RESPONSE OF CONTAINER GROWN GREENHOUSE TOMATOES TO SLOW RELEASE FERTILIZER, MICRONUTRIENTS, AND NUMBER OF PLANTS PER CONTAINER

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PREFACE

This study is concerned with the treatment of container grown greenhouse tomatoes with slow release fertilizer, micronutrients, and number of plants per container. The objective is to find an improved method for growing greenhouse tomatoes in a culture void of soil. We used Osmocote 18-6-12, Frit 504 and Lycopersicon esculentum (Mill.) 'Tropic' transplanted to each container singly or in multiples of two and three as treatments to try and improve this soil free method of growing greenhouse tomatoes.

The author wishes to express his sincere appreciation to Dr. Carl E. Whitcomb, Assistant Professor of Horticulture, for his valuable guidance, encouragement, constructive criticism and arrangement help in the preparation of this thesis. Appreciation is also extended for his help in designing and analyzing this study.

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CHAPTER I

INTRODUCTION

Many ideas have been introduced into the production of greenhouse tomatoes primarily to increase production and quality, improve efficiency, and decrease cost. In recent years several slow release fertilizers have been developed and refined. Experimentally and commercially, these materials have been used largely on nursery and greenhouse floral crops giving improved plant growth and control of nutrients released to the growing medium. These fertilizer materials show promise in the production of other greenhouse crops.

Methods for producing greenhouse tomatoes have varied over the years. Hydroponic and other nutriculture methods such as gravel, trough, and ring culture have been and are presently used for producing the tomato commercially. Generally good results have been obtained, but not without considerable trial and error and close attention to details. Production from plants grown in the soil, however, remains the major method. Other methods have been devised for various reasons such as reduction of diseases, lack of good soil at the location selected for production, and to avoid the complexity of soil in trying to provide the desired balance and quantity of nutrients to the plants for maximum production. These methods limit root production somewhat, especially ring production. This problem must be dealt with in using containers for production as was done in this study.

The alternatives to production in soil are generally dependent on a growing medium made up of various materials other than soil. However, steam sterilized soil has been incorporated into the growing medium for some methods such as trough and ring cultures. A medium void of soil was used in this study. Because the media used in these types of culture are virtually free of nutrients, it is possible, theoretically, to provide to the plant the exact balance and quantity of nutrients deemed to be required for maximum production. Though the idea is relatively simple, the methods for administering nutrients to the plant as a frequent liquid application through these soil free media are not. These methods have been dependent on daily monitoring and even daily administering of nutrients to the medium in order to keep plant health and production at its peak. Because of the intensive care which must be provided plants produced in these various cultures, it must follow that cost of production will increase as time spent monitoring the crop increases.

It was thought that even though these production methods have proved successful in some cases and are presently used commercially, introduction of a less complex method of administering nutrients through a soil free medium such as the use of a slow release fertilizer might be beneficial to the greenhouse tomato producer. The slow release material, Osmocote, used in this study is relatively expensive, however, if the efficiency for producing tomatoes in soil free culture can be improved sufficiently, such a material may become economical for use when considering time saved and possible errors avoided.

Because it is always desirable to produce maximum fruit which effectively lowers production cost and increases the potential for higher income, use of multiple plant per container was used in this study. This was to determine the maximum potential for production using a slow release fertilizer to produce a tomato crop from containers using a soil free medium.

CHAPTER II

REVIEW OF LITERATURE

The vegetative and reproductive potential of the tomato as related to nutrient availability has involved extensive research. Much of the research was done in small pots in the greenhouse or in the field.

In 1918, Krause, E. J. and H. R. Kraybill (11) made numerous observations involving the vegetative and fruiting requirements of the tomato. Some of these are:

1. Plants grown with an abundant supply of available nitrogen are vigorously vegetative and unfruitful.
   a. If plants are transplanted to a soil moderate in available nitrogen, they become less vegetative and fruitful, but if the soil is low in available nitrogen the plants will be weakly vegetative and unfruitful.
2. Fruitfulness of the tomato is dependent on a balance between nitrates and carbohydrates rather than a high concentration of either.
3. Fruit development is dependent on the nutritional condition of the plant as well as pollination and fertilization.
4. Vigorously vegetative plants have larger stem size than less vegetative plants.

5. A correlation exists between moisture content and nitrate nitrogen in plant tissue, both being needed to produce good growth or fruitfulness.

Much research has been done on the need of the tomato for the major elements. Mack (13) in 1937 reported that nitrogen in large amounts increased growth and yield in a spring crop but had no effect on a fall crop. He reported that the high nitrogen in the medium did not make the plants go vegetative. In field grown tomatoes, Garrison et al. (8) in 1967 reported that 186-250 pounds per acre of nitrogen broadcast increased flower formation and fruit set. It was reported that production was depressed if no nitrogen was applied.

In work done on the effect of irrigation and nitrogen on yield, maturation, and quality of the tomato, Wright et al. (30) reported that excessive irrigation decreased yield, delayed maturity, and lowered fruit quality. Excessive dryness hastened maturity and well colored fruit, but otherwise lowered quality and decreased yields. Nitrogen levels of 20, 80, and 200 pounds per acre, two of which were considered excessive, had no effect on yield, rate of maturity, or fruit quality.

Maynard and Barker (18) reported that excessive NH_4 is toxic to the tomato, but that potassium can have an equalizing effect on this toxicity. They also contended that excessive potassium depressed yields. Ward (24) reported that potassium and nitrogen were absorbed continually during growth and that potassium was absorbed in the highest quantity of all nutrients. Ozbun et al. (20) reported development of white tissue in ripe fruit due to potassium deficiency. The work was carried out in sand and nutrient culture. In 1964, Wilcox (28) reported increases in yield of thirty percent due to the application of potassium to soils already containing 100 to 150 pounds per acre. Plant responses to increase were: longer internodes, larger stems, lighter green terminals, and reduced fruit dropping during ripening. Leaf content of potassium needed to be twenty-three percent or higher to produce optimum yield.

Wilcox (29) reported in 1967 that relatively small rates of phosphorus placed in bands was sufficient for optimum seedling growth. Hepler (9) in 1924 reported that phosphorus enhanced early vegetative growth and caused a higher percent fruit set.

The New Mexico State University Extension Circular #387 (5) published in 1967 states that a stem diameter taken at six inches below the terminal of less than one-half inch indicates a nitrogen deficiency. If over three-fourths inch, an excess may be present. It also states that desirable soil nitrate levels vary with the amount and intensity of light.

