Inheritance of the Partly Colored Seedcoat Pattern, Bipunctata, in Common Bean

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Abstract. The development of genetic tester stocks in common bean (*Phaseolus vulgaris* L.) for the partly colored seedcoat patterns ‘bipunctata BC₃ 5-593’ (*tz bip*) and ‘virgarcus BC₃ 5-593’ (*tz*) was described. The inheritance of the bipunctata pattern was studied in the F₂ from the crosses ‘bipunctata BC₁ 5-593’ x 5-593 and ‘bipunctata BC₂ 5-593’ x 5-593. The data supported the hypothesis that a single recessive gene (*bip*) converts virgarcus (*tz Bip*) to bipunctata (*tz bip*). The inheritance of bipunctata was also studied in the F₂ from the cross ‘bipunctata BC₃ 5-593’ x ‘virgarcus BC₃ 5-593’. The data supported the hypothesis of complete dominance of *Bip* over *bip* in a *tz* genetic background highly related to the recurrent parent 5-593, where only the parental phenotypes appear in the F₂.

Partly colored seedcoats in common bean (*Phaseolus vulgaris*) depend on the genotype *t/t* for expression, where *T/-* gives totally colored seedcoats (Leakey, 1988). Partly colored seedcoats have a colored zone, and the remainder of the seedcoat is white, whereas totally colored seedcoats (usually *T/-*) have no white zone that is due to *t/t*. In most genetic backgrounds, the action of *t* produces the expansa pattern, which has only a limited area of white at the micropile end of the seed. Most of the partly colored patterns reported by Lamprecht (1940) and Schreiber (1940) are produced by the action of two genes: the *Z* locus for zonal effects and the *L* locus for limiter effects. Most partly colored patterns are the result of *t* combined with one of the many possible alleles at *Z*, according

of Schreiber (1940) supported the hypothesis that the bipunctata pattern requires only *tz bip*.

This paper reports the results of inheritance studies of the bipunctata pattern. Only those partly colored patterns observed in the present research will be illustrated in this paper. For illustration of other partly colored patterns mentioned in discussion, see Literature Cited.

Materials and Methods

In 1985, a program was begun at Gainesville, Fla., to backcross marker genes, especially those controlling seedcoat color and color pattern, into a recurrent parent, 5-593. Line 5-593 is a Florida dry bean breeding line with determinate habit, purple flowers, and black seeds with genotype *T Mar P [C r] D J G B V Rk* (Bassett, 1994). Genetic stocks ‘*t ers ers-2* BC₃ 5-593’ with pure white seedcoats and ‘*t* totally colored BC₂ 5-593’ with unpatterned black seedcoats were developed during the investigation of the unusual genotype for white seedcoats found in ‘Early Wax’ (Bassett and Blom,

Table 1. The genetic model of Lamprecht for the partly colored seedcoat pattern, bipunctata, where all genotypes have *t/t*.²

Genotype	Phenotype
<i>Bip Arc</i>	Virgarcus
<i>Bip arc</i>	Arcus; same as virgarcus except for loss of the micropile stripe
<i>bip Arc</i>	Virgata; same as virgarcus except for loss of the arcs on either side of the hilum
<i>bip arc</i>	Bipunctata

²Model based on analysis of F₂ data from the cross Line 5 (PI 527715), bipunctata x Line 57, virgarcus (Lamprecht, 1940).

to the hypothesis of Schreiber (1940) and the unpublished data of M.J. Bassett. The *L* locus has drastic constriction or erasure effects (relative to *Z* locus effects) that result either in a very small colored zone or in a completely white seedcoat (Bassett and Blom, 1991; Schreiber, 1940)

The two most published authorities on the genetics of partly colored seeds agreed that the genotype *tz* produces the virgarcus pattern of partly colored seedcoats, but they disagreed on the inheritance of the partly colored seedcoat pattern, bipunctata (Lamprecht, 1940; Schreiber, 1940). The results of Lamprecht (1940) led to the hypothesis that bipunctata was produced by the genotype *tz bip arc*, where the *Arc* locus is also involved in the expression of the arcus and virgata patterns (Table 1). The results

Fig. 1. A ventral view (left seed) and a side view (right seed) of the bipunctata pattern of partly colored seedcoat.

