

Evaluation of Maturity Characteristics and of Yield Components of High Protein Bean (*Phaseolus vulgaris* L.) Varieties in Morogoro, Tanzania

Mduruma, Z. O., S. Nchimbi-Msolla, S.O.W.M. Reuben* and R.N. Misangu

Department of Crop Science, Sokoine University of Agriculture, e, P.O. Box 3005, Morogoro, Tanzania.

Abstract

Several Bean growing areas in Tanzania have unreliable and marginal rains necessitating use of short maturing and high yielding varieties. Such varieties however, are not readily available. This study was done to evaluate varieties for maturity, yield and its components in the bean growing areas of Morogoro, Tanzania. Sixty four varieties from the Sokoine University of Agriculture (SUA) collection and from a high percentage protein population were grown at two locations, Mgeta (high altitude) and SUA (low altitude) in 8 x 8 partial lattice with 3 replications during the 1991 season. Yield levels were low, ranging between 0.2 - 0.8 t/ha at Mgeta and 0.06 - 2.0t/ha at SUA. Earlier varieties were superior in yield due to a higher yield efficiency. Varieties grown in the cooler higher altitude areas matured late with consequent reduction in yield. Significant G x E interaction effects were observed for all the variables, except number of seeds per pod. Positive genetic correlations were significant ($P < 0.01$) at both locations between yield and number of pods per plant, yield efficiency and podfilling period. Yield was genetically and negatively corrected with days to first flower, 50% podfill and 85% maturity. Path coefficient showed that days to first flower had a consistent negative direct effect on yield. At both locations, the negative genetic relationship between days to 50% podfill with yield was attributed to the negative indirect influence through days to first flower. Earlier flowering and maturity, longer podfilling with high pod production and yield efficiency are recommended for higher yields of beans in the study area.

Keywords: Earliness, path coefficient, *phaseolus vulgaris* L, pods, pod filling period, yield efficiency

Introduction

A major factor associated with low bean (*Phaseolus vulgaris* L.) production in the tropics is the pattern of climate in the areas of production. Rainfall in most of these areas is irregular and marginal, resulting in moisture stress during all or part of the bean crops' critical period of growth. Thus, most farmers prefer early maturing bean cultivars to ensure successful growth

and production of the crop even though they are potentially low yielding.

Earliness, as a breeding objective, has been a major concern in many crops. In common beans, the recent awareness by breeders to develop early maturing bean varieties is challenged by the problem of how to breed varieties which combine the desired level of earliness with a reasonable yield potential. This problem is due to the fact that earliness embodies an in-

*Corresponding author

herent loss of yield potential that is associated with the short growth cycle and sub-optimal canopy development (Laing *et al.*, 1984). In Tanzania, for instance, bean grain yields are low ranging between 200 and 670 kg of dry seeds per hectare (Karel *et al.*, 1980) mainly due to unreliability of rainfall during the growing season.

The amount of seed yield produced is the product of the number of seeds and their sizes as determined by the rate and duration of dry matter accumulation in them (Al Mukhar and Coyne, 1981). Izquierdo and Hosfield (1983) reported that high yields of beans were attributed to longer pod filling period. The early maturing varieties would therefore be expected to yield less than the late maturing ones because of fewer days taken for plant growth and development which limits dry matter accumulation.

In the common bean, the reproductive stages are divided into flowering, pod development and the pod filling stages. The pod filling period comes to an end when the plant reaches its physiological maturity. It is possible that early flowering relative to the length of the rainy season can allow for a longer period of pod filling in beans, thus leading to a potentially higher yielding ability. The latter may lead to development of early maturing bean varieties which are as high yielding as late maturing varieties.

The present investigation was set out to study the relationships existing among maturity characteristics with yield among the breeding materials currently available at the Sokoine University of Agriculture Morogoro, Tanzania. Results of such an investigation may shed light on the possibility of developing bean varieties which are early but high yielding under the rainfall marginal areas.

