

Research Application Summary

Water stress effects on common bean genotypes with four growth habits

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Abstract

This study evaluated 22 common bean (*Phaseolus vulgaris* L.) genotypes for yield and yield components performance under drought stress conditions. The genotypes were grouped into four growth habits IIIa, IIIb, IVa and IVb, according to International Center for Tropical Agriculture (CIAT) classification. A split-plot design, laid out in a randomized complete block design (RCBD) with three replications was used in the study. Drought was imposed at flowering stage (terminal drought). Data were recorded on number of pods/plant, pod length, seed size and grain yield. Results showed higher significant differences ($P < .001$) between stressed and non-stressed genotypes in number of pods/plant (NPP), number of seeds/pod (NSP) and seed size (hundred seed weight). Similarly growth habits differed significantly amongst the genotypes in their response to water conditions. A comparison between all four growth habits showed that Genotypes VTTT 923/10/3, BCB2 and Sugar 131 (growth habit IIIa); A286 (growth habit IIIb); 12D/2, Kanzama (growth habit IVa) and MBC 33, Cim-climb 01-03-40 (growth habit IVb) were drought tolerant. Therefore, inclusion of these genotypes in the drought tolerance breeding programme is recommended.

Key words: Coefficient of correlation, drought, growth habits, susceptibility index, yield components

Résumé

Cette étude a évalué 22 génotypes d'haricot commun (*Phaseolus vulgaris* L.) pour le rendement et les composantes de performance en rendement dans des conditions de sécheresse. Les génotypes ont été regroupés en quatre habitudes de croissance IIIA, IIIB, IVa et IVb, selon la classification du Centre International d'Agriculture Tropicale (CIAT). Un split-plot dans un dispositif de blocs aléatoires complets (RCBD) avec trois répétitions a été utilisé. La sécheresse a été imposée au stade de la floraison. Les données ont été collectées sur le nombre de gousses / plants, la longueur des gousses, la taille des graines et le rendement en grain. Les résultats ont montré de très grandes différences significatives (P

<0,001) entre les génotypes stressés et les non stressés en termes de nombre de gousses / plants (NPP), nombre de graines / gousses (PSN) et la taille des graines (poids de 100 graines). De même des différences significatives ont été observées entre les habitudes de croissance des génotypes dans leur réponse aux traitements d'eau appliqués. Une comparaison entre les quatre habitudes de croissance a montré que les génotypes VTTT 923/10/3, BCB2 et Sugar 131 (habitude de croissance IIIa); A286 (habitude de croissance IIIb); 12D / 2, Kanzama (habitude de croissance IVa) et MBC 33, Cim-montée 03/01/40 (habitude de croissance IVb) sont tolérants à la sécheresse. Par conséquent, l'introduction de ces génotypes dans le programme de sélection contre la sécheresse est recommandée.

Mots clés: Coefficient de corrélation, sécheresse, habitudes de croissance, indice de sensibilité, composantes du rendement

Introduction

Two-thirds of common bean production in the world is estimated to occur under drought conditions. According to McClean (2011), climate change in the coming decades will be dramatic, resulting in decreased water availability and increasing air temperature in the main areas of agricultural production in the world. The need to feed the ever rising population expected to reach 9.2 billion by 2050 amidst climate change situation requires the cultivation of plants more adapted to drought conditions (FAO, 2009). As such, the need for climate change adaptation measures has become more necessary to ensure farmers continue to produce for their own food security and that of the growing population. One such adaptation measure is to produce tolerant genotypes which can survive, yield better and adapt in different environments (World Bank, 2014). In Malawi farmers relying on rain-fed agriculture for large and small scale farming are no longer producing the required quantities from their fields partly due to drought stress conditions. Yet the demand for food continues to increase every passing year and food shortages is particularly frequent in Malawi.

Identification of drought tolerant genotypes is therefore essential for germplasm improvement and production of drought tolerant varieties which are high yielding and resilient to climate change. Improved drought tolerant genotypes are critical for optimal expression of crop genetic potential over the long term in each environment. However, there is limited information on how the 22 genotypes under study, perform under water stress conditions. Thus, 21 genotypes selected from CIAT germplasm and one genotype from the Bean Cowpea Project at Bunda College Students Research Farm were studied with the overall objective of identifying drought tolerant genotypes with contrasting growth habits for use in breeding bean lines suitable for drought prone areas. The information gathered from this research will inform the Bean Breeding Program in Malawi and hopefully, some of the promising lines would be included in the advanced breeding populations.

