Research Reports

Influence of Diploid Pollinizer Frequencies on Triploid Watermelon Quality and Yields

Dena C. Fiacchino¹ and
S. Alan Walters²

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SUMMARY. During the 1999 and 2000 growing seasons in Illinois, studies were conducted to determine the influence of two pollinizers ('Crimson Sweet' and 'Fiesta') and three pollinizer frequencies (11%, 20%, and 33%) on 'Millionaire' seedless watermelon (*Citrullus lanatus*) quality and yields. More large-sized [>16 lb (7.2 kg)] 'Millionaire' watermelons were produced when 'Crimson Sweet' was used as the pollinizer compared to 'Fiesta', which resulted in 'Crimson Sweet' leading to greater marketable

and total 'Millionaire' yields. Pollinizers responded similarly over the pollinizer frequencies for 'Millionaire' watermelon yields as no pollinizer by pollinizer frequency interaction was observed. The 20% and 33% pollinizer frequencies produced similar 'Millionaire' yields per acre and both resulted in greater yields compared to the 11% pollinizer frequency. Soluble solids in 'Millionaire' fruits were not influenced by pollinizer or pollinizer frequency. However, hollow heart disorder followed a quadratic response with respect to pollinizer frequency with the lowest amount of hollow heart observed at the 33% pollinizer frequency and greatest at the 11% pollinizer frequency. No significant interaction ($P \leq 0.05$) was observed for pollinizer by pollinizer frequency for hollow heart disorder in 'Millionaire'; although, more hollow heart disorder in 'Millionaire' was observed when 'Fiesta' was used as the pollinizer.

Watermelon growers are currently shifting from seeded (diploid) to seedless (triploid) production due to increased consumer demand and a greater economic profit obtained from growing seedless watermelons (Karst, 1990; Marr and Gast, 1991). Seedless watermelons do not produce sufficient pollen to fertilize female flowers (Rhodes et al., 1997) and require specialized cultural practices, compared to seeded watermelons, to produce adequate yields. A standard seed producing cultivar (hereafter referred to as a pollinizer) must be interplanted with a seedless cultivar as a source of pollen (Rubatzky and Yamaguchi, 1997).

Little research has been published on the influence of seeded pollinizer frequencies on seedless watermelon

yield and quality. For field production of seedless watermelons, Kihara (1951) suggested that one diploid plant should be planted for every four to five triploid plants to ensure that the triploids would produce adequate fruit yield. The greatest yield of 'Genesis' triploid watermelon with 'Ferarri' as the pollinizer resulted from a 20% pollinizer frequency (NeSmith and Duval, 2001). Currently, it is recommended that one row of pollinizer be planted for every two or four rows of seedless watermelon to provide adequate pollen for fruit set (Maynard and Elmstrom, 1992; Parsons et al., 1992; Robinson and Decker-Walters, 1997; Rubatzky and Yamaguchi, 1997). It is essential to select a pollinizer that is easily distinguishable from the seedless cultivar for ease of harvesting and marketing purposes (Parsons et al., 1992; Robinson and Decker-Walters, 1997; Rubatzky and Yamaguchi, 1997).

Additional research is needed to determine the optimal frequency of pollinizers needed under field conditions to obtain maximum yields in seedless watermelon production. Use of the minimum pollinizer frequency needed to maximize seedless watermelon yields could expand the profit margins for growers. Pollinizers are important to seedless watermelon production, and more studies are needed to obtain information about the effects of pollinizers on seedless watermelon quality and yield. Hollow heart, a hollow area that develops from splitting of the interior flesh of watermelon, is a serious quality problem in seedless watermelon production and could be related to the pollen source. Knowledge of the best pollinizers and appropriate seedless-to-pollinizer ratios could possibly improve seedless watermelon quality and yield. The objectives of this research were to determine the influence of pollinizer and pollinizer frequency on 'Millionaire' seedless watermelon quality and yield.

Materials and methods

This research was conducted during the 1999 and 2000 growing seasons at Scates Farm, a commercial vegetable farm in Shawneetown, Ill. Three pollinizer frequencies (11%, 20%, and 33%) were evaluated using two seeded pollinizers, 'Crimson Sweet' (North Carolina State University, Raleigh) and 'Fiesta' (Rogers Seed Co., Boise, Idaho), on 'Millionaire' (Harris

Department of Plant, Soil, and General Agriculture, Southern Illinois University, Carbondale, IL 62901-4415.

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¹Former graduate student.

²Assistant professor, corresponding author; e-mail awalters@siu.edu.

Fig. 1. Pollinizer frequency study design for 1999 to show distance between treatment combinations (pollinizer frequency and pollinizers for 'Millionaire' seedless watermelon production) and honeybee hive locations; 1000 ft = 304.8 m, 500 ft = 152.4 m.