Romshe (22) in 1938 reported from work with field tomatoes that shade increased bloom, fruit set, yield of mature fruit, and fruit quality. Marr and Hillyer (16) reported in 1968 that self-pollination and shade in or out of the greenhouse caused reduced yields and percent misshapened fruit.

A publication by the Ohio Extension Service, Growing Greenhouse Tomatoes in Ohio (3), makes observations on the requirements of the tomato for the major elements and micronutrients as well. Data were obtained from tissue analysis. Some of the relevant points are:

1. Nitrogen sufficiency is dependent on the season, and nitrogen needed decreases as the growing season progresses.

2. Sufficient phosphorus level in the plant ranges from .20%-1.5%.
3. Sufficient potassium is 2.5% and 8-12% might cause plant and fruit defects.

However, MacLean et al. (14) in 1968 reported they found tissue analysis, as a tool for determining a deficiency, was too late in determining a deficiency to allow for corrections. Several possible causes of green shoulder and blotchy fruit ripening of the tomato fruit are discussed (3). Suggested causes are: high or low temperatures while on the vine, low or high moisture, potassium deficiency, insufficient light, or high nitrogen. Collins and Cline (4) reported that blotchy ripening was dependent on the N:K ratio. They reported that in the field where sufficient light was present that blotchy ripening could be controlled by keeping nitrogen and potassium in balance with each other.

Davis et al. (6) reported that a great deal of variation exists between first fruit set and first fruit to mature. Dempsey and Boynton (7) reported that tomato maturity was significantly correlated to seed number. Fruit size was found to increase with additional seed.

Knavel (10) found that growing transplants in containers improved with increased container size and wider spacing. These plants also yielded more.

Malison (15) reported on the use of several growing media for tomato production in trough and ring culture. He found that satisfactory results could be obtained using such medium amendments as peat moss and pine bark. The results by Malison also showed those media with pine bark as an amendment yielded less than other amendment combinations.

All media combinations, however, where pine bark was included as an amendment also included peanut hulls, which break down rapidly causing nitrogen deficiency problems. This work, therefore, may not give a good account of pine bark as a medium component. Schales (23) reported that loblolly pine bark screened through a 1.27 x 1.27 cm. mesh was found to be a satisfactory substitute for sphagnum peat moss in greenhouse tomato production. He indicated equally satisfactory results using a liquid fertilizer program or slow release Osmocote formulations.

Very little was found in the literature on Osmocote relating to the tomato. Matkin (17) in 1971 related that Osmocote is a completely soluble fertilizer material incapsulated in a plastic coating. Oertli and Lunt (19) noted the following points on coating inorganic fertilizer salts: (a) That the availability of nutrients from such materials can be regulated by coating. (b) The release rate approaches linearity for a considerable time; thereafter the rate drops off. (c) Release rate is largely independent of pH. (d) Temperature has a very definite effect on the release rate. (e) The release rate can be regulated very effectively through coating thickness. (f) Sterile conditions slightly reduce the release rate. They concluded that diffusion is the most likely mechanism by which the nutrients are released and that coated fertilizers possess the properties required for the regulation of nutrient availability.

A commercial brochure published by Sierra Chemical Company* on Osmocote makes reference to Oertli and Lunt's findings and indicated nitrogen and potassium ions to be released more rapidly than phosphate

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*The Osmocote Process, Sierra Chemical Company, Sycamore Street, Newark, California.

ions. They term Osmocote 18-6-12 as an eight to nine month release formulation more suited for long-term crops. They termed Osmocote 14-14-14 or 18-9-9 having a thinner coating as being more suited to a short term crop such as the tomato. These formulations are said to have a three to four month release period.

Poole and Waters (21) reported the 18-6-12 formula gave the best results on azaleas. Azaleas would be considered a long-term crop. Bateman (1) reported the best container shrubs are produced by Osmocote as compared to those produced by other slow release materials such as PKU Tablets, a 14-4-6 slow release fertilizer. White (26) reported in a comparison of slow release and soluble fertilizers for greenhouse roses that no significant differences were found between soluble fertilizers and Osmocote though significant differences did exist between these and other slow release materials. Waters and Llewellyn (25) reported good results using Osmocote 14-14-14 incorporated in the medium to produce heartleaf philodendron. They also indicate that release rate is lowered when the fertilizer is placed on the medium surface rather than being incorporated. This is in agreement with Oertli and Lunt (19) regarding container grown materials in a greenhouse. Lorenz et al. (12) reported work with slow release nitrogen materials such as Urea-formaldehyde, in soil grown tomatoes and other plants. Their findings were that slow release fertilizers produced less yield but did remain in the soil longer than a readily released material such as ammonium sulfate. Block (2) relating to the growing of pine trees in soil and in containers gives good acclaim to Agriform tablets, another slow release material.

The purpose of this study was to consider the yield potential of greenhouse tomatoes when grown in containers in a medium where all plant nutrients must be supplied. Nutrient needs were supplied by Osmocote, a fritted form of micronutrients, single superphosphate (0-20-0), and dolomite. Plant competition as it affected plant growth and yield was also studied. Fruit quality and quantity were monitored throughout the experiment.

CHAPTER III

MATERIALS AND METHODS

This study was conducted in a 32' x 50' greenhouse section of the Oklahoma State University greenhouse range. The greenhouse has glass side walls with a fiberglass roof and is joined on each end by other sections of greenhouse. The facility is oriented north and south. It is equipped with steam heat and a space heater. Ventilation is accomplished by drawing air through the house south to north by means of two thermostat controlled 48" exhaust fans located one on each side at the north end of the building. Air is pulled through an evaporative cooling pad in the south end of the house.

Experimental design was a randomized block using a 3x3x3 factorial set of treatment combinations with six replications. Treatments were as indicated in Table I. Randomization of treatments within each block was accomplished using randomized tables.

Initial slow release fertilizer treatments were 800, 1600, and 2400 pounds of nitrogen per acre per year from Osmocote* 18-6-12. Fertilizer treatments were increased to 1600, 2400, and 3600 pounds on March 4th due to the appearance of phosphorus deficiency symptoms. Osmocote is a plastic incapsulated slow release source of N-P-K. The nitrogen source is ammonium nitrate and ammonium phosphates thus of the

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*Manufactured by Sierra Chemical Co., Newark, California.

18%, 9.6% was ammonical nitrogen and 8.4% nitrate nitrogen. Approximately 13.5% was controlled release, the remainder is released quickly. Phosphorus is from ammonium and calcium phosphates. Soluble potassium is from potassium sulfate. Osmocote was applied to the surface of the growing medium following planting. The treatment levels of Osmocote were based on the amount of nitrogen in the slow release fertilizer. The application was made one time to run for the duration of the test which ran from February 12th through June 20th.

