Effect of Alternative Methods of Advancing Early Generation Populations of Common Bean in the Tropics[1]

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ABSTRACT

Effect of single pod bulk (SPB) and single seed bulk (SSB) methods of advancing early generations (F_2 to F_5) was studied in three populations (TR 4678, TR 4683, and TR 4685) of common bean. Twelve high-yielding F_5-derived F_8 lines from each population and method of generation advance, along with their respective bulks, 20 parents involved in three populations, and two checks were evaluated for three years. Also, single plant harvests were made in the F_2 of TR 4683 and its SPB of the F_3, F_4, and F_5. Fourteen high-yielding F_8 lines derived from each of the four generations, along with the SPB, six parents, and a check cultivar, were tested separately for three years. In both experiments, data were recorded for seed yield (in kg/ha and adjusted to 14% moisture by weight). Considerable increases and decreases in population size in successive generations of inbreeding in the SPB and SSB, respectively, were observed. Mean yields of SPB and lines derived from it were significantly ($P < 0.05$) higher than those of SSB. No significant ($p > 0.05$) differences were found for seed yield among lines derived from the F_2, F_3, F_4 and F_5 of the intraracial population TR 4683, all of whose parents were small-seeded, a characteristic of the race Mesoamerica.

RESUMEN

Se estudió la eficiencia de los métodos masal de una vaina (MUV) y masal de una semilla (MUS) por planta, para adelantar generaciones tempranas (F_2 a F_5) en tres poblaciones, TR 4678, TR 4683 y TR 4685, de frijol común. Las doce líneas F_8 derivadas de F_5, con mayor rendimiento en cada población y método, sus respectivos masales y 20 padres involucrados en los tres cruzamientos se evaluaron durante tres años. Adicionalmente se realizaron selecciones individuales en las generaciones F_2, F_3, F_4 y F_5 de la población TR 4683. Las catorce líneas F_8 con mayor rendimiento de cada una de las cuatro generaciones, junto con el masal de una de sus vainas adelantado sin selección, los seis padres del cruzamiento y un testigo, se valoraron aparte durante tres años. En ambos experimentos, se midió el rendimiento (14% de humedad en kilogramos por hectárea). El tamaño de la población en las sucesivas generaciones de avance se incrementó y disminuyó notablemente en los MUV y MUS, respectivamente. El rendimiento promedio de MUV y de sus líneas derivadas fue significativamente superior ($P < 0.05$) al de MUS y sus líneas. No hubo diferencias significativas ($P > 0.05$) en el rendimiento de las líneas derivadas de F_2, F_3, F_4, y F_5 del cruzamiento intrarracial TR 4683, en el cual todos sus padres son de semilla pequeña, característica de la raza Mesoamérica.

INTRODUCTION

The amount of genetic variance that could be generated by hybridization in populations of an autogamous crop such as common bean (*Phaseolus vulgaris* L.) may depend largely upon genetic distance among parents (i.e., crosses between versus crosses within different races), number of parents involved in each population, type of crosses, number of genes controlling inheritance of a trait, and population size.

Also, evaluation, selection, and fixation of desirable traits within hybrid populations could be carried out simultaneously, as is often the case in the pedigree method beginning from the F_2. On the other hand, character fixation could be sought first, followed by evaluation and selection in advanced generations, as in the bulk and single seed descent methods of breeding. In addition, modifications of these methods are adopted, depending upon the number of populations to be managed, number of traits to be selected, nature of inheritance of characters, facilities available for screening, relative time and costs involved, and collaboration among scientists from different disciplines and institutions.

Intergenotypic competition occurs in genotypic or varietal mixtures of common bean. It is affected by seed size, growth habit, planting density, and interactions with environments (1, 2, 3, 5). Therefore, when bulk breeding, the method of forming a bulk for advancing generations may play an important role in determining the frequency and type of genotypes surviving into the advanced generations. One possible method of forming a bulk could be harvesting the entire plot, and then taking a sample of seed for growing the next generation.

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However, this method is prone to loss of genotypes because of sampling errors. To remedy this situation, breeders, when not interested in natural selection, try to assure a uniform contribution from each plant harvested in the population by taking a sample either by weight, volume, or number of seeds to form the bulk to be used for growing the subsequent generation. The single pod bulk (SPB) and single seed bulk (SSB) methods are used for advancing generations in common bean. Because the relative effect of the two methods on population changes and yield performance of surviving genotypes was not known, this was the objective of our investigation. Also, comparative performance of the F_2-, F_3-, F_4-, and F_5- derived lines was studied in an intraracial population, all of whose parents possessed characteristics of the small-seeded (< 25 g/lOO-seed weight) race Mesoamerica.

