Heritabilities and phenotypic correlations for seed yield and seed yield components of beans[1]

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ABSTRACT

Indeterminate bean (*Phaseolus vulgaris* L.) lines derived from crosses between small-seeded indeterminate and large-seeded determinate genotypes were used to estimate the heritabilities and phenotypic correlations for seed yield and seed yield components. The F_2 generation of six bean populations was planted at the Fortuna Substation, Juana Díaz, Puerto Rico, in October 1984. Seed yield per plant, 100 seed weight, number of pods per plant, and number of seed per pod were measured for 50 plants selected at random from each population. A total of 50 F_3 plant rows of each population were planted in February 1985 at the Fortuna Substation, and in March 1985 on a small farm in the Constanza valley of the Dominican Republic. Narrow sense heritabilities were estimated by using parent-offspring regressions of the F_2 and F_3 generation, and phenotypic correlations were estimated by using means of the F_3 lines. Mean seed yields per plant of the indeterminate F_3 lines were significantly less than the indeterminate parents, whereas the 100-seed weights of the indeterminate F_3 were significantly less than the determinate parents. Narrow sense heritabilities for seed yield and seed yield components were intemediate to low. These results indicate that selection for greater seed yield would be more effective by evaluating advanced lines in replicated trials. Spearman rank correlations between locations for seed yield and seed yield components varied among populations. Multilocation testing of advanced generation lines may be the most effective way to identify bean genotypes that perform well in contrasting environments.

INTRODUCTION

In spite of the fact that climatic and edaphic conditions differ greatly for beans grown in the Dominican Republic, farmers tend to use the same group of cultivars for all plantings. Therefore, in order to be successful, bean cultivars need produce predictable yields over a wide range of environmental conditions. Results from field trials conducted on small farms and experiment stations in the Dominican Republic found determinate, red-mottled bean cultivars to have lower and less predictable yields

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than indeterminate, small-seeded genotypes (2). In an attempt to improve yield level and stability of beans in the Dominican Republic, a plant breeding program was initiated to develop erect, indeterminate bean genotypes with seed characteristics acceptable to the Dominican consumer. Crosses between large-seeded determinate and small-seeded indeterminate bean genotypes can result in genetic dwarfs (5,10) which, perhaps, have discouraged bean breeders from making wide crosses. Nienhaus and Singh (8) noted that effective selection procedures to simultaneously increase yield and seed size depend on the knowledge of the inheritance of seed yield and its components and also on an understanding of the strength and stability of the relationships among these traits. The objectives of the research were to 1) determine the yield potential of indeterminate F_3 lines derived from crosses between small-seeded indeterminate and large-seeded determinate bean genotypes; 2) measure the strength and stability of the relationship of yield components with seed yield; and 3) estimate the narrow sense heritabilities of seed yield and its components.

MATERIALS AND METHODS

Six bean populations derived from crosses between large-seeded determinate and small-seeded indeterminate bean genotypes were used in the study. The large-seeded determinate genotypes were Pompadour checa, José Beta, B241-168A and Borinquen. The small-seeded, indeterminate genotypes were H-376, La Vega, and PAI 92. The F_2 generation was planted in blocks at the Fortuna Substation, Juana Díaz, Puerto Rico, 20 October 1984. Rows were spaced 60 cm and the spacing of plants within the row was approximately 10 cm. At harvest maturity, 50 plants were selected at random from each block. Seed yield and its components were measured. Seed yield was measured as seed weight per plant. Seed size was measured as the weight of 100 seeds. Number of pods was measured on a per plant basis and number of seed per pod was estimated by dividing the number of seed per plant by the number of pods per plant.

Fifty F_3 plant rows of each population were planted 22 February 1985 at the Fortuna Substation [soil type: Mollisols (Ustolls)] and 22 March 1985 on a small farm in the El Río parish, Constanza, Dominican Republic [soil type: Alfisols (Udalfs)]. A replication within blocks design was used (6). The experiment consisted of 5 blocks with 3 replications per block. Each replication of a block consisted of 10 F_3 lines selected at random from a population, and the two parents used to create the population. The experimental units consisted of 10 seeds planted in 1-m long rows spaced 0.6 m apart. Two bordered F_3 plants with the same growth habit as the plant from which they were derived were selected from each row. Seed yield and its components were measured by the previously described methods.