TABLE I

TREATMENT COMBINATIONS

	Levels per container		
Osmocote lbs./A.	Osmocote after March 4	Micronutrients oz/cubic yard	No. Plants /container
800#	1600#	0	1
1600#	2400#	5	2
2400#	3200#	10	3

Micronutrient levels were 0, 5, and 10 ounces of Frit 504* per cubic yard of medium, a blend of all micronutrients shown to be adequate for good plant growth with nursery stock. Micronutrients were incorporated with the growing medium.

*Manufactured by Frit Industries, Ozark, Alabama.

Lycopersicon esculentum (Mill.) variety 'Tropic' was used. The experiment was initiated February 12th by transplanting one, two, or three plants approximately 6"-12" tall into previously filled and placed containers. Transplants were seeded in flats in late December and transplanted to peat pots approximately two weeks after seeding. Transplants were left in these pots when transplanted to experimental containers. Plants were older than desired, beginning to crowd for light and as a result somewhat uneven in size at the time of transplant.

The growing medium used in the experiment was a 1-1-1 by volume mix of peat, pine bark, and sand mixed in a small concrete mixer. This provides a growing medium relatively free of nutrients, but well aerated while retaining considerable moisture for plant growth. This mix was adopted from container culture of nursery stock. To supply necessary nutrients, single superphosphate (0-20-0) and dolomite were incorporated into the medium at the time of mixing at rates of eight and twelve pounds per cubic yard respectively.

Containers were three gallon plastic containers manufactured by Zarn Corporation.* Replications were set up as blocks containing the twenty-seven treatment combinations. Each replication was made up of four rows of six containers plus a fifth row of three with two feet separating the containers in the row and between rows. A depression between each row provided for removal of excess moisture from the containers making it possible to maintain a good plant moisture relationship. Two foot strips of black plastic were placed under each row of containers to control weeds and prevent plants from rooting

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*Zarn Corporation, Reedsville, North Carolina.

into the soil. The experiment took up approximately three-quarters of the greenhouse. The remaining space was used to grow greenhouse tomatoes by the conventional soil method for comparison.

Cultural practices were carried out the same as for standard grown greenhouse tomatoes. Plants were trained to a single stem by pruning side shoots on a regular basis. Plants were supported by wrapping with a nylon string and tying to a wire approximately eight feet high. Pollination was done during the heat of the day, each day, after start of bloom using a mechanical vibrator and by shaking the vines. Temperature was maintained near the recommended temperatures of 80°-85°F. daytime and 62°F. at night and 55°F. at night during cloudy periods (27). Watering was done by hand using a hose with attached water breaker.

Insect and disease problems were monitored during the experimental period but were negligible. The only control practice needed was fumigation for white fly.

The first harvest date was May 4th and fruit was harvested at least once per week, twice during peak production, until termination of the experiment on June 20th. Measurements taken and observations made were: (a) Total weight of fruit in grams for each treatment combination. (b) Total number of fruit of acceptable size as recorded in Growing Greenhouse Tomatoes in Ohio (3). All fruit two inches or more across were considered acceptable while all under two inches were culled. (c) Total number of fruit harvested fully ripe compared to total with ripening disorders. (d) Stem size of all plants was measured on May 31st. A mean was established for each treatment combination which involved multiple plants per pot. Stem measurement

was taken one foot above the surface of growing medium. (e) Tissue analysis was determined by the Oklahoma State University Soil Science Department on samples taken from ten selected treatment combinations in the experiment. Samples were taken from leaf tissue at the fifth and sixth nodes down from the terminal. Two samples were also taken from the soil grown tomatoes for analysis. This was for comparison as the soil grown tomatoes were not a part of the experiment.
(f) Samples of the growing medium were taken and analyzed near termination of the experiment to check the depletion of nutrients over the test period. Ten samples were taken from the experimental treatment combinations and one from the soil grown tomatoes.

CHAPTER IV

RESULTS AND DISCUSSION

Effects of Treatments on Quantity of Fruit Harvested

Analysis of variance showed that only fertilizer rate significantly influenced total weight of fruit harvested (Table II). Duncan's new multiple range test showed that as fertilizer rate increased a significant increase in total weight of fruit resulted (Table III). A graphic presentation of the data (Figure I) shows this to be a strong linear increase, thus suggesting that additional fertilizer was needed for further increase in total fruit production. However, the rates of nitrogen used in this work are very excessive compared to the conventional levels used in growing greenhouse tomatoes. It is of particular interest that these levels did not make the plants grow excessively vegetative or cause them to be unfruitful. These results appear contrary to previous work by Krause and Kraybill (11) and in accord with others, Garrison et al. (8) and Mack (13). It must be pointed out that these levels of nitrogen are levels applied for the entire growing season in a slow release form which is dependent on temperature and moisture for release. These levels, then, do not necessarily indicate the nitrogen levels in the medium at any given time. These results will be expanded further later in this discussion.

TABLE II

ANALYSIS OF VARIANCE OF TOTAL
WEIGHT OF FRUIT HARVESTED

				Level of Probability	
Source	df	MS	F. Value	5%	1%
Total	161	333,323.4534			
Trt.	26	1,592,800.576	18.24682**	1.16	1.95
Rep.	5	177,963.6592	2.03872	2.29	3.17
Error	130	87,291.94381			
Fertilizer Rate (F)	2	19,580,911.0	224.31521**	3.07	4.79
Micronutrients (M)	2	23,865.0	.27339	3.07	4.79
No. Plants/Container (P)	2	191,030.0	2.18840	3.07	4.79
FxM	4	40,882.5	.46834	2.45	3.48
FxP	4	65,588.25	.75137	2.45	3.48
MxP	4	110,782.5	1.26910	2.45	3.48
FxMxP	8	119,023.75	1.363.51	2.02	2.66

**Indicates significance at the .01 level of probability or higher.

TABLE III

EFFECTS OF FERTILIZER RATE ON TOTAL WEIGHT OF FRUIT

Fertilizer Level (Osmocote 18-6-12)		
1600[1]	2400	3200
1761 g a[2]	2337 g b	2967 g c

[1]Pounds of nitrogen per acre.

[2]Means followed by the same letter are not significantly different at the .05 level.

