

## Research Note

### GENERAL COMBINING ABILITY EFFECTS FOR REPRODUCTIVE HEAT TOLERANCE IN SNAP BEAN<sup>1</sup>

Timothy G. Porch<sup>2</sup>, Michael H. Dickson<sup>2</sup>, Michael C. Long<sup>4</sup>,  
Donald R. Viands<sup>4</sup> and Margaret Jahn<sup>4</sup>

J. Agric. Univ. P.R. 88(3-4):161-164 (2004)

High temperature stress during reproductive development causes major yield reduction in common bean (*Phaseolus vulgaris* L.) in both tropical and temperate zones and in both fresh and dry market classes. Heat stress increases floral abscission; damages male reproductive development, thus resulting in pollen sterility; and reduces pod and seed set (Gross and Kigel, 1994; Konsens et al., 1991; Monterroso and Wien, 1990; Porch and Jahn, 2001). Genetic studies indicate that the response to temperature stress is specific to both the particular environment and genotype tested. Several physiological traits associated with reproductive heat tolerance show additive gene action and large general combining ability/specific combining ability (GCA/SCA) ratios (Shonnard and Gepts, 1994). Dominance effects have also been detected for the two genes controlling pod set in two dry bean genotypes under concurrent heat and drought stress (Bouwkamp and Summers, 1982), and for pod set in snap beans under heat stress (Dickson and Petzoldt, 1989). In addition, bud retention and pod set under heat stress were quantitatively inherited with significant additive, dominance, and cytoplasmic effects (Shonnard and Gepts, 1994). Yield and yield components under high temperature stress were found to be heritable (Baiges et al., 1996; Román-Avilés and Beaver, 2001). In summary, the trait has been determined to be heritable and both quantitative and qualitative, depending on the measurement method and germplasm used. The objective of this study was to determine GCA effects for pod number in selected snap bean lines under conditions of heat stress during reproductive development.

A diallel analysis of pod number was conducted with 10 lines under high temperature conditions in the greenhouse. The diallel consisted of snap bean inbred lines or cultivars all of which were of primarily Andean origin (Table 1). Four New York (NY) lines in the 10-parent diallel, NY8214, NY8222, NY8223, and NY8224, were originally bred for root rot tolerance at Cornell University, but were also heat tolerant. The three lines, NY8333, NY8713, and NYCT70, were originally bred for cold tolerance during vegetative and reproductive development. BBL47, BBL94, and Labrador were heat-susceptible check genotypes.

The 10-parent diallel was sown in two randomized complete block design plantings, spaced 10 days apart, in order to accommodate all plants. One seed was planted per 18-cm-diameter round pot. The plants were grown in greenhouses in Geneva, NY, with supplemental lighting to maintain a 14-hour photoperiod. A 25/20° C (day/night) temper-

<sup>1</sup>Manuscript submitted to Editorial Board 13 January 2004.

<sup>2</sup>Research Plant Geneticist, USDA/ARS, Tropical Agriculture Research Station, 2200 P.A. Campos Ave., Suite 201, Mayagüez, PR 00680.

<sup>3</sup>Department of Horticultural Sciences, Cornell University, Geneva, NY 14456, USA.

<sup>4</sup>Department of Plant Breeding, Cornell University, Ithaca, NY 14853, USA.

TABLE 1. Response of the diallel parents to high temperature treatment during reproductive development and general combining ability (GCA) for pod number per plant.

Parents <sup>1</sup>	Reported temperature response <sup>2</sup>	Temperature response reference	Mean of pods per plant for all single cross progenies	GCA effects for pods per plant <sup>3</sup>
BBL47	HS	(Gross and Kigel 1994)	2.62	-3.40
BBL94	HS	(Dickson, unpublished)	4.68	-1.35
Labrador	HS	(Dickson, unpublished)	4.92	-0.95
NY8214	CT & HT	(Dickson, unpublished)	4.52	-1.29
NY8222	CT & HT	(Dickson, unpublished)	6.32	0.80
NY8223	CT & HT	(Dickson, unpublished)	6.11	0.87
NY8224	CT & HT	(Dickson, unpublished)	5.46	-0.26
NY8333	CT & HT	(Dickson, unpublished)	9.03	3.90
NY8713	CT & HT	(Dickson, unpublished)	4.93	-0.77
NYCT70	CT & HT	(Dickson, unpublished)	7.71	2.44
Standard error				0.49

<sup>1</sup>All genotypes are Andean snap beans provided by Michael H. Dickson.

<sup>2</sup>CT, cold-tolerant; HT, heat-tolerant; HS, heat-sensitive.

<sup>3</sup>Significance ( $\alpha = 0.05$ ) for GCA effects are  $g_{ii} \pm (2 \times \text{s.e.})$ .

ature regime was used from planting until three days before anthesis of the first flower, at which time the plants were moved to a 35/27 °C greenhouse. The high temperature treatment was applied for a seven-day period and the plants were then returned to the 25/20 °C greenhouse, where they remained until plant maturity. Fans were used to maintain uniform temperature and humidity conditions. Data on pod number per plant were recorded on the second and 10th day after the return of the plants to the 25/20 °C conditions. Yield was measured as pod number; only seed-bearing pods were counted. A randomized complete block design was used with two blocks (the two plantings), four replications per block, and one plant per replication for each F<sub>1</sub> progeny. The diallel was a Griffing Model I (fixed effects) Method 4 (Griffing, 1956) diallel with  $[p(p-1)]/2$  genotypes and no reciprocals. The genetic parameters of the diallel (equation below) were estimated by using PROC REG (SAS, SAS Institute, Cary, NC, USA) according to Sanders (1986).

