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The Effect of Media and Trickle Irrigation Fertilizer Regime on the Growth of *Chrysanthemum morifolium* Ramat.

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ABSTRACT

Factors limiting growth in gravel culture are oxygen, nutrients and water. These factors are dependent on gravel diameter, nutrient solution composition, and irrigation frequency. The objective of this study was to evaluate the effect of particle size and trickle irrigation frequency on growth of Chrysanthemum morifolium Ramat. irrigated with complete nutrient solution. Plant height, fresh weight, and flower diameter were used to evaluate the effects of irrigation on media. Media used were: coarse incinerated anthracite refuse (IAR), fine IAR, and soil from the B_{21} horizon of Gatesburg sand (Entic Haplorthod, sandy, siliceous, mesic). Irrigation frequencies were: 1) once per day, 2) four times per day at 4-hour intervals, and 3) constantly during the 13 light hours. Fine IAR irrigated constantly or every 4-hours produced significantly greater height, fresh weight and flower diameter than other treatments, while Gatesburg sand irrigated daily resulted in less growth than all other treatments.

Additional Index Words: Incinerated anthracite refuse, coarse aggregates, hydroponics, Gatesburg sand.

INTRODUCTION

Trickle Irrigation

Man has been irrigating crops for thousands of years. Only in the past ten or twenty years has attention been given to increasing irrigation efficiency by applying water to only a fraction of the soil surface (5).

In recent years considerable interest has developed in trickle irrigation, especially in the countries of Israel, Australia, South Africa, and the United States. Estimates indicate the United States will have 10,000 acres under trickle irrigation by 1975 (13). In South Africa, a fairly conservative estimate is that approximately 3,000 acres are trickle irrigated (8). Reports from Australia in 1971 indicated that the total acreage under trickle irrigation was over 10,000 acres and was rapidly expanding. Israel, where the concept of trickle irrigation for field crops was first developed in 1960, reports a similar acreage as Australia (12).

Trickle or drip irrigation is the daily maintenance of an adequate part of the root zone of a plant near field capacity during the growing period (12). Trickle irrigation water is applied on top of the soil surface and not under the soil surface as in subsurface irrigation, sometimes called subirrigation.

The basic concept of trickle irrigation is to prevent moisture stress in a portion of the root system. The water is applied at

rates of 4 to 8 liters (1 to 2 gal) per hour per outlet or dripper. The spacing of outlets depends on local soil conditions and plant spacing. The drip or trickle irrigation systems apply water under low pressure $1x10^6$ Dynes/cm^2 (15 psi) or less for a sufficient time to maintain a part of the soil near field capacity.

Trickle irrigation supplemented with nutrient solution is a method of applying water and nutrients to avoid matric and nutrient stress. In many cases, increased yeilds and increased water use efficiency result (10).

Cole (5) stated that if an irrigation system can be devised which eliminates the loss of water in sprinkler irrigation (assumed to be 80 percent efficient), a capital expenditure of up to $630 per acre to eliminate this loss is justified. These figures were computed on the basis of desalted water costing 30 cents per 4228 l (1000 gal). The losses of water in sprinkler irrigation were due primarily to nonuniform distribution and evaporation; both may be alleviated by trickle irrigation.

The potential advantages of trickle irrigation vary in importance depending on local conditions. A list of the commonly accepted advantages stated by Cole are: 1) water savings in comparison with other methods, 2) crop response, 3) labor savings, 4) fertilizer savings (and pollution abatement), 5) weed control cost saving, and 6) possible use of saline water. The review of literature revealed little quantitative information of general applicability on any of these items.

Application to Rhodesia

The author taught general science for 5 1/2 years at the Matopo Secondary School 48 km south of Bulawayo, Rhodesia in an area called the Matopos. Roughly half of this area is comprised of hilly, broken, wooded land with shallow, rocky soils in the hills, and red or black clays in the valleys. The other half is rolling open woodland or grassland comprising sandy granite-derived soils and is punctuated with tree-covered granite kopjes.

The clays tend to be alkaline, whereas the granite-derived sands and sandy loams tend to be slightly acid. Reserves of nutrients are much greater in the clayey soils than in the sandy soils. Nitrogen limits the growth of plants, available phosphorous is low for grass; but the potassium supply is plentiful (2).

Isolated areas of saline soils are found varying in size from a few square meters to 20 hectares.

In the Matopos region of Rhodesia, granite outcrops often exceed 50 percent of the land area. The granite bedrock can be found in various stages of decay and could be screened to provide the particle sizes of the inert media used in this experiment.

Mean annual rainfall in this area was 57.62 cm (23 in) for the period 1926 to 1968. The highest and lowest annual rainfall for the period 1922 to 1968 was 137.59 cm (54.17 in) and 25.7 cm (10.12 in) respectively.

The Rhodesian climate is characterized by a distinct wet and dry season with the average wet season lasting from mid-November to mid-March. Little or no precipitation occurs during the rest of the year.

From May until the first half of August, the weather is cool during the day and frosts are common at night, especially in the valleys. After mid-August the weather becomes progressively warmer until the end of the dry season but absolute maximum shade temperatures are unlikely to exceed 38°C (100°F).

The latitude of Matopo Secondary School is 20° South. The minimum dark period at this latitude is approximately 10 hr 41 min. Thus the natural dark period is longer than the dark period required to flower chrysanthemums throughout the year, eliminating the cost of black cloth to artificially shorten the days and the cost of labor to cover and uncover the crop daily.

Most Africans in Rhodesia are subsistance cattle and maize farmers and live in the Tribal Trust Lands which are characterized by sandy granite-derived soils. The red or black clays found in these areas are already used for crop production with or without irrigation.

Thus the author wished to determine if trickle-irrigation was a method that could be used to irrigate the sandy soils efficiently. This method would have to be efficient since many of the wells in the Tribal Trust Lands are over 91.4 m (300 ft) deep, and supplying electric power to this sparsely settled area is not economically feasible. Many of the pumps are hand operated, supplying water for man and beast.