Materials and Methods

Sixty four bean varieties including 58 varieties from Bean Project germplasm at Sokoine University of Agriculture and 6 adapted cultivars (Selian Wonder, Kibwebwe, Canadian Wonder, Local Dumila, Lyamungu 85 and Masai Red) (used as controls) were evaluated for field performance and stability at two locations in Morogoro, Tanzania. The experimental sites were, Mafiga Farm at Sokoine University of Agriculture (525 m a.s.l; 7°S, 37.5°E) with a semi-arid climate and Mgeta (1500 m asl; 7.1°S, 37.5°E) on the slopes of Uluguru mountains with a relatively wet and cool climate. The varieties were arranged in an 8 x 8 partial lattice with 3 replications at both locations. Each plot consisted of a single row two meters long. Three seeds were sown per hill at spacing of 50 x 10 cm. Two weeks after sowing, thinning was done leaving one plant per hill.

Dimethoate (Rogor 40EC) at the rate of 800 g a.i ha⁻¹ was used to control insect pests at 14 days interval commencing 3 weeks after planting. A rhizobium inoculant, NITROSUA, was applied at sowing by mixing it with seed and small amounts of water before planting. Weeding was done using a handhoe to maintain weed free plots throughout the growing season.

The data recorded included dates for reproductive stages R5 through R9 (CIAT, 1986) based on daily observations.

The maturity characteristics were:

1. Days to first flower appearing in the plot;

2. Days to 50% podfill, that is, when 50% or more of plants had produced filled pods;
3. Days to 85% pod maturity, a period when almost all pods had changed their yellow colour to tan with the exception of one or two green pods/plant. This period is equivalent to the physiological maturity in common beans.

From the maturity characteristics recorded above, parameters for estimating duration of podfill were estimated as follow:

1. Reproductive Period (RP) as days from first flower to 85% pod maturity;
2. Podfill period (PFP) as days from 50% podfill to 85% pod maturity.

At harvest, data were recorded in each plot for average number of pods per plant, number of seeds per pod, 100 - seed weight (g), seed yield (kg/ha). Yield efficiency for each plot was calculated as (seed yield/days to 85% maturity), while harvest index (%) was computed as (seed yield/aerial biomass) x 100.

The analysis of variance was conducted for each variable using the MSTAT - C version 3 computer programme (Freed *et al*, 1988). Genotypic variances and covariances were computed by equating expected variances and covariance components to the appropriate mean squares and cross products as described by Singh and Chaudhary (1985) as follows:

The Expected Mean Sum of Squares, E (MS):

$$E(MSv) = Ve + rVg$$

$$E(MSe) = Ve$$

$$Vg = \frac{E(MSv) - E(MSe)}{r}$$

$$g_1 g_2 = \frac{MSPv - MSPe}{r}$$

Where

Vg = genotypic variance,

$g_1 g_2$ = genotypic covariance,

v = varieties, e = error, g = genotype, r = number of replications and $MSPv$ = expected mean sum of Products for Varieties.

$$r_g(X1X2) = \frac{CovX1X2}{V(X1)V(X2)}$$

Where :

$r_g(X1X2)$ = genotypic correlation between traits X1 and X2.

$Cov(X1X2)$ = genotypic covariance between X1 and X2.

$V(X1)$, $V(X2)$ = genotypic variances of X1 and X2 respectively.

Simple phenotypic correlation coefficients (r) were calculated using mean values for all parameters studied.

Combined analyses of parameters over locations were carried out, with locations considered as random variables. Test of homogeneity of the Error Mean Squares from individual analyses were performed as described by Gomez and Gomez (1984) and comparisons were based on the partitioned mean squares.

Path coefficient analysis

A detailed investigation of the interrelationships of the variables, in which the genotypic correlations among the maturity variables were broken down into components of direct and indirect effects, was done using path coefficient analysis. The method follows procedures as originally described by Wright (1921) and as revised by Dewey and Lu (1959).

For each location, six variables were included in the path coefficient analysis. The nature of the causal system is depicted in Fig. 1 and 2. In the path diagram, the double-arrowed lines indicate mutual associations as measured by the genotypic correlation coefficients, r_g , and the single-arrowed lines represent direct

