THE EFFECT OF RATE AND TIME OF APPLICATION OF THREE MICRONUTRIENT PRODUCTS DURING PRODUCTION OF WOODY AND HERBACEOUS SPECIES

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PREFACE

Many people have contributed their help and support to the completion of this study and my college career. First and foremost, I would like to express my appreciation to my parents for their belief in me and my goals. Without their emotional and moral support, the last five years would have been much more difficult.

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

With the advent of soilless growing media, the nursery industry made much progress in economizing the production of nursery stock. Growing media would no longer have to be steam or chemically pasteurized, fewer fungicides would be needed over the production period and the purchase of variable, heavy and expensive top-soil would be eliminated. However, these advantages had to be weighed against the fact that soilless media had little or no native nutrients and nursery crops need substantial quantities of nutrients in the proper proportion to fulfill their genetic potential.

The goal of this research was to determine the best source and rate of micronutrients for use in propagation and production of the woody species Japanese garden juniper, *Juniperus procumbens* and Hetzi Japanese holly, *Ilex crenata* 'Hetzi.' Since very little research has been conducted on the use of micronutrients in production of bedding plants, the herbaceous species Little Bright Eye Periwinkle, *Catharansus rosea* 'Little Bright Eye' was also included in this study. The goal was to determine which source and rate of micronutrients would produce the best crop with the highest landscape performance.

CHAPTER II

REVIEW OF LITERATURE

When Conover and Poole (2) applied Osmocote 14-14-14 at the 11,994.7 kg/hectare/year (10,700 lb./acre/year) rate, with one-third rate applications every four months, to Aglaonema 'Fransher' they found that the fertilizer had no effect on plant growth after four months. Additional applications did increase shoot number at seven and ten months on the test species. McGuire and Bunce (8) [also] used Osmocote 14-14-14 at 9.52 kg/m^3 (16 lbs./yd.^{3}) plus other treatments using coarse grade Mag-Amp with K at 11.9 kg (20 lbs.) and Urea-formaldehyde at 2.975 kg/m^3 (5 lbs./yd.^{3}) plus a treatment which contained no additives. They found that pachysandra, Pachysandra terminalis and viburnum, Viburnum plicatum 'Tomentosum' cuttings either rooted better or were not affected by the additives. However, rooting of forsythia, Forsythia intermedia 'Lynwood Gold' was decreased, not by lack of root initiation, but by restriction of root elongation. Subsequent growth of all species was improved where slow-release fertilizers had been used in propagation. Occasional side shoots were also found on treatments which included Osmocote 14-14-14, Mag-Amp with K or unreaformaldehyde. Subsequent growth was best when Osmocote was used during propagation. Gouin (6) also found that when a 7 or 14 gm/0.93 m^2 rate of Osmocote 19-6-12 was used as a top-dressing, applied immediately after propagation began, the treatment produced heavier root systems and less premature flowering than in unfertilized controls. Ward and Whitcomb (15) found a 58% increase in number of branches on Ilex crenata 'Hetzi' at the end of one growing season when 11.424 kg/m^3 (19.2 lbs./yd.^{3}) of Osmocote 18-6-12 was added to the propagation medium. In another study, they determined that 'Hetzi' Japanese holly cuttings propagated with Osmocote were much larger and more responsive to the fertilizer source and level of treatments (16). In studies to determine the proper Osmocote formulation for use during propagation, Whitcomb, Gibson and Storjohann (17) reported that 7.14-9.52 kg/m^3 (12-16 lbs./yd.^{3}) of Osmocote 18-6-12 (6-9 month formulation) produced significantly better plants at all rates than Osmocote 18-5-11 (12-14 month formulation) at any rate. Self and Washington (12) found that cuttings of 'Formosa' and 'Red Wing' azaleas and Dwarf Burford holly, Ilex cornuta 'Burfordii Nana' rooted 1-2 weeks sooner when Osmocote 18-6-12 was present in the propagation medium.

In research on production of woody ornamentals, Dickey (5) found maximum response of Viburnum suspensum to 1153.51 kg/hectare/year (1,029 lbs. N/acre/year). There were no synergistic effects from the addition of phosphorous and potassium above 13 parts per acre (ppa) and 83 ppa, respectively, supplied by the growing medium. Other studies (7, 10, 13) have shown that addition of slow-release fertilizers are prohibitive to survival and growth of cuttings of some woody ornamentals. In particular, Ticknor (13) found that rooting of Ilex cornuta 'O Spring,' Ilex hybrid 'September Gem' NA28370 and Ilex hybrid NA28371 was not increased by propagation with Osmocote 18-6-12 added to the peat-perlite medium. The rate used was 200 gm/cubic foot, which is comparable to 12 lbs./cubic yard, perhaps slightly higher than necessary for propagation. However, the unfavorable response he obtained may have been due to infrequent misting, resulting in a lack of leaching of fertilizer salts and/or drying of the rooting medium. The use of bottom heat and cool air could also have had an effect. These cuttings were not grown on and so the results cannot be considered decisive.