Seed yield and yield component means of the indeterminate F_3 lines and their parents were determined for each population and location. Means of the F_3 lines and their parents were compared by an approximate t test. Phenotypic correlations between seed yield and yield components were calculated from each population and location with means of the indeterminate F_3 lines. Narrow sense heritabilities were estimated for each population and location by regression of means of F_3 lines onto individual F_2 plant measurements. Spearman rank correlations between locations were calculated with F_3 means.

RESULTS AND DISCUSSION

Seed yield per plant of the indeterminate F_3 lines was generally significantly less than the seed yield per plant of their indeterminate parents (table 1). The difference between the means of the F_3 lines and the means of the indeterminate parents was particularly large in the low yield environment, Constanza. These results indicate that the evaluation of large populations may be necessary in order to identify F_3 lines with yield potential similar to that of the indeterminate genotypes used as parents

TABLE 1.—*Mean seed yield and number of pods per plant of parents and indeterminate F_3 lines of six bean populations grown at Constanza, Dominican Republic and Juana Díaz, Puerto Rico*

Population	Generation	Seed yield		Number of pods per plant	
		Constanza	Juana Díaz	Constanza	Juana Díaz
		g/plant			
Pomp. checa X	P_1[1]	9	16	8.0	17.1
H-376	P_2	18	23	20.9	27.7
	F_3	12*[2]	17*	11.9*	19.7*
José Beta X	P_1	10	16	7.2	12.9
H-376	P_2	19	21	22.3	24.6
	F_3	12*	17*	11.9*	18.0*
La Vega X	P_1	9	17	7.5	16.9
Pomp. checa	P_2	16	19	14.8	22.0
	F_3	10*	16	10.2*	19.6
La Vega X	P_1	8	16	6.1	11.2
José Beta	P_2	16	20	14.9	22.1
	F_3	13*	20	12.3*	20.6
8241-168A X	P_1	7	18	5.8	14.3
PAI 92	P_2	11	18	10.8	19.3
	F_3	10	14*	10.4	17.4
PAI 92 X	P_1	5	20	4.7	14.7
Borinquen	P_2	11	18	11.4	19.5
	F_3	11	20	11.0	20.7

[1] P_1 = determinate parent and P_2 = indeterminate parent.
[2] Significantly different from the indeterminate parent at the 0.05 probability level.

TABLE 2.—*Narrow sense heritabilities for seed yield and number of pods per plant. Heritabilities were estimated using parent-offspring regressions of indeterminate F_2 and F_3 plants of six bean populations grown at Constanza, Domincan Republic and Juana Díaz, Puerto Rico*

Population	Seed yield		Number of pods per plant	
	Constanza	Juana Díaz	Constanza	Juana Díaz
Pomp. checa X H-376	0.30 ± 0.02	0	0.57 ± 0.02	0.44 ± 0.03
José Beta X H-376	0.37 ± 0.03	0.60 ± 0.04	0.63 ± 0.03	0.13 ± 0.04
La Vega X Pomp. checa	0.39 ± 0.03	0.34 ± 0.05	0.33 ± 0.03	0.51 ± 0.05
La Vega X José Beta	0.18 ± 0.03	0.22 ± 0.04	0	0.47 ± 0.04
8241-168A X PAI 92	0.59 ± 0.03	0	0.19 ± 0.03	0.28 ± 0.01
PAI 92 X Borinquen	0	0	0	0.19 ± 0.03

in this study. Moreover, it may not be possible to identify indeterminate F_3 lines with adequate yield potential from the first cycle of selection. Kelly (7) found recurrent selection to be effective in the development of

TABLE 3.—*Phenotypic correlations between number of pods per plant, hundred seed-weight, number of seed per pod and seed yield. Correlations were estimated using F_3 plants of six bean populations grown at Constanza, Dominican Republic and Juana Díaz, Puerto Rico*

Population	Number of pods per plant		Hundred seed-weight		Number of seed per pod	
	Constanza	J. Díaz	Constanza	J. Díaz	Constanza	J. Díaz
P. checa X H-376	0.82**[1]	0.77**	0.07	0.23	0.28*[2]	0.46**
José Beta X H-376	0.69**	0.81**	0.14	0.11	0.17	0.23
La Vega X Pomp. checa	0.82**	0.85**	0.29	–0.05	0.47**	0.19
La Vega X José Beta	0.63**	0.79**	0.50**	–0.01	0.49**	0.01
8241-168A X PAI 92	0.80**	0.85**	0.24	0.53**	0.50**	0.41**
PAI 92 X Borinquen	0.81**	0.86**	0.39*	0.11	0.42**	0.07

[1] Significant at the 0.01 probability level.
[2] Significant at the 0.05 probability level.

erect, indeterminate pinto beans. The moderate to low narrow sense heritability values for seed yield indicate that individual plant selection for seed yield in early generation would not be effective (table 2). The magnitude of the narrow sense heritabilities is in general agreement with previous research (4,8), The results suggest that it would be more effective for breeders to select simple or highly heritable traits such as seed type, growth habit, relative maturity, and resistance to specific diseases in the early generations. Selection for seed yield would be more effective in replicated trials in advanced generations.

