DEVELOPMENT OF A MICRONUTRIENT FERTILIZER FOR USE IN CONTAINER NURSERY PRODUCTION

By

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CHAPTER I

INTRODUCTION

Container production of nursery stock has rapidly developed in the past ten years. Nurserymen are growing plants in containers because of the relative ease of handling, more efficient use of space, and the current market desires for year round plant availability. For many years nurseries attempted to grow plants in containers with field soil as the growing medium. High weed populations, diseases due to poor drainage, and poor nutrition were some of the major difficulties.

In order to provide growing media for containers with adequate aeration and fertility, nurseries have begun to use soilless mixtures. Slow release fertilizers for use in container systems have also increased in use. A total nutritional program, supplying plants with essential elements is now necessary for maximum growth in containers. Several products are available to container nurserymen today which can be used, however, whether these formulations truly satisfy all the nursery plants micronutritional need is not clear. The purpose of this experiment was to develop an effective micronutrient fertilizer for use in container nursery production.

CHAPTER II

REVIEW OF LITERATURE

Of the sixteen elements known to be essential for plant growth those necessary in smaller amounts are called micronutrients. The five micronutrient elements which are considered to be most influential in plant growth are iron, manganese, copper, zinc, and boron.

Micronutrient Elements

Iron

Iron is the fourth most abundant element in the earths crust exceeded only by oxygen, silicon, and aluminum in that order (29). Almost all rocks, minerals, and soils contain iron as well as all plants and animals (29).

Iron is not found in its free state in soils, instead it occurs in various combinations with other elements. The normal range for iron in soils is from 0.5 to 5.0 percent and the natural environment usually supplies a sufficient amount of iron for plant growth (3, 4). The concern with iron in a soil system is not presence but availability.

The most characteristic effect of iron deficiency is the failure to produce chlorophyll in young leaves (18, 19). This condition is commonly called chlorosis and is characterized by interveinal yellowing

(18, 19, 28, 31). Hewitt (18, 19) reported that as the deficiency worsens a general leaf deterioration occurs with subsequent leaves becoming smaller in size and papery with margins collapsing.

The single most important factor affecting the availability of iron to plants is the soil reaction. Iron deficiencies occur in soils of high pH which may be limed sandy soils or alkaline arid soils (4, 6). Also at very low pH values iron may become so soluable that it becomes toxic (6, 18, 29, 31, 40).

Other factors affecting iron nutrition are soil aeration, soil organic matter content, calcium and magnesium content in soils, manganese, phosphate, zinc, and potassium content in soils, and plant species (1, 2, 7, 32, 40).

Iron can be found in soils in both reduced or oxidized forms. Both forms are found in water logged soils or highly acid soils (4). In well aerated soils with high pH the oxidized form is predominant (40). If conditions exist where the ferric ion is in greatest quantity, plants will suffer from iron deficiency due to the ferric ions characteristic of being a non-exchangeable cation (11, 28, 32). Matkin et al. (27) reported that microorganisms which decay organic matter release iron as well as other elements making them available for plants. Because almost one-eighth of the cropland in the United States is calcareous, iron chlorosis due to high pH is frequent (23, 40). Hewitt (18) felt that an excess of manganese in the soil produced a deficiency of iron in the plant because it causes the iron to be oxidized in the plant to the ferric state. Black (2) reports that manganese is increasingly prevalent in steamed organic soils and will when present in excessive amounts, induce iron deficiency in plants.

High phosphate concentrations may also produce iron deficiencies by reacting with ferric ions to form stable and immobile complexes in the plant (1, 7). Lingle et al. (26) reported that zinc may suppress iron uptake. Wallace and Lunt (41) found that species vary with respect to tolerance in iron deficient situations.

Iron is absorbed by the plant as the ferrous ion and is believed to be an essential component of the catalyst involved in the formation of chlorophyll (28, 32). It is an essential component of several enzymes and carriers in the plant and is a component of ferredoxin, an electron transferring protein (6, 10, 28, 32). Iron is also recognized to function in photosynthesis, nitrogen fixation, and nitrate reduction reactions (6, 10, 32). Brown (3) explains that during times of iron inactivity, growth may be reduced as a result of inavailability of iron cations which are required by organic ligand compounds in the plant.

Manganese

Manganese occurs in many soils in the form of MnO_2, often as the hydrated form, sometimes as Mn^{+3}, and also as the divalent cation Mn^{+2} (20, 32). Sauchelli (32) believes that plants absorb primarily the Mn^{+2} form. This form is held mainly by organic matter in the soil (17). Manganese, like iron, is readily oxidized in soils and becomes unavailable in the higher oxidation states (20, 32).

The organic matter in the soil and the drainage conditions indirectly affect manganese soluability since organic matter has the ability to form various complexes with manganese, making it unavailable (17, 32). Acid soils or water logged soils low in oxygen may contain manganese levels toxic to plants, however this can usually be corrected by liming (10). Sauchelli (32) reported that the addition of ferrous salt to the soil induces the reduction of Mn^{+3} and Mn^{+4} to the divalent and more available state. This suggests the importance of a ratio of iron to manganese in the soil.

Manganese is absorbed by the plant as the Mn^{+2} ion and plays primarily three roles in the plant: a.) It acts as a catalyst in several important enzymatic and physiological reactions. Epstein (6) notes manganese is a major factor in the Krebbs cycle, and because of the role of this cycle in aerobic respiration, the effects of manganese deficiency are transmitted to other metabolic sequences. b.) Manganese can cause iron deficiencies when present in excessive amounts because it renders the ferric ion unusable by the plant (6, 19, 32). c.) Manganese also activates several enzymes directly involved in the synthesis of chlorophyll and the maintenance of chloroplast structure (6, 10, 28, 32).

Manganese deficient grasses develop grayish lesions at the leaf base followed rapidly by chlorosis of all green tissue (32). Interveinal chlorosis of newer leaves is a characteristic symptom of manganese deficiency in fruits and ornamentals (28, 32).

Copper

Copper constitutes a small fraction of the soil (from 1-50 ppm) and occurs as watersoluable, adsorbed, or fixed (32). According to Sauchelli (32) the only copper available to plants is the water soluable form which occurs when there is not an abundance of organic matter in the soil. Copper is unavailable either when adsorbed on negatively charged clay colloids in soils or in combination with available sulfur anions thus forming insoluable copper sulfide compounds.

The most important factor affecting copper availability in the soil is organic matter content (10, 20, 18, 32). In many cases addition of copper to peat or muck soils is not effective because copper placed in organic soils is held tightly in the zone of placement (10, 32, 40). The nature of the previous crop, the proportion of sand to clay, pH, and presence of other chemical elements and their interactions may also affect copper availability (20, 32, 40).

Copper is absorbed by the plant as the cupric ion (Cu^{+2}) and is a component of several enzymes in the plant (6). Copper is also essential for the formation of iron porphyrin, a precursor of chlorophyll and is part of a growing list of proteins in the plant (28, 32).

Symptoms of deficiency include stunting, shoot die back, scorching of young leaves, or chlorosis (32). The production of vigorous water shoots which later develop multiple stems called 'witches brooms' occurs in citrus. White tip is another symptom occuring in herbaceous plants, producing chlorotic young leaves or chlorotic rings along leaf internodes (19, 32).

Boron

Boron accumulates in arid regions due to the lack of moisture which provides for downward movement of ions (28).

It has been reported that amounts of boron in soil decrease with soil depth and that plants absorb it poorly from dry soil layers (28). Boron deficiencies have been associated with liming practices on sandy soils low in organic matter (32).

Soils of this type do not have good water retention and tend to leach boron out of the upper layers. Sauchelli (32) reported three main causes of boron losses in soils: a.) leaching, b.) removal by harvesting crops, and c.) the reversion to unavailable inorganic compounds. Mortvedt, Giordano, and Lindsay (28) reported that soils high in boron initially may be subject to toxicity problems after use of irrigation water high in borates. They note that crop species differ widely in tolerance to boron and point out that because of the difficulty in correcting this problem in the soil, plant species should be selected for greater tolerance. Fox (8) observed that high levels of calcium and high pH values reduced absorption of boron by 50% in cotton.

Even though the essentiality of boron to plants was established six decades ago the physiological role of the element is still undefined. Some theorize that the element plays a role in maintaining correct water relations in the plant, in protein metabolism, pectin synthesis, in the resynthesis of adenosine triphosphate (ATP), in the translocation of sugars, in the growth of the pollen tube, and in the fruiting procedure (6, 10, 11, 18, 32).

