

Precocious Yellow Rind Color in *Cucurbita moschata*

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Introduction: In a recent review, Paris and Brown (2) described 18 loci affecting fruit skin color in *Cucurbita*. Of this total, 14 loci are found in either *C. pepo*, or in both *C. pepo* and *C. maxima*. Only three loci controlling fruit color have been described in *C. moschata*: *Gr*, *Mldg* and *B*. Dominant *Gr* results in green fruit, versus the recessive buff color (5). Dominant *Mldg* causes mottled immature fruit color, while *mldg* results in a non-mottled rind (1). The *B* (*Bicolor*) gene, which confers a “precocious yellow” color to the ovaries as soon as they are differentiated, is not found naturally in *C. moschata*, but has been crossed into this species from *C. pepo*, and functions as in the latter species (3). This gene is designated *Bicolor* because it was first described in bicolor (yellow/green) gourds (6). The *B* locus and its interactions with other loci are well studied in *C. pepo* and reviewed by Paris and Brown (2). The “precociousness” of color conferred by the *B* gene differentiates it from *Y*, the incompletely dominant gene for yellow fruit color (rather than green) in intermediate age fruit. The recessive *bb* genotype produces normal green ovaries. Depending on the type and number of alleles present at two modifier loci (*Ep-1* and *Ep-2*), the degree of color can range from bicolor yellow/green to fully yellow ovaries. The yellow color remains until maturity or can be further enhanced by other modifiers. Furthermore, color can extend to the peduncle, calyx, stems, male flowers and foliage. A modifier gene, *Ses-1* suppresses the expression of yellow foliage (7). Precocious yellowing of ovaries is also found in *C. maxima*, but the locus, B^{max} , is not allelic to *B* in *C. pepo* (8).

Yellow rind colors are observed among many cultivars and landraces of both *C. pepo* and *C. maxima*; however, we found no published reports of yellow rind color in *C. moschata*. In the early 1990's, Wessel-Beaver observed bicolor fruits of *C. moschata* in a photograph taken of harvested fruits near Guayaquil, Ecuador. The fruits were of varying size and shape, suggesting that they were from a local landrace. The photograph was taken by Dr. D. Maynard (University of Florida), and he indicated that these types of fruit were quite common in the area (D. Maynard, personal communication). Wessel-Beaver grew out a sample of seed from these fruits and observed that the plants produced precocious yellow ovaries, usually bicolor. She was unable to maintain this seed stock. A few years later, Wessel-Beaver grew out seed from a single yellow-orange fruit from a farmer's market in Colombia. The fruit appeared to be from a landrace, rather than improved cultivar, as suggested by its somewhat warty skin. Like the Ecuadorian landrace, this fruit produced progeny with precocious yellow bicolor fruit. Some of the progeny had fully yellow fruit. At maturity the fruit had a golden yellow-orange color. Our objective was to study the inheritance of precocious yellow fruit color in *C. moschata*.

Materials and Methods: A selfed (S_2) line produced from the original fruit from Colombia was used for this research. This material was designated ‘Colombian Golden.’

In Puerto Rico. ‘Colombia Golden’ was crossed with Colombia 5 (a Colombian landrace with green ovaries and green mottled fruit at maturity) and ‘Soler’ (a Puerto Rican

cultivar with green ovaries and dark green fruit at maturity). The F₁ cross 'Colombia Golden' x 'Colombia 5' was selfed and backcrossed to both 'Colombia Golden' and 'Colombia 5'. Only an F₂ population was produced for the cross 'Colombia Golden' x 'Soler'. Fifty plants each of the 'Colombia Golden' x 'Colombia 5' F₂ and backcross populations were planted in April 2005 at the Isabela Substation of the University of Puerto Rico. Before anthesis, plants were classified as having (i) precocious yellow and/or bicolor ovaries or (ii) green ovaries. Plants were also classified as (i) having yellow leaves, stems, peduncles, and/or staminate flowers or (ii) all green. At maturity, plants were classified as carrying (i) yellow, bicolor and/or spotted yellow fruit or (ii) normal (green, mottled, or buff) fruit. One hundred plants of the F₂ population 'Colombia Gold' x 'Soler' were planted at the Fortuna Substation (near Juana Díaz, PR). Plants were classified as having (i) precocious yellow and/or bicolor ovaries (pre-anthesis) or (ii) green ovaries. Plants were also classified as (i) having yellow leaves, stems, peduncles, and/or staminate flowers or (ii) all green. No mature fruit data was taken in this population.

In Wisconsin. 'Waltham' (Jung Seed Company, Randolph, WI; a butternut type with green ovaries at anthesis and buff-colored fruit at maturity) was crossed to five individual S₂ plants of 'Colombian Golden'. The resulting F₁ plants were self-pollinated and five populations were independently evaluated. Twenty five plants from each F₂ population were grown in the summer of 2005 at the Arlington Agricultural Experiment Station, Arlington, WI. Conventional farming practices and no irrigation was used. Data on pigmentation was collected during anthesis. Plants were classified as described above.

