THE EFFECTS OF SLOW-RELEASE NITROGEN AND POTASSIUM ON THE PROPAGATION AND SUBSEQUENT GROWTH OF *ILEX CRENATA* 'HETZI', *PYRACANTHA COCCINEA* 'WATERI', AND *RHODODENDRON* X 'FASHION'

By

MICHEAL GEORGE CARNEY

Bachelor of Science in Agriculture

Oklahoma State University

Stillwater, Oklahoma

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Thesis Approved:

Carl W. Whitcomb
Thesis Adviser

Grant ...

D. J. Wadsworth

Norman N Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Asexual propagation by cuttings of most ornamental shrubs is currently the most widely used method in the nursery industry. There are at least two reasons for this popularity: (A) The maintenance of a cultivar or variety, and (B) shorter production time than with other methods. As a result, much research has been to increase the quality of the plant while decreasing production time.

There have been great advances in the area of plant propagation during the past half-century. The development of intermittent misting of cuttings during the 1950's hailed a new era of plant reproduction. To date, no single discovery has had as great an impact on plant propagation.

The discovery and use of root-inducing substances, such as IAA (indoleacetic acid), IBA (indolebutyric acid), and NAA (naphthalene-acetic acid), has also been an important factor in the progress of plant propagation. When properly used, these compounds enhance rooting of otherwise difficult-to-root cuttings. Rooting hormones have become a standard part of asexual propagation and research continues to improve their effectiveness.

The nutrition of stock plants from which cuttings are taken has also been identified as a major factor in asexual propagation. Although findings vary on this matter, it is generally agreed that nitrogen and potassium levels within a cutting along with its carbohydrate content have considerable effect upon root initiation and later growth of the cutting. Rooting media have probably received more attention from researchers than any other aspect of asexual propagation. Despite this, there is no one universally accepted rooting medium. It is generally acknowledged that a combination of several components (i.e., peat:perlite, peat:sand:pinebark, sand:vermiculite, etc.) will result in an acceptable medium if managed properly. Results using different rooting media vary with respect to species of plant being propagated, geographic area, and type of propagation system employed. Generally, a good propagation media will exhibit the following qualities: (A) good aeration for ample oxygen supply, (B) adequate water retention and drainage, (C) sufficient strength to hold the cutting upright, and (D) freedom from pathogens (12).

The nutrition of a cutting during rooting is a relatively new concept. During the 1960's, nutrient applications through misting proved to be somewhat beneficial to the cutting, although algae growth and blocked mist lines discouraged nursery workers from accepting this method (34). More recently, the use of nutrients incorporated into the rooting medium has proven beneficial to rooting and later growth of cuttings. With the introduction of controlled-release fertilizers in the 1960's, a new method of applying nutrients during propagation became available. Early investigators found that, when incorporated into the propagation media, a controlled-release fertilizer would allow nutrients to become available to the cutting over a period of time while avoiding excessive algae growth and mist line problems associated with nutrient misting (17). As the controlled-release fertilizer industry developed, various nitrogen/phosphorus/potassium formulations became available to the nursery worker. However, these formulations were designed for use in a container growing system using liners that had rooted and were ready to be transplanted into a second growing medium. Little research has been done to suggest an optimim formulation for use of a controlled-release fertilizer in a propagating medium.

This experiment was designed to study the effect of four levels of nitrogen in a controlled-release form combined with four levels of potassium also in a controlled-release form incorporated into a propagation medium. The rooting and subsequent growth and development of three species of ornamental shrubs were evaluated in an effort to determine an optimum ratio of nitrogen to potassium to be used during propagation.

CHAPTER II

LITERATURE REVIEW

The success of propagating a particular plant from a cutting depends upon a number of interrelated factors. Internal factors undoubtedly play a major role in the ability of a cutting to root but are largely uncontrollable by the propagator (12). Environmental factors, such as rooting media, stock plant nutrition, misting, and nutrition of the cutting itself, also influence the success of a cutting's rooting ability and can be controlled by the propagator to produce the most favorable results. Considerable research has been devoted to these areas in an effort to limit the amount of time and cost needed to produce a rooted liner that in turn will produce a quality, salable plant.

At the present, no one universally accepted rooting medium has been developed. However, it is generally agreed, that in order for a medium to be successful when used during propagation, it must exhibit certain characteristics. Hartmann and Kester (12) list the following requirements for a proper rooting medium:

(A) The medium must be sufficiently firm and dense to hold the cutting in place during rooting.

(B) It must be sufficiently retentive of moisture.

(C) It must be sufficiently porous that excessive water drains away, permitting adequate aeration.

(D) It must be free from pests and disease organisms.

