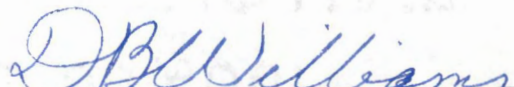


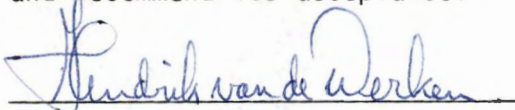
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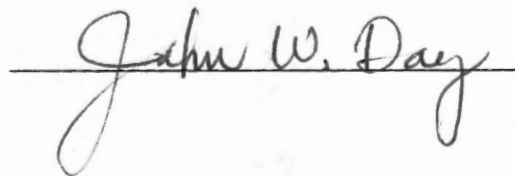
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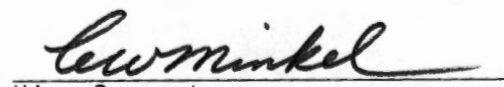

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ENHANCING THE ESTABLISHMENT OF TRANSPLANTED
WOODY ORNAMENTALS

A Thesis
Presented for the
Master of Science
Degree
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ABSTRACT

This study was initiated to investigate the effects of some cultural practices and chemical treatments that may enhance the establishment of transplanted woody ornamentals. The treatments studied were the application of indole-3-butyric acid (IBA), thiamine hydrochloride (vitamin B₁), a complete fertilizer (analysis 4-10-3), super phosphate (analysis 0-46-0) and two cultural practices of peat as a backfill soil amendment and a shredded hardwood bark as a mulch over the root zone. These treatments were applied singly and in several combinations. The plants used for this study were Euonymus kiautschovicus, Loes., 'Manhattan', Acer saccharum, Marsh., and Liquidambar styracflua, L.. The parameters measured on the Acer and Liquidambar species were length increase of central leader, caliper increase of trunk and weight of new roots. The parameters measured on the Euonymus were leaf color, number of budbreaks, top growth weight and new root growth weight. A summary of the findings shows that the application of IBA alone or thiamine alone, at all the rates tested, had either no effect or a negative effect on the parameters measured. A complete fertilizer (analysis 4-10-3) enhanced growth when applied at the two higher rates tested. The fertilizer by itself enhanced growth equally as well as a treatment consisting of a corresponding rate of

fertilizer, plus IBA and thiamine. Superphosphate incorporated into the backfill soil resulted in no effect or a negative effect on the parameters measured. Shredded bark mulch applied alone, resulted in minimum positive effects on plant growth. Combination treatments of IBA, thiamine, 4-10-3 fertilizer (at the higher rates), plus peat as a backfill amendment and shredded bark as a mulch enhanced growth most and resulted in more healthy looking plants than did any of the other treatments. Conclusions reached in this study show that the application of a mixture of IBA, thiamine and 4-10-3 fertilizer can be somewhat beneficial to the establishment and growth of transplanted woody ornamental plants, however nearly identical benefits can be obtained by applying 4-10-3 fertilizer by itself.

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CHAPTER I

INTRODUCTION

The initial establishment of transplanted woody ornamentals is critical to their future health and survival. Transplanting techniques can substantially reduce the root systems of nursery stock (44). Trees and shrubs that are transplanted into the landscape often require a year or more to overcome "transplanting shock" and to become established. Rapid root regeneration is essential for the successful establishment of those transplanted trees and shrubs. Treatments that enhance or accelerate initial establishment are likely to increase the attractiveness and survival percentages of the transplants. Increased survival and attractiveness would greatly benefit nurserymen, garden center operators and landscape contractors.

Several cultural practices are traditionally applied to newly transplanted woody ornamentals with hope of enhancing their establishment. They include amendment of backfill soil with organic compounds, mulching over the root zone, fertilizing and

watering. Growth promoting chemicals which may stimulate root initiation and growth are also applied. Among the list of root promoting chemicals are auxins such as indole-3-butyric acid (IBA), indole acetic acid (IAA), and naphthalene acetic acid (NAA). Thiamine hydrochloride or vitamin b_1 is a component of several root stimulating products currently on the market and is also thought to promote root growth. However, research failed to show consistent benefits to root growth by application of this material (1, 14, 20, 25, 33).

This study was initiated to investigate the effects of some cultural practices and chemical treatments that may enhance the establishment of transplanted woody ornamentals. The plants used for this study were Euonymus kiautschovicus, Loes., 'Manhattan', Acer saccharum, Marsh., and Liquidambar styraciflua, L.. The treatments applied were IBA, thiamine hydrochloride (vitamin b_1), a complete fertilizer (analysis 4-10-3), superphosphate fertilizer (analysis 0-46-0), and two common cultural practices of peat as a backfill amendment and a shredded hardwood bark mulch over the root zone. These six treatments were applied singly and in several combinations at various concentrations.

CHAPTER II

LITERATURE REVIEW

A. Soil Amendments

Soil amendments have been used when transplanting trees and shrubs to improve the conditions of the rootzone and promote better growth. Landscape contractors often employ a number of traditional practices in transplanting such as application of soil amendments, mulches and fertilizer as a standard routine in their every day operations. Most of these practices are well founded and are beneficial to plant growth (16, 19, 31, 42, 47). However, the effects and benefits of mixing organic amendments with soil backfill at planting time may be questionable according to research literature (34, 38, 41, 47).

Recently, Corley (9) reported results from nine years of experimenting with organic amendments on six woody species in clay topsoil and compacted subsoil. He concluded that backfill amendments produced no consistent positive results.

A common recommendation for adding soil amendments is "a rate of one part peat by volume to two parts of soil (5)." Whitcomb (47) conducted studies to determine the optimum amount of soil amendments to use in the planting hole, since recommendations varied from 5% to 50% by volume of amendment for backfill soil. Whitcomb's research found no benefit from the use of soil amendments and he concluded that "the optimum amount of soil amendment is none."

Hummell and Johnson (21), after testing various backfill amendments and finding the results insignificant, estimated the cost of planting due to the addition of amendments increased the installation cost 27% to 30% over the unamended backfill planting costs.

B. Mulch

Another practice widely used in modern landscape plantings is mulching. Any material placed on the soil surface to cover and protect it is called a mulch. Biodegradable mulches include bark, wood chips, leaves, conifer needles, lawn clippings, straw, corncobs, peanut hulls and numerous others. A good mulch should help conserve moisture, control weeds, be economical, readily available and aesthetically compatible with the surroundings (18).

It is helpful to consider each of the possible benefits to better understand how mulches can be used or modified to be most effective. Soil moisture is conserved by mulches because they reduce evaporation from the soil surface, reduce weeds that use water, and prevent runoff. Russell (37) studied soils at field capacity and found that a layer of straw mulch 40mm (1.5 in.) thick reduced evaporation primarily by blocking solar radiation (about 50 percent), shielding against wind (about 20 percent), lowering soil temperature, and obstructing vapor escape. Weeds can use a significant amount of water, depending on their size, thereby reducing water that would have been available to the trees and shrubs. A thick stand of weeds in an orchard can increase evapotranspiration by about 25 percent (18). A thick mulch (100 to 150 mm or 4 to 6 in.) can effectively suppress most weed growth, except for the more persistent weeds such as bindweed and quackgrass. When weeds are controlled by mulches more water and nutrients are available for the landscape plants and the alleopathic effects of weeds on young plants are minimized. A thick or impervious mulch will reduce weed seed germination and prevent those that do germinate from growing (18).

Soil structure is improved when soil is covered with a thick mulch, particularly under biodegradable mulches, by increasing the size of the soil aggregates and the total porosity of the soils

(23). Mulches encourage rooting and other biological activity by improving aeration, moderating temperature and conserving moisture. Improved soil structure can result in an increased rate of water infiltration, more uniform water distribution and decreased erosion, all of which promote plant growth. Soil compaction is reduced when a mulch reduces water droplet impact on the soil surface and disperses the weight of vehicles, people and animals (18).

C. Fertilizer

Fertilization may encourage the rapid development and continuing health of landscape plants (18) by improving plant vigor, making leaves healthier and reducing plants susceptibility to certain pests. Complete fertilizers are sometimes recommended for most landscape plantings (16, 18, 42).

Atmospheric nitrogen becomes available to plants after being fixed in a form that can be readily absorbed. Fixation of nitrogen often results from the effects of lightening which transforms atmospheric nitrogen to the nitrate form. It is estimated that lightening is responsible for fixing 30 to 40 pounds of nitrogen per acre per year (43) however, nitrogen is the most commonly deficient soil nutrient (18). Nitrogen becomes unavailable to plants due to leaching, denitrification by soil

organisms, absorption by nontargeted plants and through use by other organisms during the decomposition of organic matter. Deficiency symptoms of nitrogen on broadleaf plants include yellowish green color of older leaves, smaller and thinner leaves, early leaf drop and shorter shoots (18).

Although phosphorus is normally present in much lower amounts than the other major nutrients in plant tissues, it is essential to the health and growth of the plant (15). In most soils, phosphorus is present in adequate amounts for trees and shrubs and they may grow well even when soil phosphorus is available at relatively low levels. Phosphorus does not move readily in soil and tends to concentrate near the surface when additions are made. Grading soils that are low in phosphorus may aggravate phosphorus deficiencies in young or shallow rooted plants. Phosphorus fertilization has been recommended to enhance the root growth of trees growing under difficult urban conditions (3), or where soil has been filled around trees (40). However, several authors (11, 15, 24) do not mention such rooting responses from phosphorus application in their reviews of plant nutrients.

Plants absorb potassium in relatively large amounts, concentrating it in the rapidly growing shoots. Most soils contain sufficient potassium for the normal growth of woody plants (18). Potassium deficiencies occur primarily in soils that are acid, sandy, low in organic matter, and low in total cation

exchange capacity (26). Surface soil is usually higher in potassium than the subsoil, so in areas where potassium is low, grading may cause a deficiency (18).

