

SELECTION FOR SEED YIELD AND OTHER TRAITS AMONG EARLY GENERATIONS OF INTRA- AND INTERRACIAL POPULATIONS OF THE COMMON BEAN

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ABSTRACT

Twenty parents representing common bean races Mesoamerica, Durango, and Jalisco of Middle American origin, and Nueva Granada and Chile of Andean America, 47 F₁, and 47 F₂ in 1990, and the 20 parents, 47 F₂, and 47 F₃ in 1991 were evaluated at two locations in Colombia. Mean seed yield of the Middle American races and crosses within and between them was higher than the yield of parents and hybrids of Andean races.

Correlation coefficients (except between F₁ and F₃ for seed-filling duration) among the mid-parent, F₁, F₂ and F₃ for all traits were positive ($P < 0.05$). Heritability was 0.42 ± 0.07 for seed yield, 0.61 ± 0.02 for 100-seed weight, 0.49 ± 0.14 for harvest index, 0.49 ± 0.09 for dry matter, 0.47 ± 0.07 for flowering duration, 0.20 ± 0.12 for seed-filling duration, and 0.47 ± 0.05 for days to maturity. Values for predicted gains (in F₂) and actual gains (in F₃) for these same traits, respectively, were 21.0% and 14.4%, 34.0% and 39.0%, 4.5% and 7.5%, 9.1% and 11.9%, 12% and 8.7%, 8.7% and 2.3%, and 6.1% and 5.1%. These results support the use of early generation testing and selection among populations of the common bean.

INTRODUCTION

The use of early generation yield testing of bulk populations has been suggested for wheat (*Triticum aestivum* L.) by Cregan and Busch (1977) and Nass (1979). Hamblin and Evans (1976) concluded that in the common bean it is possible to estimate yield potential of crosses based on yield of parents and/or early generations. Ramalho *et al.* (1988) supported early generation testing, but significant interactions of mean components by generation and location were reported. Kornegay and Cardona (1990) successfully used yield tests of F₃ bulk populations and F₅ families to develop high-yielding lines of common bean plants tolerant of leafhopper (*Empoasca kraemeri* Ross & Moore). A positive correlation between yield of the parents and F₈ lines derived from their crosses in the common bean was also reported by Quiñones (1969). Singh *et al.* (1990) evaluated 33 random populations of the

common bean in F₂, F₃, and F₄ generations at three locations. Although interactions of populations with generations and locations were significant, the actual gains in F₃ and F₄ were similar to those gains predicted from selection in the F₂ for seed yield, 100-seed weight, and days to maturity.

Several hundred hybrid populations are being developed each year in the common bean improvement program of the International Center for Tropical Agriculture (CIAT), which has a relatively broad mandate. But high-yielding recombinant lines and cultivars originate from only a few populations. It is, therefore, essential to identify and discard as early as possible populations that give rise to low-yielding lines. The objective of this study was to obtain additional evidence for the value of performance of parents and early generations of the single-cross intra- and interracial populations.

MATERIAL AND METHODS

Five parents each from the common bean races Nueva Granada, Chile, and Mesoamerica, two from the race Jalisco, and three from the race Durango were used in

this study (Singh *et al.*, 1991a). The Jalisco and Durango races were grouped together and referred to as Durango in this manuscript. Twenty crosses within races (five crosses within each of four groups) and 30 crosses among races (five crosses for each six possible interracial combinations) were made by hand emasculation and pollination. Part of the F₁ seed of all 50 crosses and of 20 parents was grown for verification of hybrid origin and generation advance. Two F₁s between races Mesoamerica and Chile (A 767 x Coscorrón and Carioca x Tórtolas) and one between Mesoamerica and Nueva Granada (A 767 x XAN 170) were incompatible and dwarf (Shii *et al.*, 1980; Singh and Gutiérrez, 1984; Gepts and Bliss, 1985; Vieira *et al.*, 1989). The 20 parents, 47 F₁, and 47 F₂ in 1990 and 20 parents, 47 F₂, and 47 F₃ in 1991 were evaluated at CIAT farms at Palmira (1000 m elevation, mean temperature 24°C, Mollisol soil) and Popayán (1750 m, mean temperature 18°C, Inceptisol soil) in a randomized complete block design with three replications. Each plot for the F₁ was a single 5-m row, bordered by a guard-row on either side. A common, determinate short bush cultivar (PVA 1111) was used as a guard to minimize intergenotypic competition and border effects. Plots for all other entries were four rows, 5 m long. Between-row spacing at Palmira and Popayán was 0.6 m and 0.5 m, respectively. A population of approximately 200,000 plants ha⁻¹ was obtained at both locations. Data were recorded for flowering duration (d), seed-filling duration (d), days to maturity, 100-seed weight (g), and seed yield (kg ha⁻¹). The lateral rows and head borders of 0.5 m were removed from both ends of the central row(s) for yield measurements. In addition, total dry matter of the standing above-ground biomass was measured to determine harvest index from the same plot area, as was used for seed yield estimation. Values for seed yield, 100-seed weight, and dry matter were adjusted to

