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FLOWERING HABIT, YIELD, AND FRUIT SHAPE OF CALABAZA CULTIGENS

D. N. MAYNARD
Gulf Coast Research and Education Center
IFAS, University of Florida
Bradenton, FL 34203

G. W. ELMSTROM
Central Florida Research and Education Center
IFAS, University of Florida
Leesburg, FL 34748

LINDA WESSEL-BEAVER
Department of Agronomy and Soils
University of Puerto Rico
Mayaguez, PR 00708

T. G. MCCOLLUM
USDA/ARS
2120 Camden Road
Orlando, FL 32803

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Abstract. **The flowering habit and yield potential of 7 calabaza [*Cucurbita moschata* (Duchesne), Poir.] cultigens were studied in the fall 1991 season. Earliest flowering and fruit maturity were obtained from bush plant lines developed from 'Burpee Butterbush'. Time of flowering and distance of flowers and fruit from the crown were intermediate in the Florida-developed varieties 'La Primera' and 'La Segunda' and latest and farthest from the crown in the Puerto Rican-developed entries 'Borinquen', Linea C Pinta, and 'Soler'. 'La Primera' and 'La Segunda' produced the highest yields; the bush lines which had very small fruit size produced the lowest yields. Fruit size of 'La Segunda' and Linea C Pinta was mostly in the desirable range of 8 to 12 lb. Most 'La Primera' and 'La Segunda' fruit were round, 'Borinquen', Linea C Pinta, and 'Soler' fruit were flat, and the bush lines produced variable shaped fruit. Further backcrossing to round types is required to overcome the problem of small fruit size and variable fruit shape in the bush lines.**

Cucurbita moschata (Duchesne) Poir., known as calabaza in Florida and Puerto Rico, is a pumpkin-like fruit that is grown throughout the tropics and subtropics. This species is also known as auyama in the Dominican Republic, calabash or pumpkin in the English-speaking islands, ayote in Central America, and zapallo in South America. Plants are monoecious, and insects, mostly honeybees and bumblebees, are required for transfer of pollen from staminate to pistillate flowers. Fruit are produced along trailing vines that may spread up to 50 ft from the base of the plant. Each plant commonly produces 2 to 5 fruit, however, some selections may produce as many as 9 fruit per plant. Fruit weights vary from 5 to 50 lb. Fruit shape varies in unimproved types from globe, round, oval, obovate, pear, oblate and gourd, to elliptic. Likewise, there is much variation in rind color from green immature fruit to light-orange mature fruit and in rind pattern from piebald to mottled. The rind may be smooth or warted. The fruit wall varies in color through several shades of yellow to orange and is from 1 to 3 inches thick.

Economic importance. Although widely grown in tropical America, calabaza plantings are generally small and most do not exceed a few acres in size. Nonetheless, calabaza is a major crop in certain areas. For example, in 1987-88 Puerto Rico produced calabaza valued at $8 million which accounted for 29% of the income from vegetables, exceeded only by that of tomatoes (Alamo, 1990). It is estimated that 1200 to 1500 acres of calabaza are grown in Puerto Rico. Many of these plantings are less than 5 acres, however, about one-half of the total acreage is made up of larger plantings. Calabaza production in South Florida has increased from 1200 acres in 1977 with a farm value of $624 thousand (McGuire and Champagne, 1977) to an estimated 2500 acres with a farm value exceeding $5 million. Considerable area is devoted to calabaza production in the Dominican Republic, Costa Rica, and Mexico for export to the United States (Pearrow and Plummer, 1991).

Consumption and culinary usage. Calabaza is the most important traditional non-root vegetahle crop in Puerto Rico. Per capita annual consumption is more than 15 lbs of calabaza in Puerto Rico compared to 13 lbs annual per capita consumption of tomato, the second most consumed vegetable (Alamo, 1990).

Desirable fruit characteristics. In Florida (Volin et al., 1976), fruit characteristics deemed to be important in high quality calabaza by researchers, market personnel, and growers were: freedom from cracks; comparatively large, round fruit with a smooth, light-green rind; deep-yellow internal color; thick internal flesh; and high soluble solids.