The characteristic high unemployment rate is compounded by limited local markets. Inhabitants of the Tribal Trust Lands are

subsistance farmers and lack the cash needed to buy local produce. If high value crops like chrysanthemums could be grown in Rhodesia and air-freighted to Europe to take advantage of the world market, this would provide both employment and cash to improve the economy of the Tribal Trust Lands of Rhodesia. In spite of the cost of air-freighting flowers to Europe, the advantage of abundant inexpensive labor has increased the profitability of growing flowers in southern Africa and this advantage has been realized by many South African flower growers. Rathmell has reported that under Danish government foreign aid floricultural crop industries, especially carnations, are being developed in Kenya, and this nation aims to supply the world with carnation cuttings and carnation blooms (14).

Media

Successful use of inert media has been made in the greenhouse growth of floricultural crops (9, 11, 16, 18). Due to the availability of incinerated anthracite refuse (IAR) and Gatesburg sand in central Pennsylvania, and comparable sized granite particles and comparable type soil in Rhodesia, it was decided to compare two particle sizes of IAR with Gatesburg sand soil in this experiment for the growth of Chrysanthemum morifolium. This Gatesburg sand was similar in texture to a Rhodesian soil developed in granite reported by Watson (17).

The need for more research was apparent from the literature on trickle irrigation (5, 8, 12, 13). While showing promise for

irrigation in humid temperate conditions, trickle irrigation in the author's view, shows greater promise for the irrigation of arid and semi-arid tropical conditions like those found in Rhodesia, where the irrigation system can be utilized during the entire year.

Due to the high value, high labor requirements and adaptability of this crop to short Rhodesian days, Chrysanthemum morifolium was selected as the crop to be grown on sandy soil and inert media. It was hypothesized that trickle irrigation with complete nutrient solution on inert media and sandy soil using a high value crop like chrysanthemums would benefit the farmers of the Rhodesian Tribal Trust Lands.

Hanan (9) pointed out the advantages of inert media over soil as a rooting media. Over a one year's production period there was about a 14 percent increase in total yield, nearly a whole grade increase in cut flower quality and a one to three week shorter flowering peak between crops from a single pinched carnation plant. Other advantages include, 1) it is a uniform stable root medium, 2) it is relatively unaffected by sodium or saline waters, 3) it can be steam pasteurized without difficulty, 4) nutrition and irrigation can be completely automated, 5) it is not easily "overwatered," 6) it is competitive in price with the best soils, and 7) it requires no additional capital investment in pumps or tanks.

According to Hanan the following materials are preferred as inert media for greenhouses: (a) media with a wide range of particle

sizes between 20 and 0.3 mm, (b) media having not more than one percent by weight of the pasteurized particles with diameters smaller than 0.3 mm, and (c) media with a moisture content ranging from 18 to 23 liters per square meter of bench area for a depth of 17 cm. Kiplinger recommends particle sizes of from 6.3 mm to 12.7 mm (11).

Steiner (16) however states that inert media particle sizes should be uniform for the best oxygen supply. He also pointed out that while 4 mm sized particles give almost enough oxygen by diffusion for tomato roots, uniform-sized particles of 15 mm are required to give adequate oxygen to carnation roots. The author indicated that the particles with diameters smaller than 0.3 mm should be restricted to less than one percent by weight and that uniform sized particles did give a greater oxygen supply. The coarse and fine IAR used in this experiment did not meet these standards but were in the author's view not appreciably different from this standard. Gatesburg sand however did not meet this standard.

The factors limiting root growth and function are water, oxygen and nutrients. The ability of inert media to supply the root system with freely available water without inducing oxygen deficiency is its primary advantage. The internal plant water potential is reduced (less negative) by the freely available water supply in inert media, which cannot be maintained in soils without oxygen deficiency. Provided energy is sufficient for maximum photosynthesis, this lowered potential permits a faster growth rate (9).

Incinerated anthracite refuse (IAR) is the waste material resulting from the sizing and clearing of run-of-mine deep and strip-mined anthracite coal. It has been used successfully in the culture of roses, carnations, azaleas, African violets and many other plants (18) and was utilized in this research. It was compared with the Gatesburg sand (Entic Haplorthod, sandy, siliceous, mesic) B_{21} horizon sample.

The immediate objective of this research was to evaluate the effect of particle size and irrigation frequency on the growth of Chrysanthemum morifolium using a complete nutrient solution as irrigation water. Incinerated anthracite refuse (IAR) and Gatesburg sand were used as media.

The long range goal of this research was to study and develop techniques adapted to high value crops in Rhodesia.

MATERIALS AND METHODS

Experimental Conditions

In order to simulate arid Rhodesian conditions at University Park, The Pennsylvania State University floricultural greenhouse 10 was chosen as the experimental site. This greenhouse was equipped with a fan and pad cooling system to keep the experimental area near outside air temperature even though the experiment was carried out during the period of maximum solar radiation.

Two "V" bottom greenhouse benches 1.14 by 10.7 m (45 in by 35 ft) were used. Each bench was divided into 12 plots 88.9 by 114.3 cm and were from 15.24 to 22.86 cm deep (35 in by 45 in and 6 to 9 in deep). A randomized complete block design with 8 treatments and 3 replications was used. All combinations of 1) daily, 2) 4-hour, and 3) constant irrigation with a) coarse IAR, b) fine IAR, and c) Gatesburg sand were used except daily irrigation with fine IAR (Table 1). While the amount of water used per day was not identical for all treatments it was assumed that more than adequate amounts of irrigation solution were used. This excess was necessary to prevent nutrient deficiency since plants do not use nutrients in the same proportions as the solubility of the nutrient compounds.

Media

The typical composition of anthracite refuse from central Pennsylvania is given in Table 2 (15). Incineration may change this

TABLE 1

Amount of Water Applied to Media.