Many studies have been done in regard to increase in sugar translocation associated with boron. Gauch and Dugger (24) postulate that the main role of boron is to facilitate the translocation of sugars in plants by formation of sugar borate complexes that are more readily able to pass through semipermeable cell membranes. Lee and Aronoff (24) have shown that boron plays a regulatory role in carbohydrate metabolism. Skok (35) found that boron is relatively immobile in plants and that cell division and development are early casualties of boron deficiency.

Visible symptoms of boron deficiency include terminal die back, deformation or rosetting of leaves, suspended growth, or blackening of the basal marginal areas of the very young leaves, multiple branching and seedling death (19, 32).

Zinc

Because zinc is present in nearly all soils and plants require only minute amounts, most crops are satisfied with available zinc and have few problems (32). Camp (5) reported that the principle cause of zinc deficiency in the South was the removal of available zinc by continuous cropping and lack of use of green manure and cover crops to reintroduce absorbed zinc. Thompson (39) stated that zinc occurs as a cation or in combination with primary or secondary minerals. He feels the soluability of zinc is affected by pH and as the pH drops below 5.25 or rises above 6.0 the soluability is decreased. Lindsay and Norvell (25) contradict this by reporting that soluability of Zn^{+2} decreases one hundred fold for each unit increase in pH. Other soil conditions which might contribute to zinc availability are the presence of clay minerals, organic matter content, and the number of magnesium ions (28, 32). Most zinc disorders occur in calcareous soils where zinc becomes only slightly soluable in complexes with carbonates (28).

Prask and Plocke (31) suggested that zinc is essential to the stability of cytoplasmic ribosomes. Kessler and Monselise (22) noted that zinc deficiency caused a sharp decrease in levels of RNA and ribosome content of cells. Zinc is also involved as a catalyst in oxidation processes in plant cells, is believed to be vital for the transformation of carbohydrates, regulate sugar consumption, aids in auxin formulation, promotes the absorbtion of water, and increases the source of energy for the production of chlorophyll (10, 32, 36). While some crops show no obvious symptoms for zinc deficiency, others are stunted, and in some cases develop "little leaf" or rosetting (31).

Micronutrient Interactions

Olsen (30) defines a micronutrient interaction as that effect produced when two elements combine to create an effect which is not due to one of them alone. Interactions may result in improved plant growth and vigor or cause certain elements to become unavailable in the presence of others. Soil reaction, light, temperature, soil moisture, and aeration also play a part in micronutrient interactions (28).

The major interactions dealing with micronutrients involve iron-zinc-copper and phosphorus, however, manganese also interacts to some degree with iron, and boron becomes important when high levels of calcium are present. Probably the most studied interactions are those of the major metallic cations in the soil, calcium, magnesium, and potassium, and their effects upon the heavy metals iron, manganese, zinc, copper, and boron. Shear et al. (34) reported highly significant reductions in accumulation of iron, manganese, zinc, aluminum, copper, and boron when rates of calcium, magnesium and particularly potassium were increased (32). Stuckenholtz et al. (38) described a phosphorus-zinc interaction that caused zinc deficiency and pointed out that zinc deficiencies can be brought about through high rates of phosphorus applied to corn. Biddulph and Woodbridge (1) reported that high phosphorus concentrations inhibited movement of iron in the plant.

This effect was more pronounced at pH values over 7.0. Phosphorus has also been called responsible for the deficiency of copper in citrus and the enhanced uptake of molybdenum in tomato plants (28). In their work with boron and calcium Jones and Scarseth (21) found that plants grow best when a balance exists between the two elements, since calcium reduces boron availability in the soil.

The iron-zinc interaction is one of the more important interactions between two micronutrients. The metabolic function of iron in plants is connected with the supply of zinc (28). Watanabe et al. (45) found that corn yield was cut in half as zinc levels were tripled and iron levels remained the same. Lingle et al. (26) found that zinc interfered with iron uptake and translocation in soybeans more than manganese, copper, calcium, magnesium, or potassium.

Manganese at higher levels tends to restrict uptake of iron, causing iron deficiencies. This is due to manganese competition for functional sites on iron binding compounds in the plant (6). Copper has been shown to produce iron chlorosis of citrus when available in high amounts (28).

Molybdenum-iron-copper interactions have received attention by Giordano et al. (13) who indicated that high copper interfered with the role of molybdenum in the enzymatic reduction of nitrates in tomato plants. Adequate molybdenum is felt to be important for iron transport within the plant (28).

Micronutrient Fertilizers

The use of micronutrients in production of container nursery stock has only recently become a standard practice. In the past, their use was discouraged as in the statement by Matkin, Chandler, and Baker, (27, p.86) who say "since micronutrients are required in such minute amounts by plants and are natural components of peat, soil, fertilizers and water, it is improbable that a soil mix would develop micronutrient deficiencies". However, with more container nurseries using soilless growing mixtures along with higher macronutrient levels, micronutrient quantities have become inadequate for the growth of most plants in this system (9). Furuta (9) stated that the new light weight standardized soil mixes have fewer available micronutrients, (mainly because of the omission of soil) and modern fertilizers are more free of impurities; thus a need has been created for some source of micronutrients for nurserystock in containers.

There are a range of different micronutrient products on the market for use in container growing media. Most formulations have been marketed only recently and their effectiveness remains somewhat in question. Wheeles and Whitcomb (12, 46) did work with the micronutrient fertilizers Perk, Esmigran, FTE 503, and FTE 504. They concluded that Perk was the best source for Japanese Holly at 2.38 kg/m^3. Struck and Whitcomb (37) studied the effects of nutrition on germination and growth of Cedrus deodara seedlings with or without Perk as the micronutrient source and concluded that 2.38 kg/m^3 of Perk should be present in the growing mix along with the major elements. Whitcomb (47, 48) reported that Perk at 2.38 kg/m^3 was the best level when used in containers growing Juniperus chinensis 'Pfitzeriana', or 'Hetzi' and Ilex cornuta 'Bufordi'. Hathaway (14, 15, 16) propagated grape cuttings, Shumard oak (Quercus shumardi), River Birch (Betula nigra), Japanese Black Pine (Pinus thunbergi), and Pecan (Carva *illinoensis*) using Perk in the growing medium. He reported that Perk at 2.37 kg/m^3 provided best plant response and survival when in combination with 4.75 kg/m^3 dolomite and 4.45 kg/m^3 18-6-12 Osmocote. With higher rates of Osmocote, Perk did not significantly improve growth. Whitcomb (50) used Perk in propagating Purpleleaf Japanese Honeysuckle, *Lonicera japonica* 'Purpurea' and reported that 2.36 kg/m^3 assisted plant growth when 18-5-11 Osmocote was used. Self and Pounders (33) worked with Fritted Trace Elements 504, 503, and FTE 504 in combination with Sequestrene manganese chelate and Sequestrene 330 iron chelate. They observed that because of the higher level of boron in FTE 504, FTE 503 should be used. They also showed the importance of incorporating micronutrients with slow-release N-P-K fertilizers (42, 43, 44).

CHAPTER III

METHODS AND MATERIALS

Components of the Growing Medium

The growing medium was a mixture of ground pine bark, peatmoss, and sand in a ratio of 2:1:1. Osmocote 18-6-12 at 8.9 kg/m^3 (15 lbs/yd^3) was the nitrogen, phosphorus, and potassium source. Dolomite and single super phosphate (0-20-0) were added at rates of 4.75 kg/m^3 (8 lb/yd^3) and 2.38 kg/m^3 (4 lb/yd^3) respectively to provide calcium, magnesium, and phosphorus (48, 49). Magnesium sulfate ($MgSO_4$), elemental sulphur (S), and sodium molybdate ($NaMoO_4$) were added to all treatments at 1,082 g/m^3 (827.4 g/yd^3), 106.7 g/m^3 (81.6 g/yd^3), and 0.117 g/m^3 (0.09 g/yd^3) respectively.

Components of the Treatments

Iron sulfate, manganese sulfate, copper sulfate, zinc sulfate and borax can be routinely incorporated into the container medium in the form of "Perk"[a]. Whitcomb (48) reports the optimum rate of Perk for the growth of woody ornamentals to be 2.38 kg/m^3 (4 lb/yd^3). This rate provides the following grams of iron, manganese, copper, zinc, and boron per cubic meter; 87.0, 54.3, 5.5, 16.4, 0.54 respectively. To

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[a]Micronutrient fertilizer from Kerr-McGee Co. Jacksonville, Fla.

determine whether these amounts were fulfilling the micronutrient need of nursery stock a factorial arrangement with these five elements at three rates each was designed using 1/2x, x, and 2x the above rates (Table I). Hereafter these rates will be designated as low, middle, and high respectively. The total number of treatments was 81, 1/3 of the 3^5 factorial. The inter-block subgroup was selected from the total number of possible combinations so that all high order interactions would be left out. The experiment was replicated two times and provided 9 observations of each two-way interaction and 27 observations of each individual rate per replication.