A survey of Puerto Rican consumer preferences for desirable calabaza characteristics included 527 respondents (Carbonell et al., 1990). Preferences were not affected greatly by geographical region, age, sex, or frequency of consumption. Consumers preferred an orange-yellow to dark-orange fruit wall (pulp) compared to lighter-colored flesh. Unander and Varela-Ramirez (1988) described procedures for selection of flesh color and thickness in calabaza. Globe, flat, and round regularly-shaped fruit were preferred over oval or irregularly-shaped fruit. The preferred rind color was piebald or dark piebald (pinta). Most consumers preferred medium-size fruit weighing between 8 and 15 lbs. However, most of those surveyed indicated a preference for cut, rather than whole fruit. The survey results did not indicate a preference for rind thickness or hardness, but there was a clear preference for a smooth versus a rough rind. Fruit characteristics, in order of importance, deemed most important by Puerto Rican consumers were internal color, rind color, fruit size, rind type, and fruit shape.

Importers of calabaza from the Caribbean and Central America believe that their requirements are best met with regularly-shaped, flat or round fruit that weigh about 10 lbs each, and have a smooth, tough, pinta to green-colored

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rind. The fruit must have a closed blossom end and have a thick, dark-orange fruit wall.

The parameters of calabaza fruit quality developed primarily by Florida and Puerto Rican researchers and by importers are being used to guide the breeding program. The objective of this trial was to determine the flowering habit, yield, and fruit shape of several calabaza cultigens (Table 1) that differ in plant type.

Materials and Methods

Soil in the experimental area was sampled before fertilization and analyzed by the IFAS Extension Soil Testing Laboratory (Hanlon and DeVore, 1989): pH = 6.6 and Mehlich I extractable P = 34, K = 44, Mg = 124, Ca = 822, Zn = 2.0, Cu = 0.9, and Mn = 0.9 ppm.

The EauGallie fine sand was prepared in early July 1991 by incorporation of 0-24-0 lb N-P-K/acre. Beds were formed and fumigated with methylbromide:chloropicrin (67:33) at 119 lb/mulched acre. Banded fertilizer was applied in shallow grooves on the bed shoulders at 120-0-135 lb N-P-K/acre after the beds were pressed and before the black polyethylene mulch was applied. The total fertilizer applied was equivalent to 120-24-135 lb N-P-K/acre. The final beds were 32 inches wide and 8 inches high, and were spaced on 9 ft centers with 4 beds between seepage irrigation/drainage ditches which were on 41 ft centers. For the yield trial, calabaza seeds of 7 cultigens (Table 1) were planted on 25 July in holes punched in the polyethylene at 4-ft in-row spacing. The 40-ft long plots had 10 plants each and were replicated 4 times in a randomized complete block design. Seeds of the same cultigens were planted in similar fashion at 25-ft in-row spacing for the flowering habit study. The single plant plots were replicated 5 times in a randomized complete block design. Plants were thinned to one per hill in both experiments.

Before the vines covered the row middles, weed control was by cultivation and applications of paraquat. Pesticides were applied twice weekly for control of the sweetpotato whitefly (endosulfan and esfenvalerate), aphids (endosulfan), and downy mildew (metalxyl).

An infestation of sweetpotato whitefly occurred in mid-Aug, before routine insecticide applications had been initiated. This resulted in the appearance of silverleaf, a sweetpotato whitefly related disorder (Maynard and Cantliffe, 1989). Because the disorder was not uniformly distributed in the planting, each plant was evaluated for the presence of the disorder and rated on a 0 (no silverleaf) to 4 (severe silverleaf) scale.

The calabazas in the yield trial were harvested as they matured from 2 Oct. through 31 Oct. Marketable fruit were separated from cull (severely cracked) fruit and counted and weighed individually. In addition, each fruit was classed as round, flat, oval, or pear shaped. In the flowering habit study, the first occurrence of staminate and pistillate flowers on each plant was noted and the distance from the plant crown to the flower was measured and the number of nodes counted. Likewise, the distance and number of nodes from the crown to the first mature fruit was noted. The resulting data were subjected to analysis of variance and mean separation was by Duncan's multiple range test.

Table 1. Descriptions and sources of calabaza cultigens.

