J. Amer. Soc. Hort Sci. 102(4):498–501. 1977.

Inheritance of Resistance to Mechanical Damage and Transverse Cotyledon Cracking in Snap Beans (*Phaseolus vulgaris* L.)[1]

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Additional index words. seed quality, vegetable breeding

Abstract. **Colored and white seeded inbred bean lines resistant to mechanical damage (MD) and transverse cotyledon cracking (TVC) were crossed with 2 susceptible white seeded snap bean cultivars. Resistance to both MD and TVC was inherited quantitatively although colored segregants were more resistant than white-seeded segregants, MD and TVC resistant white-seeded selections were obtained. Broad-sense heritability varied from 55 to 79% for MD and 53 to 93% for TVC; narrow-sense heritability resistance varied from 22 to 73% for MD and from 22 to 58% for TVC. Severe selection pressure for MD resistance on bulked F_3 seed was shown to be a simple and practical method to obtain resistance.**

Seed quality in snap beans has long been a problem. Poor seed quality has been blamed on rough handling at harvest resulting in "snake-heads" (11); on low seed moisture at harvest resulting in increased susceptibility to mechanical damage (MD) (1, 2, 8, 10, 11, 13); on wet soils at planting resulting in a sudden shock to the seed during imbibition (10); on insufficient oxygen due to low aeration in wet soil (10); on low Ca and Mg in the seed resulting in weak seed (5); and on the effect of seed color and the association of white seed with poor seed quality (1).

Transverse cotyledon cracking (TVC) has long been associated with seed problems (7). Recently we have shown that selection for TVC is associated with resistance of seed to MD (4). We also showed that resistance to TVC is complex in inheritance, with some dominance for resistance (3). Broad-sense heritability for TVC varied from 37-57% and narrow-sense heritability varied from 27-47%.

The inheritance of resistance to MD and TVC in snap beans with emphasis on selecting for MD and TVC resistant white-seeded beans is reported here.

Materials and Methods

MD resistant F_7 selections 527, 534, and 535 with colored seed and 543 and 573 with white seed, were derived from crosses of OSU58 with 'Spartan Arrow', 'Early Wax', 'Geneva WB6-5', and 'Maestro', respectively (3, 4). They were crossed with 'Slimgreen' (SG) and 'Early Gallatin' (EG) which have white seed. The F_1 and backcross seed was produced in the greenhouse. The F_2 and backcrosses, along with the parents, were planted in the field with 15 cm between plants and 90 cm between rows. The seed was harvested on an individual plant basis. The seed was threshed on a Little Sheller roller sheller with the seed moisture above 10%.

The seed dried in storage at 20-25% RH and 2-3°C until it came to equilibrium at 5-7% moisture. For the MD resistance test, 25 seed of each family were dropped 4 times from 180 cm on to a steel plate with a 26° slope in 1975 and 12° slope in 1976. The sloped plate allowed the seed to move from the plate, facilitating handling and eliminating the chance of one seed hitting another. The dropped seed was stored in a greenhouse at high humidity for 2 weeks, which caused the seed moisture to exceed 10% before it was planted in sand. Twenty-five dropped and 25 undropped seed from each F_2 or BC-1 plant was tested. The seed from each F_2 or BC-1 plant is referred to as a family. The germination count of plants having 2 normal unifoliate leaves and the plant wt was recorded after 14 days at 21° day/15° night. In most cases 24 or 25 seedlings with 2 normal unifoliate leaves were obtained from 25 undropped seed. This permitted us to evaluate the effect of seed dropping on germination and to observe the relative reduction in seedling vigor for each family. Ten seeds of each family were tested for TVC by the methods reported previously (7).

The distributions for susceptibility to MD and TVC of the susceptible parents SG and EG, as well as progeny of crosses to resistant parents, were similar. Therefore the results from crosses between each resistant parent with SG and EG are combined for presentation in the tables. Generally, germination of seed from the backcrosses to susceptible parents SG and EG was poorer than from backcrosses to the resistant parents, resulting in smaller backcross populations in many cases. Remnant seed of selected families and remnant seed of all F_3 families involving the crosses with resistant parents 535 and 573 were planted in the field on a single family to row basis for increase. The F_4 seed was threshed on a belt thresher at 9.5-12% seed moisture.

