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Full Length Research Paper

Yield stability in common bean genotypes (*Phaseolus vulgaris* L.) in the Sudan

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Common bean is an important food legume crop in Sudan. Drought and heat stress are considered the main factors responsible for low productivity. Nine common bean genotypes were evaluated for yield stability under different sowing dates and watering regimes in three field experiments conducted in the River Nile State-Sudan during 2003 to 2006. 10 test- environments were thus achieved, representing the combined effect of drought and heat stress. Stability analysis (Eberhart and Russel model) was performed to identify the most yield-stable bean lines under limited moisture and temperature stress. The genotypes Bellenber-1, COWU-3-94-9, S/Hashim/98 and the small seeded genotype DB 190-74-1, appeared to be the most stable. It was concluded that these genotypes can be used to improve common bean tolerance to drought and heat stress conditions in the Sudan.

Key words: Drought tolerance, heat stress, Hudeiba, River Nile.

INTRODUCTION

In Northern Sudan, the common bean (*Phaseolus vulgaris* L.) is normally cultivated under residual moisture in basins and islands after recession of the Nile flood. In addition, relatively large areas are also grown under irrigation. The average productivity under farmers' field ranging between 0.5 and 1 ton/ha. However, this yield level is lesser than the yield potential (1.5 ton/ha) of this crop. Acreage planted to common bean is chiefly governed by the amount of the flood, market prices and competence with other crops. Shendi and Berber are the major producing areas of common bean in the Sudan, where more than 90% of the crop is produced. Drought and heat are the main factors limiting bean production in east, central and southern Africa causing losses of more than 395000 tons each year. Limited water availability to the crop can be due to physical and climatic factors, the soil-precipitation relationship, the soil-plant relationship, excessive demand by the plant, or any combination of these factors. These multiple constraints often act concurrently with considerably negative effects on the quantity and quality of crop product (Amede et al., 2004). The rate of temperature change, and the duration and degree of high temperatures, all contribute to the intensity of heat stress (Smith and Pryor, 1962). The high temperatures may last for hours during a specific time of the day and /or night, or they may occur for several consecutive days, possibly repeated throughout the growing season (McWilliams, 1980).

The wide occurrence of genotype x environment interaction (GEI) is the basic cause of difference between genotypes in their yield stability, or in other words: ranking of the genotype depends on the particular

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environmental conditions where it is grown. Numerous stability parameters have been developed to investigate GEI (Huehn, 1990). Parametric stability statistics obtained by linear regression models (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Shukla, 1972) are mathematically simple and biologically interpretable, however, few researchers use statistical measures of yield stability in their breeding programs. The objectives of this study were therefore to identify the most stable bean lines under limited moisture and temperature stress using Eberhart and Russell (1966) regression model.

MATERIALS AND METHODS

Two field experiments were conducted in the experimental Farm of Hudeiba Research Station (HRS), River Nile State, Sudan. HRS is located at latitude 17° 34´ N, longitude 33° 56´ E, and altitude of 350 m. above sea level. The climate of the locality was described as semi-arid (Bebawi and Neugebohrn, 1991) with relatively cool and short winter season. Each experiment was grown for three consecutive seasons (2003/2004, 2004/2005 and 2005/2006). Unfortunately, the crop of the two experiments in season 2004/2005 showed symptoms of diseases and complete sudden death occurred. Maximum and minimum temperatures for the remaining two growing seasons (2003/2004 and 2005/2006) are shown in Figures 1 and 2, respectively.

