased through the season, then the optimum IBA concentration for root production would have been progressively lower at each date, assuming exogenous auxin was substituted for the internal auxin. This did not appear to be the case as the rooting response curves were all basically the same shape at dates 1, 2 and 3, having optimums of approximately 7,000 ppm. Rooting of cuttings taken at date 4 seemed to increase as IBA levels increased to 3,000 ppm, then did not respond to further increases of IBA. It appeared as if auxin was perhaps slightly limiting until August because rooting was increased by the addition of IBA. No measurements of auxin levels were taken so it was not known if increased rooting was correlated with higher auxin levels. Vieitez and Pena (1968) found some correlations between endogenous IAA and rooting. This correlation was not consistent enough throughout the season to say that the rooting response was governed by IAA. Alternatively, the cause of adventitious root inhibition in August may have been due to other causes, such as rooting cofactors or inhibitors (Hess, 1965; Nitsch, 1957).

The stock plants were used as stock plants the previous season and if cuttings were consistently removed, carbohydrate reserves possibly decreased in the stock plants and also in each successive group of cuttings.

The removal of cuttings essentially pruned the plants decreasing the leaf area. As the older leaves still left on the plant would have decreased in photosynthetic capacity, due to their age, a drain may have occurred on the total carbohydrate reserves. Adventitious root production by softwood cuttings has been correlated with levels of carbohydrates in the cuttings (Nanda et al., 1971; Bala et al., 1970). Removing many cuttings may have also disrupted the internal balance in the stock plants of 'Morden Cardinette'.

Rooted cuttings of J1 and 'Morden Cardinette' taken at different dates also differed in survival and subsequent growth. Cuttings of J1 taken at date 1 had a survival rate of 14 of 24 cuttings, compared to cuttings taken at date 2 of which only five survived (Table 22). All cuttings from date 3 did not survive. The data from date 2 were too incomplete to analyze statistically so no comparisons were made between dates 1 and 2 other than survival rates. Cuttings of J1 did not root particularly well and plants did not grow vigorously, especially as the season progressed. It was probably the combination of these two factors that accounted for the pronounced decrease through the season in plant survival after potting.

Survival rates of 'Morden Cardinette' cuttings after potting also decreased throughout the summer, although not as dramatically as those of J1. Numbers of plants which survived at dates 1, 2, 3 and 4 were 22, 18, 12 and 10, respectively (Figure 11; Table 21). Survival at date 1 was greater than date 2 which in turn was greater than date 3; survival at date 3 did not differ significantly from date 4. The time of bud break after potting did not appear to be affected by the time of taking the cuttings. Shoot fresh weight per root weight followed the same seasonal

pattern as survival rates. Shoot fresh weights obtained from cuttings throughout the summer decreased at each successive date. The weights from cuttings at dates 2, 3 and 4 when cuttings were expressed as a percent of the weight from date 1 cuttings were 77%, 45% and 28%, respectively. All differences were significant. Response curves of heights taken at the time of fresh weight corresponded to those of shoot fresh weights. Heights of the plants taken at midway through the experiment were equal for dates 1 and 2 but less for date 3 and the lowest at date 4 (Table 21).

It appeared that differences in growth between cuttings taken at the four dates occurred fairly early in the growth of the plant. The fresh weight of the roots from dates 1, 2 and 3 did not differ but all were greater than those at date 4.

Minimum and maximum air temperatures only decreased slightly in the greenhouse from June to September (Table 18). Mean temperatures of the growing media and mean light intensity changed little over the summer (Tables 16, 17). It seemed unlikely that these parameters had significant effects on survival and growth of cuttings after potting.

Rooting generally decreased over the season, therefore cuttings rooted at the four dates were planted with differing amounts of roots. The number of roots of the cuttings at the time of planting did not appear to affect the final plant growth as shown by the rooting responses to increasing IBA concentrations (Table 19). The decrease in growth of cuttings taken throughout the season was probably not due to a decrease in rooting, but rather may have been due to some factor, or factors, affecting the growth process. Decreased top growth of cuttings which were taken later in the season was also observed for cuttings of Syringa vulgaris. Cuttings which were taken later in the season did not make

appreciable top growth during the same season (as reviewed in Kozlowski, 1971). Marston (1969) also noted higher quality rose plants resulting from cuttings taken early in the summer compared to cuttings taken in early autumn.

As with the cuttings, the initial carbohydrate levels of the stock plants may have influenced responses throughout the season. Possibly the initial growth was supported by the carbohydrates in the stem and leaf of the cutting. If the carbohydrate levels of the stock plants were lower as the season progressed, for reasons previously discussed, the initial growth of the cutting may have been limited. When the leaves developed and the plant began to rely on its own photosynthate, the differences already developed between the plants at the four dates may have been such that they could not be eliminated. Other internal factors of the stock plants which may have affected rooting may also have had some influence on the subsequent plant growth.

The daylengths under which the plants were grown may have influenced the extent of their development. Extension growth and elongation in woody plants have been shown to be affected by daylengths of woody species (as reviewed in Wareing, 1956). Chourd (1946) found that plants of Rosa pernetiana decreased extension growth under SD conditions. This decrease was due to an earlier cessation of growth, which resulted in a lesser number of internodes and reduced extension. It should be noted that cuttings of 'Morden Cardinette' taken in May grew in June and July; cuttings taken in June grew in July and August; cuttings made in July grew in July and August; and plants from August cuttings grew throughout September and October. The photoperiod decreased from July to October as listed in Table 17. Both fresh weight and height of the shoot decreased

throughout the summer, thus supporting Chourd's results. The fresh weight of the roots at dates 1, 2, 3 and 4 probably did not differ because the initial fresh weights of the cuttings were not very different in terms of actual weights and any differences which may have been present at the end of the season may have slight and non-significant differences due to variability and the lack of precision needed to show differences. It must be noted that it was not possible to ascribe the growth responses solely to the photoperiodic changes but merely to suggest daylength as a possible causal factor. More tests would have to be carried out to determine the exact effects of photoperiod lengths on the growth of 'Morden Cardinette'.