TABLE IV

ANALYSIS OF VARIANCE OF FRUIT OF MARKETABLE SIZE

Source	df	MS	F. Value
Total	161		
Trt.	26	75.9649	9.51368**
Rep.	5	12.3951	1.55234
Error	130	7.9848	
Fertilizer Rate (F)	2	832.6914	104.28449**
Micronutrients (M)	2	4.6729	.58522
No. Plants/container (P)	2	60.4136	7.56606
FxM	4	5.4228	.67914
FxP	4	14.5525	1.82252
MxP	4	7.3673	.92266
FxMxP	8	8.7701	1.09835

*Significant at the .01 level of probability.

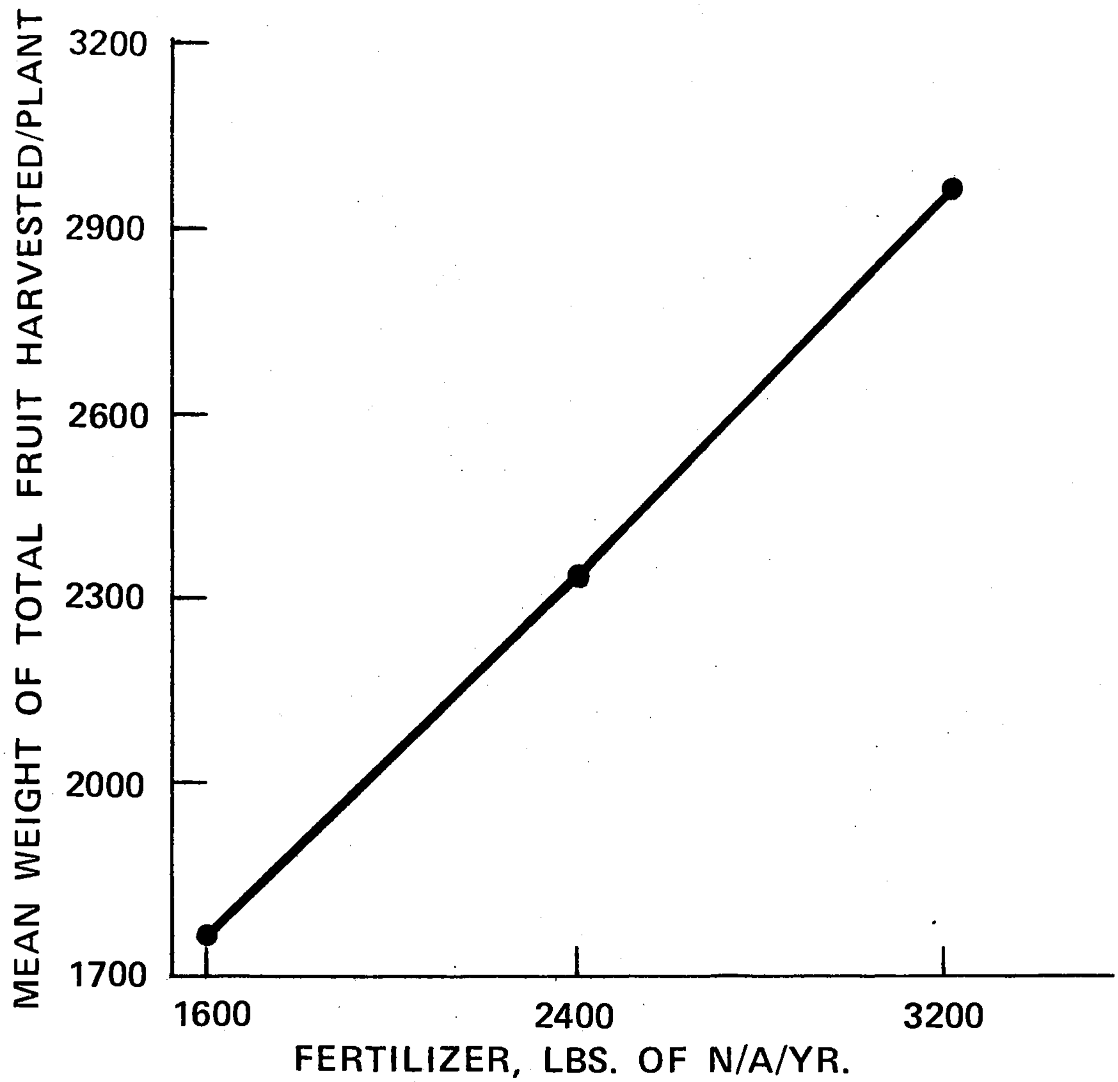

Figure 1. Effect of Fertilizer Rate on Total Weight of Fruit

Effect of Treatments on Size and Quality of Fruit

Seventy-five percent of the fruit harvested was of acceptable size (two inches or larger in diameter). Analysis of variance revealed that fertilizer level and number of plants per container influenced reuslts (Table IV). The effect of micronutrients was found to be not significant and no significant interactions were present.

A comparison of fertilizer rate means showed that quantity of acceptable fruit significantly increased with each increase in fertilizer (Table V). This positive effect may be seen clearly in Figure 2. Means for number of plants per container show a significant difference between containers with two plants and containers with one or three plants per container while no significant difference existed between containers with one plant and those with three plants per container (Table VI). Increase in fruits of acceptable size can be seen in a graphic presentation (Figure 3) which shows two plants per container to be superior with a decrease in number of acceptable fruits with one or three plants.

Fruit quality in this study was not desirable. First, from a commercial standpoint, a 25% loss of the crop due to insufficient size would be very damaging to a producer. Approximately 90% of the fruit harvested ripened abnormally. Blotchy ripening appeared on some fruit, but the major portion of the abnormal ripening was due to green shoulder, a condition where the stem end of the fruit fails to ripen during the normal ripening process of the remainder of the fruit, but rather remains green or turns whitish or yellowish. This condition of the fruit caused a loss of approximately one-third or more of some

TABLE V

EFFECT OF FERTILIZER RATE ON NUMBER OF FRUIT OF MARKETABLE SIZE

Fertilizer Levels		
1600	2400	3200
12.26 a*	16.3 b	20.1 c

*Means followed by the same letter are not significantly different at the .05 level.

TABLE VI

EFFECT OF NUMBER OF PLANTS PER CONTAINER ON NUMBER OF FRUIT OF MARKETABLE SIZE

Number of Plants/Container		
1	2	3
15.3 a*	17.4 b	16.1 a

*Means followed by the same letter are not significantly different at the .05 level.

