Patterns of Broad Normal Striping in Egg Gourd

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Introduction

There are two general patterns of striped pigmentation patterns in *Cucurbita pepo*, reverse striping (3, 7), characterized by green narrow stripes over the vein tracts (vasculature) and wide white stripes between the vein tracts, and normal striping (5, 6, 8), characterized by narrow white to blue-gray stripes over vein tracts and wide green stripes between the vein tracts. There are different phenotypes of normal striping conferred by multiple alleles at the *l-1* locus (5, 6), and two systems for reverse striping (3, 7). Striped alleles are dominant to *l-1*, but recessive to *L-1*.

I have developed bush breeding lines of egg gourd (*C. pepo* L. ssp. *ovifera* (L.) D.S. Decker (1) which carry the allele $l\text{-}1^{BSt}$ for broad normal striping, a phenotype characterized by distinct, fairly broad blue-gray stripes over the vein tracts with intervening dark green pigmentation (3). We have also developed additional BNS lines carrying the *B* gene for precocious orange or yellow pigmentation , as well as incorporated the *D* gene into BNS lines. This paper describes those phenotypes, along with inheritance data illustrating BNS phenotypes that can be generated in populations segregating for *D*/*d* and *Wf*/*wf*.

Materials and Methods

During the summer months, June through October 1, gourds were grown at the Kingman Research Farm in Madbury, NH, USA. Plants were grown on raised beds mulched with black polyethylene, and supplied with drip irrigation. Plants were either direct seeded or grown in 50-cell plug trays and then transplanted. Standard fertility and pesticide practices were used according to New England Vegetable Management Guide (2). In the greenhouse during the months of January through May, plants were grown in 8.7 L plastic nursery pots in a soil-less mix (Pro-mix, Griffin Greenhouse Supply, Tewksbury, MA, US). Daytime temperatures were 24 ^{o}C (16 h) and nighttime temperatures were 18 ^{o}C. Phenotypes of gourds segregating for fruit color and pattern traits were typically evaluated at anthesis or shortly thereafter, at 18 to 25 days after pollination (DAP) and at maturity (45 to 55 DAP).

Results and Discussion

Two populations segregating for broad normal stripes (BNS) were generated by crossing a green-fruited line (G344-22) with dark stems (*L-1*/*L-1*, *L-2*/*L-2*, *D*/*D*) to a BNS line (G424-25-3-11) with light stems, ($l\text{-}1^{BSt}$/$l\text{-}1^{BSt}$, *L-2*/*L-2*, *d*/*d*). The F_2 population segregated 46 dark stem (*D*/_) to 15 light stem (*d*/*d*) and 44 green fruit (*L1*/_) to 17 BNS ($l\text{-}1^{BSt}$/$l\text{-}1^{BSt}$) fruit (Table 1), both ratios conforming to a 3:1 segregation ratio, and in agreement with results of Paris and Burger (8) that non-striped or green pigmentation (*L-1*/_) is dominant to BNS ($l\text{-}1^{BSt}$/$l\text{-}1^{BSt}$) in plants homozygous for *L-2*/*L-2*. The backcross population segregated 40 dark stem to 33 light stem plants, and 32 plants with green fruit and 41 with BNS fruit, ratios close to the expected 1:1. Segregation in both populations conformed to independent assortment for the two loci in question, with χ^2 probabilities of 0.78 and 0.57, respectively, for F_2 and BC populations (Table 1). The results also confirm that plants homozygous for the dominant *L-2* allele do not express the reverse stripe trait in the presence of the *D* allele. However, the *D* allele alters the BNS phenotype, producing BNS fruit with narrow green and broad dark-green stripes (Fig. 1D) as opposed to *d*/*d* fruit with narrow blue-gray stripes and broad green stripes (Fig. 1A). Because the green-fruited line (G344-22) carries the recessive *wf* allele for orange flesh and G424-25-3-11 is *Wf*/*Wf* for white flesh, 3 out of 61 plants (1/16 expected) in the F_2 progeny had orange /green BNS fruit at maturity (Fig. 1E, F).