14% moisture by weight. Data for each year and location were analyzed separately and homogeneity of error variances tested (Bartlett, 1947). Because error variances were homogeneous, coefficient of variation, heritability based on the regression of F₃ on F₂ (Smith and Kinman, 1965), and predicted (F₂) and actual (F₃) gains from selection at 20% selection pressure (Frey and Horner, 1955) are given based on mean values across locations.

RESULTS AND DISCUSSION

Differences among parents, F₁, F₂, and F₃ were significant (P < 0.05) for all characters (analyses not shown). Seed yield of the Middle American races Mesoamerica, Durango, and Jalisco, and crosses within and between them, was higher than yield of parents and hybrids of Andean races Chile and Nueva Granada (Table I). The F₂ and F₃ populations between the Middle American and Andean races tended to have intermediate values. Seed yield of the Middle American common beans was reported to be higher than that of their Andean counterparts in both tropical and temperate bean-growing environments (White and González, 1990; White *et al.*, 1992). Trends for dry matter were similar to those for seed yield. Thus, Andean common bean germplasm seems to be inherently less productive than that of Middle America. On the other hand, Andean races Chile and Nueva Granada had higher 100-seed weights than Middle American races. This effect was also seen in their crosses with Middle American races. Mean values for seed yield, 100-seed weight, seed-filling duration, and days to maturity of the F₁ hybrids were comparatively higher than those for F₂ and F₃ populations, showing inbreeding depression. This was more marked for seed yield than for other traits. Only for flowering duration did the F₁ hybrids have lower values

Table I. Mean values for seed yield and other characters of common bean parents (P), F₁ hybrids, and F₂ and F₃ bulk populations grown at two locations in Colombia in 1990 and/or 1991.

Group ¹	Yield (kg ha ⁻¹)				100-seed weight (g)				Harvest index			Dry matter (kg ha ⁻¹)			Flowering duration (d)				Seed-filling duration (d)				Days to maturity			
	P	F ₁	F ₂	F ₃	P	F ₁	F ₂	F ₃	P	F ₂	F ₃	P	F ₂	F ₃	P	F ₁	F ₂	F ₃	P	F ₁	F ₂	F ₃	P	F ₁	F ₂	F ₃
M x M	1957	2500	1987	2074	19	22	19	19	0.54	0.56	0.55	2960	3217	3160	29	19	27	33	16	24	18	11	79	84	80	76
M x D	1957	2491	2150	2163	25	26	24	24	0.56	0.57	0.55	2897	3319	3131	29	19	27	32	16	24	19	13	79	83	79	76
M x C	1634	1998	1708	1660	30	30	25	25	0.53	0.53	0.54	2484	2918	2390	28	19	27	33	16	23	19	13	77	81	77	75
M x N	1660	2623	1865	1686	28	32	27	25	0.56	0.53	0.50	2687	2898	2551	27	17	26	31	15	23	18	13	77	83	79	75
D x D	1959	2650	2208	2165	30	34	31	30	0.57	0.58	0.55	2835	3317	3002	28	19	28	32	17	24	20	13	79	82	79	75
D x C	1612	2069	1676	1775	35	38	34	31	0.55	0.51	0.52	2433	2575	2430	27	19	28	31	17	24	19	14	77	82	78	75
D x N	1661	2520	1853	1889	33	40	33	31	0.56	0.54	0.52	2624	3117	2764	26	20	26	31	16	25	19	14	77	82	78	75
C x C	1265	1232	1278	1628	41	42	40	39	0.53	0.53	0.53	2031	2133	2176	26	16	24	30	17	22	18	14	75	76	74	73
C x N	1313	2137	1566	1758	39	46	42	41	0.54	0.54	0.52	2222	2836	2506	26	17	24	29	16	23	18	14	75	81	76	72
N x N	1362	1857	1595	1589	37	45	38	36	0.55	0.55	0.55	2412	2647	2439	25	16	23	30	15	22	17	12	76	81	76	72
Mean	1638	2208	1790	1849	32	36	32	30	0.55	0.54	0.53	2559	2897	2668	27	18	26	31	16	23	18	13	77	82	78	74
LSD (0.05)	132	132	93	132	0.9	0.9	0.6	0.9	0.02	0.02	0.02	272	272	272	0.7	0.7	0.5	0.7	0.7	0.7	0.5	0.7	0.7	0.7	0.5	0.7
CV (%)	17.5	25.8	19.0	15.0	25.9	27.0	27.5	27.0	6.7	5.6	7.5	14.9	15.1	15.6	7.5	14.4	9.9	7.1	7.1	10.0	6.7	8.7	4.8	5.5	4.4	3.7

