Performance of new tropical pumpkin genotypes under varying cultural practices[1]

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ABSTRACT

New tropical pumpkin (*Cucurbita moschata* Duchesne) genotypes were evaluated for yield, flesh (mesocarp) color, pest resistance and seed production as compared with the standard cultivar Soler in six field trials at three Puerto Rico locations during a two-year period (2003-2005). Genotypes included an open-pollinated population (PRShortvine-1) and four lines (E0305-1, E0305-2, E0305-3 and E0305-4) with a semi-bush growth habit, as well as a new long-vine open-pollinated population (PRLongvineSLR). Various within-row (0.9- and 1.9-m) and between-row (1.9- and 3.8-m) planting distances were tested. Not all genotypes nor planting distances were included in each trial. PRLongvineSLR was partially resistant to the melonworm (*Diaphania hyalinata*), whereas lines E0305-1 and E0305-2 were very susceptible. These same lines, as well as PRShortvine-1, were also susceptible to downy mildew, *Pseudoperonospora cubensis*. All genotypes produced similar yields. Within-row planting distance generally had no effect on fruit weight, fruit number and yield. All new genotypes had good flesh thickness (>4 cm) and small fruit cavities. Flesh color of PRShortvine-1 and PRLongvineSLR tended to be more orange than that of Soler. Lines E0305-3 and E0305-4 had poor seed production, whereas seed production in fruits of PRShortvine-1 and PRLongvineSLR was similar to that of Soler. Despite some shortcomings, PRShortvine-1 and PRLongvineSLR are two advanced open-pollinated populations that should be considered for formal release on the basis of their field performance, good fruit quality and ability to produce profitable amounts of seed in a seed production program.

Key words: tropical pumpkin, *Cucurbita moschata*, genotypes, yield

RESUMEN

Comportamiento de nuevos genotipos de calabaza bajo varias prácticas culturales

Se evaluaron nuevos genotipos de calabaza (*Cucurbita moschata* Duchesne) para rendimiento, color de la pulpa, resistencia a plagas y producción de semillas. Se comparó su comportamiento con el cultivar estándar

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Soler en seis ensayos en tres localidades en Puerto Rico, durante un periodo de dos años (2003-2005). El estudio incluyó una población experimental de polinización libre (PR Shortvine-1) y cuatro líneas (E0305-1, E0305-2, E0305-3 y E0305-4) con hábito de crecimiento semi-arbustivo, y una población experimental de polinización libre (PR longvineSLR) de bejucos largos. Se evaluaron dos distancias de siembra dentro del surco (0.9 m y 1.9 m) y dos entre surcos (1.9 m y 3.8 m). No todas las distancias de siembra se incluyeron en cada ensayo. PRlongvineSLR demostró ser excepcionalmente resistente al gusano del melón (*Diaphania hyalinata*), mientras que las líneas E0305-1 y E0305-2 fueron particularmente susceptibles. Estas mismas líneas, al igual que PRShortvine-1, fueron también susceptibles al añublo lanoso (*Pseudoperonospora cubensis*). Todos los genotipos produjeron rendimientos similares. La distancia entre plantas en el surco no afectó el peso del fruto, número de fruto ni el rendimiento. Todos los nuevos genotipos mostraron buen grosor de pulpa (>4 cm) y una cavidad pequeña. El color de pulpa de PRShortvine-1 y de PRLongvineSLR tiende a ser más anaranjado que el de Soler. Las líneas E0305-3 y E0305-4 tuvieron pobre producción de semilla, mientras que las de PRShortvine-1 y PRLongvineSLR fueron similares a la de Soler. A pesar de algunos defectos, PRShortvine-1 y PRLongvineSLR son dos poblaciones que se deben considerar para liberación a base de su rendimiento en el campo, buena calidad de fruta y habilidad para producir cantidades económicamente rentables de semilla en un programa de producción de semilla.

Palabras clave: calabaza, *Cucurbita moschata*, genotipos, rendimiento

INTRODUCTION

Tropical pumpkin or 'calabaza' (*Cucurbita moschata* Duchesne) is one of the most important vegetable crops in Puerto Rico, occupying second place in terms of the amount of revenue generated by vegetable crops (Anonymous, 2004). Currently US production is limited to Puerto Rico and subtropical areas of Florida. Tropical pumpkin is consumed throughout the Caribbean and Latin America, as well as on the US mainland, where it is important in a growing Hispanic market. Tropical pumpkin is also widely consumed in Asia, particularly in Thailand, India and the Philippines (East-West Seed Company, personal communication). US markets catering to these various ethnic groups are increasing. There appear to be ample market opportunities in Puerto Rico and the US mainland to expand production of tropical pumpkin. In a recent talk before an international group of cucurbit researchers, Frieda Caplan, of Frieda's, Inc. (a US marketer of specialty crops), spoke of the importance of innovative marketing of cucurbits and cited the need for development of new cultivars of pumpkins and squash. New cultivars developed from an effective breeding program can add value for both the grower and consumer of tropical pumpkin.

