The Seedcoat Color Genotype of ‘Prim’ and the Manteca and Coscorrón Market Classes of Common Bean

Mark J. Bassett¹

Horticultural Sciences Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611-0690

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Abstract. Anecdotal evidence exists for nonflatulence among Chilean Manteca and Coscorrón market classes of common bean (*Phaseolus vulgaris* L.), and there is an hypothesis that the seedcoat color may be associated with superior digestibility. The inheritance of seedcoat color in ‘Prim’, a Manteca market-class dry bean, was investigated using a protocol employing genetic interpretation of seedcoat colors in the F₁ from testcrosses of ‘Prim’ with a series of tester stocks. Most of the genetic tester stocks were constructed previously by backcrossing selected recessive alleles for seedcoat color into a recurrent parent (5-593) with seedcoat color genotype *P [C r] D J G B V Rk Asp*. The genetic tester stocks included two varieties, ‘Masterpiece’ and ‘V0687’, and testers constructed on the 5-593 background, viz., *j BC₂ 5-593*, *dj BC₂ 5-593*, *asp BC₂ 5-593*, *b v BC₂ 5-593*, *v BC₂ 5-593*, and *c^u BC₃ 5-593*. The seedcoat color genotype of ‘Prim’ was found to be *P [C r] d j G b v^{lae}*. The implications of this genotype for pigment chemistry are discussed.

In Chile there are two market classes of common beans, Mantecas (pale lemon-yellow seedcoats) and Coscorróns (pale lemon-yellow/white mottled or striped seedcoats), which are considered “beans for the rich man’s table” because they are reportedly nonflatulent and more expensive to grow (Leakey, 1992). Leakey (1992) hypothesized that the genes controlling seedcoat color in Mantecas and Coscorróns may concomitantly control the reduction of flatulence, but testing the validity of his hypothesis is beyond the scope of this paper. Leakey (1992) proposed that the seedcoat color genotype of Mantecas is *P C d j g b v* and that Coscorróns have the same genotype except for an allele at *C* that controls pattern (mottled or striped).

Leakey (1992) has conducted a breeding program to produce new varieties with the Manteca seedcoat color, but with determinate habit and early flowering. One variety released from this program is ‘Prim’ (Leakey, personal communication). Beninger et al. (1998) studied the seedcoat pigment chemistry of ‘Prim’ and found two flavonol glycosides: 1) kaempferol-3-*O*- β -D-glucoside and 2) kaempferol-3-*O*- β -D-glucopyranosyl (2 $\rightarrow$ 1)-*O*- β -D-xylopyranoside. Feenstra (1960) found the same two compounds in seedcoats with genotype *P C d j g b v^{lae} Rk*.

The objectives of this work were to determine the seedcoat color genotype of ‘Prim’ and to relate the results to previous findings.

Materials and Methods

In 1985, a program was initiated to develop genetic tester stocks, each with one or more recessive marker genes for seedcoat color or pattern backcrossed into the recurrent parent, Florida dry bean breeding line 5-593. Details of the backcross procedure are described elsewhere (Bassett, 1994). Line 5-593 has a determinate habit, purple flowers, and shiny, black seedcoats. The seedcoat genotype of 5-593 is *Stp T Z l⁺ Bip P [C r] D J G B V Rk*, which includes genes for seedcoat pattern, partly colored patterns, and color (Bassett, 1998). Line 5-593 also carries the shiny seedcoat

gene *Asp* (Bassett, 1996a). Genetic stocks that were developed by backcrossing a marker gene to the 5-593 recurrent parent are designated: *gene symbol BC_n 5-593*. For example, *v BC₃ 5-593* indicates that the *v* allele is in backcross three to 5-593.

The genetic tester stocks and varieties with established seedcoat color genotypes that were used as testcross parents with ‘Prim’ are listed and described in Table 1. The testcross parents P₂ through P₉ were crossed with ‘Prim’ (P₁) in Fall 1992 in the greenhouse. The F₁ progenies of the testcrosses were grown in the greenhouse in Winter 1993, and descriptive data were taken on flower color and the pattern and color of the seedcoats of the F₁ plants.

Results and Discussion

The phenotypes of the seedcoats of the testcross F₁ plants are described in Table 2. Using the phenotypes of F₁ progeny from testcrosses with special genetic test stocks was first proposed by Bassett (1992). The genetic stocks have only specified recessive alleles substituted into a genetic background having all dominant alleles at the other seedcoat color loci. The presence of the dominant alleles suppresses the complex interactions that unwanted recessive alleles would otherwise have on the expression of the selected recessive alleles for seedcoat color. In theory, the testcross should lead to only one of two results: 1) an allelic response where seed of the F₁ plants have the same phenotype as the genetic tester or 2) a nonallelic response.