Whitcomb (33) notes that there is no one ideal rooting medium but that several combinations of materials can provide a workable medium. Some of the more common materials used to compose a propagation medium include sand, peat moss, perlite, vermiculite, and pine bark. In various combinations, these components can meet the requirements of a propagation medium previously listed. Peat moss combined with some type of additive to increase air space (i.e., sand, perlite, vermiculite, etc.) will result in the most favorable medium for use during propagation, according to many researchers (5,11,19,20,23,24,31). Peat moss and perlite have been found to work well in a propagation system approximately two and one-half inches deep and can be used for rooting a wide range of woody plants under many different cultural conditions (3,33).

The nutritional condition of a stock plant from which a cutting is removed has a direct effect on the rooting ability and growth potential of that cutting. Preston, et al. (21) found that more cuttings were produced on azalea stock plants grown with high nitrogen application. However, succulent cuttings had a higher percentage of rooting when taken from stock plants grown under low nitrogen levels. Conversely, mature cuttings had a higher rooting percentage when taken from stock plants grown under high nitrogen levels. Varied levels of phosphorus and potassium applied to the stock plants had no discernable effect on rooting responses. High nitrogen levels resulted in a much higher survival rate of cuttings after eight months while varied levels of phosphorus and potassium had no effect on survival. Hess (14) noted that high nitrogen levels applied to stock plants had a detrimental effect on the rooting of cuttings taken from them. Nitrogen levels of the stock plant seemed to have the greatest effect of rooting.

A low nitrogen/high carbohydrate balance in the stock plant favors rooting of cuttings taken from them in many cases (12). This balance can be achieved in several ways: (A) reduce the nitrogen supply to the stock plants; thus, reducing shoot growth and allowing carbohydrate accmulation, (B) select portions of the plant for a cutting material that are in the desirable nutritive stage, (C) select regions of the shoot that are known to have a high carbohydrate content.

Some researchers recommend that cuttings should be taken from plants that have obviously received adequate fertilization (3,33). Those cuttings taken from plants showing nutritional deficiencies will give a lower percentage of successful rooting, take longer to root, and produce poorer quality root systems. Rooted cuttings from such plants take longer to begin growth when transplanted than cuttings from plants without nutrient deficiencies.

It has long been acknowledged that, in order for a cutting to root successfully, water loss must be kept to a minimum. Water content in a stem cutting is reduced by transpiration and evaporation from the leaves of that cutting. The most important contribution toward the reduction of water loss from a cutting was mist propagation (26). The application of mist to a cutting provides a film of water over the leaves which lowers their temperature, increases the humidity around the leaves, and reduces transpiration and respiration (12). This technique has allowed the plant propagator to root previously difficult-to-root cuttings with considerable success.

The earliest written report of the successful use of mist for rooting was by Professor M. A. Rains of Harvard University in 1940 (26). However, Snyder (26) speculates it is probable that the origin of the use of mist sprays for the rooting of cuttings was developed independently by four men: E. J. Gardner, G. E. L. Spencer, G. M. Fisher, and Rains, between the years 1936 and 1941. Misting became the subject of much research during the late 1940's and early 1950's as its immense value to plant propagation became apparent.

Constant mist rather that intermittent or "interrupted" mist was the rule during the early stages of mist development. Convenience and lack of knowledge about the effects of mist applications can probably be cited as the reasoning behind this. Hess (13) listed several advantages of intermittent mist in 1954. They included a decrease in leaching of elements from plant foliage, elimination or reduction of problems associated with drainage and oxygen displacement from the medium, and simplication of hardening-off techniques.

Since the incorporation of intermittent misting techniques into the propagation system, the basic principles of misting have not changed substantially, although the techniques of applying, regulating, and timing the mist have.

The leaching of metabolites and nutrients from the leaves and other plant tissues of the cutting being rooted under intermittent mist present a problem unique to this aspect of propagation. As a result, extensive work has been devoted toward determining the actual effects leaching has on the ability of the cutting to root and develop (8,9,28,29,30). Tukey (28) determined that metabolites leached from the leaves of a cutting by intermittent mist include inorganic materials, carbohydrates, amino acids, and organic acids. He noted that the loss of any of these important metabolic materials will greatly influence the subsequent behavior of a plant or cutting. Good and Tukey (9) compared levels of nitrogen, phosphorus, potassium, calcium, magnesium, and soluble carbohydrates found in cuttings before and after rooting in a sand medium under a distilled water mist. They found that herbaceous, softwood, and semi-hardwood cuttings increased substantially in dry weight and lost small amounts of metabolites by leaching during rooting. Hardwood cuttings grew less and lost more metabolites. It was noted that nutrient deficiency symptoms found in the cuttings under mist were due to leaching of the nutrients and growth of the cuttings, along with the dilution of the nutrients in the cuttings.

