Perfomance of F_3 Common Bean Populations Under Rain Fed Conditions in Zimbabwe

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Abstract
Common bean (Phaseolus vulgaris L.) is an important source of protein for cereal-based diets of Sub-Saharan Africa. Genetic diversity of common bean is organised into Andean and Mesoamerican. In Zimbabwe the most cultivated are the large seeded of Andean origin. Drought stress has been found to be a major constraint to production of Andean cultivars, causing a yield loss of up to 60%. Mesoamerican cultivars exhibit a wide genetic base and are tolerant to drought. Introgression of alleles from across gene pools would broaden the genetic base of cultivars, maximising gains from selection. A field experiment was carried out at Harare Research Station to evaluate performance and combining abilities of 25 F_3 Andean X Mesoamerican populations bred for drought tolerance. The experimental design was a 5 x 5 triple lattice and each plot consisted of four rows, 3 m long and 0.5 m apart. Combining ability estimates were calculated based on Beil and Atkins (1967). There were no significant differences (p>0.05) in agronomic performance of the 25 F_3 Andean X Mesoamerican populations under rain fed conditions. Average 100 seed weight for the populations was 30g with most combinations ranging between 25-33g,which falls within the medium seeded range. Parents PAN 127, PAN 148, SUG 131, SER 8, SER 22 and SEQ 11 were found to have good combining ability. Parents SEQ 11, SER 22 and PAN 127 can be used in breeding for drought tolerance in areas of intermittent and terminal drought because their progeny were early maturing. Hybrids SER22 X CAL143 and SER8 X SUG131 were the best combiners for pod and seed yield. There is also high potential to obtain superior genotypes in crosses SEQ11 X PAN 148, SER16 X SUG131, SEC16 X SUG131, SEC16 X PAN148, SER22 X PAN127, SEQ11 X CAL143 and SER16 X SUG131.

Key words: *Common bean, Andean and Mesoamerican, rainfed, introgression, combining ability.*

Introduction

Common bean (*Phaseolus vulgaris*.L) is an important annual herbaceous plant in the leguminosae family (Wortmann et al., 1998). It is grown as a food and cash crop in Zimbabwe and other parts of Eastern and Southern Africa where it is popular among smallholder farmers (Madamba et al., 2003). While common bean is thermophile, it is grown from tropical to temperate zones. Common bean provides a cheap source of protein to low-income families who cannot afford animal protein. It contains an average of 22% crude protein, 4% fibre, 1.6% fat, 58% carbohydrates and 11% water vital for human growth (Madamba et al., 2003). Common bean is also one of the best non-meat sources of iron, providing 23-30% of daily recommended levels from a single serving (Schrwart et al., 1961). Common bean also associate with *Rhizobium* and fixes atmospheric nitrogen in the soil (Key, 1979). This improves the soil nitrogen level benefiting the presiding crop. If Common bean residues are left on the field they improve the soil structure (Barret, 1990).

Despite its importance in nutrition and income generation, common bean is exposed to a large array of yield constraints during its ontology. In Zimbabwe, yields have been as low as 0.5t/ ha compared to potential yield of 3t/ ha (Madamba et al., 2003), this is attributed to biotic and abiotic constraints. Drought in particular, reduces grain yield by 392 000 tonnes each year in Africa contributing to a large gap between actual and potential yields (Wortmann et al., 1998). In the small scale farming communities more than 60% of bean production is rainfed making drought stress the second largest contributor after disease to yield reduction (Amede et al., 2004). In Zimbabwe, the expansion of the area under common bean into semi-arid areas has suppressed average national production yield, which remains at 0.5t/ha because of inadequate water supply. Although effects of drought can be reduced by supplementary irrigation and good agronomic practices (mulching, tied ridging) very few smallholder farmers have access to irrigation water and equipment.

The genetic diversity of cultivated common bean is organized into distinct gene pools, 'Andean' and 'Middle American'/ 'Mesoamerican' (Gepts et al., 1986). Most farmers in Zimbabwe prefer cultivating large seeded bean varieties of Andean origin because of their large market price. Some local varieties of Andean origin include PAN 148, NATAL SUGAR, CAL 143, SUG131, PAN 127 and red types (Madamba et al., 2003). These varieties reflect few loci that govern physiological adaptation, thus they are susceptible to drought and biotic stresses that significantly reduce their yield by 60% (Wortmann et al., 1998). Conversely, small seeded cultivars of Middle American gene pool fetch a low market price in Zimbabwe. However, these small seeded types exhibit a wide genetic base and are tolerant to drought and biotic constraints (White and Gonzalez, 1990).

