Vegetable Section

Proc. Fla. State Hort. Soc. 110:258-261. 1997.

CONTAINER VOLUME AND MEDIA PARTICLE SIZE ALTER GROWTH OF STRAWBERRY TRANSPLANTS

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Additional index words. Fragaria × *ananassa,* containerized transplants, tray plants, plug plants, propagation, stand establishment, media aeration.

Abstract. **The commercial production of containerized strawberry transplants is being considered in many strawberry growing regions. In order to produce high quality containerized transplants, a suitable growing medium must be identified. The objective of this research was to determine what effect media aeration has on root and crown growth of 'Sweet Charlie' strawberry plug transplants fertigated with a capillary mat system. Vermiculite was separated into three particle sizes (0.13-0.24, 0.31-0.43, and 0.50-0.65 cm) and was placed into three container volumes (75, 150, and 300 cm³). Root imaging analysis (*MacRHIZO™*) was used to measure root growth parameters. Four weeks after planting, the plants from the 150 cm³ volume container with the 0.31-0.43 cm particle size vermiculite had the greatest root dry mass and root branching. There was a significant quadratic response of root branching to media aeration four weeks after planting. Optimal transplant growth and quality was therefore dependent on media aeration. Media particle size can be altered, based on container volume, to achieve optimal media aeration.**

Introduction

The development of a containerized (plug) strawberry transplant could eliminate many of the problems associated with bare-root transplants (Bish et al., 1997). Media quality is an important factor in plug production and has been reported as a major source of problems among transplant producers (Argo, 1997; Styer and Koranski, 1997). The physical properties of media impact plant support, aeration, moisture level, pH, nutrient adsorption, and soluble salts. An "ideal" medium for growth of vegetative propagules was defined by Long (1933) as a substance that is pathogen free, contains sufficient porosity for optimum aeration, has high water holding capacity, and provides good drainage.

One of the primary concerns of transplant media is aeration (Argo, 1997). Aeration has been defined as the volume of air in media, after saturation and gravitational draining, but before evaporation (Bugbee and Frink, 1986). Aeration has been studied by altering total porosity, particle size, and soil moisture tension. Researchers have studied the influence of particle size (Bilderback et al., 1982) and total porosity (Hanan et al. 1981) on aeration by adjusting constituent type in the media. The observed responses may have been due to chemical, biological and/or physical properties of the media.

Container dimensions can affect media physical characteristics (such as aeration and water holding capacity) and affect production costs (such as media quantity and production area) (Dufault and Waters, 1985). Research on container volumes has produced conflicting results (NeSmith and Duval, 1997), often due to confounding variables of container volume and dimensions (Knight et al., 1993; Latimer, 1991; Marsh and Paul, 1988; Dufault and Waters, 1985). Total porosity was the same in different volume containers with the same media, but air space increased (available water decreased) as container volume increased (Milks et al., 1989).

Problems have been demonstrated with growing plants in shallow containers, because of poor aeration of growing media. The poor aeration of the media was due to a 'perched water table' after irrigation (Spomer, 1974). Small containers (2.2 cm tall) had very low media air space (less than 2%) unless a large particle sized media with a high proportion of vermiculite to peat was used (Milks et al., 1989). The large particle sized media with a high proportion of vermiculite to peat however had a low percentage of available water (50%) which could lead to plant desiccation.

The objective of the present research was to determine what effect vermiculite particle size and transplant container size has on growth of strawberry transplants with uniform moisture supplied via capillary mat irrigation and nylon screened containers. The use of a capillary mat subirrigation system in conjunction with large particle sized media may provide optimum aeration and available water. Capillary mats covered with a perforated polyethylene foil had no algae growth, reduced evaporation, and prevented root growth into the mat (Bjerre, 1983). Additionally, containers with polyester fabric bottoms increased drainage and media air space (Ruter and van de Werken, 1991). The use of an inorganic potting medium, such as vermiculite, may help maintain high porosity since total porosity of organic media has been reported to decrease and bulk density increase after potting due to shrinkage (Fonteno et al., 1981).

Materials and Methods

The experiment was conducted at the University of Florida (Gainesville, FL) in a glass greenhouse maintained at 32°C

Florida Agricultural Experiment Station Journal Series No. N-01494.