Researchers (16) have studied the effects of fertility on root and shoot growth of some landscape plants. They state that recent nursery production trends have minimized the importance of root development and have stressed vigorously growing shoot systems, both in containers and in the field. They stress that it is important to determine proper fertility programs that will maintain a proper balance in growth between shoots and roots. Studies with Cotoneaster divaricata showed that root growth was not increased by N addition up to 500 mg/liter of soil mix. High N levels actually had negative effects on root growth, whereas P slightly stimulated root growth. Some landscape nurserymen avoid using fertilizer during the first year after transplanting, since excess fertilizer in the soil backfill can damage the roots of transplants (16). However, some literature recommends the application of high phosphate fertilizers at planting time (6, 16, 52). Whitcomb (47) recommends a surface application of a complete fertilizer immediately after planting. Van de Werken (42) concluded that for an increase in the growth rate of established shade trees, a high level of N combined with low levels of P and K is most effective.

D. Thiamine

There has been interest in the effects of thiamine hydrochloride (vitamin B₁) on plant growth for over four decades. Some of the current ideas on the use of thiamine may be the result of literature references during the 1930's and 1940's. These early studies (2, 51) showed that thiamine is necessary for the sterile medium culture of detached roots in the laboratory. However, further investigations showed inconsistent benefits to root growth on cuttings of several plant species. Although thiamine is necessary for root growth, apparently the leaves of most plants produce enough to satisfy their own needs (20). Valencia orange trees transplanted with both bare and balled and burlapped root systems into soil did not respond to thiamine treatments when adequate water and mineral elements were available (33). Tissue analysis of sand grown jack pine seedlings treated periodically with thiamine showed that controls contained thiamine in the same proportions as the treated plants (1). Thiamine treatments had no effect on plant size or weight. Other researchers studied the effects of thiamine on several ornamental greenhouse crops during a series of several weekly treatments (25). No benefits were reported on roses or chrysanthemums. Parker et al. (33) concluded that for practical purposes, the application of thiamine is not justifiable. Recently, researchers

studied the effects of a commercially prepared "root stimulator" product on top weight and root weight of snapdragon plants (20). The commercial product formulation contained 0.01 percent thiamine hydrochloride, 0.015 percent alpha naphthalene acetic acid and fertilizer (analysis 3-10-3). The other treatments for comparison were a fertilizer treatment (analysis 6-9-5) and an untreated control. Two months after treatment, there were no significant top weight or root weight differences between plants that were treated with the commercial product and those that received only fertilizer. However, plants receiving either of those treatments were significantly larger than the nontreated controls. Accordingly, researchers (20) have concluded that "any significant root stimulating done by the commercial vitamin b_1 product tested was due to the fertilizer in the product and not to the thiamine hydrochloride."

E. Indole-3-Butyric Acid

Our understanding of plant growth regulating chemicals and our ability to use them to control plant behavior has increased considerably over the past 50 years. Auxins are growth regulators that are commonly used in the nursery industry. Indole-3-butyric acid (IBA) is often used to enhance the rooting of cuttings of many ornamental species that are difficult to root without the

assistance of such treatment. Since IBA greatly enhances the initiation of roots on cuttings, many researchers were interested in the effects of IBA and other auxins on the root growth of entire plants at transplanting time (31).

Maki and Marshall (31), conducted a series of experiments on the effects of indole-3-butyric acid on root growth and seedling mortality of several tree species. They found that root soaks of increasing concentrations of IBA produced significant increases in root volume of red oak seedlings. However, treatments that produced the highest increases in root volume in turn resulted in a high mortality rate. Looney and McIntosh (29) were able to significantly increase the root growth of nursery-grown pear trees by inserting IBA impregnated toothpicks into the roots at planting time. Most of these earlier studies used small or seedling plants in their tests. Prager and Loomis (36) studied the effects of IBA on landscape size trees. They reported that solutions of IBA can enhance rooting of several species when sprayed on the cut ends of the freshly cut roots.

Several researchers have successfully increased root regeneration of transplanted trees with treatments of IBA, (29, 31, 32, 36). However, some application methods tested may be cumbersome or impractical for large quantities or large transplant sizes. Prager and Loomis (36) state that the root spray application method may be more practical than others and may be commercially feasible.

CHAPTER III

MATERIALS AND METHODS

This research was conducted at the agriculture campus of the University of Tennessee, Knoxville. The research was supported by the Department of Ornamental Horticulture and Landscape Design and the Tennessee Agricultural Experiment Station. It was initiated in April of 1985 and concluded in December of 1985.

A. Shade Trees

Preliminary experiments were initiated in April, 1985. Bare root liners, 1.5 to 1.8 meters tall, with a caliper range of 14.1 mm. to 36.5 mm. of sugar maple, Acer saccharum and sweet gum, Liquidambar styraciflua were planted into a field soil of Etowah silt loam. The test consisted of two randomized complete block designs, one for each species, with three replications. There were five treatments and three samples per treatment, for a total of 45 experimental units per randomized complete block.

Before planting, the root systems of each tree were trimmed to a uniform diameter of 30 centimeters. The trees were planted on April 12, 1985 and watered thoroughly immediately after planting. They were irrigated again the day before treatment application. Treatments were applied on April 19, 1985. Each tree in this experiment received 3.78 liters (one gallon) of treatment solution.

The experiment consisted of five treatments:

- 1) Control, water only
- 2) 4-10-3 fertilizer, applied at 546.0 mg N/liter
- 3) Indole-3-butyric acid, applied at 0.055 mg/liter
- 4) Thiamine hydrochloride, applied at 20.51 mg/liter
- 5) A commercial "root stimulator" product, applied at the rate recommended on the label. This treatment solution contained 4-10-3 fertilizer at 546.0 mg N/liter, IBA at 0.055 mg/liter and thiamine hydrochloride at 20.51 mg/liter

The 4-10-3 fertilizer treatments were made by mixing laboratory grade ammonium phosphate dibasic $(\text{NH}_4)_2\text{HPO}_4$, analysis 21-53-0, with muriate of potash (KCl), analysis 0-0-60, at a ratio of 3.77 parts ammonium phosphate dibasic to one part muriate of potash. The indole-3-butyric acid treatments were made by mixing the water soluble potassium salt form of IBA with water. The thiamine treatments were made by mixing a laboratory grade of thiamine hydrochloride with water.

These treatments were applied as a soil drench over the root zone of the trees. A small rim of soil was constructed around the perimeter of each tree at the approximate radial length of the roots, to help insure that the entire treatment solution soaked into the root zone and not into peripheral areas. In another effort to insure that the entire 3.78 liter soaked into the rootzone of each tree, special applicators were constructed that would deliver the treatment solution at a rate slow enough that it would not run off into the surrounding soil. Each treatment applicator consisted of a large plastic bucket having an approximate capacity of five gallons. Three small holes were drilled through the sidewall near the bottom to accommodate three lengths of "spaghetti" type irrigation tubing. The tubing had an inner diameter of three mm. The bucket was placed next to the plant to be treated, with the ends of the tubing distributed around the base of the tree. When the treatment solution was poured into the bucket, it flowed out of the tubing and percolated into the soil very near the end of each tube.

The trees were irrigated once after treatments were applied, during a period when ambient rainfall was minimal. The plot area was kept free of weeds with a power tiller between the rows and a hoe within the rows. The trees remained in the ground for six months of the 1985 growing season, from mid-April through October.

To improve accuracy in recording of caliper increase, a small stripe of colored latex was painted on each trunk to mark the location and the direction of the Vernier caliper where the initial caliper measurement was recorded. The latex stripe was applied in five different colors, with each color corresponding to a particular treatment. Another stripe of colored latex was painted 30 centimeters above the soil level in three different colors, each corresponding to a particular replication. This color code system proved to be a valuable method for accurately locating sites of measurement, as well as labeling treatments and replication numbers.

The trees were harvested for data collection on October 27, 1985. Each tree was dug with a uniform size root ball of 61 centimeter (24 inch) diameter. This was accomplished by scribing a continuous arc using a loop of twine and a pocket knife. The twine was looped around the trunk and the knife handle to maintain a uniform 30.5 centimeter radius from the tree. Nursery spades were inserted into the soil at a slight angle toward the tree on the arc around the entire circumference of the roots. The blades were inserted to a depth of 30.5 centimeters, the length of the blade. Using two spades opposite each other, the tree was pried up while another worker grasped the trunk near the base and lifted. Once lifted, the soil was shaken from the roots and the trees were stored in moist sawdust until root data were collected.

The data recorded for all trees were: length of terminal shoot growth of the central leader, caliper increase of the trunk at 15 centimeters (6") above the soil line, and the dry weight of the new roots that extended beyond the 30 centimeter diameter root spread of the trees at planting. These new roots were excised using a Felco hand pruner and oven dried at 80 degrees C for 24 hours. After drying, dry weights were measured on a double beam gram balance and recorded.

The new growth of the central leader for the 1985 season was measured and recorded.

Analysis of variance was conducted and mean separation was determined by Duncans new multiple range test.

B. *Euonymus* In Containers

In August 1985, a study was conducted using *Euonymus kiautschovicus*, 'Manhattan' to test the effects of the same chemicals (IBA, thiamine and 4-10-3 fertilizer) but at increased concentrations, since there was no apparent effect due to the treatments at the rates applied in the initial experiment. The experiment was a randomized complete block with four replications. There were 14 treatments and two samples per treatment for a total of 112 experimental units.

The plants for this experiment were propagated from cuttings. The container grown 'Manhattan' Euonymus plants were transplanted from Zarn 300 "1 gallon" containers to Zarn 600 "2 gallon" containers on August 2, 1985. The larger containers allowed approximately five centimeters of fresh media to surround the original "1 gallon" size root ball, which was heavily rooted.