The nursery mix with micronutrient treatments was placed in black plastic, nursery trade, one gallon containers, 15.2 cm in diameter and 15 cm deep, (approximate volume 2.5 liters). The containers were placed on a black plastic covered nursery bed and watered by overhead impulse type sprinklers.

Plant Species Grown

Pyracantha, Pyracantha coccinea 'Wateri' liners, were selected from a group rooted in a 1:1 peatmoss and perlite propagation mixture with 7.08 kg/m^3 (12 lb/yd^3) Osmocote 18-6-12, 2.38 kg/m^3 (4 lb/yd^3) Perk, 4.75 kg/m^3 (8 lb/m^3) dolomite, and 2.38 kg/m^3 (4 lb/yd^3) single super phosphate. They were potted into one gallon plastic containers on May 12, 1977. The larger liners were cut back to a height of 12 inches and all fruit removed. Plants were placed in full sun on black plastic and received approximately one inch of water every two days with overhead irrigation for the duration of the experiment. Each block of 81 pots was surrounded by a border row to decrease temperature

TABLE I

IRON, MANGANESE, COPPER, ZINC, AND BORON ADDED TO GROWING MEDIUM CONSTITUTING TREATMENTS

Elements	Low Level	Middle Level	High Level
		g/m^3	
IRON	43.5	87.0	174.1
MANGANESE	27.2	54.3	108.7
COPPER	2.7	5.5	11.0
ZINC	8.2	16.4	32.7
BORON	0.27	0.54	1.07

and light variability. The study was terminated on October 10, 1977, caliper and top weights were determined.

Tomato seed, Lycopersicon esculentum, was directly sown into gallon containers on May 20, 1977. Plants were grown on the same nursery bed as the pyracantha and received the same conditions. The tomato plants grew with no significant disease problems, but were sprayed with Carbaryl for hornworms on July 10, 1977. The tomato portion of the study was terminated on July 21, 1977, and the plants were evaluated for height, fresh weight of tops and roots and weight of fruits.

Azalea, Rhododendron obtusum 'Hinodegiri', liners from a commercial nursery (approximately 18 cm tall) were planted June 9, 1977. The azaleas were grown one and one half seasons on black plastic under 30% shade and with overhead irrigation. On January 4, 1978, a visual grade was taken evaluating plant color and severity of leaf drop. On April 2, 1978, data was taken on flower number and on July 12, 1978, the experiment was terminated, visual grade and top weight were determined.

CHAPTER IV

RESULTS AND DISCUSSION

Interactions between iron and copper, iron and manganese and copper and boron were significant for both pyracantha and azalea. Increases in iron caused greater top weight and caliper when copper also increased (Table II and III, Figure 1 and 2). Conversely, as iron increased, top weight of pyracantha decreased when more manganese was added (Table IV, Figure 3 and 4). This sensitivity to high manganese is in agreement with Epstein (6) who noted that high levels of manganese caused iron deficiencies due to its competition for functional sites on iron binding compounds.

The highest rate of iron significantly increased top weight and stem caliper of pyracantha more than any other element tested (Figure 5). An increase in top weight occurred as iron increased from the low to the high level when the high levels of boron and copper are present (Figure 6). Copper at all three levels produced similar top growth as long as iron was present at the high rate (Table II, Figure 7). However, there is some indication that the high level of copper is necessary for greater top weight of pyracantha (Figure 2). This is not in agreement with Mortvedt et al. (28) who felt iron chlorosis was associated with high copper, nor with Giordano et al. (13) who indicated that high copper interfered with the role of molybdenum in nitrate reduction.

TABLE II

EFFECT OF IRON-COPPER INTERACTION
ON TOP WEIGHT OF PYRACANTHA

Fe	Cu	Top Weight[1]
g/m³		
43.5	2.7	173 d[2]
43.5	5.5	182 d
43.5	11.0	175 d
87.0	2.7	186 bcd
87.0	5.5	185 cd
87.0	11.0	211 a
174.1	2.7	210 ab
174.1	5.5	222 a
174.1	11.0	209 abc

[1]Top weight in grams, mean of 18 observations.

[2]Means in same column followed by the same letter are not significantly different at 0.05 using a protected LSD test.

TABLE III

EFFECT OF IRON-COPPER INTERACTION
ON CALIPER OF PYRACANTHA

Fe (g/m³)	Cu (g/m³)	Caliper[1]
43.5	2.7	1.04 c[2]
43.5	5.5	1.09 bc
43.5	11.0	1.04 c
87.0	2.7	1.10 bc
87.0	5.5	1.09 bc
87.0	11.0	1.19 a
174.1	2.7	1.16 ab
174.1	5.5	1.20 a
174.1	11.0	1.17 ab

[1]Caliper in centimeters, mean from 18 observations.

[2]Means in same column followed by same letter are not significantly different at 0.05 using a protected LSD test.

