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Yield Response of Watermelon to Planting Density, Planting Pattern, and Polyethylene Mulch

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Abstract. **One or two plants per hill of 'Prince Charles' and 'Royal Jubilee' watermelon were grown with drip fertigation at five in-row spacings, with or without polyethylene mulch, in four location × year combinations (environments). Rows were 1.5 m apart and in-row spacings were 45, 60, 90, 120, and 150 cm. 'Royal Jubilee' yielded more than 'Prince Charles' in all environments, and the highest yields were associated with low percent culls and high fruit numbers per hectare. Highest yields of marketable fruits (≥4.5 kg/melon) were obtained using polyethylene mulch and areas per plant between 0.4 and 0.9 m². Average weight per melon, however, was ≥9 kg only at areas per plant >0.9 to 1.0 m². Unless there is a market for small fruits (≥4.5–9 kg), optimum area per plant was ≈1.0 m². Results for one plant per hill at one in-row spacing were similar to those for the alternative planting pattern of two plants per hill at half the in-row spacing, thus supporting the feasibility of using the more economical alternative planting pattern.**

Although costly, the use of black polyethylene mulch enhances earliness, raises yields, improves fruit quality, and increases the profitability of growing many crops in the southeastern United States (Bryan, 1966; Lamont, 1993). Currently, watermelon growers may profit by using polyethylene mulch, but they may be failing to maximize yields if they are following recommendations for spacing based on earlier work with nonmulched plantings.

In general, experimental data fit models in which crop yields increase with planting density to a maximum, then plateau or decrease at some threshhold density (Holliday, 1960; Willey and Heath, 1969). This threshold density should produce higher yields as environmental conditions are optimized, as when polyethylene mulch and drip fertigation are used. Optimum plant density may also shift as growing conditions improve (Nichols, 1983). Without mulch, linear increases in watermelon yields were obtained as area per plant decreased from: 11.3 to 2.8 m² (Halsey, 1959); from 3.3 to 1.35 m² (NeSmith, 1993); and from 0.9 to 0.6 m² (Srinivas et al., 1989). Watermelon yield per hectare also increased as area per plant decreased from 10.8 to 0.9 m², and mulch increased yields at all spacings when irrigation was adequate (Brinen et al., 1979). Apparently, a threshold density at which yield leveled off or decreased was not reached in these experiments, and thus optimum spacings for watermelon remain uncertain. In Georgia, the recommended population density for watermelons is 2500 to 3000 plants/ha (area per plant of 4 m²; Granberry et al., 1986). For North Carolina, Schultheis (1995) recommends spacing of 3.7 to 4.7 m²/plant if not irrigated, and 2.3 m²/plant when supplemental irrigation is used. Thus, there is a need to evaluate the response of watermelon to high planting density when polyethylene mulch and drip fertigation are used.

Another technique for enhancing earliness is the use of transplants. Like the use of polyethylene mulch, this is more expensive, but the extra cost can usually be more than repaid with premium prices in the early market. One possibility for lowering the cost of transplanting would be the use of two plants/hill. For instance, if the in-row spacing were doubled to two transplants/hill (thus maintaining average area per plant), the number of transplant operations per hectare would be halved. This work was undertaken to evaluate the effects of in-row spacing and of planting pattern (one vs. two plants/hill) on yield variables of watermelon using black polyethylene mulch and drip fertigation.

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Materials and Methods

Watermelon hybrids 'Prince Charles' (Charleston Grey type) and 'Royal Jubilee' (Jubilee type) were used in experiments in four environments in 1988, 1989, and 1990. The effects of inrow spacing and planting pattern on yield variables were evaluated with and without polyethylene mulch. A split-split plot design was used, with location × year combinations as main plots, in row spacing, planting pattern and mulch treatments as subplots and cultivars as sub-subplots. Experiments were replicated four times in each environment. Statistical analysis was conducted using the SAS GLM Procedure (SAS Institute, 1985).

