17. Zaumeyer, W.J. and H.R. Thomas. 1957. A monographic study of bean diseases and methods for their control. USDA Tech. Bul. 868.

18. Zapata, M. and A.K. Vidaver. 1987. Differentiation of *Xanthomonas campestris* pv. *phaseoli* into pathogenic races based on the Tepary bean reactions. Phytopathology 77:1709. (Abstr.)

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Yield Compensation of Bean Genotypes Grown in Hill-plots

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Abstract. **Field experiments were conducted at two locations in Puerto Rico to measure the effect of growth habit on the ability of bean (*Phaseolus vulgaris* L.) genotypes to compensate for variation in plant population in hill-plots. Five determinate and five indeterminate bean genotypes were grown in 1-m-diameter hill-plots ranging in population from two to 10 plants per hill-plot. The indeterminate genotypes produced a greater seed weight per hill-plot, a smaller 100-seed weight, a greater number of pods per plant, and a greater number of seeds per pod than the determinate genotypes. Number of seed per pod and 100-seed weight did not differ significantly as the number of plants decreased from 10 to two plants per hill-plot. Number of pods per plant and seed yield per hill-plot increased in a linear fashion as the number of plants per hill-plot decreased. A covariance analysis using number of plants per hill-plot as the covariate would be appropriate for adjusting hill-plot yields for variation in plant population. The similarity of the seed yield response of determinate and indeterminate bean genotypes to varying population density would permit both habits to be analyzed in a single covariance analysis.**

The use of hill-plots can reduce the number of years required for cultivar development and recurrent selection by eliminating the need for seed increases and permitting the evaluation of lines in earlier generations (2). Compared with larger plots, hill-plots also permit the evaluation of a greater number of genotypes per unit of area (1).

The performance of genotypes in hill-plots is affected by both distance between hills and the number of plants per hill (6, 7). Garland and Fehr (2) found that a 1-m spacing between rows of soybeans [*Glycine max* (L.) Merr.] minimized inter-row competition and permitted researchers to walk between plots to make observations without damaging the plants. Indeterminate soybeans grown in hill-plots have been found to compensate for a reduced number of plants per hill-plot (7). As a consequence, reliable yield estimates of indeterminate soybeans can be obtained from a wide range of hill-plot populations (8).

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Determinate and indeterminate bean genotypes have been found to differ in their yield response to plant density (5, 9). Kueneman and Wallace (3) found that increasing the within-row spacing from 50 to 100 mm resulted in a greater increase in number of pods per plant for indeterminate than for determinate bean genotypes.

Knowledge of the yield response of determinate and indeterminate beans to varying hill-plot populations would be useful in establishing the minimum number of plants per hill-plot needed to obtain reliable estimates of seed yield. Therefore, the objective of this research was to measure the ability of determinate and indeterminate bean genotypes to compensate for variation in plant population in hill-plots.

Experiments were conducted on a Coto soil (Tropetic, Haplorthox, clayey, kaolinitic, isothermic) at Isabela, P.R. and on a San Anton soil (Cumulic, Haplustolls, fine-loamy, mixed, isohyperthermic) at Fortuna, P.R. Five determinate bean genotypes (Guayamera, Borinquen, Pompadour checa, Cuarentena, and 3M-152) and five indeterminate bean genotypes (2W-33-2, B-190, L227-1, L226-10, and La Vega) were planted on 17 Oct. 1983 at Isabela and on 27 Oct. 1983 at Fortuna. The experimental design was a factorial arrangement of a randomized complete block with six replications. One factor consisted of the 10 bean genotypes, the second factor consisted of five hill-plot populations (10, eight, six, four, and two plants per hill-plot). To obtain the desired hill-plot populations, 12 seeds were planted in each hill-plot and thinned to the appropriate population at the V1 stage a development (4). Interplot competition was minimized by use of 1-m spacing between the 1-m-diameter hill-plots.

At harvest maturity (R9), the number of plants per hill-plot was counted. Number of pods per hill-plot, seed weight per hill-plot, and 100-seed weight were also recorded.

The linear and quadratic responses of determinate and indeterminate genotypes to varying hill-plot populations were compared using F tests in the analysis of variance of each experiment. Means of the determinate and indeterminate genotypes were compared using LSD ($P = 0.05$).

The indeterminate genotypes produced a greater number of pods per plant, had a greater number of seed per pod, had smaller 100-seed weights, and produced a greater seed weight per plant than the determinate genotypes (Tables 1 and 2). The number of seed per pod and 100-seed weight showed no significant difference as the number of plants decreased from 10 to two plants per hill-plot (Table 3).

Number of pods per plant increased linearly as the number of plants per hill plot decreased (Tables 1 and 2). At Fortuna the number of pods per plant of the indeterminate genotypes increased at a greater rate than the determinate genotypes (Table 3). Kueneman and Wallace (3) similarly found that the increase in number of pods per plant was greater for indeterminate genotypes than for determinate genotypes when plant density was decreased.

Seed weight per plant increased as the number of plants per hill-plot decreased from 10 to two plants (Tables 1 and 2). The increase, however, was greater for the indeterminate than for the determinate genotypes (Table 3).

Average seed weight per plot was ≈40% greater at Fortuna than at Isabela (Tables 1 and 2). As expected, yields of the smaller-seeded indeterminate genotypes were greater than the larger-seeded determinate genotypes. Seed yield response of determinate and indeterminate bean genotypes was similar within each location (Table 3).