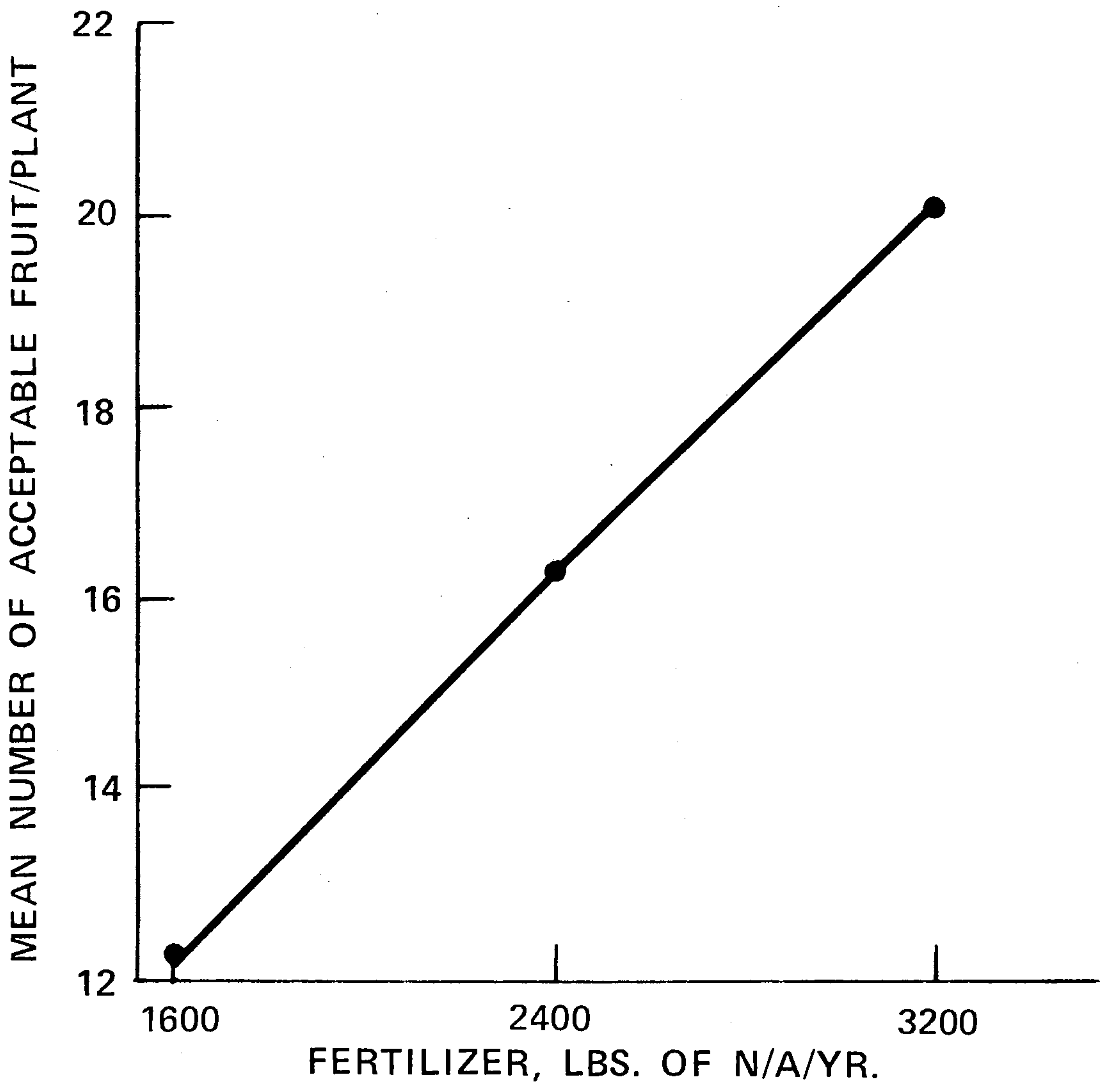

Figure 2. Effect of Fertilizer Rate on Number of Fruit of Marketable Size

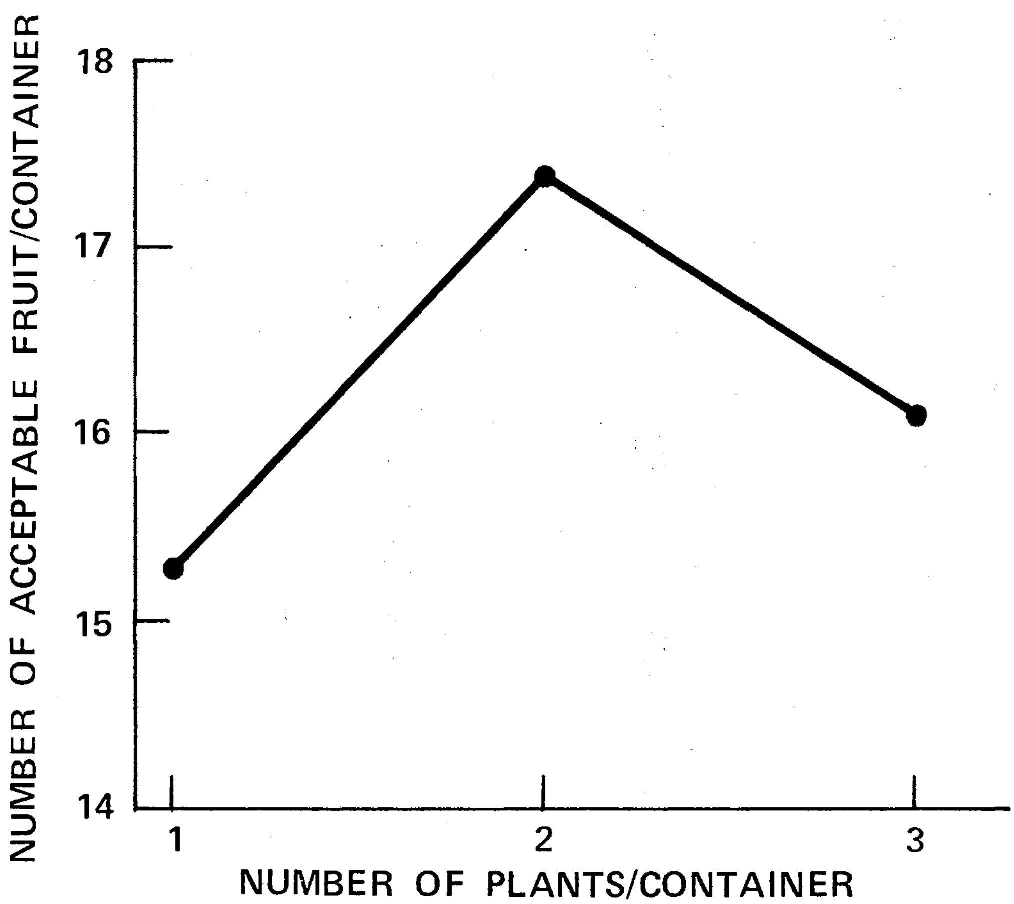

Figure 3. Effect of Number of Plants per Container on Number of Fruit of Marketable Size

