Patterns of Inheritance of Maturity Characteristics and Pod Fill Period of Tropically Adapted Common Beans (*Phaseolus vulgaris* L.) Early x Late Crosses

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Abstract

Two early maturing determinate pure lines TMO 101 (P1) and TMO 216 (P2) were crossed to two late maturing lines A87 (P5) and CIAT 16-1 (P6) in order to study the inheritance pattern on maturity characteristics. Parental lines and F_2 seeds of P1 x P5 and P6 were planted in the field in a randomized complete block design with three replications at the Sokoine University of Agriculture farm. Frequency distribution tables for maturity traits were prepared and segregation data tested by the Chi- square test. A continuous distribution for number of days to first flower were observed in F_2 of TMO 216 x CIAT 16-1 while for cross TMO 101 x A87 it seemed to be skewed on the early side. Results show that more than one gene is involved in controlling days to first flower especially for the cross TMO 216 x CIAT 16-1. A satisfactory fit to a 1:2:1 segregation ratio of early, intermediate and late flowering plants occurred in both crosses. Results showed that days to first flower (DFF) in both crosses were controlled primarily by additive gene action. Transgressive segregation for lateness occurred in the cross (TMO 216 x CIAT 16-1). The segregation data fitted a 13:3 ratio suggesting segregation of two major genes, dominant for late maturity. Days to maturity (DM) in the cross TMO 101 x A87 was found to be monogenically controlled with partial dominance for earliness. Transgressive segregation for long reproductive period was observed in the F_2 of cross TMO 216 x CIAT 16-1 indicating some quantitative inheritance for this trait. The segregation data did not fit the expected ratio of 3:1, further suggesting the involvement of many genes with small effects. For both crosses the data shows continuous distribution in pod fill period-2. Pod fill period-2 was found to be inherited quantitatively in the cross TMO 216 x CIAT 16-1.

The knowledge obtained from this study together with heritability values obtained from other studies will be valuable in determining breeding procedures for improvement of maturity characteristics and pod fill periods in tropical conditions.

Key words: Maturity characteristics, common beans, patterns of inheritance.

Introduction

Early maturity is a desirable trait for common beans (*Phaseolus vulgaris* L) in the tropics because it serves as a mechanism for avoiding stresses like drought and diseases (Scheneider *et al.*, 1997; Wright and Redden, 1998; Frahm *et al.*, 2004). In addition, earliness has an economic value of providing farmers with a rapid source of food as well as income (White and Izquirdo, 1991).

The awareness by breeders to develop early maturing common bean cultivars is challenged by the problem of how to breed cultivars which combine the desired level of earliness with a reasonable yield potential (Mduruma and Nchimbi, 1991). Selection for

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high seed yields, however, has been found to lead to loss of the desired earliness (White, 1989; White and Singh, 1991; Wallace, 1985; Acosta-Gallegos, 1996). Hence, breeders have to find efficient ways to simultaneously select for earliness and high yield potential through genetic studies of appropriate populations. This problem is due to the fact that earliness embodies an inherent loss of yield potential that is associated with short cycle and sub optimal canopy development.

Partitioning of genetic variance into the different components due to the additive, dominance and epistatic effects of genes, is useful in providing information on inheritance of quantitative characters and in formulating breeding procedures. Studies on inheritance of earliness in common beans indicate that only a few genes are involved (Coyne and Mattson, 1967; Bliss, 1971; Coyne, 1978; Singh, 1991). One or two genes have a direct effect on flowering while a third gene affects maturity traits through its effect on growth habit (Freire Filho, 1980).

Most genetic studies on earliness in maturity, however, have been conducted in the temperate regions of the world using materials partly adapted to the tropics. Knowledge of the mode of inheritance of maturity traits of tropically adapted common beans should facilitate selection of early maturing genotypes, which are also high yielding.

This paper reports on the inheritance of maturity characteristics and duration of pod fill period of Early and Late common bean crosses adapted to the tropics. The implications of these traits in breeding for earliness and higher seed yields are discussed.

