Diploid Watermelon Pollenizer Cultivars Differ with Respect to Triploid Watermelon Yield

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SUMMARY. As triploid watermelons (*Citrullus lanatus*) increase in popularity, production has shifted away from seeded watermelons. To achieve successful fruit set in triploid watermelons, a diploid watermelon cultivar must be planted as a pollen source. Three diploid cultivars in 2005 and seven diploid cultivars in 2006 were evaluated at one and three locations, respectively, to determine their effectiveness as pollenizers. Each cultivar was planted within plots of the triploid watermelons 'Tri-X 313' (2005) and 'Supercrisp' (2006) with buffers on all sides of the plots to contain pollen flow within individual plots. Performance of pollenizers was based on triploid watermelon yield, soluble solids concentration, and incidence of hollowheart. In 2005, there were no significant differences in total weight, fruit per acre, average weight, or soluble solids concentration among pollenizers. In 2006, significant differences in yield were observed, and plots with 'Sidekick' as a pollenizer yielded the highest but were not significantly different from 'Patron', 'SP-1', 'Jenny', or 'Mickylee'. In 2006, there were no significant differences in fruit per acre, soluble solids concentration, or incidence of hollowheart between pollenizers. The experimental design was successful in isolating pollenizers and there was minimal pollen flow outside of experimental plots as indicated by minimal fruit set in control plots.

Over the last decade, the popularity of triploid watermelons has increased. However, unlike diploid or seeded watermelons, triploid watermelon plants have an uneven number of chromosomes and consequently are not able to produce viable pollen (Maynard, 1992; Maynard and Elmstrom, 1992). Hormones provided by pollen tube growth and ovule fertilization are needed for triploid fruit set (Gillaspy et al., 1993). Diploid cultivars can provide pollen for the pollination of the triploid cultivar. To achieve optimal triploid watermelon yields, 20% to 33% of the plants in the field should be diploid to provide pollen for triploid cultivars (Fiacchino and Walters, 2003; NeSmith and Duval, 2001).

Traditionally, dedicated rows have been set aside for the diploid cultivars. A wide range of pollenizer cultivars are now available for in-row planting between existing triploid plants. By eliminating dedicated row space in the field for pollenizers, the number of triploid plants per acre increases and per-acre yield should increase. These pollenizer cultivars are relatively new and the concept itself is new in the United States, so little work has been done comparing the attributes of these cultivars in this specific role.

Pollenizer cultivars may have distinctly different growth habits. The most important characteristics of these cultivars are: 1) abundance of male flowers and pollen, 2) noncompetitive growth habit, and 3) distinct fruit size or rind pattern. It is important that the cultivars have high numbers of male flowers throughout the season to provide adequate pollen for fruit set in the triploid crop. Walters (2005) reported that between 16 and 24 honeybee (*Apis mellifera*) visits were required for maximum fruit set in triploid watermelon. These results were attributed to the dilution of viable diploid pollen with nonviable triploid pollen in a field. Increased staminate flower numbers produced by pollenizer cultivars could lead to greater reproductive success and greater triploid watermelon yields. It is also important that the pollenizer growth habit does not compete with the triploids. It has been shown in pumpkin (*Cucurbita pepo*) and watermelon that intraspecific competition can shift the size distribution and amount of fruit produced by the plant (Cushman et al., 2004; Motsenbocker and Arancibia, 2002; Sanders et al., 1999). Other important characteristics of the pollenizer cultivar are the size and rind pattern of the fruit, which enable a harvesting crew to distinguish marketable fruit from pollenizer. Fiacchino and Walters (2003) observed differences in yield and quality characteristics of triploid watermelons when different pollenizers were used, and it was hypothesized that these differences may also be seen when newer pollenizers are used. Greater yields and lower incidence of hollowheart were reported in 'Millionaire' seedless watermelon when 'Crimson Sweet' was used as the pollenizer when compared with 'Fiesta'. Fiacchino and Walters (2003) also reported greater incidence of hollowheart at lower pollenizer-to-triploid ratios. Other studies on 'Crimson Sweet' and 'Fiesta' have reported that there were no significant differences in staminate flower or pollen production between these two cultivars (Stanghellini and Schultheis, 2005). Walters (2005) reduced pollination in triploid watermelon by controlling honeybee visitations, but observed no effect on hollowheart in triploid fruit. It is unclear whether hollowheart disorder in watermelon is a result of poor pollination of existing

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
0.1242	gal/100 ft	$L \cdot m^{-1}$	8.0520
2.5400	inch(es)	cm	0.3937
0.4536	lb	kg	2.2046
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
6.8948	psi	kPa	0.1450

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fruit, excessive growth of the reduced number of fruit, or some other reason. Pollenizer seed costs vary greatly so which pollenizer provides the greatest return on the investment needs to be researched.

