International Journal of Agricultural Policy and Research Vol.4 (4), pp. 62-66, April 2016
Available online at http://www.journalissues.org/IJAPR/
http://dx.doi.org/10.15739/IJAPR.16.009
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ISSN 2350-1561

Original Research Article

Genetic variability and heritability of seedling vigour in common beans (*Phaseolus vulgaris* L.) in sudan savanna

Received 9 March, 2016 Revised 7 April, 2016 Accepted 11 April, 2016 Published 21 April, 2016

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Phaseolus vulgaris **L. is a major source of protein in the world and Africa. Seedling vigour is an important aspect in the early life of common bean. Two experiments were carried out to examine variations in seedling vigour and the effectiveness of emergence (E %), emergence index (EI), emergence rate index (ERI), growth rate (GR) and relative growth rate (RGR) among 5** ***Phaseolus*** **accessions. For each experiment, accessions were laid out in randomized complete block design with three replications. Significant differences were observed for E%, ERI, GR and RGR in accessions, environment and the interaction between accessions and environment, suggesting that selection for further improvement is possible due to the large variability present. Accession 2 had the highest E%, all accessions had about the same ERI value. Accession1 had the highest GR while accession 4 recorded the lowest GR.Accessions 2 and 5 had highest values for RGR, while accession 4 maintained the lowest RGR value. Genotypic and phenotypic variances were generally high for E%. High heritability values for E%, EI and RGR were observed. The results of the study indicates the potential of** ***Phaseolus*** **cultivation in the Sudan Savanna and a good establishment of the plants**.

Key words: Emergence, genotypic, heritability, phenotypic, variances

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is a dicotyledonous plant that belongs to the family Fabaceae. The species evolved from a wild-growing vine ancestor in the highlands of Middle America and the Andes (Gepts and Debouck, 1991). Middle America is the origin of races Durango, Jalisco, and Mesoamerica, and the Andes is the origin of races Chile, Nueva Granada, and Peru (Singh et al., 1991).

Seed vigour is an important quality parameter which needs to be assessed to supplement germination and viability tests to gain insight into the performance of a seed lot in the field or in storage. Several factors like; genetic constitution, environment and nutrition of mother plant maturity at harvest, seed weight and size, mechanical integrity, deterioration and ageing and pathogens are known to influence seed vigour (Perry, 1984). High germinating seed lots may differ substantially in field emergence when sown at the same time in the same field, and/or may differ in performance after storage in the same environment or transport to the same destination. The questions that must be asked when looking at the germination data for these seed lots are: "Were the germination results wrong?" and "Why the difference in performance?" The answer to the first question is no, the germination results were correct. The answer to the second question is that it has become apparent that the germination test is not sensitive enough to indicate subtle but significant quality differences among high germinating seed lots. These differences are caused by another component of seed quality known as seed vigour (ISTA, 1995).

This work compares the variability in seedling vigour among selected *Phaseolus* accessions to give an insight into their performances in Sudan savanna. The results will serve as a basis for understanding the extent of variability in vigour of seeds and its importance to the early life of *Phaseolus* seedlings in Sudan savannas. The objective of this

Table 1. Expected Mean Squares for *Phaseolus* Accessions

Source of Variation	Df	MS	EMS
Environment (E)	1	MSl	$\delta^2 e + r\,\delta^2 g{*}l + g\,\delta^2 l$
Accession (A)	4	MSg	$\delta^2 e + r\,\delta^2 g{*}l + l\,\delta^2 g$
E*A	4	MSgl	$\delta^2 e + r\,\delta^2 g{*}l$
Error	16	MSe	$\delta^2{}_e$

MSl: environment mean square, MSg: accession mean square, MSgl: mean square for environment X accessions, MSe: error mean square, δ^2 e: environmental variance, δ^2 g: genotypic variance, r: replication, l: environment

study was therefore, to evaluate the genetic potential of *Phaseolus* establishment in Sudan savanna.

MATERIALS AND METHODS

Two experiments were carried out. The first experiment was carried out at the plants nursery (11.975°N, 8.429°E) and the second, at the Research and Teaching Farm (11.980N°, 8.420°E) of Department of Agronomy, Faculty of Agriculture, Bayero University, Kano.