fruit. Some fruit which appeared ripe, had considerable green tissue internally. There are several possible causes of the poor ripening of the fruit in this study. The Ohio Extension Service Publication, Growing Greenhouse Tomatoes in Ohio (3) suggests that high or low temperatures on the vine could be a contributing factor. In this study, low temperatures were not a problem because of the season, however, temperature ranged above 85 on several occasions. Thus, high temperatures may have contributed slightly toward the condition as it was difficult to maintain a uniform moisture condition of the growing medium when watering by hand. It was necessary late in the experimental period to water as much as four times daily to prevent wilting of the plants. A drip or tube type watering system would appear essential to production of this type. Bloom end rot, a condition also associated with wet and dry conditions of the medium, showed only slight incidence during the fruiting period and generally not until very late in the experiental period. Therefore, it seems unlikely that the green shoulder problem in this study was a result of the moisture conditions. It should be pointed out that the growing medium was not allowed to dry out for any extended period during the study that would have likely had a contributing effect on the green shoulder condition of the fruit. Most tomatoes growing in soil produced fruit which ripened normally, thus insufficient light is not thought to have been a contributing factor. The soil grown plants were more heavily covered with foliage than the container grown plants.

Brooks (3) suggests high nitrogen to be associated with ripening disorders, mainly blotchy ripening. However, this appeared not to be the case, as the ripening disorder in this study more nearly appeared to be green shoulder rather than blotchy ripening, although some fruit appeared intermediate between the two disorders. Another reason for this conclusion is the deficiency of nitrogen both in the plant and growing medium as shown in Tables VII and VIII. Tissue analysis results show only 1.9 percent nitrogen for sample 3-1-1. This is the highest level determined for any of the samples taken. Brooks (3) and Kraus and Kraybill (11) indicate that nitrogen is needed in decreasing amounts as the season progresses, however, the level determined in the tissue was less than the suggested minimum requirement at any time during the season. Nutrient tests of the growing medium for plant nutrients indicate that nitrates were deficient as shown in Table VIII compared to levels recommended by the Horticulture Department for soil grown tomatoes.* Even though apparent high levels of nitrogen were added to the surface of the growing medium at the time the experiment was started, it apparently was released and leached from the medium too quickly. Another possibility is that since the high demand for nutrients is placed on a very limited volume of growing medium, the method of calculating levels of fertilizer applied may have been in error and therefore, levels were in fact too low. Also a problem may have existed between medium and plant nutrients, thus preventing uptake by the plants, such as the carbon-nitrogen ratio. Malison (15) reported nitrogen deficiencies existing in trough and ring cultures with medias containing pine bark and peanut hulls. He corrected for the deficiency by adding calcium nitrate to the growing medium. This test, however, did not include a media involving only one of these

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*Unpublished recommendations, O.S.U. Horticulture Department.

TABLE VII

TISSUE ANALYSIS OF TOMATOES

Treatment Combinations			Plant Nutrients*				
Fertilizer	Minor elements	No. Plants/Container	N	P	K	Ca.	Mg.
(lbs. N/A)	(oz.)						
1600	0	1	1.7	6.1	.31	2.3	1.5
2400	0	1	1.4	3.0	.29	1.7	1.3
3200	0	1	1.9	3.4	.33	1.6	1.1
1600	5	1	1.4	2.8	.29	1.6	.9
2400	5	1	1.5	3.7	.30	1.8	1.2
3200	5	1	1.7	2.8	.33	1.6	.9
1600	10	1	1.6	7.1	.35	2.1	1.5
2400	10	1	1.5	3.4	.34	1.6	1.0
3200	10	1	1.6	2.8	.35	1.6	1.1
Plants in soil			2.0	7.5	.33	2.1	.6
Plants in soil			2.2	11.0	2.28	2.8	.8

*Suggested levels by the Ohio State Extension Lab. (3) for the time period May 25-30. Nitrogen 3.00-3.50, Phosphorus .20-1.5, Potassium 2.5, Calcium 6.0, and Magnesium .2-.3.

TABLE VIII

SOIL TEST FOR GROWING MEDIUM

Treatment Combinations			Nutrients in ppm**					
Fertilizer	Minor Elements	No. Plants/Container	N	P	K	Ca	pH	Solubridge
(lbs. N/A)	(oz.)							
1600	0	1	7	1.5	0	30	6.6	10
2400	0	1	8	.5	0	40	6.5	20
3200	0	1	1	.5	0	40	6.6	22
1600	5	1	2	.5	0	30	6.6	12
2400	5	1	20	1.0	7	40	6.4	49
3200	5	1	25	1.5	5	30	6.3	35
1600	10	1	10	.5	0	20	6.5	20
2400	10	1	25	1.5	0	20	6.3	38
3200	10	1	25	1.0	0	30	6.25	42
Plants in soil*			50	12.0	10	125	6.35	125

*Two samples were collected and combined for analysis.

**Unpublished recommendations, O.S.U. Horticulture Dept., Nitrates 20-75, Phosphorus 5-30, Potassium 10-60, Calcium 100-300, pH 6.0-7.2, and Solubridge 30-90.

materials as a media constituent. Schales (23) reported that loblolly pine bark could be substituted satisfactorily for sphagnum peat moss in medias for tomato growing. No satisfactory conclusion can be reached based on the data taken in this study as to why nitrogen was apparently limiting to the tomato plants for a large part of the test period.

In addition to the green shoulder that prevailed in fruit from this study, the skin of all fruit was very tough and fibrous. The Ohio State Extension publication (3) indicates that these conditions could be related to a potassium deficiency. Their findings from tissue analysis were that a 2.5% level of potassium is needed in the plant tissue to prevent fruit defects. It is apparent in Table VII that potassium was deficient in this test. Levels for the ten samples were all under 0.4 percent. The soil grown plants also were apparently slightly deficient in potassium. A small portion of fruit from these plants near the end of the season also exhibited the green shoulder symptoms and tough skins. The potassium deficiency was also noted in the growing container medium, as shown in Table VIII. Eight of the ten samples taken were completely void of potassium. Ward (24) reported white tissue in fruit from potassium deficient plants. All of the references given relating to potassium indicate the nutrient to be related to fruit maturity. Dempsey and Boynton (7) reported that tomato maturity was significantly correlated to seed number. No data were recorded in this study on the number of seeds per fruit. However, samples taken from the final harvest showed not more than twenty seeds per fruit. This is very low and when compared with the potassium deficiency is strong evidence that the ripening problem of the fruit from this study is more closely related to a potassium deficiency than other possible causes. It is felt, however, that contributing to the problem were both sunlight and high temperature on the vine during ripening because of the lack of foliage cover and results by Romshe (22) on shading tomatoes.

