Both Traditional and Semi-bush Tropical Pumpkin Can Be Intercropped with Beans or Cowpeas

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Abstract. Most cultivars of tropical pumpkin (Cucurbita moschata Duchesne) are large, trailing plants. New semi-bush (SB) genotypes need to be tested against traditional long vine (LV) types. Both types of pumpkin have large amounts of interplant space during the early stages of growth that might allow for the planting of an intercrop. To test this hypothesis, as well as the performance of tropical pumpkins of varying growth habit, double rows of beans (Phaseolus vulgaris L.) or cowpeas [Vigna unguiculata (L.) Walp.] were intercropped between rows of SB or traditional LV tropical pumpkin in Spring and Fall 1993 in Lajas and Isabela, Puerto Rico. In general, interactions between intercrop treatment and pumpkin genotype were not significant. At its maximum percentage cover (MC) the LV genotype covered, or nearly covered, the entire plot while the SB genotype covered 50% or less of the plot or less. The SB pumpkin was harvested 5 to 27 days earlier than the LV type. Yield was two to 12 times greater, and average fruit size three to six times greater in the latter. Planting of an intercrop did not reduce pumpkin yield. Green-shelled yields of intercropped legumes averaged ≈700 kg·ha\(^{-1}\). Genotype of the pumpkin maincrop did not affect legume green-shelled yields in Lajas. In Isabela, legume green-shelled yields were 50% higher in SB than in LV pumpkin plots. Legume dry grain yields were greatly reduced in LV compared to SB plots. Intercropping of tropical pumpkin with a short season legume that can be harvested green-shelled is an efficient intercropping system that offers additional yield from the legume without sacrificing yield from the pumpkin maincrop. Both SB and LV pumpkins can be used in an intercrop system, but pumpkin yields were much greater with the LV genotype.

In Puerto Rico, Florida, and other areas of the Caribbean Basin, tropical pumpkin is commercially planted in monoculture. Tropical pumpkin cultivars and landraces used in commercial plantings have vines that may reach 15 m in length, requiring wide planting distances. In Puerto Rico, the trend has been to decrease the within-row planting distance while increasing the space between rows to 3 m to allow mechanical cultivation during the first few weeks following planting. Rows fill in 8 to 10 weeks after planting. Recently, various semi-bush (SB) tropical pumpkin lines and hybrids have been developed (Maynard et al., 2002), but limited testing of these new types have been carried out. These pumpkins have a compact growth habit, although some may become viney at maturity. When wide row spacings are used, both types of pumpkins have an initial period when the canopy is open. A short-season crop, such as a determinate bean or cowpea, intercropped with the pumpkin maincrop, could potentially contribute additional income without reducing that from the pumpkin maincrop. These legumes can be harvested at physiological maturity, a class of legume call “green-shelled.” If the legume can be harvested before the pumpkin rows fill in, the morphophysiological differences between pumpkin and legume contribute toward temporal and spatial complementarity. Moreover, early harvest of the legume has the potential effect of contributing residual nitrogen to the pumpkin that can optimize nitrogen use as it coincidentally changes growth phenology at the time of legume harvest. The population density of an intercrop is critical to the attainment of yield similar or superior to the corresponding sole crops. In Arizona, Itulya (1982) found that the harvest index of mung bean [Phaseolus aureus Roxb. [syn. Vigna radiata (L.)] and P. vulgaris was not influenced by intercropping or by increasing the plant population of summer squash (C. pepo L.). However, in Kenya, where bean-based intercropping is common, Itulya and Oebker (1989) found that C. pepo planted at intrarow spacings below 100 cm significantly reduced the yield of P. vulgaris and V. radiata (L.).

Materials and Methods

Studies were conducted in Puerto Rico on a clayey, kaolinitic, and isohyperthermic Oxisol (Isabela, spring and fall), on a fine, montmorillonitic isohyperthermic Vertisol (Lajas, spring) and on a fine-loamy, mixed isohyperthermic Mollisol (Lajas, fall). Land preparation consisted of disc plowing and two harrowings.

