Estimate of Heritability for Maturity Characteristics of an Early x Late Common Bean *(Phaseolus vulgaris l.)* Cross (TMO 216 x CIAT 16-1) and Relationships Among Maturity Traits with Yield and Components of Yield

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Abstract

Narrow sense heritabilities of maturity characteristics of common beans were estimated using the standard unit method of regression of F_3 on F_2 plants of Early x Late crosses grown in the field plots of the Sokoine University of Agriculture during the growing season of 1991. Correlations and genetic advances (GA) of maturity traits and seed yield were also determined. Estimated narrow sense heritabilities were high (0.59) for days to first flower (DFF), medium (33.3) for days to physiological maturity (DPM) and low (25.6) for duration of pod fill period (PFP). The high standard errors of PFP indicated high environmental influence on the expression of this trait. The results indicated that additive gene effects play an important role in the inheritance of DFF, hence early generation selection for this trait would be successful. Selection for duration of PFP should be done at later generations in replicated yield trials.A positive and significant relationship ($P< 0.05$) between seed yield and PFP-2 ($r=0.44$) suggested that a longer pod fill period might result in a higher seed yield potential. The family means for all maturity characteristics were similar to the mid parent means resulting in small positive values of genetic advance indicating that early maturing lines could easily be selected. Significant negative association between 100 seed weight and maturity indicates that selection for earliness would result in large seeded bean genotypes, which generally have a high preference for most farmers and consumers in the tropics.

Key words: Common beans, heritability, maturity characteristics, *Phaseolus vulgaris,*

Introduction

Designing effective procedures to increase yield in early maturing genotypes requires knowledge of strength and stability of genetic relationships among maturity characteristics as well as inheritance of such traits. Heritability of a particular trait determines its effectiveness of selections.

In studies involving 100 genotypes of common beans, most of the characters were identified as promising for improvement except that pod length had consistently low heritability values (Vaid and Singh, 1986). Heritability values of 0.65 to 0.87 were recorded for seed yield, yield components and earliness in F_2 progenies of common bean varieties (Diaz-Carrasco *et al.*, 1984; Urrea and Singh, 1989). Davis and Evans (1977) reported narrow-sense heritability of 0.83 for days to first flower (DFF) and suggested using days to flowering in selection for early maturity.

In a study of three crosses between indeterminate early and late bean cultivars, Cerna and Beaver (1990) reported narrow sense heritability estimates of 0.29- 0.75 for DFF and 0.31-0.63 for days to maturity. Heritability values for reproductive period (RP) were low indicating hat selection for this trait would be effective only in later generations.

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Tanzania J. Agric.Sc. (2007) Vol. 8 No. 1, 11-18
Accepted March, 2008

Earliness in common bean is a desirable character preferred by most farmers in areas with tropical climate. One of major factors associated with low bean production in the tropics is the unreliable rainfall pattern. Rainfall in most of these areas is erratic resulting in moisture stress during all or part of beans crop's reproductive phase. It has been suggested that, drought escape of bean plants through earliness in maturity and low desiccation due to efficient root system are important mechanisms in drought tolerance (White and Singh, 1991, Wright and Redden, 1998, Frahm *et al.*, 2004). Therefore, early maturing varieties are important in areas with frequent droughts. Sometimes, varieties with drought tolerance are not of the preferred seed types. In such cases hybridization is required between the preferred types and the early maturing types. When doing hybridization, the information about heritability of maturity traits is required in order to predict the success of selection from populations created from such crosses. Apparently, very little information is available on the inheritance of maturity characteristics in common beans, especially for the length of pod fill period.

The objectives of this study therefore, were to estimate the heritability (narrow sense) in F_2 and F_3 populations of a cross TMO 216 x CIAT 16 B_1 (Early x Late) for maturity characteristics and to estimate the correlations among maturity traits with yield and components of yield.

Materials and methods

The parents and F_2 progenies of TMO 216 x CIAT 16-1 cross were planted in the field at the Sokoine University of Agriculture (SUA), Morogoro, Tanzania. The field was located at 6° 17' S and 37° 40' E at elevation of 525 meters above sea level. Bean line TMO 216 is an early maturing line while CIAT 16-1 is a late maturing line. A randomized complete block design (RCBD) with three replications was used. Each replication consisted of two-row plots of 2 meters long for each parent and each F_2 line. These were bordered on each side by a guard row of TMO 216. The plant spacing was 50 cm between rows and 20 cm within rows.

