Effect of inbreeding on the quality traits of squash fruit

Efecto de la endocría en caracteres relacionados con la calidad del fruto de zapallo

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Abstract

Yield and traits related to fruit quality were evaluated for six squash introductions *Cucurbita moschata* Duch. from open pollination (S_0) and their respective inbreeding lines (S_1 and S_2). The inbreeding that accompanied selection did not cause negative effects on yield, nor the agribusiness traits of: weight of fruit pulp, color of fruit pulp, and fruit dry matter.

Key words: Cucurbitacea*, Cucurbita moschata* Duch., inbreeding, yield, fruit wall thickness.

Resumen

Se evaluó el rendimiento y características relacionadas con la calidad del fruto de seis introducciones de zapallo, *Cucurbita moschata* Duch., a libre polinización (S_0) y en las líneas endocriadas S_1 y S_2. La endocría acompañada de selección no causó efectos negativos en las variables producción por planta, espesor de la pulpa del fruto, color de la pulpa del fruto y materia seca en el fruto.

Palabras clave: Cucurbitacea, *Cucurbita moschata*, endogamia, producción vegetal, pulpa de legumbres, zapallo, ayote, Colombia, América Central.

Introduction

The squash, *Cucurbita. moschata* Duch*.,* is allogamous and monoecious; the flowers are abundant, ephemeral, solitary and unisexual (Vallejo, 1984). The staminate flowers are precocious (28 to 35 days post-planting), emerging from the middle of the stem with long peduncles. The pistillate flowers emerge later (30 to 45 days post-planting), and emerge at the apices of the stems, with short, fat peduncles, followed by an inferior ovary (Montes, 2003). The ratio between staminate and pistillate flowers varies between 4:1 and 17:1 per plant (Vallejo and Gil, 1998), ensuring cross pollination by bees, and reducing to a minimum the possibility of endogamy (Whitaker, 1984). However, in a typical home-garden possessing, only one squash plant, pollen transport will occur between pistillate and staminate flowers on the same plant, a process that has occurred in a recurrent manner over many years (Allard, 1978), and which has generated a mechanism of self-fertilization in an allogamic plant, apparently without loss of productive performance.

Inbreeding has been used in plant breeding programs to fix favorable genotypes of agricultural interest (Allard, 1978), to separate favorable genotypes (Vallejo & Gil, 1998), and to reduce the percentage of heterozygotes in the population (Jansen & Jansen, 1990; Della Vecchia et al., 1993). However, inbreeding reduces population fitness, particularly in allogamous species (Vallejo & Gil, 1998), increases the genetic variance between families, and reduces it within families (Falconer & Mackay, 1996), with a progressive increase in the additive variance (σA) at the expense of dominance (σD) in totally homozygote lines (Ceballos, 1998).

In squash, inbreeding is considered an obligatory strategy in the selection of good progenitors (Vallejo & Estrada, 2002). Inbreeding depression is not notable in Cucurbitaceas (Allard, 1978) although it has been registered in advanced lines of cucumber *Cucumis sativus*, the 'ahuyama' squash *Cucurbita moschata* Duch, the melon *Cucumis melo* and watermelon *Citrullus lanatus* (Robinson, 1999; Cardoso, 2004; Berenjl, 1986; Hallaver, 1999).

Given this, it is necessary to explore further the response to inbreeding in different introductions of squash, originating from the Horticultural Program of the National University of Colombia, Palmira campus, with the aim to identify the progenitors tht will constitute the base for advancing studies aimed at obtaining improved varieties. This study had the objective to document the behavior in six introductions of squash (*Cucurbita moschata* Duch.) in three generations of inbreeding: free pollination (S_0), first and second generation of inbreeding (S_1 and S_2, respectively).

Materials and Methods

This work was carried out in the second semester of 2006, in the Experimental Center of the National University of Colombia, Palmira campus, located in the municipality of Candelaria (03° 25' N and 76° 25' W, at 980 m.a.s.l., 26 °C, 1100 mm average annual precipitation, and 76% relative humidity) (Montes, 2003), in the Department of Valle del Cauca, Colombia.

Six free pollination introductions (S_0) were used, as well as their derived inbreeding lines S_1 y S_2, selected for fruit quality traits (Box 1). Amongst these, the following traits were evaluated:: production per plant (PPL, kg), weight of fruit wall (EPF, cm.), color of fruit pulp

(COLOR, 1-15 on the Roche scale, where 1 is white and 15 is intense yellow), and fruit dry material (MSF, %).