Pods per plant of the F_3 lines were significantly fewer than their indeterminate parents for four of the six populations at Constanza, the low yield environment (table 1). Narrow sense heritability estimates for number of pods per plant were similar in magnitude to the narrow sense heritabilities for seed yield (table 2). As in previous research (3,4,9) number of pods per plant was highly correlated with seed yield at both locations (table 3).

TABLE 4.—*Mean hundred seed-weight and number of seed per pod of parents and indeterminate F_3 lines of six bean populations grown at Constanza, Dominican Republic and Juana Díaz, Puerto Rico*

Population	Generation	Hundred weed weight		Number of seed per pod	
		Constanza	J. Díaz	Constanza	J. Díaz
		g			
Pomp. checa X	P_1[1]	35.9	29.2	3.1	3.2
H-376	P_2	24.3	19.6	3.8	4.3
	F_3	26.1#[2]	22.2#	4.0	3.9*[3]
José Beta X	P_1	48.4	41.0	2.9	3.1
H-376	P_2	20.9	19.8	4.6	4.3
	F_3	29.7#	26.5#	3.6*	3.7
La Vega X	P_1	35.4	30.0	3.2	3.3
Pomp. checa	P_2	23.2	20.2	4.7	4.2
	F_3	28.5#	24.5#	3.5*	3.4*
La Vega X	P_1	49.9	45.5	2.6	3.1
José Beta	P_2	22.0	20.1	4.1	4.4
	F_3	27.9#	25.5#	4.0	3.9*
8241-168A X	P_1	37.1	32.4	3.4	3.8
PAI 92	P_2	23.7	21.7	4.1	4.3
	F_3	27.0#	24.6#	3.5*	3.4*
PAI 92 X	P_1	29.2	29.7	3.2	4.2
Borinquen	P_2	24.1	22.3	4.1	4.6
	F_3	25.9	23.7#	3.8	4.1*

[1] P_1 = determinate parent and P_2 = indeterminate parent.
[2] Significantly different from the determinate parent at the 0.05 probability level.
[3] Significantly different from the indeterminate parent at the 0.05 probability level.

Hundred seed weight of the F_3 lines was higher at Constanza than at Juana Díaz (table 4). This difference is possibly due to a lack of rainfall during flowering and pod set. The plants, however, were able to compensate for this lack when with more favorable environmental conditions in the latter part of the growing season they produced larger seeds (1). Hundred seed weight of the indeterminate F_3 lines was significantly less than that of their determinate parents. These results point again to the need to evaluate large populations in order to identify indeterminate F_3 lines with seed sizes similar to their determinate parents. Results from research to develop erect indeterminate pinto beans indicated that desirable plant types are often associated with small seed size (7). Narrow sense heritabilities for 100 seed-weight was low to intermediate in magnitude at both locations (table 5). Since it is such a simple trait to measure, selection for greater seed size could begin in the early generations. Phenotypic correlations between seed size and seed yield were generally positive or nonsignificant (table 3). The lack of negative phenotypic correlations between seed yield and 100 seed weight indicates that the simultaneous selection for greater seed yield and seed size might be possible.

Number of seed per pod of the F_3 lines tended to be intermediate between their determinate and indeterminate parents (table 4). Little difference was observed between locations for number of seeds per pod. Narrow sense heritability estimates for number of seeds per pod were low to intermediate (table 5). Only two of the six populations had significant phenotypic correlations between seed yield and number of seed per

TABLE 5.—*Narrow sense heritabilities for hundred seed-weight and number of seed per pod. Heritabilities were estimated using parent-offspring regressions of indeterminate F_2 and F_3 plants of six bean populations grown at Constanza, Dominican Republic and Juana Díaz, Puerto Rico*

