PERFORMANCE OF CHRYSANTHEMUM MORIFOLIUM 'MANDALAY', 'PEACOCK' AND 'WINTER CARNIVAL' IN A CONVENTIONAL AND SOLAR HEATED GREENHOUSE TO GROWING MEDIA AND NUTRITIONAL CONDITIONS

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CHAPTER I

INTRODUCTION

Pot mum production increased 50 percent from 1966 to 1970 and is considered as the most profitable crop for many pot plant growers. As production increased, the need for production improvements proportionately increased, since a high quality plant is the goal of every producer.

With increased energy costs, even greater emphasis must be placed on heating costs while maintaining good plant quality. Greenhouses heated with solar energy and waste heat from power plants have been studied. Improved greenhouse insulation, particularly at night, has reduced total energy requirements for pot plant production. However, energy costs have increased so sharply that total expenditures for energy have increased many fold.

Studies of alternate energy sources and greenhouse insulation have concentrated mainly on heating the greenhouse air, as has been the common practice for many years. Few studies have addressed the alternative of heating the root system of the plant while reducing the air temperature in the greenhouse.

In preliminary studies, a difference in nutritional responses has been observed between the gas heated greenhouse in which the air temperature remains constant, and the solar heated greenhouse in which the pot temperature remains constant. In an effort to produce a high quality plant under both systems, both the NPK release rate and the micronutrient level should be studied to reduce the possibility of one or both becoming a limiting factor.

Alterations in the total nutritional program, use of floor heat, and other cultural factors, may affect the performance of the plant. As other factors are changed, altering the growing medium should also be considered.

The purpose of this study was to find the optimum growing medium porosity, N and K release rate for Osmocote, and Micromax level for the production of a high quality pot mums in a gas heated greenhouse where air temperature was kept optimum, and a solar greenhouse where the floor and container were heated but the air temperature was allowed to fall below the suggested range.

CHAPTER II

LITERATURE REVIEW

Micronutrients

The process of adding micronutrients in the production of plants in containers has, until recent years, been the subject of little research. In the past, most growers used some field soil in the growing medium, and adding micronutrients was discouraged. Matkin, Chandler, and Baker (33) state since micronutrients are required in such minute amounts by plants, and are natural components of peat, soil, fertilizer, and water, it is impossible that a soil mix would develop micronutrient deficiencies.

Due to the reduction in weight that can be achieved, and thus lower transportation costs and easier handling, many growers have switched to soilless growing media. Soilless growing media may be composed of wood byproducts, peatmoss, or other organic matter, and are generally much lower in micronutrients than media containing some field soil (19, 36).

Pool and Conover (41) studied the effects of dolomite and Perk (a micronutrient fertilizer) on the yield of leatherleaf fern (Polystichum adiantiforme) produced in a soilless mix, and concluded that both dolomite and Perk reduced foliage production. Conover, Simpson and Joiner (12) reported that when three levels of the micronutrient sources Perk, Vigoro Supplement X, and FTE 503 were applied to Aphelandra squarrosa, Brassaia actinophylla, and Philodendron oxycardium, no treatments increased quality or growth over those plants with no micronutrients added. Dickey and Joiner (14) tried to produce Cu, Mn, and Zn deficiencies in sand culture, but were unable to do so, thus furthering the belief that no micronutrient sources were needed. Conover and Pool (11) reported toxic effects of Perk on the rooting of cuttings. Their research stated that when three pounds of Perk/cu.yd. was added to the rooting medium of Aphelandra, Aglaonema, Maranta, and Dieffenbachia, the root grade was reduced.

When Poole and Conover (41) suggested that no micronutrient additions were needed, research was run with nitrogen used at the rate of 400 pounds N/acre/year. Whitcomb (58) found that when nitrogen was used at the rate of 900 pounds of N/acre/year, the addition of micronutrients caused little improvement in the quality of Juniperus horizentalis 'Wiltoni', Ligustrum japonicum, Hibiscus rosa-sinensis, and Ixora coccinea. However, when nitrogen was used at the rate of 1800 pounds of N/acre/year, the addition of micronutrients increased bud breaks and growth index of these species. Also, deeper green foliage and more brilliant flowers were obtained on Ixora coccinea. Washington and Self (54, 55, 56) also showed the need for the incorporation of micronutrients in container production. This suggests that in earlier experiments, nitrogen or some other micro- or macronutrient may have been the limiting growth factor.

The use of soilless growing media and new macronutrient sources has greatly stimulated interest in the use of micronutrients. Nutrient proportion in relation to each other may be as important as the quantity of nutrients available. It is of interest to note the vast differences in the ratios and relative porportions of micronutrients between these sources, when used at the recommended rate (Table 1).

Perk has been available since the mid 1960's and is widely used in Florida. Perk is a blend of the sulfates of iron, magnesium, manganese, zinc, copper, sodium borate, and sodium molybdate. Early recommendations were, 0.3 to 0.4 kg./m^3 (1/2 to 3/4 lbs./cu.yd.). However, Whitcomb (58, 61) found that when higher nitrogen levels were used in a soilless media, 2.38 kg./m^3 (4 lbs./cu.yd.) was optimum for woody plants.

Hathaway (24, 25, 26) grew seedlings of shumard oak (*Quercus shumardi*), river birch (*Betula nigra*), Japanese black pine (*Pinus thunbergi*) and pecan (*Carya illinoensis*) and reported that Perk at the rate of 2.38 kg./m^3 (4 lbs./cu.yd.) provided best plant response and survival. Whitcomb (62) reported that Perk at the rate of 2.38 kg./m^3 improved top weight, root weight, and visual root grade in the propagation of purpleleaf Japanese honeysuckle, (*Lonicera japonica* 'Purpurea') when used in conjunction with 18-5-11 or 18-6-12 Osmocote.

Struck and Whitcomb (48) investigated the effects of Perk in the medium used to germinate and grow deodar cedar seedlings (*Cedrus deodara*), and reported that 2.38 kg./m^3 (4 lbs./cu.yd.) of Perk should be present along with the macronutrients for best growth. Whitcomb (59, 60) reported that Perk at the rate of 2.38 kg./m^3 was the optimum level to use when producing container grown *Juniperus chinensis* 'Pfitzeriana' or *Juniperus chinensis* 'Hetzi' and *Ilex cornuta* 'Burfordi'. Ward and Whitcomb (52) reported that liners rooted with Perk in the rooting medium were darker green in color than those with no Perk.

Slow release fritted trace element sources (FTE) are produced by heating sand in a rotating smelter, until the melting point is reached.

TABLE 1

RELATIVE PROPORTION OF MICRONUTRIENTS IN A GROWING MEDIUM FROM 4 COMMERCIAL PRODUCTS AT THE RECOMMENDED RATE

	Product, Rate/Unit Volume and Rate of Element/Unit Volume											
	Esmigran 4 lb./cu.yd.(2.38 kg./m³)			FTE 503 4 oz./cu.yd.(.149 kg./m³)			Micromax 1.5 lb./cu.yd.(.892 kg./m³)			Perk 4 lb./cu.yd.(2.38 kg./m³)		
	Percent	lbs./yd.³	kg./m³	Percent	lbs./yd.³	kg./m³	Percent	lbs./yd.³	kg./m³	Percent	lbs./yd.³	kg./m³
Boron	0.02[1]	.0008[2]	(.0005)	9.75[1]	.0244[2]	(.0145)	0.10[1]	.0015[2]	(.0009)	0.074[1]	.0030[2]	(.0018)
Chlorine	2.50	.1040	(.0619)	-	-	-	-	-	-	1.0	.040	(.0238)
Copper	0.30	.0120	(.00714)	3.75	.0094	(.0056)	0.5	.0075	(.0045)	0.29	.0116	(.0069)
Iron	2.0	.080	(.0476)	25.7	.0644	(.0383)	12.00	.180	(.1070)	5.25	.210	(.1250)
Manganese	0.50	.020	(.0119)	9.5	.0238	(.0142)	2.5	.0375	(.0223)	2.96	.1184	(.0705)
Molybdenum	0.0006	.000024	(.00001)	0.30	.0008	(.0004)	0.005	.0001	(.0001)	0.003	.0001	(.0001)
Sulfur	1.0	.040	(.0238)	_	_	_	15.0	.225	(.1338)	4.5	.180	(.1071)
Zinc	1.0	.040	(.0238)	8.75	.0219	(.0130)	1.0	.015	(.00892)	0.86	.0344	(.2005)

[1] Guaranteed minimal analysis of product, percent.

[2] Based on percentage times rate recommended, i.e. Esmigran contains .002 percent Boron x 4 lbs., equals .08 lbs./cu.yd. (kg./m³).

The micronutrients are added and the molten mass is quenched in water. The hardened mass is then ground to varying degrees of fineness. The size of particles determines the release rate of the nutrients. The surface area of a given weight of the finer ground frit will be greater, causing the release rate to be faster. The two most widely used formulations are FTE 503 and FTE 504, which vary in proportions of micronutrients. FTE 503 and 504 may be incorporated into the growing medium. Both products release micronutrients for a period of approximately 10 months when used at the recommended rate of 0.3175 kg./m^3 (2 oz./cu.yd.) (39). Wheless and Whitcomb (57) used FTE 503 and FTE 504 at the rates of 0.15, 0.30, and 0.59 kg./m^3 (0.25, 0.5, 1 lbs./cu.yd.) and reported that the 0.30 and 0.59 kg./m^3 rates of both sources produced dark green Ilex crenata 'Hetzi', while the lowest rate of both 503 and 504 produced plants more chlorotic and smaller in top and root weight. Conover, Simpson and Joiner (12) reported that the use of FTE at the rate of 0.15, 0.30, and 0.450 kg./m^3 (0.25, 0.5, 0.75 lbs./cu.yd.) induced chlorosis on Aphelandra squarrosa 'Dania' and the two highest rates resulted in chlorosis of Brassaia actinophylla. Christie (9) reported Chrysanthemum morifolium 'Nob Hill' was grown in two different media, with FTE 503 incorporated into both media at the rate of 0.1 kg./m^3 (0.2 lbs./cu.yd.). One growing medium contained more iron before the micronutrient source was added. This medium produced more healthy and darker green plants before and after the micronutrient source was added. In response to foliar application of iron, the plants showing interveinal chlorosis became dark green, losing all signs of deficiency, indicating that an iron deficiency was being observed. Relatively high rates of Boron in FTE 503 and 504 (Table 1) suggest the possibility of boron toxicity. Several authors (8, 17) have reported boron toxicity in chrysanthemums and other crops from FTE 503 and 504. Self and Pounders (43) reported that when FTE 503 and FTE 504 were compared, 503 should be used due to the lower amount of B present.

Esmigran is a relatively new micronutrient source made by spraying calcined clay granules with a solution of micronutrients. The clay granules are large enough (16-30 U.S. standard sieve mesh) to permit rapid and uniform blending with media components. The recommended rate of application is 2.974 kg./m^3 (5 lbs./cu.yd.) (55). However, the elements in Esmigran are not released at the same rate from the granules, making comparisons of micronutrients available to the plant at any point in time uncertain. Whitcomb, Storjohann and Wheless (63) reported that Esmigran incorporated at the rate of 4.75 kg./m^3 (8 lbs./cu.yd.) produced dark green _Ilex crenata_ 'Hetzi'. However, at the rates of 2.38 (4 lbs./ cu.yd.) and 3.56 kg./m^3 (6 lbs./cu.yd.) some plants were chlorotic and stunted, while others receiving the same treatment had good color and were comparable to the best treatment. Whitcomb (64) also showed that Esmigran at the rates of 2.38, 3.56, and 4.75 kg./m^3 increased the number and quality of roots produced when compared to no micronutrients with _Ilex crenata_ 'Hetzi', _Juniperus chinensis_ 'Hetzi', and _Rhododendron spp._ 'Fashion'. It was further shown in this experiment that cuttings taken from the plants grown with Esmigran produced liners that initiated growth faster than liners whose parent plant had no micronutrients added.

The newest micronutrient source at this time is Micromax. This micronutrient fertilizer is a blend of the sulfate forms of iron, manganese, copper, and zinc, plus sodium borate and sodium molybdate. The ratios were determined from research and computer analysis (45, 65). Plant response to each of the micronutrients contained in the blend was studied in determining the optimum ratio (47). Micromax is available in a granular form for incorporation into a soilless medium. The micronutrients are soluble when moistened and attach to organic matter in the growing medium.

In work by Whitcomb (65), Micromax incorporated into the propagation medium at 0.59, 1.19, and 1.78 kg./m^3 (1, 2, 3 lbs./cu.yd.), resulted in a higher percentage of liners of Hetzi Japanese holly (*Ilex crenata* 'Hetzi'), Hetzi juniper (*Juniperus chinensis* 'Hetzi'), and fashion azalea (*Rhododendron spp*. 'Fashion') graded as acceptable. It was also noted that the percentage of liners showing new growth prior to transplanting was higher if Micromax had been incorporated into the growing medium of the parent plant.