Media	One Irrigation at 0600	Four Irrigations Beginning at 0600 at 4-hour Intervals	Constant Irrigation Beginning at 0600 Ending at 1900
Coarse IAR	22.8 l	7.6 l	28.5 l
Fine IAR	Not Determined	7.6 l	28.5 l
Gatesburg Sand	22.8 l	7.6 l	28.5 l
Total per Day	22.8 l	30.4 l	28.5 l

TABLE 2

Typical Composition of Anthracite Refuse from Central Pennsylvania (11).

Constituent	Percent
SiO_2	50-57
Al_2O_3	30-37
Fe_2O_3	3-10
TiO_2	1-2
CaO	1-2
MgO	0-1
K_2O and Na_2O	1-3
SO_3	0-1

composition and lower the pH (4). The percent carbon in this refuse material is assumed to be less than 5 to 10 percent (4). Comparing the IAR with soil characterization data for Gatesburg sand from the B_{21} horizon was difficult since the analytical procedures were different. The amount of alumina in IAR was 30 to 37 percent. The amount of alumina in Gatesburg sand would be much lower than this.

Media Data

Water retention data were obtained for each of the three media using Tempe Pressure cells (Soilmoisture Equipment Corp.,

Santa Barbara, California). Tensions of 0, 10, 30, 50, 80, 100, 500 and 1000 cm of water were determined.

Summation particle size distribution curves were developed from data gathered by the dry sieve technique for particles larger than .05 mm from a 2 Kg sample. The hydrometer method (3) was then employed to determine the percentage of silt and clay in the remaining material. Conductivities and pH's of the leachate were taken on June 30th, September 4th and September 12th.

Samples of each of the three media were taken and sent to the Merkle Soil and Forage Testing Laboratory of The Pennsylvania State University for soil analysis.

Irrigation

Chapin Ooze irrigation headers (Chapin Watermatics, Inc., Watertown, New York) were used with the daily and 4-hour irrigation system. DuPont "Viaflo" (E. I. DuPont De Nemours and Co., Wilmington, Delaware) spunbonded polyethylene irrigation tubing 7 m (23 ft) long was used with the constant system. Nine Cole-Parmer Masterflex (Cole-Parmer Instrument Company, Chicago, Illinois) variable speed tubing pumps and 113 l (30 gal) tanks were used to pump irrigation solution into the "Viaflo" tubing. A Rainbird Rain Clox (Rainy Sprinkler Sales, Peoria, Illinois) controller with solenoid valves directed irrigation solution for 10 minutes to the daily irrigation system and 12 minutes to the 4-hour system.

Nutrition

A modified Baker's solution (1) was used as the irrigation solution in this experiment. The potassium level used was 5 times that of Baker's solution since chrysanthemums are known to require high amounts of potassium. Correction was made in the solution for the amount of calcium and magnesium in the tap water used. Calcium nitrate, magnesium sulfate, monopotassium phosphate, potassium sulfate, Nutra-min (E. C. Geiger, Harleysville, Pennsylvania) enriched with borax and iron (Sequestrene 330 Fe) were used to produce the following concentrations: N - 140 ppm, P - 15 ppm, K - 95 ppm, Ca - 200 ppm, Mg - 24 ppm, Fe - 3 ppm, B - 0.5 ppm, Mn - 0.25 ppm, Cu - 0.01 ppm, Zn - 0.14 ppm and Mo - 0.0014 ppm. This solution was injected into the 4-hour and daily systems using 2 Merit injectors (Merit Industries Inc., Craston, Rhode Island) in series (one injected $Ca(NO_3)_2$ while the other supplied the other salts). Fertilizer for the constant system was mixed directly in the 113 l tanks. The stock solution had a pH of 7.0 and a conductivity of 71 millimhos/cm.

Monocalcium phosphate was preplant incorporated at the rate of 4.25 Kg m^{-3} (2 lbs/6.3 bu) to prevent the removal of excessive amounts of phosphorous by the media from the solution as recommended by Kiplinger (11). After 40 hours of constant leaching the pH of the leachate ranged from 6.65 to 7.2. The media was steam pasteurized with free flowing steam for 1.5 hours until all points in the bench reached a minimum of 82°C (180°F).

Culture

In each of the 24 plots, 66 rooted cuttings of Chrysanthemum morifolium Ramat. "BGA Southern Comfort' were benched on June 30, 1972. The culture of these flowers was according to commercial practice for cut chrysanthemums with modifications as described above. Since they were grown during the summer "BGA Southern Comfort' was the cultivar used. The cuttings were syringed periodically for five days. Thermostats were set to maintain a minimum of 15.6°C (60°F) at night and 24°C (75°F) during the day. Some August day temperatures were about 5.4°C (10°F) higher even with the use of fan and pad cooling.

Plants were sprayed on August 2 and 25, 1972 with thiodan (Endosulfan - Hexachlorohexahydromethane-2,4,3-benzodiozathiepin oxide) and meta-systox R (S-(2-(ethylsulfinyl) ethyl) 0, 0-dimethyl phosphorothioate) for the control of white fly and aphids.

Plant Data

Plant height, fresh weight and flower diameter were determined for each flower such that there were more than 50 observations per plot.

The chrysanthemum quality was evaluated by measuring the following: plant height, fresh weight, flower diameter and subsamples from each plot were randomly taken for the determination of dry weight and keeping quality. One medial leaf from each of 30 plants per plot was removed and composited for spectrographic analysis.

Plant height was measured from ground level to the tip of the meristem in centimeters. Fresh weight was the total weight of the

stem, leaves and flower immediately after harvest measured in grams on a Mettler P1200 electric balance. Flower diameter was the maximum distance across the petals of the flower measured in centimeters. Typical wholesale commercial harvesting practices were followed in this study, so that as flowers became mature they were harvested irrespective of treatments.

Seven subsamples were taken from each plot for the determination of dry weight. The total above ground portion of the chrysanthemum plant was inserted in a paper bag and oven-dried at 60°C (140°F) for 48 hours. The samples were weighed 48 hours after removal.