The objective of these experiments was to evaluate each pollenizer according to fruit yield and other fruit quality parameters of the triploid plants that it pollenized.

Materials and methods

These experiments were performed at one location (Blackville, SC) in 2005 and three locations (Blackville, SC; Citra, FL; Quincy, FL) in 2006. The experimental design used was a randomized complete block with four replications. Experimental plots consisted of three raised bed rows that were spaced 8.0 ft center-to-center and covered with black polyethylene plastic. Watermelon plants were spaced 3.0 ft in-row. Replications consisted of three rows 381 ft long with a 25-ft buffer between replications. A diagram of the experimental layout is shown in Figure 1. The two outside rows were planted with 'Tri-X Palomar' (Syngenta Seeds, Boise, ID) and the interior row was planted with 'Tri-X 313' (Syngenta Seeds) in 2005 and 'Supercrisp' (Zeraim Gedera Seed Co., Ltd., Palm Desert, CA) in 2006. In 2005, pollenizer cultivars used were 'Jenny', 'Mickylee', and 'SP-1'. In 2006, the pollenizer cultivars used were 'Companion', 'Jenny', 'Mickylee', 'Patron', 'Pinnacle', 'Sidekick', and 'SP-1'. 'Tri-X Palomar' was used as a control in 2005 and 2006. Pollenizer seed sources are listed in Table 1. To reduce pollen contamination from neighboring plots, an eight-plant buffer (24 ft) of 'Tri-X Palomar' was planted in the center row between each plot (Fig. 1). It has been demonstrated that distance from a diploid pollenizer of 6.0 m or greater will greatly reduce the triploid fruit set (NeSmith and Duval, 2001). 'Tri-X Palomar' was chosen as the buffer cultivar and control plot "pollenizer" because it does not produce viable pollen and its rind coloration is distinctly different from the harvested cultivars, 'Tri-X 313' and 'Supercrisp'. Eight triploid watermelon plants were transplanted into each plot, including the control or control plot. Three plants of a pollenizer

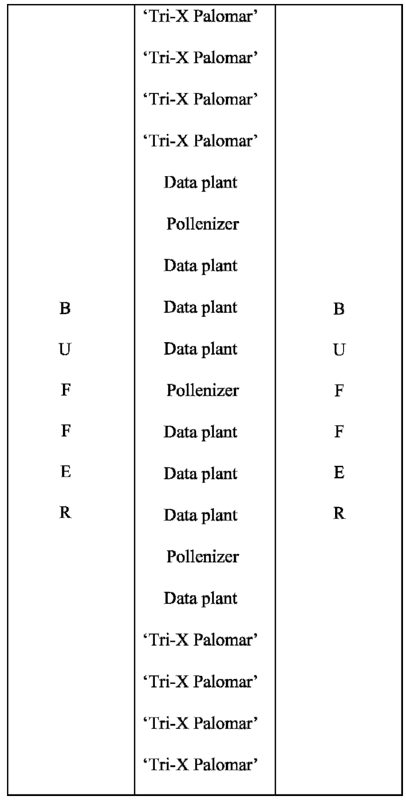

Fig. 1. Individual three-row plot design for pollenizer experiments at Blackville, SC, Citra, FL, and Quincy, FL, in 2005 and 2006. 'Tri-X 313' watermelon was used in Blackville in 2005. 'Supercrisp' watermelon was used at all locations in 2006. Plot shown is using a pollenizer recommended to be planted at a 1:3 pollenizer-to-seedless ratio. Buffer rows were planted with 'Tri-X Palomar'. All rows were planted at 3 ft (0.9 m) in-row spacing and 8 ft (2.4 m) between-row spacing. In-row spacing between pollenizer cultivars and data plants was 18 inches (45.7 cm).

cultivar were planted in each plot except the control plot in which 'Tri-X Palomar' was planted in place of a pollenizer. Control plots were in place to observe if pollen was moving from plot to plot. 'Jenny', 'Mickylee', 'Patron', 'Pinnacle', 'Sidekick', and 'SP-1' were planted at a 1:3 pollenizer-to-triploid ratio, whereas 'Companion' was planted at a 1:2 pollenizer-to-triploid ratio. These ratios are recommended by producers of the various pollenizers. Three plants of the 1:3 ratio pollenizers and four plants of the 1:2 ratio pollenizer were included in each plot in the same row as the harvested watermelon.