Remnant F_3 seed (0.5-1.0 kg) from the crosses involving the resistant parents 534, 527, and 543 were bulked and dropped repeatedly a total of 16 times from a height of 180 cm onto the steel plate. It was found by testing small samples that this no. of drops was required with this sample size to damage all but 3-5% of the seed. The seed was planted in the field and any seedlings showing signs of mechanical damage such as snake-heads or single first true leaves were removed. The seed from the remaining plants was harvested when ripe and bulk threshed on a belt thresher.

Heritabilities using colored plus white seed data, were estimated using the backcross and F_2 variances for the narrow sense (NSH) estimates (14) and F_2 and parental variances for the broad sense (BSH) estimates (6). In addition NSH was estimated using the regression of the F_4 on F_3 families (6).

Results and Discussion

Transgressive segregation in the F_2 for MD susceptibility and resistance occurred in all crosses except the cross involving the 543 white, resistant parent (Table 1). In crosses of white and colored seeded parents, the mean of the white portion of the F_2 population was always lower than the mean of the colored portion indicating susceptibility of the former. There was still a wide range of susceptibility, however, indicating the possibility of selection for MD resistant, white-seeded lines. This association was even more apparent in the backcross to the susceptible white-seeded parents, where the colored seeded segregates were on the average superior to the white. The segregation patterns in some populations resulted in artifi-

[1]Received for publication March 14, 1977. New York State Agricultural Experiment Station, Geneva, NY 14456, as Journal Paper No. 3054.

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Table 1. Number of families in parental and derived progeny populations in emergence classes, based on mechanical damage resistance tests.

Pedigree generation	Seed[z] color	Distribution of families: Emergence class[y] 1	3	5	7	9	11	13	15	17	19	21	23	25	n	Mean ± SE
534 P_1	C							2	2	10	6				20	17.0 ± .40
SG & EG P_2	W					9	5	11	9	5	1				40	12.9 ± .45
$P_1 \times P_2$ F_2	C					4	6	9	22	12	20	17	7	1	98	17.1 ± .38
$P_1 \times P_2$ F_2	W		3	1	8	2	5	1	5	3	1	2			31	11.1 ± .94
$P_1 \times P_2$ F_2	C+W		3	1	8	6	11	10	27	15	21	19	7	1	129	15.6 ± .43
$(P_1 \times P_2)$ P_1 BC	C						1	1	2	2	11	6	4	2	29	19.5 ± .60
$(P_1 \times P_2)$ P_2 BC	C						1	1	0	0	2	2	0	1	7	18.4 ± 1.84
$(P_1 \times P_2)$ P_2 BC	W				2	1	0	1	3	0	1	3	2		13	16.1 ± 1.61
$(P_1 \times P_2)$ P_2 BC	C+W				2	1	1	2	3	0	3	5	2	1	20	16.9 ± 1.23
Narrow sense heritability = .29								Broad sense heritability = .79								
527 P_1	C							1	1	7	7	4	15	3	20	18.2 ± .47
SG & EG P_2	W					9	5	11	9	5	1				40	12.9 ± .45
$P_1 \times P_2$ F_2	C				1	5	5	9	22	22	20	22	15	3	124	17.7 ± .36
$P_1 \times P_2$ F_2	W			2	4	2	2	4	5	2	0	1	2	1	25	13.2 ± 1.20
$P_1 \times P_2$ F_2	C+W			2	5	7	7	11	27	24	20	23	17	4	149	16.8 ± .41
$(P_1 \times P_2)$ P_1 BC	C							1	2	0	6	4	6		19	19.9 ± .69
$(P_1 \times P_2)$ P_2 BC	C								4	2	0	1			7	17.8 ± .43
$(P_1 \times P_2)$ P_2 BC	W					1	3	1	1	1	1	3			8	13.3 ± 1.22
$(P_1 \times P_2)$ P_2 BC	C+W					1	3	1	5	3	1	1			15	14.7 ± .85
Narrow sense heritability = 1.23								Broad sense heritability = .76								
535 P_1	C								2	6	6	4	2		20	18.8 ± .52
SG & EG P_2	W					9	5	11	9	5	1				40	12.9 ± .45
$P_1 \times P_2$ F_2	C		1	1	2	6	7	5	8	15	21	16	10		92	16.9 ± .49
$P_1 \times P_2$ F_2	W	2	1	3	1	3	7	5	2	3	5		1	1	34	12.4 ± 1.02
$P_1 \times P_2$ F_2	C+W	2	2	4	3	9	14	10	10	18	26	16	11	1	126	15.7 ± .48
$(P_1 \times P_2)$ P_1 BC	C						1	1	3	5	12	9	3		34	18.8 ± .47
$(P_1 \times P_2)$ P_2 BC	C							1	0	0	2	2	1		6	19.3 ± 1.40
$(P_1 \times P_2)$ P_2 BC	W				1	1	0	1	1						4	11.0 ± 1.82
$(P_1 \times P_2)$ P_2 BC	C+W				1	1	0	2	1	0	2	2	1		10	16.0 ± 1.72
Narrow sense heritability - .73 and .52[x]								Broad sense heritability = .77								
543 P_1	W						1	2	1	3	5	3	4	1	20	18.9 ± .68
SG P_2	W					5	2	5	6	1	1				20	12.9 ± .66
$P_1 \times P_2$ F_2	W			3	3	7	7	11	2	2	2	0	1		42	11.0 ± .69
$(P_1 \times P_2)$ P_1 BC	W									2	6	0	2	2	12	20.3 ± .83
$(P_1 \times P_2)$ P_2 BC	W					2	1	1	2	2	2				12	14.4 ± 1.09
Narrow sense heritability = .86								Broad sense heritability = .55								
573 P_1	W							1	2	3	9	4	1		20	18.6 ± .53
SG & EG P_2	W					9	5	11	9	5	1				40	12.9 ± .45
$P_1 \times P_2$ F_2	W		1	5	13	13	30	21	12	17	10	4	2		128	12.7 ± .40
$(P_1 \times P_2)$ P_1 BC	W					2	1	1	5	2	2	2	0	1	16	16.0 ± 1.10
Narrow sense heritability = .27[w]								Broad sense heritability = .66								