Prior to bedding the rows, 5 kg·ha^{-1} N and 83 kg·ha^{-1} K fertilizer was broadcast. Rows were raised beds 0.8 m wide, 1.5 m apart on centers, and 6.1 m long. Drip irrigation tubing (Roberts RoDrip, Roberts Irrigation, San Diego) was placed 0.10 m from the row center and 0.05 m deep in the soil at least 5 d prior to planting. Black polyethylene mulch (0.03 mm thick, 1.5 m wide) was applied. All plots were fumigated with 220 kg·ha^{-1} 98/2 methyl bromide/chloropicrin. After 5 to 7 d, the polyethylene was removed from treatments without mulch and plots were direct-seeded with three seeds/hill. In-row spacings were 45, 60, 90, 120, and 150 cm for polyethylene mulch treatments, and 45, 90, and 150 cm for plots without mulch. Upon emergence, hills were thinned to one or two plants according to treatment.

In 1988, seeds were planted on 27 Apr. and fruits were harvested 17 July and 2 Aug. at Clinton, N.C., in a Wagram loamy sand (Arenic Paleudult-loam, Siliceous, Thermic). In 1989, seeds were planted on 28 Apr., and fruits were harvested 15 July and 1 Aug. at Clinton, in a Norfolk sandy loam (fine-loamy siliceous thermic Typic Paleudults). In 1990, seeds were planted on 29 Apr. and fruits were harvested 16 July and 3 Aug. at Clinton, in an Orangeburg sandy loam (fine-loamy, siliceous, thermic Typic Paleudults), and at Lewiston, N.C., seeds were planted 2 May and fruits were harvested 17 July and 2 Aug in a Norfolk loamy sand. For all environments, fertigation was applied weekly. Irrigation was applied daily when soil tension reached –0.2 mPa and was terminated when soil tension reached –0.1 mPa. Fertilization was applied weekly for a final application of 120 kg·ha^{-1} N and 175 kg·ha^{-1} K. Alanap (sodium 2-[(1-naphthalenylamino) carbonyl] benzoate), Sevin (l-naphthyl *N*-methyl carbamate), and Thiodan (hexachlorohexahydromethano-2,4,3 benzodioxathiepin 3-oxide), and Maneb (manganese ethylene bisdithio carbamate) were applied according to labels. Marketable melons were large (≥9.0 kg) plus medium (4.5–9.0 kg). Culls were misshapen, <4.5 kg, or partially injured or rotted.

Results

Variety. In all locations and years, 'Royal Jubilee' yielded significantly ($P \leq 0.05$) more than 'Prince Charles' (Table 1). 'Royal Jubilee' had higher numbers of marketable fruit per hectare (significant in all comparisons) and tended to have higher individual weights (statistically significant in only two of the four comparisions). There was no varietal difference in percentage of culls except in the 1990 Clinton study.

Polyethylene mulch. Polyethylene mulch increased marketable yield at nearly all in-row spacings at either one or two plants/hill (Fig. 1A). Also, the number of marketable fruits per hectare (Fig. 1B) was increased 30% to 60% by polyethylene mulch at close spacings. However, LSDs indicated nonsignificance at 90- and 150-cm in-row spacings. Weight per melon was increased by polyethylene mulch at nearly all in-row spacings and both planting patterns (Fig. 1C); this increase effectively decreased the percentage of culls from 40% to 25% in the very high density (close spacing) treatments where many melons were borderline in size (Fig. 1D). The mulch significantly increased the number of larger melons per hectare at all plant spacings (Fig. 2A), but had little effect on the numbers of medium-sized melons except for an increase at the closest spacing (Fig. 2B).

Spacing. The in-row spacing or area per plant also significantly affected the yield variables (Fig. 1). Yield was highest in a range between 0.7 and 0.9 m^2/plant. A significant decrease was observed at the highest density planting (45-cm in-row spacing for the two plants/hill pattern) both with and without mulch, and a trend towards decreased yields at lower density (higher area per plant) as well (Fig. 1A). Generally, the number of marketable melons per hectare decreased as in-row spacing increased. However, at the closest in-row spacing (45 cm, two plants/hill), marketable fruit number decreased both with and without polyethylene mulch (Fig. 1B). Average weight per melon increased with both in-row spacing and area per plant (Fig. 1C). For melons grown on polyethylene mulch, the 9.0-kg size was reached at ≈1 m^2/plant. Percentages of culls were 12% to 20%, and were unaffected by spacing except in the 45-cm, two plants/hill treatment (Fig. 1D). At this spacing a significant increase in culls occurred, to 26% (with polyethylene) and 40% (without polyethylene). As in-row spacing and area per plant increased, the number of medium-sized melons decreased and the number of larger melons increased significantly (Fig. 2 A and B).