The media used in the original one gallon containers and in the larger containers consisted of a 3:1:1 mix of pine bark, sand and peat by volume. Mineral elements added to the media at time of mixing were; 1.784 kg./cu.m. (3 lbs./cu.yd.) Esmigram brand micronutrients, 1.189 kg./cu.m. (2 lbs./cu.yd.) gypsum, 4.165 kg./cu.m. (7 lbs./cu.yd.) ground dolomitic lime, 1.189 kg./cu.m. (2 lbs./cu.yd.) 0-46-0 superphosphate and 3.570 kg./cu.m. (6 lbs./cu.yd.) 14-14-14 fertilizer.

The plants were moved up to the larger containers on August 2, 1985 and treated on August 5, 1985. The experiment consisted of fourteen treatments:

- 1) IBA @ A rate, 3.78 liters of aqueous solution applied at 0.055 mg/liter
- 2) IBA @ B rate, 3.78 liters of aqueous solution applied at 2.75 mg/liter
- 3) IBA @ C rate, 3.78 liters of aqueous solution applied at 5.5 mg/liter
- 4) Thiamine hydrochloride @ A rate, 3.78 liters of aqueous solution applied at 20.51 mg/liter

- 5) Thiamine hydrochloride @ B rate, 3.78 liters of aqueous solution applied at 1025.5 mg/liter
- 6) Thiamine hydrochloride @ C rate, 3.78 liters of aqueous solution applied at 2051.0 mg/liter
- 7) 4-10-3 fertilizer @ A rate, 3.78 liters of aqueous solution applied at 546.0 mg N/liter
- 8) 4-10-3 fertilizer @ B rate, 3.78 liters of aqueous solution applied at 2730.0 mg N/liter
- 9) 4-10-3 fertilizer @ C rate, 3.78 liters of aqueous solution applied at 5460.0 mg N/liter
- 10) Combination A, 3.78 liters of aqueous solution containing 0.055 mg IBA/liter, 20.51 mg thiamine/liter and 4-10-3 at 546.0 mg N/liter
- 11) Combination B, 3.78 liters of aqueous solution containing 2.75 mg IBA/liter, 1025.5 mg thiamine/liter and 4-10-3 at 2730.0 mg N/liter
- 12) Combination C, 3.78 liters of aqueous solution containing 5.50 mg IBA/liter, 2051.0 mg thiamine/liter and 4-10-3 at 5460.0 mg N/liter
- 13) Commercial "root stimulator" product at rate recommended on the label. Treatment 10 and treatment 13 were very similar in chemical composition.
- 14) Control, 3.78 liters of tap water

These treatments were applied as a media drench to the containers of each plant. The 3.78 liters of treatment solution was enough to saturate the media in the containers to the point that a small amount drained out the bottom.

The experiment was set up in a gravel bed in a container growing area where overhead irrigation was applied three times a week or as needed. The data recorded were leaf color, number of bud breaks, fresh weight of tops and fresh weight of roots that extended beyond the original one gallon size root ball.

Leaf color data were recorded on October 10, 1985, nine weeks after treatment application and nine weeks before harvesting. The method for recording leaf color was to have two persons agree upon a single leaf from each plant having a color that was most representative of the average color of the remaining leaves on that plant. As each leaf was selected, the treatment and replication numbers were recorded directly on the back side of the leaf with permanent ink. After collecting a representative leaf from each plant, a range of five color categories was selected. The end points of the color categories were located using the darkest green and the lightest yellow leaves. The leaf that exhibited the darkest green color was chosen to represent color category V. The leaf that exhibited the lightest yellow was chosen to represent category I. Three color categories that were intermediate to these two end points were chosen. Each of the the

harvested leaves were placed into one of the five categories that most closely matched its own color.

The actual color of each of five categories can be described using the Nickerson color fan. The categories and their respective colors according to that fan are:

Category I was a range from 10Y 6/7 dark greenish yellow to
2.5GY 6/8 strong yellow green

Category II was a range from 2.5GY 5/5 moderate yellow
green to the lighter shades of 5GY 5/6
moderate yellow green

Category III was the darker shades of 5GY 5/6
moderate yellow green

Category IV was the lighter shades of 7.5GY 4/4
moderate olive green

Category V included the darker shades of 7.5 GY 4/4
moderate olive green and anything darker

On December 5 and 6, 1985, the plants were harvested and data were recorded on the number of buds that broke (expanded and grew), the fresh weight of the tops and on the fresh weight of the new roots that extended into the soil around the original Zarn 300 "one gallon" sized root ball. The method for collecting the root weights began by removing the plants from containers and rinsing the bulk of the media off the perimeter of the root ball with a pressurized stream of water. The roots that grew beyond the edge

of the original root ball were then excised using a Felco hand pruner. The perimeter of the original root ball was readily evident by large sized roots that were lining its edges. After the roots were excised, they were rinsed twice by hand using a colander and two large washtubs filled with water. The first tub separated the bulk of the soil from the roots and the second tub was a clear rinse. This rinsing method was effective in removing the bulk of the media particles from the excised roots. However, a small amount of pine bark remained inseparable from the root mass since some of the roots had grown between the layered plates of pine bark. After rinsing, the root mass was squeezed to remove excess moisture and then put in a paper bag labeled with treatment and replication numbers. The roots were air dried for 48 hours, to evaporate the free moisture. The root weights were then measured with a double beam gram balance and recorded.

The method for recording the fresh weight of tops began with tagging and excising the plant tops at soil level. The weights were then measured and recorded with a double beam gram balance.

Analysis of variance was conducted and mean separation was determined using Duncan's new multiple range test.

C. *Euonymus* In Field

The third experiment was initiated in August 1985. The conditions of this experiment were similar to those experienced by landscape contractors planting container grown plants into the landscape, since they commonly plant container grown nursery stock throughout the year. This experiment was conducted to test the effects of indole-3-butyric acid, thiamine hydrochloride, a complete fertilizer (4-10-3), treble superphosphate (0-46-0), peat as a backfill soil amendment and shredded hardwood bark as a mulch over the root zone. Container grown *Euonymus kiautschovicus* 'Manhattan' were transplanted from one gallon containers into a field soil of Etowah silt loam on August 29th. They were planted in hand dug holes that were approximately twice as wide and the same depth as the containers in which the plants had been grown. A small rim of soil was mounded around each plant and they were watered thoroughly immediately after planting. Several hours later the treatments were applied.

The IBA treatments were applied as a liquid soil drench using the water soluble potassium salt form of IBA. The thiamine treatments were applied as a liquid soil drench using thiamine hydrochloride. The 4-10-3 fertilizer treatments were made by mixing a laboratory grade of ammonium phosphate dibasic $(\text{NH}_4)_2\text{HPO}_4$ (21-53-0) with muriate of potash KCl (0-0-60) at a

ratio of 3.77 parts ammonium phosphate dibasic to one part muriate of potash. The 4-10-3 fertilizer treatments were also applied as a liquid soil drench.

The treble superphosphate, 0-46-0, was applied in granular form to the backfill soil at the rate of .5 grams/l (0.5 oz/ft³) of backfill soil. The sphagnum peat was mixed into the backfill soil at the rate of one part peat by volume to two parts backfill soil by volume. The mulch treatment was an application of shredded hardwood bark 7.5 centimeters deep and extending 20 centimeters from the base of the plant in all directions.

All treatments were applied to this experiment the same day plants were planted. The experiment consisted of twenty treatments:

- 1) IBA @ A rate, 3.78 liters of aqueous solution applied at 0.055 mg/liter
- 2) IBA @ B rate, 3.78 liters of aqueous solution applied at 2.75 mg/liter
- 3) IBA @ C rate, 3.78 liters of aqueous solution applied at 5.5 mg/liter
- 4) Thiamine hydrochloride @ A rate, 3.78 liters of aqueous solution applied at 20.51 mg/liter
- 5) Thiamine hydrochloride @ B rate, 3.78 liters of aqueous solution applied at 1025.5 mg/liter
- 6) Thiamine hydrochloride @ C rate, 3.78 liters of aqueous solution applied at 2051.0 mg/liter

- 7) 4-10-3 fertilizer @ A rate, 3.78 liters of aqueous solution applied at 546.0 mg N/liter
- 8) 4-10-3 fertilizer @ B rate, 3.78 liters of aqueous solution applied at 2730.0 mg N/liter
- 9) 4-10-3 fertilizer @ C rate, 3.78 liters of aqueous solution applied at 5460.0 mg N/liter
- 10) Combination A, 3.78 liters of aqueous solution containing 0.055 mg IBA/liter, 20.51 mg thiamine/liter and 4-10-3 at 546.0 mg N/liter
- 11) Combination B, 3.78 liters of aqueous solution containing 2.75 mg IBA/liter, 1025.5 mg thiamine/liter and 4-10-3 at 2730.0 mg N/liter
- 12) Combination C, 3.78 liter of aqueous solution containing 5.5 mg IBA/liter, 2051.0 mg thiamine/liter and 4-10-3 at 5460.0 mg N/liter
- 13) Control, 3.78 liter of tap water
- 14) 0-46-0, granular treble superphosphate at 0.5 g/liter (0.5 oz/ft.³) of backfill soil
- 15) Peat amended backfill, ground sphagnum peat moss incorporated into backfill soil at one part peat by volume to two parts soil by volume
- 16) Bark mulch; shredded hardwood bark on the soil surface 7.5 cm. deep and extending 20 cm. from the base of the plant in all directions

- 17) Combination 0-46-0, peat and mulch; (combination of treatments 14,15 and 16)
- 18) Combination A⁺; Combination of IBA, Thiamine and 4-10-3 each at their respective A rates, plus peat amended backfill soil and bark mulch over the root zone
- 19) Combination B⁺; Combination of IBA, Thiamine and 4-10-3 each at their respective B rates, plus peat amended backfill and bark mulch over the rootzone
- 20) Combination C⁺; Combination of IBA, Thiamine and 4-10-3 each at their respective C rates plus peat amended backfill and bark mulch over the root zone

The experiment was a randomized complete block design with four replications. There were twenty treatments and three samples per treatment per replication, for a total of 240 experimental units.

