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9. ABSTRACT

This paper reports the methods and results of a study designed to evaluate the effect of media of three sizes and the effect of irrigation frequency on the growth of Chrysanthemum morifolium Ramat. Factors limiting growth in media culture are oxygen, nutrients, and water. These factors are dependent on particle diameter, nutrient solution composition, and irrigation frequency. This study evaluated combinations of trickle irrigation frequencies and particle sizes of media on the growth of chrysanthemums irrigated with a complete nutrient solution. Plant height, fresh weight, dry weight, and flower diameter were used to measure growth. Media used were coarse incinerated anthractie refuse, fine incinerated anthracite refuse, and soil material from the B21 horizon of Gatesburg sand. Fine incinerated anthracite refuse irrigated either constantly or every four hours produced the best results, whereas Gatesburg sand irrigated daily resulted in less growth than other treatments. Excess water held in finer-textured media causes oxygen deficiency and substandard growth.

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RELATIONSHIP AMONG IRRIGATION-MEDIA REGIMES AND PLANT GROWTH*

by J. H. STERN, J. W. WHITE, R. L. CUNNINGHAM and R. H. COLE**

SUMMARY

Factors limiting growth in media culture are oxygen, nutrients and water. These factors are dependent on particle diameter, nutrient solution composition, and irrigation frequency. This study evaluated combinations of trickle irrigation frequencies and particle sizes of media on the growth of *Chrysanthemum morifolium* Ramat. irrigated with a complete nutrient solution. Plant height, fresh weight, dry weight, and flower diameter were used to measure growth. Media used were: coarse incinerated anthracite refuse, fine incinerated anthracite refuse, and soil material from the B21 horizon of Gatesburg sand. Irrigation frequencies were: once per day, four times per day at 4–h. intervals, and constantly during the 13 daylight hours. Fine incinerated anthracite refuse irrigated constantly and every 4 hours produced chrysanthemums with significantly greater height, fresh weight and flower diameter than other treatments, whereas Gatesburg sand irrigated daily resulted in less growth than other treatments. Excess water held in finer textured media causes oxygen deficiency and substandard growth.

INTRODUCTION

Trickle irrigation applies water to the soil surface under low pressure (1×10^6 dynes/cm^2) at frequent intervals, and prevents moisture stress. A complete nutrient solution can be injected into the irrigation water to eliminate water and nutrient stresses. With this

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system of irrigation, the supply of oxygen to roots can become a limiting factor in soil. By using media of large particle size, aeration is improved. Thus optimum growth takes place when air, nutrients, and water are present in optimum proportions in the rhizosphere for the crop being grown [9].

The objective of this study was to evaluate the effect of media of 3 sizes and the effect of irrigation frequency on the growth of *Chrysanthemum morifolium* Ramat., using a complete nutrient solution as irrigation water, and using coarse incinerated anthracite refuse (IAR) fine IAR, and Gatesburg sand soil material as media. These media are similar to certain Rhodesia soils. Chrysanthemums were used in this study because they are a high value crop with a high labor requirement, adopted to short tropical days, and suitable for growing in developing countries, such as Rhodesia, for export to Europe.

Hanan [7], pointing out the advantages of inert media over soil as a rooting media in greenhouses, reported a 14% annual increase in total carnation yield, an increase in cut-flower quality, and a one-to-three week shorter growing cycle for single pinched carnations. He recommended particle sizes ranging from 20 to 0.3 mm [7]. Kiplinger recommended 12.7 to 6.3 mm [8]. Steiner suggested that the particle size of the inert media should be uniform for maximum porosity and oxygen supply. Large particles allow more oxygen to diffuse than small particles. Modification of particle size has been reported to satisfy species with different oxygen requirements: *e.g.*, 4 mm uniform-sized particles support tomatoes, but 14 mm uniform-sized particles are required for carnations [9]. Hanan noted that the media should have a moisture content ranging from 18 to 23 liters per square meter of bench area that has a depth of 17 cm [7].

The ability of inert media to supply the root system with freely available water without inducing oxygen deficiency is their primary advantage [10]. The internal plant water potential is reduced by the freely available water supply in inert media. The same low potential cannot be attained in soils or soil materials without creating oxygen deficiency. Provided that solar energy is sufficient for maximum photosynthesis, the low water potential permits a faster growth rate [7].

