Cell Size and Pretransplant Nutritional Conditioning Influence Growth and Yield of Transplanted 'Jubilee' Watermelon

Charles J. Graham,¹
James T. Payne,² and
Eric J. Molnar²

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SUMMARY. Increasing cell volume or pretransplant nutrient conditioning (PNC) reduced the time to flowering for staminate and pistillate flowers in watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]. Larger cell volumes increased the number of early harvested watermelons and average watermelon weight in two of three studies. Similarly, larger cell volume increased the early and total yield per area of watermelons harvested in 1995 and 1998, but not in 1997. Effect of transplant cell volume on soluble solids varied seasonally. PNC increased the number of melons and the yield per area harvested early in 1995 and soluble solids in early harvested fruit in 1997, but had no significant effect on total 'Jubilee' watermelon size or total production in Louisiana for 1995, 1997, or 1998. PNC offers the transplant grower little advantage, while increasing transplant cell size provides a grower with a better opportunity to produce increased early and total yields.

Transplanting is the most efficient method to establish a watermelon crop because of the increasing costs of hybrid dip-

loid and triploid seed. Transplants can also increase earliness (Ivanhoff et al., 1960; Nettles, 1963; Norton, 1968) and reduce field establishment costs of direct seeding in the field with expensive hybrid seed (Ivanhoff et al., 1960; Giacchetti, 1997). Cell volume of transplant flats and nutrition during transplant growth can affect subsequent transplant growth and development, and yield in the field.

Multicell seedling flats are convenient for both propagating and handling vegetable transplants. Plants grown in small cells are less expensive to produce than those in large cells because less greenhouse space and media are required (Dufault and Waters, 1985; Weston and Zandstra, 1986). Small cells also permit the handling of fewer trays for transport and transplanting. Smaller cell volumes, however, often produce smaller transplants that grow less vigorously (Dufault and Waters, 1985; Marsh and Paul, 1988; Weston and Zandstra, 1986) and sometimes produce lower yields than comparable plantings established from larger transplants produced by large cell volumes (Marsh and Paul, 1988; Vavrina, 1997; Weston and Zandstra, 1986).

Pretransplant nutritional conditioning (PNC) has been shown to influence transplant quality, seedling establishment, and yield for several crops (Adler et al., 1984; Melton and Dufault, 1991; Schultheis and Dufault, 1994; Weston and Zandstra, 1989). Early harvests were increased by high PNC vs. low PNC for muskmelon (*Cucumis melo* L.) (Dufault, 1986) and tomato (*Lycopersicon esculentum* Mill.) (Weston and Zandstra, 1989), but total yields of both crops were unaffected.

Research is needed to better understand the influence of cell volume and nutrition on watermelon transplant size, plant development, and production in the field in order to determine the most economic production practices. The primary objective of this study was to compare the effect of flat cell volume and PNC on early and cumulative production and quality of transplanted 'Jubilee' watermelons.

Materials and methods

On 7 Apr. 1995, 22 Apr. 1997, and 9 Apr. 1998, 'Jubilee' watermelon seeds were planted 0.5 inch deep in a peat-vermiculite mix (Metro-Mix 366,

Scotts-Sierra, Marysville, Ohio) placed in 18-, 32-, 72-, and 128-cell TODD planter flats (Speedling, Inc., Sun City, Fla). Two seeds were planted per cell and thinned to one plant per cell after germination. The 4 × 4 factorial experiment consisted of four cell volumes [1.9 (30.7), 4.0 (65.5), 9.0 (147.5), and 21.3 inch³ (349.6 cm³)] and four fertilizer rates (0, 25%, 50%, and full strength Hoagland's solution) arranged in a randomized block design with five replications. Full strength Hoagland's solution contained the following concentration of nutrients: 15 μM N, 1 μM P, 6 μM K, 5 μM Ca, 2 μM Mg, 46 μM B, 9 μM Mn, 0.8 μM Zn, 0.5 μM Mo, and 0.3 μM Cu (Hoagland and Arnon, 1950). The watermelon seedlings were irrigated daily with the nutrient solutions for 3 weeks and transplanted on 28 Apr. 1995, 13 May 1997, and 30 Apr. 1998.

Before planting, the Ruston fine sandy loam soil (fine-loamy, siliceous, thermic, Typic Paleudults) was prepared in late April by incorporation of 550 lb/acre (617 kg·ha⁻¹) of 8N-10.5P-19.9K. The final beds were formed and white and black polyethylene mulch was laid. The raised beds [6 inches (15 cm) high × 18 inches (45 cm) wide on 10 ft (3 m) centers] were irrigated using drip lines underneath the mulch.