Following treatment, the plants were grown in the field for 14 weeks. The data collected in this experiment were leaf color, number of bud breaks, fresh weight of tops and fresh weight of roots that extended beyond the original one gallon size root ball. Leaf color data were recorded on September 29, 1985, four weeks after treatment. The method for recording leaf color differences was the same as that used in the previous experiment on the *Euonymus* in containers.

The number of bud breaks on each plant was counted and recorded on December 6, 1985, fourteen weeks after treatment. On

December 9, 1985, fourteen weeks after treatment, the plants were harvested and data were recorded on the fresh weight of the tops and on the fresh weight of the roots that extended beyond the original "one gallon" size root ball. Due to time and labor limitations, root weight data was recorded on only one of the three sample plants receiving the same treatment. The particular sample to be dug and analyzed for root weight was chosen at random using a table of random numbers. Each plant was dug in the same manner as the shade trees with a uniform sized root ball of twenty-four inch diameter. After they were dug, the bulk of the field soil was washed from the root ball with a pressurized stream of water. The roots that grew beyond the edge of the original one gallon size root ball were then excised. The original root ball was readily evident by the large sized roots that were lining its edges. After the roots were excised, they were rinsed twice by hand using a colander and two large wash tubs filled with water. The first tub separated the bulk of the soil from the roots, and the second tub was a clear rinse. The rinsing method was effective in removing the field soil from the roots. After rinsing, the excess moisture was squeezed from the root mass. They were then put in small paper bags labeled with treatment and replication numbers. The roots were air dried for 48 hours, to evaporate the free moisture. The root weights were then taken with a double beam gram balance and recorded.

The method for recording fresh weight of tops began with tagging and excising the tops at ground level. The weights were measured with a double beam balance and recorded.

Analysis of variance was conducted and mean separation was determined using Duncan's new multiple range test.

CHAPTER IV

RESULTS AND DISCUSSION

A. Shade Trees

The results of the experiment using sugar maples and sweet gums showed that neither of the individual components or the combination of components caused any statistically significant effects on the parameters measured, at the time they were measured (Tables 1 and 2). The lack of significant treatment effects is probably due to the low concentration of solutes in the treatment solutions, or to the time period that elapsed between treatment application and growth parameter measurement. If there were significant effects shortly after the treatment application, it is possible that the trees outgrew the effects by the time growth measurements were recorded. These results are in agreement with those of two later experiments, in which identical treatment solutions applied to Euonymus kiautschovicus 'Manhattan'

TABLE 1. Effects of fertilizer, IBA, thiamine and a commercial "root stimulator" product on growth of Acer saccharum.

Treatment	Caliper Increase (mm)	Central Leader Length Increase (cm)	Root Weight Increase (g)
1. Control	5.0	20.2	8.9
2. 4-10-3	1.5	15.2	12.6
3. IBA	2.2	13.0	11.9
4. Thiamine	1.8	12.4	10.7
5. Commercial Product	0.8	21.6	9.1

note: All means within individual columns are not significantly different at the 5% level according to an F test.

TABLE 2. Effects of fertilizer, thiamine, and a commercial "root stimulator" product on growth of Liquidambar styraciflua.

Treatment	Caliper Increase (mm)	Central Leader Length Increase (cm)	Root Weight Increase (g)
1. Control	3.7	13.2	41.6
2. 4-10-3	3.5	17.0	42.0
3. IBA	3.7	13.6	35.4
4. Thiamine	3.2	22.6	40.2
5. Commercial Product	4.7	16.6	37.7

note: All means within individual columns are not significantly different at the 5% level according to an F test.

did not cause effects which were significantly different from the controls.

B. Euonymus in Containers

The plants treated with IBA only or thiamine only had mean leaf colors that were not significantly different from that of the control (Table 3 and Figure 1). The plants treated with 4-10-3 fertilizer at the A rate had mean leaf colors that appeared to be somewhat greener but were not statistically different from those of the control or from the combination treatment at the A rate. The plants treated with 4-10-3 fertilizer at the B rate, C rate, combination at the B rate and combination at the C rate shared the highest leaf color rating. The commercial product had a mean leaf color that was not significantly different from the fertilizer at the A rate or the combination at the A rate.

The plants treated with IBA only or thiamine only, at all the rates tested, did not have an increased number of bud breaks compared to the control (Table 3 and Figure 2). The plants treated with fertilizer at the A rate did not have bud breaks different from the control. Fertilizer applied at the B and C rates did result in a high number of bud breaks. Fertilizer applied at the B and C rates enhanced bud break equal to that of the combination treatments at the B and C rates. The commercial product treatment

TABLE 3. Effects of IBA, thiamine and fertilizer on growth of Euonymus kiautschovicus 'Manhattan' in containers.

Treatment	Leaf Color Mean**	Number of Budbreaks Mean	Top Growth Mean (g)	Root Growth Weight Mean (g)
1. IBA @ A rate	1.88 d*	0.00 b	58.14 e	14.38 de
2. IBA @ B rate	1.38 d	0.00 b	65.00 e	11.75 e
3. IBA @ C rate	2.25 cd	0.12 b	79.00 cde	12.38 e
4. Thiamine @ A rate	1.33 d	0.00 b	69.25 de	10.88 e
5. Thiamine @ B rate	1.75 d	0.00 b	74.63 de	14.62 de
6. Thiamine @ C rate	2.25 cd	0.00 b	78.25 cde	12.25 e
7. 4-10-3 @ A rate	3.00 bc	0.62 b	100.50 cd	17.25 de
8. 4-10-3 @ B rate	5.00 a	11.75 a	179.88 b	40.00 bc
9. 4-10-3 @ C rate	5.00 a	9.67 a	201.00 ab	64.67 a
10. Comb. @ A rate	3.17 b	0.83 b	99.17 cd	16.50 de
11. Comb. @ B rate	4.88 a	9.50 a	183.00 b	57.38 ab
12. Comb. @ C rate	5.00 a	9.75 a	221.88 a	53.88 ab
13. Product @ A rate	3.75 b	0.25 b	110.25 c	31.88 cd
14. Control	2.25 cd	0.00 b	63.38 e	12.12 e

* Means followed by the same letter are not significantly different at the 5% level according to Duncan's new multiple range test.

** Leaf color categories ranged from 1, dark greenish yellow to 5, moderate olive green based on the Nickerson color fan.

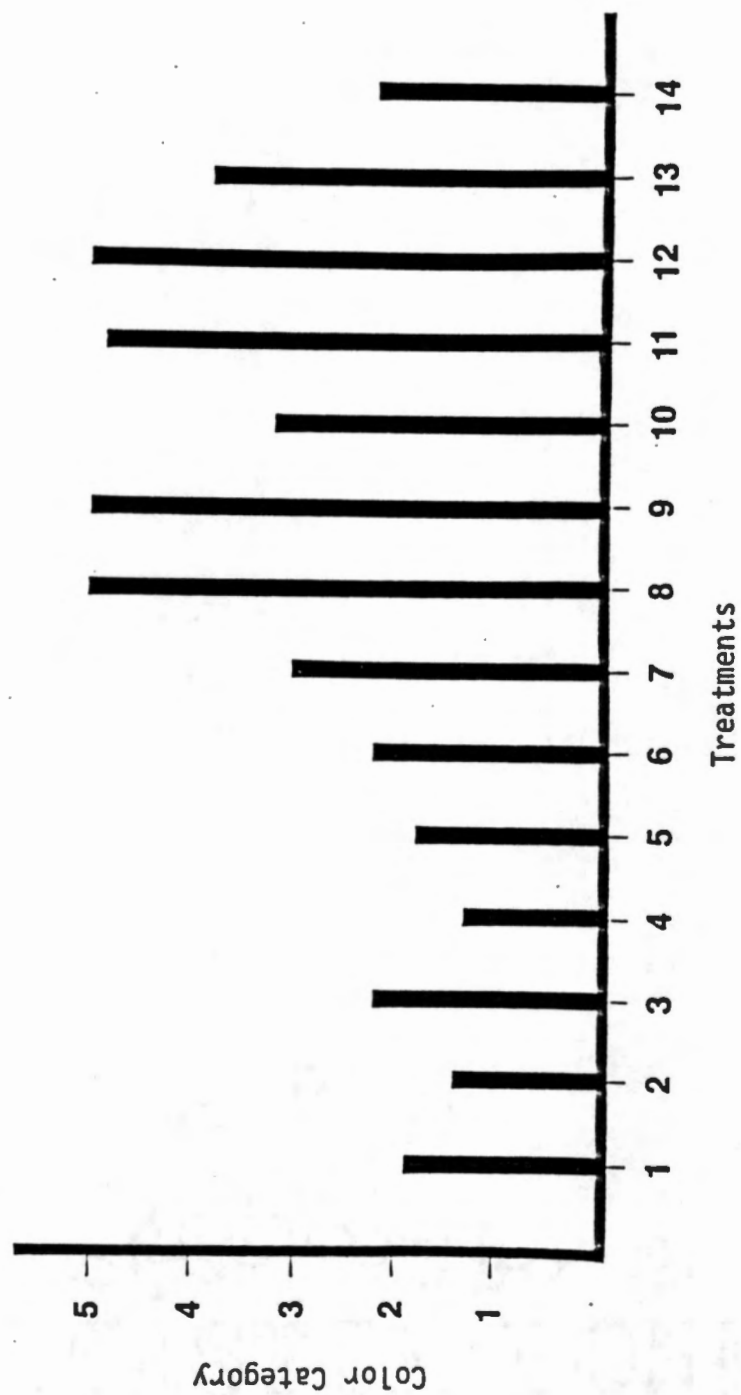


Figure 1. Effect of treatments on leaf color. Euonymus kiautschovicus 'Manhattan' in containers.