The yield of both determinate and indeterminate beans declined in a linear fashion as hill-plot population declined from 10 to two plants per hill-plot (Tables 1 and 2). These results indicate that a covariance analysis using number of plants per hill-plot as a covariate would be appropriate for adjusting hill-plot yields for variation in plant

Table 1. Mean seed weight per plot, mean seed weight per plant, and means of yield components of determinate and indeterminate bean genotypes grown in hill plots at the Fortuna Substation.

		Plants per hill plot (no.)						
Characteristic	Growth habit	10	8	6	4	2	Mean	LSD[z]
Seed wt per hill-plot (g)	Determinate	153	141	119	100	63	115	
	Indeterminate	217	195	170	146	121	170	27
Seed wt per plant (g)	Determinate	18	20	23	25	33	24	
	Indeterminate	28	27	33	42	66	39	7
No. of pods per plant	Determinate	16.5	17.7	20.5	23.5	28.9	21.4	
	Indeterminate	28.2	29.4	36.9	45.9	62.2	40.3	5.4
No. of seed per pod	Determinate	3.4	3.7	3.6	3.5	3.7	3.6	
	Indeterminate	4.3	4.5	4.5	4.4	4.9	4.5	0.3
Hundred-seed wt (g)	Determinate	34.3	33.0	32.7	33.5	31.9	33.1	
	Indeterminate	20.6	20.5	20.4	20.9	20.8	20.6	1.7

[z]LSD (0.05) to compare means of the determinate and indeterminate genotypes.

Table 2. Mean seed weight per plot, mean seed weight per plant, and means of yield components of determinate and indeterminate bean genotypes grown in hill plots planted at the Isabela Substation.

		Plants per hill-plot (no.)						
Characteristic	Growth habit	10	8	6	4	2	Mean	LSD[z]
Seed wt per hill-plot (g)	Determinate	101	99	92	74	45	82	
	Indeterminate	153	146	136	121	76	126	28
Seed wt per plant (g)	Determinate	11	16	16	19	23	17	
	Indeterminate	18	20	24	34	43	28	7
No. of pods per plant	Determinate	10.3	13.3	15.3	16.4	19.9	15.1	
	Indeterminate	18.7	21.7	25.2	33.0	37.7	27.3	4.7
No. of seed per pod	Determinate	3.5	3.5	3.3	3.7	3.6	3.5	
	Indeterminate	5.4	5.4	5.2	5.4	5.7	5.4	0.4
Hundred-seed wt (g)	Determinate	31.9	32.8	32.8	31.5	32.8	32.4	
	Indeterminate	18.0	17.9	18.4	19.2	19.1	18.5	1.7

[z]LSD (0.05) to compare means of the determinate and indeterminate genotypes.

Table 3. Results of F tests of mean squares of number of plants per hill-plot (linear), number of plants per hill-plot (quadratic), growth habit × number of plants per hill-plot (linear), and growth habit × number of plants per hill-plot (quadratic) for seed weight per hill-plot, seed weight per plant, number of pods per plant, number of seed per pod, and 100-seed weight.[z]

Source of variation	Seed wt per plot	Seed wt per plant	No. of pods per plant	No. of seed per pod	Hundred-seed wt
	Fortuna				
No. of plants per hill-plot (linear)	*	NS	*	NS	NS
No. of plants per hill-plot (quadratic)	NS	NS	NS	NS	NS
Growth habit × no. of plants per hill-plot (linear)	NS	*	*	NS	NS
Growth habit × no. of plants per hill-plot (quadratic)	NS	NS	NS	NS	NS
	Isabela				
No. of plants per hill-plot (linear)	*	NS	*	NS	NS
No. of plants per hill-plot (quadratic)	NS	NS	NS	NS	NS
Growth habit × no. of plants per hill-plot (linear)	NS	*	NS	NS	NS
Growth habit × no. of plants per hill-plot (quadratic)	NS	NS	NS	NS	NS

*,NS Mean square of source of variation significant at the 5% level or not significant, respectively.

population. The similarity of the yield response of determinate and indeterminate bean genotypes to variation in hill-plot population would permit the yields of both growth habits to be analyzed in a single covariance analysis.

Literature Cited

1. Buzzell, R.I. and B.R. Buttery. 1984. Determining soybean yield in hill plots. Can. J. Plant Sci. 64:415–417.
2. Garland, M.L. and W.R. Fehr. 1981. Selection for agronomic characters in hill and row plots of soybeans. Crop Sci. 21:591–595.
3. Kueneman, E.A. and D.H. Wallace. 1978. Simplified growth analysis of non-climbing dry beans at three spacings in the tropics. Expt. Agr. 15:273–284.
4. Lebaron, M.J. 1974. Developmental stages of the common bean plant. Univ. of Idaho, College of Agr. Current Info. Ser. 228.
5. Nienhius, J. and S.P. Singh. 1985. Effects of location and plant density on yield and architectural traits of dry beans. Crop Sci. 25:579–584.
6. Shannon, J.G., J.R. Wilcox, and A.H. Probst. 1971. Response of soybean genotypes to spacing in hill plots. Crop Sci. 11:38–40.
7. Shannon, J.G., J.R. Wilcox, and A.H. Probst. 1971. Population response of soybeans in hill-plots. Crop Sci. 11:477–479.
8. Sumarno and W.R. Fehr. 1982. Response to recurrent selection for yield in soybeans. Crop Sci. 22:295–299.
9. Westerman, D.T. and S.E. Grothers. 1977. Plant population effects on seed yield components in beans. Crop Sci. 17:493–496.