MATERIALS AND METHODS

On June 30, 1972, *Chrysanthemum morifolium* Ramat. cuttings of the cultivar 'BGA Southern Comfort' were planted in two 'V' bottom, 1.14 × 10.7 m greenhouse benches, each divided into 12 plots 88.9 × 114.3 × 15.2 to 22.9 cm, 66 plants per plot. A randomized complete-block design with 3 replications including all combinations of daily, 4-hour, and constant irrigation with coarse IAR, fine IAR, and Gatesburg (Entic Haplorthod, sandy, siliceous, mesic) sand B21 horizon soil material [4] were used except that daily irrigation was not used with fine IAR due to limits of space (Table 1). While the amount of water used per day was not identical for all treatments, excess amounts of irrigation solution were used to supply more than adequate nutrients for each regime. Slight differences in the total nutrients applied to each treatment would be compensated by the excesses not utilized by the plants.

TABLE 1

Media and irrigation regimes

Treatment	Media	Irrigation* application	Quantity applied, l
1	Coarse IAR	Daily	22.8
2	Coarse IAR	Every 4 h	30.4
3	Coarse IAR	Constant	28.5
4	Fine IAR	Every 4 h	30.4
5	Fine IAR	Constant	28.5
6	Gatesburg soil	Daily	22.8
7	Gatesburg soil	Every 4 h	30.4
8	Gatesburg soil	Constant	28.5

* Applications began at 0600 and ended at 1900 h.

TABLE 2

Soil analysis data for coarse IAR, fine IAR and Gatesburg Sand

Medium	% of sample							% Saturation		
	20–2 mm	<2 mm	<0.3 mm	<0.05 mm	CEC	Soil pH	Buffer pH	K	Mg	Ca
Coarse IAR*	73	27	11.5	6	10.7	4.3	6.6	2.4	9.7	54.0
Fine IAR*	40	60	23.3	13	7.2	5.3	6.5	1.5	4.1	24.3
Gatesburg Sand**	3	97	70.0	14	5.1	5.7	6.7	1.5	5.8	34.3

* Chemical composition: SiO_2 – 50 to 75%, Al_2O_3 – 30 to 37%, Fe_2O_3 – 3 to 10%, TiO_2 – 1 to 2%, CaO – 1 to 2%, MgO – 1 to 2%, K_2O – 1 to 3%, Na_2O – 0 to 1%, and SO_3 – 0 to 1%.

** Monocalcium phosphate was preplant incorporated at the rate of 4.25 Kgm^{-3} to Gatesburg sand B2 horizon before a sample was taken for analysis.

Table 2 gives the characteristics of the 3 media used. The data indicate that these materials are not inert. Particle size analyses were obtained by the dry sieve technique for particles larger than 0.05 mm from a 2-kg sample of each median and the hydrometer method was employed to determine the percentage of silt and clay in the remaining material [2]. Water retention was determined at 0, 10, 30, 50, 80, 100, 500, and 1000 cm of water for each of three media using Tempe Pressure Cells.

Chapin Ooze irrigation headers were used with the daily and 4-hour irrigation system, DuPont 'Viaflo' polyethylene irrigation tubing was used with the constant system. A controller with solenoid valves directed irrigation solution for 12 min to the daily irrigation system and 10 min. to the 4-hour system.

A modified Baker's solution [1] was the irrigation solution for this study, except the potassium level was 5 times that of Baker's solution since chrysanthemums 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, and trace element mix* enriched with borax and iron** were used to produce the following concentrations: 140 ppm N, 15 ppm P, 95 ppm K, 200 ppm Ca, 24 ppm Mg, 3 ppm Fe, 0.5 ppm B, 0.25 ppm Mn, 0.01 ppm Cu, 0.14 ppm Zn, and 0.0014 ppm Mo. This solution was injected into the 4-hour and daily systems using 2 injectors in series (one injected $Ca(NO_3)_2$ while the other supplied the other salts). The stock solution had a pH of 7.0 and a conductivity of 71×10^{-5} mhos/cm.

Monocalcium phosphate was preplant incorporated at the rate of 4.25 kg m^{-3} to prevent the media from removing excessive amounts of phosphorus from the solution. After 40 h of constant leaching the pH of the leachate ranged from 6.6 to 7.2. The media was steam pasteurized with free flowing steam for 1.5 h until all points in the bench reached a minimum of 82°C.