The 3-week-old watermelon seedlings were transplanted into holes punched in the polyethylene mulch at 3 ft (0.9 m) in-row spacing. Each transplant received 16 oz (0.5 L) of 20N-8.7P-16.6K water soluble fertilizer mixed at a concentration of 200 ppm (mg·L⁻¹) nitrogen. Each treatment plot contained six plants and was replicated five times in a randomized complete block design. Weed control in the row middles was controlled by application of trifluralin, dimethyl tetrachloroterephthalate, paraquat, and hand weeding. Pesticides were applied as needed for control of insects (carbaryl, endosulfan, and esfenvalerate) and gummy stem blight (chlorothalonil, mancozeb, and benomyl).

Following transplanting, the plants were checked daily for flowers and the date of first open staminate and pistillate flower were recorded for each plant. Mature fruit were harvested on 27 June, 11 July, and 18 July 1995; 23, 30 July, and 6 Aug. 1997; and 29 June, 6, 13, and 20 July 1998. The

Calhoun Research Station, P.O. Box 539, 321 Highway 80 East, Louisiana State University Agricultural Center, Calhoun, LA 71225.

¹Assistant professor.

²Research associate.

Table 1. Days to first staminate and pistillate flowers of watermelon transplants as affected by different root cell volumes and fertility during transplant production for 1995 and 1998.

Effect	1995		1998	
	Staminate	Pistillate	Staminate	Pistillate
Cell volume [inch ³ (cm ³)]				
1.9 (30.7)	25	31	29	34
4.0 (65.5)	23	30	26	32
9.0 (147.5)	21	28	24	31
21.3 (349.6)	18	27	23	29
Contrasts				
Linear	***	***	***	***
Quadratic	NS	NS	NS	NS
Hoagland's concentration				
Water	23	29	27	32
25% strength	22	29	25	31
50% strength	22	28	24	31
Full strength	21	28	25	31
Contrasts				
Linear	***	***	**	NS
Quadratic	NS	NS	*	NS
Interaction				
Cell volume × fertility	NS	NS	NS	NS

NS, ***, ****, ***** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

first harvest in 1995 and 1997 and the first two harvests in 1998 were used to determine early yields. All of the harvests for each individual year were combined for the total harvest data. The

harvested fruit were counted, weighed, and the soluble solids determined by use of a hand-held refractometer (model 852057; Fisher, Pittsburgh, Pa.) to evaluate treatment effects on

fruit quality. All data were subjected to general linear models procedure of SAS (version 6.07, SAS Institute, Cary, N.C.). Regression analysis was used to determine trends of significant main effects.

Results

TIME OF FLOWERING. Increasing cell volume linearly reduced the length of time of appearance of the first staminate and pistillate flowers following transplanting to the field in 1995 and 1998 (Table 1). Increasing nutrition significantly shortened the time of appearance of the first staminate flowers following transplanting to the field in 1995 and 1998 and appearance of pistillate flowers in 1995. Flowering data were not completed in 1997 and are not presented. No significant cell volume × nutrition interaction was observed for flowering of the watermelon transplants in any year.

YIELD (FRUIT NUMBER). Increasing cell volume linearly increased watermelon number per area in 1995 for both early and total harvests (Table 2). Early yield also linearly increased with higher fertility rates. Early yield was much more affected by cell volume than total yield. Neither cell volume nor fertility rate affected the number of watermelons per area in 1997. Adverse growing conditions and disease

Table 2. Number of fruit per acre for early and total harvest of 'Jubilee' watermelon as affected by root cell volumes and fertility during transplant production in 1995, 1997, and 1998.

Effect	1995		1997		1998	
	Early	Total	Early	Total	Early	Total
Cell volume [inch ³ (cm ³)]						
1.9 (30.7)	254	653	363	774	459	1137
4.0 (65.5)	399	895	433	981	726	1149
9.0 (147.5)	666	956	427	954	920	1379
21.3 (349.6)	672	895	423	853	944	1234
Contrasts						
Linear	***	*	NS	NS	***	NS
Quadratic	NS	NS	NS	NS	NS	NS
Hoagland's concentration						
Water	341	690	446	892	702	1186
25% strength	460	859	397	892	802	1210
50% strength	656	980	399	932	835	1331
Full strength	535	871	399	826	726	1174
Contrasts						
Linear	*	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS
Interaction						
Cell volume × fertility	NS	NS	NS	NS	NS	NS

²1 fruit/acre = 2.47 fruit/ha.