Combinations of two tropical pumpkin types (LV and SB) and three intercrop treatments (bean, cowpea, or no intercrop) were direct seeded in two locations on three dates (on 22 Feb. 1993 in Lajas, 3 Sept. 1993 in Isabela, and 7 Oct. 1993 in Lajas). The LV genotype, PRB-150, originated from Puerto Rico. The SB genotype was either I25 × I21 (Lajas and Isabela, spring), (I25 × I21)F3 (Lajas, fall), or I25 (Isabela, fall), all originating from Florida. Slightly different SB genotypes were used in each planting because of limited availability of seed. The bean cultivar was ‘Dorado’, the cowpea cultivar was ‘Gorda.’ In each environment, the 2 pumpkin genotypes × 3 intercrops factorial combination of treatments was replicated three (Lajas) or five (Isabela) times in a randomized complete-block design. Plots consisted of either three rows (Isabela) or 0.9-m-high raised beds (Lajas), 1.92 m long and spaced 1.82 m center to center. Twelve pumpkin plants per row (bed), at an in-row spacing of 0.91 m, were planted in the outside rows. The center row of each plot was either left unplanted (no intercrop), or planted in either beans or cowpeas in a double "row," spaced 0.25 m from each side of the center of the plot. Beans and cowpeas were planted at an in-row...
spacing of 0.08 m, a planting density typical of the region. Pumpkin plants were thinned to one per hill, leaving a population of 3005 plants per hectare, typical of commercial plantings in the Caribbean. A drip irrigation line was used in each pumpkin row and between the double row of the legume intercrop.

A single application of 87 kg·ha⁻¹ N, 72 kg·ha⁻¹ P, and 37.5 kg·ha⁻¹ K was made to the legume intercrops 7 d after planting (DAP). Pumpkin plantings received two side dressings of N–P–K: 50 kg·ha⁻¹ N, 21.5 kg·ha⁻¹ P, and 41 kg·ha⁻¹ K at seven DAP, and 100 kg·ha⁻¹ N, 43 kg·ha⁻¹ P, and 83 kg·ha⁻¹ K at floral initiation. Lajas fall pumpkins received similar total kg·ha⁻¹ P, and 83 kg·ha⁻¹ K at floral initiation.

Pumpkin plants were thinned to 60%, and 80% cover. Maximum cover (MC) was determined by threshing and weighing all grain from another 3.6 m of the remaining plot area.

Results and Discussion

Results of Bartlett’s test of homogeneity of variance disallowed combined analyses over the three plantings for all variables except MC. Consequently, results and discussion of all variables are based on individual environments since no statistical tests could be made of apparent differences between environments. With one exception (discussed below), no genotype x intercrop interactions were observed. Thus, the relative performance of LV compared to the SB genotypes was generally unaffected by intercrop treatment.

In the Lajas spring planting, the SB genotype reached MC nearly 3 weeks earlier than the LV type (Table 1). However, MC in LV plots was more than four times that in SB plots. SB plots flowered 27 d earlier than LV plots. The type of intercrop planted with the pumpkin maincrop did not affect days to MC, MC, or DTF.

In the Isabela fall planting, the genotype x intercrop interaction was significant for days to MC. In SB plots the number of days to MC did not vary with intercrop (data not shown). In contrast, the LV genotype reached MC nearly a week earlier (at 7 weeks) in plots with no intercrop compared to those with beans or cowpeas (data not shown). SB plots in this planting covered nearly twice as much plot area (MC) compared to SB plots in the spring Lajas planting, but MC of the LV genotype was still two or a half times more than that of SB type. SB plots again flowered much earlier than LV plots. Type of intercrop did not affect the MC of the pumpkin maincrop. Pumpkins planted together with an intercrop produced more vegetative growth (MC) than plots with no intercrop, indicating that the legumes may have contributed nutritionally to the pumpkin maincrop. DTF was unaffected by intercrop.

In the Lajas fall planting, both SB and LV genotypes reached MC in 7 to 8 weeks (Table 1). As in the spring Lajas and fall Isabela plantings, MC of the LV type was significantly greater than that in SB plots. MC was greater in pumpkin plots with bean than in those with cowpea. However, type of intercrop had no effect on days to MC. DTF was not determined in this planting.