Plant height, fresh weight and flower diameter were measured for more than 50 samples per plot. Seven subsamples of above ground parts from each plot were oven dried at 60°C for 48 h and then weighed. Plant height in centimeters was measured from the media surface to the tip of the meristem. Fresh weight in grams was the total weight of the stem, leaves, and flower immediately after harvest. Flower diameter in centimeters, was the maximum distance across the petals of the flower. The commercial harvesting practice of cutting as flowers matured was followed irrespective of treatments.

Harvest began 78 days after planting and continued at an increasing rate until completion, 84 days after planting. According to The Society of American Florists Grading System, the highest grade for cut chrysanthemums is 'Standard'. Standard cut chrysanthemums weigh from 85 to 127.5 g, have a flower diameter of at least 14 cm, and have a plant height of 76.2 to 106.7 cm. This standard was used to evaluate the flowers in this experiment.

* Nutra-min (E. C. Geiger Co., Harleysville, Pa., USA).

** Sequestrine 330 Fe – (Geigy Chemical Co., Ardsley, NY, USA).

RESULTS AND DISCUSSION

As irrigation regimes change, the characteristics of the media for optimum growth change. Plots irrigated constantly with 'Viaflo' received oxygenated water due to the large surface of 'Viaflo' exposed to the atmosphere. The water retention curves (Fig. 1) plot water content in percent by volume against media matric tension in centimeters of water. By taking the water tension value of 17 cm (the bench depth) from the water retention curves and calculating the number of liters of water retained per square meter, the following values were obtained: for coarse IAR, 27.5 l m^{-2}; fine IAR, 44.7 l m^{-2}; and Gatesburg sand, 72.8 l m^{-2}. Hanan recommended 18 to 23 l m^{-2}. Trickle irrigation apparently allowed the use of a greater variability in size of particles for greenhouse media even though greater amounts of water were retained than for material 20 to 0.3 mm. Summation particle-size distribution curves are presented in Fig. 2 for the 3 media. Treatments 5, 7, and 8 on Gatesburg sand soil material contained 70 per cent material with particles less than 0.3 mm.

Means of plant height of all chrysanthemums produced in this experiment were greater than 106.7 cm, the maximum allowed for the standard grade (Table 3). This indicated that the flower induction period could have begun one week earlier. Hanan pointed out that time to anthesis in carnations could be reduced by 1 to 3 weeks

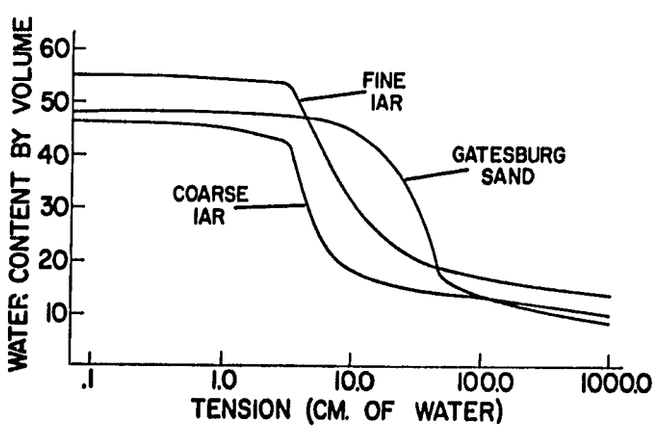

Fig. 1. Water retention of media.

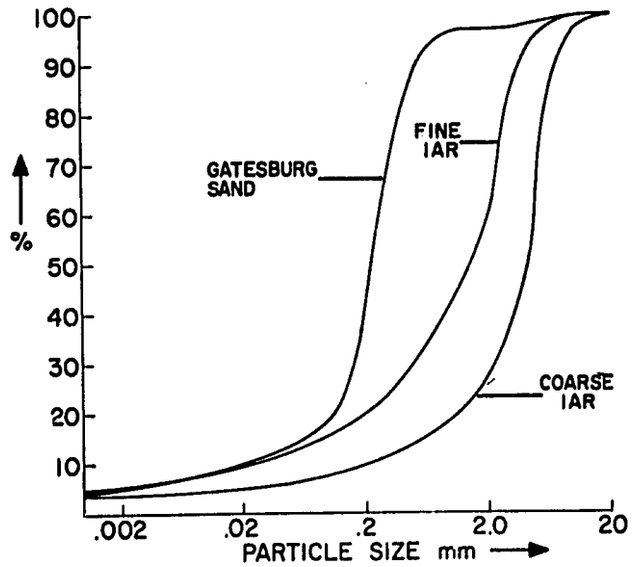

Fig. 2. Summation particle size of media.