Cultigen	Source[z]	Plant type	Mature fruit description
Borinquen	PRAES	Vine	Dark green, slightly ribbed flat fruit (many with flattened bell-shape at stem end)
La Segunda	GCREC	Vine	Piebald, round fruit
L18-4	CFREC	Bush	Cream, tan, variable shaped fruit
L26-3	CFREC	Bush	Cream, tan, variable shaped (mostly pear-shaped) fruit
La Primera	GCREC	Vine	Piebald, round fruit
Linea C Pinta	PRAES	Vine	Piebald, slightly ribbed, mostly flat fruit
Soler	PRAES	Vine	Dark green, slightly ribbed, mostly flat fruit

[z]PRAES = Puerto Rico Agricultural Experiment Station; GCREC = Gulf Coast Research and Education Center, University of Florida; CFREC = Central Florida Research and Education Center-Leesburg, University of Florida.

Results and Discussion

Maximum and minimum temperatures during the experimental period from 25 July through 31 October were slightly higher than the 38-year averages at the Gulf Coast Research and Education Center (Table 2). Rainfall was lower than normal, particularly in Sept. and Oct.

The occurrence of silverleaf as recorded on 21 Aug. was higher and the severity was greater in calabazas originating in Puerto Rico, i.e., 'Borinquen', Linea C Pinta, and 'Soler' than in calabazas originating in Florida (Table 3). At this time, the reasons for varying susceptibility to silverleaf are not known, however, future breeding and selection for silverleaf tolerance appears to be a possibility.

Table 2. Mean temperature and rainfall at the Gulf Coast Research and Education Center from 25 July to 31 October 1991 and 38-year monthly averages (Stanley, 1992).

	Average daily temperature (°F)					
	1991		38-year average		Rainfall (inches)	
Month (date)[z]	Max.	Min.	Max.	Min.	1991	38-year average
July (25-31)	92	73	91	72	2.97	9.37
August	92	74	91	72	8.18	9.80
September	92	72	90	71	2.74	8.28
October	87	67	85	64	1.21	2.80

[z]1991 data are for the dates shown; 38-year averages are for the entire month.

Table 3. Incidence and severity of silverleaf on calabaza plants. 21 August 1991.

	Silverleaf	
Cultigen	(%)[z]	Severity[y]
Borinquen	90 a[x]	4.0 a
La Segunda	25 b	1.8 cd
L18-4	53 b	1.3 d
L26-3	45 b	2.0 c
La Primera	35 b	1.6 cd
Linea C Pinta	90 a	3.0 b
Soler	85 a	3.0 b

[z]Percent of plants affected.
[y]0 = no silverleaf, 4 = severe silverleaf.
[x]Mean separation in columns by Duncan's multiple range test, 5% level

Table 4. Calabaza yield and average fruit weight. Fall 1991.

Cultigen	Fruit yield per acre		Avg fruit wt (lb)
	No.	Wt (cwt)	
Borinquen	4084 b[z]	280.2 bc	6.8 d
La Segunda	3902 bc	462.8 a	12.0 b
L18-4	5385 a	190.2 cd	3.5 e
L26-3	5990 a	105.2 d	1.8 f
La Primera	3086 bc	458.2 a	14.9 a
Linea C Pinta	3570 bc	306.6 b	8.8 c
Soler	2995 c	376.3 ab	12.4 b

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 5. Weight distribution of calabaza fruit. Fall 1991.

Cultigen	Percentage by weight (lbs)				
	≤4	4.1-8.0	8.1-12.0	12.1-16.0	>16.0
Borinquen	1 c[z]	75 a	20 cd	4 b	0 c
La Segunda	0 c	10 d-e	50 a	26 a	14 b
L18-4	75 b	16 cd	9 de	0 b	0 c
L26-3	99 a	0 e	1 e	0 b	0 c
La Primera	0 c	1 e	29 bc	36 a	34 a
Linea C Pinta	0 c	45 b	43 ab	10 b	2 c
Soler	0 c	20 c	35 bc	25 a	20 b

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 6. Calabaza fruit shape distribution. Fall 1991.