Materials and methods

Six-pure lines of common beans were selected from the germplasm in the SUA breeding project to be used as parents in the crosses. Three lines of determinate growth habit namely, TMO 101 (P_1), TMO 216 (P_2) and 86 EP 5070-B (P_3) represented the early maturing parents. Lines TMO 216 and 86 EP 5070-B are resistant to Bean Common Mosaic Virus (BCMV), bean rust and Angular Leaf Spot (ALS). Bean line TMO 216 has also tolerance to drought, good cooking qualities and has high yielding potential. TMO 101 is a large seeded accession with a good root system, which could possibly be of advantage in drought has tolerance.

Lines, A55 (P_4), A87 (P_5) and CIAT 16-1 (P_6) were chosen as late maturing parents. A55 and A87 exhibit an upright growth habit. Line A55 also has a good root system, is resistant to *Fusarium* wilt and tolerant to Bean Stem Maggot attack.

Crosses (half diallele) between early and late maturing lines were made as follows: P_1 x P_4, P_1 x P_5, P_1 x P_6, P_2 x P_4, P_2 x P_5, P_2 x P_6, P_3 x P_4, P_3 x P_5 and P_3 x P_6.

Due to insufficient seeds, the F_2 seeds of all crosses could not be planted in the field. Therefore, only the parents, F_1 and F_2 progenies of TMO 101 x A87 (P_1 x P_5) and TMO 216 x CIAT 16-1 (P_2 x P_6) were planted in the field plots of the Sokoine University of Agriculture (SUA). A randomized complete block design, with three replications was used for each cross. Each replication consisted of two-row plot of 2 meters long for each generation. The plots were bordered on each side by a guard row of TMO 216.

The spacing was 50 cm between rows and 20 cm between plants. Twenty-two F_2 seeds and parental lines were sown per plot, and thus for three replications there were a total of 66 plants for observations. The number of days from seeding to each maturity trait was recorded by examining each plant on a daily basis. Data recorded were as follows:

Days to first flower (DFF) =Days from planting to when the first flower appeared on the plot. Days to 1st pod formation = Days from planting to when at least one plant had produced the first pod. Days of 50% pod formation = Days from planting to when 50% or more of plants in each plot had produced the first pod.

Days to First pod fill = Days from planting to when the first pod had reached 8 cm long.

Days to 50% pod fill = Days from planting to when 50% or more plants had first pod filled.

Days to 85% pod maturity = Days from planting to when almost all pods (85%) 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 1st 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 1st pod fill to 85% maturity.
Dimethoate (Rogor 40 EC) at the rate of 800 a.i ha^{-1} was used to control insect pests(mainly the foliage beetles especially the *Ootheca* spp.) and was applied at 14 days intervals commencing at three weeks after planting. A *Rhizobium* inoculant NITROSUA was applied at sowing and no other nitrogen fertilizer was added.

The analysis of variance was conducted using MSTAT-C version 3 programme (Freed *et al.,* 1988). Frequency distribution tables for the maturity traits in the parent and F_2 lines were prepared and the segregation data was tested using Chi- square.

Results and Discussion

Significant differences for all maturity characteristics were observed among parents and the mean of F_2 generations grown in the field for the cross TMO 101 x A87, while for the other cross (TMO 216 x CIAT 16-1) there were no significant differences for reproductive period and pod fill period -2 among parents and the mean of F_2 generations (Table 1). Comparing the late parent and the F_2 values, for both crosses it showed that values for F_2 were slightly lower than the late parent for first flower, first pod fill and 85% maturity while that for reproductive period and pod fill period-2 were slightly higher than those of late parents. A continuous distribution for number of days to first flower were observed in F_2 of TMO 216 x CIAT 16-1 while for cross TMO 101 x A87 it seemed to be skewed on the early side (Table 2). For two classes classification, plants were classified as early flowering if they bloomed within 28-33 days from planting and as late if they bloomed later than 35 days. For three classes classification, plants were classified as early if they bloomed within 28-33 days from planting; intermediate within 34 -36 and late within 37-45 days. Results show that more than one gene is involved in controlling days to first flower especially for the cross TMO 216 x CIAT 16-1.