Tukey (28) determined that the amounts and types of metabolites leached from cuttings varied with respect to plant species being propagated. He found that there are differences in leachability between species, differences within cultivars of the same species, and differences between leaves of the same plant. Potassium and sodium were leached with relative ease in young leaves with 80 to 90 percent of the potassium being leached in 24 hours. Tukey and Tukey (29) proposed that an indirect benefit may be obtained when rooting inhibitors and promoters are leached from a cutting to the rooting medium by intermittent misting. They may be reabsorbed by the plant and utilized in a desirable or undesirable way. Investigations concerning the nutritional state of a cutting being propagated coincided with the development of mist propagation. Pridham (22) immersed cuttings in aqueous solutions of sucrose, dextrose, maltose, potassium nitrate, ammonium nitrate, and alphanapthalenacetic acid for a period of 24 hours in an effort to supply cuttings with nutrients lost when the cutting was removed from the parent plant. He concluded that rooting of cuttings and subsequent growth of the young plant depended primarily upon the maturity and treatment of the stock plant, and, that responses of cuttings to treatments of cuttings with growth substances, sugars, and nitrogenous compounds, alone or in combination, are of secondary magnitude and much more variable. Kamp and Bluhm (16) studied the effects of a nutrient "dip" on the rooting of cuttings. They immersed chrysanthemum and carnation cuttings in various solutions containing water-soluble nitrogen, phosphorus, and potassium for periods of one hour and concluded that, in general, the employment of nutrients increased rooting approximately 10 percent. Zimmerman (38) soaked cuttings in a liquid fertilizer for 24 hours, then applied liquid fertilizer to the cuttings in the propagation medium. He concluded that the liquid fertilizer soak had no effect on rooting or root growth and only a slight effect on shoot growth. The liquid fertilizer applications after sticking increased root and shoot growth at least 25 percent although no increase in rooting percentage was noted.

Wott and Tukey (35) compared nutrient mist to water mist on hardwood, softwood, and herbaceous cuttings of 29 species or ornamental plants. They determined that the nitrogen, phosphorus, and potassium content increased in the cuttings being propagated under nutrient mist, as did the dry weight of most species. The water mist had a higher percentage of rooting even though nitrogen, phosphorus, and potassium content decreased in the plants. Softwood cuttings were more responsive to nutrient mist than hardwood cuttings. Nutrient mist had little or no effect on root initiation but did influence quality and percentage of cuttings which rooted. Cuttings that were propagated under nutrient mist produced more linear stem growth and lateral bud growth following propagation than cuttings under water mist. Species differed in responses to nutrient mist, and timing of application was important. They concluded that nutrient mist was more effective when used during root elongation than during root initiation and that sanitation was critical. Pathological and physiological disturbances spread more rapidly under nutrient mist than water, and algae growth was a problem. Wott and Tukey (36) found that nutrient mist was beneficial when applied to cuttings of chrysanthemums but also noted the disease problem associated with nutrient mist.

Sorenson and Coorts (27) conducted experiments to determine the effect of nutrient mist on the rooting of selected woody ornamental plants and rate of leaching and replacement of nutrients during propagation with a medium consisting of equal parts peat and perlite. They found that nitrogen, phosphorus, and potassium levels rose with increased applications of nutrient mist and decreased under water mist at time of callus and root formation. All species except Buxus had a greater number of roots and a higher percentage rooted under water mist. Nutrient mist did not increase rooting but did contribute to darker green foliage. On Ilex and Taxus, there was a significant decrease in the number of roots per cutting as the potassium content increased significantly under the nutrient mist. Potassium was readily lost from plant tissues by leaching.

Wott and Tukey (37) found that softwood and herbaceous cuttings grew many more new roots, shoots, and leaves during propagation under nutrient mist than under water mist. Nitrogen, phosphorus, and potassium content of cuttings was higher under nutrient mist than under water mist. Softwood cuttings increased substantially in dry weight and nutrient content. Large increases in linear growth and lateral bud growth after propagation were noted.

Although nutrient mist was shown to be beneficial when used during propagation, problems associated with its use were numerous; algae growth was the biggest problem. Nine algae types were discovered on the surface of peat/perlite rooting medium under nutrient mist (1). The algae growth decreased photosynthesis and increased disease potential on the cuttings.