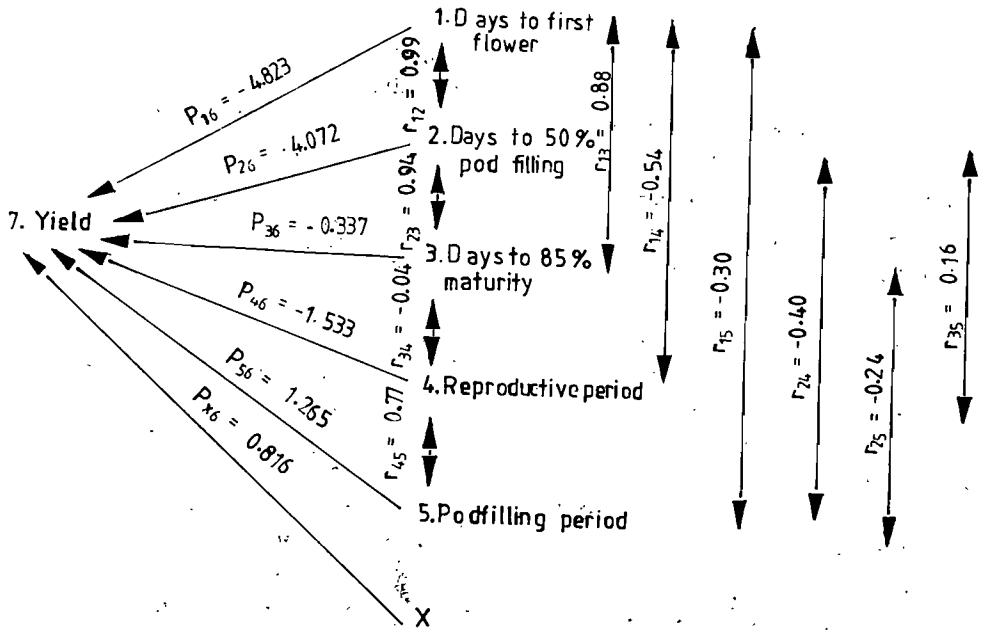


Figure 1: Paths of influence among maturity traits and seed yield in the common bean at Mgeta (higher altitude)

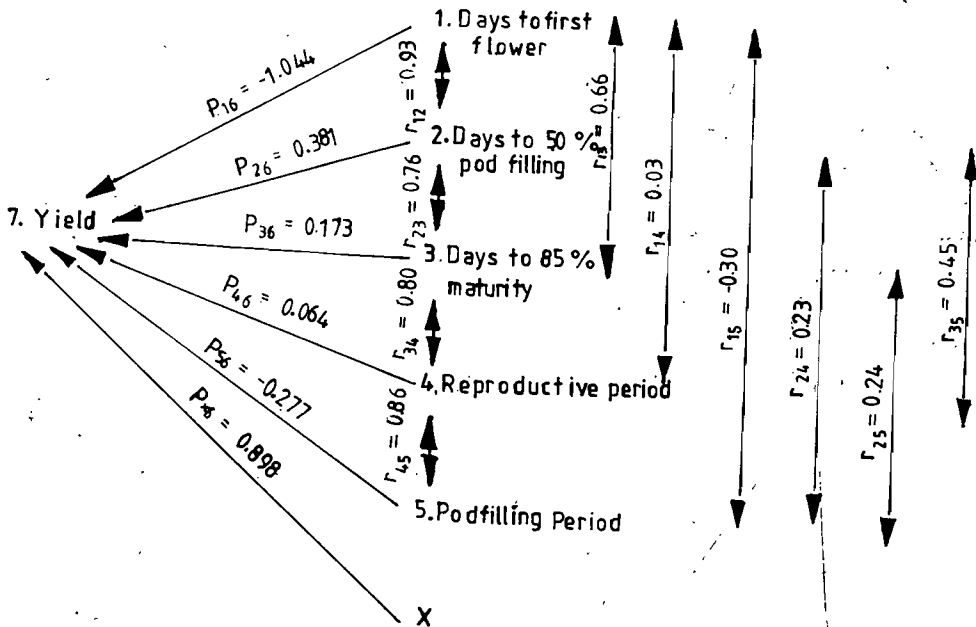


Figure 2: Paths of influence among maturity traits and seed yield in the common bean at SUA (lower altitude)

influence as measured by path coefficients, P_{ij} . The direct effect of one variable upon another is the influence it has when other variables are held constant. The indirect effect, $r_{ij}P_{ij}$, is the effect one variable has on another through its influence on another variable. The path coefficients were obtained by the simultaneous solution of the following equations arranged in matrix notation, which express the basic relationships between correlation and path coefficients as shown below:-