The carotenoids that give tropical pumpkin its orange or yellow color are an important source of vitamin A in the diet of its consumers. Beta-carotene is the principal pigment of its carotenoid fraction (Hidaka et al., 1987). Betacarotene is the precursor of vitamin A, an essential vitamin for vision. Betacarotene has also been linked to a reduced risk of certain cancers (Haenszel et al., 1976; Phillips, 1975). Fruit quality, especially flesh (mesocarp) color, is an important aspect of our tropical pumpkin breeding program at the Agricultural Experiment Station of the University of Puerto Rico, Mayagüez (AES-UPRM). Orange is preferred by Puerto Rican consumers over a more yellow color (Carbonell et al., 1990) for its culinary aspect.

Traditional long-vine cultivars and landraces used in commercial plantings in Puerto Rico have vines that may reach 15 m in length, produce their fruit far from the crown of the plant, and are often very late maturing. The usual practice for tropical pumpkin is to plant at a distance of 1.8 m within and between rows. However, the trend has been to decrease the within-row planting distance to about 0.9 m while increasing the space between rows to 3 to 4 m to allow mechanical cultivation during the first few weeks following planting. Planting distances and other cultural practices may need to vary for cultivars with different growth habits.

Like any genetically controlled trait, growth habit responds to selection. Over the past five years, the Tropical Pumpkin Breeding Program of the AES-UPRM has been developing semi-bush (SB) tropical pumpkin populations and lines, as well as populations with the more traditional long-vine growth habit. When developing new cultivars the breeder must take into consideration how these genotypes perform under different cultural practices. Cultivars with different growth habits are especially likely to respond to differences in planting distance. Likewise, the use of new cultural practices on the part of the grower requires that the breeder consider these practices when developing new cultivars.

The objective of this study was to evaluate the most promising of these newly developed semi-bush and long-vine genotypes and compare their performance for yield, quality and pest resistance to that of the standard cultivar Soler.

MATERIALS AND METHODS

Two field trials were conducted at each of three locations (Isabela, Lajas and Juana Díaz, Puerto Rico) from November 2003 through September 2005. Seven genotypes were tested: Soler, the local standard; PRShortvine-1, an open-pollinated, semi-bush (SB) cultivar developed by recurrent half-sib selection; PRLongvineSLR, an open-pollinated, long-vine, silverleaf-resistant (SLR) cultivar developed by recurrent half-sib selection; and E0305-1, E0305-2, E0305-3 and E0305-4, four S_2 lines selected from the PRShortvine-1 population. All new genotypes were developed in the tropical pumpkin breeding program of the AES-

UPRM. Some of the morphological characteristics of the genotypes are described in Table 1. Not all genotypes were tested in each trial. Table 2 summarizes the genotypes, planting distances and cultural practices used in each trial. Entries in all trials were arranged in a randomized complete block design. The number of entries and blocks varied among trials. Genotypes were direct seeded (Isabela) or transplanted (Lajas and Juana Díaz) in four-row plots. Rows were 14.8 m long and spaced 1.8 m apart in Trials 1 to 4. Trials 5 and 6 included four-row plots of Soler and PRLongvineSLR with only the first and third row planted, effectively making a between-row distance of 3.7 m. Plants within rows were spaced 0.9 m or 1.8 m apart, depending on the trial and genotype tested. In Lajas and Juana Díaz, genotypes were transplanted into raised beds with silver-colored plastic mulch. Plots were direct-seeded in Isabela. Drip irrigation was used in all trials. Weed control methods varied from trial to trial and included mechanical and hand cultivation and application of glyphosate. The melonworm, *Diaphania hylianata*, was controlled with Bt- (*Bacillus thuringiensis*) and endosulfan-based insecticides. Benomyl was used in Lajas to control fungal foliar diseases.