NS, ***, ****, ***** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

pressure reduced watermelons per area compared with 1995 values. Increasing cell volume linearly increased watermelons per area for early yield in 1998, while total yield was unaffected.

YIELD (CWT PER ACRE). Increasing cell volume linearly increased water-

melon yield per area in 1995 for both early and total harvest (Table 3). Early yield linearly increased with higher fertility rates. One-half strength Hoagland's solution produced the greatest watermelon yield per area. Cell volume or fertility rate had no

significant influence on 1997 yields because of poor growing conditions and severe disease pressure reduced yield. Increasing cell volume linearly increased watermelon yield per area for both early and total harvest in 1998, while no affect due to nutrition

Table 3. Yield of fruit for early and total harvest of 'Jubilee' watermelon as affected by root cell volumes and fertility during transplant production in 1995, 1997, and 1998.

Effect	1995		1997		1998	
	Early	Total	Harvest (cwt/acre) ^z		Early	Total
			Early	Total		
Cell volume [inch ³ (cm ³)]						
1.9 (30.7)	61.5	174.1	85.7	164.3	102.8	229.9
4.0 (65.5)	98.9	237.9	99.4	204.8	172.9	257.5
9.0 (147.5)	171.8	253.0	106.2	202.3	217.0	302.9
21.3 (349.6)	179.7	244.5	94.2	173.2	233.9	286.4
Contrasts						
Linear	***	*	NS	NS	***	*
Quadratic	NS	NS	NS	NS	NS	NS
Hoagland's concentration						
Water	87.0	188.2	98.3	178.9	172.4	262.3
25% strength	117.6	231.4	100.1	191.0	191.3	264.4
50% strength	168.8	258.5	96.7	196.7	197.4	293.2
Full strength	138.4	231.6	88.0	171.6	170.0	256.8
Contrasts						
Linear	*	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS
Interaction						
Cell volume × fertility	NS	NS	NS	NS	NS	NS

^z1.0 cwt/acre = 112.1 kg·ha⁻¹.

NS,*,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 4. Average fruit weight for early and total harvest of 'Jubilee' watermelon as affected by root cell volumes and fertility during transplant production in 1995, 1997, and 1998.

Effect	1995		1997		1998	
	Early	Total	Harvest (lb/fruit) ^z		Early	Total
			Early	Total		
Cell volume [inch ³ (cm ³)]						
1.9 (30.7)	24.2	27.1	23.6	21.4	22.6	20.6
4.0 (65.5)	24.6	26.5	21.5	20.2	24.2	22.3
9.0 (147.5)	25.1	26.2	24.0	21.1	24.0	22.0
21.3 (349.6)	27.6	27.4	24.2	20.9	25.0	23.4
Contrasts						
Linear	***	NS	NS	NS	*	**
Quadratic	NS	NS	NS	NS	NS	NS
Hoagland's concentration						
Water	25.4	27.5	22.6	19.8	24.9	22.5
25% strength	25.0	26.9	23.9	21.8	24.1	21.7
50% strength	25.7	26.5	24.1	20.7	23.3	22.2
Full strength	25.6	26.2	22.7	21.3	23.6	21.9
Contrasts						
Linear	NS	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS
Interaction						
Cell volume × fertility	**	NS	NS	NS	NS	NS

^z1.0 lb/fruit = 0.454 kg/fruit.

NS,*,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

treatments were detected.

AVERAGE FRUIT WEIGHT. The average weight of early harvested fruit was significantly increased as cell volume increased, but this did not hold true for the total harvest data in 1995 (Table 4). Although PNC had no influence on average fruit weight in 1995, there was a significant interaction between cell volume and nutrition on the average fruit weight of early harvested melons. Cell volume or fertility rate had no significant influence on watermelon fruit weight measured in 1997. Although not significant, the smallest cell volume tended to produced the least number of watermelons per area but the largest average melon weight. The average weight of harvested fruit was significantly increased as cell volume increased for both the early and total harvest data in 1998. Nutritional conditioning had no statistically measurable role in fruit size regardless of growing year.

FRUIT SOLUBLE SOLIDS. Soluble solids concentration linearly increased with increasing cell volume for early and total harvests in 1995 (Table 5). Fertility had no significant effect on the concentration of soluble solids in 1995, but did linearly increase the soluble solids concentration of early harvested watermelons in 1997. Soluble solids were not affected by cell volume or transplant PNC in 1998.