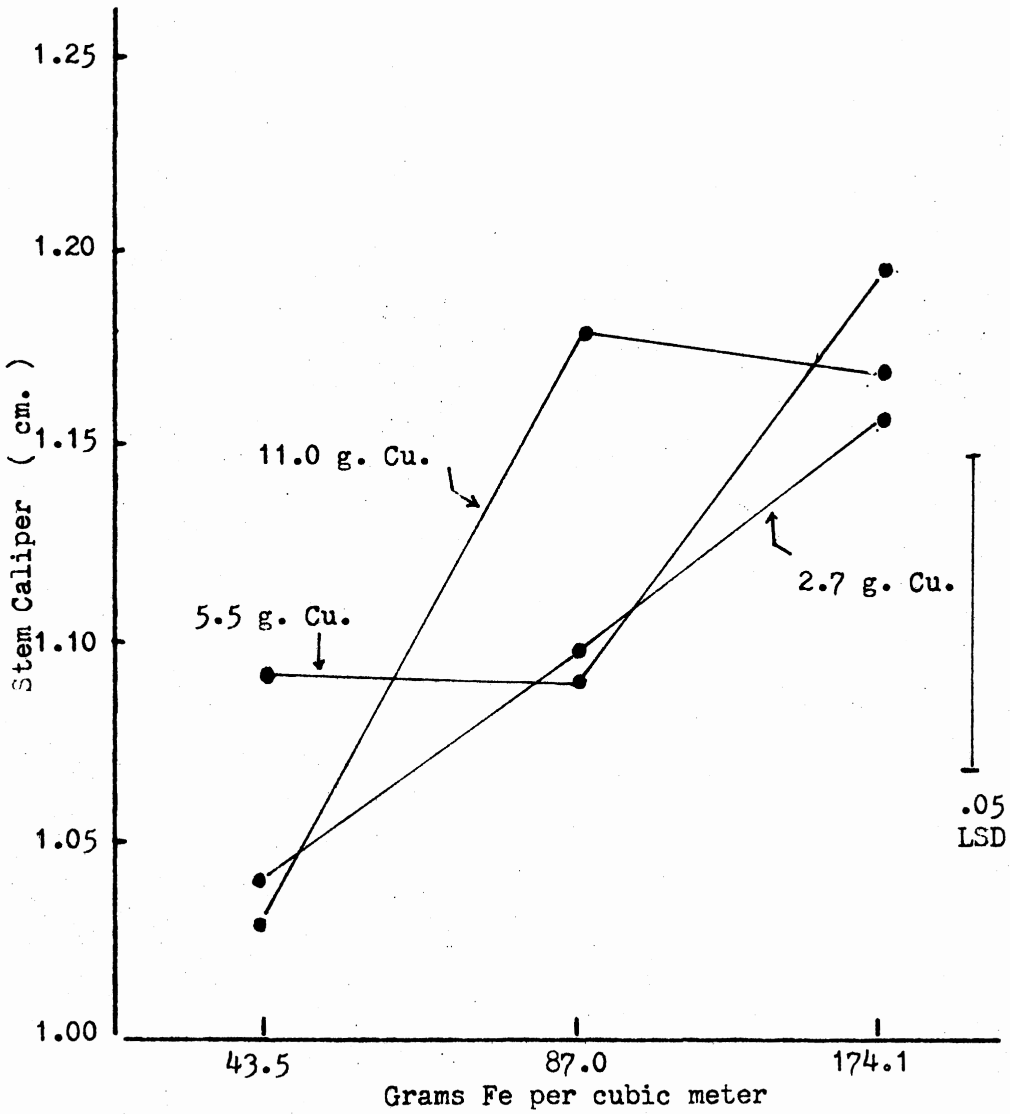

Figure 1. Interaction of Fe and Cu on Stem Caliper of Pyracantha

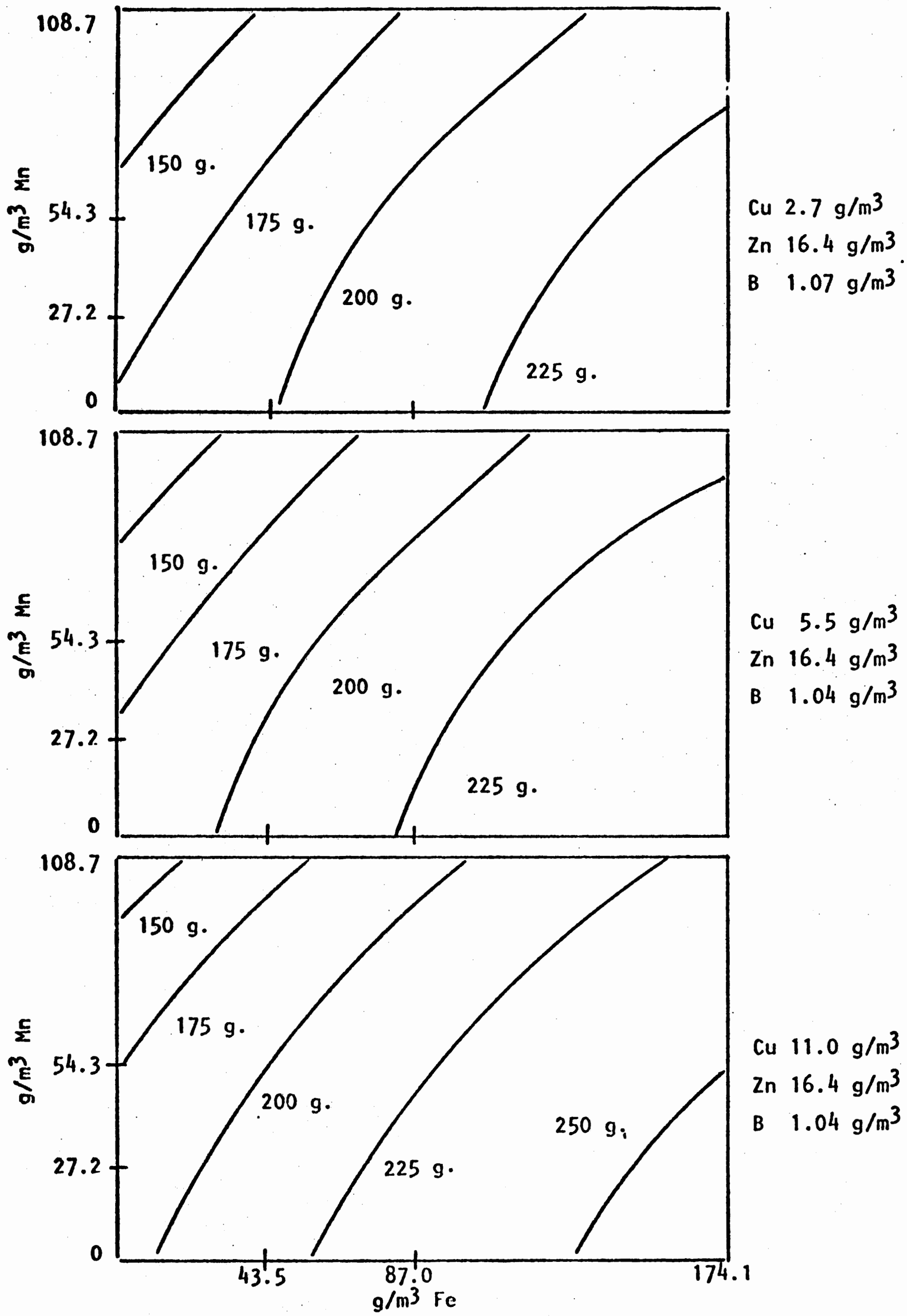

Figure 2. Quadratic Response Surface of Fe, Mn, and Cu Showing Effect of Cu Increase on Pyracantha Top Weight

TABLE IV

EFFECT OF IRON-MANGANESE INTERACTION ON TOP WEIGHT OF PYRACANTHA

Fe (g/m^3)	Mn (g/m^3)	Top Weight[1]
43.5	27.2	197 abc[2]
43.5	54.3	174 de
43.5	108.7	159 e
87.0	27.2	182 bcde
87.0	54.3	204 ab
87.0	108.7	196 abcd
174.1	27.2	215 a
174.1	54.3	217 a
174.1	108.7	211 a

[1]Top weight in grams, mean from 18 observations.

[2]Means in the same column followed by the same letter are not significantly different at 0.05 using a protected LSD test.