Although the number of days to MC varied among the three plantings, the LV genotype consistently covered, or nearly covered, the entire plot whereas the SB type covered about half or less of the plot. Canopy growth continued in the LV plots after MC was reached, but semi-bush plants began to senesce soon after attaining MC. The SB pumpkin genotypes consistently flowered at ≈36 DAP whereas the LV genotype flowered ≈25 d later. The SB genotypes were developed in Florida from crosses between temperate and tropical types of C. moschata while the LV genotype is a typical tropical cultivar developed in Puerto Rico. Wessel-Beaver and Varela (1991) and Wessel-Beaver and Velázquez (1991) also found that temperate pumpkin varieties flowered and set fruit earlier than tropical varieties. During the fall plantings, pistillate flowers in SB plots appeared 1 to 2 weeks before pollen was available from staminate flowers, and this may have reduced fruit production. The first harvest of the SB genotype occurred 5 to 27 d earlier than the LV type (Table 2). We did not observe any effects of intercropping on pumpkin maturity. Within a particular growth habit type, both intercropped and nonintercropped pumpkins were harvested at the same dates. The green-shelled legume intercrops were harvested 14 to 21 d before the SB type and 26 to 44 d before the first harvest of the LV genotype. At those dates the legumes could be

Table 1. Means, F tests, single degree of freedom contrasts, and coefficients of variation for days from planting to maximum cover (MC), MC (percentage of total plot area), and days from planting to flowering (DTF) of pumpkin genotypes planted in Lajas and Isabela, Puerto Rico.

| Treatments               | Lajas, spring | Isabela, fall | Lajas, fall* |
|--------------------------|---------------|---------------|--------------|
|                          | Days to MC    | Days to MC    | Days to MC   |
|                          | MC (%)        | MC (%)        | MC (%)       |
|                          | DTF           | DTF           | DTF          |
| Pumpkin genotype (G)     |               |               |              |
| Long vine                | 78.3          | 100.0         | 64.4         |
| Semi-bush                | 58.0          | 23.5          | 37.3         |
|                        | **            | **            | **           |
| Significance             |               |               |              |
| Intercrop (I)            |               |               |              |
| No intercrop             | 66.8          | 63.6          | 51.5         |
| With bean                | 69.5          | 60.0          | 40.6         |
|                        | **            | **            | **           |
| With cowpea              | 68.2          | 61.6          | 51.5         |
|                        | **            | **            | **           |
| Contrasts                |               |               |              |
| No intercrop vs. intercrop | NS            | NS            | NS           |
| Bean vs. cowpea          | NS            | NS            | NS           |
| G x I                    |               |               |              |
|                        | 6.2           | 8.6           | 3.8          |
| CV                      |               |               |              |
|                       | 6.2           | 8.6           | 3.8          |

*Days to flowering (DTF) not determined in this environment.

**Pumpkin means for each genotype were averaged over three intercrop treatment levels. Long vine genotype = PR150; semi-bush genotype = I25 x I21 (Lajas, spring); I25 (Isabela, fall); I25 x I21 x I3 (Lajas, fall).

\[ ^{\text{a}} \] Pumpkin means for each intercrop treatment were averaged over two pumpkin genotypes.

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\[ ^{\text{b}} \] Nonsignificant or significant at \( P \leq 0.05 \) or 0.01, respectively.

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Table 2. Days from planting to harvest of legume intercrops and pumpkin maincrops in spring and fall plantings in Isabela and Lajas, Puerto Rico.

| Environment   | Cowpea | Bean | Long vine | Pumpkin maincrop |
|---------------|--------|------|-----------|------------------|
|               | Harvest |       | Harvest   |                  |
| Lajas, spring | 64     | 81   | 66        | 81               |
| Lajas, fall   | 59     | 70   | 63        | 74               |
| Lajas, fall   | 70     | ND   | 77        | ND               |

Table 3. Means, F tests, single-degree-of-freedom contrasts and coefficients of variation for yield, number of fruit and average fruit weight of the pumpkin maincrop planted in Lajas and Isabela, Puerto Rico.

| Treatments | Lajas, spring | Isabela, fall | Lajas, fall |
|------------|---------------|---------------|-------------|
|            | Yield (kg·ha⁻¹) | No. of fruit | Avg fruit wt (kg) | Yield (kg·ha⁻¹) | No. of fruit | Avg fruit wt (kg) | Yield (kg·ha⁻¹) | No. of fruit | Avg fruit wt (kg) |
| Pumpkin genotypes (G)¹ | | | | | | | | | |
| Long vine  | 10.089 | 2.128 | 4.8 | 38.593 | 6.347 | 6.1 | 31.099 | 6.148 | 5.0 |
| Semi-bush  | 5.692 | 3.886 | 1.5 | 3.176 | 3.750 | 0.9 | 10.578 | 5.526 | 1.8 |
| F test     | NS     | **    | **  | **    | **    | **  | **    | **    | **  |
| Intercrop (I)² | | | | | | | | | |
| No intercrop | 8.537 | 3.206 | 3.2 | 21.615 | 4.862 | 3.6 | 18.829 | 5.400 | 3.4 |
| With bean   | 5.625 | 2.335 | 2.9 | 20.191 | 5.051 | 3.4 | 28.196 | 7.482 | 3.6 |
| With cowpea | 9.507 | 3.480 | 3.3 | 20.849 | 5.232 | 3.4 | 15.491 | 4.634 | 3.1 |
| Contrasts   | | | | | | | | | |
| No intercrop vs. intercrop | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Bean vs. cowpea | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| G x I       | 55.5  | 35.4 | 33.4 | 16.4 | 15.1 | 8.1 | 36.8 | 22.0 | 20.8 |
| CV (%)      | NS     | NS | NS | NS | NS | NS | NS | NS | NS |