A review of the literature has yielded much information on the use of micronutrients in soilless media, but very little is available on the use of micronutrients. It was not until the late 1960's that serious investigation of micronutrient nutrition for container plants in soilless media began. In 1967 and 1968, Coorts (4) explored the effects of micronutrient deficiencies in two woody ornamentals. He reported that cuttings of Juniperus chinensis 'San Jose' with a deficiency of zinc or boron had more roots than cuttings propagated without deficiencies. However, fewer cuttings with deficiency conditions rooted. Ilex crenata 'Convexa' showed a decreased percentage of rooting except when grown under an iron deficiency condition. This was accounted for by possible outside contaminants unspecified by the researcher. Studies by Self and Cobb (11), utilizing specific micronutrient sources, discovered that adding Esmigran with additional iron and manganese improved the rooting of 'Coral Bell' azaleas above the already increased rooting from addition of micronutrients. A combination of micronutrients (Mobile Ornamental Research Station #008) with and without supplemental iron and maganese increased rooting of 'Coral Bell,' except at the lowest rate with supplemental iron and manganese. The lowest rate with supplemental iron and manganese actually reduced root development below the control level. Results from the Fritted Trace Element 175 treatments were inconsistent. When the aforementioned treatments were applied to the azalea cultivar 'H. H. Hume,' all treatments increased rooting with the exception of the one pound rate of Esmigran without supplemental iron and manganese. Schulte and Whitcomb (9) also showed a slight increase in rooting of *Juniperus chinensis* 'Hetzi' from Perk and Frit 504. In a rooting media fertility study by Cobb (1), significant increase in rooting of azaleas was reported with the use of Special 7 (a combination of micronutrients developed by the Auburn Ornamental Research Station, Mobile, Alabama). However, these data are questionable, as the rate of Osmocote was changed when Special 7 was added as compared to Osmocote alone. It has been demonstrated that the use of Osmocote can mask the effects of micronutrient additives (16).

In 1973, Conover and Poole (2) found Perk, a granular micronutrient source, decreased root grades in four out of six tropical and subtropical foliage plants. However, Perk had no effect on shoot grades of any species. They attributed the reduced root grades to phytotoxicity and theorized that newly stuck plants drew up micronutrient ions by mass flow through cut ends. Self and Washington (12), using FTE 400 and Esmigran at 0, 1, 2 and 3 lbs. per cubic yard, found that all cuttings showed improvement in the rate of growth and general appearance from the micronutrients applied during propagation with little difference between sources. In another study in containers utilizing Perk as one of the micronutrient sources, Whitcomb, et al. (18) emphasized that the best results with Japanese holly, *Ilex crenata*, were obtained with Perk at 4 or 6 lbs. and Esmigran at 6 or 8 lbs. per cubic yard and poorest results were obtained with FTE 503 and FTE 504 at the 0.25 lb. rate. These plants were "more chlorotic and smaller than the other rates and sources of micronutrients."

The micronutrient fertilizers Micromax, Esmigran and Frit 503 were chosen for this study. All three sources are manufactured by different methods and the micronutrients are released by different mechanisms. Micromax is a formultion of micronutrients immediately soluble in water, in the forms of ferrous sulfate, manganese sulfate, zinc sulfate, copper sulfate, sodium borate and sodium molybdate.

Esmigran is manufactured by the adsorption of micronutrients onto clay granules. The nutrients are slowly released by ion exchange. The micronutrients are in the forms of ferrous chloride, zinc sulfate, manganese sulfate, boric acid, copper sulfate and ammonium molybdate.

Frit 503 is manufactured by combining molten sand and micronutrients. Sulfur and chlorine are not included as they are highly volatile and would escape from the smelting process at these high temperatures. The molten mass is quickly cooled and ground. The particles release micronutrients as they weather, the fineness determines how quickly the nutrients are released. No information is available on the form of the micronutrients present in the final product. Most micronutrients are added to the molten sand as carbonates, but it is assumed that the high temperature may cause some change. The guaranteed analyses of these products vary widely, but true indication of how much of each element is getting into the medium depends on the rate used for each source of micronutrients (see Table I).

TABLE I

RELATIVE PROPORTIONS OF MICRONUTRIENTS SUPPLIED BY MICROMAX, ESMIGRAN AND FRIT 503 AT VARIOUS RATES

	Micromax (kg)			Esmigran (kg)		Frit 503 (kg)	
Element	0.4463	0.8925[z]	1.3388	1.785	3.57	0.1488	0.2975
Sulphur	0.0667	0.1339	0.2008	0.0179	0.0357	--	--
Iron	0.0536	0.1071[y]	0.1607	0.0357	0.0714	0.0383	0.0765
Manganese	0.0112	0.0223	0.0335	0.0089	0.0179	0.0142	0.0283
Copper	0.0023	0.0045	0.0067	0.0054	0.0107	0.0056	0.0112
Molybdenum	0.000023	0.000045	0.000067	0.000011	0.000021	0.00045	0.0009
Boron	0.00045	0.0009	0.0014	0.0004	0.0007	0.0145	0.0290
Zinc	0.0045	0.0089	0.0134	0.0179	0.0357	0.0130	0.0261
Chlorine	--	--	--	0.0464	0.0928	--	--

[z]Rates generally recommended.