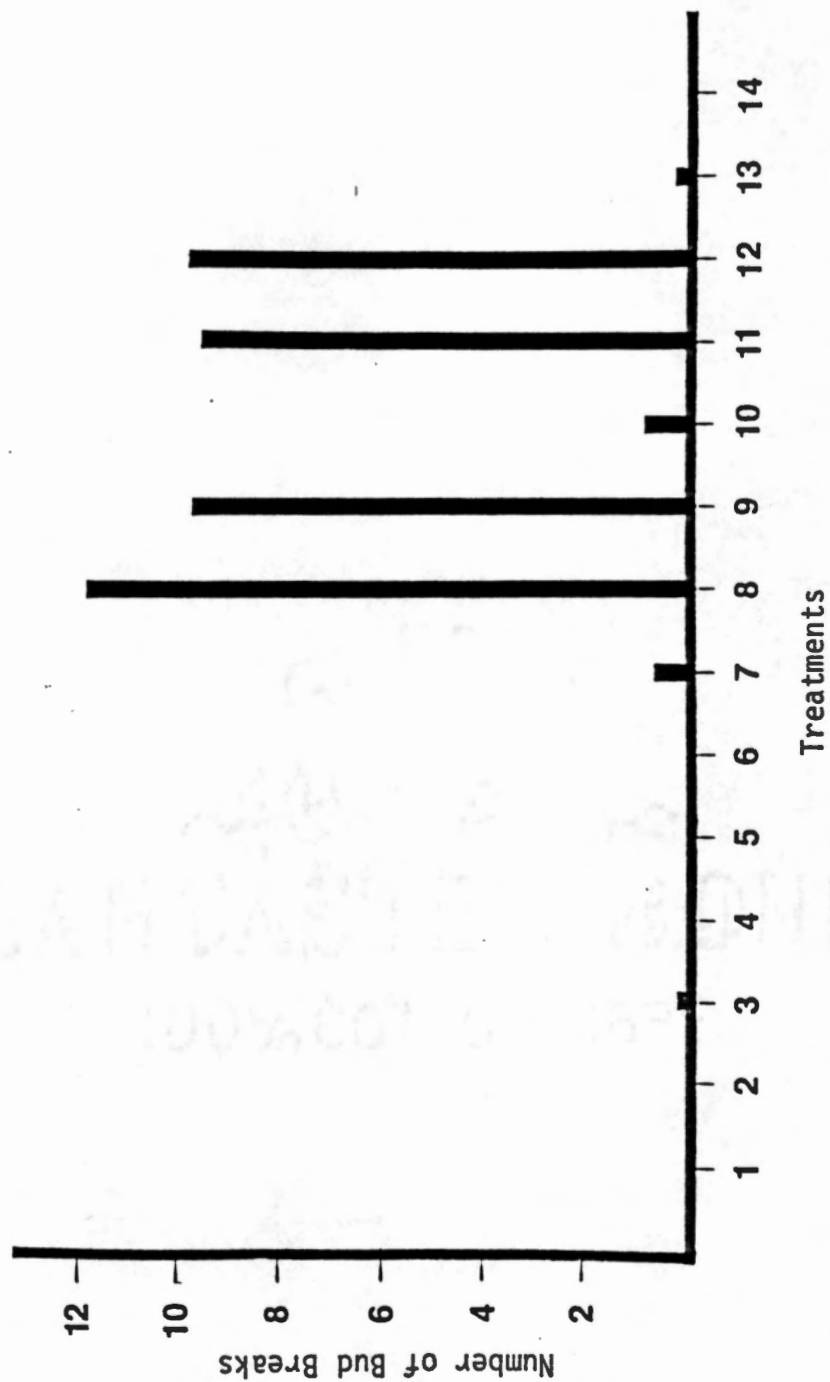


Figure 2. Effect of treatments on bud breaks. Euonymus kiautschovicus 'Manhattan' in containers.

did not effect bud break and was not different from the control or fertilizer at the A rate.

The plants treated with IBA or thiamine only, at all the rates tested, did not affect top growth weight significantly compared to the control (Table 3 and Figure 3). Fertilizer at the A rate as well as the combination at the A rate and the commercial product each had an effect on top growth weight. The plants treated with fertilizer at the B rate had top weight that was not significantly different from those that were treated with fertilizer at the C rate or the combination at the B rate. The plants treated with the combination at the C rate and those treated with fertilizer alone at the C rate, had the highest mean top weight.

The plants treated with IBA or thiamine only, at all the rates tested, fertilizer at the A rate and the combination at the A rate all had mean new root growth weights which were not different from that of the control (Table 3 and Figure 4). The plants treated with fertilizer at the B rate, combination at the B and C rate had mean new root growth weights which were greater than those of the control. The plants treated with fertilizer at the C rate and those treated with the combination at the B or C rate had the highest mean new root growth weight.

The main objective of this study was to determine the effects of the three major components (IBA, thiamine, 4-10-3 fertilizer) of a commercial "root stimulator" product and to determine which

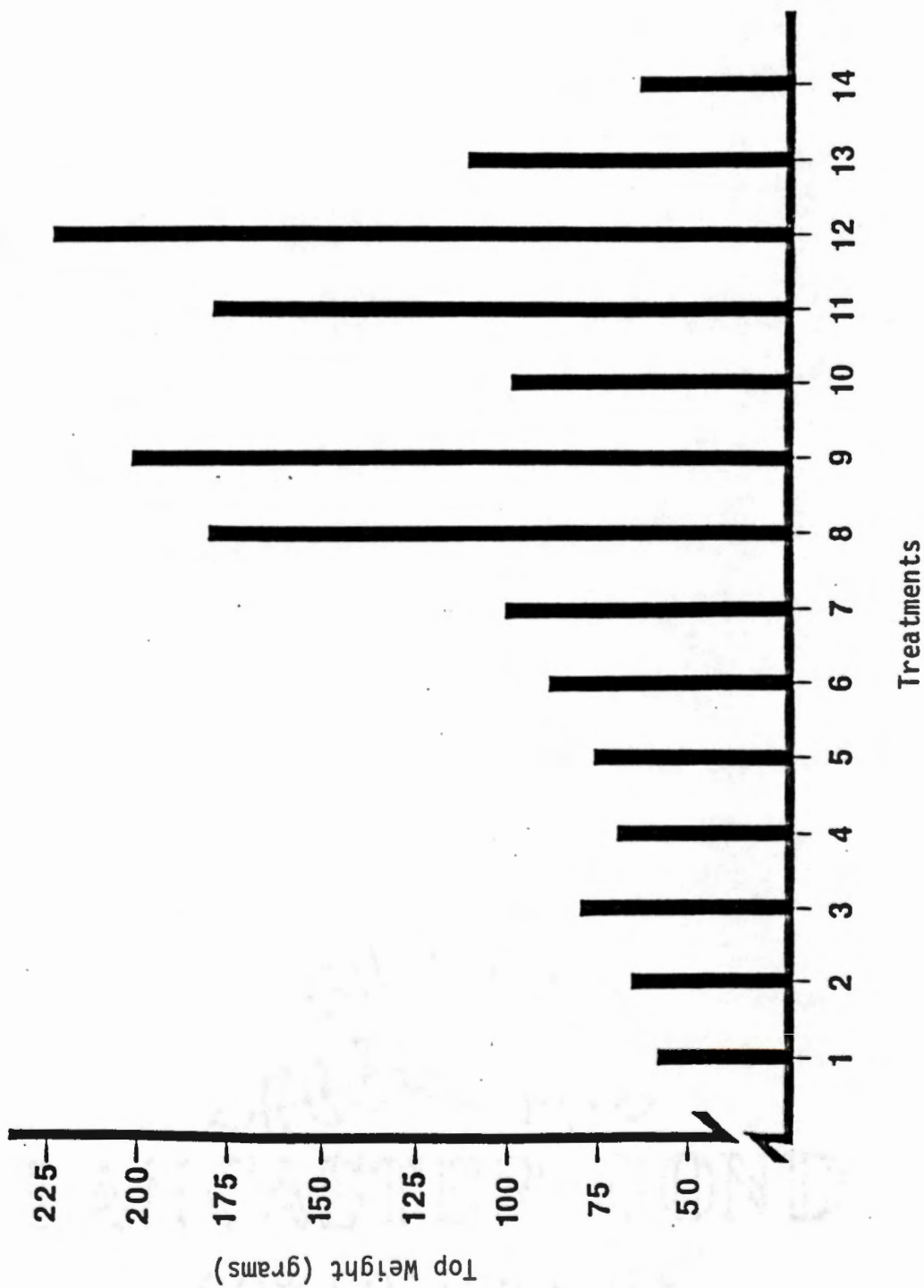


Figure 3. Effect of treatments on top weight. *Euonymus kiautschovicus* 'Manhattan' in containers.