In Experiment 1, two water regimes were used: watering every 10 days (W1) commencing from the third irrigation throughout the growing season and watering every 20 days starting after complete germination (W2) throughout the growing season. The amounts of irrigation water applied and consumed were determined by measuring the moisture content of the soil (Table 1). Nine genotypes were tested in this study and were grouped according to their seed size; small (<24 g/100 seed.), medium (25 to 35 g/100 seed) and large (>39 g/100 seed). Morphological description of the nine genotypes is shown in Table 2. In Experiment 2 the same nine genotypes were tested at three sowing dates namely; early planting (SD1) Ist October, optimum or recommended planting date (SD2) 30 October and Late planting (SD3) 30 November. The design used in each experiment was the split plot with three replicates. Each replication consisted of two main plots for Experiment 1 and three main plots for Experiment 2. The nine genotypes were randomly assigned within water regimes and sowing dates (main plots). Each sub plot consisted of two rows, 6.0 m long and 60 cm apart. Sowing was on both sides of the ridge at a rate of three seeds per hole with intra row spacing of 20 cm between plants. Plants were thinned to two plants / hole after two weeks from germination. Analysis of yield stability (Eberhart and Russel, 1966) over the ten macro-environments (seasons × water treatments and season × sowing dates) was carried out for the nine genotypes. The statistical package Agrobase Gen II (2008) was used to run the analysis.

RESULTS

Mean squares from combined analysis of variance over the 4 watering (W), 6 sowing dates (SD) and the 10 environments (W+SD) are presented in Tables 3, 4, and 5, respectively. In all environments, differences among genotypes for grain yield were highly significant. Genotype by environment interaction was also significant. Table 6 shows the performance of the nine genotypes under different water regimes (water regimes ×season). The large seeded genotypes, namely, Ibarya and S/Hashim/98 showed the lowest deviation from regression and a slope (bi) close to 1.0. The varieties Giza 3 and Turki-2 ranked top in seed yield, with above unity regression coefficient (bi = >1.2).

Under heat stress (Table 7), the medium seeded genotype Bellenber-1, gave seed yield (1099 kg/ha) higher than the average (1051 kg/ha), regression coefficient (bi) around 1.0 and non-significant deviation from regression ($\bar{s}d^2$). The large seeded genotype S/Hashim/98, showed regression coefficient close to unity, non–significant deviation from regression with below average seed yield (890 kg/ha).

On the basis of the 10 macro-environments created by 2 watering regimes × 2 seasons + 3 sowing dates × 2 seasons (Table 8), the genotypes Bellenber-1, S/Hashim/98 and the small seeded genotype DB 190-74-1, ranked fourth, sixth and eighth in seed yield, respectively. However, it should be noted that these genotypes exhibited low values of regression coefficient (bi ≤ 1) and the smallest deviation from regression (non-significant $\bar{s}_d^2$). The genotype COWU-3-94-9 showed the same trend as it gave a good seed yield (1011 kg/ha), bi around the unity (0.9592) and to some extent large deviation from regression.

DISCUSSION

The development of high yielding cultivars with wide adaptability is the ultimate aim of plant breeders. However, attaining this goal is more complicated by genotype-environment interaction (GEI). In this study, although the observed differences among genotypes for seed yield could be largely attributed to genetic effects (P< 0.00), yet the GEI was also significant indicating that some genotypes showed differential response in seed yield across environments, hence, the need to perform stability analysis to investigate which of these genotypes have better adaptability or stability under the studied environments. According to the definition of Eberhart and Russell (1966), a stable preferred variety would have approximately bi =1, ($\bar{s}d2$ = 0) and a high mean performance. However, Lin et al. (1986), Paroda et al. (1973) and Johnson et al. (1955) considered the squared deviation from regression as a measure of stability, while the regression was regarded as a measure of response of a particular genotype to environmental indices.

In the present study, under the two moisture environments created by different watering regimes, the large seeded genotypes, namely, Ibarya and S/Hashim/98 were considered stable under moisture stress environments, as they showed the lowest deviation from regression and a slope (bi) close to 1.0 (Table 6). On the other hand, according to Finlay and Wilkinson (1963) regression values increasing above 1.0 describe varieties