In further research by Whitcomb (66) Micromax was found to enhance tree seedling growth if present in the germination and growing medium at the rate of 0.45 kg./m^3 (0.75 lbs./cu.yd.). This was only true however, if Osmocote was present at the rate of 5.34 kg./m^3 (9 lbs./cu. yd.). In this same experiment it was noted that when the rate of Micromax was increased to 1.78 kg./m^3 (3 lbs./cu.yd.), in conjunction with Osmocote, plant response was better than Osmocote alone. This margin of safety is desirable since a double application could occasionally be made in error.

Slow Release Fertilizers

For optimum plant growth, all nutrients should be continually available. This may be accomplished by a liquid fertilizer program which requires frequent fertilizer applications of low concentrations. Labor costs make it essential to automate fertilization as much as possible.

Slow release fertilizers are in a sense a method of automation, since the labor needed for repeat applications of fertilizers is eliminated. Slow release fertilizers make it possible to incorporate enough nitrogen and potassium for production of the crop in one application. This cannot be done in the case of soluble inorganic fertilizers, due to the high salt levels that would be induced (35). The reduction in labor and equipment are not the only advantages in using a slow release fertilizer program. A steady supply of nutrients is made available to the plants throughout production, and a higher percentage of the fertilizer applied is used (1). Baron (4) described an ideal slow relase fertilizer as having a release pattern which coincides with the uptake pattern of the crop. Allen and Mays (1) noted that when availability is more in tune with the needs of the plant, there is less leaching of nutrients, causing less nitrate pollution, and less risk of toxicity from a single large application of readily available fertilizer. Slow release fertilizer may be custom fitted to specific production time of a crop because nutritional release may be varied by the use of materials with different release rates (29). Slow release of nutrients may result from chemical, physical, or biological factors. Ways in which release rates may be controlled are (1) application of low solubility coatings to soluble fertilizer, (2) manufacturing of compounds with low solubility, (3) manufacture of low solubility compounds which also require microbial activity for release of nutrients, and (4) treated natural organic materials which require microbial action.

Accurate and reliable liquid fertilizer proportioners became available before slow release fertilizers were introduced. For growers with the equipment necessary for liquid feed, there are few advantages in converting to a total slow release program (35). However, slight advantages in quality of plants produced, using a combination of slow release and liquid feed fertilizer, have been reported when compared to the use of liquid feed or slow release fertilizers alone (6).

Osmocote

The most promising of the slow release fertilizers is Osmocote. These products consist of plastic coated spheres of dry, water soluble inorganic fertilizers. The coating material and process has not been extensively described outside of patent literature (46). The rate of nutrient release of Osmocote can be varied by the coating composition, coating thickness, and fertilizer source. The release rate is influenced little by soil moisture, soil pH, or microbial activity, but is enhanced by increased temperature (4, 31, 32).

With temperature being the dominant factor in release rate, soil sterilization with heat should be done before Osmocote is incorporated. Steam treatment results in the immediate release of all nutrients, causing a buildup of soluble salts to levels that may be toxic to plants (50). The release of nutrients from Osmocote is initiated by the movement of water vapor through the plastic membrane which dissolves the soluble core. The dissolved nutrients then diffuse outward through the membrane and into the growing medium (5, 32, 35, 38). There is little breakdown of the membrane during the release period, and decomposition of the coating does not contribute to the release of nutrients.

Osmocote is available in the grades 14-14-14, 19-6-12, and 18-9-9, with a release period of three to four months; 18-6-12, with a seven to nine month release period; and 18-5-11 or 17-7-12, with a 12-14 month release period. The shorter release periods are well suited for short term greenhouse crops with the longer release generally used for woody ornamentals grown out-of-doors (4, 35, 38, 42, 44).

Whitcomb, Gibson, and Storjohann (64) found that the optimum level and source of Osmocote, for incorporating into rooting media for woody ornamentals, depends upon the species begin evaluated. Plant vigor was increased when cuttings of crapemyrtle (Lagerstroemia indica), purple-leaf wintercreeper (Euonymus fortunei 'Coloratus'), and golden vicary privet (Ligustrum vicary) were rooted in a medium containing Osmocote. Increased vigor was probably due to nutrients absorbed by the cuttings during and after rooting had taken place (53). Budbreaks on crapemyrtle increased with the addition of Osmocote 18-6-12 to the rooting media, producing a more desirable ornamental plant with little additional cost (44, 64). Whitcomb (59) also showed in an earlier study that burford holly (Ilex cornuta 'Burfordi') had an incrase of budbreaks when 2.38 kg./m^3 (4 lbs./cu.yd.) 18-6-12 was added to the rooting medium, and budbreaks started to decrease when more nitrogen was added. For bedding plants, 18-6-12 is recommended at the rate of 5.34 kg./m^3 (9 lbs./cu.yd.). However, for a quicker initial release, 2.38 kg./m^3 (4 lbs./cu.yd.) of 19-6-12/cu.yd. in conjunction with 18-6-12 may be used (44).

Osmocote may be either applied as a surface application or incorporated. Simpson et al. (45) studied the response of Hostess chrysanthemum with incorporated or surface applied Osmocote, and combination of liquid fertilizers. They found surface applications to be superior to incorporation. However, the best results were noted with the combination of surface applied Osmocote and liquid feed. This corresponds with the findings of Kofronek and Lunt (30) in experiments conducted on Albatros and Good News chrysanthemums.

Ward (52) reported that in propagation studies, Japanese holly supplied with Osmocote during propagation were much larger and had more bud breaks than those that were not, and were more responsive to all sources of fertilizers supplied after transplanting.

One of the major disadvantages to the use of Osmocote is the initial cost. This is especially true if Osmocote is top dressed rather than incorporated into the medium, due to the additional labor cost. Temperature control is also a problem in that when temperatures drop, the rate of Osmocote release slows down, despite the fact that the roots still have absorptive abilities. High temperatures can also have adverse effects in that the rate of release is proportionately higher, while nutrient absorption by the roots is decreased. Thus high temperatures may cause damage to plants from salt accumulation (20).

Growing Media

In order for a growing medium to support optimum plant growth, there are several functions that must be performed. The medium should serve as a reservoir for plant nutrients and water, and facilitate an exchange of gases between the roots and the atmosphere. The growing medium must also provide support for the plant (22, 35, 38, 51).

Plant growth is probably restricted more often by a deficiency of water than any other enviornmental factor (54). In order to have a proper moisture level available to the plant, several properties must be considered; total porosity, drainable pore space, and water retention. The growing medium, immediately after watering, is composed of three phases--the solid particles, the water held by the particles, and the air which occupies the drainable pore space (38). Where frequent irrigation is required, container plants must be grown in a well aerated medium to allow healthy root formation (15). Since water retention of a growing media is a function of depth, and water retention and aeration go hand-in-hand (35, 38), it is possible that portions of a root system in a shallow container may be damaged by low aeration (28). After watering, 10 to 20 percent of volume of the growing medium should be occupied by air and 35 to 45 percent should be occupied by water (38, 40). These figures vary however, depending upon the crop and growing condition. Bunt (7) reported that a drainable pore space of 25 percent was optimum for snapdragons, but only 5 percent was needed for tomatoes. Matkin (34) reported that minimum free air space should be no less than 8 percent.

Compounding the problem of deciding what the proper drainable air space is, Flocker et al. (18) reported that maximum growth of a plant may be achieved at different drainable air space for different growing media. Two growing media having the same air porosity may perform differently, due to the distribution of air filled pores and the fineness of these pores.

Many materials seem to fulfill most of the requirements for a growing medium, but in reality, many materials are impractical. Coarse sand for instance, provides support and is well aerated, but due to small particle surface area, it needs frequent irrigation, is low in nutrient holding capacity, and is extremely heavy. For a growing medium to have all of the properties needed, and also be practical to use, a blend of different components is generally needed. Peat moss works well as part of a growing medium (10, 20, 21), even though it is low in micronutrients (36) and strongly binds copper, zinc, iron, and manganese (49). Peat may be classified into four types: (1) sphagnum moss peat; (2) hypnaceous moss peat; (3) reed and sedge peat; and (4) humus peat or muck (35).

Sphagnum moss peat is tan to brown in color and is composed of mostly sphagnum moss and some hypnum moss. The nitrogen content of sphagnum moss is generally between 0.6 and 1.4 percent. Therefore it decomposes slowly and accounts for only a small amount of nitrogen tieup (38). Sphagnum peat has the highest moisture holding capacity (about 60 percent) of all the peats and retains this property when rewetted after air drying (16). Air porosity of sphagnum peat is approximately 25 percent (34). Sphagnum peat is the most acid of the peats with a pH generally between 3.4 and 4.0.

Hypnaceous moss is very comparable to sphagnum moss except that other types of moss may also be present. Hypnaceous moss decomposes more rapidly than sphagnum moss. Reed and sedge mosses and humus, or muck, are so well decomposed that their use should be avoided as a growing medium component in most cases (35, 38).

Tree barks are a by-product of the wood pulp and plywood industries and therefore may be obtained at a relatively low cost. DeWerth (13) reported that shredded pinebark made a satisfactory substitute for sphagnum moss peat. It has been noted that the addition of both hard wood bark and pine bark suppress Pythium irregulare, Phytophthora spp., and Fusarium spp. (27). The suppression of disease may be partially due to the increased aeration achieved when bark is used. Bark ranging in size of 7.32 cm to 1.59 cm (1/8 inch to 5/8 inch) has a drainable pore space of approximately 55 percent and water retention of only 15 percent by volume (35). Due to its low water retention and bulk density, bark is very economical when considering shipping and handling costs.

A grower has many choices of coarse aggregates that may be used in preparing growing media. Sand and perlite are frequently included in the growing medium to increase the number of large pores, decrease water retention, and to improve aeration and drainage (35).

Sand that contains silt or clay particles does little to improve drainage. Therefore sands that have been washed and contain particle sizes ranging from 0.5 mm to 2 mm should be obtained (38).

Sand is inexpensive, but its high bulk density (approximately 115 lbs./cu.ft. wet) makes it very expensive to ship and difficult to handle. Baker (3) suggested using peat moss and sand in the ratio of 1 to 1 by volume. This mixture results in water retention of 48 percent by volume. Because of satisfactory performance and to reduce weight of the media, Oklahoma State University uses ground pine bark, peat, and sand at the ratio of 2:1:1 or 3:1:1 by volume (60, 61).

Perlite is a good substitute for sand for providing aeration in a growing media while reducing weight. It weighs about six pounds per cubic foot as compared to one hundred pounds per cubic foot of dry sand. Perlite is produced from crushed aluminum silica volcanic rock. When this rock is heated rapidly to 1800^{o}F (968^{o}C) the rock fragments expand to form white lightweight particles with sealed internal spaces (35). Perlite is sterile due to high temperatures in manufacturing, has a pH of 7.0 to 7.5, is chemically inert, has no cation exchange capacity, and is void of both macro and micro nutrients (23). Matkin (34) reports perlite with diameter between 1/16 and 3/16 of an inch (horticultural grade) to have a drainable pore space of approximately 30 percent by volume and a water retention of approximately 47 percent by volume. Drainage capacity, low bulk density and water retention, make a combination of sphagnum peat and perlite 1:1 v:v a good rooting medium for cuttings (10, 20, 31, 37).

CHAPTER III

MATERIALS AND METHODS

The variables of this experiment were (a) two fertilizer release rates using Osmocote, (b) three porosities of growing media, (c) four levels of the micronutrient source Micromax, and (d) a conventional gas heated greenhouse and a solar heated greenhouse.

The two release rates of Osmocote were created by using 100 percent 19-6-12 Osmocote (Fertilizer I), or a combination of 50 percent 19-6-12 and 18-6-12 Osmocote by weight (Fertilizer II), at the rates required to give the equivalent of 7.7 kg./m^3 (13 lbs./cu.yd.) of Osmocote.

Porosity of the media was adjusted by varying the ratio of sphagnum peat to one-half inch screened pine bark with sand remaining constant for the three growing media at 20 percent by volume. The least porous growing medium (Mix I) was 50 percent peat, 30 percent pine bark and 20 percent sand, with 18 percent drainable pore space. The intermediate mix (Mix II) in terms of porosity, was 30 percent peat, 50 percent pine bark and 20 percent sand, with 27 percent drainable pore space. The most porous mix (Mix III) was 10 percent sphagnum peat, 70 percent pine bark, and 20 percent sand, with 38 percent drainable pore space.

Micromax was used at rates of 0, 0.298, 0.595, and 1.189 kg./m^3 (0, 0.5, 1, and 2 lbs./cu.yd.).

Constant throughout all growing media were eight pounds/cu.yd. (4.76 kg./cu.m) dolomite, and two pounds (1.189 kg./m^3) triple superphosphate.

All growing media and nutrient additives were mixed in a small cement mixer.