Two keeping trials were established by selecting three subsamples for each trial from each of the 24 plots. The leaves on the lower third of the plants were removed. The flowers were placed in 38°C (100°F) city tap water with Smithers Oasis preservative added at the rate of 11.1 g/l (1 1/2 oz/gal) or in city tap water at 38°C. These 144 flowers were kept under light from 0800 to 1700 hours each day. An air conditioner was used to simulate ordinary house conditions.

Statistical Analysis

The significance of each plant parameter was determined by Analysis of Variance and significantly different means were separated by Duncan's Modified (Bayesian) Least Significant Difference Test using the Statistical Package Programs at the Computation Center of The Pennsylvania State University. The

"ANOVUM" program was used, since the number of observations per plot were unequal. This program conducted a Bartlett's test on the individual cell variances.

A computer program was written by the author to map out each observation with its deviation in each plot. This map was compared with a map of cracks in the benches in an effort to explain the variance of replications within treatments.

RESULTS AND DISCUSSION

Media

Summation particle size distribution curves are presented in Figure 1. The media used in this experiment do not meet the standards for preferred inert media as defined by Hanan (9). Coarse IAR had 11.5 percent, fine IAR - 23.3 percent and Gatesburg sand - 70.0 percent of the particles less than 0.3 mm in size, while Hanan indicated that less than 1 percent of this material was desirable. The water retention curves (Figure 2) plot content in percent by volume against media matric tension in centimeters of water. By taking the values for 17 cm of water from the water retention curves and calculating the number of liters of water retained per square meter the following values were obtained: coarse IAR - 57.46 l m^{-2}, fine IAR - 44.71 l m^{-2} and Gatesburg sand - 72.76 l m^{-2}. Hanan recommended 18 to 23 l m^{-2}.

Based on results of soil tests conducted at The Merkle Soil and Forage Testing Laboratory of The Pennsylvania State University (Table 3) coarse IAR had a CEC of 10.7 meq per 100 g, but only 27.16 percent of this sample was under 2 mm and only 6 percent was under 0.05 mm in diameter. This small percentage of the sample had a CEC of 10.7 meq per 100 g. Fine IAR had more particles under 2 mm (60 percent) and more in the less than 0.05 mm diameter particle size (13 percent). The CEC of fine IAR was 7.2 meq per 100 g.

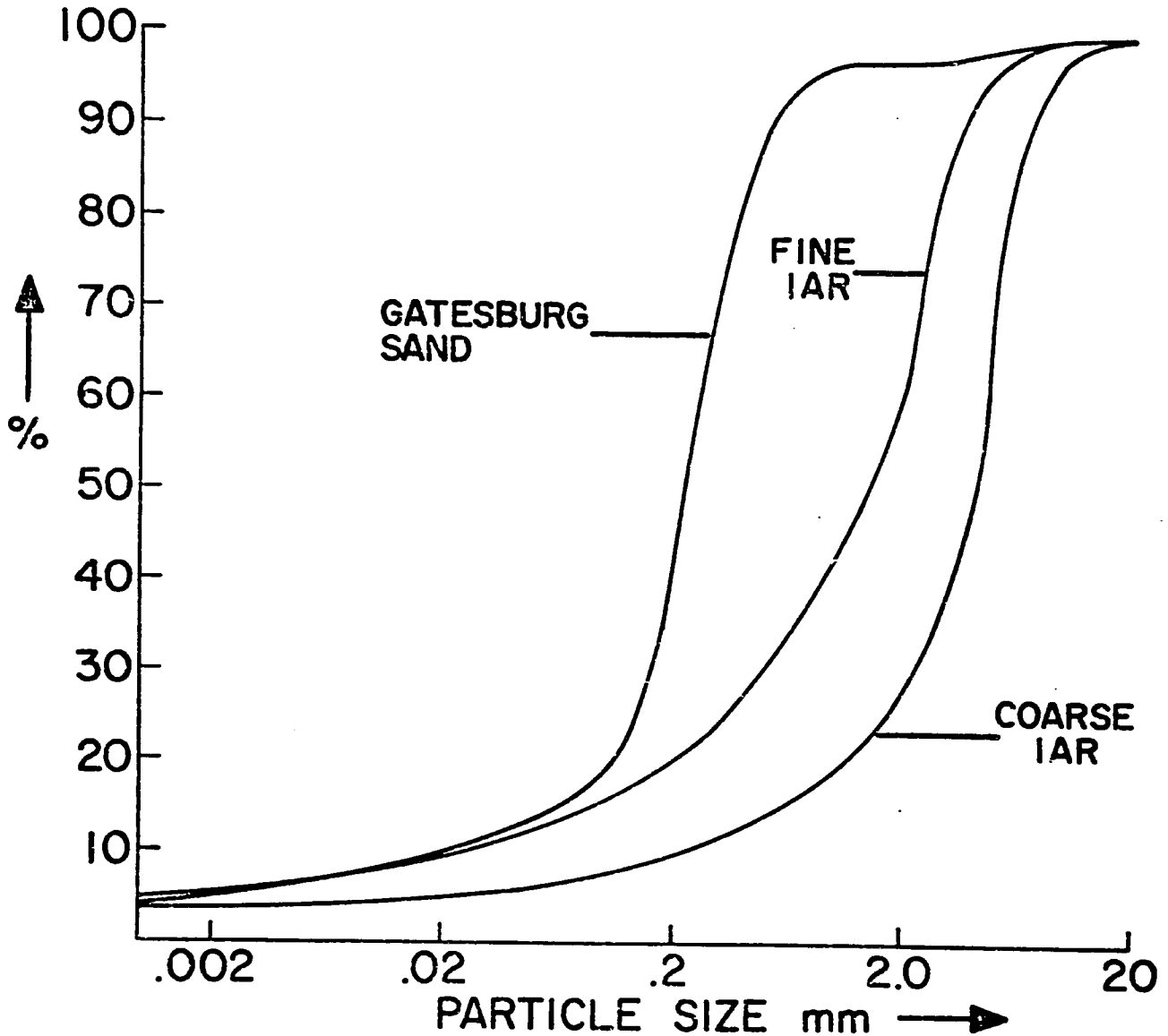

Figure 1. Particle Size of Media.