Any discussion of possible explanations for differences between the plant growth of cuttings rooted at various dates then grown was made increasingly complicated by the fact that more factors may have acted on the plants than on the cuttings. There may have been effects carried over from the stock plants and cuttings, and also direct effects on the plants themselves.

The time of taking cuttings appeared to be important for overwintering the plants the first winter. Eriksen (1968) found that 97% of the cuttings taken in early June survived the winter, while only 35% survived the winter from mid-July cuttings. The crucial factor was the maturation of the shoots before winter. A preliminary experiment was performed in 1979 which indicated better survival of 'Morden Cardinette' cuttings taken early in the summer than cuttings taken later.

By integrating the results determined for cuttings and for plants, it appeared that cuttings with few roots developed into plants equal in size to cuttings planted with many roots. Possibly the cuttings with

larger root systems underwent greater root damage during planting compared to the cuttings with fewer roots as it was harder to plant cuttings with large root systems without breaking some roots compared to planting cuttings with small root systems. If this was the case, two groups of cuttings could have been essentially equal in terms of the amount of effective roots at planting, and thus theoretically supported equal amounts of shoot growth. In this experiment, however, the perlite:peat moss mixture provided a cohesive medium so that all cuttings were transplanted with a minimum amount of root damage. Perhaps only a critical number of roots was needed, beyond which time allowed for rooting was wasted.

The lack of differences between the time of bud break of the IBA-treated cuttings indicated that growth of all cuttings appeared to begin at approximately the same time. Photosynthesis of the shoot was probably near maximum most of the time because water, light, and nutrient supplies did not appear limiting. Root growth generally depends to a large degree upon the supply of photosynthetic products and growth hormones from the shoot. If photosynthesis is not limiting, then shoot growth occurs and excess photosynthate is transported to the root for growth processes (Kozlowski, 1971). It was hypothesized that shoot growth occurred similarly in cuttings treated with different IBA concentrations and also that substances were probably transported to the root, supporting its growth. The differences among root fresh weights of the cuttings were not large in terms of actual weights because the root lengths were short and the numbers relatively low. With this in mind, and the hypothesis that photosynthate was transported to the root, enhancing growth, it was realistic not to observe any differences between the root fresh weights of the plants. However, in stressed environments or under sub-optimal conditions a less

developed root system may have a decreased ability to supply water and nutrients to the shoot. This could limit shoot growth to a greater degree than well-rooted cuttings and result in varying plants.

Variability. A separate section discussing variability was appropriate because the coefficient of variability (CV) was very high in this experiment. The CV is a measure of relative variation, independent of the unit of measurement used and the higher the percentage the greater the variation. Low CV values (less than 15%) are desirable but certain material, such as fruit trees, appear to be associated with high variability and thus high CV values (20% to 54%) (Pearce, 1949; Batchelor and Reed, 1918). The CV values associated with rooting experiments in 1979 ranged from 10% to 20%, usually about 13%, while those found in experiment 7 were 76% to 95%. It appeared that the very high variability was perhaps isolated to the cuttings or to the rooting phenomenon, compared to measures of plant growth. Coefficient of variability values for shoot weights were 14% to 27% and for root weights were 12% to 31%.

The differences between the CV values in 1979 and 1980 may have been accounted for by two causes. A liquid-IBA dip was used in 1979 experiments compared to the IBA-talc formulation applied in 1980. The CV's associated with root length and number when cuttings were dipped into a liquid-IBA solution were 35% and 39% compared to CV's of 76% to 95%, in 1980 when powder-IBA preparations were applied. These were only broad comparisons as it was recognized that many other factors could have contributed to the variability because the cuttings were taken in two different years from one- and two-year stock plants. However, the variability was probably partly caused by the method of IBA application. Hartmann and Kester

(1975) stated that uniform results were difficult to obtain using powder-IBA preparations due to the variability in the amount of powder adhering to the cutting. The uptake of IBA from ethanol-water solutions was not influenced as much by surrounding conditions as was the case with powder application, therefore the uniformity was higher.

Secondly, a root scale was used in 1979 to evaluate rooting, whereas actual numbers and lengths of roots were measured in 1980, the latter evaluation being obviously more variable. In the preliminary root hormone experiment, performed in 1979, both methods of root evaluation were practised. The CV value for the root scale ratings was 14% compared to the root length and root number which were associated with 35% and 39%, respectively.

The nodal position and maturity of the bud were separated in statistical blocks whenever possible. The size and woodiness of the cuttings were usually correlated to the nodal position on the stock plant. The variation between replicates was almost always non-significant which indicated there was little effect due to nodal position, size and bud maturity of 'Morden Cardinette' cuttings.

Although very high variability was not consistently mentioned in the literature, certain researchers did recognize the occurrence. Brandon (1939) did not find a close agreement between replicates when working with Rosa spp. She concluded that large numbers of cuttings must be used to ensure uniform results. Experiments involving the rooting of cuttings have had CV values of 30% to 50% and in a few cases much higher (personal communication; Chong, 1981). Eliasson (1980) using pea stem cuttings, found a variation in the number of roots per cutting from one experiment to another. Variations in 15 to 30 roots per cutting for the control

treatment were noted. No reason for this variation was known. Vieitez and Pena (1968) stated that variations in root shape and the manner of rooting on cuttings of Salix atrocinerea were not easy to explain or correlate with other physiological phenomena in the plant.

If the high variability in experiment 7 occurred as a result of inequal amounts of powder adhering to the stem, the variances should have increased at higher IBA concentrations. The talc had little or no effect on rooting, therefore extra particles of it adhering to the cutting would not have influenced rooting. The CV's associated with each concentration level at each date did not vary systematically, indicating that the variances for each concentration were probably equal. Following from this observation was the hypothesis that there must have been a single factor or factors contributing to this variance. The variance associated with the 0 ppm treatment was lower than the IBA treatments indicating that the application of IBA may have increased the variation in rooting, but the observation that within the 0 ppm treatment, the cuttings still had high CV values indicated other sources of variation. Hartmann and Kester (1975) stated that:

> "--- Fluctuations in adventitious root formation by cuttings of woody plant species maintained under what appear to be constant conditions have been an an obstacle to the complete understanding of the process of regeneration of an intact plant".