Three rooted cuttings of Chrysanthemum morifolium cultivars; 'Mandalay' (10 week short), 'Winter Carnival' (10 week tall) and 'Peacock' (10 week tall), were planted per six inch container, having a volume of 2311 cm^3 (141 cu.in.). The experimental design was a 2 x 3 x 4 factorial set of treatment combination in a randomized complete block with six replications in each greenhouse. Each chrysanthemum cultivar was treated as a separate experiment. A single container was the experimental unit. The three cultivars were used in two greenhouses of the same size, shape, and exposure. One greenhouse was a conventional, under the bench forced air, gas heated type, while the other was an experimental solar heated type in which the collected heat from solar panels was stored in the floor.

In the gas heated greenhouse, all pots were placed on expanded metal benches on 15.24 cm. (6 inch) centers that were raised 45.72 cm. (18 inches) above the greenhouse floor. The thermostats at plant level were set at 21.1^{o}C (70^{o}F) and remained at that setting throughout the experiment.

In the solar heated greenhouse, all pots were placed on the fine gravel floor on six inch centers, which by the use of solar heating and a natural gas water heater as a backup system, was kept at the constant temperature of 21.1^{o}C (70^{o}F). This resulted in the pots keeping a temperature of between 15.5 - 18.3^{o}C (60 - 65^{o}F), but allowed the air temperature around the plants to fall to approximately 10^{o}C (50^{o}F) night temperature, with 3.89^{o}C (39^{o}F) the lowest temperature recorded.

The following cultural practices were constant for all cultivars and both houses, unless otherwise noted. On February 14, cuttings were potted and placed on 15.24 cm. (6 inch) centers (rim to rim) and given 24 hr. light by the use of one 100 watt light bulb for every 26 square feet, placed 121.9 cu. (48 inches) above the tops of the plants. Watering was by hand, as needed, throughout the experiment. On March 2, short days were begun, using natural day length, and all terminals were pinched back 1.9 cm. (3/4 inch). On this same date, spacing was increased to 30.5 cm. (12 inch) centers. On April 2, pot spacing was increased to 45.72 cm. (18 inch) centers, due to vigorous plant growth. On May 14, the experiment was terminated, with no insect or disease problem having been noted. Plants were evaluated for leaf chlorosis, plant height, flower diameter, stem diameter, percent of open buds, and top weight.

Leaf chlorosis was evaluated, by two individuals, by a visual rating of zero through five with zero having no chlorosis and five being very chlorotic. Reference standards of 0, 1, 2, 3, 4, and 5 were set by using selected leaves to increase accuracy. The average rating from the two individuals was used for analysis and variance. Plant height was taken from container rim to mid crown. Flower diameter was determined by measuring three flowers from each plant to make a total of nine flowers measured per container. The mean of the nine flowers was recorded as the flower diameter for that experimental unit. Stem diameter was determined by taking the measurement immediately below the lowest laterial branch on all three plants in the pot, the mean of these three being recorded as the stem diameter for that treatment and replication. Percent of open flower buds was calculated by dividing the number of flowers that were open to the diameter of 2.54 cm. (one inch) or greater, by the total number of buds that had formed on the three plants in the container. The plants were then sacrificed and fresh top weight recorded.

CHAPTER IV

RESULTS

Mandalay - Gas House

Flower diameter of plants grown in Mix I increased when Micromax was used at the low rate compared to no micronutrients (Figure 1). Mix III showed the same trend, but differences were less dramatic. When Fertilizer I was combined with the low rate of Micromax, a larger flower diameter was produced, compared to no micronutrients (Figure 2).

Mandalay - Solar House

Increasing Micromax micronutrients in the growing medium increased stem diameter when Fertilizer I was used (Figure 3). However, when Fertilizer II was used, stem diameter response was less dramatic, but followed the same trend. Increasing Micromax micronutrients in the growing medium decreased foliage chlorosis dramatically, regardless of which Osmocote system was used. However, when Micromax was used at the one pound rate, plants grown with Fertilizer I were less chlorotic than plants grown with Fertilizer II (Figure 4).

Peacock - Gas House

Increasing the micronutrient level from zero to the low rate of Micromax resulted in the production of smaller diameter flowers, with Fertilizer I (Figure 5). However, as the micronutrient level was

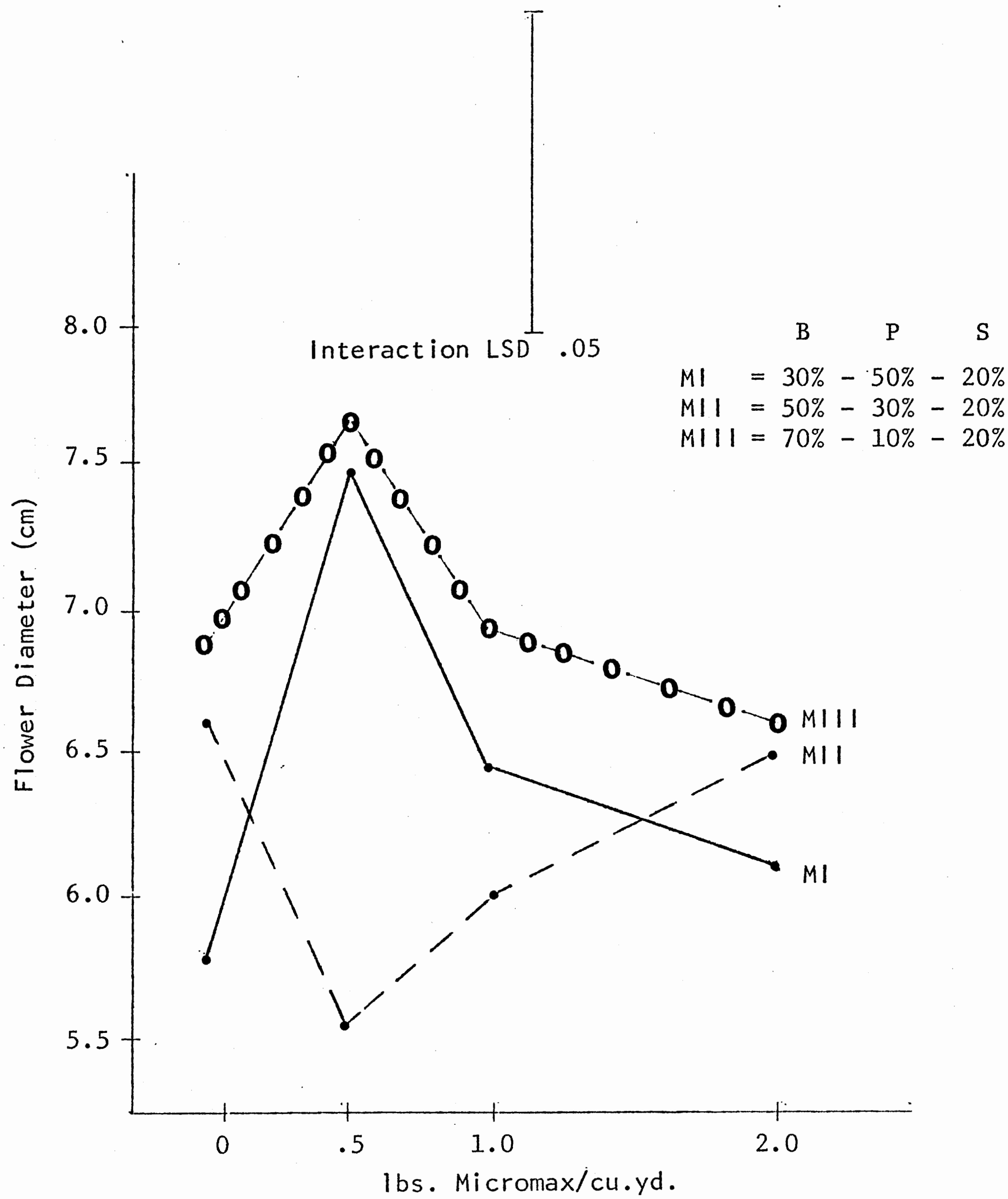

Figure 1. Effects of Mix Porosity and Micromax Level on Flower Diameter of Chrysanthemum Mandalay Grown in a Gas Heated Greenhouse

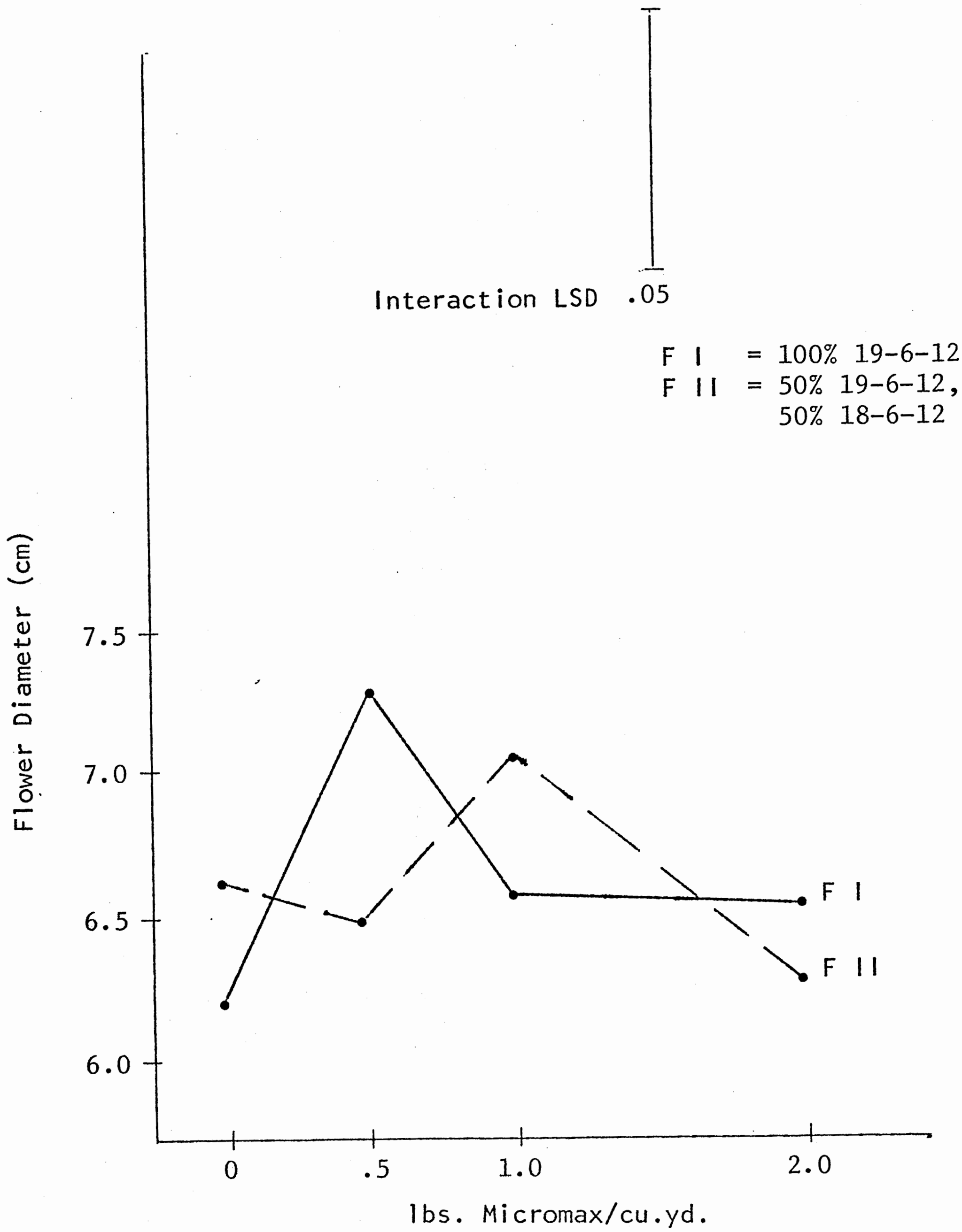

Figure 2. Effects of Osmocote Release Rate and Micromax Level on Flower Diameter of Chrysanthemum Mandalay Grown in a Gas Heated Greenhouse