Genetic improvement of drought tolerance is more rewarding (Saxena, 2001). The seed based technology seems to be easier to transfer to farmers than more complex knowledge based agronomic practices such as improved weed control and mulching at soil surface. The development of bean genotypes that are more resistant to water stress is a more practical and economical approach to lessen the negative effects of drought on the productivity of bean crops (Ramirez-Vallejo and Kelly, 1998). Singh (2001) reported an increase in yield under drought through hybridisation between races and gene pools, involving high yielding and water stress tolerant progenitors derived from different origins. Moderate to high levels of drought resistance are found in beans (Amede et al., 2004) and cultivars from Durango race posses the highest levels of drought resistance. Introgression and pyramiding of useful alleles from within and across cultivated races and gene pools, wild populations of common bean, and its secondary and tertiary gene pools would broaden the genetic base of cultivars, maximising gains from selection, and increase the durability of resistance to biotic and abiotic constraints.

The only cheap and viable option for small-scale farmers of Zimbabwe is the genetic improvement of commercially grown cultivars. This can be done by crossing cultivars from the two gene pools, carrying out yield tests of segregating populations to help obtain necessary information to enhance the screening for drought tolerance in common bean (Amede et al., 2004). It is also important to estimate combining ability effects in connection with testing procedures so as to predict the potential of lines in hybrid combination. The objective of this study was to assess the agronomic performance and estimate general and specific combining ability of F_3 common bean populations derived from Andean X Mesoamerican gene pools under -rain fed conditions in Zimbabwe.

Materials and Methods

Study Site

The study was conducted at Harare Research Station, which is located in agro ecological region IIa of Zimbabwe at an altitude of 1506 masl (Vincent and Thomas, 1961). The soils (Salisbury 5E.2 series) are classified as Fersiallitic soils derived from epidiorite and greenstone schist. These soils are deep and well drained with an average pH of 5.8 (Nyamapfene, 1991). The area receives an average annual rainfall of 700 to 1000 mm, which occurs during a single rainy season extending from Mid-November to April and mean temperatures of 21-27 ^{0}C (Vincent and Thomas, 1961).

Genotypes

Twenty five F_3 segregating populations derived from parents of the Mesoamerican and Andean origin generated using North Carolina design II were used in the experiment. The Mesoamerican male parents are well known for their drought tolerance and the Andean female parents are large seeded. Table 3.1 shows the populations that were used in the study.

Table1: Populations used in the experiment

SER8 X CAL 143	SER16 X CAL 143	SER22 X CAL 143	SEC16 X CAL 143	SEQ11 X CAL 143
SER8 X SUG 131	SER16 X SUG 131	SER22 X SUG 131	SEC16 X SUG 131	SEQ11 X SUG 131
SER8 X NATAL SUGAR	SER16 X NATAL SUGAR	SER22 X NATAL SUGAR	SEC16 X NATAL SUGAR	SEQ11 X NATAL SUGAR
SER8 X PAN 127	SER16 X PAN 127	SER22 X PAN 127	SEC16 X PAN 127	SEQ11 X PAN 127
SER8 X PAN 148	SER16 X PAN 148	SER22 X PAN 148	SEC16 X PAN 148	SEQ11 X PAN 148

Experimental Design trial establishment and measurements

The experimental design used was a 5 x 5 triple lattice. The trial had 15 incomplete blocks, each incomplete block consisting of 5 plots. Treatments were replicated three times. Randomization of blocks was done separately and independently within each replication and treatments were randomized separately and independently within each block. Land was ploughed using a tractor drawn plough, and disced using a disc harrow to obtain a fine tilth. Plots were marked using hoes and pre-marked wire cable and each plot consisted of four rows, 3 m long and 0.5 m apart. A one meter pathway was left between plots across rows. Forty seeds were planted, two seeds per station at a depth of 4 - 5 cm within each row length, at an intra-row spacing of 0.1 m. Weeds were controlled manually using hoes when necessary. Compound D (7: 14: 7) was applied at a rate of 300 kg/ha to the planting rows and slightly covered with soil prior to sowing. Thirty days after planting, ammonium nitrate was applied as top dressing at a rate of 80 kg/ha. Sprinkler irrigation was used to irrigate the field only after planting to encourage germination and plants were left to depend on natural precipitation for the rest of the growing season. Data collected included grain yield, days to 50 % flowering as number of days when 50 % of the plants in each plot had one or more first flowers. Days to 95% maturity as number of days from date of planting to date when 50% of plants in each plot attained physiological maturity at this stage pods would be dry and brown. Number of pods per plant, pod yield and 100 seed weight were also measured. Rainfall records were also taken for the growing period.