$$\begin{aligned}
 r_{16} &= P_{16} + r_{12} P_{26} + r_{13} P_{36} + r_{14} P_{46} + r_{15} P_{56} \\
 r_{26} &= r_{12} P_{26} + P_{26} + r_{23} P_{36} + r_{24} P_{46} + r_{25} P_{56} \\
 r_{36} &= r_{13} P_{16} + r_{23} P_{36} + P_{36} + r_{34} P_{46} + r_{35} P_{56} \\
 r_{46} &= r_{14} P_{16} + r_{24} P_{26} + r_{34} P_{36} + P_{46} + r_{45} P_{56} \\
 r_{56} &= r_{15} P_{16} + r_{25} P_{26} + r_{35} P_{36} + r_{45} P_{46} + P_{56} \\
 1 &= P^2 X_6 + P^2_{16} + P^2_{26} + P^2_{36} + P^2_{46} + P^2_{56} + 2P_{16} \\
 &\quad r_{12} P_{26} + 2P_{16} r_{13} P_{36} + 2P_{16} r_{14} P_{46} + 2P_{16} r_{15} \\
 &\quad P_{56} + 2P_{26} r_{23} P_{36} + 2P_{26} r_{24} P_{46} + 2P_{26} r_{25} P_{56} \\
 &\quad + 2P_{36} r_{34} P_{46} + 2P_{36} r_{35} P_{56} + 2P_{46} r_{45} P_{56}
 \end{aligned}$$

The X variable consists of all residual factors that influenced grain yield, which include sampling errors.

Results and Discussion

Results of the present study show an appreciable amount of genetic variation for maturity characteristics, seed yield and components of yield in the bean varieties (Table 1). Similarly, locations differed significantly in all the variables except number of seeds per pod and yield efficiency. Drought which occurred up to flowering and podfilling affected yield potential of many varieties evaluated. Thus yield levels were low, with an overall mean yield of 572.7 kg/ha at SUA (low altitude) and 502.0 kg/ha at Mgeta (high altitude) (Table 2). The investigation clearly indicated superiority of early maturing varieties which were able to escape drought with consequent higher yields. Genetic variation for maturity characteris-

Table 1: Mean squares and coefficients of variation from the combined analyses of variance for 10 traits of 64 bean varieties grown at the location in Morogoro

Trait	Mean squares				
	Genotype	Locations	Lines x Locations	Error	CV %
Days to first flower	71.5**	3031.9**	12.9**	1.56	3.5
Days to 50% podfill	82.3**	9240.0**	11.7**	3.36	3.8
Days to 85% maturity	90.7**	14086.7**	20.5**	7.16	3.2
Reproductive period (days)	42.5**	4048.1**	20.3**	6.42	5.2
Podfill period (days)	36.7**	509.1*	13.8**	7.21	7.7
No. Pods/plant	11.2**	1293.0*	13.9**	3.71	32.2
No. Seeds/pod	2.2	6.1	0.5	0.55	20.4
Seed yield (kg/ha)	385274.4*	158115.6	221553.4**	130067.71	65.8
Harvest Index (%)	288.4	16539.1*	209.2**	101.99	26.7
Yield efficiency	65.8*	225.4	39.0**	21.84	69.9

*, ** $p \leq 0.05$ and 0.01 respectively

Table 2: Mean and overall range of maturity variables and components of yield of 64 bean varieties at two locations in Morogoro

Trait	Mgeta (High altitude)		Mafiga -SUA (Low altitudes)	
	Mean	Range	Mean	Range
Days to first flower	38.8	33.0 - 50.0	31.9	27.0 - 40.5
Days to 50% podfill	54.7	49.8 - 65.1	42.8	37.5 - 55.5
Days to 85% maturity	91.2	83.3 - 102.9	76.4	66.0 - 87.5
Reproductive period (days)	52.4	43.6 - 62.4	44.5	37.1 - 58.0
Podfill period (days)	36.5	29.7 - 46.1	33.5	26.0 - 46.5
No. Pods/plant	3.6	1.8 - 6.4	8.2	2.8 - 16.9
No. Seeds/pod	3.4	1.7 - 5.0	3.8	2.3 - 5.7
Seed yield (kg/ha)	502.0	208.9 - 844.4	572.7	59.4 - 2008.8
Harvest Index (%)	48.7	15.6 - 81.8	29.8	7.3 - 61.4
Yield efficiency (kg/ha/day)	5.5	0.9 - 9.4	7.6	0.013 - 29.6

tics has also been reported in other studies (White, 1989).