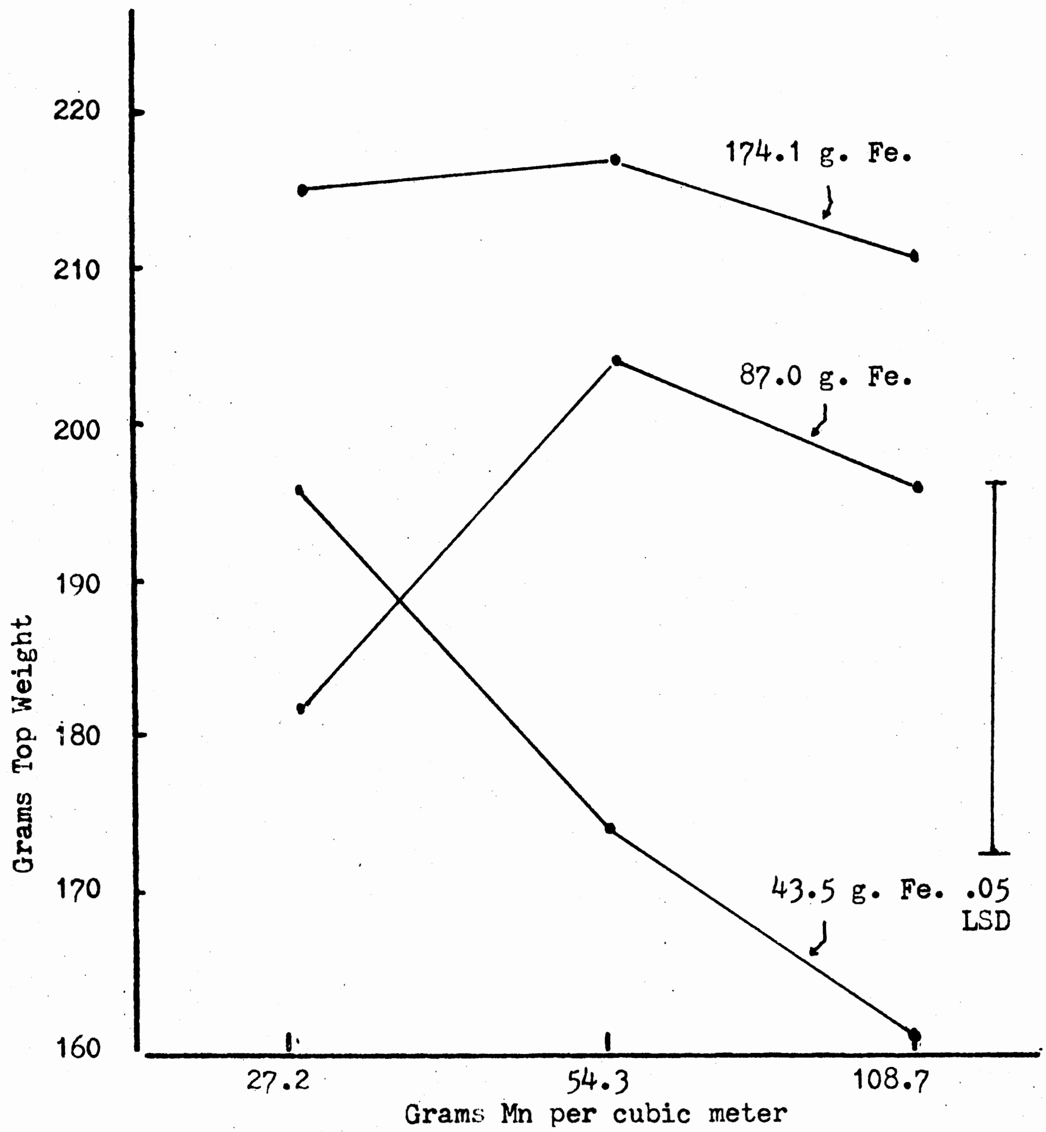

Figure 3. Interaction of Mn and Fe on Top Weight of Pyracantha

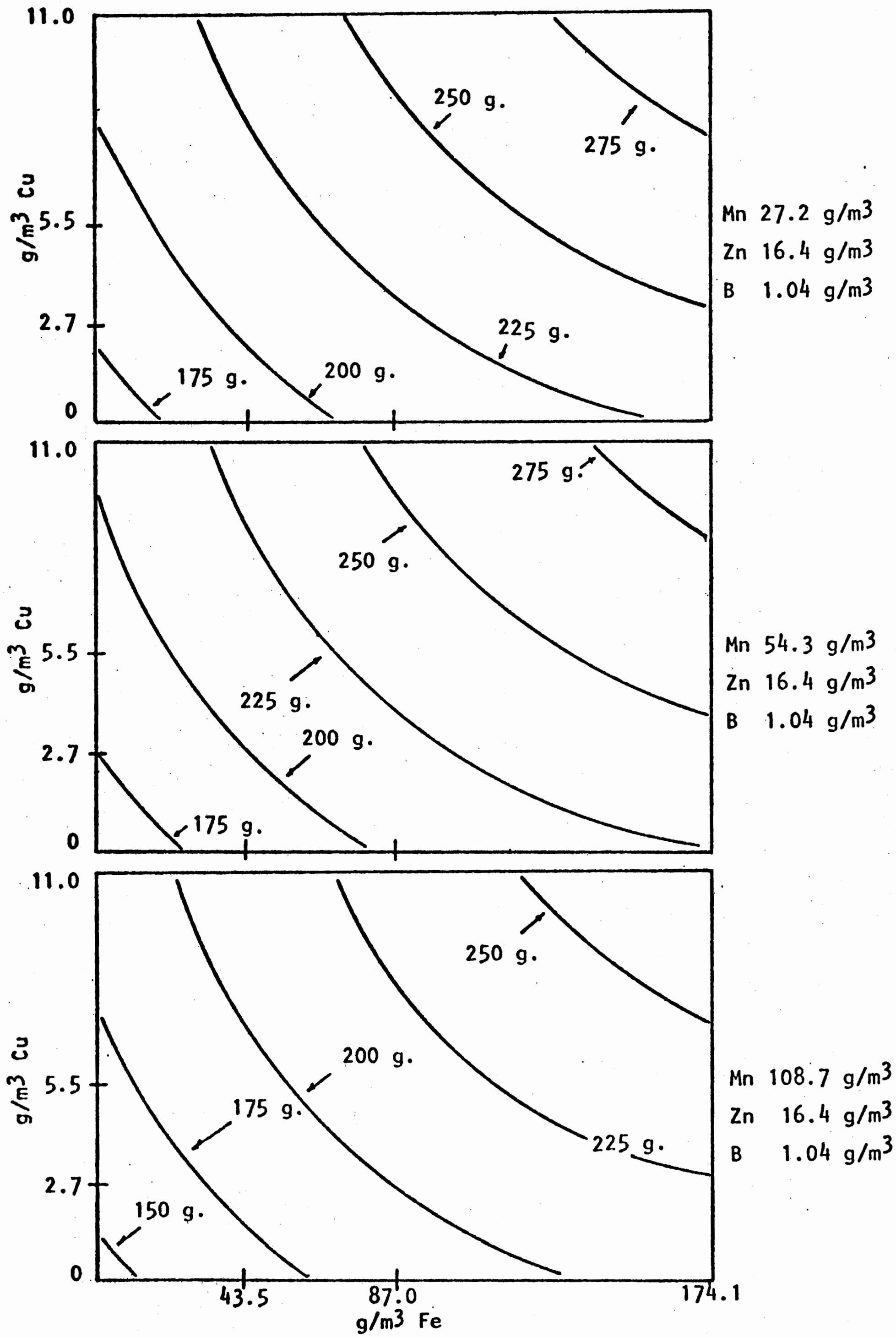

Figure 4. Quadratic Response Surface of Fe, Mn, and Cu Showing Effect of Mn Increase on Pyracantha Top Weight