TABLE 3

Growth parameters of chrysanthemums (means of 3 replications)*

Treatment	Medium	Irrigation	Height (cm)	Fresh wt. (g)	Flower diameter (cm)	Dry wt. (g)
1	Coarse IAR	Daily	114.6 ef	87.7 e	13.7 c	17.4 a
2	Coarse IAR	4-hour	118.7 cd	99.5 d	14.2 b	18.7 a
3	Coarse IAR	Constant	123.8 bc	108.3 c	14.1 b	20.4 a
4	Fine IAR	4-hour	126.1 b	119.6 b	14.5 a	22.4 a
5	Fine IAR	Constant	135.4 a	132.5 a	14.7 a	20.7 a
6	Sand	Daily	109.8 e	80.7 e	13.1 d	20.6 a
7	Sand	4-hour	121.2 bc	107.3 cd	14.2 b	19.6 a
8	Sand	Constant	124.0 bc	108.0 c	14.0 b	21.6 a

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

by using inert media. 'BGA Southern Comfort' is listed in commercial catalogs as a '10 week' chrysanthemum, but in this experiment it flowered with just 7 weeks of short days. Early anthesis has been a significant finding in other trickle irrigation and inert media research [3 5 6 7].

Gatesburg sand material irrigated daily produced flowers with a mean fresh weight of 80.7 g and flower diameter of 13.1 cm, both parameters below the standard grade.

The tallest (mean 135.4 cm) and heaviest (mean 132.5 g) plants were produced in treatment 5 (constant irrigation on fine IAR). Treatments 4 and 5 produced the largest flowers, 14.5 and 14.7 cm respectively. Within the two irrigations used in fine IAR, there were significant increases in plant height and fresh weight, but not a significant increase in flower diameter, under constant irrigation. Plant height and flower diameter were significantly lower in treatment 6 (daily irrigation on Gatesburg sand) than for other treatments except treatment 1 (daily application on coarse IAR).

The large pore spaces in coarse and fine IAR allowed immediate infiltration of irrigation solution, and only daily applications on coarse IAR resulted in less favorable growth probably because of water stress. In treatments 6 (daily irrigation on Gatesburg sand) and 7 (4-hour irrigation on Gatesburg sand) water remained on the surface of the media until 10 min. after irrigation. The more frequent irrigation resulted in more favorable growth. 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 nor frequently enough in only daily application to supply oxygenated solution.

The water retention curves indicate three relationships. First, the water retention curve for Gatesburg sand shows very little release of water until tensions greater than 15.2 to 22.9 cm (depth of the bench) are reached. The Gatesburg sand remained near saturation throughout the experiment irrespective of irrigation treatments. Steiner [9] pointed out that oxygen could be supplied to plant roots in irrigation water.

Oxygen deficiency 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 treatment 6 received oxygenated solution less frequently. Better growth was realized when oxygenated solution was applied more frequently.

Second, 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 15.2 to 22.9 cm depth

of the greenhouse bench created sufficient tension to remove substantial amounts of water from both fine IAR and coarse IAR, allowing pore space for oxygen diffusion to roots, but this depth was not sufficient for the finer-textured Gatesburg sand material. Within a 30-minute period after the irrigation of plots of the Gatesburg sand soil material, excess solution drained away; whereas the irrigation solution held with less tension in the fine and coarse IAR drained continuously at a decreasing rate between irrigations. This suggests that the water in coarse IAR and to a greater extent in fine IAR, was more available to plants than the water in Gatesburg sand soil material.

Third, water content by volume of fine IAR in the 0 to 15 cm of water tension range was 10% greater than the content of coarse IAR. With the greater water content, hydraulic conductivity would be faster in fine IAR than in coarse IAR. The oxygen-water-nutrient balance in fine IAR, irrigated constantly or every 4 h, produced the best chrysanthemum growth.

CONCLUSIONS

1. Incinerated anthracite refuse is suitable media for the growth of chrysanthemums.
2. 'Viaflo' can be satisfactorily used to supply nutrients, water, and oxygen to plants.
3. Early anthesis occurs in chrysanthemums when grown with inert media and trickle irrigation.

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