Table 1. Physical properties of three particle sizes of vermiculite in three container volumes.

Container volume (cm^3)	Particle size (cm)	Media physical characteristics: Total porosity (%)	Aeration (%)	Bulk density (g/cm^3)
75	0.13-0.24	96	45	0.101
	0.31-0.43	96	62	0.104
	0.50-0.65	96	71	0.107
150	0.13-0.24	96	34	0.101
	0.31-0.43	96	56	0.104
	0.50-0.65	96	69	0.107
300	0.13-0.24	96	50	0.102
	0.31-0.43	96	66	0.105
	0.50-0.65	96	76	0.107
Source:	df	P>F	P>F	P>F
Particle size (P)	2	0.8328	0.0001	0.8706
Volume (V)	2	0.9165	0.0001	0.7222
P × V	4	0.9453	0.0001	0.8974
$LSD_{(0.05)}$ =			1.8	

Table 2. Nutrient concentrations of fertigation solution.

Element[z]	Concentration ($mg\ l^{-1}$)
N	30
P	10
K	30
Ca	30
Mg	10
S	16
B	0.2
Cu	0.05
Fe	1.2
Mn	0.1
Mo	0.01
Zn	0.1
EC = 700 µS	
pH = 5.7	

[z]Nutrients derived from: calcium nitrate, potassium nitrate, potassium phosphate, magnesium sulfate, boric acid, di-sodium copper, sodium EDTA ferric, di-sodium manganese, sodium EDTA molybdate, sodium EDTA zinc.

day and 25°C night. Shade cloth (30% shade) was used to provide a light intensity of 700 µmol m^{-2} s^{-1} during full sunlight. The photoperiod was extended to 16 hours with high pressure sodium halide lamps (150 µmol m^{-2} s^{-1}). Coarse vermiculite (Verlite Company, Tampa, FL) was screened to obtain three particle sizes (0.13 to 0.24, 0.31 to 0.43, and 0.50 to 0.65 cm). Three container volumes (75, 150, and 300 cm^3) were made by cutting 5.4 cm inside diameter polyvinyl chloride pipe to 3.25, 6.5, and 13 cm lengths, respectively. The containers were sealed on the bottom with nylon screen (0.6 mm).

Physical properties of the media were measured on five replicates and are listed in Table 1. Total porosity was calculated as [1- (bulk density/particle density)] × 100, where particle density was 2.61 (Wilson, 1983). Aeration was calculated as follows: masses of empty containers were recorded, dry media were placed in the containers and masses of media-filled containers were recorded. Media-filled containers were then placed on a capillary mat, media was saturated, and remained on the mat for 24 hours. Container, plus media, plus water mass was recorded after 24 hours on the mat. The percentage by volume of water was determined and subtracted from the total porosity to calculate aeration percent by volume.

On 3 Oct. 1995 'Sweet Charlie' strawberry (*Fragaria* × *ananassa* Duch.) daughter plant tips were rooted in each container particle size treatment by placing them under an intermittent mist (30 sec. mist each 12 min.) for one week (Bish et al., 1997a). Twenty-eight containers were grouped together (4 containers by 7 containers) to form an experimental unit (tray). Trays were arranged in a randomized complete-block design with one tray of each treatment per block replicated four times. After the plants were rooted in the containers for one week under an intermittent mist, the containers were placed on a capillary mat (Vattex F/M, OS Plastics, Inc., Norcross, GA) that was covered with perforated (5000 holes m^{-2}) black plastic (0.05 mm). Two drip irrigation tubes (30.5 cm emitter spacing with an output of 62 ml h-1 emitter-1 at 55 × 103 Pa) were placed underneath the capillary mat but above a white on black plastic mulch (0.03 mm thickness). Plants were fertigated (Table 2) three times a day for ten minutes each fertigation. The experiment was repeated 12 November 1995 using the same design.

Five plants were harvested from each treatment replication at 1, 2, and 4 weeks after planting. The response variables recorded were crown dry mass, root dry mass, projected root area, and number of root branches. Dry masses were obtained after plant material was dried for 72 hours at 70°C in a forced-air drying oven. Projected root area (two dimensional) and root branch number were measured using MacRHIZO™ (Regent Instruments, Quebec, Canada), a computer aided scanning analysis system (Arsenault et al., 1995).