Box 1. Production per plant (PPL), fruit pulp weight (EPF), fruit pulp color (COLOR) and dry fruit material (MSF) of the introductions of squash *Cucurbita moschata* Duch. Included in the study.

Introduction (no.)	Origin		PPL (kg/plant)	EPF (cm)	COLOR[a]	MSF (%).
	Municipality	Department				
2	Pradera	Valle del Cauca	10.2 ± 4.5	2.74 ± 0.46	11.4 ± 2.0	17.9 ± 4.5
6	Pradera	Valle del Cauca	18.9 ± 4.9	3.69 ± 0.80	10.0 ± 2.7	13.9 ± 3.8
28	Patía	Cauca	30.0 ± 13.0	4.25 ± 0.88	9.0 ± 3.0	12.8 ± 2.6
34	Patía	Cauca	19.2 ± 8.0	3.99 ± 0.75	9.7 ± 3.4	12.7 ± 2.7
79	Santa Marta	Magdalena	11.89 ± 3.1	3.66 ± 0.76	8.3 ± 1.1	18.8 ± 6.2
80	Santa Marta	Magdalena	10.6 ± 3.2	5.36 ± 1.43	6.6 ± 2.2	13.4 ± 7.0

a. . 1= white; 15= intense yellow. SOURCE: Doctoral thesis, first author.

An experimental design of completely randomize blocks was applied, with three repetitions, and five plants per repetition. The results were analyzed using the statistical package SAS with the protocol of Cadena *et. al.* (1998), based on the hypothesis of no inbreeding depression between generations S_0, S_1 y S_2 ($H_0 = \mu_0 = \mu_1 = \mu_2$). The value of the inbreeding depression as a function of inbreeding generations is:

$$1-\left(W_s / W_o \right)$$

where W_s is the average value of the trait in the inbred plants, and W_o is the average value of the trait in the non-inbred plants (Hayes et al., 2005).

Results and Discussion

Box 1 presents the effects of inbreeding on the traits for production per plant(PPL), fruit pulp weight(EPF), fruit pulp color (COLOR) and fruit dry material (MSF) in squash.

In the case of plant production and fruit pulp weight, the introduction 2 presented reductions in both traits due to inbreeding ($P < 0.01$) on passing from generation S_0 to S_1. However, on passing from S_1 to S_2 production increased ($P < 0.01$); and S_0 to S_2 was stable (Box 2). The introductions, 6, 28 and 80 showed stable behavior in production across the three generations. The introduction 79 saw an increase in production on passing from S_0 to S_2, while the introduction 34 saw a reduction.

Fruit pulp color in the introductions 2, 6, 79, and 34 was similar in the three generations. In the introduction 28 it increased on passing from S_0 to S_1 and stabilized in the generation S_2, ending up the same color as in S_0. The behavior of this trait was erratic in the three generations in the introduction 80 (Box 2).

Box 2. Effect of inbreeding on the traits: production per plant (PPL), fruit pulp weight (EPF), fruit pulp color (COLOR), fruit dry material (MSF) in the squash *Cucurbita moschata* Duch.

Introduction (No.)	Generation of inbreeding	PPL (kg)	EPF (cm)	COLOR[a]	MSF (%)
2	S_0	16.86	3.39	10.63	13.52
	S_1	2.73	1.99	8.73	14.77
	S_2	16.82	3.45	8.39	8.30
6	S_0	15.01	3.48	9.88	9.08
	S_1	12.36	3.64	10.85	14.33
	S_2	9.27	3.35	9.12	18.09
28	S_0	7.07	3.56	6.36	8.74
	S_1	6.49	3.30	8.54	10.73
	S_2	9.29	2.72	6.31	12.34
79	S_0	8.28	4.42	11.11	16.38
	S_1	6.49	3.30	8.54	10.73
	S_2	15.91	3.92	9.38	13.72
80	S0	10.18	4.14	9.50	10.34
	S1	10.41	4.73	10.90	11.83
	S2	15.70	4.44	6.44	9.51
34	S_0	13.95	3.56	9.77	9.90
	S_1	13.78	4.52	8.73	13.89
	S_2	8.31	4.15	9.10	12.64
Average		11.08	8.89	12.77	1.38
Min.		2.73	6.31	8.3	0.4
Max		16.86	11.11	16.09	2.28
LSD		3.03	0.98	1.89	0.38

a. 1= white; 15= intense yellow.