[y]Based on percentages in products with adjustments made for rates used, i.e. Micromax has 12% iron * 0.8925 kg = 0.1071 or Frit 503 has 25.70% iron * 0.1488 kg = 0.0383. Amounts present are in kg/m^3.

CHAPTER III

METHODS AND MATERIALS

Propagation of Hollies and Junipers

In the propagation phase of the study, a randomized complete block design was used with six replications, ten treatments and four subsamples per treatment for each species. Japanese holly cuttings were taken from existing stock plants on November 23, 1979. Japanese garden juniper cuttings were taken from the OSU campus on November 30, 1979. The propagation medium consisted of 1 part peat, 1 part perlite and 5.355 kg Osmocote 18-6-12 per meter^3 (9 lb. per yard^3). The peat, perlite and Osmocote were mixed in a 1.5 cubic foot cement mixer before adding the micronutrients for each treatment. Treatments were Micromax[a] at 0, 0.4463, 0.8925 and 1.3388 kg per meter^3 (0, 0.75, 1.50 and 2.25 lbs. per yard^3); Esmigran[b] at 0, 1.785 and 3.57 grams per meter^3 (0, 3 and 6 lbs. per yard^3) and Frit 503[c] at 0, 0.1488 and 0.2975 grams per meter^3 (0, 0.25 and 0.50 lbs. per yard^3). The treatments of each

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[a]A micronutrient fertilizer manufactured by Sierra Chemical Co., Milpitas, CA.

[b]A micronutrient fertilizer manufactured by Mallinkrodt Chemical Co., St. Louis, MO.

[c]A micronutrient fertilizer manufactured by Frit Industries, Ozark, Alabama.

source were mixed in order of increasing concentration and the mixer was cleaned between sources.

All cuttings were of similar stem diameter and maturation. In addition, cuttings were trimmed to uniform length, with the shoot tip removed from the junipers. Both holly and juniper were treated with 8,000 ppm Hormex rooting powder. Four cell bedding plant trays measuring 5.715 cm (2.25") on each side and 5.715 cm (2.25") in depth per cell were used to hold the rooting medium, and thus created the four subsamples. Trays were placed in a forced-air, gas-heated propagation greenhouse with an automatic mist system. The mist cycle was 4 seconds mist every 8 minutes during the daylight hours. The average night temperature was 17°C (65°F) and the average day temperature was 33°C (91.4°F).

A visual evaluation of root development was made on March 20, 1980. In order to be more accurate, a set of standards (1 = no roots, 4 = minimum acceptable roots for transplanting, 7 = good root development, 10 = excellent roots) were selected and all cuttings were compared to these standards for evaluation.

Production of Hollies and Junipers

In the production phase of the study, a randomized complete block design was used, with six replications and 34 treatments. The treatments consisted of a 4 x 4 factorial using Micromax (i.e. the 4 levels used during propagation and the same 4 levels during production), a 3 x 3 factorial using Esmigran and a 3 x 3 factorial using Frit 503. The holly and juniper liners were transplanted into 1 gallon laminated black inside white outside poly bags on April 9 and 10, respectively.

At the time of transplanting, the rooted cuttings of holly and juniper were blocked based on the visual root evaluation. The hollies were placed in a structure with 30% saran shade while the junipers were placed in full sun on a container bed covered with black polyethylene, in full sun.

The production medium for all treatments was ground pine bark, Canadian peat and builder's sand in a 3:1:1 ratio on a volume basis. Standard for all treatments was 8.33 kg (14 lbs./yd.^{3}) 18-5-11 Osmocote (12-14 month formulation), 0.8925 kg (1.5 lbs./yd.^{3}) triple superphosphate, 1.785 kg (3 lbs./yd.^{3}) dolomite and 1.785 kg (3 lbs./yd.^{3}) gypsum per cubic meter. The treatments were applied to the medium by mixing in a 1.5 cubic foot concrete mixer as described in the propagation phase.

The hollies were pruned on May 27 and the junipers on July 1, 1980. The hollies were pruned again on August 12. At this time, chlorosis was evident on some plants, but was not consistent by treatment throughout the six replications. Data were recorded for the number of growing terminals for hollies on June 19 and for junipers on July 28.

Final data recorded for hollies were: visual evaluation of the shoot (on a scale of 1-10 with 1 = poor, 4 = fair, 7 = good, 10 = excellent; based on four evaluations of visual grade), number of growing terminals, stem caliper, height, average diameter of plant crown (width at widest part and width at 90° to first measurement), and fresh weight of roots and shoots. These data were collected from September 26 through October 4. The same data were collected for junipers (except height) on September 29 through October 3, 1980.