Smith and Thorpe (1975 a,b) found variations in the mean number of root primordia found in cuttings grown under constant conditions. They also looked at the fluctuations in rooting of Pinus radiata D. Don cuttings taken a few days apart and rooted under constant conditions (Smith and Thorpe, 1976). Variations in the number of root primordia per cutting ranged from 3 to a high of 16 primordia. They did not know if this

fluctuation was part of a regular cycle. The effects of exogenous compounds varied from experiment to experiment. The possibility existed of daily variations in the physiological state of the experimental material and could have accounted for contradictory reports in the literature on the effects of applied growth substances (Smith and Thorpe, 1976).

Despite the existence of high variability, rooting experiments appear to be reproducible (personal communication; Chong, 1981). Smith and Thorpe (1976) concluded that, despite variations in rooting, they were confident of the treatment effects if the standard errors of the means did not overlap. It appeared then that the high variability associated with the rooting parameters in experiment 7 was probably due to unequal amounts of powder adhering to the cuttings, the type of measurements taken and the innate variability between the cuttings. According to the literature, although variability was high, results should have reflected the rooting response of the population if statistical differences were found.

Morphological Features

All cuttings treated with 7,000 or 10,000 ppm IBA had developed callus tissue within 5 days after insertion. Stem diameters doubled due to development of sub-epidermal callus. In many cuttings the callus began to emerge on the side of the leaf and axillary bud, splitting the epidermis, then developed around the stem to form a complete ring. Throughout the rooting, the callus rarely developed on the basal cut surface of the cutting. By the 5th day, the base of the cuttings treated with 0 or 20,000 ppm IBA appeared swollen due to sub-epidermal callus development.

Pressure of the callus tissue had begun to split the epidermis of

the cuttings of the 0 ppm treatment by day 7. Cuttings treated with 20,000 ppm IBA had callus development encircling the stem and beginning to split the epidermis under the leaf. Tincker (1938) also observed that callus developed internally and pressed outwards, usually breaking the bark. By day 9 callus had developed partially around the stems of cuttings which had been treated with 0 ppm IBA and had developed completely around those treated with 20,000 ppm IBA. Some cuttings of the 7,000 and 10,000 ppm treatment developed quite extensive amounts of callus tissue at the base and up the stem of the cutting. Even at this point in root development, wide variation was noted, two cuttings of the 7,000 ppm treatment showed internodal and basal callus development and supported protrusions resembling the rudiments of adventitious roots, while the other two cuttings had only developed intermediate amounts of callus.

All cuttings of the 0 ppm treatment were callused by the 13th day after their insertion. Two cuttings of the 20,000 ppm treatment had developed one and two short roots while the remaining two cuttings had only callus. Cuttings from the 7,000 ppm treatment were varied: two were heavily callused, another had one root initiated and the remaining two cuttings had developed seven and 13 roots. All cuttings which were treated with 10,000 ppm IBA had developed roots by this point, averaging more roots per cutting than those of the 7,000 ppm treatment. When many roots were initiated almost simultaneously, they tended to emerge in vertical rows from the internodal epidermis. Orlov (1977) also noted this type of root emergence for other species of roses.

Sixteen days after the IBA applications, roots began to develop on some of the cuttings of the 0 and 20,000 ppm treatments while roots had formed on all cuttings treated with 7,000 and 10,000 ppm IBA. All

cuttings from the four treatments had rooted 21 days after the hormone had been applied. Although the number of roots produced by each cutting did not differ greatly, cuttings which had been treated with 7,000 or 10,000 ppm IBA averaged longer roots than those treated with 0 or 20,000 ppm. It should be noted that these results were observational and statistical analysis was not performed. There appeared to be necrotic tissue at the base of some cuttings of the 10,000 ppm treatment which may have been caused by IBA toxicity, but this was not known conclusively. High quantities of auxin have injured or killed tissue of cuttings (Hess, 1969; Tincker, 1938). Frequently roots developed in longitudinal lines from the internodes of cuttings treated with 7,000 or 10,000 ppm IBA. Tincker (1938) also noted this type of root development at high hormone concentrations. All adventitious roots which developed were white, succulent and very brittle, in accordance with results found by Brutsch et al. (1977) and Cameron and Thomson (1969). By the end of the experiment, the leaves of the 10,000 ppm treated cuttings were becoming more chlorotic than cuttings of the other treatments. This observation was concurrent with that of Kirkpatrick (1940) who found yellowing of the leaves of rose cuttings treated with high concentrations of growth substances.

CONCLUSIONS

1) Leaf-bud cuttings appeared to be a feasible method of propagating Rosa x 'Morden Cardinette' plants.
2) The type of rooting medium did not affect the degree of rooting of cuttings but influenced the type of root systems which developed.
3) The use of containers during the propagation of 'Morden Cardinette' plants did not affect rooting, subsequent greenhouse growth in pots or growth in pots and frames outdoors.
4) Applications of IBA increased rooting more than applications of indole acetic acid or naphthalene acetic acid. As the concentration of IBA increased to 7,000 ppm, the rooting of 'Morden Cardinette' cuttings increased. The concentrations of IBA applied to 'Morden Cardinette' cuttings did not affect the survival, shoot height or shoot fresh weight of the cuttings after planting, although cuttings which were only callused or cuttings with few roots did not survive after planting.
5) Rooting and subsequent growth of cuttings taken in August were decreased compared to cuttings taken in May, June or July.