The testcross of ‘Prim’ with P₂ gave an allelic response, except for the mottling (Table 2). The result indicates that ‘Prim’ carries the “test allele” *j*. However, the mottling may be due to ‘Prim’ carrying an allele at *C* that has some of the attributes of the dominant unpatterned *C* allele and some attributes of the standard recessive allele *c* as described by Prakken (1970). The subtle mottling is produced by the heterozygote *C/c*, but the allele at *C* carried by ‘Prim’ does not have all the attributes of standard *c*. The contrary evidence

Table 1. The seedcoat phenotypes and genotypes of ‘Prim’ and the stocks used in testcrosses to determine the seedcoat genotype of ‘Prim’.

Parent no.	Stock name	Seedcoat color		Reference ^z
		Phenotype	Genotype	
P ₁	Prim	Yellowish white with pale purple corona	<i>P C d j G b v^{lae} Asp</i>	
P ₂	<i>j BC₂ 5-593</i>	Dull dark purple with margo pattern	<i>P C D j G B V Asp</i>	Bassett, 1996a
P ₃	<i>dj BC₂ 5-593</i>	Dull dark purple with white hilum ring	<i>P C d j G B V Asp</i>	Bassett, 1996a
P ₄	<i>asp BC₂ 5-593</i>	Dull black	<i>P C D J G B V asp</i>	Bassett, 1996a
P ₅	<i>b v BC₂ 5-593</i>	Yellow brown	<i>P C D J G b v Asp</i>	Bassett, 1995a
P ₆	Masterpiece	Pale beige to greenish-yellow with purple corona	<i>P C J g b v^{lae} Asp</i>	Nakayama, 1961
P ₇	V0687	Light red kidney	<i>P c^u J g b v^{lae} rk Asp</i>	Lamprecht, 1961 ^y
P ₈	<i>v BC₂ 5-593</i>	Mineral brown	<i>P C D J G B v Asp</i>	Bassett, 1995b
P ₉	<i>c^u BC₃ 5-593</i>	Cartridge buff	<i>P c^u D J G B V Asp</i>	Bassett, 1996a

^zThe references cited provide the supporting evidence for the seedcoat color genotype listed for each parental stock.

^yThe work of Lamprecht (1961) only gives *c* and *v*, but Bassett (unpublished data) has determined that V0687 carries *c^u* by means of an allelism test with P₉ and *v^{lae}* by means of an allelism test with P₅.

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¹Professor.

Table 2. Results of testcrosses between 'Prim' and a series of genetic stocks and varieties with known seedcoat genotypes.

Testcross	Phenotype of seedcoats of seeds on F ₁ plants from the testcross
P ₁ × P ₂	Typical margo pattern produced by <i>j</i> , pale corona and black hilum ring, but mottling in dark greenish purple/gray buff.
P ₁ × P ₃	Margo pattern with colorless hilum ring and corona; color highly variable from brown to purple
P ₁ × P ₄	Shiny unpatterned black
P ₁ × P ₅	Yellow-brown with purple corona
P ₁ × P ₆	Yellow-brown with purple corona
P ₁ × P ₇	Yellow-brown/cartridge buff marbling with patterned purple corona
P ₁ × P ₈	Subtle mottling with mineral brown/pale brown; highly variable from seed to seed.
P ₁ × P ₉	Black/cartridge buff marbling

is presented below from the results of other testcrosses. The testcross of 'Prim' with P₃ gave an allelic response with no complications (Table 2), and indicates that 'Prim' carries the genotype *d j*.

The *asper* gene (*asp*) is the common and widely distributed gene for dull seedcoats and, unlike *j*, has no effect on seedcoat color. 'Prim' has a dull seedcoat due to *j*, and only a testcross with the *asp* tester can determine whether *asp* may be carried cryptically by 'Prim'. The testcross of 'Prim' with P₄ gave a nonallelic response (Table 2), which indicates that 'Prim' carries *Asp*.