Materials and methods

A field experiment was carried out from June to September, 2015, to evaluate performance of 22 genotypes under drought stress conditions based on four contrasting growth habits of

beans. A split-plot design laid out in randomized complete blocks design (RCBD) was used in this experiment. Two levels of moisture conditions (fully irrigated and partial- irrigation to simulate terminal drought) were used as main plots and the 22 genotypes as sub-plots. Each experimental plot measured 12.75m² and consisted of four rows, each 4m long, with a between row spacing of 0.75 m. Plants were spaced at 0.10 m within the row for the type IIIa and IIIb bean genotypes and at 0.20 m apart for the type IVa and IVb genotypes. A 10 m buffer zone was left between adjacent sites of drought stress and irrigated plots to prevent water seepage from irrigated to drought stressed main plots according to Mukeshimana *et al.* (2014). The genotypes used under the study are listed in Table 1.

Cultural practices were performed as recommended for the crop. Water was supplied by furrow irrigation. Irrigation was suspended soon after the flowering stage to induce terminal drought stress conditions. Since the growth habit were four, there was a need to monitor each group individually (independent experiments), accordingly to their specific days to flowering and physiological maturity.

Data collected included: phenological data such as days to flowering (DF) and number of days to physiological maturity (DM), plant height, number of pods plant⁻¹, pod length, seed weight, number of seeds pod⁻¹, grain yield (GY) and drought susceptibility index calculated as: $1 - (X_d/X_p)$ where X_d is the mean yield averaged across genotypes in the water treatment and X_p is the mean yield averaged across genotypes in the non-water stressed treatment (Fischer and Maurer, 1978). The data on all the parameters measured were subjected to analysis of variance using General Statistics (GenStat 17th edition) to differentiate any significant genotypic differences among the genotypes. The least significant difference (LSD) and Fischer's protected ($P < 0.05$) were used to evaluate differences between genotypes and growth habits. Standard errors and coefficients of variation were determined for the traits under study. The analysis of variance was performed for each experiment and growth habit, evaluating the effect of genotype and growth habit interaction.

Results

For all the growth habits, drought affected significantly ($P < 0.05$) the number of pods/plant, with overall mean of 21 pods under drought and 30 pods under irrigated conditions. Growth

Table 1. Genotypes evaluated at Bunda Students' Farms during June to September, 2015

¹ Growth habit IIIa	Growth habit IIIb	Growth habit IVa	Growth habit Ivb
Sugar 131	A286	DC 86-263	MBC 41
DRK 57	A344	12D/2	CIM-Climb-01-03-34
VTTC 924/4-4	UBR (92) 25	Kanzama	CIM-Climb-01-04-42
VTTC 923/10-3	AFR 703	MAC 109	MBC 33
VTTC 925/9-1-2	BF 13607-9	CIM-Climb 01-03-40	CIM-RWV 1040-5-1-2
BCB 2 (Bunda 2)	BAT 477		

¹CIAT classification

habit IIIa had 18 pods/plant, IIIb had 26 pods/plant, IVa had 25 pods/plant and IVb had 33 pods/plant. Drought also reduced BCB2 pod number from 26 to 20, followed by Sugar 131 from 25 to 13 and VTTT 925/9-1-2 with only 7.33 pods/plant. In growth habit IIIb, genotype BAT477 had more pods/plant (23.67) under drought and 27.33 under irrigated conditions, followed by A286 and BF 13607-9. Genotype AFR 703 had (17.00) under drought and (21.00) under irrigated conditions. In general AFR 703 had less number of pods/plant.

In growth habit IVa, genotype 12D/2 had more pods (38.0) under irrigated condition, followed by Cim-climb 01-03-40 (33.67). Under drought, the same genotypes had 14 pods/plant and 15.67 pods/plant, respectively. In growth habit IVb, genotype Cim-climb-01-03-42 had more pods/plant (41.00) under irrigated, followed by Cim-RMV 1040-5-1-2 with 37.67 pods/plant. The last genotype in terms of number of pods/plant was MBC 41, with 18.67 and 16 pods/plant under irrigation and drought conditions. The variable expressions of growth habits show genetic variability for drought tolerance. Similarly, Nielsen and Nelson (1998) and Rosales *et al.* (2004) observed a reduction in the number of pods in plants subjected to drought which could have been due to ovule or pollen abortion Kokubun *et al.* (2001). The number of pods per plant is considered the most important yield attribute and is determined by thermal units and the duration between emergence and flowering. The results in the current study are similar to the ones reported by Amanullah *et al.* (2011) that the differences in pod number per plant could be due to genetic variability among the genotypes.