Seeds of parents and 11 F_3 families from the cross TMO 216 x CIAT 16-1 were planted in the field at SUA. The treatments were laid out in a RCBD with 3 replications. Each replication consisted of 1 row of each parent, 11 rows of F_3 and guard rows of TMO 216. Seeds were spaced 20 cm apart in the four-meter rows spaced 50 cm apart.

The number of days from seeding to each of the maturity trait was recorded by examining each plant on a daily basis. Plants with the same growth habit were grouped together as to avoid confounding effects of growth habit. Maturity characteristics recorded as from the day of planting, were as follows:

Days to first flower (DFF) = Days to when the first flower appeared on the plot
Days to 1st pod formation = Days to when at least one plant had produced first pod
Days of 50% pod formation = Days to when 50% or more of plants in each plot had produced the first pod Days to First pod fill = Days to when the first pod had reached 8 cm. long
Days to 50% pod fill = Days to when 50% or more plants had first pod filled
Days to 85% pod matu5rity = Days to when almost all pods had changed yellow color to tan i.e. physiological maturity.
Variables for estimating duration of pod fill were calculated as follows:
Reproductive period = Days from 1^{st} flower to 85% maturity
Pod fill period -1(PFP-1) = Days from 50% pod formation to 85% maturity
Pod fill period - 2 (PFP-2) = Days from 1^{st} pod fill to 85% maturity

Data for components of yield and seed yield were also recorded. The analysis of variance was conducted using MSTAT-C version 3 (Freed *et al*, 1988).

The standard unit-method of Frey and Horner (1957) was used to determine the narrow sense heritability on the individual F_2 plants.

Simple correlation coefficients (r) were determined for all traits measured.

The expected genetic advance (GA) was calculated as given by the formula: $GA = K.\delta.h^2_{ns.}$

Where: K = Selected differentiate in standard units. 1% of F_2 were selected to produce the F_3, thus giving $(K = 2.64)h^2_{ns.}$ = Narrow sense heritability

δ_p= the phenotypic standard deviation (estimated as the square root of the variance of the F_2 population.

The GA values were calculated from the population means as:
GA due to selection $R = X_s - X_o$ is, the difference between the mean of selected F_3 (X_s) and the mean of the original F_2 population (X_o).

Results and discussion

The analysis of variance showed highly significant differences ($P \leq 0.01$) among the F_3 bean lines for all traits (Table 1). Indicating that there was high variation among F_3 in both maturity and yield traits.

Table 1. Mean squares and Coefficient of variation (CV%) for eight metric traits in 11F_3 common bean lines and their parents tested at SUA 1992

Source	d.f.	First flower	First podfill	85% maturity	R.P.	PFP-2	Seeds/pod	100-seed weight (g)	Seed yield kg/ha
		Days							
Replication	2	42.231	53.103	65.410	2.641	0.641	0.292	32.006	120243.795
Line	12	26.808**	57.303**	103.667**	71.974**	90.081**	0.595**	192.909**	1044706.581**
Error	24	.8.231	10.964	8.410	15.724	13.113	0.193	35.177	50093.850
CV%		7.1	6.1	3.4	8.6	11.1	11.4	20.0	60.9

** Significant at $P \leq 0.01$
R.P Reproductive period
PFP-2 Pod fill period-2

Table 2. Mean values of maturity traits, Genetic advance (GA) and broad sense heritability (h^2b) of parents and selected 11F_3 families for maturity traits