TABLE 1. *Known and observed characteristics of tropical pumpkin genotypes tested at various locations in Puerto Rico from 2003 to 2005.*

Genotype	Description
Soler	Open pollinated cultivar; vine growth habit; canopy closed at six weeks post-transplant when using recommended 0.9 m × 0.9 m distance; segregating for leaf mottle (*M*); latest flowering of genotypes tested (60 days after transplant); fruit is flat with dark green rind
PRShortvine-1	Open-pollinated experimental population; most plants had a semi-bush growth habit but some plants were segregating for this trait; at six weeks the canopy was closed in plots planted at 0.9 m within rows but some gaps remained in plots with 1.8-m distance; mottled leaves (*MM*); fruit round to globe shaped with a green-turning-to-orange mottled rind
PRLongvineSLR	Open-pollinated experimental population; at six weeks the canopy was closed in plots planted at 0.9 m within rows but some gaps remained in plots with 1.8 m distance; leaf mottle with distinct yellow rather than grey patches; fruits flat with a dark green rind
E0305-1	Experimental S2 line; semi-bush growth habit (with some segregation); canopy closed at six weeks; mottled leaves (*MM*)
E0305-2	Experimental S2 line; vine to semi-bush growth habit; mottled leaves (*MM*)
E0305-3	Experimental S2 line; semi-bush growth habit; canopy almost closed at six weeks; greenleaf (*mm*) with slight vein clearing
E0305-4	Experimental S2 line; compact vine growth habit; canopy closed at six weeks; segregating for leaf mottle gene (*MM* or *Mm*)

TABLE 2. *Summary of locations and dates, genotypes and planting distances tested, and cultural practices used in six trials evaluating new tropical pumpkin cultivars against the standard cultivar Soler.*

Trial	Location	Planting date	Genotypes planted	Planting distances tested (m) Within-row	Between-row	Cultural practices used
1	Isabela	Nov 2003	Soler	1.8	1.8	Direct
			PRShortvine-1	1.8	1.8	seeded; drip
				0.9	1.8	irrigation
			PRLongvineSLR	1.8	1.8	
				0.9	1.8	
			E0305-1	0.9	1.8	
			E0305-2	0.9	1.8	
			E0305-3	0.9	1.8	
			E0305-4	0.9	1.8	
2	Lajas	March 2004	Soler	1.8	1.8	Trans-
			PRShortvine	1.8	1.8	planted; drip
				0.9	1.8	irrigation;
			PRLongvineSLR	1.8	1.8	raised beds;
				0.9	1.8	silver-colored plastic mulch
3	Juana Díaz	April 2004	Soler	1.8	1.8	Trans-
			PRShortvine	1.8	1.8	planted; drip
				0.9	1.8	irrigation;
			PRLongvineSLR	1.8	1.8	raised beds;
				0.9	1.8	silver-colored plastic mulch
4	Lajas	June 2004	Soler	1.8	1.8	Trans-
			PRShortvine	1.8	1.8	planted; drip
				0.9	1.8	irrigation;
			PRLongvineSLR	1.8	1.8	raised beds;
				0.9	1.8	silver-colored plastic mulch
5	Isabela	Dec 2004	Soler	1.8	1.8	Direct
				0.9	3.7	seeded; drip
			PRShortvine	1.8	1.8	irrigation
				0.9	1.8	
6	Juana Díaz	March 2005	Soler	1.8	1.8	Drip irriga-
				0.9	3.7	tion; raised
			PRShortvine	1.8	1.8	beds;
				0.9	1.8	silver-colored
			PRLongvineSLR	1.8	1.8	plastic mulch
				0.9	3.7	

Pest control was not always completely effective. Incidence of whitefly (*Bemisia argentifolii*)-induced leaf silvering in plots was rated on a scale of 0 (no silvering in plot) to 5 (all leaves in plot highly silvered). Ratings were taken between five and six weeks after planting. Damage due to melonworm was rated on a scale of 0 to 5 (0 = no visible damage; 2 = 10 to 20% defoliation; 3 = 40 to 60% defoliation; 4 = 60 to 80% defoliation; 5 = more than 80% defoliation). Damage due to downy mildew was rated on a scale of 0 to 5 (0 = few or no lesions; 5 = lesions on more than 80% of leaf surface). At maturity, fruits in each plot were harvested, weighed and counted. A sample of 10 fruits per plot was saved for evaluating fruit size, flesh thickness and color. In trial 2, seed was extracted from the fruit, dried, weighed and counted. In trials 1 to 4, flesh (mesocarp) color was measured with a HunterLab ColorFlex™ spectrophotometer (45°/0° optical geometry) measuring CIELAB, where L* = lightness; a* = bluish-green/red-purple hue component; b* = yellow/blue hue component. From those values (i) C* (from $[(a^{*2} + b^{*2})^{1/2}]$ = chroma, and (ii) h° (from arctangent b*/a*) = hue angle (0° = red-purple, 90° = yellow, 180° = bluish-green, 270° = blue) were calculated as suggested by McGuire (1992). Trial variances were heterogeneous for most of the measured traits. Thus, we carried out individual analyses of variance for each trial. Means were separated by using Fisher's Protected Least Significant Difference Test at 0.05 level of probably of error.