McGuire and Bunce (17) noted that with nutrient mist, root initiation was not increased greatly, but subsequent growth and development was enhanced. They also noted algae problems and used this as a basis to study the effects of incorporating a slow-release fertilizer into the propagation medium as an alternative means of supplying nutrients to the cutting to replace those lost through leaching. They compared a propagation medium of peat moss and perlite alone to medium containing either Osmocote[y], ureaformaldehyde, or Mag-Amp[z]. They found that in two species of ornamental plants, rooting was improved or not affected by the addition of the slow-release products to the medium and in one species rooting was decreased. However, subsequent growth of rooted cuttings was significantly better in all treatments with slow-release fertilizers. Best results were obtained by using Osmocote.

Deen (2) rooted cuttings in a peat and sand medium with and without Osmocote (18-6-12). There was no difference in rooting of cuttings of Cotoneaster dammeri 'Skogholm' and Symphoricarpos orbiculatus after three weeks, but at five weeks, those cuttings rooted with Osmocote were taller and had developed side shoot growth. Without Osmocote in the

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[y]A product of Sierra Chemical Company, Milpitas, California.

[z]A product of Jiffy Products of America, Chicago, Illinois.

propagation medium, no new growth appeared. After seven weeks, the differences were even more marked. Cuttings allowed to develop in the amended mix were 25 percent larger.

Schulte and Whitcomb (25) found that incorporating Osmocote (18-6-12) into a peat and perlite propagation medium resulted in increased root grade and rooting percentage of Ilex cornuta 'Burford' with increasing levels of Osmocote, up to 1,200 lbs/acre/ year. Soil tests showed that increased levels of nitrates and potassium paralleled increased rooting.

Gouin (10) studied the effects of top-dressed Osmocote on cuttings of Rhododendron obtusum 'Coral Bells,' 'Delaware Valley White,' 'Tradition,' and 'Hershey Red.' Cuttings were top-dressed with Osmocote (18-6-12) at 0,7, or 14 grams per 0.93 square meters immediately after sticking and placed under water mist. He concluded that cuttings that were top-dressed developed heavier root systems, produced more top growth, and flowered less than those without top dressing.

Glenn, et al. (7) incorporated Osmocote (18-6-12) at three levels into a peat and perlite rooting medium. As the level of Osmocote increased, root grades increased for 'Hetzi' Japanese holly and 'Burford' holly but had no effect on the rooting of Foster's holly, wax leaf ligustrum, or 'Hetzi' juniper. After one growing season, the number of branches per plant increased approximately 40 percent when Osmocote had been used in the rooting medium at 1,345.2 kg/hectare per year (1,200 lbs/acre/per year). Overall plant quality was increased using Osmocote in the propagation medium.

Dinter and Eaton (4) used equal parts of peat and perlite as a rooting medium and added various fertilizer formulations or applied liquid fertilizers to cuttings after roots had initiated. Rooting was better in an untreated medium or with liquid fertilizer than in a medium supplemented with 2.97 kg/m^3 super-phosphate (0-18-0), Osmocote (18-6-12), or Mag-Amp (7-40-6). Rhododendron indicum root quality was best without nutrients but Ilex aquifolium roots were better with Osmocote present. They found that the presence of a fertilizer in the rooting medium brought on a physiological response that either prohibited rooting or brought on necrosis. They recommended not adding fertilizer to the rooting medium unless it was known that the species would respond favorably.

Gilliam and Wright (6) applied nitrogen at rates of 50, 150, and 300 parts per million, in the form of a nutrient solution, to Ilex crenata which had been rooted in winter. Potassium nitrate was used for the 50 ppm nitrogen applications and ammonium nitrate increased the levels of N to 150 ppm and 300 ppm. Each plant received 20 milliliters of the basic nutrient solution weekly. The same treatments were made to summer-rooted Japanese holly. The number of shoots on winter-rooted plants increased with nitrogen levels. Summer-rooted liners showed a 30 percent increase in shoot number at the 300 ppm level as compared to the 50 ppm level. The majority of growth occurred in the shortest amount of time at the higher nitrogen levels. Plants rooted at the 300 ppm level grew more during subsequent growth.

Johnson and Hamilton (15) showed that percent rooting of Ligustrum japonicum and Juniperus conferta was improved after two weeks by top-dressing Osmocote in two formulations (18-6-12 and 14-14-14) to a rooting medium consisting of either peat and sand or sand only. After ten weeks, all J. conferta rooted better with Osmocote than without. Root development was also improved by Osmocote. Leaf analysis showed that nitrogen and potassium levels were higher when Osmocote was used in the rooting medium. Osmocote, 18-6-12, resulted in higher N and K levels than 14-14-14. Osmocote 18-6-12 at $7.5g/0.093m^2$ improved rooting of Ligustrum. Osmocote also produced higher fresh root weights and greater shoot development. However, top-dressing Osmocote had little effect on rooting percentage of either species. Osmocote 18-6-12 produced more desirable results than Osmocote 14-14-14, possibly due to the longer nutrient release period of the 18-6-12 formulation.