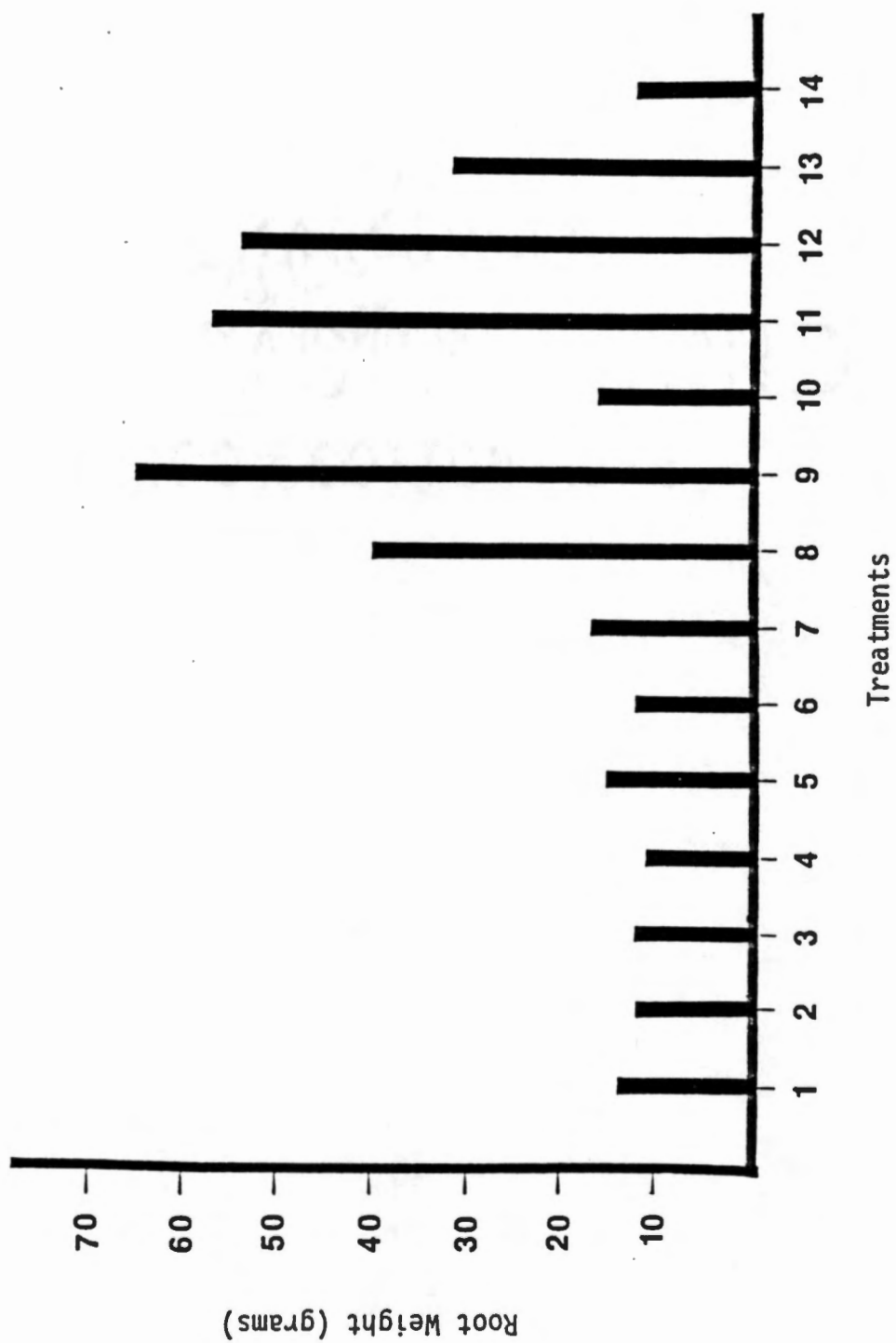


Figure 4. Effect of Treatment on root weight. *Euonymus kiautschovicus* 'Manhattan' in containers.

component was most responsible for enhanced growth, especially root growth since that is what the product is advertised to promote.

The results showed that treatment with IBA or thiamine alone, at the rates applied, did not significantly increase growth of

Euonymus kiautschovicus 'Manhattan' in containers.

However, the third component (4-10-3 fertilizer), resulted in greater top growth weight and new root growth weight when applied at the A rate and enhanced growth for all parameters measured when applied at B and C rates. When fertilizer, IBA and thiamine were mixed into a combination treatment, it did not increase the growth parameters above those of the corresponding fertilizer treatment. These results are in agreement with that of a previous study (20).

A study with a similar root stimulator product containing a complete fertilizer, an auxin (NAA) and thiamine showed that fertilizer alone at rates similar to the rate of fertilizer in a combination treatment resulted in equivalent growth effects on snapdragon plants (20).

C. *Euonymus* in Field

Treatments resulting in leaf color means less than or not significantly different from those of the control were; IBA at all the rates tested, thiamine at all the rates tested, fertilizer at the A rate, combination at the A rate, superphosphate in the

backfill, peat amended backfill, bark mulch and the combination of superphosphate plus peat amendment plus bark mulch (Table 4 and Figure 5). Treatments which gave the greatest values for leaf color means were; fertilizer at the B and C rates, combination at the B and C rates and combination at the B+ and C+ rates. Plants receiving combination A, bark mulch and combination A+ treatments had leaf color means which were not different from the above treatments.

Treatments resulting in mean number of bud breaks less than or not significantly different from that of the control were: IBA at the A, B and C rates, thiamine at the A, B and C rates, fertilizer at the A rate, combination at the A rate, superphosphate in the backfill and peat amended backfill (Table 4 and Figure 6).

Treatments which resulted in a higher number of bud breaks than that of the control were: fertilizer at the B and C rates, combination at the B and C rates and combination at the A+ rate. The treatments that resulted in the four highest means for the number of bud breaks were; bark mulch, combination of 0-46-0 plus peat plus mulch and the combinations at the B+ and C+ rates.

Treatments resulting in plants having mean top growth weights less than that of the control were: IBA at the C rate and the peat amended backfill (Table 4 and Figure 7). The treatments which resulted in plants having mean top growth weights which were not different from that of the control were: IBA at the B and C rates,

TABLE 4. Effects of IBA, thiamine, fertilizer, granular superphosphate, peat amended backfill and mulch on growth of Euonymus kiautschovicus 'Manhattan' transplanted into field soil.

Treatment	Leaf Color Mean**	Number of Budbreaks Mean	Top Growth Weight Mean (g)	Root Growth Weight Mean (g)
1. IBA @ A rate	2.42 ef*	1.25 c	82.33 efg	23.67 b
2. IBA @ B rate	1.83 f	0.75 c	81.83 efg	41.00 ab
3. IBA @ C rate	2.92 de	0.67 c	67.08 fg	14.50 b
4. Thiamine @ A rate	2.67 def	0.50 c	77.25 efg	22.75 b
5. Thiamine @ B rate	3.12 cde	1.50 c	78.17 efg	17.75 b
6. Thiamine @ C rate	2.83 de	2.92 c	91.17 cdefg	24.25 ab
7. 4-10-3 @ A rate	3.25 cde	1.00 c	84.17 defg	30.75 ab
8. 4-10-3 @ B rate	5.00 a	6.00 b	111.17 cde	16.50 b
9. 4-10-3 @ C rate	4.92 a	6.33 b	121.00 bc	30.25 ab
10. Comb. @ A rate	4.08 abc	2.33 c	85.92 defg	16.25 b
11. Comb. @ B rate	4.83 a	6.42 b	112.00 cde	40.25 ab
12. Comb. @ C rate	4.92 a	5.92 b	118.33 bcd	27.25 ab
13. Control	3.25 cde	2.83 c	104.58 cde	40.75 ab
14. 0-46-0	3.00 de	2.08 c	80.08 efg	18.50 b
15. Peat Amended	2.92 de	1.75 c	58.83 g	24.00 b
16. Bark Mulch	4.17 abc	7.42 ab	111.73 cde	38.25 ab
17. Comb. 0-46-0 + Peat + Mulch	3.67 bcd	7.33 ab	100.83 cdef	30.00 ab
18. Comb. A+ rate	4.58 ab	6.83 b	118.58 bcd	38.00 ab
19. Comb. B+ rate	4.92 a	8.58 ab	147.67 ab	56.00 a
20. Comb. C+ rate	4.92 a	10.17 a	163.83 a	39.67 ab

* Means followed by the same letter are not significantly different at the 5% level according to Duncan's new multiple range test.

** Leaf color categories ranged from 1, dark greenish yellow to 5, moderate olive green based on the Nickerson color fan.