Table 2 shows segregation of both reverse and broad normal stripes in two F_2 populations derived from reciprocal F_1 crosses in which all plants were homozygous for the $l\text{-}1^{BSt}$ allele and segregating for *D/d* and *L2/l-2*. These populations are exceedingly small to reflect correct ratios of the six expected phenotypes, but data fit expectations and Chi-square probabilities were relatively high. Data show four different phenotypes displaying broad normal striping. Two phenotypes are conferred when *L-2* is homozygous and in combination with either *D/_* or *d/d* as in Table 2 above. The other two phenotypes occur when plants are recessive for the *d* allele and have either the genotype *L-2/l-2*, producing fruit with narrow white/wide light green stripes, or are *l-2/l-2*,

producing the wh/wh BNS fruit phenotype. In the latter phenotype, fruit appear white, but expression of homozygous *l-1*^{BSt} alleles can be detected by slightly raised ridges over the vein tracts. Type 1 RS plants show the complete reverse stripe phenotype, narrow dark green stripes over the vein tracts and white pigmentation between vein tracts. In Type 2 RS, there are various degrees of mottled green and white pigmentation between the vein tracts.

As shown in Table 1, when plants are homozygous for *L-2*, then plants with either genotypes *L-1*/*l-1*^{BSt} or *L-1*/*L-1* have dark green fruit, regardless of whether plants are *D*/_ or *d*/*d* as illustrated in Table 2, and no striping or at most very minimal striping is evident in any of the fruit. However, when the *L-2* gene is heterozygous in plants carrying a *D* allele, some degree of intermediate reverse striping (some degree of green-white mottling between narrow dark green stripes) occurs regardless of whether *L-1* is homozygous or heterozygous (*L-1*/*l-1*^{BSt}), and the degree of white-green mottling varies with maturity of fruit.

The *B* gene in combination with *L-2* produces orange fruit (4), and when combined with BNS (*l-1*^{BSt}), can produce attractive striped fruit. The range of phenotypes is further expanded by expression of genes which result in bicolor pigmentation patterns, whereby the *B* gene is expressed only in a portion of the fruit. Genes which affect the degree of expression of the *B* gene have been designated as *Ep* genes (9); the inheritance of these genes has not been determined in egg gourd. Figures 2A and 2B show a BNS breeding line (G14-2-1-10) homozygous for the *B* gene but segregating for white (*WF/_)* versus orange (*wf/wf*) flesh. When the *Wf* allele is present, stripping is white/yellow when *B* is expressed; when fruit is *wf/wf*, stripping is yellow/orange. Figure 2C shows a BNS egg gourd line with the *B* gene in combination with orange flesh and the *D* gene. Fruit with the *D* gene show darker yellow/orange and orange/green stripping than fruit which are *d/d*, in either *B*/_ or *b/b* backgrounds.

Acknowledgement

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Table 1. Dihybrid segregation of progeny with either broad normal stripes (BNS), *l-1*^{BSt}/*l-1*^{BSt}) or green (*L-1*/_) fruit and with either light (*d/d*) or dark green (*D*/_) stem color. G07-1, F_2, was derived from G424-25-3-11 (*l-1*^{BSt}*/l-1*^{BSt}*, L-2/L-2* , d/d) x G344-22 *L-1*/*L-1*, *L-2*/*L-2*, *D*/*D*) ⊗, and G07-2 was derived from G424-25-3-11 (male parent) backcrossed to the above F_1.

	Distribution of phenotypes				Expected		
Parental	gr fr/dk st[z]	gr fr/lt st	BNS/dk st	BNS/lt st	ratio	χ^2	P
G07-1 F_2	35	9	12	5	9:3:3:1	1.09	0.78
G07-2 BC	17	15	23	18	1:1:1:1	1.99	0.57

[z]gr – green; dk st – dark stem; lt st = light stem; BNS/dk st = narrow green/wide dark-green stripes, dark stem; BNS/lt st = blue-gray narrow/wide green stripes, light stem.