Propagation of Periwinkles

The periwinkle seeds were sown on April 12, 1980 in a seed flat 51.435 cm (20.25") x 26.67 cm (10.50") x 5.715 cm (2.25") containing Redi-Earth, a commercial soilless growing medium, plus 1.785 kg (3 lbs./yd.^{3}) per cubic meter 18-6-12 Osmocote added. The seed flat was placed on an expanded metal bench in a forced-air heated greenhouse. The propagation medium was kept moist by an automatic mist system with 4 seconds mist every 6 minutes. The average night temperature was 14°C (57°F) and the average day temperature was 36°C (97°F). The seed flat was kept in the propagation greenhouse until seedlings were about 1.91 to 2.54 cm in height. The seed flat was moved to a conventional greenhouse on May 2 and watered regularly until there were enough seedlings of uniform size to transplant.

Production of Periwinkles

The experimental design for the production phase was a randomized complete block consisting of 6 replications, 10 treatments and 3 subsamples per treatment. The production medium for all treatments was peat and perlite 1:1 on a volume basis plus 4.165 kg (7 lbs./yd.^{3}) 19-6-12 Osmocote (3-4 month formulation), 0.8925 kg (1.5 lbs./yd.^{3}) triple super-phosphate, 1.785 kg (3 lbs./yd.^{3}) dolomite and 1.785 kg (3 lbs./yd.^{3}) gypsum per cubic meter of medium. The production containers were four cell bedding plant trays with each cell measuring 6.35 cm (2.5") x 6.35 cm (2.5") x 6.35 cm (2.5") for a total of 256.05 cm^3 (11.4 cubic inches).

The treatments were 0, 0.4463, 0.8925 and 1.3388 kg (0, .75, 1.50

and 2.25 lbs./yd.^{3}) Micromax; 0, 1.785 and 3.57 kg (0, 3 and 6 lbs.) Esmigran; and 0, 0.1488 and 0.2975 kg (0, 0.25 and 0.50 lbs./yd.^{3}) Frit 503 per meter^3 of medium. Seedlings of uniform size were planted in each flat on May 12, 1980 and remained in the conventional greenhouse. The average night temperature was 23°C (72°F) while the average day temperature was 35°C (95°F).

On May 28, more seedlings were transplanted into the 0.8925 kg (1.50 lbs./yd.^{3}) Micromax and the 0, 0.1488 and 0.2975 kg (0, 0.25 and 0.50 lbs./yd.^{3}) Frit 503 per meter^3 as a check for the primary (main experiment) treatments. On June 7, the primary treatment seedlings experienced severe water stress and the experiment was repeated on June 11, utilizing seedlings from the original seed flat. Water stress was again experienced on June 14 and the one seedling most damaged of the 3 subsamples was removed and replaced by 2 seedlings from the original seed flat. This created 4 subsamples per treatment, 10 treatments per replication and 6 replications for a total of 240 plants. The plants were moved to a lath house on June 19, where they were watered as needed by an overhead irrigation system.

Fresh top and root weight were recorded on July 11 for one randomly selected subsample from the 3 subsamples from the secondary treatments 0.8925 kg. Micromax and 0, 0.1488 and 0.2975 kg Frit 503 per meter^3 (1.50 lbs. Micromax and 0, 0.25 and 0.50 lbs. Frit 503 per yard^3). Fresh top and root weight were recorded on July 7 for the plants in the primary treatments. Data were recorded for the smaller of the original seedlings and the larger of the replacement seedlings for a total of two subsamples per treatment per replication.

Field Testing of Periwinkles

A clay loam flowerbed was used for the field test, and the two remaining subsample plants from the primary treatments, one original plant and one replacement plant, were transplanted into the same flowerbed on July 5. The experimental design was a randomized complete block with the primary and secondary treatments kept separate. All plants were planted on 6" centers, with 12" separating plants from surrounding turf areas.

On July 19, two weeks after the last seedlings had been planted, Treflan 5G was broadcast on the bed at the rate of 88.78 kg (79.2 lbs./acre) A.I./hectare. Stem caliper, height and numbers of flowers were recorded for all plants on July 28 and 29. The bed was then left undisturbed, except for watering and trimming of grass around the edges, until August 16, when the majority of the plants exhibited nutritional deficiency (chlorosis) on the lower leaves. At this time, 10-20-10 fertilizer was broadcast on the bed at the rate of 48.83 kg (43.56 lbs./acre) N/hectare. Final data on the periwinkles were recorded from October 7 to October 13 and included height, stem caliper, number of flowers and fresh top weight.

Dunnett's test and least significant difference were used to analyze data from propagation of junipers and hollies and from production of periwinkles. Analysis of variance and least significant difference were used to analyze data from production of junipers and hollies.

CHAPTER IV

RESULTS AND DISCUSSION

Hollies

Esmigran

The visual rating of holly was highest when 1.785 kg (3 lb.) Esmigran was used during propagation and 3.57 kg (6 lb.) during production (Table II). All levels of Esmigran either during propagation or production improved the visual rating of plants at the ened of the growing season, compared to the no micronutrient control (Table II).

Overall plant diameter of holly increased with any level of Esmigran during propagation or production when compared to the control (Table III). No other parameters evaluated on holly were significant for Esmigran.