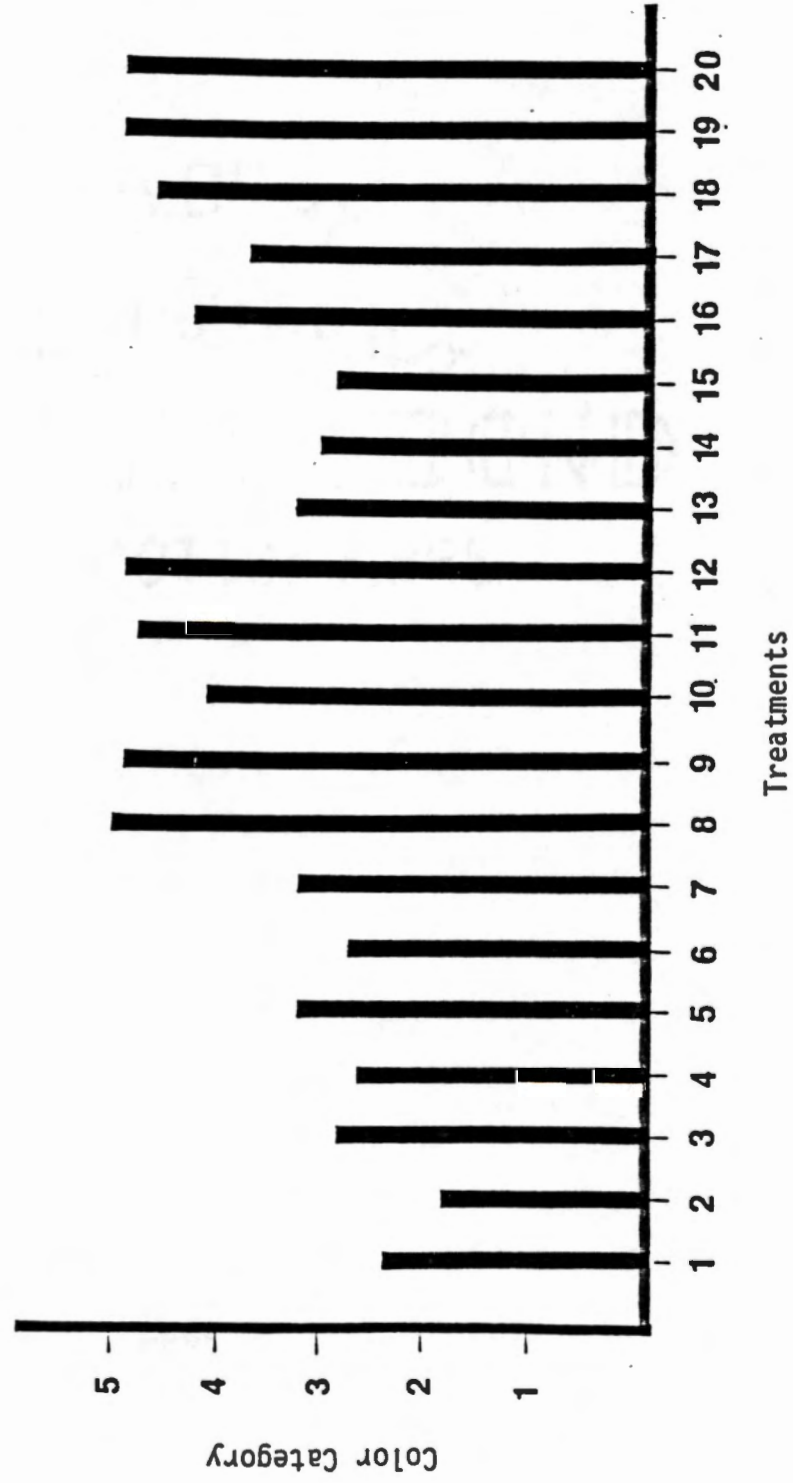


Figure 5. Effect of treatments on leaf color. Euonymus kiautschovicus 'Manhattan' in field.

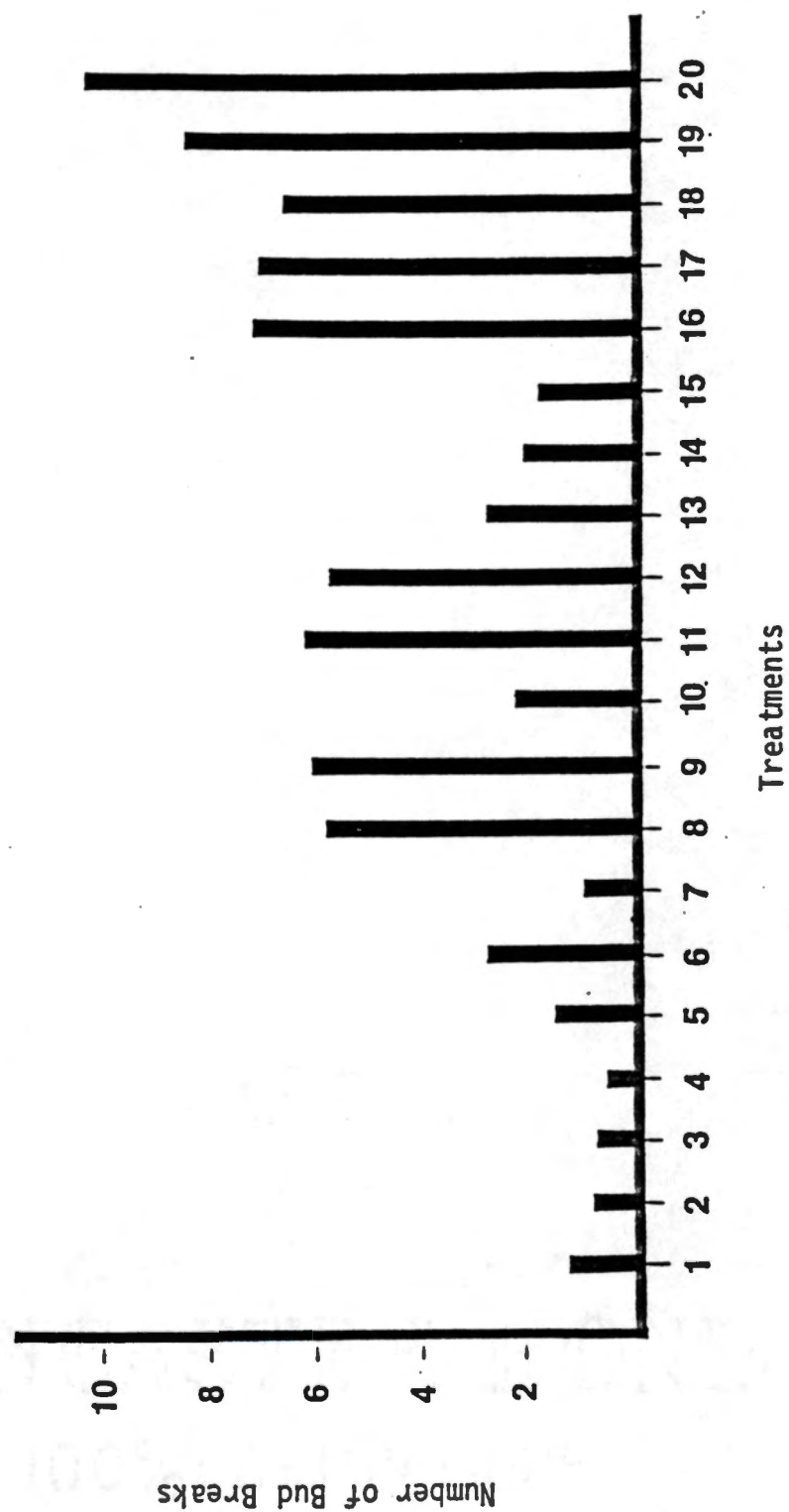


Figure 6. Effect of treatments on bud breaks. Euonymus kiautschovicus 'Manhattan in field.

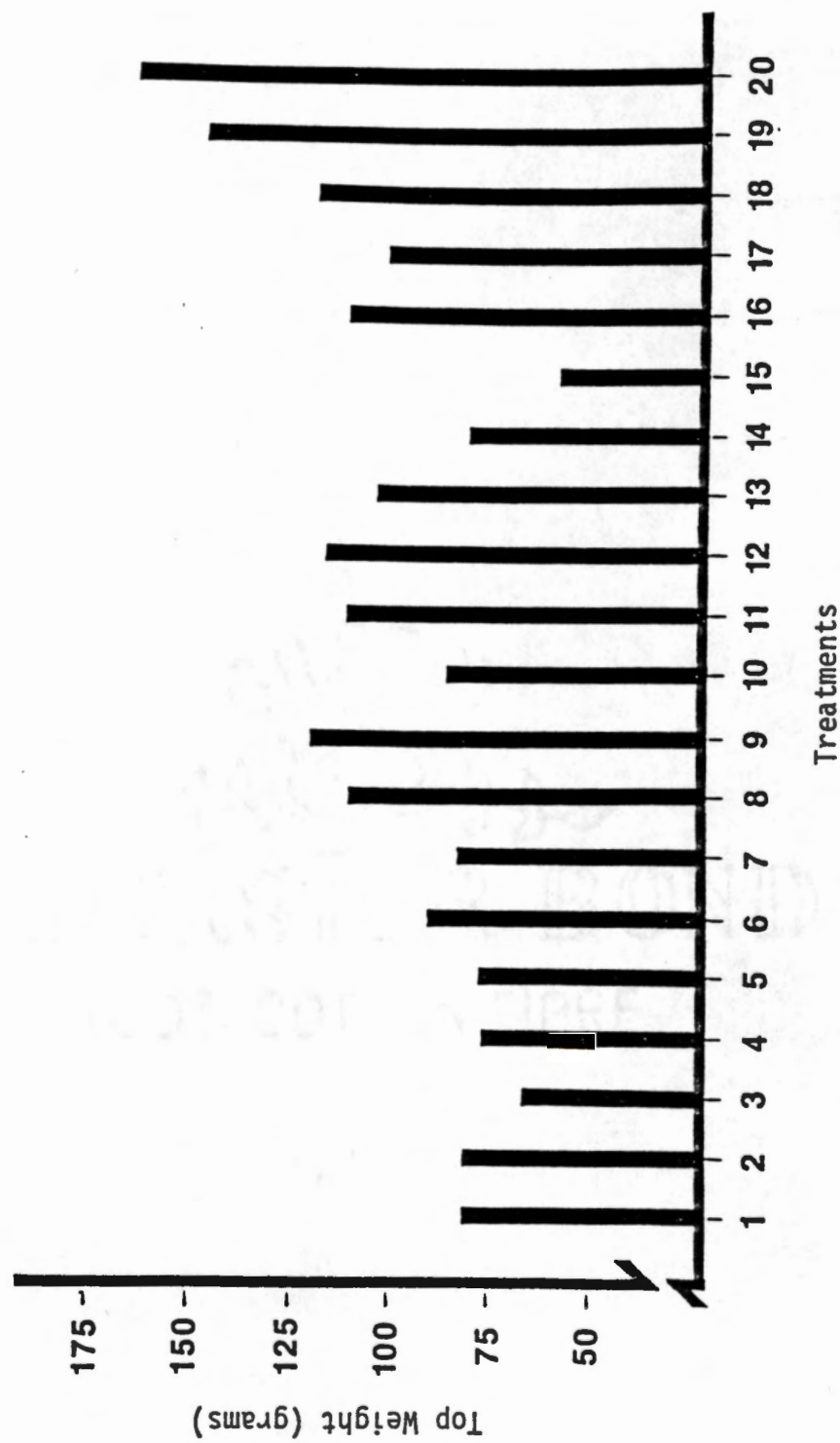


Figure 7. Effect of treatments on top weight. *Euonymus kiautschovicus* 'Manhattan' in field.

thiamine at the A, B and C rates, fertilizer at the A, B and C rates, combination at the A, B and C rates, superphosphate, bark mulch, combination superphosphate plus peat plus bark mulch and combination at the A+ rate. The treatments which resulted in plants having mean top weights greater than that of the control were the combinations at the B+ and C+ rates.