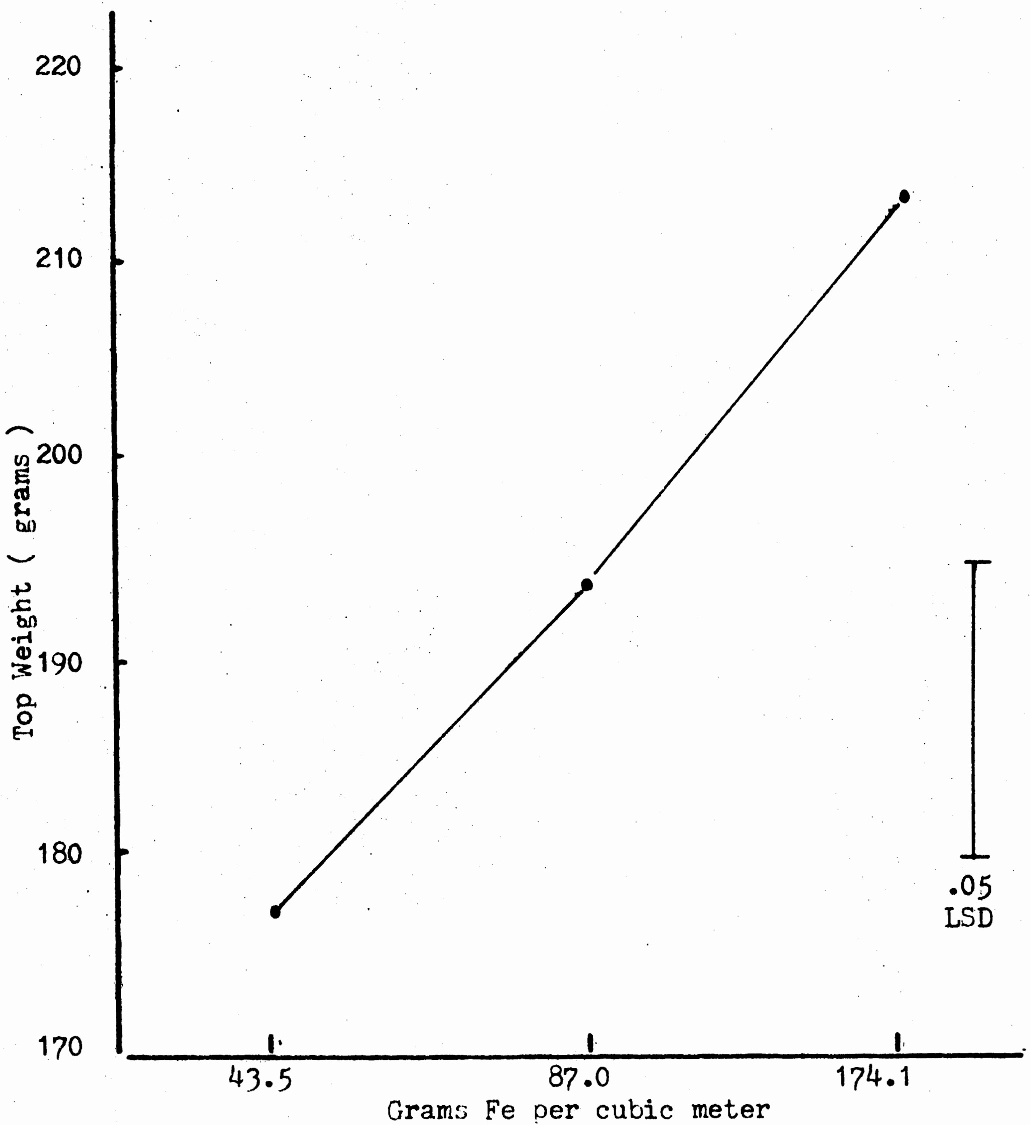

Figure 5. Effect of Fe on Top Weight of Pyracantha

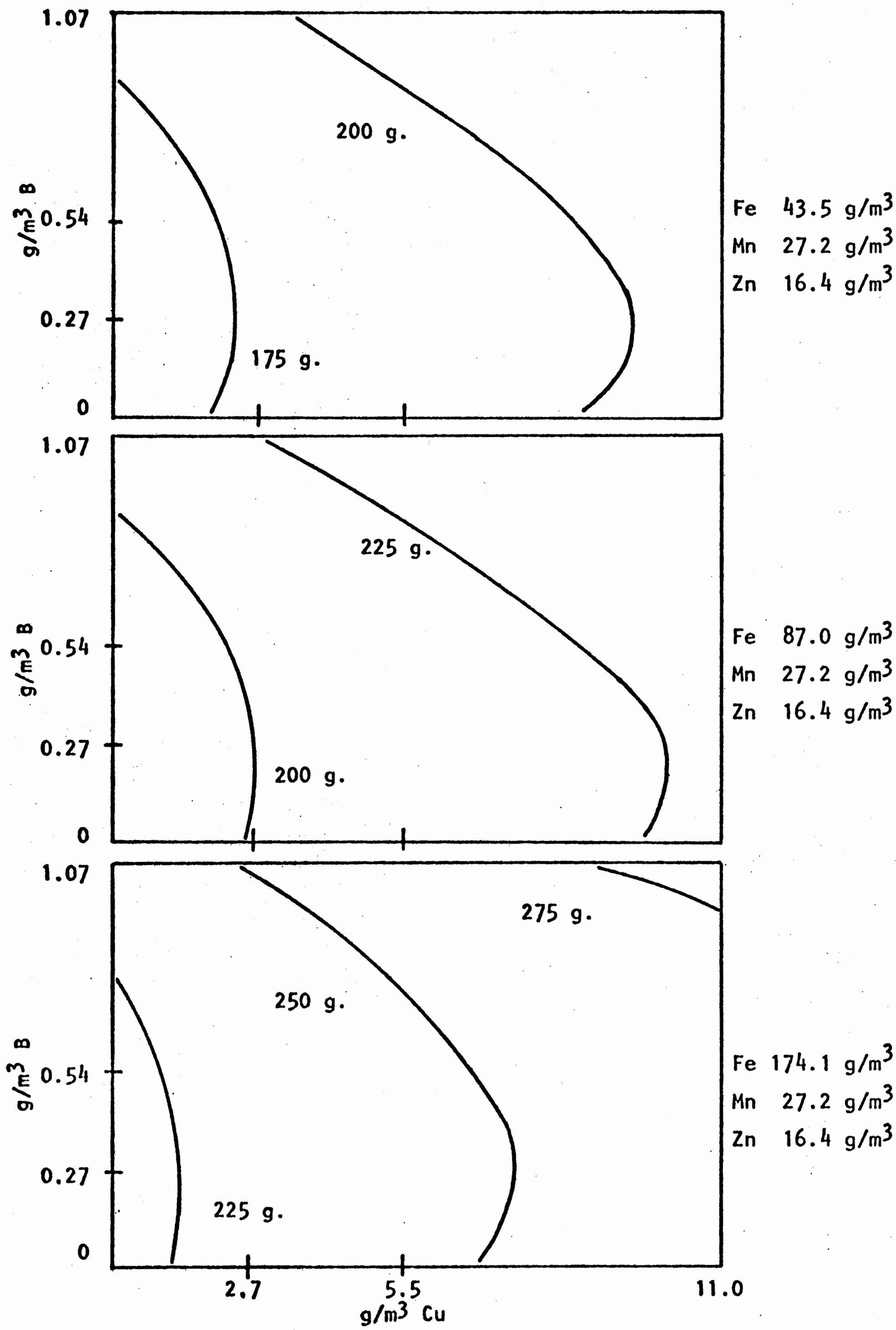

Figure 6. Quadratic Response Surface of Cu, B, and Fe Showing Effect of Fe Increase on Pyracantha Top Weight

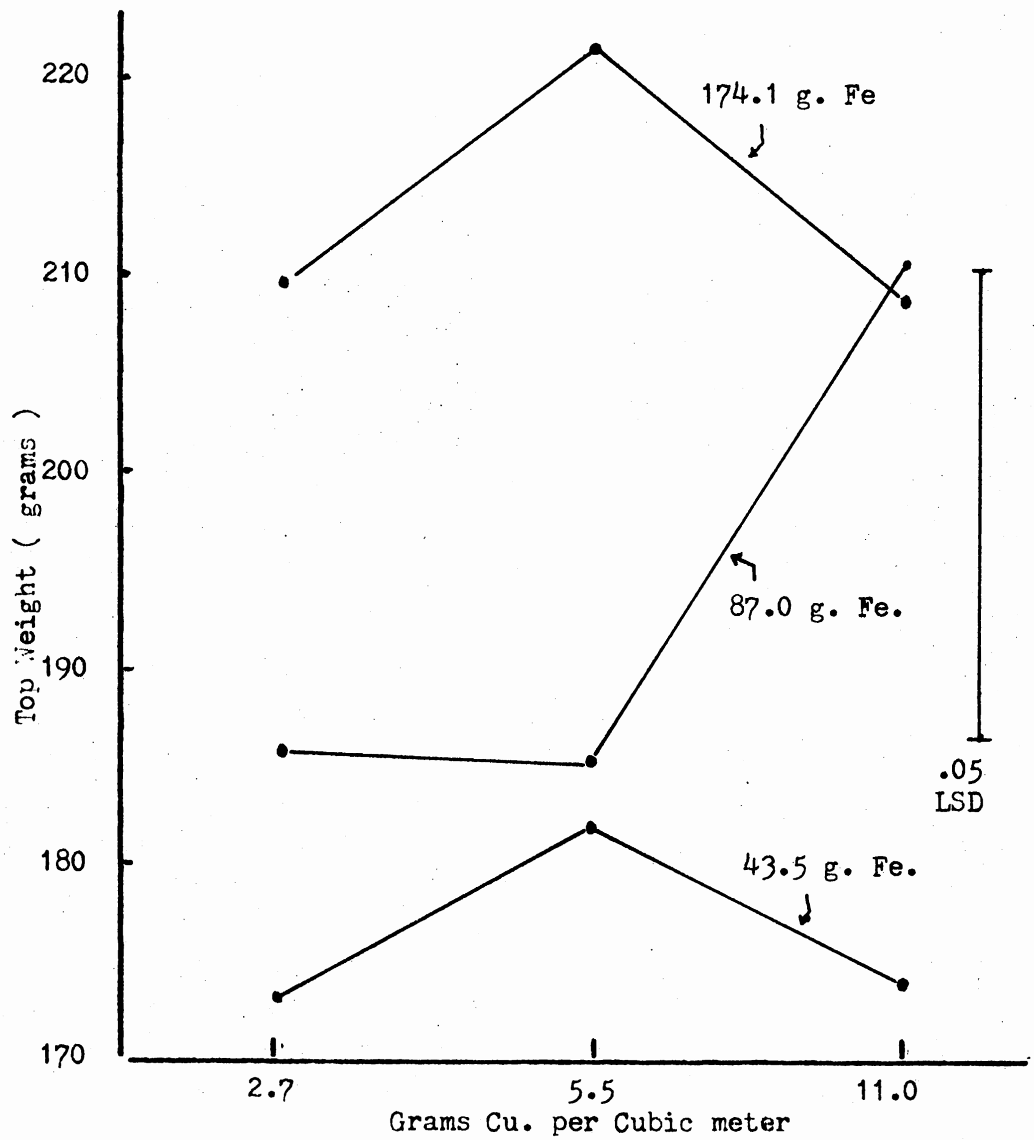

Figure 7. Interaction of Fe and Cu on Top Weight of Pyracantha

The copper-boron interaction showed that pyracantha top weight increase was greater as iron also increased (Figure 6). Boron at the high level enhanced growth of pyracantha more than boron at the middle level (Figure 8). Iron, manganese, or zinc interactions with boron were not significant, however, boron seems to have some effect upon their mutual interactions.

Pyracantha top weight decreased as zinc increased from the middle to the high rate (Figure 9). The middle rate provided the best growth response in pyracantha but was not significantly better than the low rate. This is in agreement with Watanabe et al. (45) who found iron uptake to be inhibited by high rates of zinc.

High copper significantly reduced visual grade of azaleas at the low rate of iron compared to high copper and the high rate of iron (Figure 10). Low copper significantly reduced flower number (Table V). There appears to be a definite advantage to incorporating high boron with high copper for azaleas (Figure 11).

No treatment was significant for tomatoes. This can be attributed to inconsistancies in germination, inadequate container size which tended to limit growth, and insect damage.

Studying quadratic response surfaces assists in forecasting plant responses to combinations of these elements not included in the experiment. Such projections will aid in further studies of the micronutrient needs of container grown plants.