Frit 503

The only significant differences in holly response from the use of Frit 503 were during the production stage. The 0.1488 kg (0.25 lb.) rate was optimum for both visual rating and overall plant diameter (Table IV).

TABLE II

EFFECT OF ESMIGRAN DURING PROPAGATION AND PRODUCTION ON THE VISUAL RATING OF HOLLY

	Esmigran kg/m^3			
Production/Propagation	0^z	1.785	3.57	Main Effect Means
0	3.4_{a1}	5.6_{b1}	6.2_{b1}	5.7
3	6.8_{b3}	5.8_{a1}	5.8_{a1}	6.1
6	5.7_{a2}	7.0_{b2}	5.8_{a1}	6.2
Main Effect Means	5.3	6.1	5.9	

^{x}1 = poor, 4 = fair, 7 = good, 10 = excellent; based on average of four observations.

^{y}Means within a row followed by the same letter or means within the same column followed by the same number are not significantly different.

^{z}LSD for columns = 0.55; LSD for rows = 0.63.

TABLE III

EFFECT OF ESMIGRAN DURING PROPAGATION AND PRODUCTION ON OVERALL PLANT DIAMETER (CM) OF HOLLY

	Esmigran kg/m^3			
Production/Propagation	0^z	1.785	3.57	Main Effect Means
0	24.3_{a1}	30.5_{c3}	28.7_{b2}	27.8
3	31.8_{c3}	27.2_{a1}	30.5_{b3}	29.8
6	29.2_{b2}	29.2_{b2}	28.0_{a1}	28.8
Main Effect Means	28.4	28.9	29.1	

[y]Means within a row followed by the same letter or means within the same column followed by the same number are not significantly different.

[z]LSD for columns = 0.9; LSD for rows = 1.00.

TABLE IV

EFFECT OF FRIT 503 ON VISUAL RATING AND OVERALL PLANT DIAMETER OF HOLLY DURING PRODUCTION

	Frit 503 During Production kg/m^3			
	0	0.1488	0.2975	
Visual Rating^x	5.5$_a$	6.9$_c$	6.6$_b$	LSD 5% = 0.3
Overall Plant Diameter (cm)	27.2$_a$	30.4$_c$	29.3$_b$	LSD 5% = 0.5

^{x}Visual rating: 1 = poor, 4 = fair, 7 = good, 10 = excellent; based on average of four observations.

^{y}Numbers in the same row followed by the same letter are not significantly different.

Micromax

There was a striking interaction of Micromax, between the propagation and production stages on the visual rating of holly. The highest visual rating resulted from use of Micromax at the 0.4463 kg (0.75 lb.) rate during propagation and the 1.3388 kg (2.25 lb.) rate during production (Table IV). However, there was no significant differences between 0.4463 kg (0.75 lb.) and the control during propagation at the 1.3388 kg (2.25 lb.) rate during production. Use of Micromax during either propagation or production greatly increased visual rating compared to the no micronutrient control.

For overall plant diameter, the optimum rates of Micromax were again 0.4463 kg (0.75 lb.) during propagation and 1.3388 kg (2.25 lb.) during production (Table VI). Micromax significantly increased root and top weight during propagation. The 0.4463 kg (0.75 lb.) rate significantly increased root weight, although the 0.4463 kg (0.75 lb.) and 0.8925 kg (1.50 lb.) rates were not significantly different for top weight (Table VII).

Root and top weight and number of growing terminals were significantly greater at the 1.3388 kg (2.25 lb.) rate during production while the 0.8925 kg (1.50 lb.) rate was optimum for stem caliper (Table VIII).

Junipers

Esmigran

The only parameter significant for Esmigran on Juniper during propagation was visual rating which was highest at the 3.57 kg/m^3

TABLE V

EFFECT OF MICROMAX ON VISUAL RATING OF HOLLY DURING PROPAGATION AND PRODUCTION

	Micromax kg/m^3				
Production/ Propagation	0[z]	0.4463	0.8925	1.3388	Main Effect Means
0	2.9_{a1}	6.0_{c1}	5.3_{b1}	5.4_{b1}	4.9
0.75	7.6_{b2}	8.7_{d3}	7.8_{c23}	7.3_{a24}	7.8
1.50	7.6_{ab2}	8.0_{d2}	7.4_{a2}	7.8_{bc3}	7.7
2.25	8.6_{c3}	8.9_{c3}	8.2_{b3}	7.6_{a34}	8.3
Main Effect Means	6.7	7.9	7.2	7.0	

[x]1 = poor, 4 = fair, 7 = good, 10 = excellent; based on average of four observations.

[y]Numbers within a row followed by the same letter or numbers within a column followed by the same number are not significantly different.

[z]LSD 5% for columns = 0.5; LSD 5% for rows = 0.4.