RESULTS AND DISCUSSION

Genotypes Soler and PRLongvineSLR had a vine growth habit (Table 1), although plants of Soler were much more vigorous than the latter genotype. E0305-2 and E0305-4 had what could be described as a semi-vine growth habit. PRShortvine-1, E0305-1 and E0305-3 initially exhibited a very bushy growth habit and later sent out one main vine with lateral branches. Fruit tended to set much closer to the crown than in vine types. Plants of Soler, planted at 1.9 m × 1.9 m, completely filled plots six weeks post-transplant. Semi-bush types like PRShortvine-1 had to be planted 0.9 m apart in order to completely fill plots at six weeks. A description of leaf mottle [mottle-leaf (*MM*) or greenleaf (*mm*)] is included in Table 1 because it is a simply inherited trait (Coyne, 1970) that can be useful in the identification or description of a cultivar. PRLongvine SLR has a distinct sort of leaf mottle with yellow, rather than grey, patches. Staminate flowers began to open about 35 to 38 days after transplanting in all genotypes except Soler, which flowered about 50 days after transplanting (data not shown). Pistillate flowers opened about 48 to 50 days after transplanting, with the exception of Soler, which flowered at about 60 days after transplant.

Insects and Diseases

PRShortvine-1 generally had a silverleaf rating similar to that of Soler (Table 3), although even in those genotypes the incidence was very low. PRLongvineSLR was always free of silverleaf symptoms.

TABLE 3. *Insect and disease evaluation of tropical pumpkin genotypes evaluated at various locations in Puerto Rico during 2003 to 2005.*

Genotype	Silverleaf[1]	*Diaphania hyalinata*[2]	*Pseudoperonospora cubensis*[3]
	Isabela—November 2003 to February 2004—Trial 1		
Soler	1.6 b[4]		
PRShortvine-1	1.1 bc		
PRLongvineSLR	0.0 c		
E0305-1	2.7 a		
E0305-2	0.7 bc		
E0305-3	1.0 bc		
E0305-4	0.7 bc		
	Lajas—March to June 2004—Trial 2		
Soler	0.0 c	1.5 b	1.5 bcd
PRShortvine-1	0.7 b	2.5 ab	2.5 ab
PRLongvineSLR	0.0 c	1.5 b	0.2 d
E0305-1	1.5 a	4.0 a	3.0 a
E0305-2	0.0 c	4.0 a	2.5 ab
E0305-3	0.0 c	1.0 b	1.2 bcd
E0305-4	0.0 c	2.0 b	1.0 cd
	Juana Díaz—April to August 2004—Trial 3		
Soler	1.0 a		
PRShortvine-1	0.9 a		
PRLongvineSLR	0.0 b		
	Lajas—May to August 2004—Trial 4		
Soler	2.0 a		
PRShortvine-1	2.1 a		
PRLongvineSLR	0.0 b		
	Isabela—December 2004 to February 2005—Trial 5		
Soler	2.9 a		
PRShortvine-1	2.2 b		
	Juana Díaz—March to June 2004—Trial 6		
Soler	2.0 a	5.0 a	
PRShortvine-1	1.2 b	5.0 a	
PRLongvineSLR	0.0 c	2.0 b	

[1]Whitefly (*Bemesia argentifolii*)-induced leaf silvering rated on a scale of 0 (no silvering in plot) to 5 (all leaves in plot highly silvered). Ratings were taken between five and six weeks after planting.

[2]Whole-plot damage due to melonworm rated on a scale of 0 to 5 (0 = no visible damage, 2 = 10 to 20% defoliation, 3 = 40 to 60% efoliation, 4 = 60 to 80% defoliation, 5 = more than 80% defoliation).

[3]Whole-plot damage due to downy mildew rated on a scale of 0 to 5 (0 = few or no lesions, 5 = lesions on more than 80% of leaf surface).

[4]Within a trial, means within a column followed by the same letter are not significantly different according to Fisher's Protected Least Significant Difference at the 0.05 probability level.

Silvering is induced by the feeding of whitefly nymphs (Yokomi et al., 1990; Costa et al., 1993).