Statistical and Genetic analysis

Variables recorded were analysed using IRRISTAT version 4.4 statistical package. Separation of means was done using the Least Significant Difference (LSD) test at 5%. Mention of statistical significance refers to P<0.05 unless otherwise stated. Combining ability estimates were calculated using formulas based on Beil and Atkins (1967):

General Combining Ability

1. gi = wi-w 2. gj = wj-w

where, gi is the female combining ability
gj is the male combining ability
wi is the mean of female line
w is the grand meam
wj is the mean of male line

Specific combining ability

1. gij = wij- w)

where, gij is the specific combining ability
yij is the mean yield for interaction

Percentage contribution of male and female lines and their interaction towards the different traits was calculated basing on combining ability Mean Squares (MS) as follows:

1. % Contribution of male line

$$= \frac{\text{MS of male line}}{\text{Total MS (MS male + MS female + MS interaction)}} \times 100$$

2. % Contribution of female line

$$= \frac{\text{MS female line x 100}}{\text{Total MS}}$$

3. % Contribution of male X female

$$= \frac{\text{MS interaction}}{\text{Total MS}} \times 100$$

4. % Overall contribution of male and female (GCA) = %Male contribution + %Female contribution

Results

Agronomic performance of F_3 common bean populations derived from Andean X Mesoamerican gene pools under rain fed conditions in Zimbabwe

The populations evaluated did not vary significantly (*P<0.05*) for their growth parameters, yield and its components. Although there were no significant differences, the progenies, SER 8 X SUG 131 and SEQ11 X SUG131 gave high seed yield of 1.7 t/ha and 1.6 t/ha respectively compared to other populations (Table 2). Two progenies, SER 8 X SUG 131 and SER 22 X PAN 127 flowered earlier (Table 2). Three progenies, SER 8 X SUG 131, SER 22 X NATAL SUGAR and SEQ11 X CAL 143 matured earlier in about 80 days, 79 days and 76 days respectively.

Combining ability mean squares

The Specific combining ability (male x female) was significant ($p<0.05$) for 50% flowering (Figure 1). However, GCA of both female and male lines were not significant for all traits.