The testcross of 'Prim' with P₅, the yellow-brown tester, gave an allelic response, except that the F₁ had purple corona due to genotype *v^{lae}/v* (Table 2) (Bassett, 1995b). 'Prim' has the pink flower color and purple corona that are pleiotropic effects of the *v^{lae}* allele at *V* (Bassett, 1995b). That result is interpreted to mean that 'Prim' carries *b v^{lae}*. Also, the failure of the F₁ with P₅ to express either an unpatterned or mottled dominant red color indicates that 'Prim' must carry the *r* allele for dominant red color in the complex *C* locus.

The testcross of 'Prim' with P₆ (with *g b v^{lae}*) permits a test for the genotype of 'Prim' at *G*. The testcross result was yellow-brown with purple corona (Table 2), which is a nonallelic response at *G*. That result indicates that 'Prim' carries *G*. The testcross of 'Prim' with P₇ (with *g b v*) gave yellow-brown/cartridge buff marbling with a patterned purple corona (Table 2). The purple in the corona was also marbled with cartridge buff. The yellow-brown color is produced by allelism at *b* and *v^{lae}* in 'Prim', but the marbling is an interaction of the *c^u* in V0687 with the allele at *C* in 'Prim'. The latter interpretation was tested directly in the testcross with P₉ discussed below. The yellow-brown color also is a nonallelic interaction with the *G* in 'Prim'.

The above results are consistent with the hypothesis that 'Prim' has the genotype *G b v^{lae}*, and are not consistent with the hypothesis of Leakey (1992) that 'Prim' carries *g*.

The testcross of 'Prim' with P₈ gave F₁ plants having seedcoats with subtle mottling of mineral brown/pale brown (Table 2). The allelism at *v* already is known/established and needs

no further comment, but the appearance of mottling is usually interpreted as an expression of the heterozygous genotype *C/c* (Prakken, 1970). Extensive observation of F₂ progeny from the testcross grown in the field and greenhouse failed to produce the expected true breeding *c/c* genotype with pale brown seedcoats (data not shown). In a previous paper, Bassett (1996b) described 'Prim' as carrying [*c r*] to account for the apparent heterozygous *C/c* mottling described above, but, as will be shown below, the allele at the *C* locus in 'Prim' does not adequately meet other criteria for being defined as a recessive *c*.

The testcross of 'Prim' with P₉ gave a nonallelic response, viz., black/cartridge buff marbling (Table 2). In unpublished work by the author, the original source ('Wachs Digoïn') of the standard recessive *c* allele (Prakken, 1970) was testcrossed with P₉, and the F₁ produced seed that were brown tinged with grayish-indigo. Thus, the allele at the *C* locus in 'Prim' cannot be the same allele as that in 'Wachs Digoïn', and neither is it the *c^u* allele. 'Prim' must carry a dominant allele at *C* that is not the same as the dominant allele in 5-593. Therefore, the chromosome region of the *C* locus of 'Prim' must carry [*C r*], where the brackets indicate the virtually unbreakable linkage between the *C* and *R* genes in what Prakken (1970) calls "the complex *C* locus."

Combining all the above testcross results, I conclude that the seedcoat color genotype of 'Prim' is *P [C r] d j G b v^{lae}* with *Asp* carried cryptically, which Beninger et al. (1998) found to produce two flavonol glycosides: 1) kaempferol-3-*O*-β-D-glucoside and 2) kaempferol-3-*O*-β-D-glucopyranosyl (2→1)-*O*-β-D-xylopyranoside. Feenstra (1960) found the same two flavonol glycosides produced by the genotype *P C d j g b v^{lae}*, which differs from the genotype of 'Prim' only by the substitution of *g* for the *G* of 'Prim'. In the presence of *j* (and especially with *d j*) the yellow pigment produced by *G b v* (or *G b v^{lae}*) is greatly reduced.

When the same laboratory procedures (as with 'Prim'; Beninger et al., 1998) were used to analyze flavonoid compounds in seedcoats of three genetic tester stocks—*P C J G b v BC₃* 5-593, *P C J G b v BC₃* 5-593, and *P C J g b v*

BC₃ 5-593—the only kaempferol compound detected in any appreciable quantity was kaempferol-3-*O*-β-D-glucoside (astragalin) (Beninger et al., unpublished data). Unexpectedly, the quantity of astragalin (a yellow pigment) was about twice as great in *P C J g b v BC₃* 5-593 as in *P C J G b v BC₃* 5-593, where the former genetic tester stock is a pale greenish-yellow and the latter stock a much stronger yellow-brown. The current hypothesis under investigation by Beninger et al. is that tannins may play a much more important role than flavonoids in producing the visible colors in genetic stocks with genotype *P C J v* (includes all gene combinations at *G* and *B*).

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