In Trial 2, damage due to melonworm was greater in PRShortvine-1 than in Soler, whereas damage in PRLongvineSLR was equal to that of Soler (Table 3). Melonworm populations were extremely high in Trial 6. All plots eventually became completely defoliated except for those planted with PRLongvineSLR. The appearance of this trial was quite dramatic; one could clearly identify plots of PRLongvineSLR distributed throughout the field. Interestingly, PRLongvineSLR is also resistant to silverleaf whitefly. Silverleaf resistance is associated with the greenleaf genotype (*mm*) (Wessel-Beaver, 2000) which PR-LongvineSLR carries. It is possible that there is a similar relationship between the greenleaf genotype and melonworm resistance. The other genotypes tested in Trial 6 are mottle-leaf. The possible resistance of PRLongvineSLR must be tested further.

Powdery mildew, caused by *Sphaerotheca fuliginea*, was observed on plantings in Isabela but not in Lajas or Juana Díaz. Downy mildew, caused by *Pseudoperonospora cubensis*, was a problem on some genotypes, particularly E0305-1, E0305-2 and PRShortvine-1 (Table 3).

Yield and Yield Components

Overall yield and yield component means varied considerably from trial to trial. No statistical test of genotype by environment interaction is available since trials were analyzed separately. However, inspection of the data suggests that interactions were not very important in this study. Soler had the greatest fruit weight in every trial, although this difference was not always significant (Table 4). PRLongvineSLR consistently produced small fruits (low weight), whereas the semi-bush types (PRShortvine-1 and E0305 1 to 4) tended to produce fruits of intermediate size. Soler tended to produce the smallest number of fruits. The other genotypes showed no consistent trend, with the possible exception of PR-LongvineSLR, which tended to produce among the greatest numbers of fruit. No significant yield differences were observed in two of the five trials where yield was recorded. Only small differences were recorded in a third trial. Experimental line E0305-4 had either the highest yield, or was among the highest yielding genotypes, in the two trials where it was included. Planting distance (within row distances of 0.9 m or 1.8 m) generally had little effect on the performance of genotypes PRShortvine-1 and PRLongvineSLR. Average fruit weight and yield were never significantly different between the two distances. There were some significant differences between planting distances for number of fruit, but even for that variable the trend was not consistent over trials.

TABLE 4. *Yield and yield components of tropical pumpkin genotypes evaluated at various locations in Puerto Rico during 2003 to 2005.*

Genotype	Planting distance (m)[1]		Average fruit weight (kg)	No. of fruit per hectare	Yield (kg/ha)
	Within row	Between row			
Isabela—November 2003 to February 2004—Trial 1					
Soler	1.8	1.8	8.0 b[2]	3,256 abc	25,980 bc
PRShortvine-1	0.9	1.8	3.8 a	5,572 de	21,204 abc
PRShortvine-1	1.8	1.8	4.3 a	3,058 a	13,050 a
PRLongvineSLR	0.9	1.8	2.6 a	9,712 f	25,122 bc
PRLongvineSLR	1.8	1.8	2.5 a	5,910 de	14,673 ab
E0305-1	0.9	1.8	3.9 a	4,753 bcd	19,086 abc
E0305-2	0.9	1.8	4.4 a	4,839 cd	21,208 abc
E0305-3	0.9	1.8	3.6 a	3,138 ab	11,317 a
E0305-4	0.9	1.8	4.3 a	6,623 e	28,345 c
Lajas—March to June 2004—Trial 2					
Soler	1.8	1.8	5.4 f	4,578 a	24,728 a
PRShortvine-1	0.9	1.8	2.9 b	8,409 bc	24,348 a
PRShortvine-1	1.8	1.8	2.9 b	9,347 bc	24,283 a
PRLongvineSLR	0.9	1.8	2.5 a	12,704 d	31,705 a
PRLongvineSLR	1.8	1.8	3.2 c	8,736 bc	27,739 a
E0305-1	0.9	1.8	2.9 b	8,724 bc	25,287 a
E0305-2	0.9	1.8	3.7 d	8,708 bc	32,177 a
E0305-3	0.9	1.8	3.2 c	6,844 ab	22,107 a
E0305-4	0.9	1.8	5.1 e	9,991 c	50,497 b
Juana Díaz—April to August 2004—Trial 3					
Soler	1.8	1.8	5.0 c	7,288 a	36,470 a
PRShortvine-1	0.9	1.8	3.9 b	9,026 a	35,410 a
PRShortvine-1	1.8	1.8	3.4 b	10,337 a	36,774 a
PRLongvineSLR	0.9	1.8	2.2 a	11,734 a	26,250 a
PRLongvineSLR	1.8	1.8	1.8 a	8,222 a	15,957 a
Lajas—May to August 2004—Trial 4					
Soler	1.8	1.8	3.7 a	3,393 a	12,838 a
PRShortvine-1	0.9	1.8	2.3 bc	6,671 b	15,378 a
PRShortvine-1	1.8	1.8	2.6 b	5,948 ab	15,341 a
PRLongvineSLR	0.9	1.8	1.8 cd	5,230 ab	9,807 a
PRLongvineSLR	1.8	1.8	1.7 d	6,157 b	10,542 a
Isabela—December 2004 to Febrary 2005—Trial 5—trial not harvested					
Juana Díaz—March to June 2005—Trial 6					
Soler	1.8	1.8	6.9 a	5,034 ab	34,410 a
Soler	0.9	3.7	6.8 a	3,765 c	25,432 ab
PRShortvine-1	1.8	1.8	5.5 b	6,143 ab	32,670 a
PRShortvine-1	0.9	1.8	4.8 bc	6,277 ab	29,261 ab
PRLongvineSLR	1.8	1.8	4.0 c	6,827 a	27,055 ab
PRLongvineSLR	0.9	3.7	4.0 c	4,895 b	19,350 b