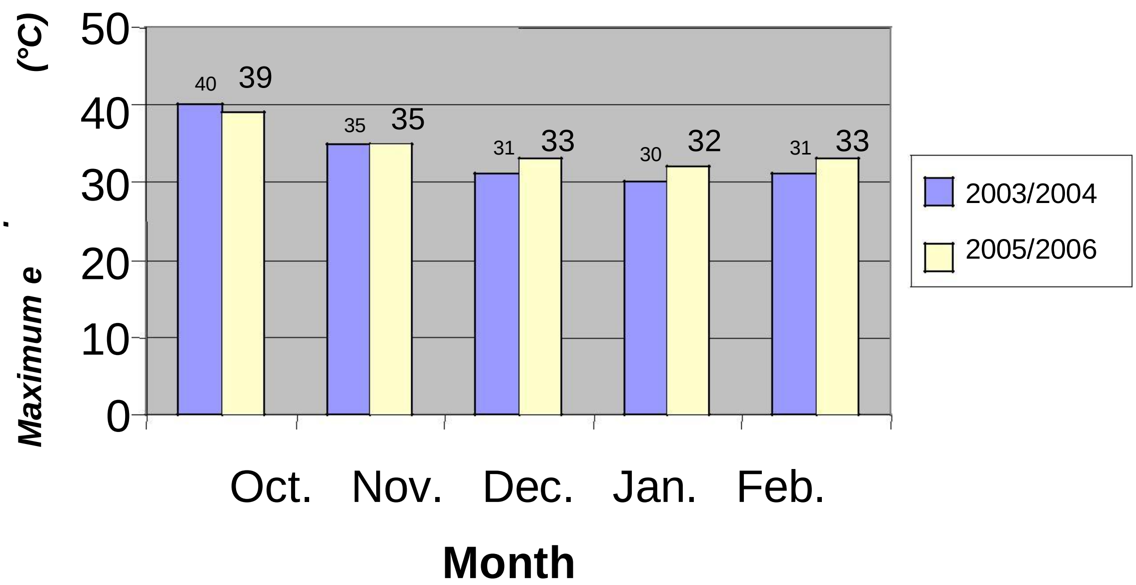

Figure 1. Maximum temperature (°C) prevailing during the growing seasons: 2003/2004 and 2005/2006.

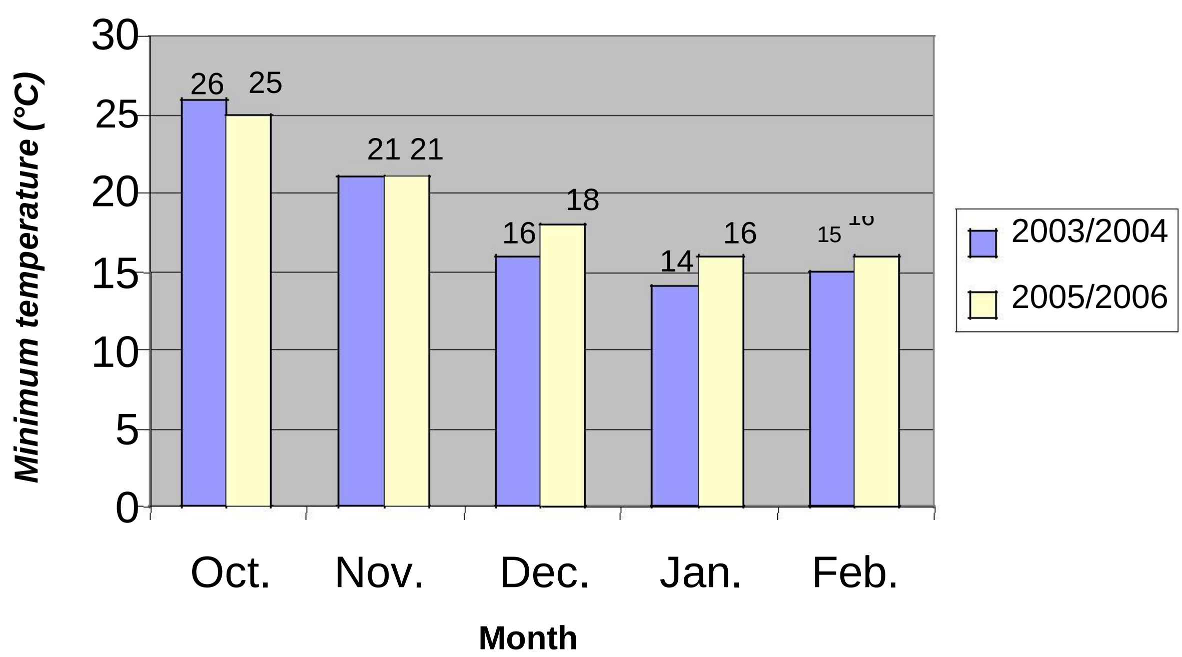

Figure 2. Minimum temperature (°C) prevailing during the growing seasons: 2003/2004 and 2005/2006.