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Fig. 2. A ventral view (**left seed**) and a side view (**right seed**) of the virgarcus pattern of partly colored seedcoat.

Fig. 3. Ventral view of expansa with fibula arcs (**left seed**), side view with minimal white area (**middle seed**), and side view with maximal white area for an expansa type (**right seed**).

Fig. 4. A series of seeds illustrating the variation that occurs with the ambigua pattern, which is very unstable, even for a partly colored seed type, as the Latin name implies.

1991). The stock '*t* totally colored BC₂ 5-593' was originally named '*t* self-colored BC₂ 5-593' (Bassett and Blom, 1991). The term self-colored, which is often seen in literature on partly colored seedcoats, has the same meaning as totally colored.

Line 5 of Lamprecht [now plant introduction (PI) accession 527712] was derived from 'Incomparable' and has the bipunctata pattern in black dots on white background. The bipunctata pattern is illustrated with seeds from 'bipunctata BC₃ 5-593', which was derived from Line 5 during the work described below (Fig. 1).

The cross PI 527712 x *t* *ers* *ers*-2 BC₃ 5-593 was made, and the F₂ was planted in the field in 1991. A selection was made in the F₂ for a plant with bipunctata seeds, which was found to be true breeding in a 16-plant F₃ progeny test in the greenhouse. One F₃ plant was selected and designated 'F₃ bipunctata'. The cross 'F₃ bipunctata' x '*t* totally colored BC₂ 5-593' was made, and the F₂ was planted in the field in 1992. Selection was made in the F₂ for plants with either bipunctata or virgarcus seed patterns. A bipunctata selection found to be true breeding in a 16-plant F₃ progeny test was designated 'bipunctata BC₁-F₃ 5-593'. Several virgarcus pattern selections were progeny tested in F₄ plots in the field in 1993, and a virgarcus selection was made that was designated 'virgarcus BC₁-F₄ 5-593'.

The cross 'bipunctata BC₁-F₃ 5-593' x 5-593 was made and the F₂ was planted in the field in 1993. Seed was harvested only

Table 2. Segregation for partly colored seedcoat patterns and genotypes among F_2 segregants carrying t/t from two crosses: 1) bipunctata BC_1-F_3 5-593 ($t z bip$) x 5-593 ($T Z Bip$) and 2) bipunctata BC_2-F_3 5-593 ($t z bip$) x 5-593 ($T Z Bip$).

Cross no.	Seedcoat pattern classes			χ^2 12:3:1	<i>P</i>
	Totally colored, expansa, ambigua ^z $t Z/-$ -/-	Virgarcus $t z Bip/-$	Bipunctata $t z bip$		
1	221	56	19	0.023	0.99
2 ^y	97	19	5	1.898	0.39
Total	318	75	24	0.381	0.83

^zThe totally colored segregants are known to carry t/t because of their white flowers (vs. purple flowers for $T/-$).

^yData were taken on the number of segregants with purple flowers and unpatterned black seeds, viz., 408. For the data 408, 97, 19 and 5 the χ^2 (48:12:3:1) = 3.013, P = 0.39.

from F_2 segregants with white flowers, and data were taken on seedcoat pattern. Selection was made in the F_2 for a plant with bipunctata seeds, which was found to be true breeding in a 16-plant F_3 progeny test and designated 'bipunctata BC_2-F_3 5-593'.

The cross 'bipunctata BC_2-F_3 5-593' x 5-593 was made, and the F_2 was planted in the field in 1994. Data were taken on the F_2 segregation for flower color and seedcoat pattern. Selection was made for plants with seeds having either bipunctata or virgarcus pattern. True-breeding selections were developed by the usual progeny testing routine described above. The result was the development of the genetic stocks: 'bipunctata BC_3 5-593' (Fig. 1) and 'virgarcus BC_3 5-593' (Fig. 2).