[z]C = colored; W = whiteseed.

[y]No. of undamaged seedlings which emerged per 25 seeds.

[x].52 by regression of F_4 on F_3.

[w].27 by regression of F_4 on F_3.

cially high NSH values of .86 and the irregular value of 1.23 due to relatively small variances of the backcross (due to its smaller size) to the resistant parent compared to the F_2 variances and the confounding effect of the seed color. A partial dominance for resistance was generally apparent as evidenced by the mean of the F_2 colored or colored + white being higher than the mean of the parents. The similarity of performance of the backcross to the resistant parent and the resistant parent itself was especially notable.

The TVC data (Table 2) indicated slightly higher NSH and BSH than previously reported (3) and this may be accounted for by the more specific classification for damage and larger populations used than in the previous test. Resistance was incompletely dominant with white-seeded segregates generally being more susceptible to TVC than the colored segregates. However, the association of colored seed with resistance was not as strong for TVC as for MD resistance.

NSH estimates for MD based on the F_4 on F_3 regressions for the 2 populations involving resistant parents 535 and 573 were .52 and .27, respectively. The higher value was about as expected from performance of resistant selections reported on earlier (4). The more severe damage occurring in 1976 indicated the screening in 1975 might not have been as severe as desirable. In 1975 the slope of the steel plate was 26°. In 1976 we reduced it to 12° to increase the impact effect, which may have accounted for damage comparable to that obtained in 1974 (4) when a flat plate was used. In 1976, the susceptible parents SG and EG averaged 5.4 and 7.3 undamaged seedlings per 25 seeds following damage resistance tests, compared to 12.9 in 1975.

The sources of resistance to MD were standard cultivars and OSU58 was a common parent for each resistant line. OSU58 is very susceptible to TVC (3) but is a good combiner for MD resistance. The lines used as resistant parents were selected because of their proved resistance to MD and not because of their common parent OSU58.

Table 2. Number of families in parental and derived progeny populations in TVC resistance classes, based on tests of 10 seeds per plant.