For each year, no significant interactions occurred between cell size and fertility for fruit soluble solids data.

Discussion

The decreases in time to flowering with respect to cell size and nutritional conditioning agree with other reports on watermelon transplant production (Liu and Latimer, 1995; Schultheis and Dufault, 1994). The larger cell volume transplants became established more quickly and vined sooner than transplants produced in smaller cell volume trays, while the nutritional conditioning was variable in plant response with the smaller cells being the most affected. Hall (1989) also noted that the rate of vine growth was greater in plants grown in larger than smaller ones once transplanted to the field. Transplants with relatively large root systems generally suffer less postplant shock and thus come into production earlier than plants with small root systems (Weston and Zandstra, 1986).

Many morphological and physiological responses of plants to varying container sizes and root restriction conditions have been reported. However, of most concern to the end user of the transplant is the postplant performance of the seedling. Of particular concern is crop yield resulting from transplants grown in different con-

tainer sizes (NeSmith and Duval, 1998). In our studies, varying transplant container size when growing watermelon has shown mixed results for early and total yields. The increases in total number of watermelons per area in 1995 and the total yield per area in response to increasing cell volume in 1995 and 1998 for this study agree with research by Liu and Latimer (1995). They reported the number of watermelons and the total yield of 'Starbrite' watermelons significantly increased as cell volume increased, but there was no significant effect on fruit weight. Hall (1989) reported that 'Charleston Gray' watermelon plants grown in 2.4-inch³ (40-cm³) cells produced greater late and total yields than those grown in 1.2-inch³ (19-cm³) cells, but 'Crimson Sweet' yield was not affected by cell size. Vavrina et al. (1993) also reported no significant differences in total yield of 'Charleston Gray' transplants produced in 1.2-, 1.9-, and 4.0-inch³ (19-, 30.7-, and 65.5-cm³) cells. The data from this study and previous research suggest that an environmental interaction as well as differences in cultivar response may be influencing watermelon yield.

Commercial production of transplants needs to be as pragmatic as possible. Complex nutritional practices are only justified if the subsequent transplants perform better in

Table 5. Fruit soluble solids concentration of 'Jubilee' watermelon as affected by root cell volumes and fertility during transplant production in 1995, 1997, and 1998.

Effect	1995		1997		1998	
	Harvest (%)		Harvest (%)		Harvest (%)	
	Early	Total	Early	Total	Early	Total
Cell volume [inch ³ (cm ³)]						
1.9 (30.7)	10.8	10.8	10.2	10.2	11.3	10.9
4.0 (65.5)	11.2	11.1	9.8	10.2	11.2	10.9
9.0 (147.5)	11.9	11.5	10.0	10.0	11.2	11.1
21.3 (349.6)	12.0	11.6	10.1	10.2	11.4	11.2
Contrasts						
Linear	***	***	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS
Hoagland's concentration						
Water	11.7	11.3	9.6	10.0	11.3	11.0
25% strength	11.4	11.2	9.9	10.0	11.2	11.0
50% strength	11.4	11.3	10.5	10.4	11.2	11.0
Full strength	11.6	11.2	10.2	10.2	11.2	11.0
Contrasts						
Linear	NS	NS	*	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS
Interaction						
Cell volume × fertility	NS	NS	NS	NS	NS	NS

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

the field. Performance includes improvements in stand establishment coupled with enhancements in one or more attributes of earliness, uniform maturity, yield quantity and quality, and postharvest holding superiority (Dufault, 1998). In this study, PNC significantly increased the fruit number and tonnage for early harvests in 1995 and soluble solids in early harvested fruit in 1997 but had no significant effect on total 'Jubilee' watermelon production or fruit quality in Louisiana for 1995, 1997, or 1998. This agrees with reports by Schultheis and Dufault (1994) on watermelons grown in North Carolina and South Carolina. They found total yield of 'Queen of Hearts' and 'Crimson Sweet' watermelons were unaffected by PNC treatments of 25 to 225 ppm (mg·L⁻¹) nitrogen and 5 to 45 ppm phosphorus. The limited research of PNC on watermelon suggests that there is no significant advantage of using low or high rates of nutrients in transplant production in regard to the total production of watermelons.

This study provides supporting evidence that container size is an important consideration for watermelon transplant consumers who seek to optimize early production and maximize total production. While transplant producers opt for smaller cell volumes to reduce transplant cost, a median must be found to provide the least expensive transplant while not sacrificing yields and profits for the vegetable grower.

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