For each experiment, five *Phaseolus* accessions (accessions 1 to 5) were used and planted in a Randomized Complete Block Design. One hundred seeds of each accession, replicated three times, were planted on seed beds measuring 1m × 1m, with spacing of 0.1m between seedlings and 0.3m between blocks and between replications. A total of 15 beds were used for the experiment. Seeds were sown on 23rd June, and 15th September, 2015, under rainfed condition and irrigation was done when necessary.

Emergence counts were carried out 5, 7 and 9 days after planting (DAP). The data obtained was used to compute Emergence Index (EI) according to the formula of Smith and Milett (1964) and Fakorede and Ojo (1981);

$$EI = \sum \frac{(plants\ emerged\ in\ a\ day)(days\ after\ planting)}{plants\ emerged\ by\ 9\,DAP},$$

The total number of seedlings that emerged at 9 DAP was also expressed as a percentage of seeds planted to obtain emergence percentage (E %).

$$E\% = \frac{seedlings\ emerged\ by\ 9DAP \times 100}{Seeds\ planted}$$

A third index, the emergence rate index (ERI) was calculated by expressing EI as a proportion of E% i.e.

$$\text{Emergence Rate Index (ERI)} = \frac{EI}{E\%}$$

Emergence rate index (ERI), estimates the number of days it would take for 100% emergence to occur, assuming other factors are not limiting.

From 9 days after planting, 5 seedling samples were collected from each block at 4 days intervals until 29 DAP to give a total of 6 samples from each block. Samples were oven dried to constant moisture content at 80°C and weighed. Dry matter per plant (W_1 to W_6) was used to estimate growth rate (GR) and relative growth rate (RGR) for 5 sampling intervals using the formulae (Radford, 1967).

$$GR = \frac{(W_n + 1 - \ln W_n)}{(tn+1-tn)}\ \mathrm{mg/day}, \text{ and}$$

$$RGR = \frac{(\ln W_n + 1 - \ln W_n)}{(tn+1-tn)}\ \mathrm{mg/day}, \text{ which was modified to;}$$

$$RGR = \frac{((\ln W_n + 1) - \ln W_n)}{((tn + 1) - tn)}\ \mathrm{mg/day}$$

Where n = sampling number; n = 1, 2, 3.....5

W = dry matter per plant (in mg), and

t = number of days after planting;

$\ln W_n$ = log transformation of dry matter weight.

Analysis of variance (ANOVA) for randomized complete block design was performed using SAS 9.4 (2015) for each trait and the expectations of mean of squares from the ANOVA tables (Table 1) were used in the estimation of environmental variance (δ^2e), genotype × environment interaction variance (δ^2ge) and genotypic variance (δ^2g).

Genotypic and phenotypic coefficients of variation were calculated by the formula suggested by Burton and Devane (1952).

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\delta g}{m} * 100$$

Where δg= genotypic standard deviation and m= population mean

$$\text{Phenotypic Coefficient of variation (PCV)} = \frac{\delta p}{m} * 100$$

Where δp = Phenotypic standard deviation and m= population mean

GCV and PCV values were categorized as low (0-10%), moderate (10-20%) and high (>20%) as indicated by Siva Subramanian and Menon (1973).

Heritability in broad sense (H^2) was calculated as a ratio of genotypic variance to the phenotypic variance (Hanson et al., 1956).

$$H^2 = \frac{\delta^2 g}{\delta^2 p} * 100$$

Where,

δ^2 g = genotypic variance

δ^2 p = phenotypic variance

The heritability percentage was categorized as low (0-20%), moderate (30-60%) and high (>60%) as given by

Table 2. Mean Square Effects of *Phaseolus* Seedling Vigour Traits

Source of Variation	Df	E%	EI	ERI	GR	RGR
Rep	2	148	0.17	0.00016	0.23	0.25
Environment (E)	1	4320**	0.31	0.0023*	4.96*	15.11**
Accessions (A)	4	1161**	0.15	0.0011**	2.84**	0.66**
E*A	4	897**	0.08	0.00098**	3.27**	0.04*
Error	16	94	0.08	0.00008	0.21	0.08

Rep: replications, E%: emergence percentage, EI: emergence index, ERI: emergence rate index, GR: growth rate, RGR: relative growth rate.