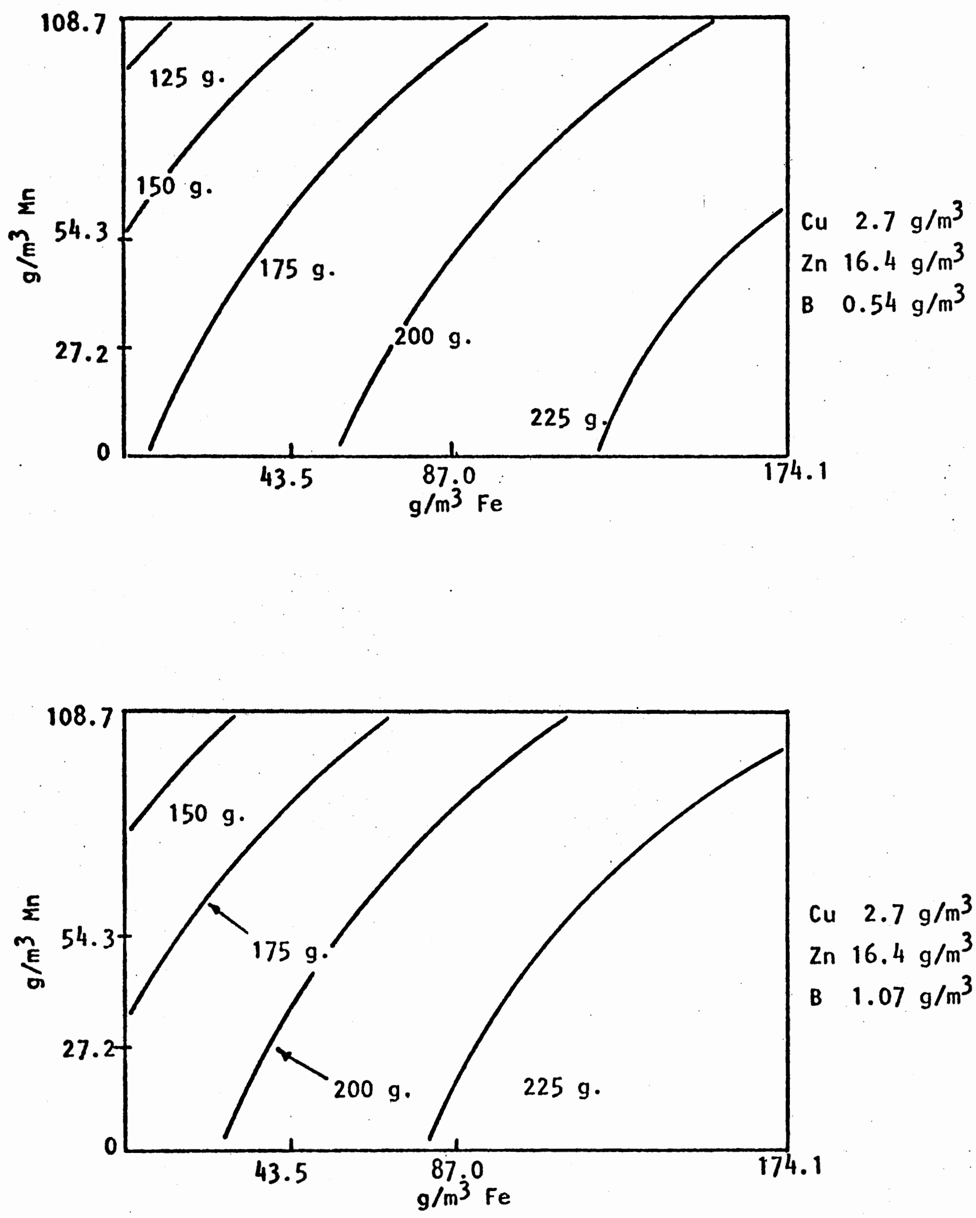

Figure 8. Quadratic Response Surface of Fe, Mn, and B Showing Effect of B Increase on Pyracantha Top Weight