Planting pattern. There were no significant differences between the two plants/hill and the one plant/hill planting patterns at any spacing (m^2 per plant) for any of the variables (Figs. 1 and 2).

Discussion

Polyethylene mulch did not appear to shift the density at which yield per hectare began to drop. However, it increased yields at all in-row spacings. Its effects on fruit number and yield per hectare were slightly greater at the closest spacings (higher planting densities). These results are in general agreement with past work with watermelons (Brinen et al., 1979; Bryan, 1966; Nettles, 1963; Soltani et al., 1995), extending it to very high densities.

Yield was highest in the range of 0.7 to 0.9 m^2/plant with polyethylene mulch. However, high yields combined with individual average fruit mass of ≥9.0 kg occurred only at spacings ≥0.9 to 1.0 m^2/plant or at in-row spacing >≈70 cm in single-seeded rows 1.5 m apart. At wider spacings, yield per hectare began to drop. At closer spacings, average weight per melon

Table 1. Mean yield variables for 'Prince Charles' and 'Royal Jubilee' watermelons grown in four year × location combinations (environments).

Environment	Cultivar	Yield[z] (Mg·ha^{-1})	Wt per melon[z] (kg)	No. per hectare[z] (1000s)	Culls (%)[y]
Clinton '88	Prince Charles	68.7	7.9	8.6	21.2
	Royal Jubilee	83.2	8.3	10.0	20.6
Clinton '89	Prince Charles	96.8	7.5	12.7	20.1
	Royal Jubilee	120.8	7.7	16.0	17.4
Clinton '90	Prince Charles	145.7	8.9	16.5	16.3
	Royal Jubilee	195.3	9.6	21.1	12.0
Lewiston '90	Prince Charles	90.5	9.3	9.6	9.4
	Royal Jubilee	115.7	9.4	12.4	13.0
	$LSD_{0.05}$ (environment × cultivar)	12.1	0.3	0.6	3.7

[z]Yield, wt/melon, and no./ha refer to marketable melons, [medium (≥4.5 kg) + large (≥9.0 kg)].
[y]Culls were calculated as percentage of total yield.