TABLE VI

EFFECT OF MICROMAX ON OVERALL PLANT DIAMETER (CM) OF HOLLY DURING PROPAGATION AND PRODUCTION

	Micromax kg/m^3				
Production/ Propagation	0^z	0.4463	0.8925	1.3388	Main Effect Means
0	23.0_{a1}	28.2_{b1}	29.2_{c1}	29.0_{bc1}	27.3
0.75	32.7_{b3}	34.8_{c3}	31.0_{a2}	31.3_{a2}	32.5
1.50	30.0_{a2}	32.5_{b2}	30.7_{a2}	32.7_{b3}	31.5
2.25	34.7_{c4}	35.7_{d4}	32.8_{b3}	31.8_{a2}	33.8
Main Effect Means	30.1	32.8	30.9	31.2	

^{y}Numbers within a row followed by the same letter or numbers within a column followed by the same number are not significantly different.

^{z}LSD 5% for columns = 0.7; LSD 5% for rows = 0.9.

TABLE VII

EFFECT OF MICROMAX ON ROOT WEIGHT AND TOP WEIGHT OF HOLLY DURING PROPAGATION

	Micromax kg/m^3				
	0	0.4463	0.8925	1.3388	
Root Weight (g)	4.83_a	6.75_d	6.45_c	5.73_b	LSD 5% = 0.9
Top Weight (g)	7.34_a	8.98_d	8.06_c	7.60_b	LSD 5% = 0.7

[y]Numbers within a row followed by the same letter are not significantly different.

TABLE VIII

EFFECT OF MICROMAX ON ROOT WEIGHT, TOP WEIGHT, NUMBER OF GROWING TERMINALS AND STEM CALIPER OF HOLLY DURING PRODUCTION

	Micromax kg/m^3				
	0	0.4463	0.8925	1.3388	
Root Weight (g)	45.1_a	64.2_c	60.6_b	67.7_d	LSD 5% = 0.9
Top Weight (g)	59.3_a	84.8_b	84.8_b	92.9_c	LSD 5% = 0.9
Terminals	4.9_a	7.8_b	7.7_b	8.3_b	LSD 5% = 1.1
Caliper (mm)	7.5_a	8.5_c	9.0_d	8.4_b	LSD 5% = 0.3

[y]Numbers within a row followed by the same letter are not significantly different.

(6 lb./yd.^{3}) rate (Table IX).

Several of the parameters evaluated were significant for use of Esmigran during production. The 1.785 kg (3 lb.) rate produced the highest visual rating, number of growing terminals, overall plant diameter and top weight (Table X). The 3.57 kg (6 lb.) rate of Esmigran produced significantly larger stem caliper and root weight (Table XI).

Frit 503

The production stage of plant growth produced the only significant results with use of Frit 503 on Junipers. The 0.2975 kg (0.50 lb.) rate produced the highest visual rating, number of growing terminals, overall plant diameter, stem caliper, root weight and top weight (Table XI).

Micromax

The 0.8925 kg (1.50 lb.) rate of Micromax used during propagation generally resulted in the greatest visual rating, overall plant diameter and top weight. However, differences from the 1.3388 kg (2.25 lb.) and the 0.4463 kg (0.75 lb.) rates were small (Table XII). The 1.3388 kg (2.25 lb.) rate produced the greatest stem caliper. The 0.8925 kg (1.50 lb.) rate of Micromax during production gave the greatest plant response for all of the parameters evaluated except for stem caliper (Table XIII). Micromax produced the greatest stem caliper at the 1.3388 kg (2.25 lb.) rate and all rates were significantly better than the control.

TABLE IX

EFFECT OF ESMIGRAN ON VISUAL RATING OF JUNIPER DURING PROPAGATION

	Esmigran kg/m^3			
	0	1.785	3.57	
Visual Rating	5.2$_a$	6.4$_b$	6.7$_c$	LSD 5% = 0.3

[y]Numbers within a row followed by the same letter are not significantly different.

[x]1 = poor, 4 = fair, 7 = good, 10 = excellent; based on average of four observations.

TABLE X

EFFECT OF ESMIGRAN ON VISUAL RATING, NUMBER OF GROWING TERMINALS, OVERALL PLANT DIAMETER, STEM CALIPER, ROOT WEIGHT AND TOP WEIGHT OF JUNIPER DURING PRODUCTION

	Esmigran kg/m^3			
	0	1.785	3.57	
Visual Rating[x]	4.1_a	7.2_c	7.0_b	LSD 5% = 0.3
Terminals	37.2_a	81.8_c	75.5_b	LSD 5% = 1.4
Overall Plant Diameter (cm)	30.4_a	42.9_c	40.9_b	LSD 5% = 0.7
Caliper (mm)	6.0_a	7.4_b	7.9_c	LSD 5% = 0.3
Root Weight (g)	21.6_a	30.3_b	33.3_c	LSD 5% = 0.9
Top Weight (g)	65.6_a	108.6_c	104.1_b	LSD 5% = 1.2

[y]Numbers within the same row followed by the same letter are not significantly different.

[x]Visual rating: 1 = poor, 4 = fair, 7 = good, 10 = excellent; based on average of four observations.