The dry material content (MSF) was constant in the three inbreeding generations of the introduction 28, 80 and 34. For this trait, the introduction 2 was stable between the generations S_0 and S_1 and reduced ($P < 0.01$) the performance in the generation S_2. The introduction 6 showed a tendency to increase MSF content on passing from one generation to the next (Box 2). The introduction 79 presented more drastic changes in the percentage of MSF ($P < 0.05$). In general, the introduction 2 was the most sensitive to inbreeding and presented a reduction in the traits PPL and EPF on passing from S_0 to S_1. The introductions 79 and 80 presented non-significant changes for EPF and pulp color, respectively (Box 3).

Box 3. Clustering of introductions in the squash *Cucurbita moschata* Duch. According to depression, stability or synergy resulting from inbreeding for the traits: production per plant (PPL), fruit pulp weight (EPF), fruit pulp color (COLOR), fruit dry material (MSF)

Variable (character)	Introductions with depression effect Passing from:		Stable introductions on passing from :		Synergistic effect on passing from:	
	S_0 to S_1	S_1 to S_2	S_0 to S_1	S_1 to S_2	S_0 to S_1	S_1 to S_2
PPL (kg)	2	—	6, 28, 79, 80, 34	6, 28	—	2, 79, 80, 34
EPF (cm)	2, 79	—	6, 28, 80, 34	6, 28, 79, 80, 34	—	2
COLOR[a]	—	80	2, 6, 28, 79, 80, 34	2, 6, 79, 34	—	28
MSF(%)	—	2	2, 6, 28, 80	28, 80, 34	79, 34	6, 79

a. 1= white; 15= intense yellow.

The stability and positive synergy (increase in the variables) in the traits being studied across introductions and generations of *C. mochata* are important finds, and corroborate the results of Vallejo and Gil (1998) working with species in the genus *Cucurbita.* These findings were evident in the increase in the evaluated variables in the generations S_0 and S_1 of the introductions 79 and 34 , and especially for MSF on passing from S_1 to S_2 in the introductions 2, 79, 80 and 34. Previous work supposes inbreeding depression, yielding subvital plants and little productivity (Falconer & Mackay, 1996), findings which were not sen in the present study, and which where uncommon, such as seen by Cardoso (2004).

On the other hand, in inbreeding is an alternative for changing the genotypic frequency of a population, and also the expression of a triat being studied (Falconer y Mackay, 1996), the possible reason for the stability and increase in the analysed variables could be the heterogeneity of the heterozygote genotypes on the introductions to free pollination S_0 of *C. moschata*, which assumes high dominance (σ^2D) when inbreeding is absent (Ceballos, 1998), and dominance by dominance (σ^2DD) interactions with a probably presence of remnant dominance at the expense of additive, as it accentuates inbreeding (Roy, 2000).

Hayes et. al. (2005) inbred plants of *Cucurbita pepo* cv. Texana for three years, and found that the inbreeding depression might or might not affect the pollen vigor and germination, the number of fruits per plant or seeds per fruit, which could be influenced by environmental factors.

Thus, inbreeding depression, in the strict sense is due to direct consequences of allelic interactions or of dominance, and does not occur when the genic action is entirely additive, that is, when inbreeding is 100% (Fox, 2005). In the present case, there only exists 0%, 50% and 75% of inbreeding in the introductions to free pollination (S_0), and S_1 and S_2,. respectively. In early inbreeding generations the phenomenon of synergistic epistasis can occur (Crow & Kimura, 1970) increasing the production variables, as happens with the number and commercial weight of the fruit of *C. sativus* in 12.6% and 7.72% when passing from S_0 to S_1, respectively (Godoy et. al., 2005).

Conclusions

- All the introductions presented stable behavior or synergy on passing from freely pollinated variety to the S_1 line, except the introductions 2 and 79, in which the fruit wall weight was reduced.
- The lines presented stable behavior or synergy on passing from line S_1 to S_2, except 2 and 80, in which the were reduced the color and the dry fruit material, respectively.
- Some introductions and lines of the squash *C. moschata* Duch. Were refractory to the negative effect of inbreeding when accompanied by selection.

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