Whitcomb, et al. (34) compared three formulations of Osmocote (19-6-12, 18-5-11, and 18-6-12), incorporated into a rooting medium of peat and perlite or peat and ground bark (1-1), at 4.76, 7.14, and 9.52 kg/m^3 (8, 12, and 16 lbs/yd^3). Perk (micronutrients) and dolomite were added to all treatments at 2.38 and 4.76 kg/m^3 (4 and 8 lbs/yd^3) respectively. Lagerstroemia indica, Euonymus fortunei 'Coloratus,' and Ligustrum vicaryi were used as test species. Euonymus had the greatest top weight, best visual root grade, and most bud breaks when rooted with 7.14 kg/m^3 (12 lbs/yd^3) of Osmocote, regardless of formulation. Ligustrum produced similar top and root weights and visual root grade at 4.76 or 7.14 kg/m^3 (8 or 12 lbs/yd^3) and the 18-6-12 formulation produced the greatest top weight and best root visual grade. Lagerstroemia had the greatest long-range benefits from the 19-6-12 and 18-6-12 formulations due to their initial release rate. It was concluded that Osmocote in the rooting medium has a substantial impact on plant growth and quality following transplanting.

Ward and Whitcomb (32) conducted a study to determine the effects of Osmocote (18-6-12) incorporated into a propagation medium of sphagnum peat and perlite in equal proportions on the propagation and subsequent growth of Ilex crenata 'Hetzi.' Plants propagated with Osmocote were much larger and more responsive to subsequent fertilizer sources than those propagated without Osmocote. Maximum subsequent growth was obtained only when Osmocote was incorporated into the rooting medium during propagation. Salable, quality plants were produced in one growing season by using Osmocote in the propagation medium combined with a slow-release fertilizer program after transplanting. Nutrition during propagation was essential for best growth and utilization of subsequent container nutrition.

CHAPTER III

METHODS AND MATERIALS

Terminal stem cuttings of Fashion hybrid azalea (*Rhododendron* 'Fashion'), Hetzi Japanese Holly (*Ilex crenata* 'Hetzi'), and Wateri Pyracantha (*Pyracantha coccinea* 'Wateri') were taken November 8, 15, and 16, 1979, respectively, from stock plants grown under uniform nutritional and cultural conditions. To insure that all cuttings were as uniform as possible within each species, each cutting was selected individually from the parent plant on the basis of stem diameter and overall appearance. Upon removal from the parent plant, the cuttings were prepared for sticking by trimming to a uniform height and removing the two lower leaves. All cuttings were treated with a talc preparation of indolebutyric acid (IBA) with a concentration of 0.8 percent of 8,000 parts per million (Hormodin Powder Number 8).

Experimental Treatments

The experimental treatments were four levels of nitrogen and four levels of potassium in factorial combination incorporated into the propagation medium. The nitrogen source was a plastic, resincoated, controlled-release fertilizer with an analysis of 27-12-0. The nitrogen in the form of approximately 60 percent ammoniacal nitrogen and 40 percent nitrate nitrogen derived from ammonium nitrate and ammonium phosphate. The potassium source was potassium sulfate with the same plastic-resin coating with an analysis of 0-0-46. The levels of nitrogen and potassium are shown in Table I.

1.08 X 0.45369 = .4899852
0.4899852
.7646

TABLE I

LEVELS OF NITROGEN AND POTASSIUM INCORPORATED DURING PROPAGATION

NITROGEN LEVELS		
Level	27-12-0	Actual Nitrogen
1	0.0	0.0
2	4.0 lbs./yd^3 (2.38 kg/m^3)	1.08 lbs./yd^3 (0.6 kg/m^3)
3	6.67 lbs./yd^3 (3.97 kg/m^3)	1.80 lbs./yd^3 (1.0 kg/m^3)
4	9.33 lbs./yd^3 (5.55 kg/m^3)	2.52 lbs./yd^3 (1.5 kg/m^3)
POTASSIUM LEVELS		
Level	0-0-46	Actual Potash
1	0.0	0.0
2	1.57 lbs./yd^3 (0.93 kg/m^3)	0.72 lbs./yd^3 (0.45 kg/m^3)
3	2.60 lbs./yd^3 (1.55 kg/m^3)	1.20 lbs./yd^3 (0.72 kg/m^3)
4	3.65 lbs./yd^3 (2.17 kg/m^3)	1.68 lbs./yd^3 (1.10 kg/m^3)