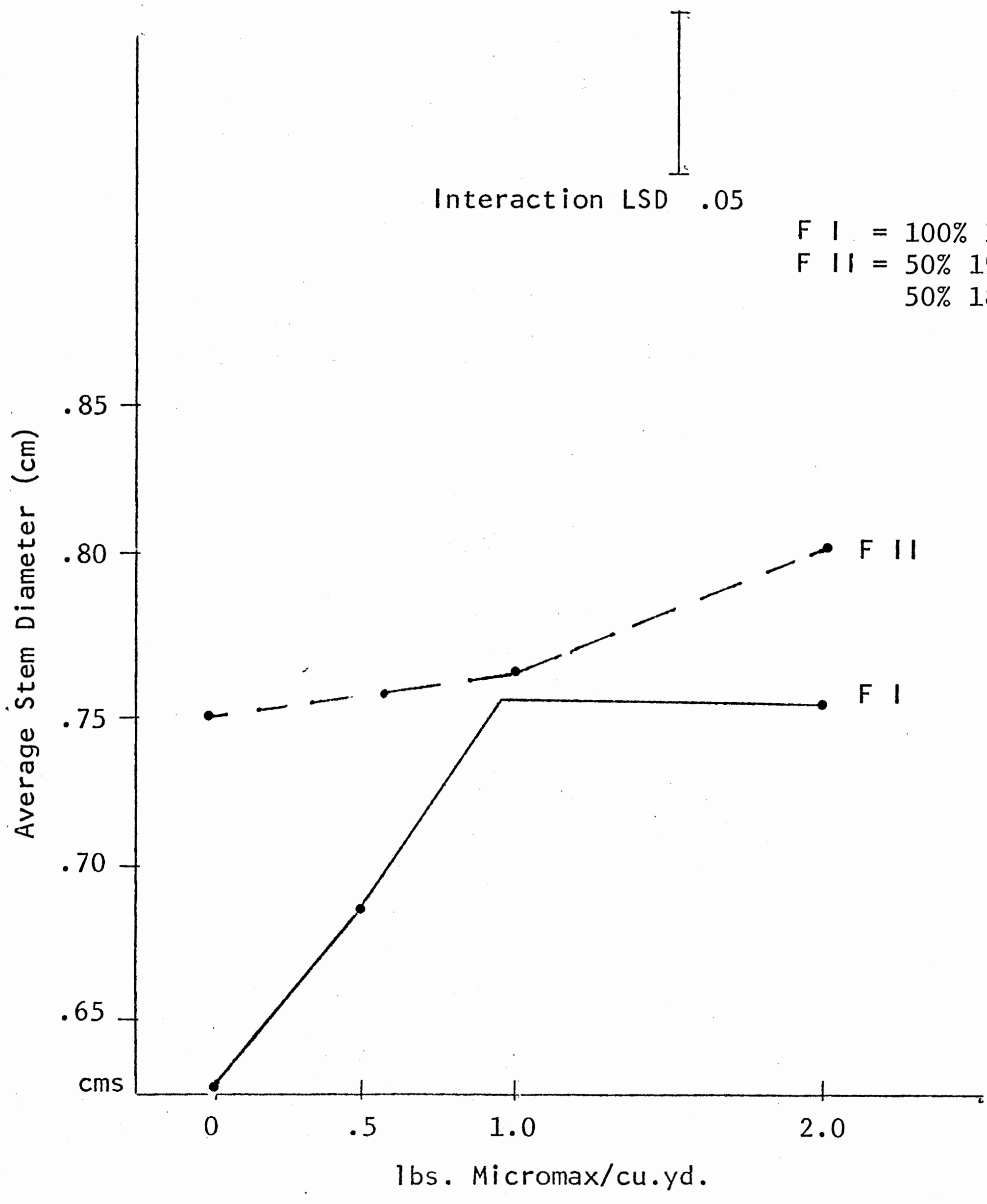

Figure 3. Effects of Osmocote Release Rate and Micromax Level on Stem Diameter of Chrysanthemum Mandalay Grown in a Solar Heated Greenhouse

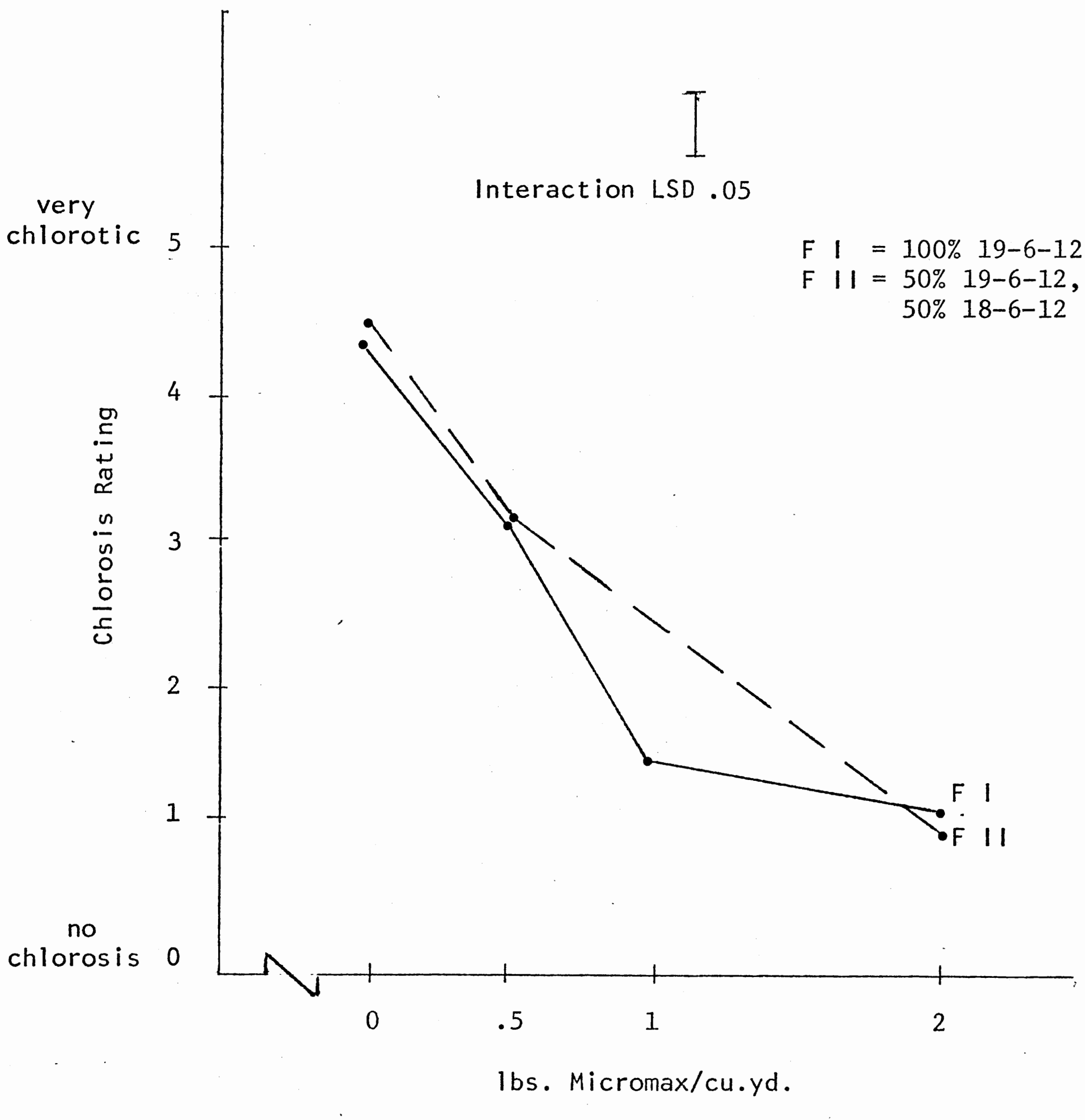

Figure 4. Effects of Osmocote Release Rate and Level of Micromax on Chlorosis Rating of Chrysanthemum Mandalay Grown in a Solar Heated Greenhouse

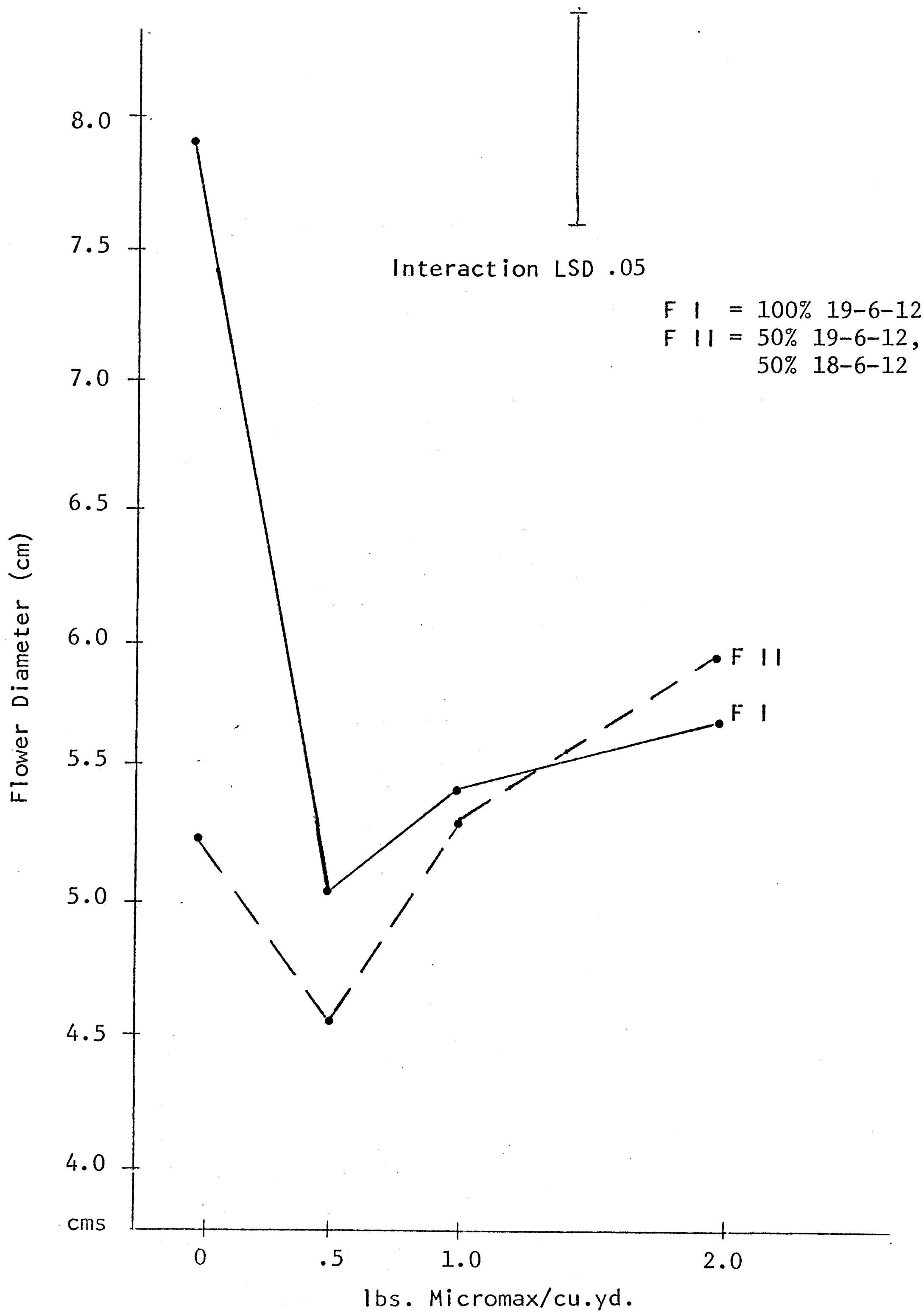

Figure 5. Effects of Osmocote Release Rate and Level of Micromax on Flower Diameter of Chrysanthemum Peacock Grown in a Gas Heated Greenhouse

increased from the low to the high rate, flower diameter increased with either fertilizer source. When no micronutrients were added, Fertilizer I produced much larger flower diameters than did Fertilizer II (Figure 5). When no micronutrients were added, very few flowers were formed, which may explain the slightly larger diameter flowers when compared to plants grown with the low rate of micronutrients, which had more flowers. As the rate of micronutrients increased, chlorosis decreased for plants in all three mixes (Figure 6). Fertilizer II, in general, produced less chlorotic plants at the low and medium rate of Micromax; however, both fertilizer systems were similar at the two pound rate of Micromax (Figure 7).

Peacock - Solar House

The medium and high rate of Micromax increased plant stem diameter in conjunction with Fertilizer I, compared to 0 or the low rate of Micromax. However, with Fertilizer II, there was no increase in stem diameter between 0 or the high rate of Micromax (Figure 8). For both fertilizer sources, chlorosis was reduced when Micromax was used at the low, medium, or high rate (Figure 9). Fertilizer I produced less chlorotic plants at the high level of Micromax than did Fertilizer II.