Cultigen	Fruit shape (%)			
	Round	Flat	Oval	Pear
Borinquen	7 b[z]	93 a[y]	0 a	0 c
La Segunda	78 a	16 b	6 a	0 c
L18-4	30 b	33 b	8 a	29 b
L26-3	10 b	9 b	9 a	73 a
La Primera	82 a	11 b	8 a	0 c
Linea C Pinta	3 b	75 a	16 a	7 c
Soler	28 b	72 a	0 a	0 c

[z]Mean separation in columns by Duncan's multiple range test, 5% level.
[y]A high proportion of flat 'Borinquen' fruit had a dome at the stem end.

The number of fruit produced per acre ranged from 2995 for 'Soler' to 5990 for L26-3 (Table 4). Weight of fruit produced per acre varied from 105.2 cwt for L26-3 to 458.2 cwt for 'La Primera' and 462.8 cwt for 'La Segunda'. High yields were also produced by 'Soler' plants. Average fruit weight varied from 1.8 lb for L26-3 to 14.9 lb for 'La Primera'. Some calabaza importers and brokers have indicated that 10 lb fruit are most acceptable. None of the cultigens in this trial produced fruit whose average weights were 10 lb. 'La Segunda', 'La Primera', Linea C Pinta, and 'Soler' produced a high proportion of fruit in the 8 to 16 lb weight range that was identified as being desirable in the survey of Puerto Rican consumers (Carbonell et al., 1990). L18-4 and L26-3, the bush types that were developed from crosses between 'La Primera' and 'Burpee's Butterbush' produced fruit that weighed less than 4 lbs.

The distribution of fruit into weight classes (Table 5) usually provides a better indication of acceptable size than does average fruit weight. 'Borinquen' produced a high proportion of fruit that weighed between 4 and 8 lb. Linea C Pinta fruit were mostly in the 4 to 12 lb weight class. Most 'La Primera', 'La Segunda', and 'Soler' fruit were in heavier weight classes, whereas, most L18-4 and L26-3 fruit were less than 4 lbs each.

A high proportion of 'La Primera' and 'La Segunda' fruit were round (Table 6). This is consistent with selection for round fruit leading to their development in Florida (Volin et al., 1976). 'Borinquen', Linea C Pinta, and 'Soler' fruit were predominantly flat, the generally preferred shape in Puerto Rico (Carbonell et al., 1990). The variability in shape and high proportion of pear-shaped fruit in L18-4 and L26-3 is indicative of their stage of development in the breeding program. With further backcrossing to round types, this problem as well as the small fruit size problem should be overcome.

Yields of 'La Primera' in 1991 were somewhat less than the 550 cwt/acre produced at this location in 1987 and the 488 cwt/acre produced in 1990 (Maynard and Elmstrom, 1991). In 1987, the higher yield was attributed to very large fruit size. On the other hand, yield of 'La Segunda' was 463 cwt/acre in 1991 compared to 301 cwt/acre in 1990. Average fruit weight was greater in 1991 which accounted in part for the difference.

In the flowering habit study, the first open staminate flowers appeared on L18-4 and 'La Primera' 40 days after planting (DAP) and 41 DAP in L18-4 (Table 7), whereas, the first open staminate flower did not appear on 'Soler' until 50 DAP. Open pistillate flowers appeared on L26-3, 'La Primera', and L18-4 at 33, 37, and 38 DAP, respectively. But the first open pistillate flower did not appear on 'Soler' and Linea C Pinta until 54 and 58 DAP, respectively.

There appeared to be good agreement between the distance and number of nodes from the crown for each entry (Table 7). 'La Segunda', L18-4, L26-3, and 'La Primera' staminate flowers were produced relatively close to the crown, whereas, 'Borinquen', Linea C Pinta, and 'Soler'

Table 7. Flowering and fruiting habits of calabaza. Fall 1991.

Cultigen	First open flower		Distance from crown		Nodes from crown		First mature fruit		
	Staminate (DAP[z])	Pistillate	Staminate (inch)	Pistillate	Staminate (no.)	Pistillate	Nodes (no.)	(inch)	(DAP)
Borinquen	46 b[y]	48 ab	19.3 ab	124.0 b	5 a-c	23 b	18 b	116.5 bc	85 a
La Segunda	45 b	42 bc	6.7 bc	85.0 c	3 bc	15 bc	11 b	52.0 cd	86 a
L18-4	41 c	38 c	1.2 c	12.2 d	3 bc	6 d	7 c	14.2 d	69 b
L26-3	40 c	33 c	0.8 c	3.9 d	2 c	4 d	3 c	4.3 d	63 b
La Primera	40 c	37 c	3.5 bc	66.5 c	3 bc	13 c	6 c	33.5 cd	85 a
Linea C Pinta	46 b	58 a	30.3 a	326.4 a	7 a	38 a	28 a	185.4 ab	95 a
Soler	50 a	54 a	28.3 a	137.4 b	5 ab	19 b	32 a	241.7 a	92 a

