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CORRELATION AND PATH-COEFFICIENT ANALYSIS OF COMPONENT OF AGRONOMIC CHARACTERS IN LIMA BEAN (*PHASEOLUS LUNATUS*)

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Abstract

Phenotypic variance, genotypic variance, genotypic-phenotypic variance ratio and environmental-genotypic variance ratio were estimated for 30 Lima bean accessions in Ghana. The characters studied were number of days to pod maturity, pod length, number of seeds per pod, 100-seed weight, number of pods per plant, seed width, seed length and seed yield per plant. A large proportion of the phenotypic variance of number of days to pod maturity (78%), pod length (99%), number of seeds per pod (99%), 100-seed weight (99%), number of pods per plant (60%), seed width (98%), seed length (95%) and seed yield per plant (87%) was attributable to genotypic differences among the accessions. Phenotypic and genotypic correlations were of the same sign in all cases. Correlations among number of pods per plant was significantly and negatively correlated with number of days to pod maturity ($P < 0.05$), pod length ($P < 0.001$), 100-seed weight ($P < 0.001$), seed width ($P < 0.001$) and seed length ($P < 0.001$). Number of days to pod maturity and number of seeds per pod had a positive direct relationship with seed yield per plant. Pod length, number of pods per plant, 100-seed weight, seed width and seed length had negative direct effect on seed yield per plant. There was significant correlation between seed size and the other characters, thus, suggesting possible pleiotropic effects of genes controlling seed size and these other characters. Selection for high seed yield per plant through high number of days to pod maturity would result in reasonably high seed yield per plant without sacrificing pod length, seed per pod, seed weight and seed width. High number of days to pod maturity would mean that the plant would stay longer in the soil to increase soil fertility as a result of nodulation. Therefore, there is the double benefit of soil fertility and high seed yield.

Introduction

Lima bean (*Phaseolus lunatus* L.) is the most important food legume within the neotropical genus *Phaseolus* (Baudoin *et al.*, 1991). In Ghana it is the fourth in importance after cowpea, groundnut and bambara groundnut in that order (Doku, 1977), while in Nigeria it is second in importance to cowpea (FAO/CTTA. 1958). In tropical Africa the crop is interplanted with crops such as maize, sorghum, sweet potatoes, coffee, cotton and yams. The crop is hardy and may be advantageous in adverse conditions where other leguminous vegetables do not prosper (FAO, 1984).

Pod yield is a quantitative character, which is largely influenced by the environment and, therefore, has a low heritability. As a result, the response to direct selection for pod yield may be unpredictable, unless there is good control of environmental variation. Plant breeders are normally interested in more than one trait and, therefore, it is necessary to examine the relationships among various characters, especially between yield and other traits. As the number of independent variables influencing a particular dependent variable is increased, a certain amount of interdependency is expected. In such situations, correlations may be insufficient to explain the associations in a manner that will enable breeders to decide either a direct or an indirect selection strategy (Singh & Singh, 1979).

Path-coefficient analysis provides a method of separating direct and indirect effects and measuring the relative importance of the causal factors involved. Several researchers have used this method to assess the importance of yield components (Sukchain & Sidhu, 1992; Pathirana, 1993; Ofori, 1996).

Crossing to improve lima bean is a difficult task due to the small nature of the flowers. The main objective of the study was to use correlation and path-coefficient analysis to examine the relationships between seed yield per plant and the following yield components: seed per pod, seed weight, seed width, seed length, pod length, pod per plant and days to pod maturation. This is to enhance Lima bean improvement through selection.

Experimental

The accessions were grown at the University of Ghana farm, Legon. Each entry had two rows per replication and each row was 5.0 m long. The rows were 50 cm apart and plants within a row were 30 cm apart. Two seeds were planted per hill and thinned out to one plant per hill at 10 days after seedling emergence. A randomized complete block design with three replications was used.

The plots were weeded at 3 weeks after seedling emergence and again 3 weeks later. Supplementary irrigation was provided by manual watering when necessary. Pods were harvested between 100 and 120 days. The following data were collected: days to pod maturation, pod length (cm), number of seeds per pod, number of pods per plant, 100-seed weight (g), seed width (cm), seed length (cm), and seed yield per plant (g).