In addition to the nutrients already discussed, analysis for phosphorus, calcium, and magnesium were also determined (Table VII). Phosphorus and magnesium appear to be sufficient in the plant tissue. However, workers in Ohio (3) could not establish a minimum for calcium, but indicated presence of approximately 6% calcium in most samples submitted. Analysis of the growing medium (Table VIII) shows both phosphorus and calcium as deficient. The medium pH and soluble salts content were within the suggested range. Soluble salts were high in the soil grown plants.

Analysis of Variance Applied to Stem Diameter

The vegetative condition of the experimental plants indicated deficiencies throughout the experiment. Plant conditions, therefore, appear to be correlated closely with the apparent deficiencies which developed in the fruit.

Stem diameter was chosen as an index by which to measure the vegetative condition of the plants. Analysis of variance shows treatments to be significant at the one percent level (Table IX). Fertilizer and plant number were significant at the one percent level of probability as main effects. Also a highly significant interaction between fertilizer and plant numbers was found to exist. The larger F. value for plant number per containers indicates that this effect had the

TABLE IX

ANALYSIS OF VARIANCE OF PLANT STEM DIAMETER

Source	df	Ms	F. Value
Total	161		
Trt.	26	.189146	34.88**
Rep.	5	.01476	2.722
Error	130	.0054223	
Fertilizer Rate (F)	2	.9538	175.0**
Micronutrients (M)	2	.01072	1.977
No. Plants/Container (P)	2	1.38365	255.1776**
FxM	4	.01316	2.42701
FxP	4	.02671	4.92**
MxP	4	.01095	2.01943
FxMxP	8	.002265	.41772

**Indicates significance at the .01 level of probability or higher.

greatest influence on stem diameter and general vegetative development of all plants.

Table X shows that each increasing level of fertilizer significantly increased stem diameter. These data also indicate a significant decrease in stem size with each increase in number of plants per container. Figure 4 shows that means for stem diameter increased with increased fertilizer and stem diameter increases as number of plants decrease. The greatest increase is with one plant per container.

The general appearance of plants where more than one was growing in one container was characterized by stunting. Plant internodes were very short, leaves failed to expand fully giving plants a very light foliage cover. Leaves and stems were very fibrous and tough. Pruning side shoots for training of plants to a single stem was made difficult by this condition. Side shoots as well as the entire plant was very flexible and would not snap off but rather had to be torn away leaving a stringy stub. This was quite different from the soil-grown plants which were very heavy with foliage with leaves larger than normal and stem size only one foot below the terminal being one to one and one quarter inches, or approximately three centimeters. Stem sizes for experimental plants were recorded in centimeters and all plants were found to be less than one-half inch in diameter. Side shoots were very tender and brittle and were easily broken off. Soil grown plants were excessively brittle, in that it was very easy to break off the plant top while trying to remove lateral branches. This type of development is characteristic of excessive nitrogen. This was a direct contrast with the experimental plants which were deficient in nitrogen as indicated by tissue analysis. However, typical deficiency symptoms

TABLE X

INTERACTION OF FERTILIZER LEVEL AND NUMBER OF PLANTS PER CONTAINER ON MEAN PLANT STEM DIAMETER IN CENTIMETERS

Fertilizer Level	Number of Plants/Container 1	2	3
1600 lbs. N*	0.949 a 1**	0.754 b 1	0.674 c 1
2400 lbs. N	1.028 a 2	0.862 b 2	0.746 c 2
3200 lbs. N	1.271 a 3	1.015 b 3	0.877 c 3

*Express as pounds of nitrogen per acre from 18-6-12.

**Means within a row followed by the same letter or within a column followed by the same number are not significant at the .05 level.