The data were grouped by sampling date (1, 2, or 4 weeks) and subjected to Analysis of Variance (General Linear Models) to test for significance at the 95% confidence level (Littell et al., 1991). After determining significance, means were separated using Least Significant Difference.

Results and Discussion

Increasing vermiculite particle size resulted in increased media aeration in all container volumes (Table 1). Within each particle size of vermiculite, aeration increased from the 150 to the 300 cm^3 container, which might be due to increased gravitational draining (Bilderback and Fonteno, 1987). However, aeration also increased from the 150 to 75 cm^3 container. This could have been due to the lower mass of the 75 cm^3 container (60 g) as compared to the 150 cm^3 container (130 g) or the 300 cm^3 container (225 g). Therefore the smaller 75 cm^3 container may not have had sufficient mass to provide optimal contact between the vermiculite and the capillary mat for maximum water transfer.

Increased strawberry crown dry mass is important because it has been correlated with increased fruit production (Strik and Proctor, 1988). Increased container volume (depth) did not alter crown dry mass up to four weeks after planting. This observation supports previous research with other species that determined increased container depth did not alter broccoli or cauliflower transplant shoot dry mass after four weeks (Dufault and Waters, 1985). Crown dry mass decreased with all particle size treatments between one and two weeks after planting (Table 3). Crown dry mass increased between two and four weeks in the 0.31-0.43 cm particle size treatment, while crown dry mass decreased with the other two particle sizes during the same time period. Therefore the plants grown in the 0.31-0.43 cm particle size vermiculite had better crown development.

Table 3. Media particle size alters crown dry mass of strawberry transplants (cv. Sweet Charlie).

Container volume (cm^3)	Particle size (cm)	Sampling time after planting (weeks) 1	2	4
		Crown dry mass (mg)		
All	0.50-0.65	165	141	117
	0.31-0.43	171	139	154
	0.13-0.24	171	139	116
Source:	df	P>F		
Particle size (P)	2	0.0001		
Volume (V)	2	0.5581		
Time (T)	2	0.0001		
P × V	4	0.4480		
P × T	4	0.0001	$LSD_{(0.05)}$ = 13.2	
V × T	4	0.2425		
P × V × T	8	0.6208		

Root growth and quality are important for establishment of transplants (Weston and Zandstra, 1986). Except for the 75 cm^3 volume at 4 weeks, root dry mass was greatest in the 0.31-0.43 cm particle size for each container volume at each sample time (Table 4). Plants grown in the 150 cm^3 volume had the greatest root dry mass after four weeks for each particle size. Root projected area increased from two to four weeks in all the container volumes with the 0.31-0.43 and 0.50-0.65 cm particle sizes (Table 5). Although root projected area also increased from two to four weeks in the 300 cm^3 volume with all particle sizes, root dry mass was lower in the 300 cm^3 volume than in the 150 cm^3 volume for each particle size. The lower root dry mass in comparison to greater root area represents reduced dry matter accumulation and possibly a lower root quality.

Root systems with greater root branching may hold rooting media together better during transplantation and provide better transplant establishment through greater uptake of nutrients. There was a significant interaction of the main effects with root branching (Table 6). Root branching in the 75 or 150 cm^3 container volumes was greater after four weeks with the 0.31-0.43 cm particle size. However, root branching in the 300 cm^3 volume was greater after four weeks with the 0.13-0.24 and 0.31-0.43 cm particle sizes than the 0.50-0.65 cm particle size.

Table 5. Media particle size and container volume alter projected root area of strawberry transplants (cv. Sweet Charlie).