Table 3. Mean Performance for Some Traits of Different Accessions of *Phaseolus*

Accession	E%	EI	ERI	GR	RGR
Accession 1	82.17	2.44	0.030	2.31	1.16
Accession 2	86.17	2.56	0.030	2.25	1.17
Accession 3	82.33	2.78	0.034	2.28	1.14
Accession 4	54.17	2.41	0.063	1.63	0.86
Accession 5	64.17	2.38	0.039	2.17	1.17
Level of Significance	**	NS	**	**	**
Environment (E)					
E1	61.8	2.41	0.05	2.29	0.81
E2	85.8	2.61	0.03	1.96	1.39
Level of Significance	**	NS	*	*	**

E%: emergence percentage, EI: emergence index, ERI: emergence rate index, GR: growth rate, RGR: relative growth rate, NS: Not Significant

Robinson et al. (1949).

RESULTS

The mean square effects of some agronomic traits for *Phaseolus* are presented in Table 2. There was highly significant difference (P<0.01) in emergence percentage (E %) for the environments, accessions, and interactions between environments and accessions. No significant difference (P>0.05) was observed in emergence index (EI) for environments, accessions and interaction between environments and accessions. Significant difference(P<0.05) was observed in emergence rate index (ERI) for environments, and highly significant difference (P<0.01) for accessions and interaction between environments and accessions for ERI. Significant difference (P<0.05) in growth rate (GR) was observed for environments and highly significant difference (P<0.01) for accessions and interactions between environments and accessions. Highly significant difference (P<0.01) was observed in relative growth rate (RGR), for environments while accessions and significant difference (P<0.05) was observed for interaction between environments and accessions.

The mean performances of some agronomic traits for *Phaseolus* are presented in Table 3. There was a highly significant difference (P<0.01) between accessions for all traits evaluated except for EI which showed no significant difference. Accession 3 however, gave the highest value for EI (2.78), while accession 5 gave the lowest EI value (2.38).

Highly significant differences (P<0.01) between the two environments were observed for E%, and RGR. Significant differences (P<0.05) were obtained for ERI and growth rate GR, while there was no significant difference for EI between the two environments. However, environment 2 gave a higher value (2.61) for EI when compared to environment 1 which gave a lower value (2.41).

The estimation of some genetic parameters for evaluated accessions is presented in Table 4. There were low values for environmental variance (VE), genotypic variance (VG), phenotypic variance (VP) and interaction between environmental and genotypic variances (VGE).However, among the traits, GR had the highest values for VE(0.21), VG (0.44), VGE (1.02) and VP (0.65), while the lowest values for VE (0.0001), VG (0.0002), VGE (0.0003) and VP (0.0003) were observed in ERI. There was no VGE value for EI, while RGR had a negative VGE value. There were high broad sense heritability (h^2B) values for E % (62%), ERI (61 %) and RGR (91 %), while moderate h^2B values were obtained for EI (46 %) and GR (53 %).

High values for genotypic coefficient of variability (GCV) were obtained for ERI (33 %), GR (31 %) and RGR (28 %). Moderate values for GCV were obtained for E % (18 %), while low values for GCV were obtained for EI (4 %).High phenotypic coefficient of variability (PCV) values were obtained for E % (22%), ERI (40%), GR (38 %) and RGR(39%), while a moderate PCV value was obtained for EI

Table 4. Estimation of Genetic Parameters for *Phaseolus* Accessions

	VE	VG	VGE	VP	H	GCV	PCV	GCV%	PCV%
EI%	94	178	267.7	272	0.63	0.18	0.22	18	22.34
EI	0.08	0.012	0	0.1	0.47	0.04	0.12	4.30	12.06
ERI	0.0001	0.0002	0.0003	0.0003	0.62	0.33	0.40	32.60	39.53
GR	0.21	0.44	1.02	0.65	0.54	0.31	0.38	31.08	37.80
RGR	0.08	0.10	-0.013	0.18	0.92	0.29	0.39	28.79	38.92

E%: emergence percentage, EI: emergence index, ERI: emergence rate index, GR: growth rate, RGR: relative growth rate, VE: environmental variation, VG: genotypic variation, VP: phenotypic variation, VGE: genotype X environment variation, H: heritability, GCV: genetic coefficient of variability, PCV: phenotypic coefficient of variability

(12%).