1 Cubic meter = 1.308 C.Y.
1# = 0.45369 Kilograms

The amounts of actual nitrogen and potassium listed are comparable to the amount of actual nitrogen and potassium found in 0, 6, 10, and 14 pounds per cubic yard of Osmocote 18-6-12 (0, 3.57, 5.95, and 8.33 kg/m^3). Included in all treatments was Micromax micronutrients at one pound per cubic yard (0.595 kg/m^3). All treatments were incorporated into a 1:1 v:v ratio of peat moss to coarse perlite propagation medium which was mixed in a rotating drum concrete mixer to insure equal distribution of nutrients. A randomized complete block design was used with ten replications and four subsamples per replication. A propagation unit consisting of four individual containers joined together was used to hold the four subsamples making up each treatment. Each individual container had dimensions of 5.7 cm by 5.7 cm by 5.7 cm. One cutting per individual container (four per propagation unit) was stuck 3 to 4 centimeters deep in the propagation media. A total of 640 cuttings per species were stuck with 160 propagation units per species used.

After filling, the containers were placed on an expanded metal bench in an unshaded fiberglass-covered propagation greenhouse. Cuttings grouped by species were misted for 3 seconds every 4 minutes. Heat was provided by a gas-fired furnace and a polytube distribution system beneath the bench. The temperature was maintained at a minimum of 20°C (68°F) and a maximum of 35°C (95°F). After all cuttings were sufficiently rooted, they were moved from the propagation house and held in a solar-heated greenhouse until transplanted into large containers.

Ilex crenata 'Hetzi'

On February 7, 1980, the holly cuttings were evaluated for root visual grade, number of bud breaks, and height, then returned to the propagation unit. On April 9, 1980, just prior to planting out, a second evaluation of the holly liners was made. Overall visual grade, number of branches, and height of each liner was recorded. On April 14, 1980, the holly liners were potted into 3.785 liter (one-gallon) white-on-black poly bags. A soilless medium consisting of a 3:1:1 ratio of ground pine bark, peat moss, and sand was used. Incorporated into this medium was Osmocote 18-5-11, gypsum, dolomite, triple superphosphate (0-46-0), and Micromax micronutrients at 6.36, 0.91, 2.72, 0.68, and 0.68 kg/m^3, respectively (14, 2, 6, 1.5, and 1.5 $lbs./yd^3$). The potted holly liners were grown in a quonset structure covered with 30 percent saran shade cloth. Water was supplied through overhead sprinklers, as needed, and all plants were trimmed lightly twice to stimulate branch-ine. Weed control was by Ronstar (oxidiazon) 2 percent G at 6.726 kg/hectare (6 pounds active ingredient per acre). A third and final evaluation of the holly plants was made on September 16, 1980. The ten-month-old plants were evaluated for branch number, overall visual grade, and fresh top and root weight.

Rhododendron 'Fashion'

Azalea cuttings were evaluated for root visual grade on February 25, 1980. A fungus disease was observed and noted at this time and replication number ten was eliminated to protect against the spread of the pathogen. On April 15, 1980, an overall visual evaluation was made of the remaining nine replications. The azalea liners were then potted into the 3.785 liter (one-gallon) white-on-black poly bags and treated the same as the holly. A final evaluation of the azalea plants was made on September 18, 1980. Branch number, height, overall visual grade, fresh top weight, and visual root grade was recorded.

Pyracantha coccinea 'Wateri'

On January 24, 1980, the pyracantha cuttings were evaluated for root visual grade, number of bud breaks, and height. On April 24, 1980, the pyracantha liners were potted into 7.57 liter (two-gallon) white-on-black poly bags and grown on under full sun. Media, watering, and weed control was similar to the holly and azalea. On September 22, 1980, the pyracantha plants were evaluated for height, stem caliper, overall visual grade, fresh root and top weight.

CHAPTER IV

RESULTS AND DISCUSSION

After twelve weeks, most cuttings had rooted but few significant differences among treatments were detected. This is in agreement with several researchers who found that nutrient applications, either through the mist or incorporation into the rooting medium, had little effect on rooting or early stages of development of the cuttings (10, 15, 35). Ward (32) found that, after ten weeks, rooting percentage and root quality of cuttings of *Ilex crenata* 'Hetzi,' showed no significant differences between those stuck in containers and flats or between Osmocote levels. However, Johnson and Hamilton (15) found that ligustrum cuttings increased rooting percentage after six weeks with low rates of Osmocote but at twelve weeks, there was no difference in percentage rooting between treatments.