Analyses of variance were performed using the PROC GLM procedure with MANOVA option of SAS/STAT (SAS, 1987). Phenotypic and genotypic correlation coefficients were calculated from the variance and covariance components. The estimates of the genetic correlation coefficients, r_g, for any two traits, x and y, are defined as:

$$r_g = COV_{xy}/s_x s_y,$$

where COV_{xy} is the genotypic covariance of the two characters, and $\sigma_{x \text{ and }} \sigma_y$ are the genotypic standard deviations (Falconer, 1989). In a similar manner the phenotypic correlation r_{ph} can be obtained. Phenotypic variance, genotypic variance, error variances and broad sense heritabilities were also estimated. Path coefficient analysis was performed with PROC CALIS procedure of SAS/STAT (SAS, 1987).

Results and discussion

Genotypic and phenotypic variances and ratios of genotypic and error variances to the phenotypic variances are shown in Table 1. A large proportion of the phenotypic variance of days to pod maturation (78%), pod length (99%), seeds per pod (99%), 100-seed weight (99%), pods per plant (60%), seed width (98%), seed length (95%) and seed yield per plant (87%) was attributable to genotypic differences among the accessions.

Genotypic and phenotypic correlation coefficients are listed in Table 2. In about 28.6 per cent of cases, genotypic correlations were higher than phenotypic correlations. Phenotypic and genotypic correlations were of the same sign in all cases. Correlations among pods per plant was significantly and negatively correlated with days to pod maturation ($P < 0.05$), pod length ($P < 0.001$), 100-seed weight ($P < 0.001$), seed width ($P < 0.001$) and seed length ($P < 0.001$). However, the relatively low genotypic variance of pod per plant was reflected in the low values of genotypic correlations involving number of pods per plant.

Estimates of direct and indirect effects of the yield characters on seed yield per plant are shown in Table 3.With the correlation coefficient

TABLE 1

Genotypic (σ^2_g), phenotypic (σ^2_p) variances and variance ratios of seed yield and other characters

Character	(σ^2_g)	(σ^2_p)	(σ^2_g)/(s^2_p)	(σ^2_e)/(σ^2_g)
Number of days to pod maturation	160.54	207.16	0.78	0.22
Pod length (cm)	2.30	2.32	0.99	0.01
Number of seeds per pod	1.73	1.76	0.99	0.01
Number of pods per plant	112.03	186.92	0.60	0.40
100-seed wt (g)	337.02	339.32	0.99	0.01
Seed width (cm)	0.048	0.049	0.98	0.02
Seed length (cm)	0.138	0.146	0.95	0.05
Seed yield per plant (g)	699.70	803.04	0.87	0.13

partitioned into its components, one can clearly see what is contributing to the observed correlation. Days to pod maturation had a positive direct relationship with seed yield per plant, and this positive direct effect could not be masked by the indirect negative cumulative effects through pod length, number of seeds per pod, 100-seed weight and seed width. A negative influence of days to pod maturation was present through pod length, number of seeds per pod, seed weight and seed width on seed yield per plant. However, the indirect effects through number of pods per plant and seed length were positive. Pod length had a negative direct effect on seed yield per

TABLE 2

Genotypic (below) and phenotypic (above) correlations among the agronomic characters studied

Character	*Days to pod maturation*	*Pod length*	*Seeds per pod*	*Pods per plant*	*100-seed weight*	*Seed width*	*Seed length*	*Seed yield per plant*
Days to pod maturation		0.678***	-0.229*	-0.396*	0.706***	0.658***	0.690***	0.173
Pod length	0.776		-0.231*	-0.459**	0.920***	0.876***	0.930***	0.124
Seeds per pod	-0.327	-0.116		0.305*	-0.315*	-0.371*	-0.308*	-0.005
Pods per plant	-0.365	-0.395	0.260		-0.449**	-0.345*	-0.417**	-0.116
100-seed weight	0.795	0.929	-0.387	-0.629		0.906***	0.950***	0.102
Seed width	0.743	0.100	-0.468	-0.297	0.926		0.956***	0.041
Seed length	0.775	0.938	-0.389	-0.358	0.958	0.973		0.085
Seed yield per plant	0.173	0.091	0.008	-0.083	0.056	0.065	0.068	

TABLE 3
Path coefficients showing direct and indirect effects of the six agronomic characters on seed yield per plant