Table 1. Number of irrigations and the amount of water used (m^3 /ha) during the two growing seasons.

Treatment	2003/2004		2005/2006	
	Number of irrigations	Amount of water ($m^{3)}$	Number of irrigations	Amount of water ($m^{3)}$
W1	7	2673	8	2776
W2	3	1646	4	1838

W1= watering every 10 days; W2= watering every 20 days.

Table 2. Morphological description of the nine common bean genotypes under study.

Genotype	Growth habit	Seed type	Seed color	Seed size
Basabeer	Indeterminate bush habit, long guides with climbing	Navy	White	Small
DB 190-74-1	ability Indeterminate bush habit, without guides.	Panamito	White	Small
UBR (92)25-2	Indeterminate bush habit, long guides with climbing ability	Navy	White	Small
Giza –3	Indeterminate growth habit, short guides with climbing ability	Great Northern	Creamy-white	Medium
Bellenber –1	Indeterminate growth habit, erect stem and branches, with climbing ability	Great Northern	White	Medium
COWU -3-94-9	Indeterminate growth habit, short guides with climbing	Great Northern	White	Medium
Ibarya	ability Determinate habits, strong, erect stem and branches.	Alubia	White	Large
Turki –2	Indeterminate growth, erect stem and branches with climbing ability	Fabada	White	Large
S/Hashim/ 98	Indeterminate, short guides without climbing ability	Kidney	White	Large

Table 3. Mean squares from combined ANOVA carried for grain yield (kg/ha) of nine common bean genotypes under four environments formulated by combination of 2 season × 2 water regimes.

Source	Df	MS	Pr>F
Total	107		
Environments	3	4245078.63	0.0002
Reps within environment.	8	171079.26	
Genotypes	8	718301.93	0.000
Genotypes ×environment.	24	70952.442	0.0469
Residual	64	41603.235	

Grand Mean = 1307, C.V (%) = 15.6.

Table 4. Mean squares from combined ANOVA carried for grain yield (kg/ha) of nine common bean genotypes under six environments formulated by combination of 2 season × 3 sowing dates.

Source	Df	MS	Pr>F
Total	161		
Environments	5	6266535.9	0.000
Reps within environment	12	118328.77	
Genotypes	8	1604646.22	0.000
Genotypes × environment	40	195439.45	0.000
Residual	96	34054.54	

Grand Mean = 1051, C.V (%) =17.6.

Table 5. Mean squares from combined ANOVA carried for grain yield (kg/ha) of nine common bean genotypes under 10 environments formulated by different combination of watering regimes and sowing dates.

Source	Df	MS	Pr>F
Total	269		
Environments	9	5370098.20	0.000
Reps within environment	20	139428.969	
Genotypes	8	2182252.184	0.000
Genotypes × environment	72	147861.176	0.000
Residual	160	37074.018	

Grand Mean = 1154, C.V (%) = 16.7.

Table 6. Means of seed yields (kg/ha) and estimates of stability parameters in nine common bean genotypes, across four macro environments formulated by 2 watering regimes and 2 seasons (2003/2004 and 2005/2006, HRS).

Genotype	Seed yield	Significance level	Regression coefficient (bi)	Deviation from regression ($\bar{s}_d^2$)
Basabeer	1548 (3)	0.773	1.5204	-13844.9
DB 190-74-1	1060 (8)	0.918	0.7736	-17069.3
UBR (92)25-2	980 (9)	0.195	0.6893	12503.7
Giza -3	1643 (1)	0.610	1.2152	-9367.0
Bellenber -1	1426 (4)	0.081	0.9720	29947.6
COWU -3-94-9	1219 (5)	0.818	0.8287	-14899.8
Ibarya	1208 (6)	0.318	0.8641	3078.9
Turki -2	1572 (2)	0.673	1.2239	-11244.3
S/Hashim/ 98	1112 (7)	0.342	0.9159	1689.6
Grand mean	1308			

* Number in brackets indicates rank.