¹Pumpkin means for each genotype were averaged over three intercrop treatment levels. Long vine genotype = PR150; semi-bush genotype = I25 (Lajas, spring); I25 (Isabela, fall); (I25 x I21)F3 (Lajas, fall).

²Pumpkin means for each intercrop treatment were averaged over two pumpkin genotypes.

**NS** Non-significant or significant at P ≤ 0.05 or 0.01, respectively.

**Pumpkin yield and yield components.** In the Lajas spring planting, long and SB pumpkin yields were different (Table 3). The SB genotype produced more fruit than the LV type, but average fruit weight was greater in the latter. The presence of an intercrop did not affect pumpkin yield, number of fruit, or average fruit weight.

In the Isabela fall planting, the LV genotype was superior to the SB type for yield, number of fruit, and fruit weight (Table 3). The LV type produced more than 10 times the yield and nearly twice as many fruit as the SB type. LV fruits were about six times heavier than those of the SB genotype. Intercrop had no effect on pumpkin yield or its components.

In the Lajas fall planting, the long-vine genotype again produced higher yield and fruit weight than the SB type, but number of fruit was not significantly different between genotypes (Table 3). A higher pumpkin yield and more fruits were produced in bean than in cowpea plots. This agrees with the greater MC observed in bean plots (Table 1). Yield and weight of pumpkins were not reduced in intercrop plots compared to nonintercrop plots.

Commercial pumpkin yields in Puerto Rico are variable. Average yields reported by Alamo (1992) varied from 8,000 to 15,000 kg·ha⁻¹ depending on location. In our plantings, the LV genotype, PRB-150, exceeded these averages in two of three trials, and yielded three to 12 times as much as the SB pumpkin. Wessel-Beaver and Varela (1991) also found that tropical pumpkin genotypes yielded more than their temperate, usually shorter vine, counterparts. Over the three plantings, number of plants ranged from 2100 to 6300/ha or 0.7 to 2.1 fruits per plant. Although no statistical comparisons can be made, fewer fruits were produced in the spring planting than in the fall plantings. Average fruit weight was similar in all three environments. The LV genotype produced very large fruit (4.8 to 6.1 kg), whereas the fruit of SB types was small (0.9 to 1.8 kg). Compared to the two Lajas plantings, Isabela had a higher mean LV fruit weight and a lower mean SB fruit weight. Wessel-Beaver and Varela (1991) found that the average fruit weight of PRB-150, the LV genotype used in this study, was 4.2 kg compared to 0.3 to 0.5 kg for temperate short-vine varieties. Although no statistical test is possible because data were not significantly different between genotypes (Table 3). A higher pumpkin yield and more fruits were produced in bean than in cowpea plots. This agrees with the greater MC observed in bean plots (Table 1). Yield and weight of pumpkins were not reduced in intercrop plots compared to nonintercrop plots.

Consumer preference for orange-yellow to dark orange pulp color and globe or flat shaped fruit described by Carbonell et al. (1990) were characteristic of fruits of PRB-150 but not of the SB genotype. The inclusion of these desirable fruit characteristics may increase the acceptability of SB cultivars of tropical pumpkin. Recent efforts in Florida and Puerto Rico have increased fruit size, yield, and quality of SB cultivars and hybrids (Maynard et al., 2002). We have also conducted studies that suggest that SB yields can be increased by increasing planting density (data not shown).

**Legume intercrop yields.** There were differences in green-shelled yields of bean and cowpea intercrops in the Lajas spring and Isabela fall plantings, but not in the fall in Lajas (Table 4). In the Lajas spring planting, bean yield was less than half that of cowpea. In the Isabela fall planting, by contrast, bean yield was superior to cowpea yield. For legume green-shelled yield, the interaction of intercrop with genotype was nonsignificant. Román-Hernández (1991) found that beans planted in Puerto Rico produced the highest green-shelled yields from October to December. Monar-Benavides (1992) reported that cowpea yield was greater when planting in January than in May.