Winter Carnival - Gas House

Plant stem diameter increased in all three mixes as micronutrients were increased from none to the low, medium, or high rate, except for 0 and the medium level of Micromax, with Mix III (Figure 10). The most dramatic increase was observed between the zero and the low rate, with Mixes I and II. Plant stem diameter increased using Ferti-

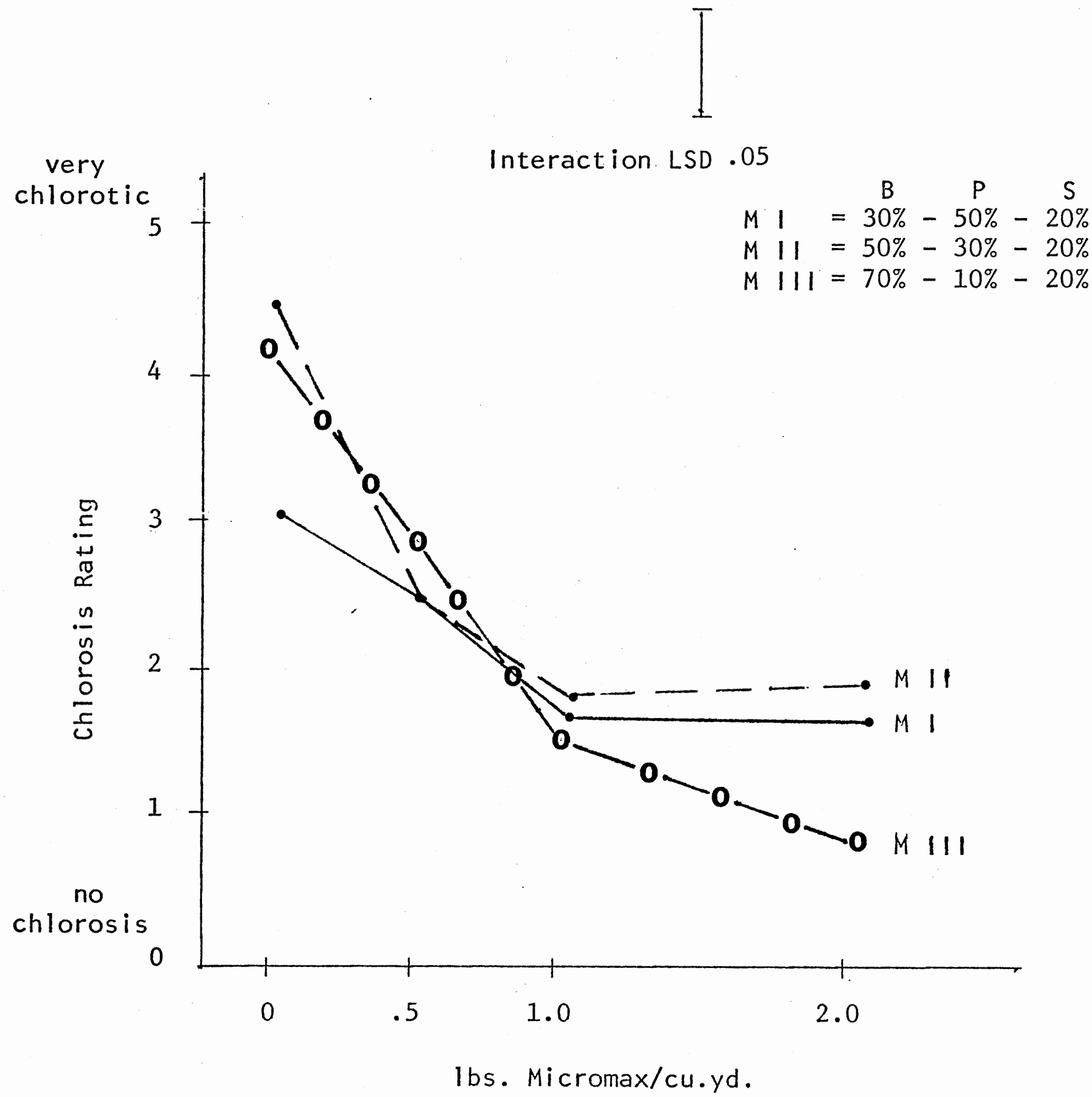

Figure 6. Effects of Mix Porosity and Level of Micromax on Chlorosis of Chrysanthemum Peacock Grown in a Gas Heated Greenhouse

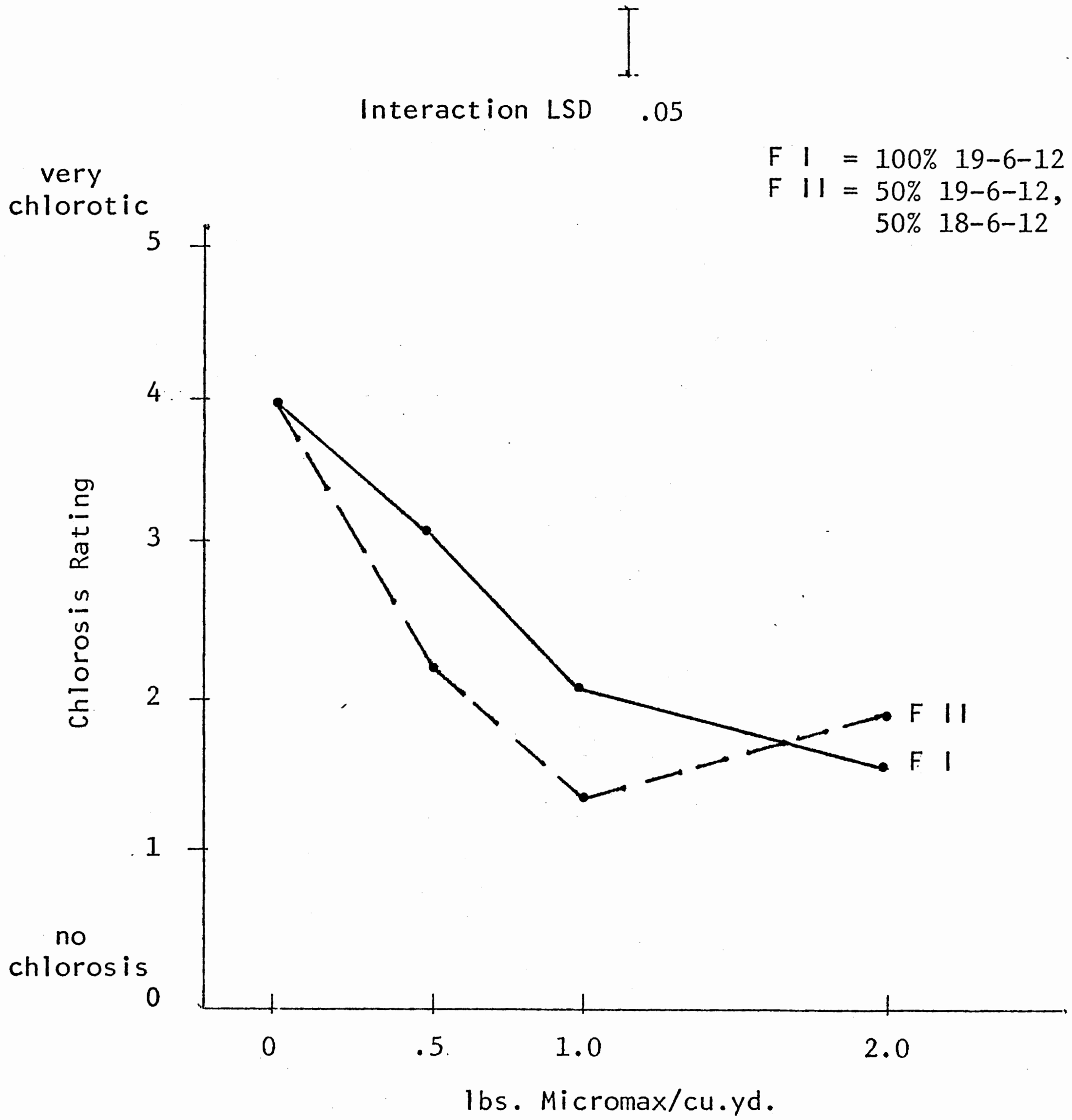

Figure 7. Effects of Osmocote Release Rate and Level of Micromax on Chlorosis of Chrysanthemum Peacock Grown in a Gas Heated Greenhouse

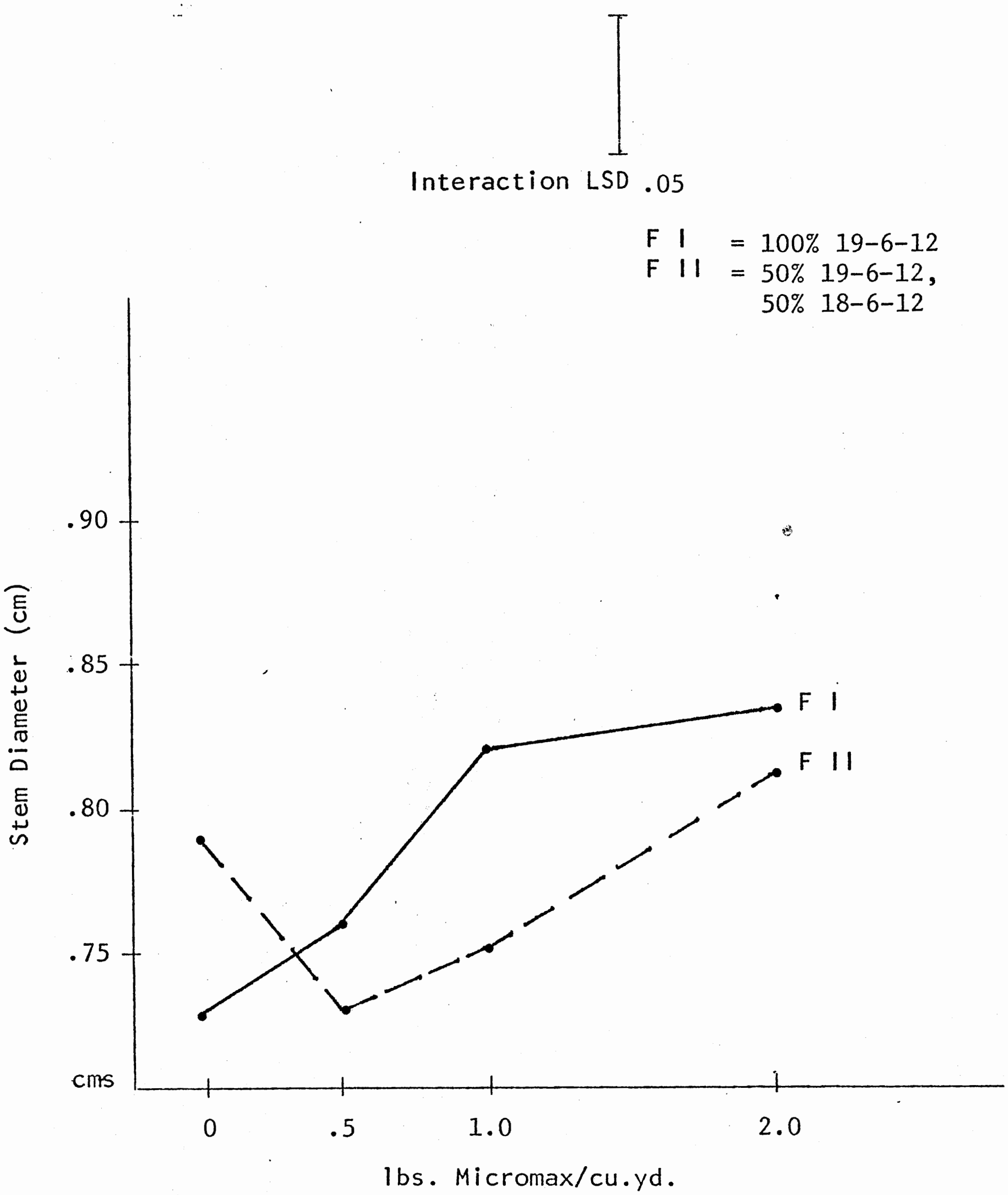

Figure 8. Effects of Osmocote Release Rate and Level of Micromax on Stem Diameter of Chrysanthemum Peacock Grown in a Solar Heated Greenhouse