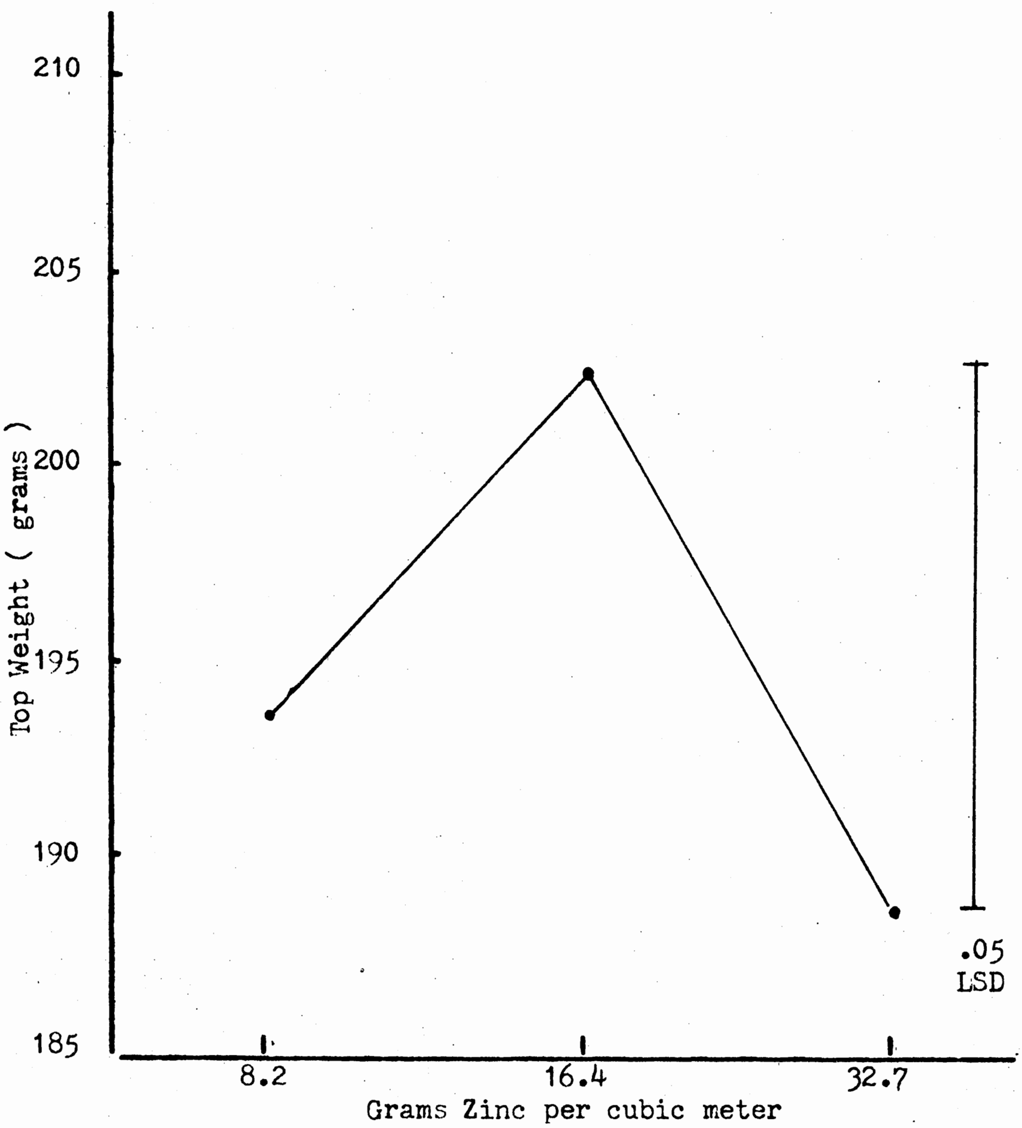

Figure 9. Effect of Zinc on Top Weight of Pyracantha

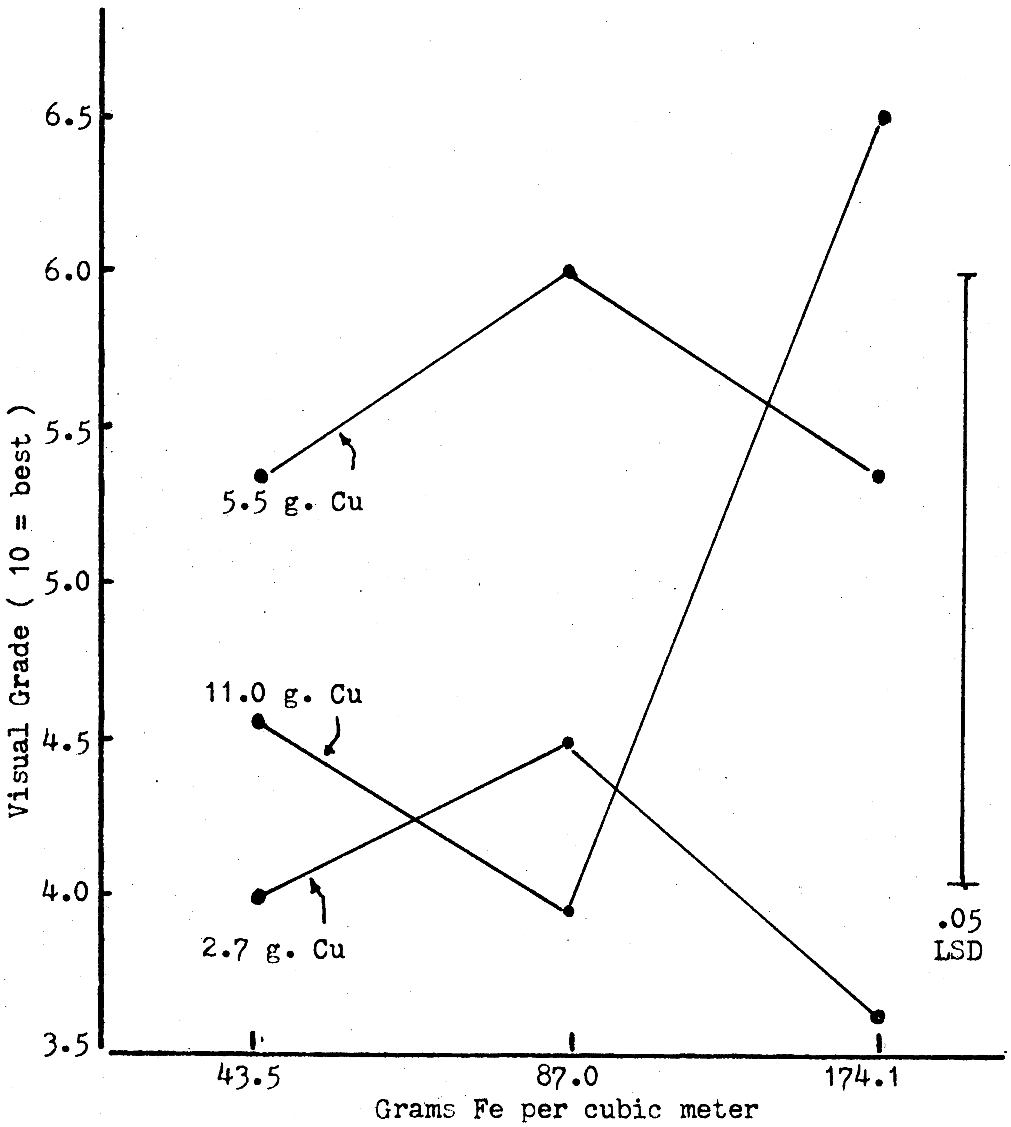

Figure 10. Interaction of Fe and Cu on Visual Grade of Azalea

TABLE V

EFFECT OF COPPER ON AZALEA FLOWER NUMBER AND TOP WEIGHT

Copper (g/m^3)	Flower Number[1]	Top Weight (grams)[1]
2.7	65.8 b[2]	86.9 b[2]
5.5	83.7 a	78.8 a
11.0	79.2 a	106.6 a
	.002	.01

[1]Mean of 54 observations.

[2]Means in the same column followed by the same letter are not significantly different at 0.05 using a protected LSD test.

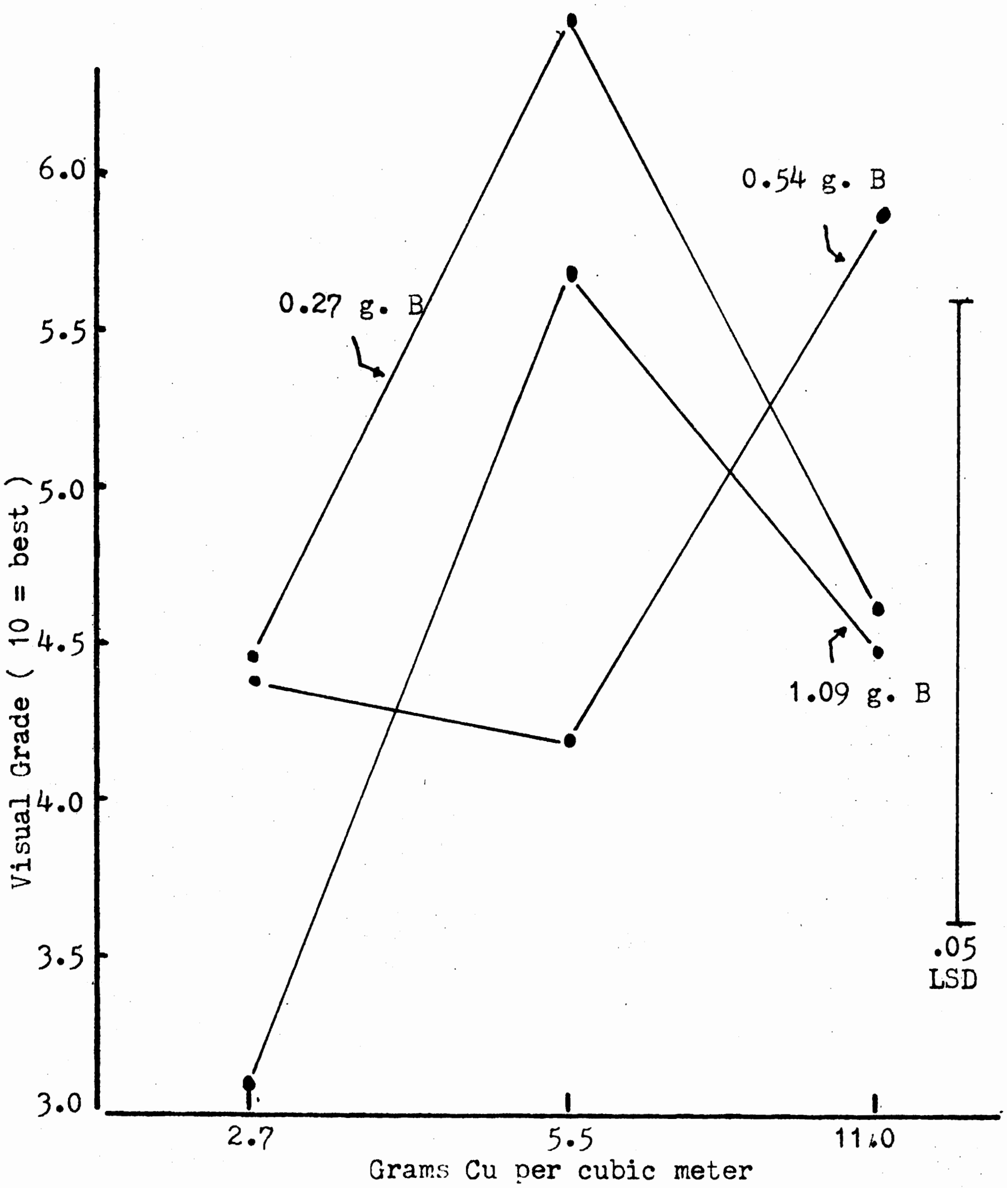

Figure 11. Interaction of Cu and B on Visual Grade of Azalea

CHAPTER V

SUMMARY AND CONCLUSIONS

The objective of this experiment was to develop a micronutrient fertilizer for use in container nursery production. Wateri Pyracantha, Hinodegiri Azalea, and Tomato were grown at three levels each of iron, manganese, copper, zinc, and boron in a 1/3 of 3^5 factorial arrangement.

High rates of iron and copper produced greater top weight and caliper of pyracantha and significantly increased visual grade of azalea. Low manganese and middle zinc were the best rates for pyracantha while higher rates produced less growth. High boron was necessary for best growth of pyracantha while azaleas responded similarly to either the middle or the high rate.

Iron-copper, iron-manganese, and copper-boron are important interactions which produced differences in pyracantha and azalea.

Based on this research with pyracantha and azalea, an effective micronutrient fertilizer for use in container nursery stock should contain:

1. Iron equivalent to or greater than the high level (174.1 g/m^3).
2. Manganese equal to the low level (27.2 g/m^3).
3. Copper at the high level (11.0 g/m^3).
4. Zinc at the middle level (16.4 g/m^3).
5. Boron at the high level (1.07 g/m^3).

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APPENDIX

REGRESSION B VALUES FOR THE RESPONSE SURFACE
PYRACANTHA TOP WEIGHT

Source	B Values
Intercept	133.45679012
Fe	12.78174603
Mn	-3.55357143
Cu	7.83730159
Zn	9.06646825
B	-1.98313492
Fe^2	-0.59027778
Mn^2	-0.44830247
Cu^2	-0.49382716
Zn^2	-1.26388889
B^2	0.52237654
FeMn	0.64087302
FeB	-0.48901644
FeCu	-0.25708617
FeZn	-0.03153345
MnB	0.31072846
MnCu	-0.20797902
MnZn	0.64384921
BCu	-0.00368481
BZn	-0.16588719
CuZn	0.14448696

VITA - 2

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