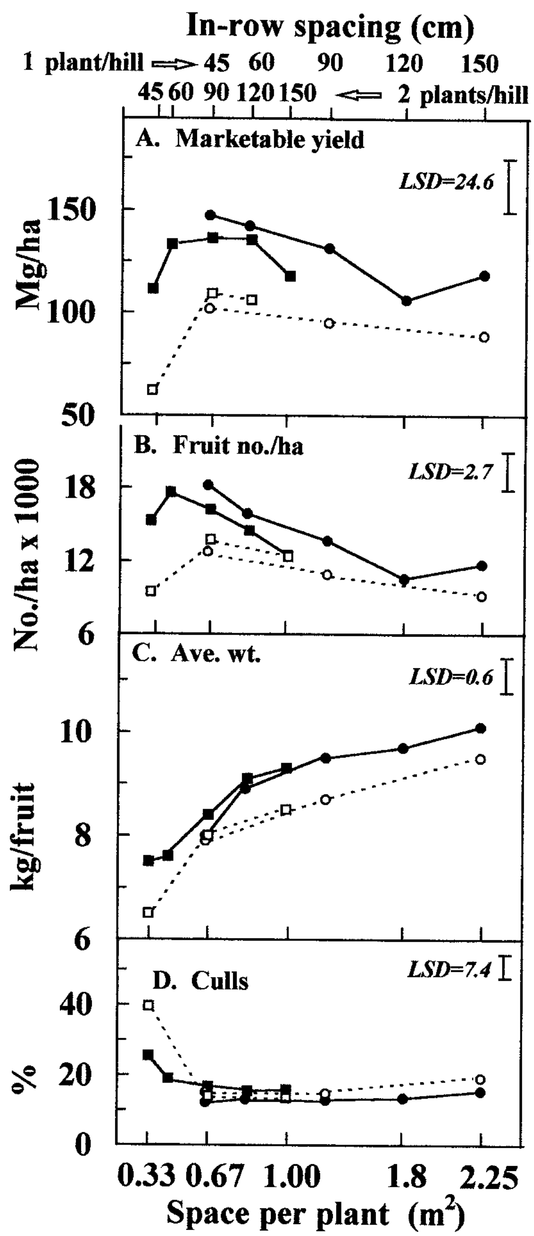

Fig. 1. Yield variables for watermelon grown at five in-row spacings and one or two plants/hill with or without poleyethylene mulch. Each point represents a mean of four replicates from each of four year × location combinations. ■—■, two plants/hill + mulch; ❑—❑, two plants/hill – mulch; ●—●, one plant/hill + mulch; ❍—❍, one plant/hill – mulch.

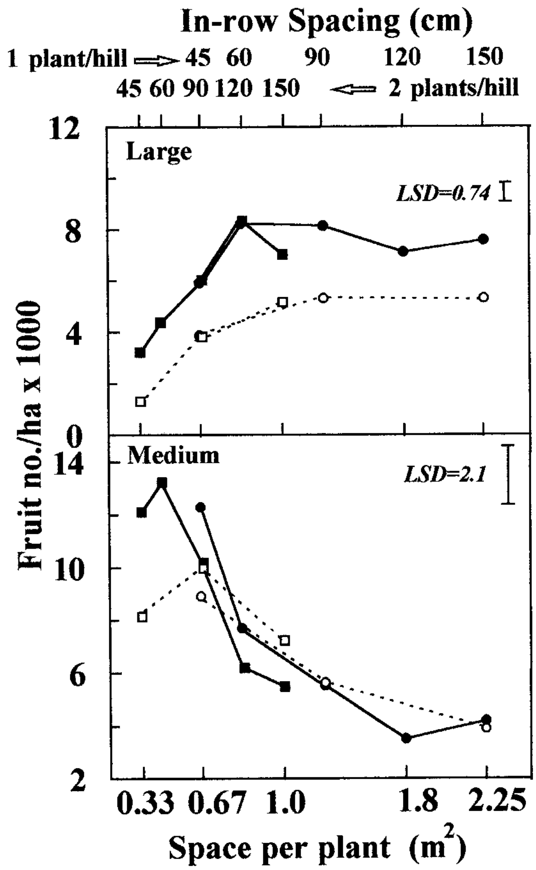

Fig. 2. Fruit number per hectare for large (≥9.0 kg) and medium (4.5–9.0 kg) watermelons grown at five in-row spacings and one or two plants/hill with or without polyethylene mulch. Each point represents the mean of four replicates from each of four year × location combinations: ■—■, two plants/hill + mulch; ❑—❑, two plants/hill – mulch; ●—●, one plant/hill + mulch; ❍—❍, one plant/hill – mulch.

dropped below 9.0 kg. If there were a market for the smaller melons, spacings as close as 0.45 m^2/plant could be used. This is the density recently proposed for production of mini-watermelons (2- to 4-kg fruits) in Australia (Barnes et al., 1994).

One plant at a given in-row spacing behaved similarly to two plants at double the in-row spacing. This observation contrasts with results for asparagus, in which yield increases of up to 100% were obtained when plants were spaced at 15 cm in three rows/bed vs. spacing at 5 cm in one row per bed (Sanders et al., 1997). Nichols (1983) proposed the concept of rectangularity, the ratio of between-row to within-row spacing, observing that ratios >1 reduced asparagus yields. Watermelons appear to be able to exploit the below- and aboveground resources (water, nutrients, light) equally well whether or not they are uniformly spaced.

These data provide a basis for new, closer spacing recommendations for watermelons (0.9–1.0 m^2/plant) on the coastal plain of North Carolina and neighboring regions, as long as water and nutrients are not limiting. They also support the option of planting double-seeded transplants at half the sites in a row, at a significant savings in labor and transplant cost per hectare.

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