MATERIALS AND METHODS

Three populations, TR 4678 = [[(A 156 x BAT 271) x (BAT 85 x A 114)] x (A 322 x XAN 6)] x [(XAN 93 x (NEP Bayo 22 x A 21)], TR 4683 = (BAT 477 x Carioca) x [(A 170 x XAN 93) x (A 25 x BAT 332)], and TR 4685 = [A 445 x (A 249 x BAT 1297)] x [Catu x XAN 112) x (A 25 x Negro Zacatecas)], were utilized in this study. For development of these populations, approximately 30 F_1 plants were used at each step of single, double, three-way, and multiple cross combinations. All parents of TR 4683 possessed characteristics of the small-seeded race Mesoamerica (8). Of nine parents of TR 4678, six resembled Mesoamerica in characteristics, one resembled the race Jalisco, and two resembled the race Durango.

Population TR 4685 contained five parents possessing characteristics of race Mesoamerica and two parents having those of the race Durango. The F_2 seed (approximately 1OOO/population) of each population was sown in plots four rows, 5 m long, with three replications at CIAT-Quilichao, Colombia (very fine, kaolinitic, isohyperthermic Plinthic Kandiudox soil; 990 m elevation, with mean growing temperature of 24°C). The spacing between rows was 60 cm, and 85 seeds were sown in each row. At harvest, two kinds of bulks were made: the SPB, by taking a single pod, and the SSB, by harvesting a single seed from each plant without selection. The respective bulks from each population were kept separate. The SPB and SSB were advanced in F_3 and F_4 by using similar procedures.

The F_5 generation was moved to CIAT-Palmira, Colombia (fine-silty, mixed, isohyperthermic aquic Hapludoll soil; 1000 m elevation, with mean growing temperature of 24°C) because of increasing problems with root rots at CIAT-Quilichao. After forming SPB and SSB to grow the F_6, approximately 200 single plants were taken randomly in each SPB, and all of the SSB were harvested. While on the one hand SPB and SSB were advanced until F_8 as in the previous generations, the single plants harvested in the F^5 were grown in the plant-to- progeny rows in F_6. Each plot consisted of a single row, 3 m long, without replication. Parents were sown every 20th plot.

At maturity, each plot was harvested (leaving 25 cm head borders on either end). Based on seed yield, an average of 50 F_6 lines from each of the SPB and all lines from each of the SSB were saved. In the F_7, the SSB and SPB lines from each population were evaluated in yield trials. Each plot consisted of four rows, 3 m long, with two replications. After harvest and data analysis, the 12 highest-yielding lines were saved from each SSB and SPB for comparative yield trials. Seventy-two selected lines, six bulks, 20 parents, and two check cultivars were evaluated in a 10 x 10 partially balanced lattice design with three replications in 1989, 1990, and 1992 at CIAT-Palmira. Each plot had four rows, 5 m (in 1989) and 7 m (in 1990 and 1991) long. The spacing between rows was 60 cm, and 25 seeds/m were sown. The two central rows, leaving head borders of 50 cm on either end, were harvested for seed yield (in kg/ha and adjusted to 14% moisture by weight).

Additionally, in the SPB of population TR 4683, an average of 200 random single plant harvests were made in each F_2, F_3, F_4, and F_5 for sowing in the plant-to-progeny rows in the next generations. This was followed by seed increase and replicated yield trials in subsequent generations. From the progeny tests to eventual identification of the 14 highest yielding lines derived from each generation, seed yield was used as the principal selection criterion. No selection was made for seed characteristics, maturity, and/or growth habit. Thus, 14 lines derived from each of the F_2, F_3, F_4, and F_5 generations, one SPB, six parents, and one check cultivar were evaluated in an 8 x 8 lattice design with three replications at CIAT-Palmira in 1989, 1990, and 1991 plot size, agronomic management and data recording were similar to those of the previous experiment, which was always grown in an adjacent plot. Data from both experiments were subjected to standard statistical analysis using the GENSTAT statistical package

(Numerical Algorithms Group, Oxford, U.K), whereby populations and lines were considered fixed effects and years random effects.