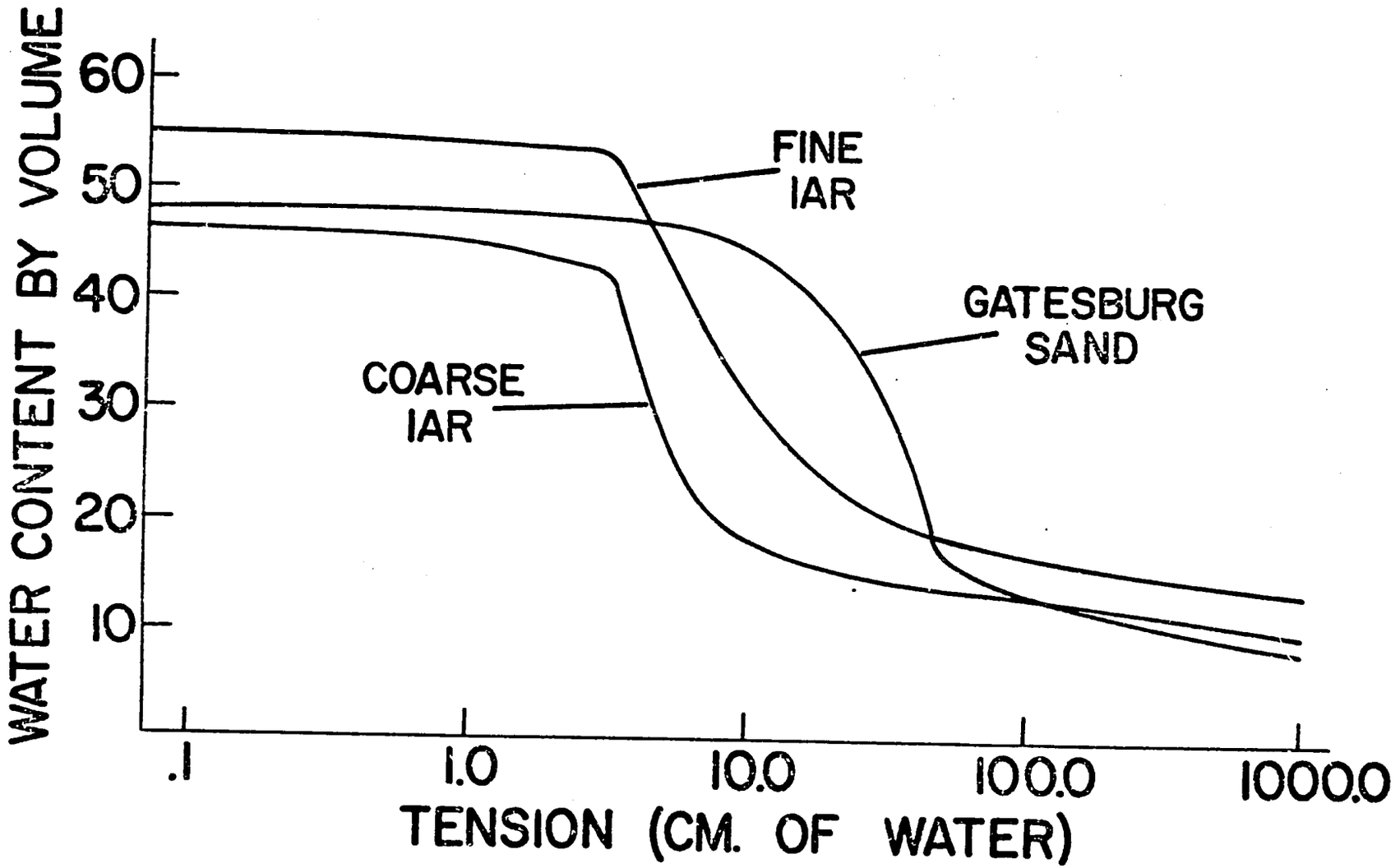

Figure 2. Water Retention of Media.

TABLE 3

Soil Analysis Data for Coarse IAR, Fine IAR and Gatesburg Sand.

Media	% of Sample < 2 mm	% of Sample < 0.05 mm	CEC	Soil pH	Buffer pH	% Saturation K	Mg	Ca
Coarse IAR	27.16	6	10.7	4.3	6.6	2.4	9.7	54.0
Fine IAR	60.00	13	7.2	5.3	6.5	1.5	4.1	24.3
Gatesburg Sand*	97.13	14	5.1	5.7	6.7	1.5	5.8	34.3

*Monocalcium phosphate was preplant incorporated at the rate of 4.25 Kg m^{-3} (2 lbs/6.3 bu) to Gatesburg sand before a sample was taken for analysis.

The material tested made up 60 percent of the fine IAR sample. It was found that 97.13 percent of the Gatesburg sand was smaller than 2 mm while only 14 percent of this sample was smal r than 0.05 mm. Gatesburg sand had a CEC of 5.1 meq per 100 g. This sample of Gatesburg sand had been treated with monocalcium phosphate at the rate of 4.25 Kg m^{-3} (2 lbs/6.3 bu).

The CEC value of coarse IAR is 10.7 meq per 100 g and much higher than Gatesburg sand, but only 6 percent of this sample is in the clay size range. The CEC of fine IAR, 7.2 meq per 100 g is higher than that of sand, 5.1 meq per 100 g, but in this case 13 percent of the sample is in the clay size range. Thus the CEC of fine IAR is higher than that of Gatesburg sand. The above information indicates that these media contain from 6 to 14 percent of their particles in the clay size range and would be able to supply cations to plant roots and so may not be considered totally inert due to its CEC.