[z]Days after planting.
[y]Mean separation in columns by Duncan's multiple range test, 5% level.

staminate flowers were at some distance from the crown. The first pistillate flowers were very close to the crown on L18-4 and L26-3 plants, intermediate on 'La Segunda' and 'La Primera' plants, at some distance in 'Borinquen' and 'Soler' plants, and farthest from the crown in Linea C Pinta plants.

The first mature fruits were earliest and closest to the crown on L18-4 and L26-3 plants. There was no difference in maturity among the other entries. Apparent discrepancies in the distance and number of nodes to the first pistillate flower and first mature fruit can be explained by the fact that not all pistillate flowers develop into fruit. In addition, pistillate flowers that develop on branches other than the one where the first pistillate flower appeared may set closer to the crown than the first one.

Results of these studies indicate that 3 distinct calabaza populations were included. L18-4 and L26-3, the bush types developed at CFREC-Leesburg, produced flowers closest to the crown, were earliest, but produced very small fruit. At the other extreme, 'Borinquen', Linea C Pinta, and 'Soler', developed in Puerto Rico, produced flowers farthest from the crown, were latest in fruit maturity, and produced medium to large flattened fruit. 'La Primera' and 'La Segunda' were intermediate in distance of flower production from the crown, intermediate in fruit maturity, and produced medium to large fruit.

The bush types offer promise in the goal to produce short-vined calabazas. Further backcrossing to large-fruited, long-vined types will be made to improve fruit size and shape and selection for intermediate vine length will be made.

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DEVELOPMENT AND BREEDING OF HERBICIDE TOLERANT LETTUCE

R. T. NAGATA AND J. A. DUSKY
Everglades Research and Education Center
IFAS, University of Florida
Belle Glade, FL 33430-8003

A. C. TORRES, D. J. CANTLIFFE,
R. J. FERL AND T. A. BEWICK
Horticultural Sciences Department
IFAS, University of Florida
Gainesville, FL 32611-0690

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Abstract. **Weed control measures for lettuce, *Lactuca sativa* L. on south Florida high organic soils (>70%) can exceed $600 per acre due to the high use of manual labor. Available chemical herbicides are ineffective for broad spectrum control of weeds. It is the approach of the lettuce breeding program of the University of Florida to develop herbicide tolerant lettuce cultivars through classical and gene splicing methodology. Sulfonylurea herbicide resistance was derived from prickly lettuce, *L. serriola* L. and backcrossed into crisphead, cos, bibb and leaf lettuce that have desirable disease resistance and commercial quality. Inheritance of the herbicide resistance was through an incomplete dominance gene action. Good expression of resistance in lettuce was observed at 2 oz/acre rate of imazethapyr. Segregation ratios for backcrossing was 1:1, tolerant:susceptible. F_2 segregation for resistance:tolerant:susceptible was in a 1:2:1 ratio. Breeding lines of leaf, cos, crisphead and butterheads resistant and tolerant to sulfonylurea herbicides have been developed. Closed heading types are progressing slower than open head types due to multiple genes involved in heading. Glyphosate resistance was bioengineered into 'South Bay' lettuce through the use of *Agrobacterium tumefaciens* as the vector. A total of 73 individual family lines, each representing a independent transformation event have been generated. Seed were collected for each line. Initial screening of regenerated 'South Bay' crisphead lettuce with the incorporated gene have indicated good resistance to glyphosate at a use rate of 2 lb/acre. The mechanism of gene action is believed to be dominant. Homozygous lines have been identified and studies are continuing.**

Currently, it is standard procedure to evaluate individual vegetable crops for tolerance to various herbicides. The efficacy of weed control at various application rates is correlated to crop response. When efficacy and crop tolerance are identified, registration of the herbicide for the crop is pursued. A radically different approach is now being un-