Research Note

HIGHER PLANTING DENSITY INCREASES YIELD OF SEMI-BUSH TROPICAL PUMPKIN[1, 2]

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Limited research has been conducted concerning the effect of planting distances and densities on the production of tropical pumpkin (*Cucurbita moschata* Duchesne). The *Conjunto Tecnológico para la Producción de Calabaza* suggests that tropical pumpkin in Puerto Rico be planted at a distance of 183 cm x 183 cm (within and between rows) but notes that many growers use narrower within-row and wider between-row distances, especially 91 cm x 366 cm (Martínez, 2012). Both arrangements yield a planting density of about 2,900 plants per hectare. These recommendations were made for traditional, vining types of tropical pumpkin where individual plants occupy a great deal of space. Growth habit may influence the effect that planting distance and density have on fruit size and yield of tropical pumpkin. Breeding efforts at the Agricultural Experiment Station of the University of Puerto Rico, Mayagüez Campus have led to the development of cultivars with a semi-bush growth habit such as 'Taína Dorada' (Wessel-Beaver, 2013). Tropical pumpkin cultivars with a semi-bush growth habit may have reduced plant-to-plant competition and may benefit from denser planting. Wessel-Beaver et al. (2006) evaluated an experimental semi-bush tropical pumpkin line (from which 'Taína Dorada' was derived) at two planting densities in trials at the Agricultural Experiment Substations located at Isabela, Lajas and Juana Díaz, Puerto Rico. Plants were arranged at distances of 183 cm x 183 cm (2,890 plants per hectare) and 91 cm x 183 cm (5,980 plants per hectare), within and between rows. There was a slight, but non-significant, tendency towards greater production at the higher planting density. Broderick (1982) observed that the winter squash (*C. maxima*) cultivar 'Autumn Pride' with a bush growth habit had greater yields at higher planting densities. Cushman et al. (2004) evaluated the effect of planting densities ranging from 1,495 to 7,581 plants per hectare on yield components in vining and semi-vining Halloween-type (*C. pepo*) pumpkin cultivars. Fruit size is an important attribute for Halloween pumpkins. The semi-vining cultivar had the largest fruit weight with a density of 5,053 plants per hectare while the vining cultivar had the best performance at a much lower planting density of 1,495 plants per hectare. Paris et al. (1986) tested zucchini (*C. pepo* with a bush growth habit) at plant densities

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of 10,000 to 66,666 plants per hectare. The highest yields were obtained at densities over 30,000 plants per hectare. Zucchini is harvested as immature fruit, and plants are generally much more compact than tropical pumpkin. In this study we compare the response of a semi-bush tropical pumpkin planted under conventional and organic conditions at various planting densities, including densities much greater than in the study by Wessel-Beaver et al. (2006).

Two spacing trials were conducted at the Lajas Substation on a Vertisol, series Fraternidad (fine, smectitic, isohyperthermic Typic Haplusterts): Experiment 1 (Exp 1) under conventional conditions and Experiment 2 (Exp 2) under organic conditions. In Experiment 1, six experimental semi-bush tropical pumpkin hybrids were transplanted at three within-row planting distances (91, 137 and 183 cm) on 15 January 2000 in a split plot design. Whole plots were the six hybrids in a complete block design with three replications. Subplots corresponded to the three within-row planting distances. Prior to transplanting, 45 kg/ha of N and P, and 36 kg/ha of K were broadcast and incorporated. A total of 45 kg/ha of N and P, and 36 kg/ha of K was later supplied via drip irrigation. Each plot consisted of two 7.7 m long raised beds. The distance between bed centers was 183 cm. Beds were laid with drip irrigation and covered in silver plastic mulch. Presence of melonworm (*Diaphania hyalinata*) was monitored and controlled with *Bacillus thuringensis* ssp. *kurstaki* when necessary. Foliar diseases were controlled with chlorothalonil. Plots were harvested from 11 April to 20 April 2000. Number and weight (yield) of fruit and average fruit weight were recorded for each plot. Data was analyzed as a mixed model using InfoStat (Di Rienzo et al., 2019). Hybrids and planting distances were treated as fixed effects and blocks were treated as a random effect. Only the results of planting distance (density) are reported here. Distance means were compared using Fisher's least significant difference at $P = 0.05$.

In Experiment 2, 'Taína Dorada' was direct-seeded 12 January 2012 in seven plots in a certified organic field. Each plot consisted of six rows measuring 762 cm in length with 76 cm between rows. On 22 February 2012, four plots were thinned to a within-row spacing of 152 cm (treatment 1 = 8,611 plants per hectare). The other three plots were not thinned, i.e. they remained at a within-row distance of 76 cm (treatment 2 = 17,223 plants per hectare). A completely randomized design was used. Soils in the experimental area were previously amended multiple times with organic fertilizers and compost. No additional fertilizer was added. Presence of melonworm was monitored and controlled as in Exp 1. Foliar diseases were controlled with applications of organic fungicides based on neem oil (Trilogy[6]), potassium sorbate, sesame oil, lecithin, edible fish oil (Organoside), and hydrogen peroxide and peracetic acid (Oxidate). Plots were harvested on 24 April 2012. Data was subjected to analysis of variance in InfoStat (Di Rienzo et al., 2019) and means were compared using Fisher's least significant difference at $P = 0.05$.