Table 1. Seed sources for various watermelon pollenizer cultivars used during 2005 and 2006 for the evaluation of pollenizer performance.

Pollenizer cultivar	Source
Patron	Zeraim Gedera Seed Co., Ltd., Palm Desert, CA
Jenny	Nunhems USA, Inc., Acampo, CA
Sidekick	Harris Moran Seed Co., Modesto, CA
Companion	Seminis, Inc., Oxnard, CA
Mickylee	Many sources
SP-1	Syngenta Seeds, Inc., Boise, ID
Pinnacle	Southwestern Vegetable Seed, LLC, Casa Grande, AZ

Soil type at the Edisto Research and Education Center (EREC) in Blackville, SC, was Dothan loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults). Soil type at the North Florida Research and Education Center (NFREC) in Quincy, FL, was Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults). Soil type at the Plant Science Research and Education Unit (PSREU) in Citra, FL, was Hague sand (loamy, siliceous, semiactive, hyperthermic Arenic Hapludalfs). Drip tapes (0.5 gal/100 ft/min at 10 psi; 12.0-inch emitter spacing) were laid 1.5 to 2.0 inches under the soil surface and concurrently with the plastic mulch. Beds were fumigated with methyl bromide/chloropicrin 67:33 at a rate of 400 lb/acre broadcast at EREC in 2005 and PSREU and NFREC in 2006. Fertilizer recommendations for EREC were 140 lb/acre N, 0 lb/acre P, and 116 lb/acre K in 2005 and 2006 (Franklin, 1998). Fertilizer recommendations for PSREU and NFREC were 150 lb/acre N, 42 lb/acre P, and 125 lb/acre K and 164 lb/acre N, 21 lb/acre P, and 135 lb/acre K, respectively (Olson et al., 2006). All fertility recommendations were based on soil test results. Four-week-old watermelon plants were transplanted at EREC on 27 Apr. 2005 and 17 Apr. 2006. Four-week-old seedlings were transplanted at PSREU and NFREC on 21 March and 3 Apr. 2006, respectively.

Plots were sprayed with fungicides and insecticides as recommended (Olson et al., 2006; Sanders et al., 2006). Pesticide applications were timed so that there was minimal effect on pollinators. One honeybee hive was located near the center of each replication at Citra and Quincy, FL, in 2006, whereas at Blackville, SC, in both years, a grouping of 20 honeybee hives was maintained 300 ft north of test plots. At all locations in 2005 and 2006, watermelons were harvested once per week for 3 weeks. At the last harvest, all marketable melons were harvested. The center of each fruit, cut longitudinally from stem end to blossom end, was sampled for soluble solids concentration using a handheld refractometer. Hollowheart measurements were taken by measuring the length and width of hollow cavities in watermelons that had been cut longitudinally from stem end to blossom end. Soluble solids and hollowheart data were taken from three melons per plot during the first harvest at all locations in 2006. Soluble solids data were taken from three watermelons per plot during the first harvest at Blackville, SC, in 2005 but no hollowheart data were taken.

Yield and soluble solids concentration data from 2005 and hollowheart data from 2006 were analyzed using PROC GLM and means separation was accomplished using Duncan's multiple range test in the SAS system (SAS Institute, Cary, NC). In 2006, there were multiple locations and because location was not of primary interest in this study, location was set as a random effect. The MIXED procedure was used to analyze cultivar effect on fruit yield (lb/acre, no./acre, and lb/fruit) and soluble solids concentration. This allows for greater inference of the results and how they may relate to many locations as compared with setting location as a fixed effect (Cushman et al., 2003; Schabenberger and Pierce, 2002). Pollenizer cultivar was set as a fixed effect and location, replication, and location-by-cultivar interaction were set as random effects.