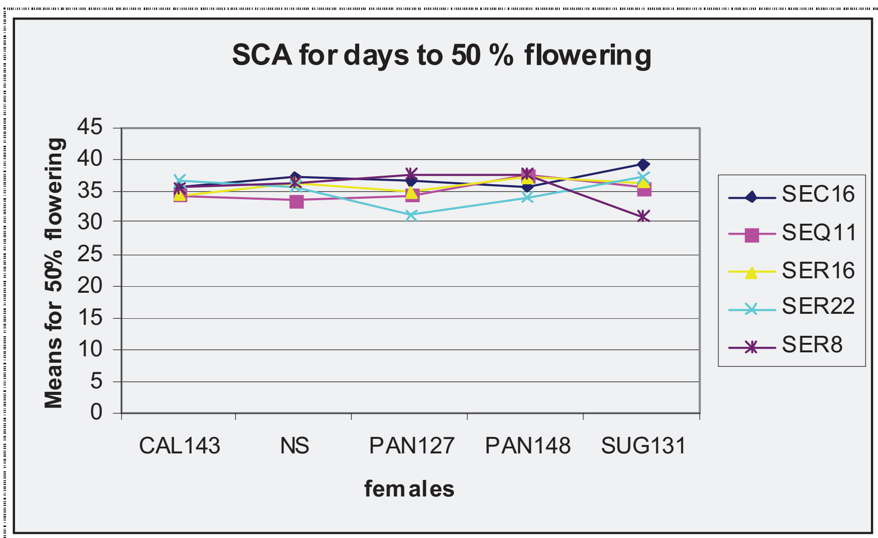

Figure 1: Male x Female (SCA) for days to 50 % flowering

The progeny of SER22 X PAN127 and SER8 X SUG131 flowered early within 31days. SEQ11 X NATAL SUGAR flowered in 33 days. SEQ11 X CAL143, SEQ11 X PAN127, SER16 X PAN127, SEC16 X CAL143, SEC16 X PAN148, SEQ11 X SUG131, SER16 X SUG 131, SER22 X SUG131 and SER22 X CAL143 flowered significantly the same time. SEC 16 X SUG131 took the longest days to reach 50% flowering, which was 39 days.

Contribution of male, female lines (gca) and male x female (sca) to total entry variability

Mesoamerican male lines contributed a greater percentage to the total entry variation of seed yield, days to 50% flowering, 95% physiological maturity number of pods per plant and pod yield. The male GCA contributed 44.7% to the number of pods per plant, 18.1% to seed yield, 20% to pod yield, and 32.8% to 50% flowering and 56.2 to 95% maturity (Table 3). Andean female lines gave a higher percentage contribution of 42.8% to 100 seed weight, 37.3% to seed yield, 36% to pod yield, (Table 2). The interaction of Male and female lines (SCA) gave a greater contribution of 51% to number of days to 50% flowering.

Table 2 Contribution of Mesoamerican males, Andean females and male x female to six different traits

Source	Traits					
	Pods per plant	100 seed weight	Seed yield	Pod yield	50% flowering	95% maturity
Female GCA (%)	13.6288	42.7795	37.2925	36.0000	16.2055	11.3479
Male GCA (%)	44.6767	30.3124	18.0498	20.0000	32.8063	56.1476
GCA Effects (%)	29.1528	36.5460	27.6712	28.0000	24.5059	33.7478
SCA Effects (%)	41.6950	26.9082	44.6577	43.3500	50.9881	32.5044

SCA effects (male x female) contributed higher than overall GCA effects for number of pods per plant, seed yield, pod yield and 50 % flowering. There were high additive genetic variance effects for 100 seed weight and days to 95 % maturity as a result of the high overall GCA effects than the SCA effects (Table 2).

Identification of parents with desirable GCA on individual traits

Seed Yield

The parents PAN 127, PAN 148, SUG 131, SER 22, SER 8 and SER 16 gave positive GCA values significantly different from zero with respect to seed yield (Table 3).

Table 3 General Combining abilities for seed yield of males and females

		Seed yield t/ha		
Parent		Parent mean	Grand mean	GCA
CAL 143	F	1.237	1.315	-0.078
NATAL SUGAR	F	1.193	1.315	-0.122
PAN 127	F	1.332	1.315	0.017*
PAN 148	F	1.414	1.315	0.099*
SUG 131	F	1.400	1.315	0.085*
SEC 16	M	1.236	1.315	-0.079
SEQ 11	M	1.258	1.315	-0.057
SER 22	M	1.321	1.315	0.006*
SER 8	M	1.391	1.315	0.076*
SER 16	M	1.371	1.315	0.056*

F *Female*
M *Male*

Pod Yield

Parents that were found to have positive GCA values for pod yield per hectare were PAN 127, PAN 148, SUG 131, SER 22 and SER 8 (Table 4)

Table 4 Combining abilities for pod yield of males and females

		Pod yield t/ha		
Parent		Parent mean	Grand mean	GCA
CAL 143	F	1.806	1.920	-0.114
NATAL		1.734	1.920	-0.186
SUGAR	F			
PAN 127	F	1.980	1.920	0.06*
PAN 148	F	2.052	1.920	0.132*
SUG 131	F	2.030	1.920	0.11*
SEC 16	M	1.813	1.920	-0.107
SEQ 11	M	1.839	1.920	-0.081
SER 22	M	2.079	1.920	0.159*
SER 8	M	1.968	1.920	0.0048*
SER 16	M	1.903	1.920	-0.017

F Female

M Male

100 Seed weight

NATAL SUGAR, PAN 127, SUG 131, SEC 16, SEQ 11, SER16 and SER 8 had a positive GCA for 100-seed weight (Table 5). NATAL SUGAR, PAN 127 and SUG 131 are large seeded and preferred market class in Zimbabwe.