In Exp 1 data was collected only on a per-hectare basis. The two higher planting densities (3,987 and 5,980 plants per hectare) resulted in approximately a 30% increase in number and yield of fruit per hectare compared with number and yield of fruit per hectare under a density of 2,890 plants per hectare (Table 1). Increasing planting density had no significant effect on average fruit weight although there was a slight tendency towards lower fruit weight with higher densities. In Exp 2 we tested the hypothesis that there would be a positive yield response to even higher densities than those tested in Exp 1. Data was gathered on both a per-plant and a per-hectare basis in Exp 2. On a per-

[6]Company or trade names in this publication are used only to provide specific information. Mention of a company or trade name does not constitute an endorsement by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

TABLE 1.—*Number of fruits and yield per hectare, and average fruit size of semi-bush tropical pumpkin subjected to three planting densities in a conventional planting in Lajas, Puerto Rico, in 2000 (Experiment 1).*

Spacing (cm)[1]	Planting density (plants/ha)	Number of fruits/ha[2]	Yield (kg/ha)[2]	Average fruit weight (kg)[2]
183 x 183	2,890	9,807 b[3]	29,575 b	3.07 a
137 x 183	3,987	13,835 a	39,562 a	2.89 a
91 x 183	5,980	15,351 a	42,170 a	2.79 a
Mean		12,872	36,905	2.93
CV (%)		18.4	12.8	13.0

[1]Planting distance within x between rows
[2]Means are the average of six experimental semi-bush hybrids.
[3]Within a column, means followed by a common letter are not significantly different at the 0.05 probability level according to Fisher's least significant difference test.

plant basis, number and yield of fruit per plant were greater in plants subjected to the lower planting density (Table 2). Plants in plots with the lower density of 8,611 plants per hectare yielded 20% more fruit per plant and 30% more yield per plant compared to plants at a density of 17,223 plants per hectare. However, at the higher density, the larger number of plants more than compensated for the lower individual plant production. About 30% more fruit per hectare was produced at the higher planting density compared to the lower planting density. Similarly, yield (kg/ha) was about 25% greater under the higher planting density. As in Exp 1, average fruit size did not vary between the two planting densities.

Except for the lowest density in Exp 1, the tested densities were greater than the current recommendation of 2,890 plants per hectare in the *Conjunto Tecnológico para la Producción de Calabaza* (Martínez, 2012). The planting densities in Exp 2 are greater than those evaluated by Wessel-Beaver et al. (2005). Yields under the higher densities of Exp 2 were lower than in Exp 1. However, the two trials were conducted under differ-

TABLE 2.—*Mean number of fruits and yield per plant, number of fruits and yield per hectare, and average fruit size in an organic planting of semi-bush tropical pumpkin 'Taína Dorada' in Lajas, Puerto Rico, in 2012 under two planting densities (Experiment 2).*

Spacing (cm)[1]	Planting density (plants/ha)	Number of fruits/plant	Yield/plant (kg)	Number of fruits/ha	Yield (kg/ha)	Average fruit size (kg)
152 x 76	8,611	0.98 a[2]	2.79 a	9,257 b	26,398 b	2.87 a
76 x 76	17,223	0.77 b	1.97 b	13,490 a	34,546 a	2.58 a
LSD(0.05)[3]		0.175	0.132	1,760	3,574	0.600
CV(%)		10.0	2.8	8.1	6.1	11.2

[1]Planting distance within x between rows.
[2]Within a column, means followed by a common letter are not significantly different at the 0.05 probability level according to Fisher's least significant difference test.
[3]Fisher's least significant difference at $P = 0.05$.

ent environmental conditions, so no direct comparison is possible. Further studies are needed to compare densities of 6,000 to 17,000 plants per hectare in the same trial. The effect of varying within- and between-row distances also needs further study.

Higher planting densities make more efficient use of land, better control soil erosion and aid in weed suppression. However, wider between-row spacing and the resulting lower planting densities may be attractive to growers despite a yield penalty. Wider rows allow easier access for cultivation, pesticide application and harvesting. Lower planting densities also lower seed costs per hectare. While our research presents evidence that higher yields are obtained when planting semi-bush tropical pumpkin under planting densities higher than the current recommendation for vining cultivars, growers should also consider other factors when deciding on the best planting arrangement.

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