Results

Treatments with pollenizer cultivars had significantly greater yield of triploid watermelons at all locations and in both years compared with the control (Tables 2 and 3). In addition, there were significant differences among pollenizer cultivars in 2006 (Table 3). There were no significant differences in triploid watermelon yields among pollenizer cultivars in 2005 (Table 2). In 2006, plots pollenized by 'Sidekick' had the greatest yields at 58,252 lb/acre but were not significantly different from plots pollenized by 'Patron', 'SP-1', 'Jenny', or 'Mickylee', which yielded 56,864, 55,148, 55,135, and 53,213 lb/acre, respectively (Table 3). Plots pollenized by 'Companion' had the lowest yields at 44,621 lb/acre, which were significantly lower than those pollenized by 'Jenny', 'SP-1', 'Patron', or 'Sidekick' but not significantly different from plots pollenized by 'Pinnacle' or 'Mickylee', which yielded 47,618 and 53,213 lb/acre, respectively. Plots containing 'Pinnacle' had significantly lower yields than plots pollenized by 'Sidekick' but were not significantly different from plots containing 'Mickylee', 'SP-1', 'Jenny', or 'Patron' (Table 3). Pollenizers had a significant effect on number of triploid watermelons compared with the control. All plots with pollenizer cultivars had significantly greater numbers of melons per acre than the control plots at all locations in both years (Tables 2 and 3). There were no significant differences in fruit production between the pollenizer cultivars in 2005 and 2006. In 2006, plots pollenized by 'Patron' produced the greatest numbers of fruit at 3893 fruit/acre, which was not significantly greater than 'Companion' that produced the fewest fruit at 3063 fruit/acre. Pollenizer cultivars had a significant effect on average triploid watermelon fruit weight in 2006, but not in 2005 (Tables 2 and 3). Pollenizer cultivars did not have a significant effect on soluble solids in either year (Table 4).

In 2006, pollenizer cultivars did not have a significant effect on hollowheart at the Citra, FL, and Blackville, SC, locations (Table 5). Pollenizer cultivars did have a significant effect on hollowheart at Quincy, FL, with all plots with pollenizers having significantly less hollowheart in the triploid watermelons when compared with the control plots

Table 2. Pollenizer cultivar effect on Tri-X 313 watermelon yield at Blackville, SC, during 2005.

Pollenizer cultivar	Total wt (lb/acre)[z]	Total fruit (no./acre)[z]	Avg wt (lb/fruit)[z]
Jenny	60,326 a[y]	3800 a	16.7 NS[y]
SP-1	57,092 a	3913 a	15.2
Mickylee	55,141 a	3629 a	15.4
Tri-X Palomar[x]	9369 b	566 b	19.1

[z]Means of four replications; yield estimates are based on plant populations of 1815 plants/acre (4485 plants/ha); 1 lb/acre = 1.1209 kg·ha^{-1}, 1 fruit/acre = 2.4711 fruit/ha, 1 lb = 0.4536 kg.
[y]Means with the same letter are not significantly different at $P \leq 0.05$ by Duncan's multiple range test; NS = nonsignificant.
[x]Triploid cultivar control.

Table 3. Pollenizer cultivar effect on Supercrisp watermelon yield and average fruit weight at Blackville, SC, Citra, FL, and Quincy, FL, during 2006.

Pollenizer cultivar	Total wt (lb/acre)[z]	Total fruit (no./acre)[z]	Avg wt (lb/fruit)[z]
Sidekick	58,252 a[y]	3800 a	16.1 ab
Patron	56,864 ab	3893 a	15.4 b
SP-1	55,148 ab	3687 a	15.4 b
Jenny	55,135 ab	3722 a	15.2 b
Mickylee	53,213 abc	3686 a	14.7 b
Pinnacle	47,618 bc	3176 a	15.8 ab
Companion	44,621 c	3063 a	15.2 b
Tri-X Palomar[x]	7629 d	435 b	17.2 a
Least significant difference ($P = 0.05$)	9660	856	1.5

[z]Means of four replications and grand means of three locations; yield estimates are based on plant populations of 1815 plants/acre (4485 plants/ha); 1 lb/acre = 1.1208 kg·ha^{-1}, 1 fruit/acre = 2.4709 fruit/ha, 1 lb = 0.4535 kg.
[y]Means with the same letter are not significantly different by least significant difference at $P = 0.05$.
[x]Triploid cultivar control.