No problem was experienced in the movement of a complete nutrient solution through the "Viaflo" tubing in this experiment even though the openings in the walls of the tube were only 4 microns (15). Algae growing in the nutrient solution occasionally plugged the plastic tubes leading to the "Viaflo" tubing before the plastic 113 l tanks were coated with aluminum paint.

Statistical Analysis

The results of the statistical analysis indicated that the variances were not homogenous. Bartlett's test for homogeneity of

variances was significant at the 5 percent level. In an effort to reduce the variances the border observations (plants on the edges of the bench) were excluded. Bartlett's test indicated that the variances of flower diameter were not significant at the 5 percent level, but were significant for plant height, fresh weight and dry weight. The computation of an analysis of variance excluding treatment 6 was a further unsuccessful attempt to produce homogeneous variances.

Plant Data

Harvest began 78 days after planting and continued at an accelerated rate until completion, 84 days after planting. According to the Society of American Florests Grading System the highest grade for cut chrysanthemums is titled standard. Standard cut chrysanthemums weigh from 85 to 127.6 g (3 to 4 1/2 oz), have a flower diameter of at least 14.0 cm (5 1/2 in) and have a stem length of 76.2 to 106.7 cm (30 to 42 in). This was the standard used to compare flowers in this experiment. Means of plant height of all chrysanthemums produced in this experiment were taller than 106.7 cm (the maximum required for the standard grade). This indicated that short days or flower induction period could have begun one week earlier (Table 4).

Gatesburg sand irrigated daily (treatment 6) produced flowers whose means for fresh weight (80.69 g) and flower diameter (13.09 cm) were below the standard grade, while fine IAR irrigated constantly

TABLE 4

Height, Fresh Weight, Flower Diameter and Dry Weight of 'BGA Southern Comfort' Chrysanthemums (means of 3 replications).

Treatment	Media	Irrigation	Height (cm)	F. Wt. (g)	Fl. D (cm)	Dry Wt. (g)
1	Coarse IAR	Daily	114.57 ef*	87.68 e	13.68 c	17.39 a
2	Coarse IAR	4-hour	118.68 cd	99.48 d	14.18 b	18.65 a
3	Coarse IAR	Constant	123.76 bc	108.27 c	14.05 b	20.35 a
4	Fine IAR	4-hour	126.05 b	119.57 b	14.53 a	22.38 a
5	Fine IAR	Constant	135.38 a	132.53 a	14.68 a	20.66 a
6	Sand	Daily	109.83 e	80.69 e	13.09 d	20.63 a
7	Sand	4-hour	121.22 bc	107.30 cd	14.20 b	19.62 a
8	Sand	Constant	123.99 bc	108.04 c	14.02 b	21.60 a

*Means within a column followed by the same letter are not significantly different at the 5 percent level as determined by Duncan's Modified (Bayesian) Least Significant Difference Test.

(treatment 5) produced flowers whose mean for flower weight (132.53 g) was greater than that required for the standard grade.

The tallest and heaviest plants and largest chrysanthemum flowers were produced in treatment 4 (4-hour irrigation on fine IAR) and 5, (constant irrigation on fine IAR) with treatment 5 producing plants which were taller and had greater fresh weight than those in treatment 4. Chrysanthemum plants were taller, had larger flower diameter and had greater fresh weight on fine IAR than either of the other two media. Within the two irrigations used on fine IAR, there were significant increases in plant height and fresh weight, but not a significant increase in flower diameter when constant irrigation was used. Plant height and flower diameter were significantly lower in treatment 6 (daily irrigation on Gatesburg sand) than for all other treatments. There were no significant differences among treatment means for dry weight.

Irrigation

The large pore spaces in coarse and fine IAR allowed immediate infiltration of irrigation solution, but in treatments 6 (daily irrigation on sand) and 7 (4-hour irrigation on sand) water accumulation was observed on the surface of Gatesburg sand until 10 minutes after irrigation. On one of the treatment 6 plots, channels were observed at the side of the plot conducting water to the drain. Since the sand plots remained near saturation throughout the experiment, the

oxygenated irrigation solution may not have infiltrated uniformly through these plots to provide the roots with oxygen (16).

Media Data

The water retention curves (Figure 2) indicate three relationships. First, the water retention curve for sand shows very little release of water until tensions greater than 15.24 to 22.86 cm (the depth of the bench) are reached. The Gatesburg sand remained saturated throughout the experiment irrespective of irrigation treatments. Steiner (16) pointed out that oxygen could be supplied to plant roots in irrigation water. It was for this reason that he recommended the application of water in soilless culture to the top of the media and not flooded from below. It was postulated that oxygen could have limited growth in treatment 6 (Gatesburg sand irrigated daily) to a greater extent than in treatment 7 (Gatesburg sand irrigated every 4-hours) and treatment 8 (Gatesburg sand irrigated constantly) since it received oxygenated solution less frequently. It was postulated from the Gatesburg sand water retention curve that oxygen did limit growth in sand treatments.

Secondly, the slope of the curves for fine IAR and coarse IAR indicate a sharp decrease in water content by volume as the tension increases from 0 to 15 cm of water. Thus the depth of the greenhouse bench created sufficient tension to remove substantial amounts of water from both fine IAR and coarse IAR. During the experiment this effect was observed over the time interval between irrigations.

Within a 30 minute period after the irrigation of the Gatesburg sand plots essentially all of the leachate was collected from that irrigation, whereas the irrigation solution held with less tension in the fine and coarse IAR continued to drain from these plots throughout the time interval between irrigations. This would suggest that the water in the coarse IAR and to a greater extent in fine IAR was more available than in Gatesburg sand.

Third, at Θ values (water content by volume) in the 0 to 15 cm of water tension range (the bench was from 15.24 to 22.86 cm deep) fine IAR has approximately 10 percent more water by volume than did coarse IAR and would result in greater water conductivity in fine IAR. Fine IAR irrigated every 4 hours and constantly (treatments 4 and 5) was the media on which significantly taller, heavier and larger diameter chrysanthemums were produced. The author concluded that fine IAR provided more water for chrysanthemum roots.