RECOMMENDATIONS

1) Potted stock plants overwintered in cold storage should be used to enable propagation to begin during spring, before outdoor plants can develop new growth for cuttings. However, outdoor stock plants may be a suitable source for later cuttings of 'Morden Cardinette'.
2) One-year-old potted plants are more suitable for stock plants than are two-year-old plants, due to the predominance of thick woody stems unsuitable for cuttings of the two-year-old plants.
3) Leaf-bud cuttings are a feasible method of propagating 'Morden Cardinette'. Chances of survival and growth may be increased if two or more leaves are used, however, the number of leaves from one plant suitable for cuttings is limited.
4) Cuttings of 'Morden Cardinette' should be taken earlier in the growing season than July to ensure good rooting and growth.
5) Applications of 3,000 to 7,000 ppm IBA are recommended to increase rooting.
6) Cuttings can be rooted in the propagation bed or in containers then planted or rooted and grown within the same container. The use of containers for cutting propagation

of 'Morden Cardinette' does not affect rooting of subsequent growth if irrigation is applied.

7) Rooted cuttings may be grown equally well in pots or in frames. Field planting is suitable if irrigation is applied.

FURTHER RESEARCH

1) The effect of photoperiod on rooting and growth of 'Morden Cardinette' cuttings could be studied. The results would have practical implications in that the season suitable for rooting cuttings could be lengthened artificially if long day conditions promoted rooting.
2) Endogenous levels of hormones, especially indole acetic acid, carbohydrates, nitrogenous compounds and enzymes could be monitored throughout the season in the stock plants and cuttings, then correlated with rooting. The influence of pruning on endogenous compounds could also be studied simultaneously to determine the effect of repeatedly removing cuttings from the stock plant. Experiments could be performed to differentiate any changes of endogenous compounds due to photoperiodic and natural growth cycle changes.
3) If cuttings could be rooted late in the season under artificially lengthened photoperiods, a production procedure would have to be established for growth and overwintering of the cuttings. Perhaps a dormant period need not be imposed and the plants could grow throughout the winter within a cool greenhouse. Alternatively, the cessation of growth and onset of dormancy could perhaps be controlled by light and temperature regimes.

4) The influence of the number of leaves per cutting could be investigated to determine an optimum number for maximization of plants surviving and growth associated with a realistic degree of input time and maintenance.

5) Anatomical sections could be studied to determine the tissue of origin of adventitious roots of 'Morden Cardinette'. Also the amount and location of callus could be correlated with rooting.

6) Detailed anatomical and chemical studies of the effect of exogenously applied auxin would be valuable to the understanding of adventitious root promotion by auxins. Does root initiation begin earlier, in different tissues or by different developmental stages compared to cuttings among various auxins? What is the exact mechanism by which these exogenously applied auxins promote root formation, or is there more than one mechanism?

7) Histochemical studies could be performed to relate chemical compounds to physical events during adventitious root initiation and development.

8) The cause of why adventitious roots of 'Morden Cardinette' cuttings develop in vertical rows could be investigated.

9) Experiments could be designed to evaluate the transplant shock of cuttings rooted in various containers and grown in stressed environments.

10) Tissue analyses of 'Morden Cardinette' plants illustrated that the internal nutrient levels were marginally sufficient. A study involving various fertilization

regimes would be very beneficial to optimizing conditions for growth of 'Morden Cardinette' plants.

11) Problems have been encountered at the end of the growing season in that some plants of 'Morden Cardinette' retain their leaves too long. Possibilities of inducing leaf drop could be investigated.

12) Guidelines for the greenhouse growing and blooming of 'Morden Cardinette' plants must still be established. Temperatures, nutrients, light intensities, time of disbudding and pruning are main factors affecting the time to flowering and the resulting plant shape and flower colour.

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APPENDIX

Table 9. Measurements of physical properties of media used in experiment 1.[z]

Medium	g per cm^3		Water at saturation		Water at field capacity			% Total porosity
	Particle density	Bulk density	% Wt basis	% Volume basis	% Wt basis	% Volume basis	% Porosity	
Sand	2.70	1.40	25	35	13	18	30	48
Turface	2.11	0.60	98	59	64	38	34	72
Shale	1.61	0.80	70	57	42	34	16	50
Peat moss	1.22	0.07	1090	79	764	56	38	94
Perlite	0.51	0.12	490	60	227	28	48	76
Sand:Turface	2.48	1.23	37	45	24	29	21	50
Sand:Shale	2.16	1.34	32	42	20	27	11	38
Sand:Peat	2.43	0.86	66	57	52	44	21	65
Sand:Perlite	1.91	0.86	47	41	19	17	38	55
Turface:Shale	1.73	0.74	77	57	49	37	20	57
Turface:Peat	1.99	0.37	204	76	134	50	31	81
Turface:Perlite	1.27	0.39	143	56	89	39	30	69
Shale:Peat	1.58	0.60	119	72	87	53	9	62
Shale:Perlite	1.31	0.53	109	58	66	35	25	60
Peat:Perlite	0.60	0.08	756	59	537	42	45	87

[z]Tested by the Manitoba Provincial Soil Testing Laboratory.

Table 10. Relative weights, ease of handling and comments for rooting media tested in experiment 1.

Medium	Relative weight	Ease of handling	Comments
Sand	heavy	easy	cuttings difficult to remove as wet sand compacts
Turface	heavy	intermediate	thick roots
Perlite	light	difficult	not dense enough to hold cuttings in place, roots were short and thick, cuttings were easy to pull out
Shale	intermediate to heavy	easy	numerous branches, long roots, small diameter
Peat moss	intermediate	difficult	hard to separate peat fibers to get roots out, difficult to evaluate as roots grow through the fibers, peat was held together by the roots, small diameter of roots
Sand:Turface	heavy	easy	thick roots but longer and more developed than cuttings in perlite
Sand:Perlite	intermediate to heavy	intermediate	-
Sand:Shale	heavy	easy	-
Sand:Peat moss	intermediate	easy	roots were long and branched, medium adhered to roots upon removal
Turface:Perlite	intermediate	intermediate	thick roots, cuttings were easily removed
Turface:Shale	heavy	intermediate	well branched roots, thicker diameter than roots in shale alone
Turface:Peat moss	intermediate	intermediate to difficult	medium adhered to roots, well branched fairly thick roots
Perlite:Shale	intermediate	easy to intermediate	cuttings were easily removed, long roots, thicker roots than those in shale only
Perlite:Peat moss	light	easy to intermediate	cuttings were easily removed, medium adhered to roots upon removal
Shale:Peat moss	intermediate	intermediate	long roots, small diameter, well branched, roots broke easily