Legume yields in SB and LV plots were different only in the Lajas fall planting (Table 4). A higher legume green-shelled yield was observed in SB plots than in LV plots.
Green-shelled beans are a very high-value crop in the Caribbean. Legume green-shelled yield exceeded dry grain yield (data not reported here) by more than 60%. Badillo-Feliciano et al. (1985) found that bean green-shelled yield was 70% more than bean grain yield in plantings in Puerto Rico. In Puerto Rico, the retail value of green-shelled beans is at least 10 times that of dry grain (J.S. Beaver, personal communication). Legumes were harvested green-shelled ≈15 d earlier than as dry grain (Table 2). The pumpkin–legume intercropping system either did not allow for the harvest of dry legume grain, or produced grain of poor quality. These effects were more pronounced in plots with the LV genotype as the pumpkin maincrop. In these plots especially, the pumpkin allowed for harvest of green-shelled beans or cowpeas before the pumpkin maincrop vines grew over the intercrop rows. Pumpkin yields were not reduced with the inclusion of an intercrop. Tropical pumpkin intercropped with either bean or cowpea exhibited system complementarity, both temporally and spatially, thus offering growers a potential additional source of income. What additional costs may be incurred with intercropping was not considered in this research, but merits future study.

Compared to the nonintercropped plots, the presence of the legume in the intercropped plots was observed to be a deterrent to weed growth in the area between pumpkin rows. In Puerto Rico, both pumpkins and beans are often hand weeded. However, if chemical herbicides would be used, the presence of two different crop species would complicate weed control.

Conclusion. SB tropical pumpkin types may need different cultural practices, especially greater planting densities, to achieve yield levels of traditional LV types. Continued breeding efforts will also likely result in improve SB cultivars. Both types of tropical pumpkin allowed for harvest of green-shelled beans or cowpeas before the pumpkin maincrop vines grew over the intercrop rows. Pumpkin yields were not reduced with the inclusion of an intercrop. Tropical pumpkin intercropped with either bean or cowpea exhibited system complementarity, both temporally and spatially, thus offering growers a potential additional source of income. What additional costs may be incurred with intercropping was not considered in this research, but merits future study.

**Table 4. Means and F tests for green-shelled yield of bean and cowpea intercrops grown with long or short vine pumpkins in Lajas and Isabela, Puerto Rico.**

| Treatments            | Legume green-shelled yield (kg·ha⁻¹) |
|-----------------------|--------------------------------------|
|                       | Lajas, spring | Isabela, fall | Lajas, fall |
| Intercrop (I)         |               |               |             |
| Bean                  | 452           | 1,179         | 388         |
| Cowpea               | 1073          | 870           | 476         |
| Mean                 | 763           | 1025          | 432         |
| F test               | **   **       | **   **       | NS          |
| Pumpkin genotype (G) |               |               |             |
| With long vine       | 768           | 836           | 361         |
| With semi-bush       | 756           | 1213          | 503         |
| F test               | NS            | **   **       | NS          |
| I x G                | NS            | NS            | NS          |
| cv (%)               | 9.2           | 10.2          | 44.02       |

*Each legume mean was averaged over two pumpkin genotypes.

*Legume means for each pumpkin genotype treatment level were averaged over both beans and cowpeas. Long vine genotype = PR150; semi-bush genotype = I25 (Lajas, spring); I25 (Isabela, fall); I25 × I21 (Lajas, fall). *NS = Nonsignificant or significant at \( p \leq 0.01 \), respectively.

**Table 4. Means and F tests for green-shelled yield of bean and cowpea intercrops grown with long or short vine pumpkins in Lajas and Isabela, Puerto Rico.**

| Treatments            | Legume green-shelled yield (kg·ha⁻¹) |
|-----------------------|--------------------------------------|
|                       | Lajas, spring | Isabela, fall | Lajas, fall |
| Intercrop (I)         |               |               |             |
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| Pumpkin genotype (G) |               |               |             |
| With long vine       | 768           | 836           | 361         |
| With semi-bush       | 756           | 1213          | 503         |
| F test               | NS            | **   **       | NS          |
| I x G                | NS            | NS            | NS          |
| cv (%)               | 9.2           | 10.2          | 44.02       |

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