Population	Hundred seed-weight		Number of seed per pod	
	Constanza	Juana Díaz	Constanza	Juana Díaz
Pomp. checa X H-376	0.25 ± 0.11	0.22 ± 0.05	0.11 ± 0.10	0.40 ± 0.10
José Beta X H-376	0.37 ± 0.11	0.45 ± 0.12	0.23 ± 0.09	0.24 ± 0.10
La Vega X Pomp. checa	0.33 ± 0.06	0.23 ± 0.06	0.15 ± 0.06	0.19 ± 0.07
La Vega X José Beta	0.51 ± 0.09	0.44 ± 0.07	0.25 ± 0.08	0.30 ± 0.06
8241-168A X PAI 92	0.40 ± 0.12	0.40 ± 0.08	0.19 ± 0.07	0.10 ± 0.06
PAI 92 X Borinquen	0.33 ± 0.09	0.20 ± 0.05	0	0.64 ± 0.04

TABLE 6.—*Spearman rank correlations between Constanza, Dominican Republic and Juana Díaz, Puerto Rico for F_3 family means for seed yield, number of pods per plant, hndred seed-weight, and number of seed per pod*

Population	Seed yield	Number of pods per plant	Hundred seed-weight	No. of seed per plant
Pomp. checa X H-376	0.03	0.17	0.54*[1]	0.14
José Beta X H-376	0.32*	0.42*	0.53*	0.60*
La Vega X Pomp. checa	0.01	0.38*	0.74*	0.20
La Vega X Jos Béta	0.15	0.70*	0.68*	0.12
8241-168A X PAI 92	0.29**[2]	0.10	0.37*	0.33*
PAI 92 X Borinquen	0.31**	0.07	0.37*	0.32*

[1] Significant at the 0.05 probability level.
[2] Significant at the 0.01 probability level.

pod at Juana Díaz (table 3). In Constanza, however, five of the six populations had significant correlations between number of seed per pod and seed yield. A greater number of seed per pod might have provided an opportunity for plants in Constanza to partially compensate for a reduced number of pods per plant (1).

Spearman rank correlations between the Constanza and Juana Díaz locations for seed yield and seed yield components varied among populations (table 6). These results indicate that a large number of different populations should be developed in order to identify populations which produce lines that perform well in contrasting environments. Nienhaus and Singh (8) identified bean populations which had positive general combining ability for yield in more than one environment. These results also illustrate the desirability of multi-location testing of advanced lines in environments which are representative of the bean growing regions of the Dominican Republic. Hundred seed-weight was the only characteristic with significant rank correlations for all populations. Therefore, selection for seed size at one location would be effective for a wide range of environmental conditions.

RESUMEN

Heredabilidad y correlaciones fenotípicas para rendimiento y camponentes del rendimiento en habichuelas

Líneas indeterminadas de habichuela (*Phaseolus vulgaris* L.) derivadas de cruces entre genotipos indeterminados con semillas pequeñas y genotipos determinados con semillas grandes se usaron para estimar las heredabilidades y correlaciones fenotípicas para rendimiento de semilla

y los componentes de rendimiento de semilla. Seis grupos F_2 de habichuela se sembraron en la Subestación de Fortuna, Juana Díaz, Puerto Rico en octubre de 1984. Se determinó el peso de la semilla por planta, peso de 100 semillas, número de vainas por planta y número de semillas por vaina en 50 plantas seleccionadas al azar en cada grupo. Se sembraron 50 surcos de cada grupo en la Subestación de Fortuna en febrero de 1985 y en una pequeña finca en el Valle de Constanza de la República Dominicana en marzo de 1985. Se estimaron las heredabilidades en el sentido estrecho usando las regresiones padre-progenie de las F_2 y F_3. Se estimaron correlaciones fenotípicas con los de las líneas F_3. Los promedios de peso de semilla por planta de las líneas F_3 fueron significativamente más bajos que los de los progenitores indeterminados. En cambio, los pesos medios de 100 semillas de las líneas F_3 fueron significativamente más bajos que los de los progenitores determinados. Las heredabilidades en el sentido estrecho para rendimiento de semilla y los componentes de rendimiento de semilla fueron intermedias o bajas. Estos resultados indican que la selección para mayor rendimiento sería más eficaz en generaciones avanzadas usando siembras repetidas. Las correlaciones de rango de Spearman entre localidades para rendimiento de semilla y los componentes de rendimiento de semilla variaron entre los grupos. Valorar líneas de generación avanzada en varias localidades podría ser la manera más eficaz de identificar genotipos de habichuela que se comportan bien en ambientes distintos.

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