Table 11. Leaflet number of rose clones rooted in different containers and grown in pots.[z]

Weeks after potting / Rose clone	No. of leaflets per plant			
	Rooting container[y]			
	Propagation bed	Styroblock 20	Hillson	Mean
3 weeks				
Cuthbert Grant	32	28	21	27 a
Morden Cardinette	26	24	19	22 a
J1	14	12	13	12 b
Mean	24 a	21 ab	18 b	
5 weeks				
Cuthbert Grant	46	37	26	36 a
Morden Cardinette	47	27	26	33 a
J1	22	13	16	17 b
Mean	38 a	26 b	22 b	
6 weeks				
Cuthbert Grant	60 a	46 b	34 b	--
Morden Cardinette	59 a	35 b	35 b	--
J1	25 a	16 b	25 a	--

Clone and container interactions were not significant, 5% level, at 3 and 5 weeks but were significant at 6 weeks.

[z]Values are means of 30-32 cuttings.

[y]Means within containers and clones at 3, 5 weeks and within clones at 6 weeks followed by the same letter do not differ significantly by Duncan's multiple range test, 5% level.

Table 12. Shoot heights of rose clones rooted in different containers and grown in pots.[z]

Weeks after potting	Shoot ht (cm) per plant			
Rose Clone	Rooting container[y]			
	Propagation bed	Styroblock 20	Hillson	Mean
3 weeks				
Cuthbert Grant	14.65	13.80	9.60	12.68 a
Morden Cardinette	9.60	8.35	5.82	7.92 b
J1	4.30	5.50	5.62	5.14 c
Mean	9.52 a	9.22 a	7.02 b	
5 weeks				
Cuthbert Grant	20.95	16.65	11.58	16.39 a
Morden Cardinette	14.15	9.40	9.52	11.02 b
J1	7.68	5.98	5.90	6.52 c
Mean	14.26 a	10.68 bc	9.00 c	
6 weeks				
Cuthbert Grant	24.75	18.70	14.35	19.27 a
Morden Cardinette	15.95	10.72	10.75	12.48 b
J1	9.15	7.57	7.12	7.95 c
Mean	16.62 a	12.33 b	10.74 b	

Clone and container interactions were not significant, 5% level.

[z]Values are means of 30-32 cuttings.

[y]Means within containers and clones at each date followed by the same letter do not differ significantly by Duncan's multiple range test, 5% level.

Table 13. Shoot dry weights of rose clones rooted in different containers.[z]

Rose clone	Shoot dry wt (g)		
	Rooting container		
	Propagation bed	Styroblock 20	Hillson
Cuthbert Grant	8.128 a[y]	5.614 b	4.173 c
Morden Cardinette	3.847 a	2.028 b	1.971 b
J1	1.527 a	0.980 b	1.915 a

Clone and container interaction was significant at 1% level.

[z]Values are means of 30-32 cuttings measured 10½ weeks after potting.

[y]Means within rows followed by the same letter do not differ significantly by Duncan's multiple range test, 5% level.

Table 14. Root dry weights of rose clones rooted in different containers.[z]

Rose clone	Root dry wt (g)			
	Rooting container			
	Propagation bed	Styroblock 20	Hillson	Mean[y]
Cuthbert Grant	1.669	1.339	1.028	1.345 a
Morden Cardinette	0.658	0.393	0.398	0.483 b
J1	0.246	0.221	0.293	0.253 c
Mean[y]	0.858 a	0.651 b	0.573 b	

Clone and container interaction was not significant at 5% level.

[z]Values are means of 30-32 cuttings measured 10½ weeks after potting.

[y]Means within container and clone followed by the same letter do not differ significantly by Duncan's multiple range test, 5% level.

Table 15. Growth parameters of 'Morden Cardinette' cuttings rooted in containers and grown in pots, frames, Styroblock 20 and Tinus containers.[z]

Growth parameters	Rooting container						
	Peat pot	Hillson	Prop bed[y]	Styro 8[y]	Tinus[x]	Styro 20[yx]	PB - PP[y]
Pots							
Root fresh wt (g)	14.578 a[v]	12.815 a	13.810 a	12.735 a	13.279 a	11.563 a	--[w]
Root dry wt (g)	2.409 a	1.991 ab	2.048 ab	1.742 bc	1.522 bc	1.440 c	--
Shoot fresh wt (g)	39.689 a	30.347 b	24.144 c	23.241 c	15.047 d	14.332 d	--
Shoot dry wt (g)	13.152 a	9.736 b	7.747 c	7.230 c	4.618 d	4.993 d	--
Mid-season ht (cm)	15.79 a	14.53 ab	11.89 c	11.84 c	13.00 bc	11.82 c	--
End-season ht (cm)	28.34 a	27.45 a	25.81 a	20.48 b	21.16 b	18.88 b	--
Frame							
Root fresh wt (g)	5.733 a	4.387 a	4.255 a	3.762 a	--	--	6.446 a
Root dry wt (g)	1.667 a	1.247 a	1.228 a	1.071 a	--	--	1.936 a
Shoot fresh wt (g)	39.079 ab	27.114 bc	22.724 c	23.274 c	--	--	45.073 a
Shoot dry wt (g)	12.092 ab	8.200 b	7.055 b	6.824 b	--	--	13.968 a
Mid-season ht (cm)	13.926 ab	11.860 ab	11.084 b	11.066 b	--	--	14.818 a
End-season ht (cm)	37.616 a	32.700 ab	30.284 bc	26.934 c	--	--	37.618 a

Differences between pots and frames were significant at 5% level only for root fresh and dry weight. Pot and frame interaction with rooting container was non-significant, 5% level.

[z]Values represent means of 18-20 cuttings, measured 10 weeks after planting.