Table 5 General Combining abilities for 100-seed weight of males and females

		100 Seed weight		
Parent		Parent mean	Grand mean	GCA
CAL 143	F	28.00	29.51	-1.51
NATAL		29.80	29.51	0.29*
SUGAR	F			
PAN 127	F	30.00	29.51	0.49*
PAN 148	F	29.40	29.51	-0.11
SUG 131	F	30.33	29.51	0.82*
SEC 16	M	29.60	29.51	0.09*
SEQ 11	M	29.80	29.51	0.29*
SER16	M	30.20	29.51	0.69*
SER 22	M	28.20	29.51	-1.31
SER 8	M	29.73	29.51	0.22*

F Females

M Males

Number of Pods per Plant

The parents PAN 127, PAN 148, SUG 131, SEC 16, SER 16 and SER 8 had positive

GCA values for number of pods per plant (Table 6).

Table 6 General Combining abilities for Pods per plant of males and females

		Number of Pods per Plant		
Parent		Parent mean	Grand mean	GCA
CAL 143	F	3.734	3.813	-0.079
NATAL SUGAR	F	3.785	3.813	-0.028
PAN 127	F	3.887	3.813	0.074*
PAN 148	F	3.837	3.813	0.024*
SUG 131	F	3.821	3.813	0.08*
SEC 16	M	3.934	3.813	0.121*
SEQ 11	M	3.766	3.813	-0.047
SER 16	M	3.871	3.813	0.058*
SER 22	M	3.664	3.813	-0.149
SER 8	M	3.829	3.813	0.016*

F Female
M Male

Days to 50 % Flowering

Parents that had desirable GCA for days to 50 % flowering were SEQ 11, SER 22, CAL 143 and PAN 127 (Table 7). These parents had significantly negative GCA values hence they are early flowering.

Table 7 General Combining abilities for 50 % Flowering of males and females

		50 % Flowering		
Parent		Parent mean	Grand mean	GCA
SEC 16	M	36.73	35.60	1.13
SEQ 11	M	34.93	35.60	-0.67*
SER 16	M	35.80	35.60	0.2
SER 22	M	34.93	35.60	-0.67*
SER 8	M	35.60	35.60	0.00
CAL 143	F	35.20	35.60	-0.4*
NATAL SUGAR	F	35.73	35.60	0.13
PAN 127	F	35.00	35.60	-0.6*
PAN 148	F	36.33	35.60	0.73
SUG 131	F	35.73	35.60	0.13

F Female
M Male

Days to 95 % Maturity

Parents with desirable days to maturity were SEQ 11, SER 22, SER 8, CAL 143, and NATAL SUGAR (Table 8). The parents had negative GCA suggesting they mature early.

Table 8 General Combining abilities for days to 95 % Maturity of males and Females

		95% Maturity		
Parent		Parent mean	Grand mean	GCA
SEC 16	M	85.73	84.68	1.05
SEQ 11	M	83.60	84.68	-1.08*
SER 16	M	86.47	84.68	1.79
SER 22	M	83.27	84.68	-1.41*
SER 8	M	84.33	84.68	-0.35*
CAL 143	M	83.73	84.68	-0.95*
NATAL		84.67	84.68	-0.01*
SUGAR	F			
PAN 127	F	84.80	84.68	0.12
PAN 148	F	84.73	84.68	0.05
SUG 131	F	85. 47	84.68	0.79

F *Female*
M *Male*

Identification of combinations with desirable SCA on individual traits

SER22 X CAL143 and SER8 X SUG131 were the best combiners for pod yield and seed yield. SEQ11 X PAN 148 and SER16 X SUG131 gave high SCA values significantly above zero for weight of 100 seeds. SEC16 X SUG131 and SEC16 X PAN148 were the best combiners for number of pods per plant, giving high positive SCA values of 0.30 and 0.34 respectively. SER8 X SUG131 and SER22 X PAN127 were the favourable combiners for days to 50% flowering because they gave high negative SCA values hence they are early flowering. The earliest maturing combinations were SEQ11 X CAL143 and SER16 X SUG131 they gave the highest negative SCA values for days to 95 % maturity (Table 9).