By examining all three water rentention curves and yield data fine IAR was concluded to be the best of the three media for chrysanthemum growth. At very low tensions (0 to 2 cm of water) fine IAR contains even more water by volume than sand. In the 0 to 15 cm of water tension range, while Gatesburg sand remained almost completely saturated limiting oxygen supply to roots, fine and coarse IAR released water freely to roots. The slope of the curves for fine IAR and coarse IAR indicate that in the 0 to 15 cm tension range oxygen diffuses to roots due to the unsaturated conditions.

Hanan pointed out that the time between flowering peaks of a single-pinched carnation crop was reduced by 1 to 3 weeks by the use of inert media (9). 'BGA Southern Comfort' is listed in commercial catalogs as a '10 week' chrysanthemum, but in this experiment it flowered in just 7 weeks of short days. Early anthesis has been a significant finding in other trickle irrigation and inert media research (5, 7, 8, 9).

Keeping Quality

When the chrysanthemum flowers showed signs of plasmolysis they were discarded and the number of days of keeping was recorded. Many of the leaves showed plasmolysis before the flowers were discarded.

The chrysanthemums in the Smithers Oasis preservative keeping trial showed greater signs of plasmolysis than those kept in city tap water. Upon examination of Table 5 it can be seen that in every treatment the mean of the number of days chrysanthemums kept in city tap water was greater than in preservative. This would indicate that the application of 11.1 g/l (1 1/2 oz/gal) of preservative was too high in this experiment. When city tap water was used as the keeping medium there were no significant differences among treatments. When chrysanthemums were kept in preservative treatments 1, 2, 3, 4, 5, 7 and 8 were not significantly different from each other but were significantly different from treatment 6. Treatments 2, 3, 5, 6, and 7 were not significantly different from each other but were significantly different from 8, 4, and 1.

TABLE 5

Number of Days of Keeping in Water and in Smithers Oasis Preservative* of 'BGA Southern Comfort' Chrysanthemums (means of 3 replications).

Treatment	Media	Irrigation	Post Harvest Life (Days) Water	Preservative
1	Coarse IAR	Daily	26.40 a**	21.30 a
2	Coarse IAR	4-hour	26.00 a	19.60 ab
3	Coarse IAR	Constant	23.60 a	20.20 ab
4	Fine IAR	4-hour	25.20 a	22.90 a
5	Fine IAR	Constant	23.00 a	18.20 ab
6	Sand	Daily	25.40 a	14.60 b
7	Sand	4-hour	23.60 a	19.40 ab
8	Sand	Constant	24.00 a	21.50 a

*Smithers-Oasis, Kent, Ohio applied at the rate of 11.1 g/l (1 1/2 oz/gal).

**Means within a Column followed by the same letter are not significantly different at the 5 percent level as determined by Duncan's Modified (Bayesian) Least Significant Difference Test.

Conductivities

Conductivities and pH's of the leachate were taken on June 30th, September 4th and 12th. The pH range on June 30th was from 6.6 to 7.2 and conductivity ranged from 21 to 46 millimhos/cm. On September 4th and 21th the pH was 7.0 and conductivity ranged from 30 to 57 millimhos/cm. The pH and conductivity of the stock solution was 7.0 and 71 millimhos/cm. This would indicate that the media removed less nutrients from the solution as the experiment progressed.

Nutrient Analysis of Leaves

Leaves of some plants were lower in nitrogen and higher in phosphorous than accepted standards based on results of Spectrographic analysis (Table 6) (Soil and Plant Laboratory, Inc., Santa Clara, California). By examining this table it can be seen that the mean nitrogen value (4.20 percent) of treatment 6 (Gatesburg sand irrigated daily) is below the critical value. Figure 3 illustrates the dark green leaves of treatment 5 and the light green leaves of treatment 6 caused by differences in nitrogen content shown in Table 6. These results indicated that the irrigation solution was low in nitrogen and high in phosphorus.

TABLE 6

Leaf Analysis Values for Median Leaves of 'BGA Southern Comfort' Chrysanthemums Grown with Trickle Irrigation System (mean of 3 replications).

	Leaf Content									
	Percentage of dry weight					ppm of dry weight				
Treatment	N	P	K	Ca	Mg	Mn	Fe	Cu	B	Zn
1	4.61	0.76	4.71	2.19	0.52	103	245	12	53	38
2	5.16	0.79	4.62	2.22	0.62	133	257	11	48	35
3	5.05	0.82	5.03	2.10	0.50	126	286	10	48	41
4	5.33	0.92	5.56	2.26	0.49	190	286	15	42	51
5	5.29	0.91	5.32	2.18	0.44	169	265	12	36	44
6	4.20	0.78	5.15	2.75	0.46	134	243	13	79	51
7	5.33	0.93	5.00	2.07	0.49	217	263	12	41	41
8	4.98	0.73	5.47	1.97	0.46	141	292	9	46	48
Low Critical Level*	4.5	0.20	3.5	0.5	0.14	20	75	5	20	7
Optimum Range*	6.0-7.3	0.27-0.40	4.5-6.5	1.0-2.0	0.35-0.65	195-260	100-500	25-75	50-100	20-50

*Soil and Plant Laboratory, Inc., Santa Clara, California.