With each increasing level of nitrogen in the propagation medium from Osmocote 27-12-0, a significant increase in plant growth and quality was noted for all test species, after 22 weeks and 10 months. After 22 weeks, visual grade of azalea and visual grade, number of branches, and height of Japanese holly increased as the level of nitrogen applied during propagation increased (Tables II and III). After 10 months, visual grade, number of branches, height, and visual root grade of azalea significantly increased by the addition of Osmocote 27-12-0 to the propagating medium (Table II). Number of branches, visual grade, and top and root weight of Japanese holly and top and root weight, visual grade, height and stem caliper of pyracantha significantly increased as nitrogen level increased (Tables III and IV).

No significant benefit or detriment from potassium (0-0-46 formulation) was found in any growth parameter measured. Nitrogen/ potassium interactions were non-existent. This should not necessarily suggest that potassium is unnecessary during propagation but that under the conditions of this study no significant benefit occurred. The smallest plants at the end of 10 months were those which did not receive Osmocote 27-12-0 during propagation, regardless of the amount of Osmocote 0-0-46 present.

There were no visually detectable signs of nutrient deficiencies (i.e., leaf chlorosis, discoloration, or disfiguration) throughout the experiment. Plants differed only in size and quality. Those receiving only Osmocote 0-0-46 or no nutrients during propagation resembled the larger plants in leaf and stem color. This can be attributed to the fact that nitrogen and potassium were varied only during the propagation phase of the experiment. After transplanting, all plants received the same level of a complete, slow-release fertilizer. Although each plant had an equal opportunity to absorb and utilize these nutrients to generate growth, plants which had received no nutrients or only Osmocote 0-0-46 during propagation were unable to receive the full benefit. Plants propagated with Osmocote 27-12-0 received the maximum benefit from the transplant nutrients, probably due to the increased root area and rate of root development into the transplant medium.

TABLE II

MAIN EFFECTS OF NITROGEN DURING PROPAGATION ON THE GROWTH AND DEVELOPMENT OF 'FASHION' AZALEA

	NITROGEN LEVELS			
	0.0[x]	0.6	1.0	1.5
Root Visual Grade[y] at 12 Weeks	5.27a[z]	4.36b	5.33a	5.14ab
Visual Grade[y] at 22 Weeks	3.33a	4.39b	6.03c	7.33d
Top Weight (Grams) at 10 Months	40.97a	60.97b	71.33c	85.06d
Visual Grade[y] at 10 Months	4.99a	5.77b	6.71c	7.48d
Number of Branches at 10 Months	13.42a	17.31b	20.03c	25.25d
Height (Centimeters) at 10 Months	27.03a	31.06b	33.11b	35.89c
Visual Root Grade[y] at 10 Months	5.83a	7.08b	8.00c	8.80d

x = kg/m^3
y = Based on a scale 1 = poor; 10 = excellent
z = Means followed by the same letter are not significantly different at the .05 level using Duncan's multiple range test.

TABLE III

MAIN EFFECTS OF NITROGEN DURING PROPAGATION ON THE GROWTH AND DEVELOPMENT OF 'HETZI' JAPANESE HOLLY

	NITROGEN LEVELS			
	0.0[x]	0.6	1.0	1.5
Visual Root Grade[y] at 12 Weeks	6.80[z]ab	7.50a	6.13b	6.40ab
Number of Branches at 12 Weeks	0.80b	2.70a	2.78a	1.78ab
Height (Centimeters) at 12 Weeks	11.80b	12.18ab	12.53a	12.15ab
Visual Grade[y] at 22 Weeks	3.65a	7.53b	8.43c	8.63c
Number of Branches at 22 Weeks	4.53a	8.34b	9.53c	9.60c
Height (Centimeters) at 22 Weeks	13.28a	18.48b	19.23b	19.28b
Number of Branches at 10 Months	18.13a	27.93b	30.23b	33.80c
Visual Grade[y] at 10 Months	4.67a	7.08b	7.47b	8.07c
Top Weight (Grams) at 10 Months	55.95a	94.63b	101.83b	116.3c
Root Weight (Grams) at 10 Months	26.90a	46.70b	49.28b	56.45c

x = kg/m^3
y = Based on a scale 1 = poor; 10 = excellent
z = Means followed by the same letter are not significantly different at the .05 level using Duncan's multiple range test.