Table 9 Mesoamerican x Andean Specific combining abilities for six traits

Combination	Pod yield	Seed Yield	100 Seed weight	Pods/plant	50% flowering	95% maturity
SEC16X CAL143	-0.13	-0.17	-0.18	0.05	-0.27	1.99
SEC16X NS	0.06	0.07	-1.51	-0.04	1.4	-0.01
SEC16X PAN127	-0.09	0.05	0.16	-0.04	1.07	2.65
SEC16X PAN148	0.21	0.19	0.49	0.30*	0.07	-2.01
SEC16X SUG131	-0.59	-0.44	1.49*	0.34*	3.40	2.65
SEQ11X CAL143	-0.39	-0.22	-4.18	-0.21	-1.27	-5.68*
SEQ11X NS	-0.26	-0.19	1.82	-0.03	-2.27	1.65
SEQ11X PAN127	0.04	0.03	0.82	0.27	-1.27	-2.01
SEQ11X PAN148	-0.30	-0.22	2.82*	-0.08	1.73	-0.35
SEQ11X SUG131	0.51	0.31	0.16	-0.18	-0.27	0.99
SER16X CAL143	-0.22	-0.16	0.49	0.18	-1.27	-1.01
SER16X NS	-0.62	-0.37	0.49	-0.13	0.73	1.32
SER16X PAN127	0.17	0.11	0.49	-0.03	-0.60	1.99
SER16X PAN148	0.37	0.28	-151	-0.07	1.40	1.99
SER16X SUG131	0.22	0.20	3.49	0.35	0.73	4.65
SER22X CAL143	0.57*	0.34*	-1.84	-0.60	1.07	-1.68
SER22X NS	0.07	0.06	-0.84	0.003	0.07	-3.01
SER22X PAN127	0.002	-0.14	0.16	0.05	-4.27*	-2.68
SER22X PAN148	0.27	0.17	-2.84	0.02	-1.60	0.65
SER22X SUG131	-0.11	-0.05	-1.18	-0.21	1.40	-0.35
SER8X CAL143	-0.40	-0.19	-1.84	0.20	-0.27	1.65
SER8X NS	-0.18	-0.18	1.49	0.05	0.73	-0.01
SER8X PAN127	0.18	0.14	0.82	0.13	2.07	0.65
SER8X PAN148	0.11	0.11	0.49	-0.04	2.07	-0.01
SER8X SUG131	0.53*	0.41*	0.16	-0.26	-4.60*	-4.01*

Discussion

Agronomic Performance of 25 F_3 Meso-Andean common bean populations

The populations did not vary significantly (P>0.05) for their growth parameters and yield and its components. This could have been attributed to the fact that the male parents used in the hybrid combinations have the same pedigree, particularly SER lines are sister lines (Hallauer and Miranda, 1988).

Despite having performed significantly the same, some hybrid combinations were identified to have the potential of maturing early, these were SER 22 X NATAL SUGAR and SER8 X SUG131, which matured in 80 days. This might have been attributed to the parents SER8, SER22 and NATAL SUGAR, which exhibit earliness and were used to generate the progenies. According to Madamba et al. (2003) common bean takes an average of 90 days to reach physiological maturity hence the progenies have the potential to escape terminal drought.

The range of seed yield of hybrid combinations tested in the experiment was between 0.9 - 1.7 t/ha. Commercial farmers achieve average yields of 1.5 – 4 t/ha (Hikwa and Jiri, 2002), thus seed yield of the combinations was low. According to Jonhson and Gepts (2002) Andean and Mesoamerican were domesticated in different regions and developed specific complex and epistatic interactions thus seed yield will generally be low. Another contributing factor to the low average seed yield could have been the low average rainfall received during the growing period. Common bean require about 300-600 mm of evenly distributed rainfall (Hikwa and Jiri, 2002) and a total of 175.5 mm was received during the growth season. In drought prone areas, most smallholder farmers obtain an average of 0.2t/ha (Madamba et al., 2003) and hence a yield of 0.9t-1.7t indicates a considerable degree of tolerance. Hybrid combinations, SER8 X SUG131 and SEQ11 X SUG131 gave considerably good seed yield of 1.7 t and 1.6 t respectively.