Pedigree generation	Seed[z] color	No. of plants per TVC resistance class[y] 0	1	2	3	4	5	6	7	8	9	10	n	Mean ± SE
534 P_1	C											20	20	10.0 ± .00
SG & EG P_2	W	6	7	11	3	8	5	1	1				40	2.7 ± .31
$P_1 \times P_2$ F_2	C			3	2	3	7	5	4	11	32	41	108	8.4 ± .20
$P_1 \times P_2$ F_2	W	3	3		1	1	4	4	11	4	5	10	46	6.7 ± .44
$P_1 \times P_2$ F_2	C+W	3	3	3	3	4	11	9	15	15	37	51	154	7.9 ± .20
$(P_1 \times P_2)$ P_1 BC	C								1	1	3	19	24	9.7 ± .16
$(P_1 \times P_2)$ P_2 BC	C									1	2	7	10	9.6 ± .22
$(P_1 \times P_2)$ P_2 BC	W		1		1				1	2	1	7	13	8.2 ± .81
$(P_1 \times P_2)$ P_2 BC	C+W		1		1				1	3	3	14	23	8.8 ± .48
Narrow sense heritability = 1.05							Broad sense heritability = .90							
527 P_1	C										1	19	20	9.9 ± .07
SG & EG P_2	W	6	7	11	3	8	5	1	1				40	2.7 ± .31
$P_1 \times P_2$ F_2	C					2	1	1	3	13	35	76	131	9.3 ± .10
$P_1 \times P_2$ F_2	W	2	4	2	4	3	6	0	7	2	1	4	35	5.0 ± .51
$P_1 \times P_2$ F_2	C+W	2	4	2	4	5	7	1	10	15	36	80	166	8.4 ± .19
$(P_1 \times P_2)$ P_1 BC	C						1				4	14	19	8.5 ± .27
$(P_1 \times P_2)$ P_2 BC	C											6	6	10.0 ± .00
$(P_1 \times P_2)$ P_2 BC	W		2	3	2	1	1	1	1		2		13	4.2 ± .78
$(P_1 \times P_2)$ P_2 BC	C+W		2	3	2	1	1	1	1		2	6	19	6.0 ± .63
Narrow sense heritability = .50							Broad sense heritability = .93							
535 P_1	C									4	3	13	20	9.5 ± .19
SG & EG P_2	W	6	7	11	3	8	5	1	1				40	2.7 ± .31
$P_1 \times P_2$ F_2	C						1	1	1	4	10	83	100	9.7 ± .27
$P_1 \times P_2$ F_2	W	1				5	9	5	4	3	3	4	34	6.3 ± .39
$P_1 \times P_2$ F_2	C+W					5	10	6	5	7	13	111	158	9.0 ± .15
$(P_1 \times P_2)$ P_1 BC	C									3	7	24	34	9.6 ± .11
$(P_1 \times P_2)$ P_2 BC	C									3	1	2	6	8.8 ± .41
$(P_1 \times P_2)$ P_2 BC	W			1			1			4			6	6.5 ± 1.02
$(P_1 \times P_2)$ P_2 BC	C+W			1			1			7	1	2	12	7.7 ± .63
Narrow sense heritability = .51 and .58[x]							Broad sense heritability = .53							
543 P_1	W									3	11	6	20	9.2 ± .16
SG P_2	W	4	7	9	1	1							20	1.6 ± .21
$P_1 \times P_2$ F_2	W	4	9	5	7	4	2	8	5	3			49	3.9 ± .39
$(P_1 \times P_2)$ P_2 BC	W				1	2	3	0	2	3	2		13	6.3 ± .57
$(P_1 \times P_2)$ P_2 BC	W		2	2	0	0	2	1	3	1			11	4.6 ± .80
Narrow sense heritability = .48							Broad sense heritability = .91							
573 P_1	W								1	3	7	9	20	9.2 ± .20
SG & EG P_2	W	6	7	11	3	8	5	1	1				40	2.7 ± .31
$P_1 \times P_2$ F_2	W	3	0	11	7	19	12	27	17	15	16	18	145	6.2 ± .21
$(P_1 \times P_2)$ P_1 BC	W						2	2	0	0	2	7	13	8.5 ± .58
Narrow sense heritability = . 22[w]							Broad sense heritability = .72							

[z]C = colored seed; W = white seed.

[y]No. of seeds out of 10 without any TVC.

[x]Narrow sense heritability = .58 by regression F_4 on F_3.

[w]Narrow sense heritability = .22 by regression of F_4 on F_3.

Promising results were obtained from bulking remnant seed of the F_3 populations (Table 1) and involving resistant parents 534, 527 and 543 (Table 3). The parental germination following MD test was lower in 1976 than in 1975. However, in 1976 the white F_4 seed from the survivors of the bulked F_3 dropped 16 times germinated much better than the susceptible white parent. This very severe test appeared to be a simple but efficient method to screen for MD resistance, since white segregants with more than twice the germination following MD compared to their susceptible parent were obtained with a single screening.