[y]Propagation bed, Styroblock 8, Styroblock 20, Propagation bed transplanted to peat pots at 3 weeks.

[x]Cuttings rooted and grown in these containers.

[w]Treatment not applied.

[v]Means within rows followed by the same letter do not differ significantly by Duncan's multiple range test, 5% level.

Table 16. Mean monthly temperatures of rooting and growing media used in experiments conducted during 1980.

Location	Media temperature °C				
	May	June	July	Aug	Sept
Propagation house	32.9	29.2	33.1	25.2	25.8
Greenhouse	--	25.8	29.6	24.2	25.7
Outside pots	--	--	32.0	24.0	26.6
Outside Tinus	--	--	28.3	24.6	24.1
Outside Styro	--	--	27.0	24.6	21.3
Outside Frame	--	--	35.1	26.4	25.0

Table 17. Mean light intensity and total possible hours of sunshine used in experiments conducted during 1980.

Location	Light intensity me M^{-2} sec^{-2}					
	May	June	July	Aug	Sept	Oct
Propagation house	944	1038	1077	1060	--	--
Outside	1787	1864	1998	1670	--	--
	Total possible hours of sunshine[z]					
Outside	477	489	493	448	380	334

[z]Source as per Environmental Canada.

Table 18. Minimum, maximum and mean air temperatures of rooting and growing locations in 1980.

Month	Location and temperature °C			
	Propagation bed	Greenhouse	Outside	
			Pots	Frame
May				
Min	16.7	-	-	-
Max	40.8	-	-	-
Mean	28.8	-	-	-
June				
Min	13.5	18.5	-	-
Max	40.2	32.2	-	-
Mean	26.9	25.3	-	-
July				
Min	16.9	16.3	14.7	14.1
Max	40.6	31.2	37.4	36.4
Mean	28.8	23.8	26.0	25.2
August				
Min	14.3	15.1	12.5	12.0
Max	35.9	30.2	31.2	33.3
Mean	25.1	22.7	21.9	22.6
September				
Min	12.8	14.2	11.4	10.1
Max	35.4	28.4	36.8	36.2
Mean	24.1	21.3	24.1	23.2

Table 19. Rooting measurements for 4 dates of 'Morden Cardinette' cuttings, 3 weeks after IBA treatments.[z]

Date[x]	Concentration IBA (ppm)	No. of roots	No. of branches	Fresh wt (mg)	Dry wt (mg)	Callus[y] rating	Fresh wt per root (mg)	Length per cutting (cm)						No. rooted of 24 cuttings
								Main root		Branches		Total root		
								Total	Mean	Total	Mean	Total	Mean	
Date 1 (May 13)	0	3.5	3.8	82.9	7.9	2.4	22.6	6.3	1.7	3.0	0.8	7.0	1.9	21
	1000	7.4	7.4	225.5	21.6	3.2	29.4	16.3	2.0	6.7	0.9	19.6	2.5	23
	2000	9.7	6.5	269.5	24.9	3.4	34.3	24.5	2.6	5.5	0.8	28.2	3.0	22
	2500	11.0	8.3	310.2	30.3	4.1	34.6	26.4	2.3	6.8	0.7	30.4	2.6	24
	3000	14.2	9.4	370.2	32.5	4.0	29.3	31.4	2.4	8.3	0.9	36.9	2.9	24
	7000	27.8	6.5	481.0	43.6	4.8	20.8	58.3	2.2	4.8	0.7	61.3	2.4	24
	10000	27.2	3.8	435.7	38.7	4.8	25.6	51.6	2.3	2.8	0.7	53.2	2.6	24
	Mean (IBA)	14.4	6.5	310.7	28.5	3.8	28.1	30.7	2.2	5.4	0.8	33.8	2.6	23
Date 2 (June 7)	Water	5.6	3.6	91.1	10.3	3.0	16.4	9.1	1.5	3.3	0.8	11.9	2.2	21
	0	5.8	6.6	161.4	15.7	3.0	29.4	12.8	2.2	6.5	0.8	16.0	2.8	20
	1000	9.0	7.4	231.4	20.4	4.0	26.4	19.8	2.2	6.4	0.8	23.2	2.8	21
	2000	7.1	12.6	276.0	24.8	3.3	38.8	22.5	2.9	12.4	0.9	31.5	4.3	22
	2500	8.3	10.0	241.2	22.6	3.5	30.7	19.8	2.3	9.0	0.8	26.0	3.1	23
	3000	10.6	10.3	327.9	29.1	4.2	29.0	28.8	2.5	10.2	0.8	34.1	3.1	23
	7000	23.0	9.8	574.9	45.7	4.2	28.8	64.0	2.9	8.0	0.9	70.6	3.3	23
	10000	24.0	10.3	515.3	40.1	4.7	25.2	61.4	2.4	11.0	0.9	67.8	3.0	24
	Mean (IBA)	12.5	9.6	332.6	28.3	3.8	29.8	32.7	2.5	8.2	0.8	38.4	3.2	22
Date 3 (July 17)	Water	3.3	--	66.9	5.7	3.2	20.1	4.5	1.3	--	--	4.5	1.3	16
	Captan	3.6	--	55.1	5.8	3.1	18.0	4.0	1.2	--	--	4.0	1.2	17
	0	3.6	5.7	108.0	9.0	3.9	26.4	6.2	1.5	5.5	0.8	7.2	1.7	17
	1000	5.0	7.9	187.5	16.0	4.1	33.8	11.7	2.1	7.3	0.8	15.2	2.7	19
	2000	5.7	4.9	230.9	20.0	3.6	42.9	14.8	2.6	4.3	0.8	17.6	3.2	20
	2500	6.1	5.4	243.5	20.2	3.7	38.6	15.8	2.4	5.1	0.8	19.3	3.1	22
	3000	7.6	8.3	348.8	28.1	4.2	41.1	23.9	2.7	7.4	0.8	28.7	3.3	20
	Captan + 3000	8.0	6.0	321.0	26.1	3.5	40.0	22.2	2.8	6.3	0.8	28.6	3.4	23
	7000	18.3	6.3	514.2	34.6	4.7	35.3	44.6	2.5	6.9	1.0	45.1	2.9	22
	10000	16.3	5.1	514.4	37.8	4.4	41.7	43.1	2.8	4.4	0.8	46.0	3.2	22
	Mean (IBA)	8.9	6.2	306.8	23.7	4.1	37.1	22.9	2.4	5.8	0.8	26.0	2.9	20
Date 4 (Aug 19)	Water	4.2	--	34.0	--	3.1	8.6	2.5	0.4	--	--	2.5	0.4	12
	Captan	3.3	--	31.9	--	2.8	9.7	2.0	0.6	--	--	2.0	0.6	17
	0	4.0	--	43.6	--	2.7	10.9	3.0	0.7	--	--	3.0	0.7	11
	1000	3.4	--	35.3	--	2.9	9.8	2.1	0.6	--	--	2.1	0.6	16
	2000	4.3	--	63.1	--	3.1	12.9	3.7	0.7	--	--	3.8	0.7	16
	3000	6.6	--	98.6	--	3.3	14.4	6.6	0.9	--	--	6.6	0.9	18
	7000	6.8	--	94.4	--	3.6	14.0	6.2	0.9	--	--	6.2	0.9	23
	10000	7.1	--	94.5	--	4.0	12.4	6.2	0.8	--	--	6.2	0.8	20
	15000	6.9	--	74.7	--	3.5	11.7	4.7	0.7	--	--	4.7	0.7	19
	Mean (IBA)	5.6	--	72.0	--	3.3	12.3	4.7	0.8	--	--	4.7	0.8	18