Table 2. Segregation of reverse and broad normal stripes in F_2 populations derived from G424-25-3-11 x G12194-3 (G10-126) or its reciprocal (G10-110). Plants are homozygous for l-1^{BSt}, but segregating for *L-2*/*l-2* and *D*/*d*. Plants in the first three columns carry the *D* allele; plants in the last three columns are *d*/*d*.

	Distribution of phenotypes[z]								
Parental	Type 2 RS	Type 1 RS	BNS gr/dk gr	BNS wh/lt gr	BNS gray/gr	BNS wh/wh	Expected Ratio	χ^2	P
G10-126	35	17	8	11	8	5	6:3:3:2:1:1	5.99	0.31
G10-110	22	10	10	6	3	0	6:3:3:2:1:1	3.65	0.60
G10-110 +126	57	27	18	17	11	5	6:3:3:2:1:1	5.17	0.39

[z]Type 2 RS = narrow green /wide mottled gr/wh stripping; Type 1 RS = narrow green /wide white striping; BNS:gr/dk gr = green/dark green striped fruit, dark stem; BNS:wh/lt gr = white/light green striped fruit, light stem; BNS:gray/gr = blue-gray narrow stripes/wide green stripes, light stem; BNS: wh/wh = narrow white/wide off-white stripes, light stem.