Table 1. Mean squares of maturity characteristics and estimated pod fill periods of F_2 populations of Early x Late crosses and their parents

Generations	Mean Days to First Flower	Mean Days to First Podfill	Mean Days to 85% maturity	Mean Reproductive period (Days)	Mean Podfill period-2 (Days)
TMO 216 (P_1)	29.6	37.8	69.4	39.7	31.2
CIAT 16-1(P_6)	39.2	48.9	78.7	39.5	29.8
Mid-parent	34.4	43.3	74.0	39.6	30.5
F_2 (P_2 x P_6)	35.6	45.7	78.5	42.0	32.8
Mean square	69.963**	97.621**	85.6*	10.9n.s	6.91ns
Error M.S.	0.297	1.589	6.267	4.835	7.353
CV%	1.6	2.9	3.3	5.4	8.7
TMO 101 (P_1)	30.5	39.1	73.2	42.7	34.1
A87 (P_5)	39.8	48.8	76.7	36.9	27.9
Mid-parent	35.1	43.9	74.9	39.8	31.0

F_2 (P_1 x P_5)	34.1	43.5	74.2	40.1	30.7
Mean square	66.114**	90.97**	10.003**	25.041**	28.324**
Error M.S.	1.073	0.773	0.897	1.353	0.661
CV%	3.0	2.0	1.3	2.9	2.6

, * **Significant at $P \leq 0.05$ and $P \leq 0.01$ respectively**
n.s. **Not significant**
M.S. **Mean square**

Table 2. Frequency distributions on days to first flower for parents and F_2 generation derived from Early x Late bean crosses

	Days to First flower classes							
Generations	28-30	31-33	34-36	37-39	40-42	43-45	Total No. plants	Mean No. days
TMO 216 (P_2)	14						19	29.6
CIAT 16-1 (P_6)			3	25	10	4	42	39.2
F_2 (P_2 x P_6)	1	8	14	7	3	1	34	35.6
Mid parent								34.4
TMO 101 (P_1)	11	9					20	30.5
A 87 (P_5)				23	10	6	39	39.8
F_2 (P_1 x P_5)	4	10	23	6			43	34.1
Mid parent								35.2

A satisfactory fit to a 1:2:1 segregation ratio of early, intermediate and late flowering plants occurred in both crosses (Table 3). This confirms that days to first flower in those crosses are controlled primarily by additive action of alleles of a single major gene with partial dominance for earliness. These results are in agreement with those reported in Colombia where all 19 F_2 populations were found to be earlier than the mid parent values (White and Singh, 1991).

Table 3: Segregation ratios for days to first flower in F_2 generation derived from Early x Late bean crosses

Cross	Days to first flower classes			Expected Ratio	X^2	P
	Early 28-33	Intermediate 34-36	Late 37-45			
TMO 216 x CIAT 16-1	9	14	11	1:2:1	1.29	0.75-0.5
TMO 101 x A87	14	23	6	1:2:1	3.19	0.25-0.10

Frequency distribution for days to 85% maturity is shown in Table 4. Transgressive segregation for lateness occurred in F_2 generation of TMO 216 x CIAT 16-1 indicating that there is more than one gene involved in the inheritance of days to maturity. These results imply that breeding for earliness is difficult and appropriate selection of parents for breeding is crucial. The segregation data did not fit a 1:2:1 ratio suggesting involvement of more than one gene (Table 5). A good fit to a 13:3 ratio of number of plants in the late and early classes occurred suggesting segregation of two major genes, dominant for late maturity. For two classes classification, plants, were considered early if they matured within 65-70 days after planting, and late within 71-88 days. For three classes classification, plants were considered early if they matured within 65-70 after planting, intermediate within 71-76 days and late within 77-88 days (CIAT, 1987).