$$Y_{ijkl} = \mu + b_i + c_j + g_k + g_l + s_{kl} + e_{ijkl}$$

$$i = 1, \dots, b; j = 1, \dots, c; k, l = 1, \dots, p; e_{ijkl} \sim N(0, \sigma_e^2)$$

$\mu$	overall mean
$b_i$	fixed effect of block i
$c_j$	random effect of replication j; $c_j \sim N(0, \sigma_c^2)$
$g_k, g_l$	fixed GCA effects of the k <sup>th</sup> and l <sup>th</sup> parents, respectively
$s_{kl}$	fixed SCA effect of the F <sub>1</sub> from the cross of the k <sup>th</sup> and l <sup>th</sup> parents
$e_{ijkl}$	residual

The results indicate that there is variability for combining ability of pod number under heat stress for the specific snap bean lines investigated in this study. GCA effects for pod number were significant (32,  $p < 0.001$ ) [formula from Griffing (1956)], whereas SCA

effects were not statistically significant. NY8333, NYCT70, NY8223, and NY8222 had positive GCA effects, whereas BBL47, NY8224, NY8713, Labrador, NY8214 and BBL94 had negative GCA effects for pods per plant. The result of negative general combining ability for the controls, Labrador, BBL94 and BBL47, is consistent with results from previous field and greenhouse high temperature trials with these genotypes (M. Dickson, unpublished; Gross and Kigel, 1994; Porch, 2001); however, several of the heat tolerant lines also had negative GCAs.

All of the lines selected for this analysis were of Andean origin and are characteristic of the homogeneous breeding lines used in the United States for snap bean improvement (Nodari et al., 1992). Previous diallel studies indicated that the diversity of germplasm selected greatly affects the estimates of combining ability (Nienhuis and Singh, 1988). The origin of parental lines will likely have a strong effect on results; therefore, caution should be used in extending specific inferences about a parent's performance beyond the pool of germplasm analyzed. To further elucidate the genetics of heat tolerance and thereby speed germplasm improvement, there should be more studies that incorporate greater numbers of diverse germplasm. Selection of parents for breeding should be based on combining ability, genetic distance, and parental performance in the target environment in order to optimize genetic gain from selection.

Field-based plant breeders have long surmised that heat tolerance and cold tolerance may be genetically associated, although documentation beyond anecdotal observation is scarce. In this report, two of the most cold-tolerant genotypes, NY8333 and NYCT70, also possessed positive GCA effects for tolerance to high temperature. It is possible that there may be some similarity in mechanism, genetic control, or genetic linkage of tolerance to temperature extremes. The relationship between reproductive heat and cold tolerance, therefore, requires further investigation including quantitative trait locus (QTL) studies using populations that segregate for yield under high and low temperature stress.

In conclusion, reproductive heat tolerance has the potential to enhance bean yield and hence human nutrition and economic status in both tropical and temperate zones. Our results indicate that there is significant variance in GCA effects for pod number in bean and that improvement for heat tolerance is therefore possible.

#### LITERATURE CITED

- Baiges, S., J. Beaver, P. Miklas and J. Rosas, 1996. Evaluation and selection of dry beans for heat tolerance. *Annu. Rep. Bean. Improv. Coop.* 39:88-89.
- Bouwkamp, J. C. and W. L. Summers, 1982. Inheritance of resistance to temperature-drought stress in the snap bean. *J. Hered.* 73:385-386.
- Dickson, M. H. and R. Petzoldt, 1989. Heat tolerance and pod set in green beans. *J. Amer. Soc. Hort. Sci.* 114:833-836.
- Griffing, B., 1956. Concept of general and specific combining ability in relation to diallel crossing systems. *Aust. J. Biol. Sci.* 9:463-493.
- Gross, Y. and J. Kigel, 1994. Differential sensitivity to high temperature of stages in the reproductive development of common bean (*Phaseolus vulgaris* L.). *Field Crops Res.* 36:201-212.
- Konsens, I., M. Ofir and J. Kigel, 1991. The effect of temperature on the production and abscission of flowers and pods in snap bean (*Phaseolus vulgaris* L.). *Ann. Bot.* 67:391-400.
- Monterroso, V. A. and H. C. Wien, 1990. Flower and pod abscission due to heat stress in beans. *J. Amer. Soc. Hort. Sci.* 115:631-634.
- Nienhuis, J. and S. P. Singh, 1988. Genetics of seed yield and its components in common bean (*Phaseolus vulgaris* L.) of Middle-American origin I. General combining ability. *Plant Breed.* 101:143-154.

- Nodari, R., E. Koinange, J. Kelly and P. Gepts, 1992. Towards an integrated linkage map of common bean 1. Development of genomic DNA probes and levels of restriction fragment length polymorphism. *Theor. Appl. Genet.* 84:186-192.
- Porch, T. G., 2001. Genetics and applications of heat tolerance in common bean. PhD Dissertation, Cornell University, Ithaca.
- Porch, T. G. and M. Jahn, 2001. Effects of high temperature stress on microsporogenesis in heat-sensitive and heat-tolerant genotypes of *Phaseolus vulgaris*. *Plant Cell Environ.* 24:723-731.
- Román-Avilés, B. and J. Beaver, 2001. Heritability of heat tolerance of an Andean bean population. *Annu. Rep. Bean Improv. Coop.* 44:49-50.
- Sanders, W. L., 1986. Analysis of diallel cross designs with empty diagonals via SAS PROC GLM and PROC REG. *Southern Cooperative Series Bulletin* 324:87-98.
- Shonnard, G. C. and P. Gepts, 1994. Genetics of heat tolerance during reproductive development in common bean. *Crop Sci.* 34:1168-1175.