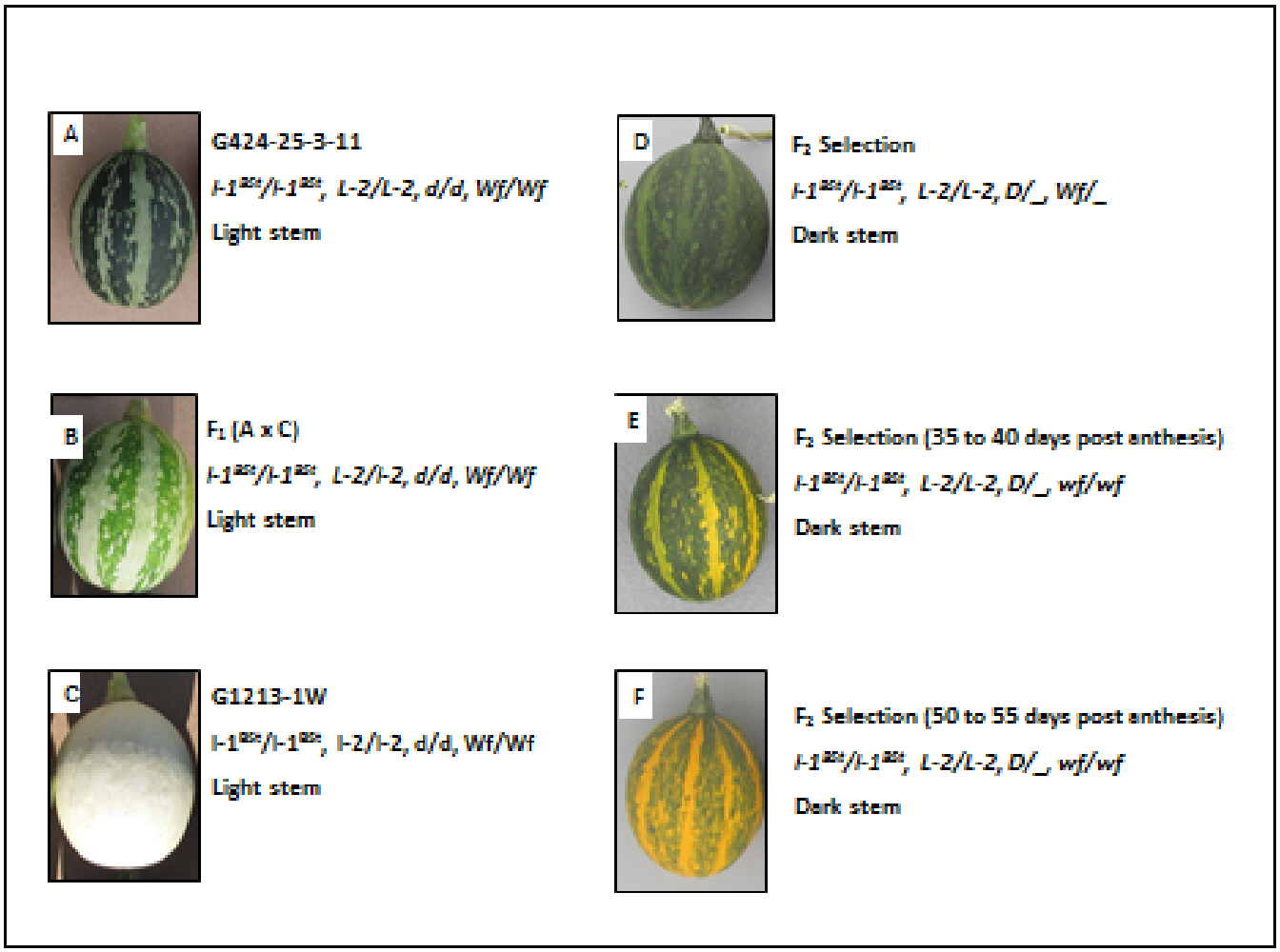

Figure 1. Illustrations and genotypes of different broad normal stripe (BNS) phenotypes.

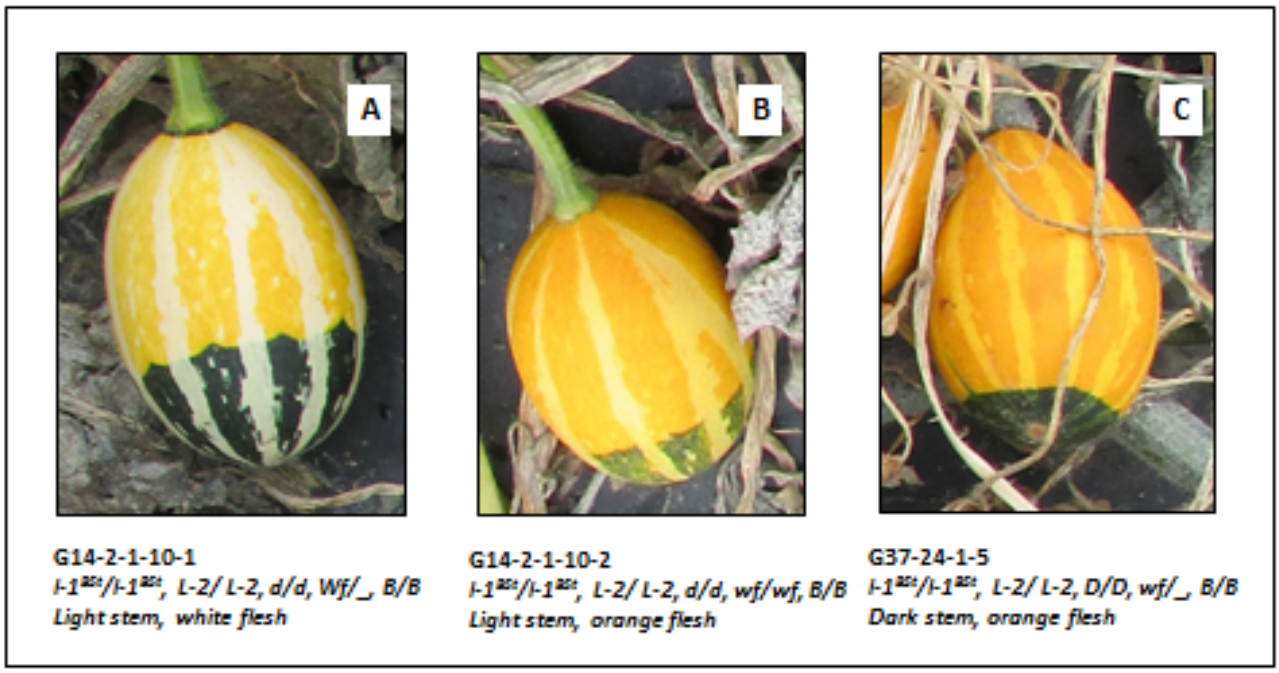

Figure 2. Interaction of the 'B' gene with the D/d alleles and Wf/wf alleles in pigmentation of mature striped egg gourds.