Data were analyzed by chi-square at $\alpha = 0.05$ using software found at <http://www.quantpsy.org> (4). The null hypothesis was the model for a single

recessive gene controlling precocious yellow color (a 3:1 model for the F₂ populations, a 1:1 model for the backcross to 'Colombia Golden' and a "all green" model for the backcross to 'Colombia 5'). The five Wisconsin F₂ populations were analyzed individually and then in a pooled analysis.

Results and Discussion: Probabilities in all chi-square tests were greater than $\alpha = 0.05$ for data collected during anthesis. Thus, there was no evidence to reject the null hypothesis that a single recessive gene controls precocious yellow coloring in *C. moschata*. In Puerto Rico, all plants with yellow foliage at eight weeks also had yellow foliage at 16 weeks. More plants developed yellow color (including leaves, stems, peduncles and staminate flowers, as well as ovaries) as the season progressed. Although some plants did not set fruit before the conclusion of the trial, plants with yellow vegetative parts always produced fruit that were either bicolor or completely yellow. The reverse was also true: plants producing yellow or bicolor fruit always had some other plant parts, usually leaves, with yellow sectors. In Wisconsin, a significant increase in the number of plants with yellow fruit pigmentation was observed as the season progressed, although formal data was not collected. In fact, it appeared that the 3:1 (non-yellow:yellow) segregation changes substantially as fruit mature. We did not observe this in the Puerto Rico populations. The non-golden parent used in crosses in Wisconsin (Waltham) has a genetic background very different from the parents used in Puerto Rico (Soler and Colombia 5), both of which are of tropical origin. While mature fruit color in the populations tested in Puerto Rico varied from bright or dull orange to green, fruit colors in the Wisconsin populations included bright orange, dull orange, green, tan and even white (a color not reported in the literature for *C. moschata*, but previously observed by Wessel-Beaver in germplasm from Colombia) (Figure 1).

Contrary to what has been reported in both *C. pepo* and *C. maxima*, we observed the precocious yellow trait to be recessive in *C. moschata*. *B* (in *C. pepo*) and *B^{max}* (in *C. maxima*) genes are known to be non-allelic (8), and it seems likely that the gene we observed in *C. moschata* is also non-allelic to these two previously known genes. We propose that the gene for precocious yellow in *C. moschata* be known as *b^{mos}*. However, genetic control of orange color in mature fruits of *C. moschata* appears to be more complex than that of precocious yellow.

Literature Cited

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Table 1. Chi-square values and probabilities associated with segregations of F₂ and backcross populations used to test a single recessive gene model for the inheritance of the precocious yellow trait in *C. moschata*.

Cross	Plant part ¹	Observed segregation ²		Model tested	χ^2 value	Probability
		Green	Yellow/Bicolor			
<i>Wisconsin</i>						
Col Golden x Waltham - A	Fruits/ovaries at anthesis	17	6	3:1	0.014	0.901
Col Golden x Waltham - B	Fruits/ovaries at anthesis	21	2	3:1	3.261	0.071
Col Golden x Waltham - C	Fruits/ovaries at anthesis	14	6	3:1	0.267	0.606
Col Golden x Waltham - D	Fruits/ovaries at anthesis	12	8	3:1	2.400	0.121
Col Golden x Waltham - E	Fruits/ovaries at anthesis	21	3	3:1	2.000	0.157
Pooled	Fruits/ovaries at anthesis	85	25	3:1	0.303	0.582
<i>Puerto Rico</i>						
Col Gold x Col 5 (F2)	Plant at 8 weeks	39	11	3:1	0.240	0.624
	Plant at 16 weeks	33	17	3:1	2.160	0.142
	Fruits at 20 weeks	27	13	3:1	1.200	0.273
(Col Gold x Col 5) x Gold (BC)	Plant at 8 weeks	28	22	1:1	0.720	0.396
	Plant at 16 weeks	25	25	1:1	0.000	1.000
	Fruits at 20 weeks	18	16	1:1	0.118	0.732
(Col Gold x Col 5) x Col 5 (BC)	Plant at 8 weeks	50	0	All green	---	---
	Plant at 16 weeks	50	0	All green	---	---
	Fruits at 20 weeks	49	1	All green	---	---
Col Gold x Soler (F2)	Plant at 16 weeks	75	25	3:1	0.000	1.000

¹ Eight and 16 week old plants were classified as “yellow/bicolor” if yellow sectors appeared on all or some of the following plant parts: immature ovaries, leaves, stems, peduncles and/or staminate flowers. Plants with yellow sectors on vegetative parts always had yellow (or bicolor) ovaries.

² Not all plants set fruit in the populations tested in Puerto Rico.



Figure 1. Range of mature fruit color observed in F_2 populations of Colombia Golden x Waltham planted in Arlington, Wisconsin. Note the all white (arrow) and bicolor fruits.