A cross 'bipunctata BC_3 5-593' x 'virgarcus BC_3 5-593' was made and the F_2 was planted in the field in 1995. Data were taken on the F_2 segregation for seedcoat pattern.

Results and Discussion

For the crosses 'bipunctata BC_1-F_3 5-593' x 5-593 and 'bipunctata BC_2-F_3 5-593' x 5-593, the F_2 populations segregated for a good fit to a 12:3:1 ratio for three classes: 1) the combined totally colored, expansa (Fig. 3), and ambigua (Fig. 4) classes; 2) the virgarcus class; and 3) the bipunctata class (Table 2). All the genetic variation can be accounted for with only two genes segregating, viz., z and bip (Table 2). Those results confirm the findings of Schreiber (1940). He also found that a single recessive gene converts virgarcus into bipunctata. Lamprecht (1940) interpreted his results to support the necessity of two recessive genes acting jointly to convert virgarcus to bipunctata (Table 1). Because Lamprecht (1940), Schreiber (1940), and I all derived our bipunctata stocks from the same source ('Incomparable'), it is probable that all have the same genotype. In Schreiber's (1940) material the heterozygote $t z Bip/bip$ produced weak virgarcus, but no distinctive phenotype for the heterozygote was observed (Table 2).

The above data (Table 2) also support the hypothesis of Schreiber (1940) that $t Z$ gives expansa and $t Z/z$ gives ambigua. It is my hypothesis that there is also a recessive gene (identity unknown) from 'Early Wax' that converts expansa to totally colored and that 5-593 has the dominant allele at that locus that maintains expansa (M.J. Bassett, unpublished data). The boundary between the expansa class and the ambigua class is very difficult to establish; hence, the classes were combined (Table 2). The ambigua class combines the classes maximus, major, and minor of Lamprecht (1940). The existence of Lamprecht's (1940) genes diffundere and expandere is a highly speculative hypothesis for which no adequate experimental data was ever provided for support. On the other hand, it was one of Schreiber's (1940) great contributions to fully substantiate the hypothesis that $t Z/z$ produces the hypervariable ambigua phenotype.

In a previous commentary on the work of Lamprecht (1940) I stated that it was highly likely that Lamprecht's genes *Arc*, *Diff*, and *Exp* were nonexistent (Bassett, 1995). Unexpected field results from 1995 have demonstrated that there may be a gene (possibly not at either Z or L) that can convert virgarcus into a weak virgarcus that is similar in appearance to the arcus illustrations of Lamprecht (1940) (M.J. Bassett, unpublished data). In light of those developments and the beginning of work with the 'Early Giant' variety with the virgata pattern of partly colored seedcoats it may be that the *Arc* gene can be recovered and verified.

The cross 'bipunctata BC_3 5-593' x 'virgarcus BC_3 5-593' segregated in the F_2 only for the parental classes, and the observed segregation fit a 3:1 ratio for virgarcus to bipunctata, respectively (Table 3). There was no distinctive phenotype for the heterozygote *Bip/bip*. It is my hypothesis that such distinctive heterozygote phenotypes may occur only when unrelated lines are crossed. When highly related (BC_3) lines are crossed, the heterozygote loses its distinctiveness.

From all the evidence provided above, it can be concluded that 1) 5-593 must have the genotype $T Z Bip$, 2) that the genotype of 'bipunctata BC_3 5-593' is $t z bip$, and 3) that the genotype of 'virgarcus' BC_3 5-593 is $t z Bip$.

Table 3. Segregation for partly colored seedcoat patterns and genotypes among F_2 progeny from the cross 'bipunctata BC_3 5-593' ($t z bip$) x 'virgarcus BC_3 5-593' ($t z Bip$).

Seedcoat pattern classes		χ^2 3:1	<i>P</i>
Virgarcus $t z Bip/-$	Bipunctata $t z bip$		
342	122	0.414	0.52

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