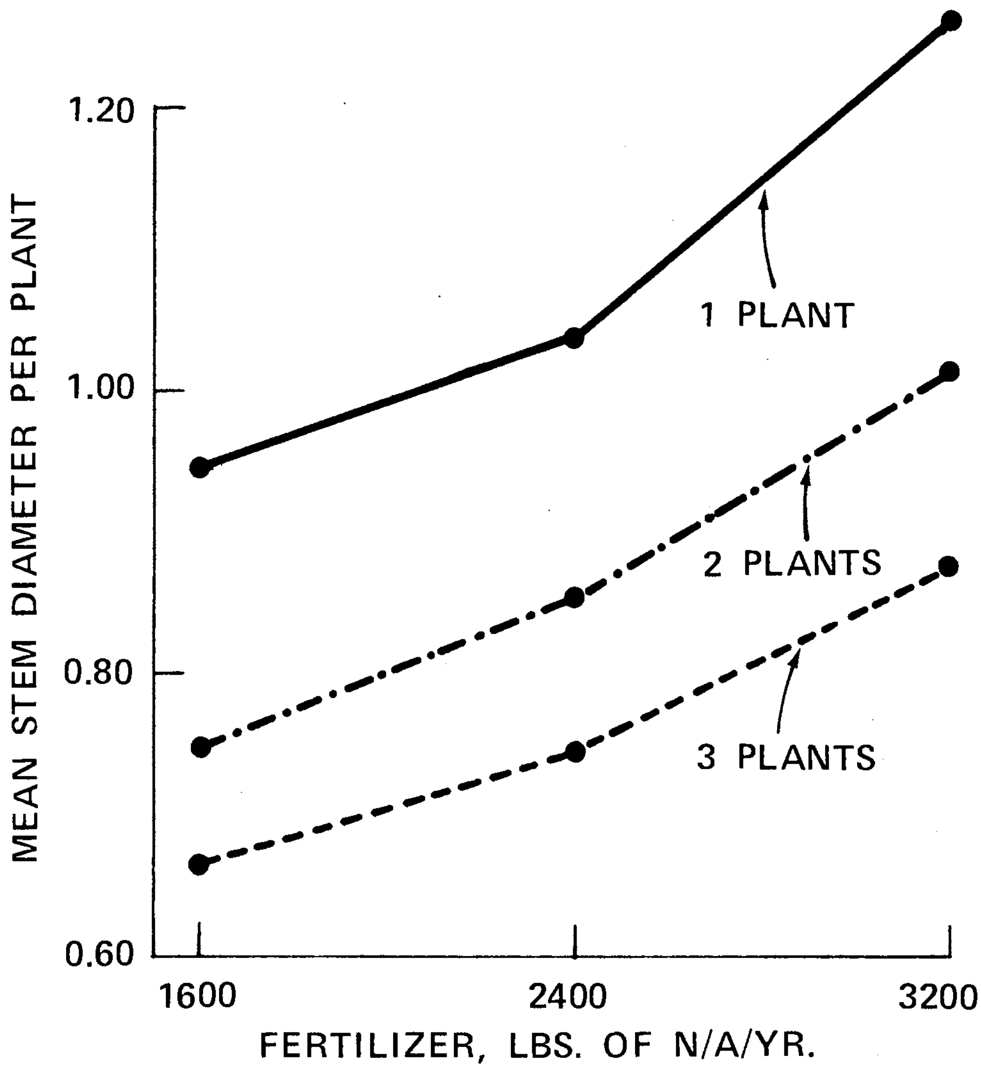

Figure 4. Interaction of Fertilizer Level and Number of Plants per Container on Plant Stem Diameter in Centimeters

were not apparent, but were apparently masked by symptoms of a potassium deficiency. Other symptoms of the experimental plants were leaf chlorosis and necrosis in the mature leaves, with leaves being deformed on much of the plant. Classic potassium deficiency symptoms appear along the leaf margin and at the tip, but in this study the symptoms advanced over the entire leaf and up the stem just below the terminal and necrosis in some terminals was apparent. The tops of some of the weaker plants died. In all cases this occurred where multiple plants existed per container. No plants were lost completely over the entire experimental period, but stunting was apparent in all treatments. This was more predominant in containers with multiple plants. Containers with three plants very often had three sizes of plants ranging in size from two to six feet tall. The New Mexico State Extension Circular #387 (5) reported that a stem diameter of less than 1/2" taken six inches below the terminal indicates a nitrogen deficiency. Stem sizes in this work were below a half inch about 12 inches above the soil line and would have been even smaller if the measurement had been taken six inches below the terminal. The circular indicates stem diameter of over 3/4" indicates a possible nitrogen excess. By such a standard, stem size for soil-grown plants produced at the time this experiment was in progress indicated an excess of nitrogen. Wilcox (28) reported increased stem size due to an increase in potassium. A deficiency of nitrogen and potassium in this study then is borne out in the literary review and by tissue analysis and soil analysis. Maynard and Barker (18) reported that ammonium ions were toxic to the tomato. This effect may have been present in this work as plants affected in this way are stunted and have deformed foliage. However, not enough evidence exists here to make a judgment on the possible effect of ammonium ions.

Phosphorus was shown to be sufficient by tissue analysis, but soil tests indicated a deficiency in the growing medium. No definite symptoms were present except in the first two weeks of growth when classical symptoms of a phosphorus deficiency appeared, including growth cessation and purple stems and leaves. Some plants were almost completely purple. However, symptoms disappeared after fertility was increased with the addition of more Osmocote as indicated in Table I. This early deficiency may have influenced the early bloom and fruit set which occurred. The first bloom occurred on 2-27-73 and had set a fruit by 3-5-73 and subsequent heavy bloom and fruit set occurred within the next two weeks.

A comparison of production with results published by the Ohio State Extension Service (3) indicates underproduction in this study based on counts of fruit per cluster. Their results indicated that under optimum production conditions as many as 13 uniform fruits may develop per cluster. Cluster size in this experiment ranged from five to nine actual fruit set. Commonly only three to seven of the fruit set matured and uniformity was lacking between fruits in a cluster.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study was to determine the usefulness of a slow release fertilizer in the production of greenhouse tomatoes in containers. The research was undertaken by transplanting approximately eight week old transplants into containers filled with a soil free growing medium. A one time application of slow release fertilizer (Osmocote) was made to the surface of the growing medium. Frit 504 was selected as a source of micronutrients and incorporated into the growing medium at the time of mixing. Also incorporated into the growing medium was a base source of phosphorus and sulfur from single superphosphate and calcium and magnesium from dolomite. One, two, or three plants were transplanted into each container in an effort to determine the maximum production efficiency for the container size selected.

Treatment effects were measured by determining (a) total production by weight, (b) fruit size, and (c) stem diameter of plants. Physical appearance of the plants and fruits were observed.

Conclusions:

1. Maximum production was not attained in this experiment.
2. Fruit size was not uniform for all treatment.
3. Increasing fertilizer increased both total fruit weight and number of marketable fruit.

4. Two plants per container produced the greatest number of marketable fruit.
5. A deficiency of all major elements except phosphorus existed in the experimental plants as determined by tissue analysis.
6. Growing medium was deficient of all major nutrients for at least part of the experimental period as determined by soil analysis.
7. Stem diameter was small for all treatments, but increased with increasing fertilizer and decreasing numbers of plants per container.
8. A green shoulder condition and blotchy ripening was observed on many fruit in all treatments.
9. Plants were generally unthrifty, being stunted with short internodes and unexpanded leaves.
10. Deficiency symptoms existed in the plant for a major part of the experiment with the predominant symptom being that of potassium which may have masked other nutrient deficiency symptoms.
11. The fruit ripening disorders are thought to be the result of a potassium deficiency and an imbalance between nitrogen and potassium.
12. Micronutrients had no significant effect on the data taken.

These results show that the tomatoes grown in this experiment requires a higher fertility program than for soil grown tomatoes. However, the container method of growing greenhouse tomatoes appears to hold promise. Perhaps by using larger container sizes, higher rates of more quickly available fertilizer and or different types of slow release fertilizers and or by altering the nitrogen-potassium balance. It is thought that Osmocote was a good selection of a slow release fertilizer for this trial. However, based on results of this study and other research, as well as manufacturer recommendations for Osmocote, perhaps a form containing an equal balance of the major elements would be more desirable. A form such as Osmocote 14-14-14 with a release period of three to four months may be superior to Osmocote 18-6-12 with a release rate of eight to nine months which was used in this trial. The ratio of nitrogen to potassium must be more evenly balanced or perhaps potassium should be in excess of nitrogen during ripening especially (3,4). A more uniform method of watering than by hand would be desirable.

A program such as the one used in this study could be useful in commercial production when the proper growing conditions are determined if cost of production under these conditions is not limiting.

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