[1]The 0.9 m × 1.8 m, 1.8 m × 1.8, and 0.9 m × 3.7 m planting distances (within row × between row) result in planting densities of approximately 5,875; 2,922; and 2,922 plants per hectare, respectively.

[2]Within a trial, means within a column followed by the same letter are not significantly different according to Fisher's Protected Least Significant Difference at the 0.05 probability level.

Fruit Characteristics

Soler was consistently observed to have the widest and flattest fruit shape (Table 5). The experimental lines E0305-1 to E0304-4 tended to be more elongated. PRShortvine-1 and PRLongvineSLR tended toward a more rounded shape. In a study of consumer preferences in Puerto Rico, Carbonell et al. (1990) found that nearly any fruit shape is acceptable.

All genotypes included in this study have passed through a selection program that emphasizes selection for thick fruit flesh. Every genotype had an average thickness (over trials) of more than 4 cm (Table 5). The advantage of the new genotypes (compared to Soler) is that a significantly smaller portion of their fruit diameter is due to the fruit cavity (52% to 62% for new genotypes versus 61% to 67% for Soler). Fruits of Soler are large (large fruit volume) but also have a large cavity. The new genotypes produce smaller fruits (smaller fruit volume), but with relatively smaller fruit cavities. Thus, they have a greater fruit weight for their size than has Soler. The compactness of these fruits makes them easier to harvest, handle and store. These smaller-fruited cultivars should be especially attractive to supermarkets that typically purchase pumpkins in 22.7-kg (50-pound) sacks.

The new genotypes have been selected for orange flesh color. In this study flesh color was measured as lightness (L^*, where higher values correspond to paler flesh); hue angle (h^o, where higher values correspond to a more yellow color; smaller values, a more orange color), and chroma or color intensity (C^*, where higher values correspond to deeper or more intense color). PRShortvine-1 and PRLongvineSLR generally were more intensely orange than Soler (low values of h^o and high values of C^*), which tended to be yellow (Table 6).

Seed Production

Seed characteristics are important when considering the economics of seed sales of a new cultivar. All tested genotypes produced seed of similar weight and size (data not shown for size) (Table 7). In Puerto Rico tropical pumpkin seed is sold by weight, often in 0.45-kg (1 lb) packages, which, for these cultivars, would contain about 5,000 seeds. Because of the lack of differences among cultivars for seed size, there was a very strong association ($r = 0.98$, $p < 0.0001$) between number of seeds per fruit and the total weight of that seed. Individual fruits of Soler produced the most seed by weight and number, whereas E0305-4 was among the poorest genotypes for seed production per fruit. Advanced population PRShortvine-1 produced amounts of seed per hectare similar to those of Soler. Planting density did not have an effect on seed yield in PRShortvine-1. In contrast, denser plantings of PR-

TABLE 5. *Fruit and flesh characteristics of tropical pumpkin genotypes evaluated at various locations in Puerto Rico from 2003 to 2005.*