TABLE XI

EFFECT OF FRIT 503 ON VISUAL RATING, NUMBER OF GROWING TERMINALS, OVERALL PLANT DIAMETER, STEM CALIPER, ROOT WEIGHT AND TOP WEIGHT OF JUNIPER DURING PRODUCTION

	Frit 503 kg/m^3			
	0	0.1488	0.2975	
Visual Rating^x	4.7_a	7.1_b	8.3_c	LSD 5% = 0.3
Terminals	41.5_a	71.2_b	80.3_c	LSD 5% = 1.2
Overall Plant Diameter (cm)	32.9_a	42.3_b	48.8_c	LSD 5% = 0.7
Caliper (mm)	6.4_a	7.5_b	8.3_c	LSD 5% = 0.3
Root Weight (g)	25.5_a	31.7_b	34.5_c	LSD 5% = 0.8
Top Weight (g)	76.1_a	108.6_b	121.6_c	LSD 5% = 1.2

^{y}Numbers in the same row followed by the same letter are not significantly different.

^{x}Visual rating: 1 = poor, 4 = fair, 7 = good, 10 = excellent; based on average of four observations.

TABLE XII

EFFECT OF MICROMAX ON VISUAL RATING, OVERALL PLANT DIAMETER, STEM CALIPER AND TOP WEIGHT OF JUNIPER DURING PROPAGATION

	Micromax kg/m^3				
	0	0.4463	0.8925	1.3388	
Visual Rating[x]	5.4_a	6.6_b	7.1_c	7.0_c	LSD 5% = 0.3
Overall Plant Diameter (cm)	36.0_a	42.4_c	42.5_c	41.5_b	LSD 5% = 0.6
Caliper (mm)	6.7_a	7.4_b	7.5_b	8.0_c	LSD 5% = 0.2
Top Weight (g)	79.6_a	107.9_c	107.7_c	105.3_b	LSD 5% = 1.1

[y]Numbers within a row followed by the same letter are not significantly different.

[x]Visual rating: 1 = poor, 4 = fair, 7 = good, 10 = excellent; based on average of four observations.

TABLE XIII

EFFECT OF MICROMAX ON VISUAL RATING, NUMBER OF GROWING TERMINALS, OVERALL PLANT DIAMETER, STEM CALIPER, ROOT WEIGHT AND TOP WEIGHT OF JUNIPERS DURING PRODUCTION

	Micromax kg/m^3				
	0	0.75	1.5	2.25 #/yd3	
	0	0.4463	0.8925	1.3388	
Visual Rating*	4.3_a	7.2_c	7.6_d	6.9_b	LSD 5% = 0.3
Terminals	46.8_a	71.5_b	81.1_d	75.2_c	LSD 5% = 1.1
Overall Plant Diameter (cm)	32.1_a	43.4_c	44.7_d	42.1_b	LSD 5% = 0.6
Caliper (mm)	6.1_a	7.9_b	7.8_b	7.8_b	LSD 5% = 0.2
Root Weight (g)	22.8_a	31.7_b	33.0_c	38.0_d	LSD 5% = 0.7
Top Weight (g)	69.1_a	105.9_b	118.0_d	107.4_c	LSD 5% = 1.1

[y]Numbers in the same row followed by the same letter are not significantly different.

[x]Visual rating: 1 = poor, 4 = fair, 7 = good, 10 = excellent; based on average of four observations.

Periwinkles

Secondary Treatments

Fresh top and root weight for the secondary treatment periwinkles prior to field planting were not significant. In addition, stem caliper, height and number of flowers recorded on July 28 and 29 were not different. However, on October 7 to 13, the number of flowers was significantly increased as a result of the micronutrient treatment (Table XIV). Frit 503 at the 0.2975 kg (0.50 lb.) rate and 0.8925 kg/m^3 (1.50 lb.) Micromax produced the greatest number of flowers.

Primary Treatments

Root weights prior to field planting were significantly greater with Frit 503 at the 0.1488 kg (0.25 lb.) and 0.2975 kg (0.50 lb.) rates and Micromax at the 0.4463 kg (0.75 lb.) rate compared to the control or other micronutrient sources or levels (Table XV). Stem caliper, height and number of flowers evaluated on July 28 and 29 were not significantly different for any micronutrient treatment.

The number of flowers produced by the replacement subsamples were greatest with Micromax at the 0.8925 kg (1.50 lb.) and 1.3388 kg (2.25 lb.) rates and Esmigran at the 1.785 kg (3 lb.) rate (Table XVI). Stem caliper was greatest with Micromax at the 0.4463 kg (0.75 lb.) and 1.3388 kg (2.25 lb.) rates (Table XVII) for the original subsamples while use of all three rates of Micromax plus the 0.2975 kg (0.50 lb.) rate of Frit 503 resulted in the largest stem caliper on the replacement plants. Plant height for original subsamples was not significantly different for all treatments, however, all three rates of Micromax, the

TABLE XIV

EFFECT OF MICRONUTRIENTS ON NUMBER OF FLOWERS IN SECONDARY TREATMENTS OF PERIWINKLES

	Frit 503 kg/m^3			
Micromax kg/m^3	0	0.1488	0.2975	
5_{ab}	4_{a}	4_{a}	6_{b}	LSD 5% = 1.56

[y]Numbers within the row followed by the same letter are not significantly different.