	Maturity traits (days)					Yield components		
Family	First flower	First podfill	85% maturity	RP	PFP-2	Seed yield (kg/ha)	Seeds per pod	100 seed weight (g)
1. 13-13	39.7	56.7	86.0	46.3	29.3	214.7	3.5	29.2
2. 13-8	37.3	50.3	89.7	52.3	39.3	316.3	3.7	32.4
3. 21-7	40.7	53.0	88.3	47.7	35.3	295.3	4.3	20.2
4. 21-6	43.7	57.3	90.7	47.0	33.3	243.3	4.0	29.6
5. 21-11	38.7	52.3	90.7	52.0	38.3	706.3	3.8	30.0
6. 21-3	42.3	58.7	90.7	48.3	32.0	247.3	3.7	27.9
7. 21-18	44.0	55.0	90.7	46.7	35.7	408.3	3.8	40.2
8. 21-2	42.3	54.3	90.0	47.7	35.7	505.0	4.3	22.4
9. 21-12	38.3	51.7	87.7	49.3	36.0	149.7	3.7	27.8
10. 21-15	36.6	47.3	75.3	38.7	28.0	507.7	3.7	44.6
11. 33-3	43.7	61.3	90.0	36.3	18.7	85.3	2.9	21.7
12. TMO 216	35.3	46.7	75.3	40.0	28.7	475.3	4.1	40.7
13. CIAT 16-1	43.3	57.7	91.3	48.3	34.0	620.7	4.7	19.9
Family mean	40.7	54.4	88.2	46.6	32.9	334.5	3.8	29.6
Mid parent	39.3	52.2	83.3	44.2	31.4	548.0	4.4	30.3
Predicted Genetic Advance	8.1	9.9	8.9	5.7	0.9	-39.0	-0.14	-0.02
Calculated Genetic Advance	4.9	8.4	8.2	4.2	-0.2			
h^2b	0.43	0.58	0.75	0.47	0.66			

The family means for all maturity traits were similar or slightly higher than the mid parent means but lower than the latest parent in maturity, CIAT 16-1 (Table 2).

The genetic advances for the maturity traits were therefore, rather small but were positive. This indicated there was slight improvement in days to first flowering, first pod fill, days to 85% maturity and reproductive period compared to the late parent. Broad sense heritability (h^2b) estimates showed moderate heritability for days to first flower and reproductive period (0.43 and 0.47 respectively).

The h^2b values for days to first pod fill and 85% pod maturity were high, indicating that it possible to improve these traits genetically.

Estimated narrow-sense heritabilities using standard unit method were high (0.59) for days to first flower and medium (0.33) for days to maturity (Table 3). The PFP-2 had the lowest heritability indicating that selection in the early generations would not be effective for this trait. The high standard error observed for PFP-2 indicates that there was high environmental influence in its expression. Results indicate that the additive gene effects play an important role in inheritance of DFF hence early generation selection for this trait would be successful.

Results have shown that probably additive genetic variance for pod fill period is very low in this population because of the low heritability observed in the population. It is suggested that bulk population breeding would be more efficient in improvement of this cross than the pedigree method in improvement for duration of pod fill period because of low heritability of this trait selection cannot be done in early generations based on single plant observations. Selection for pod fill period would be made in later generations (F_5 or F_6) in replicated trials. These results are in agreement with the findings of Cerna and Beaver (1990) who also reported of high heritability estimates for DFF and physiological maturity. Low heritability values for pod fill duration which had been observed in this study, is in agreement with White and Singh (1991) who also reported low heritability values for pod fill period.

Table 3: Narrow sense heritability for the maturity traits estimated by standard unit parent offspring regression of F_2, vs F_3 of cross TMO 216 x CIAT 16-1

Variable	Heritability (%)
Days to first flower	59.5 $\pm$ 2.3
Days to first podfill	50.0 $\pm$ 3.7
Days to 85% maturity	33.3 $\pm$ 5.1
Reproductive period	25.6 $\pm$ 5.0
Podfill period-2	3.9 $\pm$ 6.0

The genotypic correlations showed the same trend as the simple phenotypic correlations in most associations (Table 4). Days to first flower and days to 85% maturity were highly significantly ($P \leq 0.01$) and positively correlated. This suggests that days to first flower are a reliable indicator of physiological maturity and could hence be used as selection criteria in breeding for earliness. The correlations between days to 85% maturity and the reproductive period and PFP-2 were positive and highly significant ($P \leq 0.01$) (r_g = 0.91 and 0.74 respectively), indicating that by increasing the pod fill period one also increases the number of days to maturity hence lateness. Cerna and Beaver (1990) have also reported of positive relationship between days to first flower and physiological maturity. A positive genetic correlation between seed yield and PFP-2 was also detected though not significantly so (r_g = 0.44). The relationship between seed yield and reproductive period was also positive but non-significant.