[z]Values are means of number of cuttings rooted.

[y]Callus rating. 1 - low, 5 - high.

[x]Stockplants began growth in February. Date is time of taking cuttings.

Table 20. Rooting measurements for 3 dates of J1 cuttings, 3 weeks after IBA treatment.[z]

Date[x]	Concentration IBA (ppm)	No. of roots	No. of branches	Fresh wt (mg)	Dry wt (mg)	Callus[y] rating	Fresh wt per root (mg)	Length per cutting (cm)						No. rooted of 24 cuttings
								Main root		Branches		Total root		
								Total	Mean	Total	Mean	Total	Mean	
Date 1 (May 13)	0	2.2	5.0	54.3	5.0	2.9	25.4	4.5	2.0	5.8	1.2	5.0	2.2	16
	1000	4.9	4.8	171.5	15.9	3.0	33.8	13.6	2.6	5.2	0.9	16.9	3.2	24
	2000	6.0	8.1	255.9	23.7	4.2	41.4	19.8	3.1	9.4	1.0	25.5	3.8	24
	2500	6.8	5.5	245.7	22.9	4.5	42.9	21.5	3.4	6.2	1.0	26.4	4.4	23
	3000	7.4	8.0	218.4	20.5	4.1	31.0	19.4	2.5	10.1	1.1	24.9	3.1	24
	7000	23.8	5.1	447.6	39.0	4.8	24.2	53.8	2.4	5.6	1.0	57.7	2.7	24
	10000	14.6	4.8	295.5	26.3	5.0	23.0	32.0	2.3	4.5	0.9	34.8	2.5	24
	Mean	9.4	5.9	241.3	21.9	4.1	31.7	23.5	2.6	6.7	1.0	27.3	3.1	23
Date 2 (June 7)	0	2.8	2.5	50.6	5.4	2.8	18.1	4.7	1.6	9.0	2.4	6.7	2.6	9
	1000	3.9	5.6	132.5	12.6	3.0	29.3	11.8	2.3	5.6	0.7	14.1	2.5	12
	2000	6.3	3.5	132.8	12.6	4.1	22.8	12.2	1.9	3.2	0.9	14.0	2.2	14
	2500	5.5	6.5	137.8	13.2	4.3	28.7	12.2	2.2	6.2	0.8	15.4	3.0	15
	3000	4.0	3.4	130.6	13.1	3.8	31.0	9.9	2.3	3.0	0.8	12.1	2.7	18
	7000	11.2	4.4	215.1	20.1	4.8	21.4	21.6	1.9	4.2	0.8	24.1	2.2	19
	10000	9.7	4.2	201.8	18.2	4.8	20.7	19.7	1.8	3.3	0.7	21.7	2.1	18
	Mean	6.2	4.3	143.0	13.6	3.9	24.6	13.2	2.0	4.9	1.0	15.4	2.5	15
Date 3 (July 17)	0	2.0	--	27.6	3.1	3.0	12.4	1.7	0.8	--	--	1.7	0.7	5
	1000	2.0	--	78.7	7.1	3.0	47.3	4.2	2.5	--	--	4.2	2.5	5
	2000	2.9	4.4	109.3	9.8	3.3	37.1	6.9	2.4	3.5	0.8	8.8	3.1	12
	2500	8.5	6.0	257.8	19.3	4.8	32.5	21.5	2.6	4.4	0.8	23.1	2.8	11
	3000	4.4	7.1	169.9	15.4	4.4	40.8	12.0	2.5	6.2	0.8	16.0	3.6	13
	7000	8.8	8.7	240.6	19.2	4.8	25.0	22.4	2.1	7.7	0.9	26.0	2.4	15
	10000	6.5	5.0	159.6	12.3	4.9	24.0	14.2	2.0	5.4	1.0	16.4	2.3	19
	Mean	5.0	6.2	149.1	12.3	4.0	31.3	11.8	2.1	5.4	0.9	13.7	2.5	11

[z]Values are means of number of cuttings rooted.

[y]Callus rating: 1 - low, 5 - high.

[x]Stockplants began growth in February. Date is time of taking cuttings.