TABLE IV

MAIN EFFECTS OF NITROGEN DURING PROPAGATION ON THE GROWTH AND DEVELOPMENT OF 'WATERI' PYRACANTHA

	NITROGEN LEVELS			
	0.0^x	0.6	1.0	1.5
Visual Root Grade^y at 10 Weeks	8.63^za	8.35a	9.15a	9.05a
Number of Branches at 10 Weeks	1.08a	1.80b	2.55c	2.20bc
Height (Centimeters) at 10 Weeks	12.58a	13.48a	13.83a	13.68a
Top Weight (Grams) at 10 Months	194.35a	291.55b	304.90b	335.05c
Root Weight (Grams) at 10 Months	80.90a	135.70b	140.80b	159.25c
Visual Grade^y at 10 Months	5.27a	7.01b	7.66c	7.99c
Height (Centimeters) at 10 Months	79.25a	90.90b	92.88b	95.13b
Stem Caliper (Centimeters) at 10 Months	1.03a	1.20b	1.29c	1.33c

x = kg/m^3
y = Based on a scale 1 = poor; 10 = excellent
z = Means followed by the same letter are not significantly different at the .05 level using Duncan's multiple range test.

The nitrogen source used for this study contains phosphorus (12 percent P_2O_5) in the form of ammonium phosphate. Phosphorus is, thus an uncontrolled variable and may have acted with the nitrogen. Meyer, et al. (18) points out that the roles of nitrogen and phosphorus in plant metabolism appear to be interrelated in a number of ways. Earlier maturation of plants often occurs when available phosphorus is high, and a delay in reaching maturity is occasioned by phosphorus deficiency. Potassium, on the other hand, is not definitely known to be built into any organic compounds essential for the continued existence of the plant, although it is considered to be an indispensable element in relation to plant metabolism.

In general, no significant differences were apparent during early stages of growth of the cuttings. However, at 22 weeks and again at 10 months, there was a significant increase in growth with each increase in the level of Osmocote 27-12-0. These increases are directly attributable to the nutrients (particularly nitrogen) received by the cutting during propagation. All cuttings were treated similarly after transplanting and each received the same amount of additional nutrients regardless of previous treatment. The cuttings were able to absorb and utilize sufficient nutrients during propagation to significantly affect their subsequent growth performance. However, only those propagated with Osmocote 27-12-0 present could obtain the fullest benefit from additional nutrients. This suggests that nutrients, nitrogen in particular, can be applied in slow-release form during propagation to accelerate growth, not only over a short-term, but also over a longer time period.

CHAPTER V

CONCLUSIONS

The objective of this research was to determine the effects of slow-release sources of nitrogen and potassium incorporated into the rooting medium on the propagation and subsequent growth of three woody species. Osmocote 27-12-0 was used as the nitrogen source and was found to have a tremendous influence on the growth and development of the test species. Osmocote 0-0-46 was the potassium source and had little influence on plant growth.

There were no interactions between the nitrogen and potassium sources on rooting of cuttings or subsequent plant growth. Phosphorus was an uncontrolled variable in Osmocote 27-12-0 and may have played a role in the accelerated growth of the "nitrogen-only" plants.

Slow-release nitrogen nutrition during propagation is of immense benefit to plant growth and quality, and shortens the time required to produce a salable plant. The cost of this slow-release fertilizer, added to the propagation medium, would be about 1¢ per cutting at current prices. Further indirect benefits are obtained in that more vigorous plants have fewer pest problems and require fewer prunings to obtain high quality and salability. As the shrub canopy increases and the surface of the growing medium is shaded, weed problems are also decreased.

Present slow-release fertilizers are designed for use in a container system after a cutting has been rooted and transplanted. A slow-release fertilizer optimum for use during propagation is currently not available. The results of this and other studies indicate that a slow-release fertilizer should be developed for use during propagation.

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VITA

Micheal George Carney

Candidate for the Degree of

Master of Science

Thesis: THE EFFECTS OF SLOW-RELEASE NITROGEN AND POTASSIUM ON THE PROPAGATION AND SUBSEQUENT GROWTH OF *ILEX CRENATA* 'HETZI', *PYRACANTHA COCCINEA* 'WATERI', AND *RHODODENDRON* X 'FASHION'

Major Field: Horticulture

Biographical:

Personal Data: Born in Okmulgee, Oklahoma, July 3, 1956, the son of Mr. and Mrs. Thomas C. Carney.

Education: Graduated from Okmulgee High School, in May, 1974; received Bachelor of Science in Agriculture degree in Horticulture (Nursery Management) from Oklahoma State University in 1978; completed requirements for the Master of Science Degree at Oklahoma State University in May, 1981.

Professional Experience: Graduate Research Assistant, Oklahoma State University Department of Horticulture, 1978. Lab instructor, Landscape Plant Materials, Nursery Management, Fall 1979 and Spring 1980, respectively, at Oklahoma State University; member Phi Kappa Phi Honorary Fraternity.