Genotype	Fruit diameter (m)	Fruit length (m)	Ratio[1]	Flesh thickness (m)	Cavity size as % of diameter
		Isabela—November 2003 to February 2004—Trial 1			
Soler	28.6 a[2]	16.3 b	1.76 a	5.0 bc	65 a
PRShortvine-1[3]	21.7 bcd	16.8 b	1.29 d	4.9 bc	55 cd
PRLongvineSLR[3]	20.0 d	12.6 c	1.59 b	3.8 d	62 b
E0305-1	21.7 bcd	17.2 b	1.27 de	4.6 c	58 c
E0305-2	23.8 b	16.6 b	1.44 c	5.6 a	53 de
E0305-3	20.5 cd	16.0 b	1.28 de	5.1 b	50 e
E0305-4	22.8 bc	19.4 a	1.18 e	5.0 bc	56 cd
		Lajas—April to August 2004—Trial 4			
Soler	24.7 a	14.2 b	1.74 a	4.8 a	61 a
PRShortvine-1[3]	19.3 b	15.7 a	1.23 b	4.6 a	52 b
PRLongvineSLR[3]	17.6 c	12.6 c	1.40 b	4.2 a	52 b
		Juana Díaz—March to June 2005—Trial 6			
Soler	28.3 a	16.6 b	1.70 a	4.6 a	67 a
PRShortvine-1[3]	24.0 b	17.7 a	1.37 b	4.7 a	61 b
PRLongvineSLR[3]	22.3 b	15.5 b	1.44 b	4.5 a	60 b

[1]Ratio of fruit diameter to length. Larger values correspond to flatter fruit.

[2]Within a trial, means within a column followed by the same letter are not significantly different according to Fisher's Protected Least Significant Difference at the 0.05 probability level.

[3]Means are an average of two within-row planting distances.

LongvineSLR produced considerably higher seed yields. The poor seed yields of lines E0305-3 and E0305-4 suggest that seed production of these lines may not be economical.

CONCLUSIONS

Overall, the performance of new genotypes in this trial was often as good as that of Soler. PRShortvine-1 in particular is a good candidate for release among the semi-bush types because of its outstanding fruit characteristics. Besides the small cavity size and color attributes documented in this study, this genotype also has outstanding flesh texture and flavor. Production of seed for sale to farmers would be more economical than is the case with poor seed-producing genotypes E0305-3 and E0305-4. PRShortvine-1 has been rated very highly in informal tests among employees and visitors at the substations at Isabela, Lajas and Juana Díaz. Its cooking quality is excellent, yielding a firm, bright orange product when steamed or baked.

TABLE 6. *Flesh color characteristics of tropical pumpkin genotypes evaluated at various locations in Puerto Rico from 2003 to 2005.*[1]

Genotype	L*	h°	C*
	Isabela—November 2003 to February 2004—Trial 1		
Soler	68.8 cd[2]	66.9 abcd	74.3 a
PRShortvine-1[3]	68.2 cd	64.5 cde	74.5 a
PRLongvineSLR[3]	60.2 e	62.7 e	73.3 a
E0305-1	74.2 ab	68.2 ab	65.8 b
E0305-2	71.8 bc	67.9 abc	70.0 ab
E0305-3	77.9 a	69.8 a	65.3 b
E0305-4	68.0 cd	64.4 cde	55.3 c
	Lajas—March to June 2004—Trial 2		
Soler	71.22 a	68.49 a	72.20 b
PRShortvine-1[3]	72.64 a	66.99 ab	72.87 b
PRLongvineSLR[3]	62.08 a	64.56 bc	76.79 ab
E0305-1	66.11 a	64.12 c	77.24 ab
E0305-2	66.84 a	67.12 ab	84.29 a
E0305-3	72.25 a	65.20 bc	69.51 b
E0305-4	62.61 a	66.43 abc	83.20 a
	Juana Díaz—April to August 2004—Trial 3		
Soler	69.9 a	69.0 a	77.0 a
PRShortvine-1[3]	69.5 a	66.7 b	75.5 b
PRLongvineSLR[3]	61.6 b	66.1 b	74.7 b
	Lajas—April to August 2004—Trial 4		
Soler	66.7 a	67.8 a	77.8 a
PRShortvine-1[3]	68.8 a	64.9 b	73.6 b
PRLongvineSLR[3]	59.1 a	64.1 b	70.5 c

[1]Means of 10 fruit per genotype using a HunterLab ColorFlex™ spectrophotometer (45°/0° optical geometry) measuring CIELAB. L* = lightness, a* = bluish-green/red-purple hue component, b* = yellow/blue hue component, h° (from arctangent b*/a*) = hue angle (0° = red-purple, 90° = yellow, 180° = bluish-green, 270° = blue), C* (from $[(a^{*2} + b^{*2})^{1/2}]$ = chroma.