Pod length also varied significantly, the extent depending on growth habits. The overall mean pod length under drought was (8.00 cm) compared with (10.00 cm) under irrigation conditions and there was no significant interaction between water level and growth habit. Growth habit IIIa had pod length of (8.00 cm), growth habit IIIb had (10.00cm), IVa (9.00cm) and IVb (9.00). In growth habit IIIa, was the highest pod length was observed in BCB 2 (9.00 cm), followed by VTTT 925/9-1-2(8.50 cm), while sugar 131 and DRK 57 had the least pod length (7.00 cm). These results were expected since the materials had different genetic backgrounds, supporting the finding of Acquah (2007). In growth habit IIIb, genotypes A286 and BF 13607-9 had highest pod length with 10.01 cm and 9.46 cm, respectively. In growth habit IIIb, genotype A286 had pod length of (11.33 cm), followed by BF 13607-9 (11.86 cm) and the shortest was found in AFR703 with (9.67 cm). In growth habit IVa, genotypes 12D/2 had higher pod length of (10.00cm), followed by Cim-climb 01-03-40, and the lowest pod length was in genotype MAC 109 with (8.00 cm). In growth habit IVb, genotype Cim- RMV 1040-5-1-2 had pod length of (10.67 cm), followed by Cim-climb-01-03-34 (9.33 cm) and the shortest pod length was in MBC 33 (5.67 cm).

Seeds per pod varied significant from 3.80 (VTTT 925/9-1-2) to 8.00 (BCB2) under drought conditions and from 6.00 (VTTT 925/9-1-2) to 12.00 (BCB2) under irrigation regime, suggesting genotype influence in responding to water stress, as also alluded to by Amanullah and Muhammad (2011). In growth habit IIIb, genotype BF 13607-9 had (13.00) seeds/plant under irrigated and (10.67) seeds/plant under drought regime, followed by A286 with 11.00 pods/plant in both water regimes. The genotype with less seeds/pod was A344 with (10.00) pods/plant under irrigation and (9.00) under drought conditions. In growth habit IVa, genotype 12D/2 had (10.00) and (9.00) seeds/pod under irrigation and drought conditions, respectively,

followed by Cim-climb 01-03-40 with (9.00) and (7.67). The genotype with less number of seeds/pod was Kanzama with (7.33) and (6.33) seeds/pod under irrigated and water stress, respectively. In growth habit IVb, genotype Cim-climb-01-03-34 had more seeds (10.00) and (9.00) seeds/pod under irrigation and drought, followed by Cim-climb-01-04-42 with (8.00) and (7.00) seeds/pod, under irrigation and drought regimes. The genotype with least number of seeds/pod was MBC 33 with (5.67 and 5.33) under irrigated and drought, respectively.

For all the growth habits drought affected significantly ($P < 0.05$) grain yield, with overall mean of 1990 kg/ha under drought and 2287.81 under irrigated regimes (Fig. 1). Growth habit IIIa had mean yield of 1687.11 kg/ha under drought and 2400 kg/ha under irrigation conditions. Contrastingly, IIIb had 1337.5 kg/ha under drought and 1823.88 kg/ha under irrigation conditions, while IVa had 2071.05 kg/ha under drought and 2941.38 kg/ha under irrigation conditions; Ivb had 3055.43 kg/ha under drought and 3366.66 kg/ha under irrigation conditions.

Seed weight (100-seed) varied significantly from 14.00 g/100 seed (BCB2) to 51.00 g/100 seed (VTTT 925/9-1-2), with no significant interaction effect of water conditions and genotypes. These results are in conformity with those of Amanullah *et al.* (2011) who reported that common bean germplasm had significant variation in seed weight. In this study genotypes with larger seed size ((VTTT 925/9-1-2) had red colour which farmers in Malawi most like. Still, tolerant genotypes may be more efficient in assimilate production and translocation to the seeds (Rosales-Serna *et al.*, 2004).