¹ Letters M, D, C, and N refer to common bean races Mesoamerica, Durango, Chile, and Nueva Granada, respectively (Singh *et al.*, 1991a).

than the F₂ and F₃ populations. Because no attempts were made to collect fallen leaves, the values for harvest index are likely to be biased upward.

Correlation coefficients between the mid-parent, F₁, F₂, and F₃ were positive (P < 0.05) for all combinations and all traits studied except for seed-filling duration between the F₁ and F₃ (Table II). Values were generally the highest for 100-seed weight, followed by days to maturity. Harvest index and seed-filling duration tended to show lower values. Nonetheless, for all traits studied, including seed yield, the mid-parental values predicted the performance of the F₁, F₂, and F₃ generations. Similar results were reported for the common bean by Hamblin and Evans (1976), Ramalho *et al.* (1988), and Singh *et al.* (1990), and for wheat by Cregan and Busch (1977) and Nass (1979). Also, this is consistent with the predominance of additive genetic variance (Nienhuis and Singh, 1986, 1988b; Singh *et al.*, 1991b) and occurrence of moderate to high heritability values for most of these traits in the common bean (Table III).

Heritability values, based on the regression of F₃ on F₂, were the highest for 100-seed weight and the lowest

for seed-filling duration (Table III). Values were moderate for all other traits. Predicted and actual gains from selection (at 20% selection pressure) were the highest for 100-seed weight, followed by seed yield, dry matter, and flowering duration (Table III). Harvest index, days to maturity, and seed-filling duration had lower values. This could be a consequence of reduced variation available among populations for these traits and/or due to their relatively lower heritability values. Although results presented here are in general agreement with those reported by Singh *et al.* (1990), values for correlation coefficient between generations, heritability, and gains from selection are higher in this study. This could be due to more diverse parents and the use of single-cross intra- and interracial populations in this study compared to mostly multiple-parent populations used in the previous work.

Although more confirmatory data and convincing evidence in favor of parental and early generation evaluation of population bulks can only be obtained from the comparative performance of advanced-generation lines derived from contrasting populations, our unpublished results from two independent studies and those of

Table II - Correlation coefficients among early generations of common bean populations grown at two locations in Colombia.

Generations	Seed yield	100-seed weight	Harvest index	Dry matter	Flowering duration	Seed-filling duration	Days to maturity
Mid-parent and F ₁	0.60	0.92	-	-	0.55	0.65	0.86
Mid-parent and F ₂	0.78	0.95	0.66	0.72	0.83	0.73	0.93
Mid-parent and F ₃	0.69	0.94	0.43	0.68	0.92	0.41	0.87
F ₁ and F ₂	0.83	0.96	-	-	0.78	0.82	0.92
F ₁ and F ₃	0.65	0.93	-	-	0.50	0.11*	0.79
F ₂ and F ₃	0.78	0.98	0.60	0.78	0.82	0.33**	0.88

*Not significant.

**Significant at P < 0.05.

All others significant at P < 0.01.

Table III - Heritability¹ and expected and actual gains² from selection for seed yield and other traits in early generation populations of the common bean.

	Seed yield	100-seed weight	Harvest index	Dry matter	Flowering duration	Seed-filling duration	Days to maturity
Heritability ¹	0.42 ± 0.07	0.61 ± 0.02	0.49 ± 0.14	0.49 ± 0.09	0.47 ± 0.07	0.20 ± 0.12	0.47 ± 0.05
Gains ²							
Predicted (F ₂)	21.0	34.0	4.5	9.1	12.0	8.7	6.1
Actual (F ₃)	14.4	39.0	7.5	11.9	8.7	2.3	5.1

¹Obtained from the regression of the F₃ on F₂ according to Smith and Kinman (1965).