Table 7. Means of seed yields (kg/ha) and estimates of stability parameters in nine common bean genotypes, a cross six environments formulated by 3 sowing dates and 2 seasons (2003/2004 and 2005/2006, HRS).

Genotype	Seed yield	Significance level	Regression coefficient (bi)	Deviation from regression ($\bar{s}d^2$)
Basabeer	1527 (2)	0.000	0.7805	164981.9
DB 190-74-1	854 (7)	0.044	0.8294	22288.4
UBR (92)25-2	760 (9)	0.052	0.7168	20768.4
Giza -3	1535 (1)	0.021	1.111	29324.1
Bellenber -1	1099 (4)	0.185	1.0820	8359.5
COWU -3-94-9	873 (6)	0.018	0.9591	30591.3
Ibarya	799 (8)	0.004	1.0444	43954.9
Turki -2	1123 (3)	0.000	1.4800	76370.5
S/Hashim/ 98	890 (5)	0.247	0.9966	5455.4
Grand mean	1051			

* Number in brackets indicates rank.

Table 8. Means of seed yields (kg/ha) and estimates of stability parameters in nine common bean genotypes, across 10 environments formulated by different watering regimes and sowing dates over 2 seasons (2003/2004 and 2005/2006, HRS).

Genotype	Seed yield	Significance level	Regression coefficient(bi)	Deviation from regression
Basabeer	1535 (2)	0.000	0.9136	112800.177
DB 190-74-1	936 (8)	0.319	0.8124	2762.755
UBR (92)25-2	848 (9)	0.127	0.7213	9713.649
Giza -3	1578 (1)	0.037	1.0778	17839.799
Bellenber -1	1230 (4)	0.144	1.0700	8834.719
COWU -3-94-9	1011 (5)	0.101	0.9592	11338.560
Ibarya	962 (7)	0.009	1.0454	26395.614
Turki -2	1303 (3)	0.002	1.4365	36034.864
S/Hashim/ 98	979 (6)	0.467	0.9638	612.374
Grand mean	1154			

*Number in brackets indicates rank.

with increasing sensitivity to environmental change (below average stability), and greater specificity of adaptability to high-yielding environments. In this study, the varieties Giza 3 and Turki-2 that ranked top in seed yield, appeared to be adaptable to high yielding (non-moisture stress) environments as they had above unity regression coefficient (bi = >1.2). Under heat stress environments created by different sowing dates, the most stable genotype was the medium seeded genotype Bellenber-1, that gave higher than average seed yield, bi value around unity and non-significant deviation from regression (Table 7). The large seeded genotype S/Hashim/98, that showed stability parameters similar to Bellenber-1 but with lower than average seed yield could be considered as having moderate stability. On the basis of the 10 macro-environments (watering regimes + sowing dates) the most stable genotypes were Bellenber-1, S/Hashim/98 and the small seeded genotype DB 190-74-1 that showed the smallest deviation from regression. However, Bellenber-1 appeared to be the most preferable as it ranked higher in seed yield (Table 8).

Conclusions

We conclude that some of the genotypes showed moderate or high stability under drought and/or heat stress. The genotypes Ibarya and S/Hashim/98 were considered stable under drought, whereas, Bellenber-1was the most stable genotype under heat stress. When considering stressed conditions of both environments, Bellenber-1, S/Hashim/98 and DB 190-74-1, appeared to be the most promising and can be used as a source of tolerance to improve common bean under drought and heat stress conditions.

Salt tolerance, viral diseases and assessment of bean genotypes for nitrogen fixation are vital areas of research that should be seriously considered in future common bean improvement programs. New molecular biology and bio-technology techniques are attractive tools that – if properly employed in long term breeding programs - may provide potential solutions for problems facing common beans production in the Sudan.

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