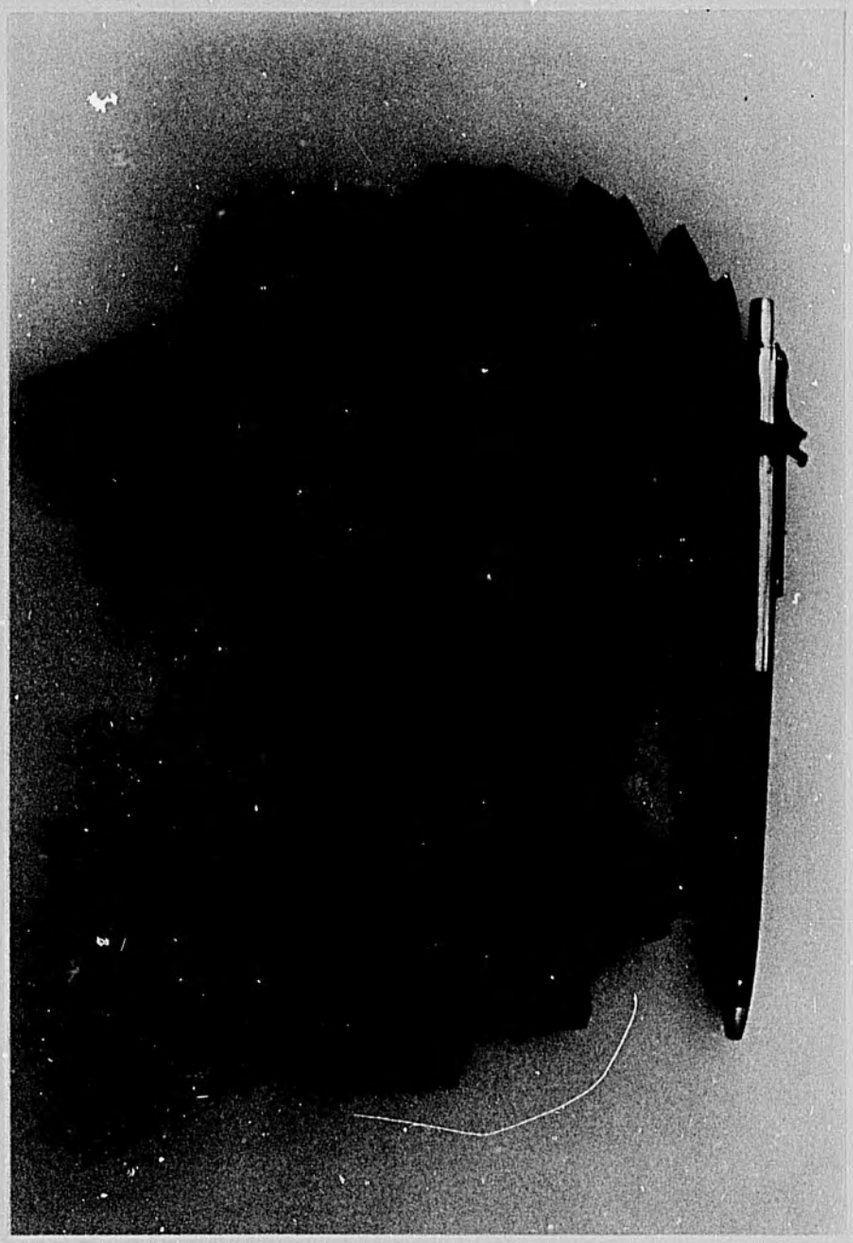

Figure 3. Photograph Illustrating Color Differences of Leaves from Treatments 5 and 6.

SUMMARY AND CONCLUSIONS

Fine IAR with constant irrigation (treatment 5) produced significant increases in height and fresh weight of chrysanthemum over all other media-irrigation treatments. Fine IAR irrigated constantly (treatment 5) and every 4-hours (treatment 4) produced larger diameter chrysanthemum flowers than all other treatments. Flower diameter was significantly smaller when chrysanthemums were grown on Gatesburg sand irrigated daily (treatment 6) than all other treatments. Height and fresh weight of chrysanthemums was significantly lower in Gatesburg sand irrigated daily (treatment 6) and coarse IAR irrigated daily (treatment 1). General trends can be seen from Table 4. Data indicate that fine IAR was the most desirable media for chrysanthemem growth and that constant irrigation tended to produce better growth over other irrigation methods while not producing a significant increase in plant height, fresh weight and flower diameter over the 4-hour irrigated plots. There were no significant differences in dry weight among treatments.

Steiner showed that oxygen supply to roots could be increased by reducing the interval of irrigation or flooding (16). This may explain why the plant height, fresh weight and flower diameter were greater with 4-hour and constant irrigation particularly on Gatesburg sand where oxygen may have been limiting.

The fact that fine IAR had approximately a 10 percent greater water content by volume than coarse IAR without remaining saturated as Gatesburg sand did in the water tension range of this experiment would indicate that it should have produced better growth of chrysanthemums as evaluated by: plant height, fresh weight and flower diameter. This did happen in this experiment. Results of this experiment agree with the findings of Hanan (9), that the ability of inert media to supply the root system with freely available water without inducing oxygen deficiency is its primary advantage.

The irrigation of a complete nutrient solution through the DuPont "Viaflo" irrigation tubing produced no plugging problems over the short time span of this experiment.

Coarse IAR with its large pore spaces had a lower water content by volume than fine IAR, while Gatesburg sand with its small pore spaces remained saturated with the possible induction of oxygen deficiency in chrysanthemum roots.

Spectrographic analysis data indicated that the irrigation solution may have had more than adequate amounts of phosphorous.

In conclusion,

1. Fine IAR irrigated constantly and every 4-hours produced taller and heavier plants and larger diameter chrysanthemum flowers than other treatments.
2. Irrigating a complete nutrient solution through DuPont "Viaflo" irrigation tubing produced no plugging during this experiment.

3. These growth techniques stimulated early anthesis in chrysanthemums which has been observed in other species.
4. Trickle irrigation on sandy soil or inert media of high value crops such as chrysanthemums could benefit farmers of the Rhodesian Tribal Trust Lands.

Further Research Proposals

Additional research is needed to determine the water use rate of plants grown on soil and inert media. Water use efficiency for each of the media and irrigation frequencies would be valuable information for commercial growers, particularly in arid climates where water is not abundant.

Tropical conditions such as those found in Rhodesia may require an irrigation solution of lower osmotic potential than the one used in this experiment. This variable should be considered in further research, with the aim of using osmotic potential to help plants in tropical countries adapt to the varying conditions of solar radiation and relative humidity.

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