Farmers require bean varieties which can grow, flower and give reasonable yields within the limits of the existing farming system and the environment. It was generally observed that varieties took more days to mature in the cooler high altitude area (Mgeta) with consequent greater reductions in yield (Tables 2, 3, and 4). Such varieties might as well be poorly adapted to the cooler conditions thus affecting their overall performance. The difference in yield between the two locations was also reflected in the components of yield (number of pods/plant and seeds/pod) which were higher in the location with shorter maturity period. The significant G x E interaction observed for grain yield, components of yield and maturity traits suggests the necessity of testing for wide adaptability before recommending a variety. The findings are consistent with reports by Wallace (1985) that processes which regulate flowering and consequently

maturity, are slowed by fall in temperature.

Early maturing varieties had higher yields at both locations, probably due to the most efficient ideotype for high yield under moisture stress conditions. Their reduced number of leaves allows better light interception even by the lower leaves and better development of pods. Such varieties need to have an optimum duration of growth and a maximum efficiency of directing photosynthates to the seeds.

Correlation coefficients between traits are helpful in understanding the behaviour of the traits and are of value in selecting for the desired traits in any breeding programme. Genotypic correlations in particular, are important first in connection with the genetic causes of correlation, and secondly, in connection with the changes brought about by selection. Highly significant and positive genetic correlations among days to first

flower, days to 50% podfill and 85% maturity were observed at both locations indicating possible simultaneous selection for these maturity traits (Table 3). Days to first flower can therefore be an important characteristic which could be used in breeding for earliness. Cerna and Beaver (1990)

genetic correlation between days to first flower and days to physiological maturity in other populations of beans.

Number of pods per plant and yield efficiency could as well be used as a selection criterion for high yielding cultivars due to the significant and consistent ge-

Table 3: Genotypic (above) and phenotypic (below) correlation coefficients among maturity characteristics (days) of 64 bean varieties grown at two locations in Morogoro

Trait	2		3		4		5		6	
	SUA	MGETA	SUA	MGETA	SUA	MGETA	SUA	MGETA	SUA	MGETA
1. Seed yield	-0.49**	-0.64**	-0.51**	-0.71**	-0.30**	-0.49**	0.02	0.43**	0.26*	0.50**
	-0.26*	-0.16	-0.31*	-0.25*	-0.14	0.06	0.02	0.31*	0.20	0.46**
2. Days to first flower			0.93**	0.99**	0.66**	0.88**	0.03	-0.54**	-0.30*	-0.30*
3. Days to 50% podfill			0.93**	0.94**	0.64**	0.76**	0.04	-0.44**	-0.29*	-0.19
					0.76**	0.94**	0.23	-0.40**	0.24	-0.24
4. Days to 85% maturity					0.72**	0.80**	0.20	-0.30*	-0.26*	-0.22
							0.80**	-0.04	0.45**	0.16
5. Reproductive period (days)							0.79**	0.26*	0.48**	0.42**
									0.86**	0.77**
6. Podfilling period (days)									0.85**	0.86***

r = 0.25 P ≤ 0.05

r = 0.33 P ≤ 0.01

have also reported a positive and significant genetic correlations between these variables

Table 4: Genotypic (above) and phenotypic (below) correlation coefficients among seed yield and components of yield among 64 bean varieties at two locations in Morogoro

Trait	2		3		4		5	
	SUA	MGETA	SUA	MGETA	SUA	MGETA	SUA	MGETA
1. Seed yield	0.47**	0.46**	0.21	0.30*	0.61**	0.55**	0.09	0.83**
	0.76**	0.27**	0.32**	0.25**	0.84**	0.82**	0.08	0.26*
2. No. pods/plant			0.02	0.87**	0.55**	0.56**	-0.22	-0.24
			0.34**	0.35**	0.57**	-0.06	-0.14	0.12
3. No. seeds/pod					0.29*	-0.36**	0.16	0.28*
					0.28*	0.28*	0.29*	0.05
4. Yield efficiency							0.10	0.79**
							0.21	0.26*
5. Harvest index								

r = 0.25, P ≤ 0.05

r = 0.33, P ≤ 0.01

and yield. Several researchers have recommended the use of pods per plant as an indirect selection criterion for increasing yield (Sarafi, 1978).