Fig. 2. Pollinizer frequency study design for 2000 to show distance between treatment combinations (pollinizer frequency and pollinizers for 'Millionaire' seedless watermelon production) and honeybee hive locations; 1000 ft = 304.8 m, 500 ft = 152.4 m.

33% = M-P-M-M-P-M-M-P-M
 20% = M-M-P-M-M-M-M-P-M-M
 11% = M-M-M-M-P-M-M-M-M

Fig. 3. Pollinizer to seedless design as set up under field conditions. The pollinizer frequencies were placed in the field according to the designs outlined in Figs. 1 and 2. To achieve the proper ratios, nine rows for both the 33% and 11%, and 10 rows for the 20% were planted. Three seedless rows were selected and harvested in each subplot (designated by M's that are underlined). P = pollinizer ('Crimson Sweet' or 'Fiesta') and M = 'Millionaire' seedless watermelon.

Moran Seed Co., Modesto, Calif.) seedless watermelon quality and yields. The percentage of seeded to seedless watermelons was calculated by rows and not by plants in the row. The two pollinizers were grown at each of the three frequencies to determine the optimal frequency that maximizes 'Millionaire' watermelon yields.

The experiment was set up as a split-plot treatment arrangement in a randomized complete block design, with pollinizer as the main plot and fre-

quency as the subplot (Figs. 1 and 2). The experiment had one replication per year and was replicated over the two growing seasons. The test was conducted in a commercial field of 'King Arthur' (Seminis Vegetable Seeds, Oxnard, Calif.) bell pepper (*Capsicum annuum*) that was about 80 acres (32.4 ha) in size. A barrier pepper crop of 1000 ft (304.8 m) between main plots and 500 ft (152.4 m) between subplots was provided to ensure adequate isolation of honeybees (*Apis mellifera*) each year (Figs. 1 and 2). Honeybee movement between the main plots and subplots was minimized, by providing these large distances between plots. Honeybee hives were placed about 50 ft (15.2 m) from each of the subplots and six honeybee hives were used each year (Figs. 1 and 2).

Watermelon seeds were planted into 72-cell plastic trays containing a soilless media consisting of peatmoss, vermiculite, and perlite in a 2:1:1 ratio. Seeds were planted in a greenhouse on 12 and 15 Apr. for the 1999 and 2000 growing seasons, respectively. Seedlings remained in the greenhouse for about 3 weeks after germination until plants had reached the proper transplant size of 1

to 2 true leaves and then were hardened-off in cold frames for about 1 week before transplanting; thus, field plantings were established using 4-week-old transplants. Watermelon plants were transplanted into raised beds that were 5 ft (1.5 m) apart center-to-center and covered with 1.25-mil [0.00125 inch (0.03175 mm) thick] black polyethylene plastic. Watermelon plants were spaced 4 ft (1.2 m) apart in the row. Plots were 60 ft (18.3 m) in length with 15 plants per row. Nine or ten rows were planted, depending on the pollinizer frequency tested (Fig. 3). The watermelon plants were fertigated every 2 to 3 d through an automated drip irrigation system under the black plastic mulch. Over each growing season, about 135 lb/acre (151.3 kg·ha⁻¹) nitrogen and 202 lb/acre (226.4 kg·ha⁻¹) phosphorus were applied through the irrigation system. Bimonthly applications of permethrin (Pounce; Syngenta, Greensboro, N.C.), mancozeb (Dithane M-45; Dow AgroSciences, Indianapolis, Ind.), and cupric hydroxide (Kocide; Griffin LLC, Valdosta, Ga.) were used to minimize the insect populations, and fungal and bacterial disease severity, respectively (Foster et al., 1999, 2000). The soil type in 1999 was a Darwin-Shiloh-Wabash association (with the Darwin a fine-montmorillonitic, noncalcareous, mesic, Vertic Haplaquoll; the Shiloh a fine-montmorillonitic, noncalcareous, mesic, Cumulic Haplaquoll; and the Wabash a fine-montmorillonitic, noncalcareous, mesic, Vertic Haplaquoll). In 2000, a different field location was utilized in which the soil type was a Darwin-Shiloh-Wabash association on the north end of the field, and an Alvin-Roby-Ruark association (with the Alvin a coarse-loamy, mixed, mesic, Typic Hapludalf; the Roby a coarse-loamy, mixed, mesic, Aquic Hapludalf; and the Ruark a fine-loamy, mixed, mesic, Typic Ochraqualf) on the south end of the field (Wallace and Fehrenbacher, 1969).