RESULTS AND DISCUSSION

Differences among parents for days to maturity and seed yield were significant. Line XAN 6 was the earliest to mature (70 days) and lowest-yielding (1313 kg/ha). On the contrary, A 445 was the highest-yielding (2621 kg/ha). Line A 156 had the most days (81) to maturity.

There was an increase in population size in successive generations of SPB (Table 1). Similarly, in each generation of SSB, there was a considerable reduction such that in F_5, 45,48, and 24 plants were left in the populations TR 4678, TR 4683, and TR 4685, respectively. Because five seeds are borne in each pod on the average, theoretically the population size should have increased proportionately in each generation of selfing of SPB. Thus, there also was considerable loss of population. Root rots accentuated by low soil fertility and continuous cropping with common bean at CIAT-Quilichao could be the principal cause for reduction in population size. However, angular leaf spot caused by *Phaeoisariopsis griseola* (Sacc.) Ferr., common bacterial blight caused by *Xanthomonas campestris* pv. *phaseoli* (Smith) Dye, and intergenotypic competition for nutrients, moisture, and sunlight could have played a role among other factors favoring natural selection.

Table 1. Changes in population size of single seed bulk (SSB) and single pod bulk (SPB) methods of advancing segregating generations of common bean grown in Colombia.

Population		Generation					
		F_2	F_3	F_4	F_5	F_6	F_7
TR	4678						
	SSB	848	394	161	45	29	28
	SPB	848	1 576	1 026	2 162	5 232	6 468
TR	4683						
	SSB	952	420	233	48	38	24
	SPB	952	NR	1 905	3 012	5 470	6 292
TR	4685						
	SSB	808	220	86	24	17	13
	SPB	808	986	173*	869	2 587	3 761

* Severe population loss was caused by waterlogging three weeks after sowing
NR = not recorded

Because differences in mean yields among three populations were nonsignificant and yields of bulks and selected lines from their SPB and SSB followed similar trends (data not shown), results were averaged over populations for simplifications (Table 2). Selection for seed yield was effective, based on mean of selected lines and mean of parents in SPB, but not in SSB (Table 2). Because the SSB, as well as lines derived from SSB, yielded relatively lower than the corresponding SPB and its derived lines, a loss of relatively more desirable genotypes in the SSB was suggested. This result was further verified by comparing the performance of the highest-yielding lines derived from SPB and SSB. As there was severe population loss in all generations of SSB advance, it is not clear whether SSB was solely responsible for losses of otherwise high-yielding genotypes, and results may thus be biased in favor of SPB.

Nonetheless, bean breeders in the tropics usually grow populations in the field and do not use glasshouses or take special precautions. Therefore, the use of SSB is not advisable for management of common bean populations for field-grown nurseries in tropical environments where soil-borne diseases and other factors affecting plant stands and productivity cannot be controlled. Instead, breeders using SSB for generation advance should use sterilized soils in a glasshouse and minimize intergenotypic competition in order to avoid stand and productivity loss, and maintain large population size throughout the early segregating generations and progress toward homozygosity.

Cuadro 2. Comparison of 12 high-yielding F_5- derived F_8 lines from single pod bulk (SPB) and single seed bulk (SSB) pooled over three populations of common bean evaluated at CIAT-Palmira, Colombia, in 1989, 1990, and 1991.

	Seed yield (kg/ha)		
Origen	Minimum	Maximum	Mean
Selected lines from SPB	1 833	2 625	2 225
Selected lines from SSB	1 727	2 452	2 140
Unselected SPB	2 062	2 318	2 162
Unselected SSB	2 016	2 070	2 039
Parents	1 313	2 621	2 092
LSD (0.05)			
Selected lines SPB vs SSB	355	355	41
Selected lines SPB or SSB *vs* unselected bulks			105
Selected lines SPB or SSB *vs*. parents			49

All parents involved in population TR 4683 possessed characteristics of the small-seeded race Mesoamerica. Most members of the race Mesoamerica are known to possess zero or negative general combining ability (GCA) for seed yield (4). This suggested that very little or no useful additive genetic variance could be generated by hybridization among parents within this group of germplasm. Unfortunately, the information on GCA of parents was not known when populations for this study were developed. Nonetheless, it should be no surprise therefore to observe nonsignificant (P > 0.05) differences among lines derived from different generations of TR 4683 (Table 3).