In the case of new root growth weight means, there were only two ranges of significance and neither was significantly different from that of the control (Table 4 and Figure 8). The only treatment which resulted in a mean in the upper range and not into the lower range was the combination at the B+ rate.

The main objective of this study was to identify which of the three major components of a commercial "root stimulator" product had the most effect on growth of containerized Euonymus kiautschovicus 'Manhattan' after transplanting to the field. Additional objectives were to determine if the combination of IBA, thiamine and fertilizer significantly enhanced growth more than the single most effective component and to test some of these factors at different rates and combinations to determine which was most influential at enhancing the growth and establishment. Another objective was to determine if some cultural practices applied singly and in combination resulted in significant positive effects on growth. The results showed that plants treated with fertilizer at the A rate performed equally as well as those treated with

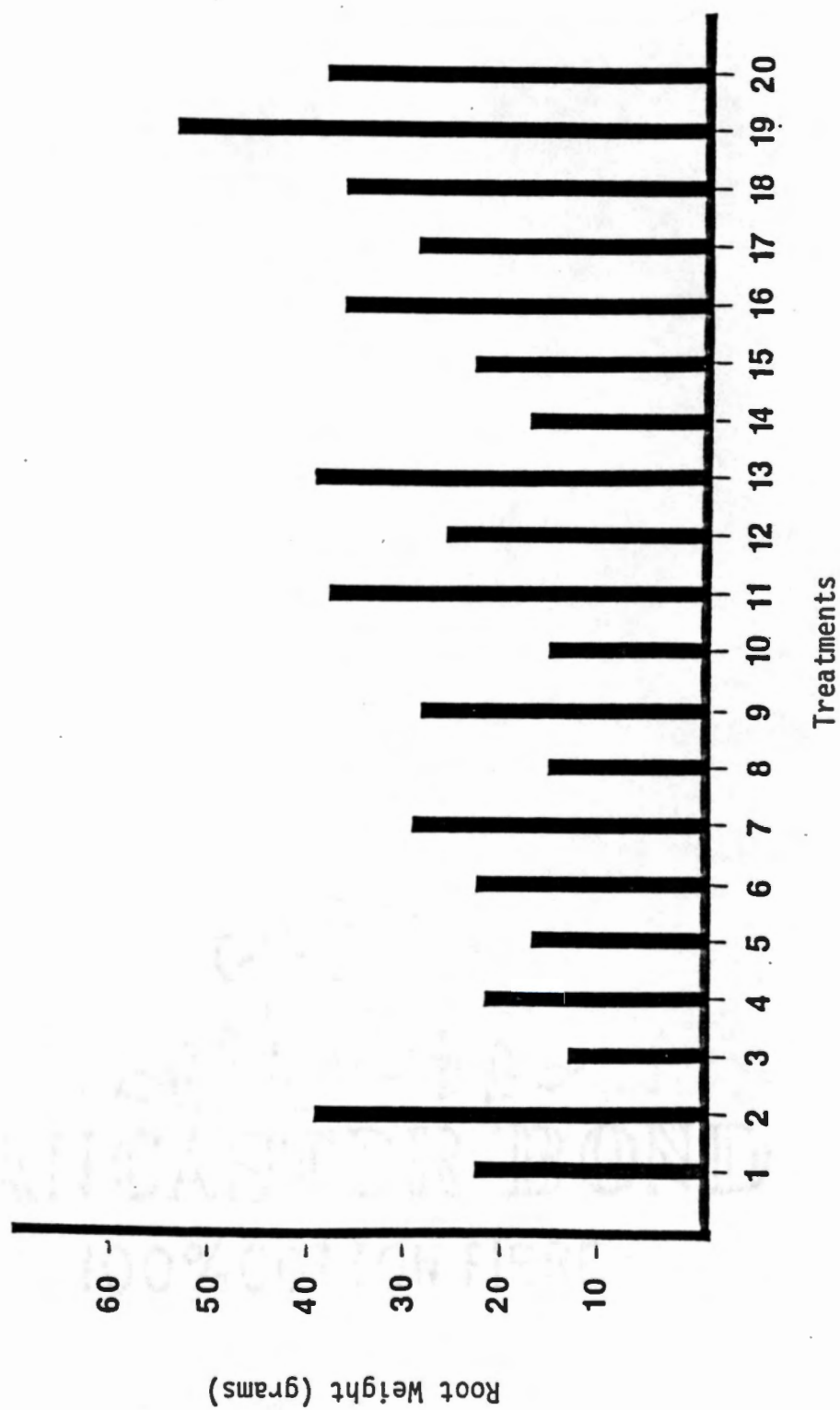


Figure 8. Effect of treatments on root weight. Euonymus kiautschovicus 'Manhattan' in field.

combination at the A rate. Likewise, those treated with fertilizer at the B and C rates did equally as well as those treated with the combinations at the B and C rates respectively. The plants treated with superphosphate performed equally as well as the control. This suggests that native phosphorus was present in the soil in adequate amounts for the normal growth of the plant and that additional phosphate was not beneficial (18).

The plants treated with sphagnum peat as a backfill soil amendment performed equally as well as the controls except for the parameter of top growth weight, where the peat amendment was deleterious and resulted in the lowest top weight mean of any treatment applied. However, this treatment did not result in detrimental effects on leaf color, number of bud breaks or new root weight. Shredded hardwood bark used as a mulch, had no effect on top weight or root weight however it did enhance the number of bud breaks and the leaf color mean significantly.

The combination of phosphate, peat amendments and bark mulch had no significant effect on top weight, root weight or leaf color, however it did enhance the number of budbreaks. This positive effect was probably due to the bark mulch since the plants receiving the mulch alone had greater means than the super phosphate or peat amendment alone than did plants treated with the combination on three of the parameters measured.

The plants receiving the combination A+ treatment had means higher than the combination at the A rate. The greater effect was probably due to the added benefits of the mulch . The plants receiving combination treatments at the B+ and C+ rates had the highest mean ratings on all of the parameters measured. These high means resulting from such combination treatments are probably reflections of the fertilizer and mulch in those combinations, since fertilizer and mulch each enhanced growth when applied singularly.

CHAPTER V

SUMMARY AND CONCLUSIONS

The primary purpose of this research was to determine which combination of a variety of chemical treatments and cultural practices tested would best enhance the establishment and growth of transplanted woody ornamentals.

The treatments which were tested were the application of: solutions of indole-3-butyric acid (IBA) at three concentrations, solutions of thiamine hydrochloride at three concentrations, solutions of a complete fertilizer (analysis 4-10-3) at three concentrations, combination solutions of IBA plus thiamine plus fertilizer, granular superphosphate (analysis 0-46-0), ground sphagnum peat as a backfill soil amendment, shredded hardwood bark as a mulch over the rootzone and several combinations of these various treatments.

This research included a series of three experiments. The first using Liquidambar styraciflua and Acer saccharum as experimental units, which were transplanted as

bare root liners into a field soil before treatments were applied. The second experiment was conducted using containerized Euonymus kiautschovicus 'Manhattan' as experimental units, which were transplanted from "one gallon" to "two gallon" containers before treatments were applied. The third experiment used container grown Euonymus kiautschovicus 'Manhattan' which were transplanted from "one gallon" size containers into a field soil before treatments were applied, or as treatments were applied in the case of peat soil amendment and superphosphate in the backfill.

The application of IBA alone or thiamine alone, at all the rates tested, had either no effect or a negative effect on the plants tested. Complete fertilizer enhanced growth at the two higher concentrations tested. It enhanced plant growth equally as well when applied alone, or in combination with IBA and thiamine. Treatments of superphosphate or peat incorporated into the backfill soil resulted in no effect or negative effect on plant growth. Shredded bark mulch treatments caused either no effect or somewhat positive effects on plant growth. Combinations of IBA, thiamine, fertilizer, peat as a backfill amendment and shredded bark as a mulch enhanced growth most and resulted in more healthy looking plants than did any of the other treatments.

The use of a certain "root stimulator" product containing extremely low rates of IBA, thiamine and 4-10-3 fertilizer, when

applied according to its labeled recommendations, resulted in insignificant increases in root growth and minimal increases in top growth. Nearly identical growth effects were obtained when fertilizer alone was applied at a rate corresponding to the rate of the fertilizer found in the product.

Judging from the results of this research, the application of a root stimulator product containing IBA, thiamine and 4-10-3 fertilizer may be somewhat beneficial to the establishment and growth of transplanted woody ornamentals. However, nearly identical benefits can be obtained much more economically by applying a complete fertilizer alone.

The results of this study concerning the use of ground sphagnum peat as a soil amendment are in agreement with other recent research which states that there is a lack of consistent positive results (10, 21, 34) or that results can be detrimental (38, 41, 47) when peat is used as a backfill amendment. Thus it is probably better, in most situations not to amend backfill soil with peat when planting woody ornamental plants.

The benefits of incorporating superphosphate into the backfill soil were negligible in this study. However, such application may be warranted if the soil is low in phosphorus (18).

The use of shredded bark as a mulch resulted in minimum positive effects when used alone. However, plants which were treated with higher rates of fertilizer, in addition to other

components, and mulched resulted in the most dramatic positive growth effects.

Further research is merited using similar and higher rates of fertilizer applied alone and in combination with shredded bark as a mulch since these two factors appear to be most effective in enhancement of growth parameters for the transplanted species tested.

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