Table 4. Genotypic (above) and simple phenotypic (below) correlation coefficients among maturity characteristics (days), estimated podfill periods (days), yield and yield components of F_3 families

Trait				**Trait number**				
Description	1	2	3	4	5	6	7	8
1. First flower (DFF)		1.02**	0.68	0.32	-0.03	0.70**	0.05	-0.18
		0.88**	0.55**	0.05	-0.12	-0.53	-0.03	-0.01
2. First podfill (FPF)			0.49	0.05	-0.24	-0.84**	-0.37	0.52
			0.46	0.01	-0.31	-0.65*	-0.24	0.15
3.85% maturity				0.91**	0.74**	-0.60*	0.39	0.03
				0.86**	0.70**	-0.38	0.54*	0.52
4. Reproductive period (RP)					0.98**	-0.28	0.38	0.15
					0.92**	-0.01	0.73**	0.62*
5. Podfill period –2 (PFP 2)						-0.03	0.54*	0.44
							-0.31	0.69*
6. 100 seed weight (g)							-0.18	0.33
								-0.15
7. Number seeds/pod								0.86**
								0.70**
8. Seed yield (kg/ha)								

*** Significant at P<0.05 and P<0.01 respectively

A highly significant relationship ($P \leq 0.01$) was observed between the reproductive period and the PFP-2 ($r_g = 0.98$) suggesting that any of the two estimates could reliably be used as an estimator of the other. Among components of yield, only 100 seed weight was negatively and significantly ($P \leq 0.05$) associated with day to 85% maturity ($r_g = -0.60$) indicating that early maturing lines had bigger seeds than the late maturing lines. A similar negative association between seed and maturity was reported by Mwandemele and Nchimbi (1992) in other populations of beans.

Estimates of heritability in narrow sense were high for days to first flower, was medium for maturity and low for reproductive period. These results indicate that the additive gene effect plays an important role for number of days to first flower. Early generation selection for days to first flower would therefore be successful. Low heritability estimates as those reported for reproductive period and pod fill period suggest that selection in the early generation would not be very effective. No improvement will be achieved through selection because of the environmental effect on the expression of pod fill duration making it difficult to identify genetically superior individuals in the early generations. Probably additive genetic variance for the trait was very low in this population. To get some improvement, selection for pod fill period duration should be made in later generations in replicated nurseries.

A positive genetic correlation between seed yield and pod fill period implies that longer duration of pod fill may result in higher seed yield potential, and therefore, pod fill duration can be used as selection criteria when selecting for high seed yield in early maturity populations. Since maturity characteristics have some direct and indirect relationship with yield, Wallace and Yan (1998) have suggested that maturity must always be factored into a breeding program for yield in bean.

Conclusion

Results from this study have demonstrated that it is possible to breed for early maturing varieties with moderate yield since the heritability of maturity traits were moderate to high that could allow effective selection to be made. The correlation analysis showed that some of the maturity traits could be used to select for other traits because of high correlation among them. For instance, days to first flower can be used to select for physiological maturity since there is high correlation between them. Heritability values obtained for maturity traits show that, some of the traits such as days to first flower (DFF), can be selected for in early generations because of high heritability values, while traits such as pod fill period (PFP) and reproductive period (RP) can be selected for in later generation for selection to be efficient and successful.

The yield potential of the germplasm used for this study as parents was moderate to low yield that is why the F_2 and F_3 families had moderate yield. Therefore, the choice of suitable parents for breeding for earliness is crucial since it determines the amount of simultaneous improvement, which can be attained at the shortest possible time. A modified pedigree selection method with early selection for maturity traits with high heritability while selection for traits with low to moderate heritability (such as yield) be conducted in later generations. This will ensure that early maturity common beans will be selected, without sacrificing yield potential of the improved lines.

Acknowledgement

The authors are grateful to the Bean/Cowpea Collaborative Research program and The Swedish Agency for Research Cooperation (SAREC) for financial support that facilitated this work. Suggestions and ideas given by Drs. Matt Silbernagel and Jim Myers when this research was initiated are also acknowledged.

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