Table 3. Mean seed yield of 14 high-yielding lines derived from each of the F_2, F_3, F_4 and F_5 of intraracial population TR 4683* of common bean grown at CIAT-Palmira, Colombia, in 1989, 1990 and 1991.

	Seed yield (kg/ha)		
Generation	Minimum	Maximum	Mean
F_2	1 801	2 288	2 059
F_3	1 579	2 241	2 009
F_4	1 811	2 361	2 067
F_5	1 868	2 423	2 085
Unselected bulk			2 980
Parents	1 890	2 263	2 025
LSD (0 05)		364	97

* All parents of population TR 4683 possessed characteristics of the race Mesoamerica.

The principal cause could be inadequate genetic variation in the base population, due in turn to the common origin of the parents. Similar conclusions were arrived at for other intraracial populations of common bean selected under different soil fertility levels (6), different plant populations (7), and different levels of disease pressure (9). Thus, in order to determine the most appropriate generation for effecting single plant selection in common bean populations, the selection experiment needs to be repeated in interracial populations involving genetically diverse, complementary, and high-yielding parents possessing positive GCA for seed yield.

CONCLUSION

There was marked reduction in plant population from F_2 to F_5 in SSB. On the other hand, population size increased in successive generations of inbreeding in the SPB. The mean yield was higher, and higher yielding lines were derived from SPB compared with SBB.

There were no significant differences for yield among lines derived from different generations of a small-seeded population (TR 4683) developed by hybridization within the race Mesoamerica. Also, none of the selected lines from this population outyielded its best parent.

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CSSA (CROP SCIENCE SOCIETY OF AMERICA). 1992. Use of plant introductions in cultivar development. II. Special Publication no. 20. 166 p.

Este libro es una compilación de los trabajos presentados en la reunión de la CSSA en Texas (1990), sobre el uso de la introducción de plantas en el desarrollo de cultivares en el caso del frijol, leguminosas de clima frío, cultivos nuevos, maní, remolacha azucarera, caña de azúcar y girasol.

Cada capítulo se inicia con un resumen sobre el origen, introducción y estado actual de un cultivo determinado en los Estados Unidos de América. A continuación se hace referencia a sus aspectos genéticos, incluyendo la lista de material disponible, los métodos genéticos de trabajo de mejoramiento empleados y, en algunos casos, las posibilidades futuras de hibridización, entre otros.

Se consideran como leguminosas de clima frío, pero de origen mediterráneo, la arveja (*Pisum sativum* L.), lenteja (*Lens culinaris* Medik), garbanzo (*Cicer arietinum* L.), haba (*Vicia faba* L.) y *jaramago* (*Lathyrus sativus* L.). Como nuevos cultivos industriales se consideran el guayule (*Parthenium argentatum* Gray), kenaf (*Hibiscus cannabinus* L.), rosela (*H. sabdariffa* L.), guar o frijol de racimo (*Cyamopsis tetragonolobus* (L.) Taubert), grindelia (*Grindelia camporum* Greene), jojoba (*Simmondsia chinensis* (Link) C. Schneider), *merdowfoam* o espuma del prado (*Limnanthes alba* Hartweg o Benth.), crambe (*Crambe abysinica* Hochat. ex R.E. Fries), nabo (*Brassica napus* L. y *B. rapa* L.), calabaza de búfalo o de coyote (*Cucurbita foetidissima* HBK), cufea (*Cuphea* spp.), vernonia (*Vernonia galamensis* (Cass.) Less.) y stokes aster (*Stokesia laevis* (Hill) E. Gueve). Del segundo grupo se espera obtener productos para producir hule, aceites con ácidos grasos específicos, lubricantes, carburantes, alcoholes, ceras, gomas, plásticos, pinturas, adhesivos, recubridores, fibras, tintas, aceites esenciales, saborizantes, perfumes, cosméticos, materiales biológicamente activos y fármacos.

En la mayoría, el mejoramiento genético de esos cultivos se orienta a la obtención de cultivares de mayores rendimiento y concentración del componente deseado y mayor resistencia a las enfermedades. Ocasionalmente se menciona el mejoramiento para lograr características de manejo deseables (p.e. porte erecto para facilidad de cosecha) o tolerancia a tipos de estrés (p.e. resistencia a la sequía).

La obra es recomendable para técnicos que laboran en los cultivos ya mencionados, y para quienes deseen conocer las posibilidades de inversión en nuevos cultivos.

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