Three seedless rows were selected within each 9- or 10-row subplot to harvest. The rows selected to harvest depended upon the pollinizer frequency (Fig. 3), with the same three 'Millionaire' rows harvested for each replication. Fruits were hand-harvested twice during each production season. Watermelons were weighed and graded as small [<8 lb (3.6 kg)], medium [8 to 16 lb (7.2 kg)], or large (>16 lb) sizes. Marketable melons (≥8 lb) were comprised

Table 1. Combined analysis over years for 'Millionaire' watermelon yields and quality characters to show significance and or nonsignificance (*P* values) of main effects and interactions.^z

Source of variation	MED	LRG	MKT	TOT	HH	SS
Year (or replication) ^y	0.0001	0.0001	0.0001	0.0001	0.0001	0.7979
Pollinizer ^y	0.4923	0.0255	0.0466	0.0475	0.0279	0.4600
Pollinizer frequency (PF) ^x	0.1104	0.0284	0.0377	0.0398	0.0007	0.3293
PF × pollinizer ^x	0.0624	0.3168	0.2500	0.2352	0.2803	0.3042

^zMED = weights of medium-sized watermelons [8 to 16 lb (3.6 to 7.2 kg)], LRG = weights of large-sized watermelons (>16 lb), MKT = weights of marketable watermelons (≥8 lb), and TOT = total weights of watermelons [sum of small (<8 lb), medium, and large-sized watermelons]. The test was replicated over the 1999 and 2000 growing seasons with one replication per year. HH = Hollow heart disorder was rated from 0-9, with 0 = no evidence of hollow heart and 9 = severe hollow heart disorder. SS = soluble solids concentrations were determined on two watermelons per plot using a refractometer measuring from 0% to 18%. Three pollinizer frequencies (11%, 20%, and 33%) were evaluated using two seeded pollinizers, 'Crimson Sweet' and 'Fiesta'.

^yTested by error (a)—pollinizer × replication.

^xTested by error (b)—residual error.

of the combination of medium- and large-sized melons. Two large-sized watermelons were randomly selected from each plot during the first harvest for hollow heart disorder and soluble solids evaluations. Hollow heart disorder was rated from 0 to 9, with 0 indicating no evidence of hollow heart and 9 indicating severe hollow heart disorder. Soluble solids concentrations were also determined on heart tissue of the two selected watermelons using a refractometer (Fisher Scientific, Pittsburg, Pa.) measuring from 0% to 18% soluble solids.

Analysis of variance procedures were performed using general linear models procedure of SAS (Cary, N.C.) appropriate for a split-plot experimental design to determine the effects of pollinizer and the pollinizer frequency over years as well as their interaction on 'Millionaire' yields. Data were also analyzed using regression analysis to determine the influence of pollinizer frequency on 'Millionaire' yield and quality measurements.

Results and discussion

The data were combined over the two years and analyzed. Year main effects were significant ($P \leq 0.05$) for 'Millionaire' watermelon yields and quality measurements (Table 1). No significant interactions of pollinizer or pollinizer frequency with year were observed, which indicated that both pollinizers responded similarly over the pollinizer frequencies for 'Millionaire' watermelon yield and quality measurements in both years.

The pollinizer significantly affected 'Millionaire' fruit production (Table 1). 'Crimson Sweet', as a pollinizer, resulted in greater large-sized 'Millionaire' watermelon yields at all pollinizer frequencies evaluated compared to 'Fiesta', which resulted in higher market-

able and total 'Millionaire' yield. Although the pollinizers responded similarly at the various pollinizer frequencies for the resulting 'Millionaire' yields, the yield performance of 'Millionaire' depended on the pollinizer.

Since no interaction of pollinizer and pollinizer frequency occurred for 'Millionaire' yields (Table 1), the two pollinizers were combined for regression analysis. 'Millionaire' fruit weight increased quadratically as the pollinizer frequency increased (Fig. 4). For all 'Millionaire' yield parameters, the 20% and 33% pollinizer frequencies produced similar weights per acre and resulted in greater 'Millionaire' yields compared to the 11% pollinizer frequency. For large-sized 'Millionaire' watermelons, the 11%

pollinizer frequency produced about 7000 lb/acre (7846 kg·ha⁻¹) less compared to the 20% and 33% pollinizer frequency (Fig. 4). Generally, marketable and total 'Millionaire' yields per acre for the 11% pollinizer frequency were about one-half of those obtained for either the 33% or 20% pollinizer frequency. The lower yields of 'Millionaire' obtained at an 11% pollinizer frequency was expected, since seedless watermelon production relies on cross-pollination from a diploid cultivar (Elmstrom and Maynard, 1990). One row of a diploid pollinizer to eight rows of 'Millionaire' did not supply an adequate amount of pollen throughout the production area to pollinate the pistillate flowers of 'Millionaire' suf-