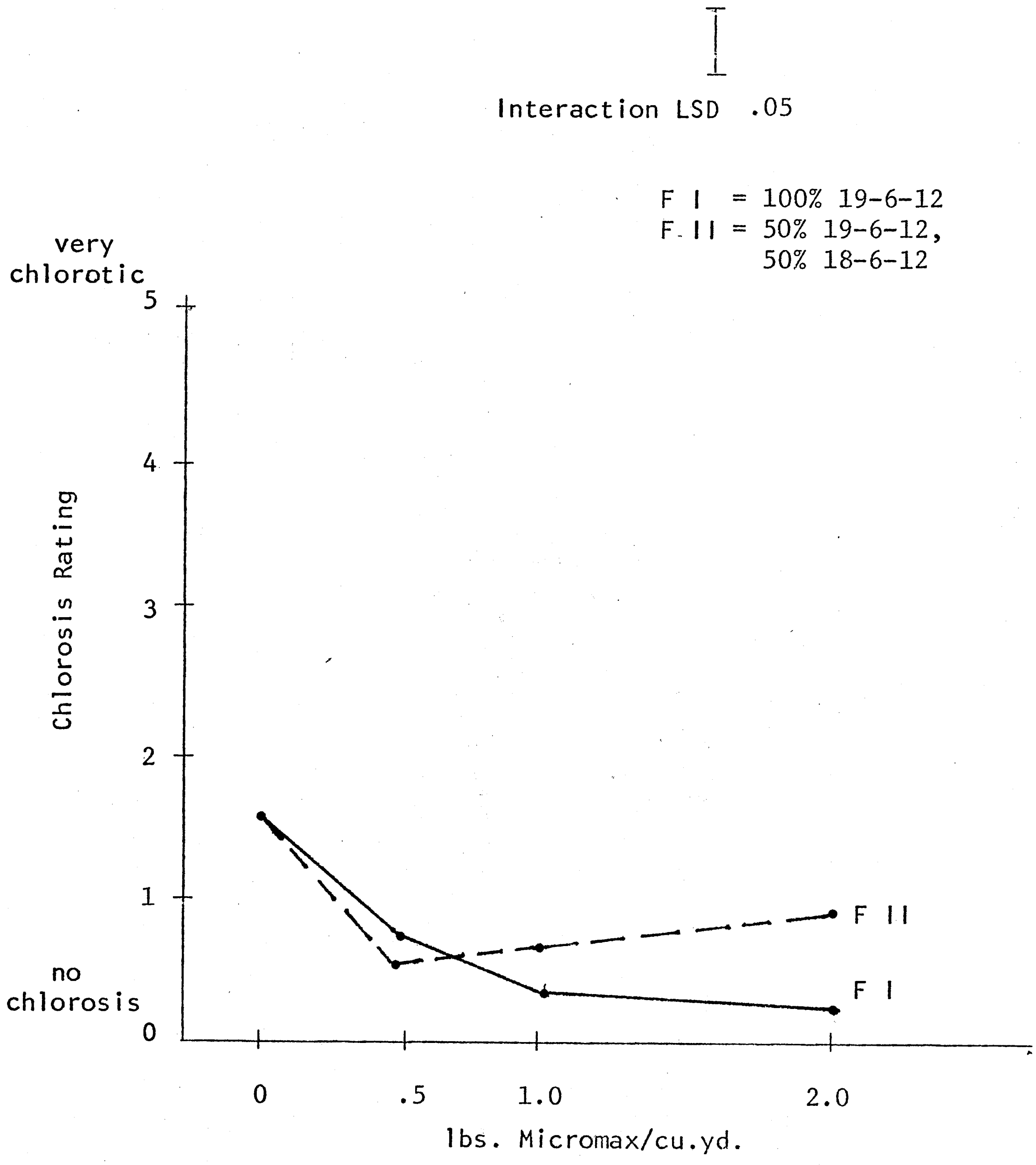

Figure 9. Effects of Osmocote Release Rate and Level of Micromax on Chlorosis of Chrysanthemum Peacock Grown in a Solar Heated Greenhouse

lizer I at the low and middle rates of Micromax, with a slight reduction noted using the high rate (Figure 11). When Fertilizer II was used, however, stem diameter continued to increase as Micromax level increased, with the largest diameter occurring at the high rate. Using Fertilizer II and the high rate of Micromax, produced much larger stem diameters than did any level of Micromax and Fertilizer I (Figure 11). For both fertilizer systems, chlorosis was dramatically reduced with each increase in the level of Micromax (Figure 12).

Winter Carnival - Solar House

Stem diameter increased as the level of Micromax increased, when used with Fertilizer I; however, when Fertilizer II was used, the low and middle rates of Micromax produced plants with larger stem diameters than did the zero or high rate (Figure 13). As levels of Micromax were increased, the chlorosis of plants grown with both fertilizer systems decreased (Figure 14). In general, Fertilizer I produced slightly less chlorotic plants than did Fertilizer II at the low, medium, and high rates.

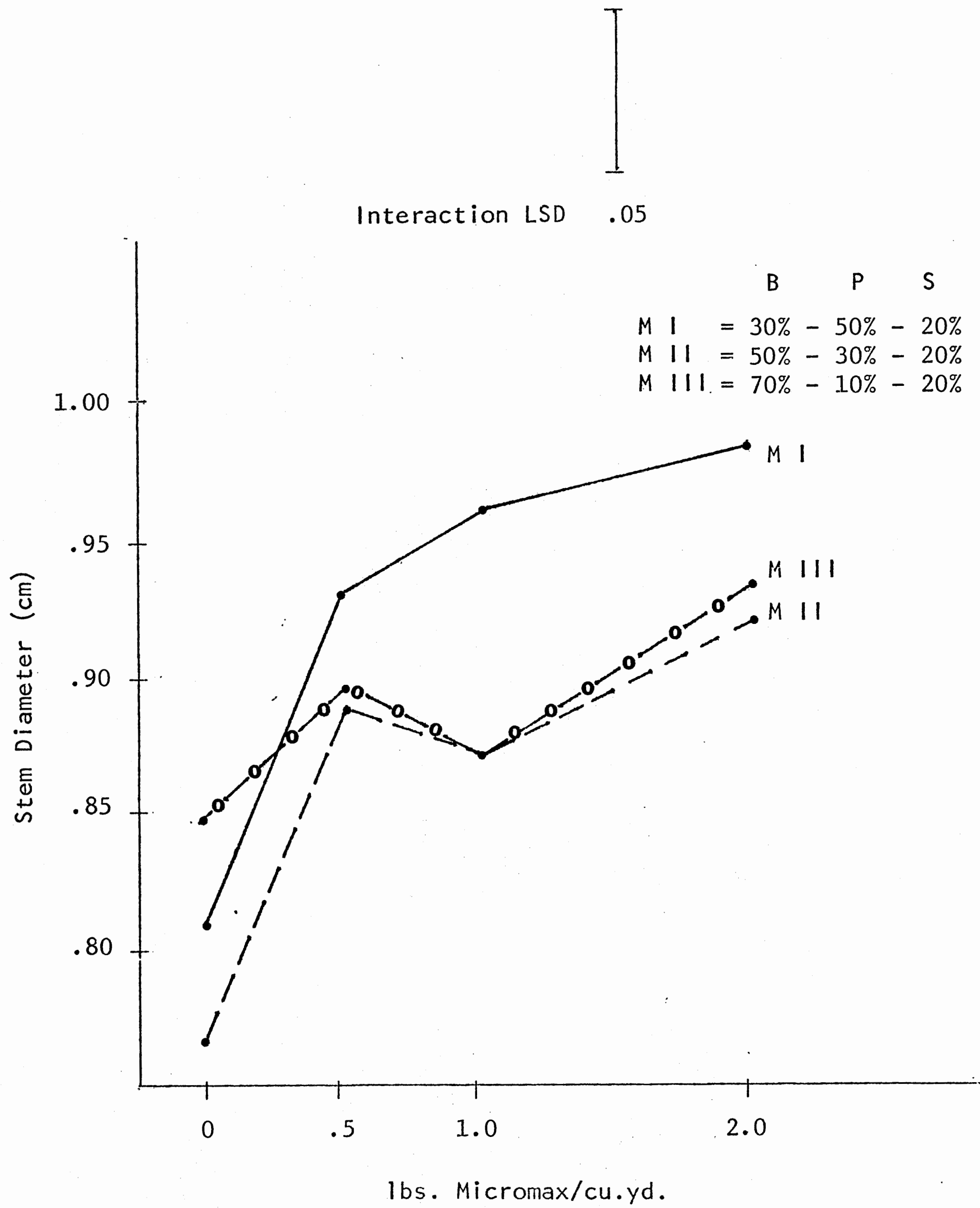

Figure 10. Effects of Mix Porosity and Level of Micromax on Stem Diameter of Chrysanthemum Winter Carnival Grown in a Gas Heated Greenhouse

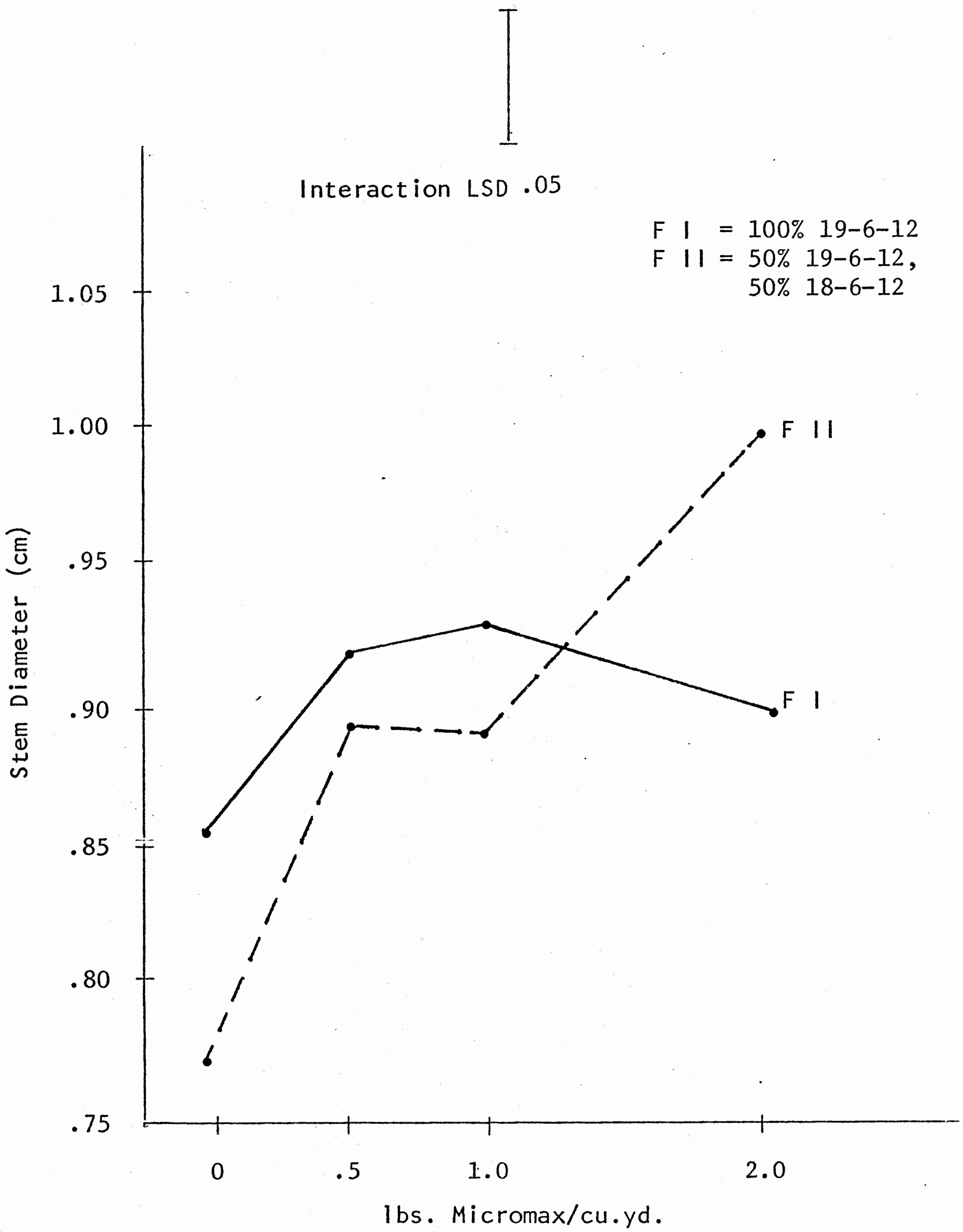

Figure 11. Effects of Fertilizer Release Rate and Level of Micromax on Stem Diameter of Chrysanthemum Winter Carnival Grown in a Gas Heated Greenhouse