²Calculated at 20% selection pressure and expressed in % of the mean of all populations according to Frey and Horner (1955).

Quiñones (1969) strongly supported these findings. Common bean breeders and geneticists often seek reliable information on parental evaluation for reaction to diseases, insects, and other stresses. Data on yield, yield components, and phenological traits are usually not taken, and evaluation and selection for these traits in early segregating generations is usually visual. This practice needs to be critically examined. Our results suggest that, in the common bean, all potential parents to be used in hybridization should be tested for yield in replicated trials across contrasting environments representative of growing regions. This should be followed by selection for hybridization of parents having a high yield and other desirable traits from different races. The amount of seed required and its excessively high production cost and values of correlation coefficients among generations (Table II) will often not justify testing F₁ hybrids. Instead, F₂ and/or F₃ populations should be tested in representative environments and undesirable populations discarded. Because positive associations between the mid-parent value and F₁, F₂, and F₃ occur, one may ask why evaluation for yield and other traits of early generation populations is required. If reliable yield data on parents are available, the need to yield test early generation populations is reduced. Nonetheless, owing to differences in combining ability (Nienhuis and Singh, 1986, 1988a; Singh *et al.*, 1992), problems of hybrid incompatibility (Shii *et al.*, 1980; Singh and Gutiérrez, 1984; Gepts and Bliss, 1985; Vieira *et al.*, 1989), segregation distortion (Koenig and Gepts, 1989; Welsh, 1993), male sterility (Sprecher and Khairallah, 1989), and hybrid dysgenesis or occurrence of inferior recombinants (Evans, 1970; Singh and Gutiérrez, 1984; Kornegay *et al.*, 1992; Welsh, 1993), it is better to test and identify promising early generation populations and families and discard undesirable, low-yielding, and inferior populations as early as possible. Further evaluation and selection of desirable recombinants and fixation of traits should then be concentrated within promising populations and families.

Evaluation of F₂ populations of common bean for yield and phenological traits is compatible with simultaneous screening and selection for resistance to diseases, insects, low soil fertility, and water deficit. All it requires is the production of adequate quantities of F₂ seed and replicated trials under appropriate pressure of biotic and/or abiotic stresses. For each stress factor, a separate trial should be conducted. Selection is mostly practiced among populations. Also, early generation yield testing in replicated trials can easily be adopted for pedigree, single seed descent, and bulk methods of breeding (Singh, 1992). In brief, one pod from each plant of all plots is harvested first, followed by harvest of the central rows for yield measurements. After data analysis, only pods from selected populations are saved. Each pod is threshed

separately to be shown in hill plots in the subsequent generation for pedigree and single seed descent selection methods. On the other hand, all pods from any population are threshed together for the bulk breeding method. For more details on these procedures, readers should refer to Singh (1992).

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RESUMO

Foram avaliados, em duas localidades da Colômbia, 20 parentais representando tipos de feijão "Mesoamerica", "Durango" e "Jalisco" originários da América Central e Nova Granada e Chile dos Andes, 47 F₁ e 47 F₂ em 1990, e 20 parentais, 47 F₂ e 47 F₃ em 1991.

Coefficientes de correlação (exceto entre F₁ e F₃ para duração da formação das sementes) entre meio-parentais, F₁, F₂ e F₃, para todas as características foram positivos (P < 0,05). A herdabilidade foi 0,42 ± 0,07 para produção de sementes, 0,61 ± 0,02 para peso de 100 sementes, 0,49 ± 0,14 para índice da colheita, 0,49 ± 0,09 para matéria seca, 0,47 ± 0,07 para duração da floração, 0,20 ± 0,12 para a duração da formação de sementes e, 0,47 ± 0,05 para dias de maturação. Valores para ganhos previstos (em F₂) e ganho atual (em F₃) para os mesmos tratamentos foram, respectivamente, 21,0% e 14,4%, 34,0% e 39,0%, 4,5% e 7,5%, 9,1% e 11,9%, 12,0% e 8,7%, 8,7% e 2,3% e, 6,1% e 5,1%. Estes resultados confirmam o valor de testar as gerações iniciais e de seleção entre populações de feijão.

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