Container volume (cm^3)	Particle size (cm)	Sampling time after planting (weeks) 1	2	4
		Projected root area (cm^2)		
All	0.13-0.24	2.9	7.0	8.8
	0.31-0.43	4.3	8.8	20.7
	0.50-0.65	2.4	5.1	14.1
75	All	3.1	6.5	8.5
150		3.3	6.0	14.8
300		3.2	8.5	20.3
Source:	df	P>F		
Particle size (P)	2	0.0004		
Volume (V)	2	0.0026		
Time (T)	2	0.0001		
P × V	4	0.3834		
P × T	4	0.0086	$LSD_{(0.05)}$ = 7.8	
V × T	4	0.0047	$LSD_{(0.05)}$ = 7.8	
P × V × T	8	0.4717		

Media aeration was altered by particle size and container volume. There was a significant quadratic response of root branching to media aeration after four weeks (Fig. 1). Optimal particle size therefore depends on container volume. The 150 cm^3 container volume with the 0.31-0.43 cm particle size had a media aeration of 56%. Previous research with overhead irrigation determined optimal aeration to be approximately 20% (Bugbee and Frink, 1986). Our research indicates that higher aeration percentages in media intended for capillary mat systems may be beneficial. Very large particle sizes, such as the 0.50-0.65 cm particle size, could have decreased root/medium contact and therefore also decreased water/nutrient uptake. In conclusion, capillary mats can be used with media of optimal aeration (56%) to grow high quality strawberry plug transplants.

Table 4. Media particle size and container volume alter root dry mass of strawberry transplants (cv. Sweet Charlie).

Container volume (cm^3)	Particle size (cm)	Sampling time after planting (weeks) 1	2	4
		Root dry mass (mg)		
75	0.13-0.24	29	93	88
	0.31-0.43	53	75	89
	0.50-0.65	18	22	77
150	0.13-0.24	30	59	120
	0.31-0.43	41	93	190
	0.50-0.64	18	28	103
300	0.13-0.24	27	66	95
	0.31-0.43	31	72	138
	0.50-0.65	17	35	94
Source:	df	P>F		
Particle size (P)	2	0.0001		
Volume (V)	2	0.0001		
Time (T)	2	0.0001		
P × V	4	0.0001		
P × T	4	0.0001		
V × T	4	0.0001		
P × V × T	8	0.0001	$LSD_{(0.05)}$ = 4.2	

Table 6. Media particle size and container volume alter root branching of strawberry transplants (cv. Sweet Charlie).

Container volume (cm^3)	Particle size (cm)	Sampling time after planting (weeks) 1	2	4
		Root branch number		
75	0.13-0.24	78	142	482
	0.31-0.43	33	220	785
	0.50-0.65	11	35	229
150	0.13-0.24	34	99	605
	0.31-0.43	101	222	1043
	0.50-0.65	30	37	570
300	0.13-0.24	93	96	873
	0.31-0.43	45	133	826
	0.50-0.65	67	117	365
Source:	df	P>F		
Particle size (P)	2	0.0001		
Volume (V)	2	0.0001		
Time (T)	2	0.0001		
P × V	4	0.0001		
P × T	4	0.0001		
V × T	4	0.0001		
P × V × T	8	0.0001	$LSD_{(0.05)}$ = 62.0	

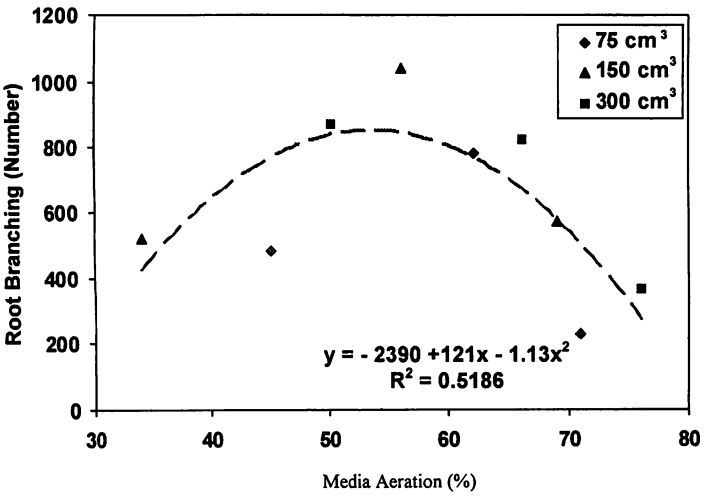

Figure 1. Strawberry root branching four weeks after transplanting as affected by media aeration.

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