Our results are in agreement with De-Souza *et al.* (1997), who reported that water stress reduced seed size. According to White and González (1990), the small seed, or a closely

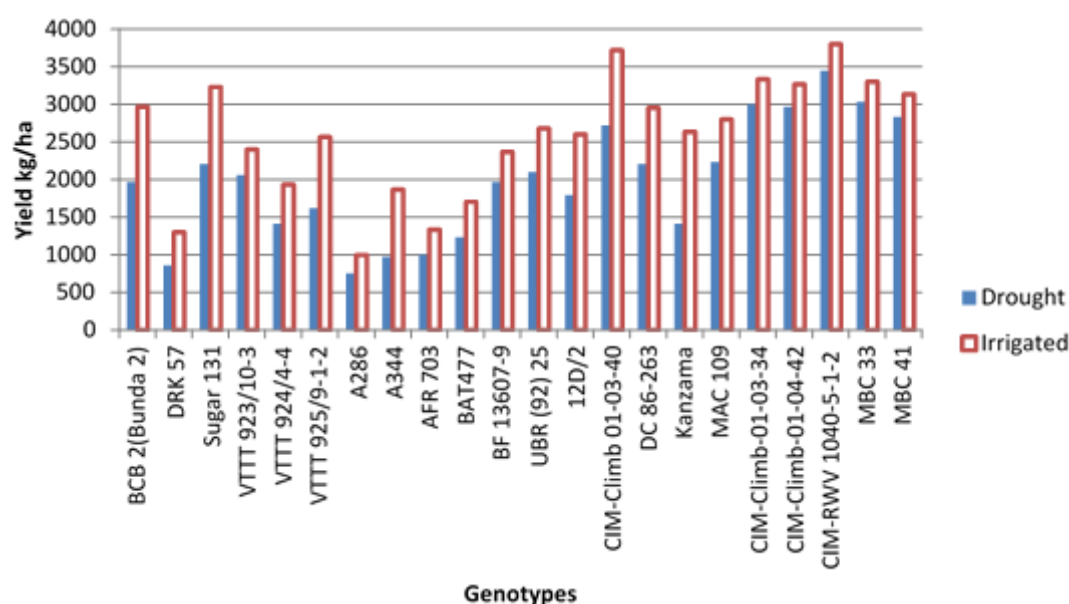


Figure 1. Yield of 22 bean genotypes under irrigated and drought stress conditions

linked characteristic such as cell size, is associated with greater physiological efficiency. Grzesiak *et al.* (1989) noted that drought stress does not affected 100 seeds weight of bean plants.

Significant differences were recorded on seed size of growth habit IIIb. BAT477 and AFR 703 had largest seed sizes of 39.67g/100 seeds and 39.33 g/100, respectively. Both genotypes had larger seed sizes compared to the rest of the genotypes. Larger seeds genotypes are reportedly preferred by farmers, due to good appearance (Mwale *et al.*, 2009) and larger genotypes have greater supply of stored energy to support early seedling, due to their larger endosperm (Singh *et al.*, 1972). Hence, these genotypes can be recommended to farmer because they do not take long to emerge and grow faster. In this study smallest seed size was recorded in BF 13607-9 and A286 of 18.67 g/100 seeds and 20.33 g/100, respectively. Smaller seeds have been known to cope better under drought conditions. In growth habit IVb, genotype MBC 33 had heavier seeds, followed by CIM-Climb-01-04-42 with 48.00g/100 and 33.00g/plant, respectively. Drought susceptibility index show that genotypes MBC 33, Cim-climb 01-03-40 (growth habit IVb); 12D/2, Kanzama (growth habit IVa); A286, (growth habit IIIb) and VTTT 923/10/3, Sugar 131(growth habit IIIa) are more drought tolerant. AFR703 and VTTT 925/9-1-2 are drought susceptible.

Conclusions

Seed yield is a key for germplasm selection. In this study, drought reduced correlated bean seed yield and yield components in all four growth habits (IIIa, IIIb, IVa and IVb). However, bean genotypes belonging to growth habit IVa and IVb had good performance under both water conditions, which means they can be recommended for use by smallholders farmers in Malawi. Genotypes MBC 33, Cim-climb 01-03-40 (growth habit IVb); 12D/2, Kanzama (growth habit IVa); A286, (growth habit IIIb) and VTTT 923/10/3, BCB2 and Sugar 131 (growth habit IIIa) were more drought tolerant than the others. Therefore, inclusion of these genotypes in the drought tolerance breeding programme could improve production and productivity of common bean in Malawi.

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