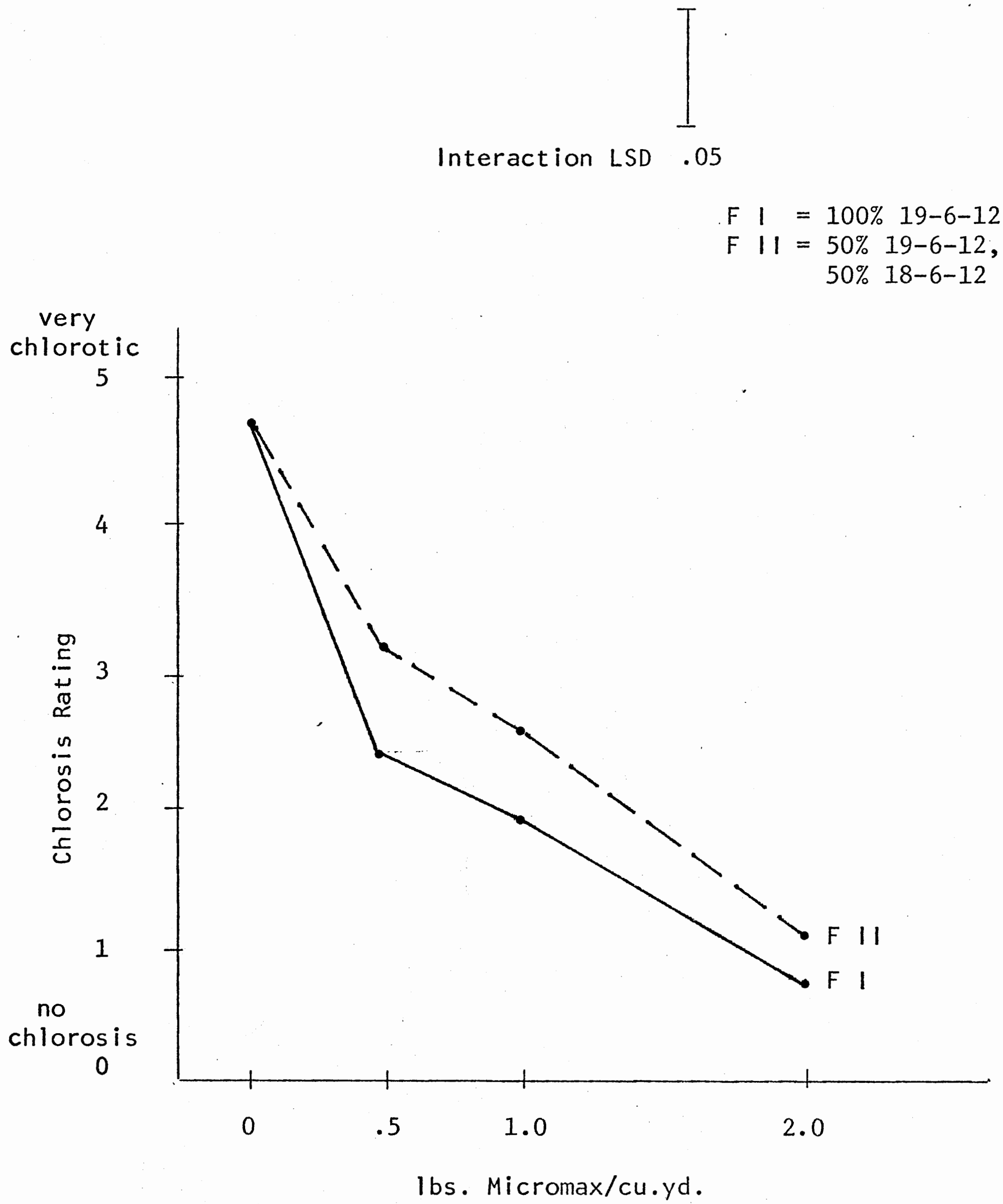

Figure 12. Effects of Osmocote Release Rate and Level of Micromax on Chlorosis of Chrysanthemum Winter Carnival Produced in a Gas Heated Greenhouse

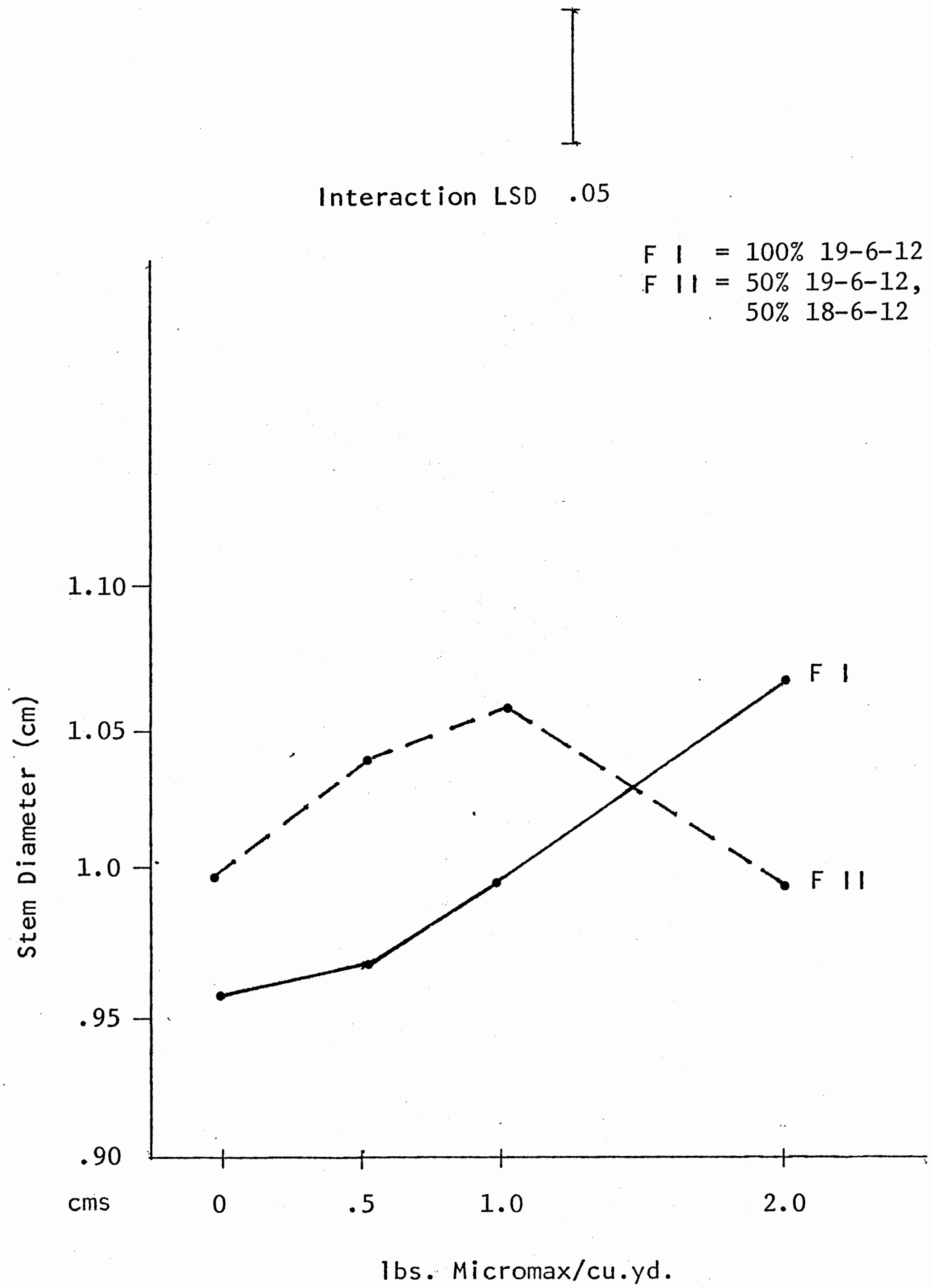

Figure 13. Effects of Osmocote Release Rate and Level of Micromax on Stem Diameter of Chrysanthemum Winter Carnival Produced in a Solar Heated Greenhouse

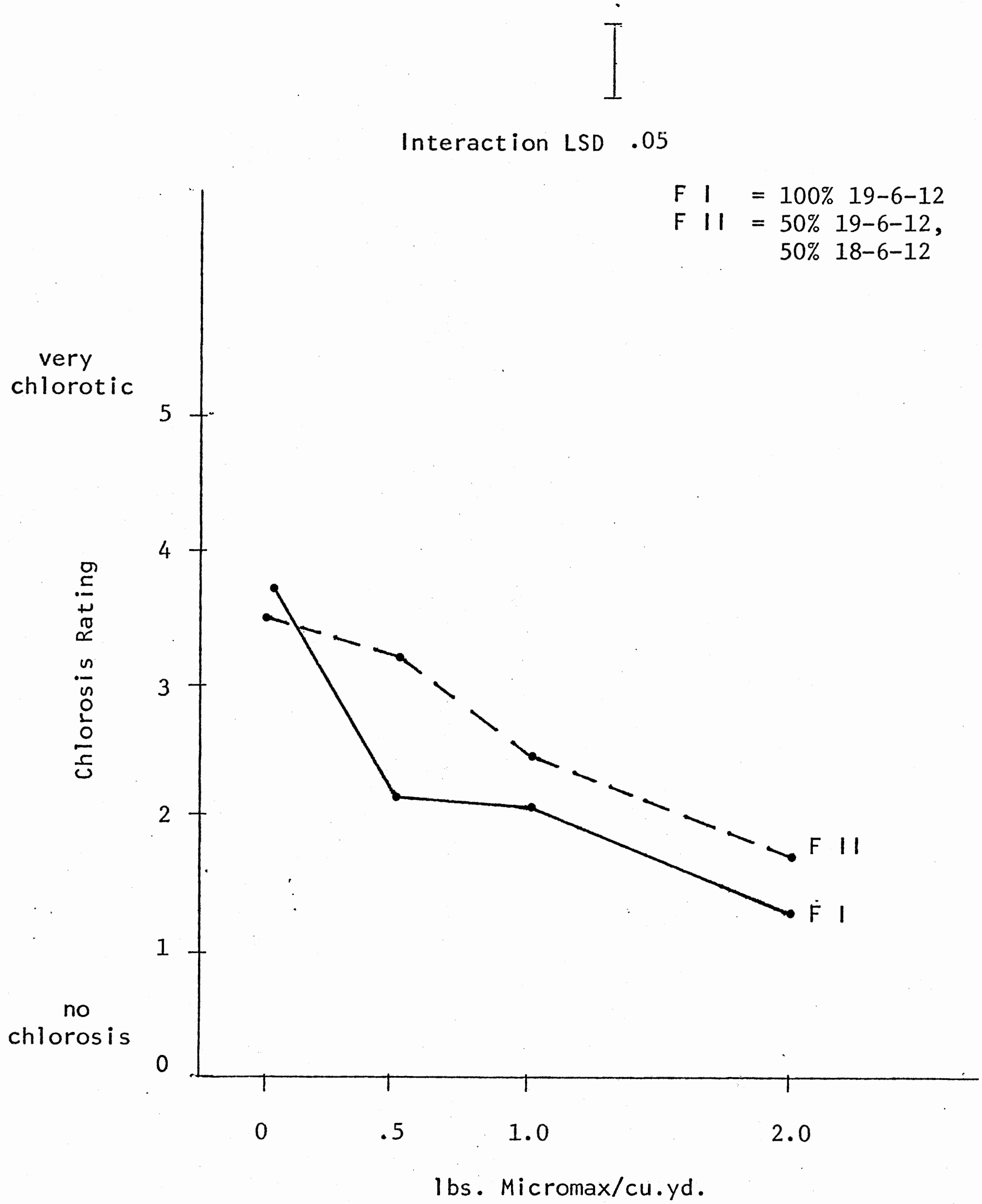

Figure 14. Effects of Osmocote Release Rate and Level of Micromax on Chlorosis of Chrysanthemum Winter Carnival Grown in a Solar Heated Greenhouse

CHAPTER V

DISCUSSION

When all treatments of each variety were averaged, it was of interest to note the differences between constant air temperature plants (gas heated greenhouse) and constant pot temperature plants (solar heated greenhouse). Stem diameter was similar for both greenhouses with the cultivars 'Mandalay' and 'Peacock', however 'Winter Carnival' had much larger stems in the solar greenhouse, especially when the micronutrients were present (Figure 15). Both flower diameter and percentage of buds open increased in the solar heated greenhouse, when compared to the gas heated greenhouse (Figure 16 and 17).

The economic advantages of a solar heated greenhouse are unquestionable. A reduction of at least 70 percent in heating costs, while still producing an equal or slightly higher quality crop, is possible at this time. However, it is necessary for a solar heating system to have a dependable fossil fuel backup system. Not only does the backup system serve to increase the safety of the crop, but also aids in keeping the plants at a more constant root temperature. This constant root temperature is needed so that crops will be predictable as to when they will reach peak salability.