Table 21. Growth measurements for 4 dates of 'Morden Cardinette' cuttings, 11 weeks after IBA applications.[z]

Date[x]	Concentration IBA (ppm)	Shoot wt (g)		Root wt (g)		Shoot/root wt (g)		Plant ht (cm)		Survival of 24 cuttings	Days to bud break[y]
		Fresh	Dry	Fresh	Dry	Fresh	Dry	Mid-season	End-season		
Date 1 (May 13)	0	3.091	0.972	1.583	0.198	1.999	4.984	6.4	13.5	21	7.6
	1000	3.489	1.102	1.869	0.215	1.940	5.235	8.2	14.2	22	6.1
	2000	3.885	1.260	2.178	0.262	1.810	4.790	9.6	14.4	23	9.2
	2500	3.537	1.258	2.073	0.243	1.750	5.352	9.8	14.6	22	6.9
	3000	4.184	1.398	2.351	0.288	1.886	5.062	10.3	15.1	23	7.0
	7000	3.763	1.245	2.201	0.264	1.726	4.829	8.8	15.2	19	11.7
	10000	3.572	1.161	2.198	0.258	1.663	4.502	8.1	13.8	21	11.3
	Mean (IBA)	3.646	1.199	2.065	0.247	1.825	4.965	8.7	14.4	22	8.5
Date 2 (June 7)	Water	2.784	0.889	1.811	0.256	1.429	3.476	8.1	11.3	15	7.1
	0	2.842	0.874	1.830	0.235	1.516	3.575	7.8	13.0	22	7.8
	1000	2.917	0.947	1.679	0.244	1.772	3.894	8.7	14.2	15	3.7
	2000	2.996	0.923	1.748	0.227	1.686	3.902	7.6	12.5	19	6.9
	2500	3.275	1.023	2.020	0.264	1.596	3.777	8.8	13.7	20	3.5
	3000	2.845	0.856	1.911	0.248	1.511	3.505	7.8	13.5	19	5.4
	7000	2.782	0.850	1.926	0.237	1.408	3.492	8.2	13.8	16	7.6
	10000	2.760	0.860	2.380	0.275	1.053	2.830	7.5	12.1	14	12.0
	Mean (IBA)	2.917	0.905	1.928	0.247	1.506	3.568	8.0	13.2	18	6.7
Date 3 (July 17)	Water	1.082	--	1.419	--	0.824	--	4.6	7.5	13	8.3
	0	0.939	--	1.384	--	0.704	--	4.4	7.6	14	8.4
	1000	1.727	--	1.755	--	0.987	--	6.3	11.1	15	8.6
	2000	1.705	--	2.038	--	0.817	--	9.0	11.7	11	8.0
	2500	1.595	--	2.056	--	0.705	--	5.4	10.6	8	10.5
	3000	2.408	--	2.542	--	0.929	--	7.4	14.4	14	7.1
	7000	1.587	--	2.073	--	0.772	--	5.9	9.8	14	9.2
	10000	1.690	--	2.010	--	0.815	--	5.6	10.3	11	9.8
	Mean (IBA)	1.664	--	2.000	--	0.818	--	6.3	10.8	12	8.8
Date 4 (Aug 19)	Captan	0.991	--	1.576	--	0.625	--	3.0	8.4	12	--
	Water	1.036	--	1.685	--	0.623	--	1.8	6.3	13	--
	0	0.655	--	1.138	--	0.592	--	2.4	5.4	14	--
	1000	1.152	--	1.681	--	0.757	--	2.6	7.7	14	--
	2000	1.470	--	1.735	--	0.866	--	3.2	7.6	6	--
	3000	1.218	--	1.660	--	0.870	--	2.2	6.8	11	--
	7000	1.476	--	2.000	--	0.760	--	3.9	8.4	7	--
	10000	0.861	--	1.135	--	0.801	--	1.5	6.1	11	--
	15000	0.949	--	1.468	--	0.641	--	2.8	6.1	8	--
	Mean (IBA)	1.111	--	1.545	--	0.755	--	2.6	6.9	10	--

[z]Values are means of number of surviving cuttings, 8 weeks after potting.

[y]Days after potting.

[x]Stockplants began growth during February. Date is time of taking cuttings.

Table 22. Growth measurements for 2 dates of J1 cuttings 11 weeks after IBA applications.[z]

Date[y]	Concentration IBA (ppm)	Shoot wt (g)		Root wt (g)		Shoot/root wt (g)		Plant ht (cm)		No. surviving of 24 cuttings
		Fresh	Dry	Fresh	Dry	Fresh	Dry	Mid-season	End-season	
Date 1 (May 13)	0	3.194	1.031	1.544	0.209	2.097	4.870	6.7	12.0	9
	1000	3.416	1.133	1.620	0.226	2.256	5.242	7.4	13.5	14
	2000	3.294	1.018	1.395	0.196	2.445	5.516	7.3	11.0	16
	2500	3.070	1.019	1.666	0.227	1.949	4.666	7.2	12.6	17
	3000	3.349	1.039	1.409	0.190	2.480	5.630	6.4	12.4	18
	7000	3.518	1.151	1.888	0.260	1.870	4.354	8.5	12.9	15
	10000	3.508	1.110	1.708	0.228	2.034	4.808	7.5	12.4	10
	Mean	3.336	1.072	1.604	0.219	2.162	5.012	7.3	12.4	14
Date 2 (June 7)	0	2.514	0.776	1.185	0.177	2.080	4.280	8.0	11.9	5
	1000	1.666	0.512	1.185	0.162	1.432	3.114	5.8	9.2	2
	2000	2.394	0.717	1.088	0.155	2.145	4.449	8.2	10.4	5
	2500	2.247	0.699	1.264	0.196	1.722	3.382	7.4	10.9	7
	3000	3.019	0.938	1.390	0.205	2.210	4.597	9.6	13.5	6
	7000	2.152	0.654	1.242	0.182	1.850	3.875	6.7	9.1	7
	10000	2.739	0.836	1.752	0.247	1.460	3.030	7.3	12.2	4
	Mean	2.390	0.733	1.301	0.189	1.827	3.818	7.6	11.0	5

[z]Values represent means of number of surviving cuttings, 8 weeks after potting.

[y]Stockplants began growth during February. Date is time of taking cuttings.