Fig. 4. Influence of pollinizer frequency ('Crimson Sweet' and 'Fiesta' combined) on 'Millionaire' yields over the 1999 and 2000 growing seasons. The relationship between the three pollinizer frequencies (PF) and yield parameters (lb/acre) in 'Millionaire' was quadratic for: yields of medium-sized [8 to 16 lb (3.6 to 7.2 kg)] watermelons [$y = -2030.57 + 642.97 (\% PF) - 13.09 (\% PF)^2$, $R^2 = 0.87$, $P = 0.045$]; yields of large-sized (>16 lb) watermelons [$y = -8529.15 + 1506.13 (\% PF) - 27.03 (\% PF)^2$, $R^2 = 0.87$, $P = 0.048$]; yields of marketable (≥8 lb) watermelons [$y = -10,560.01 + 2149.10 (\% PF) - 40.12 (\% PF)^2$, $R^2 = 0.89$, $P = 0.034$]; and total watermelon yields [$y = -10,789.03 + 2207.74 (\% PF) - 41.49 (\% PF)^2$, $R^2 = 0.89$, $P = 0.035$]. Total watermelon yields is the sum of small (<8 lb), medium, and large watermelons; 1.0 lb/acre = 1.12 kg·ha⁻¹].

Fig. 5. Influence of pollinizer frequency (PF) ('Crimson Sweet' and 'Fiesta' combined) on hollow heart disorder rating for 'Millionaire' over the 1999 and 2000 growing seasons. The relationship between the three frequencies and hollow heart disorder in 'Millionaire' was quadratic: $y = 8.604 - 0.406(\%PF) + 0.007(\%PF)^2$, $R^2 = 0.87$, $P = 0.045$. Hollow heart disorder was rated from 0 to 9, with 0 = no evidence of hollow heart and 9 = severe hollow heart disorder.

ficiently. Previous research indicated that the number of triploid watermelons decreases as the distance from the pollen source exceeds 15 ft (4.6 m) (NeSmith and Duval, 2001).

The total soluble solids in 'Millionaire' fruits were not influenced by the pollinizer or pollinizer frequency (Table 1). However, hollow heart disorder in 'Millionaire' was influenced by the pollinizer and pollinizer frequency (Table 1). Results from a combined analysis for 1999 and 2000 indicated significant ($P \leq 0.0001$) differences between the growing seasons for hollow heart disorder (Table 1), with the 2000 growing season providing greater hollow heart disorder compared to 1999 (data not presented). Although years were different with respect to hollow heart, the pollinizer and pollinizer frequencies performed similarly over both years as the interactions between pollinizer and year and between pollinizer frequency and year were not significant ($P \leq 0.05$) (data not presented). 'Fiesta' as a pollinizer resulted in greater amounts of hollow heart in 'Millionaire' compared to 'Crimson Sweet' (data not presented). A quadratic relationship was observed between hollow heart of 'Millionaire' watermelon and pollinizer frequency (Fig. 5). Although the 20% pollinizer frequency supplied enough pollen to pollinate most pistillate seedless watermelon flowers (as yields were not affected), hollow heart damage was greater at this pollinizer frequency compared to the 33% frequency (Fig. 5). The 11%

pollinizer frequency provided the greatest amount of hollow heart disorder. Lower amounts of pollen available to pollinate pistillate flowers may have resulted in greater amounts of hollow heart, which was directly related to the pollinizer frequency. However, the importance of environmental effects on hollow heart incidence should not be overlooked, as hollow heart damage was more prevalent during 2000 compared to 1999.

Conclusions

The fruit quality and yield of 'Millionaire' watermelon were influenced by the pollinizers used in this study. 'Crimson Sweet' resulted in greater 'Millionaire' yields and less hollow heart damage, compared to 'Fiesta'. Differences between the 33% and 20% pollinizer frequencies were minimal with respect to 'Millionaire' yields obtained per acre indicating that a field containing 20% diploid pollinizer plants would provide sufficient pollen to pollinate most pistillate flowers produced. However, a significant reduction in 'Millionaire' yields was observed when the 11% pollinizer frequency was used.

Hollow heart disorder was greater when 'Fiesta' was utilized as the pollinizer compared to 'Crimson Sweet'. For hollow heart in 'Millionaire', both pollinizers responded similarly over the pollinizer frequencies with more hollow heart observed at the 11% frequency and the least amount occurring at the 33% frequency.

This study indicated that seedless

watermelon yields are similar when 20% and 33% pollinizer frequencies are used. If a watermelon grower is concerned about the production of the seeded pollinizer or seedless watermelon seed costs, then a 33% frequency would allow maximum production with minimal costs as more seeded watermelons would be produced at this frequency as fewer seedless plants would be grown in the field. However, if a watermelon grower wants to minimize the amount of seeded watermelons growing in a seedless field, then a 20% pollinizer frequency may be a better choice; but, if a 20% pollinizer frequency is used, hollow heart disorder may be more prevalent.

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