TABLE XV

EFFECT OF MICRONUTRIENTS ON ROOT WEIGHT OF PERIWINKLES IN PRIMARY TREATMENTS PRIOR TO FIELD PLANTING

Control	Micromax			Esmigran		Frit 503 kg/m^3		
0	0.4463	0.8925	1.3388	1.785	3.57	0.1488	0.2975	
2.12_{bc}	2.28_{d}	2.15_{c}	1.81_{a}	1.99_{ab}	1.88_{ab}	2.26_{cd}	2.46_{d}	LSD 5% = 2.75

[y]Numbers within the row followed by the same letter are not significantly different.

TABLE XVI

EFFECT OF MICRONUTRIENTS ON NUMBER OF FLOWERS OF PERIWINKLES IN PRIMARY TREATMENTS: REPLACEMENT SUBSAMPLES

Control	Micromax			Esmigran		Frit 503 kg/m^3		
0	0.4463	0.8925	1.3388	1.785	3.57	0.1488	0.2975	
3.3_{ab}	3.5_{ab}	4.8_{abc}	6.7_{c}	5.5_{bc}	4_{ab}	3_{ab}	2.8_{a}	LSD 5% = 2.39

^{y}Numbers followed by the same letter are not significantly different.

TABLE XVII

EFFECT OF MICRONUTRIENTS ON STEM CALIPER OF PERIWINKLES IN PRIMARY TREATMENTS: REPLACEMENT AND ORIGINAL SUBSAMPLES

Control	Micromax			Esmigran		Frit 503 kg/m^3		
0	0.4463	0.8925	1.3388	1.785	3.57	0.1488	0.2975	
Replacement								
0.6_{a}	0.7_{b}	0.7_{b}	0.7_{b}	0.6_{a}	0.6_{a}	0.6_{a}	0.7_{b}	LSD 5% = 0.089
Original								
0.7_{ab}	0.8_{b}	0.7_{ab}	0.8_{b}	0.6_{a}	0.7_{ab}	0.7_{ab}	0.7_{ab}	LSD 5% = 0.10

^{y}Numbers within the same row followed by the same letter are not significantly different.

3 lb. rate of Esmigran and the 0.25 lb. rate of Frit 503 all produced taller plants with the replacement plants (Table XVIII).

TABLE XVIII

EFFECT OF MICRONUTRIENTS ON PLANT HEIGHT OR PERIWINKLES IN PRIMARY TREATMENTS: REPLACEMENT SUBSAMPLES

Control	Micromax			Esmigran		Frit 503 kg/m^3		
0	0.4463	0.8925	1.3388	1.785	3.57	0.1488	0.2975	
35.5_a	43.5_c	46.2_c	40.8_{abc}	41.0_{abc}	35.7_a	40.0_{abc}	39.2_{ab}	LSD 5% = 6.57

CHAPTER V

SUMMARY AND CONCLUSIONS

Plant response to Esmigran and Frit 503 was slight and significant only for a few parameters evaluated. Esmigran increased visual rating and overall plant diameter of holly.

Frit 503 increased visual rating, overall plant diameter and plant height, but only during production. The lack of response to treatment during the propagation phase probably reflects the very low solubility, especially for Frit 503 and perhaps to some extent for Esmigran.

Micromax increased holly growth when used in either propagation, production or both stages of plant production for every parameter evaluated. The interaction was important for visual rating, overall plant diameter and plant height. Use of Micromax during production increased number of growing terminals, stem caliper, root weight and top weight. Micromax used during propagation increased root weight and top weight. Optimum results were generally obtained by using Micromax during both propagation and production.

On the other hand Esmigran and Frit 503 increased juniper growth for all parameters evaluated, but only during production with the exception of Esmigran, at the 1.785 or 3.57 kg (3 or 6 lb.) rate during propagation. However, there was no interaction. The benefit of Esmigran and Frit 503 during production and lack of plant response during propagation is likely due to the slow availability of the micronutrients.

Micromax was important in both stages of plant production, with the exception of number of growing terminals and root weight, where it was significant only during production. This suggests that in general, Micromax should be used during both propagation and production.

For the secondary treatment perwinkles, Micromax at 0.8925 kg (1.50 lb./yd.^{3}) or Frit 503 at the 0.2975 kg (0.50 lb./yd.^{3}) rate stimulated a greater number of flowers.

Micromax and Esmigran promoted more flowers at an earlier stage of plant growth, as shown in Table XV. Stem caliper was enhanced at earlier and later stages of growth with the use of Micromax at any of the rates tested. This could be advantageous in resisting damage from wind or beating rains.

All three rates of Micromax and the lower rates of Esmigran and Frit 503 increased plant height in the subsamples at an earlier stage of growth. This should prove to be an excellent marketing advantage; plants could be started later, but achieve the same height as plants without micronutrients which were started earlier.

In general, Micromax was more consistently important in producing desirable bedding plants.

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