It is suggested that seedsmen might use this technique of making a cross between standard and resistant lines and bulk increasing the F_2 population. The F_3 or F_4 seed could be artificially damaged in severe enough fashion that only 3-5% of the seed would be viable. The seed could then be planted out, seedlings with snakeheads or other signs of MD removed, and the survivors evaluated for horticultural characters. This simple technique should obtain MD resistant lines at minimum cost or effort.

Table 3. Germination following simulated mechanical damage showing gain in germination of white F_4 seed compared to susceptible parent following selection in F_3 by dropping seed 16 times.

Pedigree	Germination (%) 1975	1976
534	88	68
SG	52	22
534 × SG F_3-F_4[y]	44[z]	54[y]
527	73	76
EG	52	30
527 × EG F_3-F_4	57[z]	53[y]
543	76	56
SG	52	22
543 × SG F_3-F_4	44[z]	54[y]

[z]Mean of F_3 in 1975.

[y]Bulk of F_3 dropped 16 times and F_4 grown out in 1976.

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J. Amer. Soc. Hort. Sci. 102(4):501–503. 1977.

Identification of ABA Stereoisomers in French Prune Seeds and Association of ABA with Ethylene-enhanced Prune Abscission[1]

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Additional index words. Prunus domestica L., gas chromatography, mass spectrometry

Abstract. **Excised fruiting branches of French prune (*Prunus domestica* L.) were treated with 15 µl/liter ethylene (ETH), which inhibited fresh weight increase and caused abscission of immature fruit. Inhibition of fresh weight accumulation was much greater 30 days after full bloom than 44 days after full bloom. Abscisic acid (ABA) in fruit pericarp and seed was extracted, purified for determination by gas chromatography, and identified by gas chromatography-mass spectrometry. ETH treatment significantly increased ABA concentration of pericarp and seed. The inhibition of growth by ETH was similar for pericarp and seed while the increase in ABA was much greater in pericarp than in seed. The *trans, trans*-ABA was detected only in the seed and the *cis, trans*-ABA: *trans, trans*-ABA ratio was reduced by ETH.**

The interrelationship of ETH and ABA in senescence is not clear. However, ETH promotes senescence (1, 2), and endogenous ABA levels increase both in senescing organs (5, 8, 9, 11) and following application of ETH (3, 5, 8, 9). Water stress also markedly increases both ETH evolution (10) and extractable ABA (13).

Ethephon stimulates abscission of immature French prune[3] fruits within 3 to 4 weeks following foliar application (7). Under field conditions, senescence, as indicated by yellowing and shriveling of fruits, precedes the ethephon-induced abscission. However, ETH-induced changes in endogenous ABA have not been reported for this fruit. The objectives of this investigation were to determine whether ABA is present in immature French prune fruits, and if so, its relation to ETH-induced fruit abscission. We attempted to distinguish between ABA increases associated with abscission and those resulting from organ senescence and tissue dehydration.

Materials and Methods

Plant material. Plant material and ETH-treatment system were similar to those previously used (12). Fruiting branches (20-40 fruit of uniform size/45 cm branch) were detached from 7 to 10-year-old French prune trees, and placed, with their bases in water, in 20-liter jars. Three branches per treatment were employed. Branches were exposed to ETH-free humidified air or 15 µl/liter ETH for 56 hr. Capillary flow meters allowed passage of gas mixtures through the jars at the rate of 12 liters/hr. The experiment was performed twice during the commercial thinning period, 30 days after full bloom (AFB), when the endocarp was soft and the endosperm primarily liquid, and 44 days AFB when the endocarp was becoming firm and the embryo had absorbed most of the endosperm. Immediately after treatment, weakening of the fruit:pedicel abscission zone was quantitatively determined by measuring the fruit removal force (FRF) with a dial push-pull gauge (Chatillon Model DPP-1 kg) adapted with a two-prong hook for attaching to prune fruits. Seed and pericarp were then separated, weighed, and frozen with dry ice.

ABA extraction and purification. Ten-fruit samples from each branch were thawed at room temp and homogenized in 30 (seed) or 60 ml (pericarp) of 0.1 M Na_2CO_3 buffer, pH 10, for 5 min using a Virtis Model 45 homogenizer at high speed. Purification steps are shown in Fig. 1. This method is rapid

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[3]French prune is the designation used by the California prune industry. This European plum has a sufficiently high sugar content for drying and is probably the cultivar Agen.