Character	*Direct effect*	*Indirect effect via*							*Total correlation with seed yield per plant*
		Days to pod maturation	*Pod length*	*Seed per pod*	*Pod per plant*	*100-seed weight*	*Seed width*	*Seed length*	
Days to pod maturation	0.2302	-	-.0181	-.0080	0.0106	-.0346	-.0320	0.0351	0.173
Pod length	-.0267	0.1561	-	-.008	0.0123	-.0451	-.0426	0.0452	0.091
Seed per pod	0.0364	-.0527	0.006	-	-.008	0.0154	0.0180	-.0112	0.008
Pod per plant	-.0267	-.0912	0.0123	-.0111	-	0.0154	0.0180	-.0112	-.083
100-seed weight	-.0490	0.1625	-.0246	-.0115	-.0120	-	-.0440	0.0346	0.056
Seed width	-.0486	0.1515	-.0234	-.0135	0.009	-.0444	-	0.0346	0.065
Seed length	0.0364	0.1588	-.0248	-.0112	0.0111	-.0466	-.0465	-	0.068

plant. There were positive indirect effects through number of days to pod maturity, number of pods per plant and seed length. The direct positive effect of number of seeds per pod was maintained as a result of the indirect positive effects of pod length, seed weight and seed width.

Number of pods per plant had a negative direct effect but positive indirect effects through pod length, seed weight and seed width. Seed weight had a direct negative effect on seed yield per plant. However, this direct negative effect was masked by the indirect positive effects through number of days to pod maturity and seed length. Seed width had a direct negative effect on seed yield per plant but indirect positive effect through number of days to pod maturation, pod per plant and seed length. Seed length had a direct negative effect on seed yield per plant and there were indirect positive effects through number of days to pod maturity and number of pods per plant. Total correlation between seed yield per plant and the other seven characters was low. If correlation coefficient is positive, but the direct effect is negative or negligible, then the indirect effects seem to be the cause of correlation. In such situations, the indirect causal factors are to be considered simultaneously for selection (Singh & Chaudary, 1977). Therefore, selection for high seed yield per plant through direct selection for pod length, 100-seed weight, and seed width would be ineffective because of the cumulative restriction imposed indirectly by the causal factors involved. Therefore, there would be the need to examine germplasm and hope for the possibility of rare recombinants with a positive relationship between seed yield per plant and pod length, 100-seed weight and seed width.

From the results, selection for high seed yield per plant, through high number of days to pod maturation, would result in reasonably high seed yield per plant without sacrificing pod length, seed per pod, seed weight and seed width. Lima bean is one of the highly nodulating leguminous crops, therefore, high number of days to pod maturity would mean that the plant would stay longer in the soil to increase soil fertility as a result of nodulation. There is therefore, the double benefit of soil fertility and high seed yield. The positive indirect effect of number of days to pod maturity was high and almost equal to the degree of relationship between seed yield per plant and pod length, seed weight, seed width and seed length.

The large ratios of genotypic to phenotypic variances for number of days to pod maturity, pod length, number of seeds per pod, 100-seed weight, seed width, seed length, number of pods per plant and seed yield per plant indicate that these characters are highly heritable and that differences between accessions are real. Genetic correlation is the correlation between the additive breeding values for two traits or between the sum of additive effects of the genes influencing the two characters (Legates & Warwick, 1990). Genotypic correlations are mainly attributed to pleiotropic effects of individual genes and,or linkage between gene segments (Gallais, 1984). The observed strong correlations among the seed characters studied can, therefore, be attributed to either linkage and,or pleiotropy. This can be investigated by linkage studies using mapping populations of Lima beans. The physiological reasons for the significant negative correlation between number of days to pod maturity, number of seeds per pod and number of pods per plant cannot be easily explained. Seed length, seed width and seed weight were significantly and positively correlated with days to pod maturation. Therefore, accessions with additive breeding values for large seed size require more days to produce mature pods.

From the results, seed yield per plant is genetically controlled, however, there were no significant close relationships between seed yield and the other yield characters. This implies that seed yield cannot be selected for by using these traits. The significant correlation between seed size and the other characters suggests possible pleiotropic effects of genes controlling seed size on the other characters. Seed size and these characters are quantitative traits, and hence, may be controlled by several loci. The more the loci involved, the greater the chances of linkages. Such linkages could be broken through the intercrossing of segregating families. Since crosses are not available yet, other breeding strategies should rather be considered. Examination of other local accessions as well as accessions from other African countries, would throw more light on the influence of seed size on these characters.

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