The average 100 seed weight for the populations was 30g/100 seeds, with most combinations ranging between 25-33 g, which falls within the medium seeded range. In Zimbabwe, the large seeded of weight greater than 40g per100 seeds is the preferred market class (Wortmann et al., 1998). Thus the 100 seed weight of all combinations did not qualify for the large seeded. This could have been attributed to the fact that there was poor grain filling as the crop was stressed due to poor rains received.

The number of pods per plant of the combinations were very low (average of four per plant). This could have been due flower abortions as a result of erratic rains.

Combining Ability Effects of the F_3 Meso-Andean common bean populations

Based on combining ability estimates, there were significant genetic variations ($P<0.05$) in the performance of combinations (male x female) (SCA) with respect to days to 50% flowering. This implies contribution of non-additive gene effects to the phenotypic variation among the populations in the experiment. SER22 X PAN127 and SER8 X SUG131 had the earliest days to 50% flowering thus they are early maturing.

Contribution of female (GCA), male (GCA) and male X female (SCA) to total entry variability

Mesoamerican male lines contributed a greater percentage to the total entry variation of seed yield, days to 50% flowering, 95% physiological maturity number of pods per plant and pod yield. Thus paternal effects contribute more to the inheritance of these traits. This is because small seeded Mesoamerican lines are high yielding, early maturing and display a wide genetic base for adaptation to abiotic and biotic constraints (White et al., 1992). Andean female lines gave a higher contribution to 100 seed weight. This is due to the Andeans being large seeded having a weight greater than 40g/100 seeds (Wortmann et al., 1998).

The interaction between male x female (SCA) gave higher contribution than overall GCA effects for number of pods per plant, seed yield, pod yield and 50% flowering. This is an indication of high non-additive gene action and can be explained by the fact that common bean are self pollinating in nature and thus self pollinators are considered to exhibit non-additive gene action (Hallauer and

Miranda, 1988). Overall GCA effects (males and female) contributed more than the SCA effects (male x female) for 100 seed weight and days to 95% maturity thus indicating more strength in the parents than the crosses and high genetic variance for additive effects. . Traits affected by additive genes are moderately to highly heritable and will be affected very little by out crossing and inbreeding. Improvement in phenotype can be made fairly rapidly if additive gene action is involved (Fehr, 1993).

Identification of parents and Combinations with desirable GCA and SCA on individual traits

The parents PAN 127, PAN 148, SUG 131, SER 22, SER 8 and SER 16 have favourable seed yield because the gave positive GCA values significantly different from zero with respect to seed yield. Parents SER8 and SUG131 gave the best hybrid combination (SER8 X SUG131) for seed yield which yielded 1.7t/ha. The superiority of the parents could be attributed to heterotic advantage as result of the diverse genetic base of the parents (Fehr, 1993). The female parents PAN148, SUG131 and PAN127 are high yielding commercial varieties widely recognised in Zimbabwe and fetch high market price (Madamba *et al*., 2003). The male parents are high yielding well adapted small seeded varieties which are tolerant to abiotic and biotic stresses.

Positive GCA values on pod yield per hectare presented by PAN 127, PAN 148, SUG 131, SER 22 and SER 8 indicate that they are ideal for generation of populations with high pod yield which leads to high final yield.

NATAL SUGAR, PAN 127, SUG 131, SEC 16, SEQ 11, SER16 and SER 8 had a positive GCA for 100-seed weight. NATAL SUGAR, PAN 127 and SUG 131 are large seeded and preferred market class in Zimbabwe (Wortmann *et al*., 1998). Thus the parents are ideal for generation of large seeded (>40g/100seed weight) populations.

The parents PAN 127, PAN 148, SUG 131, SEC 16, SER 16 and SER 8 had favourable GCA values for number of pods per plant. This maybe attributed to the presence of genes governing pod formation capacity.

SEQ 11, SER 22, CAL 143 and PAN 127 had negative GCA values for days to 50% flowering suggesting that they are early flowering. SER22, PAN127 and SEQ11 had the highest negative GCA values and their hybrid combinations, SER22 X PAN127 and SEQ11 X SUG131 also gave negative SCA values for days to 50% flowering hence thus indicating the passing of early flowering genes from the parents. These three cultivars, PAN127, SER22 and SEQ11 can effectively be used as parents when the objective of the breeding program is to achieve early maturing genotypes. Early flowering genotypes avoid mid- season and terminal droughts since, the most sensitive phenological growth stage is matched to the peak soil water availability and drought escape could be one of the most reliable strategies of drought tolerance for specific environments.