Results suggest that the superiority in yield performance of the early maturing lines observed is reflected in the significant negative genetic correlations between yield and days to maturity at both locations. Similarly, increased seed yield potential can be realized through increased podfilling period. The findings however, indicate that earliness in flowering involves lengthening of the duration of podfill, suggesting that maintenance of yield potential should be achieved by increased rate of seed weight accumulation (yield efficiency in kg/ha/day) as results of this study indicate. A breeding programme has to identify superior parents with the desired architecture and a high rate of seed weight accumulation reflected in yield efficiency.

Path analysis (Table 5, Figs. 1 and 2) indicated that the consistently negative genetic correlation between days to first flower and yield was due to the negative direct effects of days to first flower on yield at both locations suggesting that holding other variables constant, increased days to first flower sacrifices yield. It is therefore important to consider the use of early flowering genotypes of the common bean if we are to realise increased yields at these locations with erratic and low rainfall.

The compatibility between days to first flower with the reproductive period was only observed at the higher altitude area suggesting that higher yields from genotypes which flower late will be realized if it takes longer from flowering to maturity. It seems therefore that days to flowering and the reproductive period are under the influence of similar conditions and factors.

The relationship between days to 50% podfill and yield was greatly sacrificed by an unfavourable interaction between the

former and days to flowering. This was in turn, attributed to the high and negative independent effect of days to flowering on yield. Thus, it is difficult to optimize yields under the marginal rainfall areas due to the detrimental effect of days to flowering has on yield. Judicial application of irrigation water or proper husbandry practices for dryland farming are suggested to improve these interrelationships. Flowering is a critical stage of plant development which if drought stress occurs before and or up to flowering, it will greatly reduce final yields. It seems that cool environments favour to a greater extent days to 50% podfill in its effect on grain yield although this independent contribution is made less rewarding by an incompatible influence through days to flowering.

Had it not been for the detrimental effect of days to flowering on yield, the relationship between days to maturity on yield would have been greatly improved. Thus, in order to improve the relationship between days to maturity with yield in these bean growing areas, it is paramount to ensure that favourable conditions for flowering are obtained during the growing cycle.

The reproductive period has its positive relationship with yield at the high altitude area due to its favourable interaction with days to flowering and the podfilling period. The high negative direct contribution of this variable on yield suggests that holding other variables constant, the reproductive period would have a detrimental effect on yield. Similarly, the reproductive period is incompatible with days to 50% podfill in this location due to the negative relationship of the reproductive period

Table 5: Direct and indirect effects of the maturity traits on yield at two locations in Morogoro

Effects	SUA (low altitude)	MGETA (high altitude)
Days to first flower on yield		
Genotypic correlation, r_g	-0.49**	-0.64**
Direct effect, P_{16}	-1.044	-4.823
Indirect via 50% podfill, $r_{12} P_{26}$	0.354	4.031
Indirect via 85% maturity, $r_{13} P_{36}$	0.114	-0.297
Indirect via reproductive period, r_{14}, P_{46}	0.002	0.828
Indirect via podfilling period, $r_{15} P_{56}$	0.083	-0.380
Total r_g	-0.491	-0.641
Days to 50% podfilling on yield		
Genotypic correlation, $r_g =$	-0.51**	-0.71**
Direct effect, P_{26}	0.381	4.072
Indirect via first flower, $r_{12} P_{16}$	-0.971	-4.775
Indirect via 85% maturity, $r_{23} P_{36}$	0.131	0.318
Indirect via reproductive period, $r_{24} P_{46}$	0.015	0.613
Indirect via podfilling period, $r_{25} P_{56}$	-0.066	-0.304
Total r_g	-0.510	-0.712
Days to 85% maturity on yield		
Genotypic correlation, $r_g =$	-0.30*	-0.49**
Direct effect, P_{36}	0.173	-0.337
Indirect via first flower, $r_{13} P_{16}$	-0.689	-4.244
Indirect 50% podfill, $r_{23} P_{26}$	0.290	3.828
Indirect via reproductive period, $r_{34} P_{46}$	0.051	0.061
Indirect via podfilling period, $r_{35} P_{56}$	-0.125	0.202
Total r_g	-0.300	-0.490
Reproductive period on yield		
Genotypic correlations, r_g	0.02	0.43
Direct effect, P_{46}	0.064	-1.533
Indirect via first flower, $r_{14} P_{16}$	-0.031	2.604
Indirect via 85% maturity, $r_{34} P_{36}$	0.088	-1.629
Indirect via podfilling period, $r_{45} P_{56}$	0.138	-0.013
Total r_g	-0.238	0.974
Podfilling period on yield		
Genotypic correlation, $r_g =$	0.26*	0.50**
Direct effect, P_{56}	-0.277	1.265
Indirect via first flower, $r_{15} P_{16}$	0.313	1.447
Indirect via 50% podfill, $r_{25} P_{26}$	0.091	-0.977
Indirect via 85% maturity, $r_{35} P_{36}$	0.078	-0.054
Indirect via reproductive period, $r_{45} P_{46}$	0.055	-1.180
Total r_g	0.260	-0.501
Residual, P_{66}	0.898	0.8161