DISCUSSION

Highly significant differences have been observed for E%, ERI, GR and RGR, indicating that each accessions performed differently for the five traits in the two environments. The highly significant differences among the accessions for the four traits (E%, ERI, GR, and RGR) suggests therefore that selection for these traits among the *Phaseolus* accessions for further improvement is possible due to large variability resulting from the diverse genetic backgrounds of those *Phaseolus* accessions. Differences between environments might have been due to differences in soil properties such as soil organisms, soil nutrient content, and soil drainage as observed by Ajala, et al. (2003). The highly significant genotype × environment variance for the traits (E%, ERI and GR) and the significant genotype × environment variance for RGR indicate that these traits have been influenced by differences in the two environments used for this study. There was no significant difference in EI, for all sources of variation. This is in agreement with the findings of Ajala, et al*.* (2003) and Adebisi et al.(2010), who reported no significant difference in EI for cowpea and rice respectively, in similar studies.

There were highly significant differences between the five accessions for four traits (E%, ERI, GR and RGR), while there was no significant difference among them for EI. This suggests that selection for these traits is possible among genotypes due to variability in these traits. Crop improvement depends on the magnitude of genetic variability present in the base population, as suggested by Ajala et al*.* (2003). Also this indicates that *Phaseolus* beans have potentials in the Sudan Savanna zones.

The highly significant differences in E% and RGR, and the significant differences in ERI and GR between the two environments, suggest that the performances of accessions with respect to these traits are highly affected by the environment and environment itself may trigger further variation in those accessions that may be beneficial to evolution of those traits in Sudan.

There were low values for environmental (VE), genotypic (VG), and phenotypic variance (VP) of four traits (EI, ERI, GR and RGR). The relatively higher VG values, however, suggest that VG contributed higher to VP than VE and the good ERI observed areas a result of the genetic potential of the accessions in Sudan Savanna. Interactions between genotypic and environmental variances (VGE) gave higher values for all traits except EI. This suggests that the accessions were affected by environmental effect and this increases variability in some of the traits except for EI. There were however high VE and VP values for E% which suggests that E% of accessions are highly variable and highly influenced by the environment. This means that individual accessions responded differently to environmental variations with regards to emergence. This was in accordance with the suggestion of Fakorede and Ojo (1981) who indicated that percentage and rate of seedling emergence are influenced more by environment than the genetic constitution of maize plants, and also the findings of Pinthus and Kimel (1979) who concluded that differences in rate of germination of soybeans were not heritable. There were also high broad sense heritability (h^2B) values for four traits (E%, EI, ERI, and RGR) and moderate broad sense heritability values for GR. This indicates that the four traits are highly transferable and hence the accessions can be used for selection and further improvement, while GR has somewhat less transferability. This is in agreement with the findings of Adebisi et al*.* (2013), who reported high broad sense heritability (h^2B) values for E% and moderate h^2B values for GR while working on maize, but in disagreement with the findings of Pinthus and Kimel (1979), who reported that rate of germination in Soybean is not heritable. It can be inferred from the moderate heritability values for GR that this trait is moderately governed by the genotype, with the environment having a significant contribution to it. There were high values for genetic and phenotypic coefficients of variability (GCV and PCV) for all traits (EI, ERI, GR and RGR) except for E% which had a moderate GCV value. This suggests that E% has a relatively lower genotypic influence and relatively higher environmental influence. The PCV was generally higher than GCV for all traits. Johnson (1995) has however noted that improvement efficiency is related to magnitude of GCV and heritability.

The study showed that seedlings of different varieties may differ substantially with respect to traits which affect seedling vigour, and also differ in their abilities to transfer such traits. Hence the possibility of improving seeds for increased vigour can be ascertained through such studies. Highly significant differences in individual performances of tested accessions as well as highly significant differences in their interactions with the environment indicate high variability which is the backbone of any breeding programme. Also the good adaptation they have shown to the savanna agro-ecological zone indicates the possibility of further cultivation within the zone.

Competing interests

The authors declare that they have no competing interests

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