Parents with desirable days to maturity were SEQ 11, SER 22, SER 8, CAL 143, and NATAL SUGAR. The parents had negative GCA suggesting they mature early. The parents SEQ11 and CAL143 gave the earliest maturing progeny SEQ11 X CAL143 which had the highest negative SCA value for days to 95% maturity and thus is able to escape terminal drought and can be a beneficial source of food especially after drought seasons compared to maize, soybean and groundnuts which require more than 120 days.

Out of the F_3 populations derived from parents with positive g_i values, SER22 X CAL143 and SER8 X SUG131 also had positive SCA values for pod yield and seed yield. The general combining ability of CAL143 was negative for both traits thus there is a possibility of pod and grain yield variability liberation in these populations, which can be exploited for selection of superior lines. SEQ11 X PAN 148 and SER16 X SUG131 gave high SCA values significantly above zero for weight of 100 seeds and this is true for the parents SEQ11, SER16 and SUG131 which gave positive GCA for weight of seeds. SEC16 X SUG131 and SEC16 X PAN148 were the best combiners for number of pods per plant, giving high positive SCA values of 0.30 and 0.34 respectively. SER8 X SUG131 and SER22 X PAN127 were the favourable combiners for days to 50% flowering because they gave high negative SCA values hence they are early flowering. The earliest maturing combinations were SEQ11 X CAL143 and SER16 X SUG131, which gave the highest negative SCA values for days to 95% maturity

SEQ11, SER22, SER8, CAL143 and NATAL SUGAR gave negative GCA for days to 95% maturity thus indicating that they are good for generating populations which mature earlier and are able to escape terminal drought and can be a beneficial source of food especially after drought seasons compared to maize, soyabean and groundnuts which require more than 120days. Thus the populations SEQ11 X CAL143 and SER8 X SUG131 also exhibited negative SCA values for maturity and are the promising ones for line selection. SEQ11, SER22, CAL143 and PAN127 gave negative GCA values for days to 50% flowering and the hybrids SER8 X SUG131 and SER22 X PAN127 exhibited negative SCA values suggesting that they are early flowering. Early flowering genotypes avoid mid- season and terminal droughts since, the most sensitive phenological growth stage is matched to the peak soil water availability (Ramirez-Vallejo and Kelly, 1998) and drought escape could be one of the most reliable strategies of drought tolerance in environments characterised by terminal drought.

Conclusion and Recomendations

Conclusion

1. The study showed that there were no significant differences (P>0.05) in the agronomic performance of the 25 Mesoamerican x Andean F_3 populations evaluated.
2. Specific combining ability effects (SCA) were significant (p<0.05) for days to 50 % flowering this showed that it is controlled mostly by additive gene action.
3. The parents PAN127, PAN148, SUG131, SER8, SER22 and SEQ11 had desirable GCA values for yield and its components and growth parameters. Parents SEQ 11, SER 22 and PAN 127 produced progeny that matured early
4. Based on Specific combining ability SCA, the populations SER22 X CAL143, SER8 X SUG131, SEQ11 X PAN148, SER16 X SUG131, SEC 16 X SUG 131, SEC 16 X PAN 148, SER22 X PAN 127, SEQ 11 X CAL 143 and SER16 X SUG131 have high potential to obtain superior lines in advanced generations. SER22 X CAL143 and

SER8 X SUG131 were best combiners for pod yield and seed yield

5. The average 100 seed weight for the populations was 30g, with most combinations ranging between 25-33g, which falls within the medium seeded range.
6. The Andean and Mesoamerican cultivars have good combine abilities for most growth parameters, yield and its components.

Recommendations

1. The populations should be tested across many sites before use in production programmes. The low erratic rains received in the experimental area may not be representative of those occurring in major drought endemic regions of Zimbabwe. Increasing the number of environments decreases contribution of both pooled error and the genotype X environmental interaction variance to the phenotypic variance.

2. The parents PAN127, PAN148, SUG131, SER8, SER22 and SEQ11 can be used 'per ser' in plant breeding programs targeting improvement in earliness and seed yield and its components (pod yield, number of pods per plant), particularly SEQ11, SER22, SER8 and PAN 127 can be used in breeding for drought tolerance in areas of intermittent and terminal drought

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