[2]Within a trial, means within a column followed by the same letter are not significantly different according to Fisher's Protected Least Significant Difference at the 0.05 probability level.

[3]Means are an average of two within-row planting distances.

The smaller fruit size of the new long-vine genotype included in this study, PRlongvineSLR, might make this population more attractive in markets such as supermarkets, where Soler is considered to be too large. Fruits of PRlongvineSLR are similar in shape and rind color to those of Soler. Flesh color was more intensely orange than that of Soler. Another important feature of PRLongvineSLR is its complete resistance to silverleaf and partial resistance to melonworm. Whether the melonworm resistance is due to antixenosis (non-preference) or anti-

TABLE 7. *Seed characteristics of seven tropical pumpkin genotypes evaluated at Lajas, Puerto Rico during March-June 2004 (Trial 2).*

Genotype	Within-row planting distance[1]	Average seed weight per fruit (g)	Number of seed in 50-g seed sample	Number of seeds per frui	Seed production (kg/ha)
Soler	1.8 m	49.9 a[2]	582 a	581.1 a	211.9 bc
PRShortvine-1	0.9 m	32.4 b	561 a	361.5 b	228.7 abc
PRShortvine-1	1.8 m	30.6 bc	608 a	370.3 b	236.3 ab
PRLongvineSLR	0.9 m	28.0 bcd	570 a	319.2 bc	335.1 a
PRLongvineSLR	1.8 m	29.5 bc	530 a	310.0 bc	218.7 bc
E0305-1	0.9 m	29.6 bc	507 a	300.2 bcd	230.6 abc
E0305-2	0.9 m	30.0 bc	568 a	341.5 b	232.5 abc
E0305-3	0.9 m	19.7 cd	546 a	215.7 cd	120.5 c
E0305-4	0.9 m	17.7 d	535 a	186.2 d	160.1 bc

[1]All rows were planted 1.8 m apart. The 0.9 m and 1.8 m within-row planting distances result in planting densities of 5,875 and 2,922 plants per hectare, respectively.

[2]Means are the average of 10 fruits per plot over two plots. Means within a column followed by the same letter are not significantly different according to Fisher's Protected Least Significant Difference at the 0.05 probability level.

biosis could not be determined since PRLongvineSLR was always planted with other varieties.

Overall, the experimental population PRShortvine-1 appears to have promise for release as an open-pollinated cultivar. PRLongvineSLR might also be considered for release either as a cultivar or germplasm release.

LITERATURE CITED

Anonymous, 2004. Ingreso bruto de la agricultura de Puerto Rico (Cifras revisadas 2002/2003 y preliminares 2003/2004). Oficina de Estadísticas Agrícolas, Departamento de Agricultura de Puerto Rico. p. 21.

Carbonell, M., L. Wessel-Beaver, F. Varela and B. Luciano, 1990. Pumpkin (*Cucurbita moschata*) breeding priorities based on a survey among Puerto Rican consumers. *J. Agric. Univ. P.R.* 74(3):229-236.

Costa, H. S., D. E. Ullman, M. W. Johnson and B. W. Tabashnik, 1993. Squash silverleaf symptoms induced by immature, but not adult, *Bemisia tabaci* in Arizona. *Phytopathol.* 83:763-766.

Coyne, D. P., 1970. Inheritance of mottle-leaf in *Cucurbita moschata* Poir. *HortScience* 5:226-227.

Haenszel, W., M. Kurihara, M. Seigi and R. Lee, 1976. Stomach cancer among Japanese in Hawaii. *J. Natl. Cancer Inst.* 49:969-988.

Hidaka, T., T. Anno and S. Nakatsuma, 1987. The composition and vitamin A value of carotenoid of pumpkins of different colors. *J. Food Biochem.* 11:59-68.

McGuire, R. G., 1992. Reporting of objective color measurements. *HortScience* 27(12):1254-1255.

Phillips, R. L., 1975. Role of life-style and dietary habits in risk of cancer among seventh-day adventists. *Cancer Res.* 35:3513-3522.

Wessel-Beaver, L., 2000. Inheritance of silverleaf resistance in *Cucurbita moschata*. *In*: N. Katzir and H. S. Paris (eds.). Proc. Cucurbitacea 2000, Acta Hort. 510, pp. 289-295, Intl. Soc. Hort. Sci., Leuven, Belgium.

Yokomi, R. K., K. A. Hoelmer and L. S. Osborne, 1990. Relationship between the sweetpotato whitefly and the squash silverleaf disorder. *Phytopathol.* 80:895-900.