With solar heat being stored in the floor of the greenhouse, the need to have the containers on the floor causes some complications the grower must consider before attempting to grow a crop. The floor

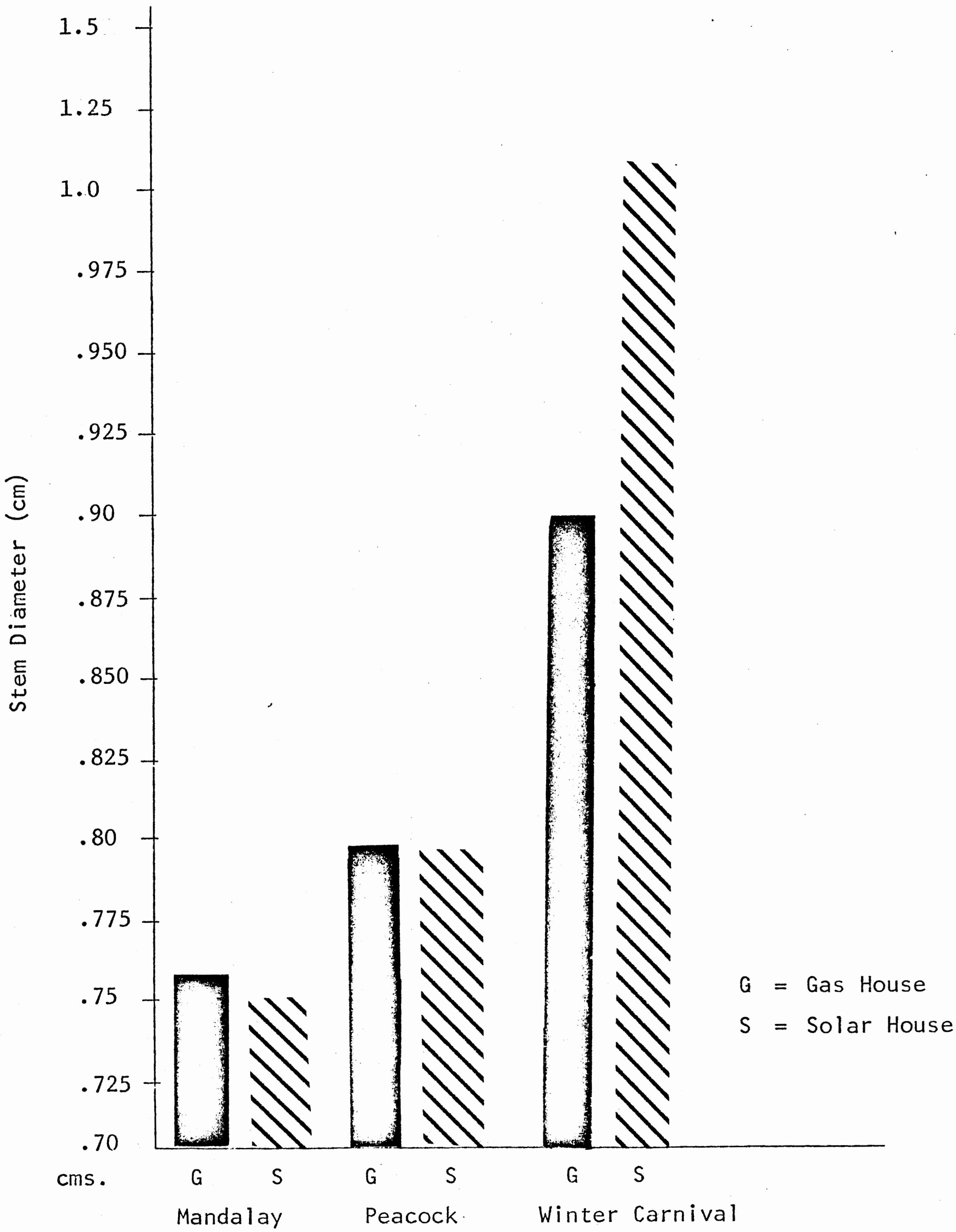

Figure 15. Comparison of Stem Diameters of Cultivars Grown in a Gas Heated and Solar Heated Greenhouse

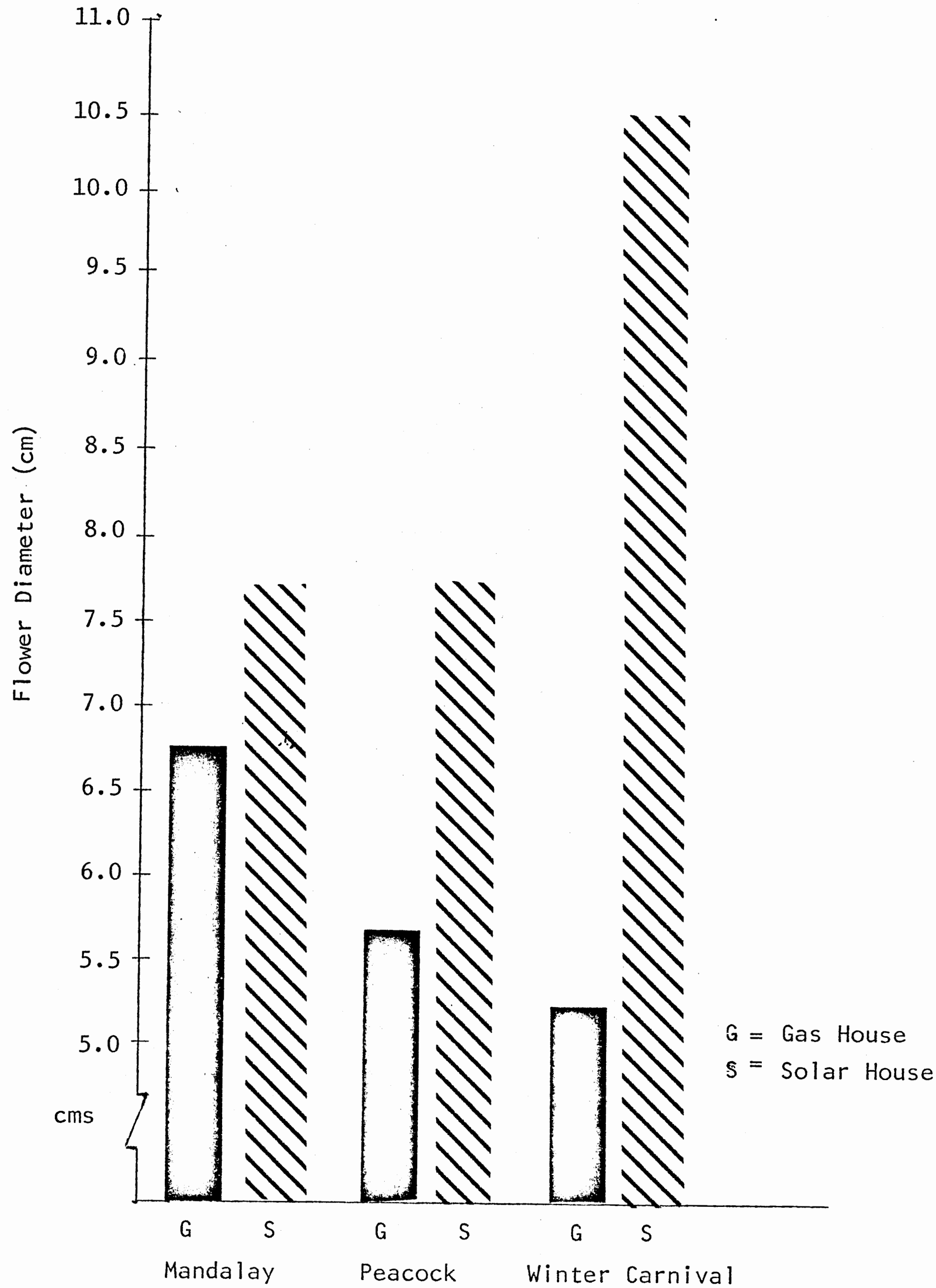

Figure 16. Comparison of Flower Diameters of Cultivars Grown in a Gas Heated and Solar Heated Greenhouse

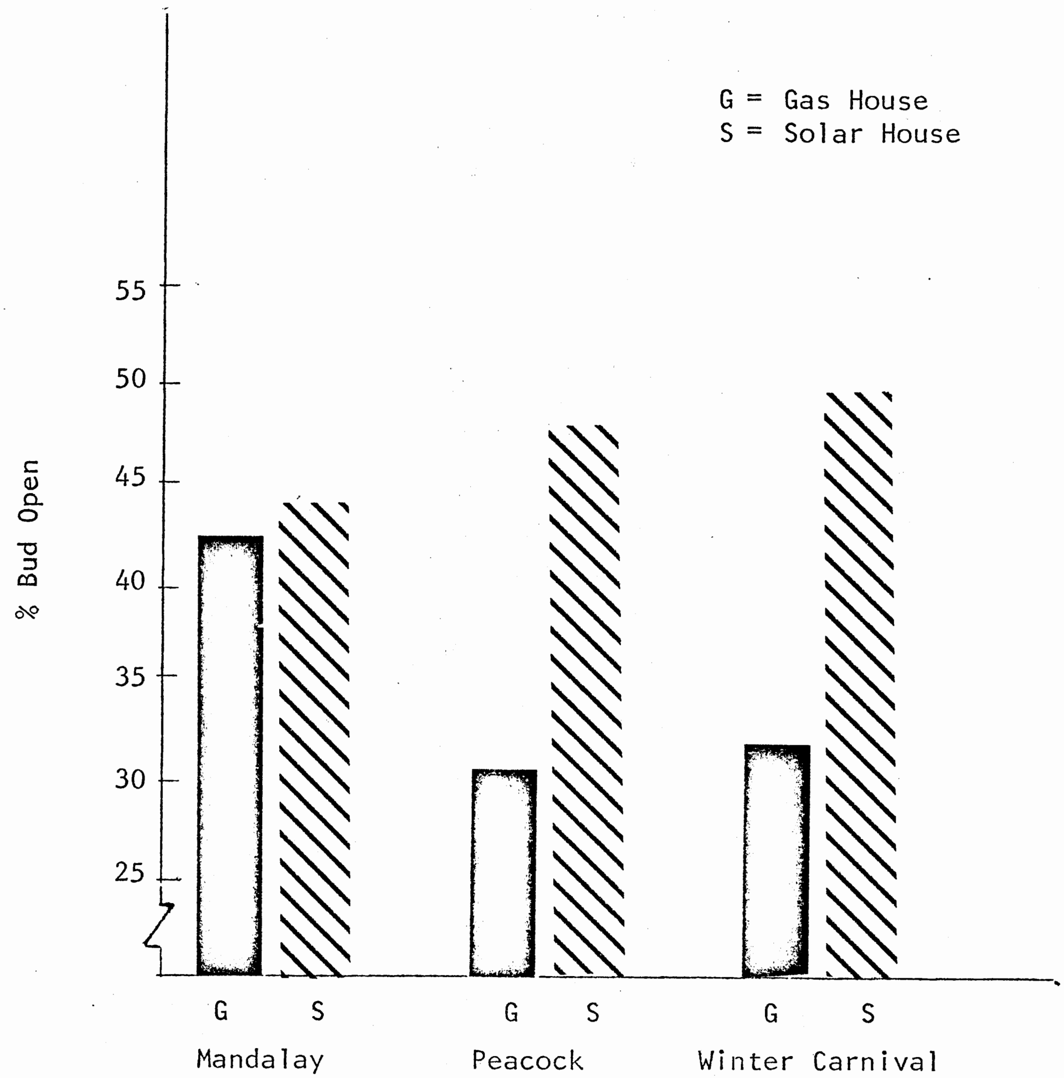

Figure 17. Comparison of Percent Bud Openage of Cultivars Grown in a Gas Heated and Solar Heated Greenhouse

drainage of the greenhouse must be good or containers will stand in water causing poor root growth. Also, if a very porous mix is used and more frequent waterings are needed, algae may become a problem. As plants mature and the foliage of one container starts to grow into the next plant, a microclimate is formed. This microclimate is the area between the floor and the canopy of the plants. There is very little air circulation in this area, and in conjunction with high humidity, produces an ideal habitat for disease organisms. It was of interest to note that there were no disease or insect problems when there were no major nutrient deficiencies. The possibility of disease and insect suppression through nutrition deserves much research.

Micromax incorporated into a growing medium has proven not only a very effective micronutrient source, but also has a wide margin of safety. One application of Micromax is sufficient to last through the production cycle, even though the nutrients are in the water soluble sulfate form when applied. Ease of incorporation is another plus for Micromax in that the amount used is large enough in volume to be dispersed evenly throughout the growing medium. Having performed well in growing media ranging from 30 to 70 percent by volume pine bark, Micromax displays the ability to perform well in growing media that range from being watered infrequently to a very porous mix that is watered quite often. In short, it appears that Micromax has the ability to perform well despite differences in cultural habits.

High quality plants were produced in growing media ranging in drainable pore space from as much as 38 percent, to as little as 18 percent. However, in order to reduce the possibility of overwatering, and at the same time, reduce labor required for watering, a mix with the porosity of approximately 25 percent appears most manageable.

CHAPTER VI

SUMMARY AND CONCLUSION

The objective of this study was to find the optimum growing medium porosity, Osmocote release system, and rate of Micromax micronutrients for the production of three cultivars of pot mums in a conventional gas heated greenhouse and a greenhouse with the floor heated by solar energy.

The optimum Osmocote system depended upon the greenhouse, micronutrient level and parameter measured as well as differences between cultivars. Both Osmocote systems produced high quality, salable plants.

All mixes produced high quality plants. However, Mix III was impractical from the standpoint of the frequent waterings needed. Mix I may not be economical, due to the high amount of peat. Mix II had enough water retention for reasonable watering intervals, and since large quantities of peat were not required, this is probably the most practical and economical for most growers.

The medium rate of Micromax, 0.595 kg./m^3 (1 lb./cu.yd.), was necessary for the production of the most salable plants for all cultivars.

There was a noted increase in the percentage of buds opening and the diameter of the flowers in plants produced in the greenhouse with the solar heated floor.

Based on this research with Chrysanthemum morifolium 'Mandalay', 'Peacock', and 'Winter Carnival':

1. Little benefit is obtained by adding 19-6-12 Osmocote to the 18-6-12 formulation for a quicker initial release rate.
2. A mixture of 30 percent peat, 50 percent pine bark and 20 percent sand v:v:v produces an economical, practical growing medium.
3. Micromax should be used at the rate equal to or greater than the medium rate (1 lb./cu.yd.), but less than the high rate (2 lb./cu.yd.).
4. The possibility of producing slightly higher quality plants in a container temperature oriented greenhouse exists, but further research is needed.

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