Table 4. Pollenizer cultivar effect on soluble solids concentration of seedless watermelons at Blackville, SC, during 2005 and Citra, FL, Quincy, FL, and Blackville, SC, during 2006.[z]

	Soluble solids concn (%)	
Pollenizer cultivar	Blackville, SC—2005[y]	Combined locations—2006[x]
Sidekick		12.2 NS[w]
Patron		12.1
SP-1	11.0 NS[v]	12.3
Jenny	11.6	12.3
Mickylee	11.2	12.3
Pinnacle		12.1
Companion		12.4
Tri-X Palomar[u]	11.6	12.2
Least significant difference (P = 0.05)		0.7

[z]Means are compared within the same column.
[y]Means of four replications.
[x]Means of four replications and grand means of three locations.
[w]Means with the same letter are not significantly different by least significant difference at P = 0.05; NS = nonsignificant.
[v]Means with the same letter are not significantly different at $P \leq 0.05$ by Duncan's multiple range test.
[u]Triploid cultivar control.

Table 5. Pollenizer cultivar effect on hollowheart disorder in Supercrisp watermelon at 1) Quincy, FL, and 2) Blackville, SC, combined with Citra, FL, in 2006.[z]

	Hollowheart area (inch^2)[y]	
Pollenizer cultivar	Quincy, FL	Blackville, SC, and Citra, FL
Tri-X Palomar[x]	28.9 a[w]	0.7 NS[w]
Patron	11.3 b	1.9
Jenny	10.8 b	0.9
Sidekick	10.5 b	1.5
Companion	9.0 b	0.5
Mickylee	8.4 b	0.4
SP-1	8.2 b	2.4
Pinnacle	5.8 b	1.6

[z]Means are compared within the same column.
[y]1 inch^2 = 6.4516 cm^2.
[x]Triploid cultivar control.
[w]Means with the same letter are not significantly different at ($P \leq 0.05$) by Duncan's multiple range test; NS = nonsignificant.

(Table 5). There were no significant differences in hollowheart incidence between pollenizer cultivars.

Discussion

This research shows that some pollenizer cultivars tested can be expected to perform better than other cultivars and do so at diverse locations. Similar results were reported by Fiacchino and Walters (2003) in which triploid watermelon yields were significantly different attributable to pollenizer cultivar used.

The only cultivar that showed questionable performance was 'Companion'. As a result of its growth and flowering habit, it may not produce enough staminate flowers and pollen at the end of fruit setting in the triploid crop. 'Companion' is a short internode plant that becomes overgrown by triploid plants near the end of the season, which may lead to staminate flowers that are not readily detectable by pollinators. Differences in staminate flower production by pollenizer cultivars have been reported; however, it does not appear that flower production is the determining factor of a pollenizer's performance (Dittmar et al., 2005; Freeman and Olson, 2007). In both of these studies, 'SP-1' produced greater numbers of staminate flowers when compared with 'Jenny' or 'Mickylee'. However, data presented here indicate no difference in triploid watermelon yields between these pollenizer cultivars. Pollenizers must be able to continue growing and producing flowers throughout the production cycle.

There were significant differences in severity of hollowheart at Quincy between the pollenizer cultivars and the control but not between the pollenizers. Unfortunately, this does not help to elucidate the cause of hollowheart because it may have been incited by reduced pollination in control plots or excessive growth of the few existing watermelons. The incidence of hollowheart at Blackville, SC, and Citra, FL, was low overall and this may be why there was no effect by the pollenizers. The experimental design was successful in reducing pollen flow out of experimental plots as indicated by minimal fruit set in control plots. Lack of available viable pollen in control plots may have led to reduced fruit set. Reduced numbers of fruit per plant may have also led to greater average fruit size in control plots. This experimental design spaced the triploid watermelon from a pollenizer cultivar by 24 ft. NeSmith and Duval (2001) illustrated that when distance of a triploid from a pollenizer was 6.0 m or greater, triploid fruit numbers diminished substantially. Triploid pistillate flowers ('Tri-X Palomar') in plot buffers served to filter viable diploid pollen before pollinators entered another plot.

Of the cultivars tested, it appears that the pollenizers 'Jenny', 'Mickylee', 'Patron', 'Pinnacle', 'Sidekick', and 'SP-1' would be good choices. Some of the tested pollenizers ('Mickylee', 'Jenny', 'Pinnacle') can be harvested and sold if the grower has a market for seeded watermelons. If growers have a strong market for seeded melons, then there may be no reason to plant pollenizers in-row. The pollenizers' costs vary greatly, so this must also be taken into consideration. The pollenizer cultivars 'Jenny', 'Mickylee', 'Patron', 'Pinnacle', 'Sidekick', and 'SP-1' were shown to perform adequately. Cultivar selection should be based on seed/plant cost and distinctness between pollenizer and market melon.

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