Table 4. Frequency distributions on days to 85% maturity for parents and F_2 generations derived from two bean crosses

Generation	Days to 85% maturity classes								Total No. plants	Mean No. days
	65-67	68-70	71-73	74-76	77-79	80-82	83-85	86-88		
TMO 216 (P_2)	7	5	6						18	69.4
CIAT 16-1 (P_6)				4	16	9	7		36	78.7
F_2 (P_2 x P_6)	3	4	2	4	2	9	3	6	33	78.5
Midparent										74.1
TMO 101 (P_1)		6	3						19	73.2
A87 (P_5)				13	12	9			34	76.7
F_2 (P_1 x P_5)	3	5	9	13	10	3			43	74.2
Mid-parent										75.0

In the cross, TMO 101 x A87, the F_2 showed a continuous distribution of plants for days to maturity. A satisfactory fit of 1:2:1 (early, intermediate, late) was observed (Table 5). It is therefore hypothesized that, days to 85% maturity in that genetic background is primarily under monogenic control with partial dominance for earliness. Similar results have been reported by Al-Mukhatar (1981) who also found out that pod maturity was controlled by one major gene with incomplete dominance for late maturity types. Coyne and Mattson (1967) reported that pod maturity was under monogenic control with complete dominance for lateness.

Table 5: Segregation ratios for days to 85% maturity in F_2 generation derived from Early x Late bean crosses

Cross	85% maturity classes					
	Early 65-70	Intermediate 71-76	Late 77-88	Expected Ratio	Chi Square	P
TMO 216 x CIAT 16-1	7	6	20	1:2:1	23.56	<0.005
TMO 216 x CIAT 16-1	7	-	26	3:13	0.018	0.90-0.95
TMO 101 x A87	8	22	13	1:2:1	1.185	0.75-0.500

Transgressive segregation for long reproductive period was observed in the F_2 of cross TMO 216 x CIAT 16-1 indicating some quantitative inheritance for this trait (Table 6). The segregation data did not fit the expected ratio of 3:1, further suggesting the involvement of many genes with small effects (Table 7). The plants were classified as having short reproductive period when they had reproductive period within 34-41 days and long within 42-53 days after planting. In cross involving TMO 101 x A87 the segregation data fitted the expected ration of 3:1 (i.e. short: long), implying that reproductive period in this cross is influenced primarily by one pair of major gene with short reproductive period being dominant. This also implies that selection for either short or long reproductive period will be easy.

Table 6. Frequency distributions of reproductive period (RP) for bean parents and F_2 generation derived from two Early x Late bean crosses

Cross	Reproductive period classes (Days)						
	34-37	38-41	43-45	46-49	50-53	Total No. plants	Mean No. days
TMO 216 (P_2)	6	6	6			18	39.7
CIAT 16-1 (P_6)	3	23	8	2		36	39.7
F_2 (P_2 x P_6)	5	10	5	10	3	32	42.0
Mid-parent							39.6
TMO 101 (P_1)	3	5	12			19	42.7
A87 (P_5)	15	13	1			34	36.9
F_2 (P_1 x P_5)	8	22	12			40	40.1
Mid-parent							39.8

Table 7. Segregation ratios for reproductive period for parents and F_2 generation derived from two Early x late bean crosses grown at SUA, Morogoro

	Reproductive period classes (Days)				
	Short 34-41	Long 42-53	Expected ratio	X^2	P
TMO 216 (P_2)	12	6			
CIAT 16-1(P_6)	26	10			
F_2 (P_2 x P_6)	15	17	3:1	7.04	0.01-0.05
TMO 101 (P_1)	7	12			
A87 (P_5)	33	1			
F_2 (P_1 x P_5)	30	13	3:1	0.33	0.5-0.25

Frequency distribution for pod-fill period-2 estimated as days from first pod fill to physiological maturity is shown in Table 8. For both crosses the data shows continuous distribution. Pod fill period-2 was found to be inherited quantitatively in the cross TMO 216 x CIAT 16-1.

The segregation data for both crosses did not fit the expected ratio of 3:1 confirming involvement of many genes in the control of the trait (Table 9). These results imply that, selection for this trait requires a breeder to develop large segregating population for effective selection.

Conclusion

The knowledge obtained from this study will be valuable in determining breeding procedures for improvement of maturity characteristics and pod fill periods. The choice of suitable germplasm is crucial since it determines the amount of simultaneous improvement of traits that can be attained at the shortest possible time. A modified pedigree selection with early generation testing is recommended for selection for early maturity in common beans. Promising bean lines in terms of early maturity and increased seed yield obtained from this study, will be used in breeding programme for further improvement of bean germplasm.

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 is also acknowledged.

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