with days to 50% podfill. However, in as much as components of yield are in a system of variable interrelations, the negative contributions were compensated to a positive and significant relationship with yield. Results clearly indicate that differences in environments give different paths of influence among the maturity variables.

It is only at the high altitude area where the paths of influence are significant on the relationship between podfilling period with yield. Both the genetic correlation and the direct contribution indicate the importance of podfilling period on yield at this location. These effects greatly compensated for the high and negative indirect

effects through days to 50% podfilling and the reproductive period to a positive relationship. The podfilling period seems to have good compatibility with days to first flower in this environment.

Conclusion

The present investigation indicates that bean varieties take longer to flower and mature in the cool high altitude areas with consequent reduction in yield. Regardless of the altitude in the Morogoro bean growing areas, early maturing varieties are important for higher yields. Among the components of yield studied, increased yields were realized through increased pod production and yield efficiency.

Acknowledgements

The financial assistance provided by SAREC and the Bean/Cowpea Collaborative Research Support Programme (CRSP) in the execution of this study is highly appreciated.

References

- Al-Mukhtar, F. and Coyne, D.P. 1981. Inheritance and association of flower, ovule seed, pod and maturity characters in dry edible beans (*Phaseolus vulgaris* L.). *J. Am. Soc. Hort. Sci.* 106(6) 713-719.
- Central International de Agricultura Tropical (CIAT). 1986. Stages of development of the common bean plant, study guide to be used as a supplement to the audio tutorial unit on the topic. Cali. Columbia CIAT, 32p (series 04EB-09.03).
- Cerna, J. and Beaver, J.S. 1990. Inheritance of early maturity of indeterminate dry bean. *Crop Sci.* 30: 1215-1218.
- Dewey, D.R. and Lu, K.H. 1959. A correlation and path coefficient analysis of components of crested wheat-grass seed production. *Agron. J.* 51: 515-518.
- Freed, R.D., Eisensmith, S.P., Reicosky, S.D., Smail, V.M., and Wolberg, P. 1988. Users guide to MSTAT-C1. A software programme for the design, management and analysis of agronomic research experiments, Michigan State University. pp230.
- Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research. John Wiley and sons. New York. 680pp.
- Izquierdo, J.A. and Hosfield, G.L. 1983. The relationship of seed filling to yield among dry beans with differing architectural forms. *J. Am. soc. of Hort. Sci.* 108(1): 106-111.
- Karel, A.K., Ndunguru, B.J., Price, M., Senguruka, S.H., and Singh, B.B. 1980. Bean production in Tanzania. In: Potential for field beans in Eastern Africa: Proceedings of a Regional workshop in Lilongwe Malawi. 226pp.
- Laing, D.R., Jones, P.G., and Davis, J.H.C. 1984. Common beans (*Phaseolus vulgaris* L.). In: P.R. Goldworthy and W. Fisher (ed.). The physiology of tropical field crops. John Wiley and Sons. New York.
- Sarafi, A. 1978. A yield component selection experiment involving American and Iranian cultivars of common bean. *Crop Sci.* 18: 5-7.
- Singh, R.K. and Chaudhary, B.D. 1985. Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi - Luthiana.
- Wallace, D.H. 1985. Physiological genetics of plant maturity, adaptation and yield. Dept. Ff Veg. Crops and of plant breeding and biometry, Cornell University, Ithaca, New York.
- White, J.W. 1989. Physiological aspects of earliness in common bean In: Beebe, S. (ed.). Current topics in breeding of common bean. Workshop document No. 47 pp. 156-181.
- Wright, S. 1921. Correlation and causation. *J. Agric. Res.* 20: 557-587.