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Response of Common Bean Genotypes (*Phaseolus vulgaris* L.) to Drought for Growth and Yield Characteristics in the Southern Highlands of Tanzania

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***Abstract*— *Common bean cultivation is affected by drought up to 60% worldwide and makes the second for yield loss contribution after diseases. Despite the loss, it is estimated that over 75% of rural households in Tanzania depend on common bean for daily sustenance. The objective of the study was to evaluate the response of common bean genotypes in growth and yield characteristics under induced moisture stress in the field at Inyala Agriculture Training Institute in the Southern Highlands of Tanzania. In this study, eighteen common bean genotypes investigated included SER125, MR13905-6, and 41-EX- VAM, BFS20, RCB233, CZ109-22, CZ104-61, KG25-21, SER82, PASS, SER83, KG104-72, SER16, KG4-30, SER45, SER124, BFS60 and RCB266. The experiment was designated in a 3 x 18 split plot arranged in a complete randomized block design (CRBD) with three replications. The main plots were the three moisture treatments such as non moisture stress, stress at flowering and stress at mid pod filling and the sub plots were the common bean genotypes. The plants' variables recorded were number of days to 50% flowering, number of days to 85% maturity, number of pods per plant, weight of pods per plant, weight of seeds per plant, number of seeds per pod, 100 seed weight and yield per hectare. The collected data were subjected to analysis of variance (ANOVA) using GenStat computer software 14th edition. The results showed significant ($p < 0.05$) differences between moisture treatments and bean genotypes. Genotypes SER16, BFS60, KG104-72 and CZ109-22 were significantly superior in grain yields Also, BFS60 was recorded with highest number of pods per plant, weight of pods per plant and weight of seeds per plant, while KG104-72 was recorded as the earliest in 50% flowering and 85% maturity. Genotype SER16 also excelled in weight of seeds per plant. These genotypes therefore can be considered as drought tolerant common bean genotypes and also can be used as parental materials for breeding programmes.*

***Keywords*— Common bean, drought, stress, yield components and yield**

I. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is one of the widely cultivated crops. It is considered to be one of the most important legumes for human consumption (CIAT, 2001; Emam *et al*., 2010) and is an important source of dietary protein, calories, dietary fibers, and minerals, especially iron and zinc. In Africa, it is a primary staple in parts of the Great Lake Regions (Singh *et al*., 2000; Tryphone and Nchimbi-Msolla, 2010). Bean consumption also has medicinal benefits to human health; eating beans may provide protection from cardiovascular disease by a small depression in blood cholesterol (Kabagambe *et al*., 2005). In epidemiological studies of colon cancer, low incidence was observed in many Latin American countries where the consumption of common bean is high (Hengen and Bennink, 2002). Clinical studies consistently showed that when consumed exclusively as a carbohydrate-rich foods, beans reduced postprandial glucose elevations in both diabetic and non-diabetic participants (Tomson *et al*., 2012).

In Tanzania, it is estimated that over 75% of rural households depend on it for daily dietary requirements (CIAT, 2008). Despite the importance of common beans in Tanzania and other developing countries, its production mostly relies on local cultivars (Miklas *et al*., 2006; Chataika *et al*., 2010). Like other plants, the development and productivity of beans is adversely affected by biotic and abiotic factors (Jaleel *et al*., 2009). Among the abiotic factors, drought is the major factor limiting crop production worldwide (Jones and Corlett, 1992). Moisture stress is ranked second after insect pests and diseases that cause grain yield losses with about 60% of world bean production area. With the evolving phenomena of climate change, it is anticipated that drought will exert increasing impacts on crop productivity (Man *et al.*, 2011). Drought causes reduction in yield, yield components and biomass accumulation of common beans (Munoz-Perea *et al.*, 2006). In the Southern Highlands of Tanzania, the bulk of bean production is done by small scale farmers who depend entirely on rainfall. In these areas intermittent and or terminal droughts are experienced in some years, whilst supplementing the crops with irrigation during drought periods is not common and unaffordable for small scale farmers. Therefore, variety evaluation for drought tolerance in common beans is the appropriate approach for plant breeders to identify superior genotypes for varieties development. The objective of this study was to determine the effect of drought on common bean production in the Southern Highlands of Tanzania.

II. MATERIALS AND METHODS

The experiment was conducted at Inyala Agricultural Training Institute which is located at latitude 84°7'S, longitude 36° 51 E' and altitude of 1100 meters above sea level (m. a. s. l). This location experiences a unimodal rainfall pattern that occurs between November and May every year. The overall average temperature is 17.5 °C. The heaviest rainfall occurs from December to March. The soil characteristics of this area are loam, slightly acidic with a pH of 5.54. Before planting, the land was cleared, ploughed and harrowed using oxen-pulled equipment. Soil sample composite was collected using a hand hoe at a depth of 15-20cm and analyses for physical and chemical characteristics at Uyole soil laboratory as presented in Table1. Weather data including rainfall, minimum and maximum temperatures, relative humidity and solar radiation were recorded at Uyole weather station (Table 2). During planting, fertilizers used were:-triple super phosphate (TSP) (45% P_2O_5) and Urea (4 6 % N). The experiment was laid out in a 3 x 18 split plot arranged in a randomized complete block design (RCBD) with three replications. Subplot, plot size was 2 x 2 m and the spacing used was 0.50 x 0.10 m making a plant population of 84 plants per plot. The main plot (factor A) was moisture treatment with three different stresses periods and sub plot (factor B) was 18 common bean genotypes. Planting was done during the offseason in June 2014 cropping season by putting two seeds per hole at 5cm depth in each row. Fertilizers were then applied uniformly at a rate of 25.3 kg P/ha and 22.5 kg N/ha. Seven days after planting seedlings were thinned to one seedling per hill. Spraying with Amecron 50 EC insecticide at the rate of 2mls/l was carried out to control bean stem maggot, termites and other insects by using a knap sack sprayer. Weeding was done three times using a hand hoe to make sure that there are no weeds in the plots. Moisture stress was induced to the main plots assigned for stress at flowering and mid pod filling when the plants had already attained 50% flowering and mid pod filling stages, respectively. Moisture supply was done through flooding. The duration for moisture stresses applied at both flowering and mid pod filling stages were 20 days. When the bean attained harvestable maturity, they were harvested, sun dried and weighed. The obtained weights of genotypes grown under non-moisture stress and moisture stress at flowering and mid pod filling were subjected to analysis of variance using GenStat computer software and the means were separated using Turkey test.

III. RESULTS

3.1 Soil Analysis

Physical and chemical properties of soil are presented in Table 1. The soil was sandy loam, with a slightly acidic condition (pH 5.3), and cation exchange capacity (CEC) of 15.41 cmol (+)/kg which was high. The quantity of exchangeable bases for potassium and calcium were low (0.12 cmol (+)/kg) and medium (4.49 cmol (+)/kg) respectively, while magnesium was 2.14 cmol (+)/kg, which was also medium. Total nitrogen of the soil was medium (0.13%), while phosphorus was 15.30 mg/kg which was also medium and percent organic carbon was low (0.82%).

Table 1: Physical and chemical characteristics of soil collected from the experimental site

Parameter	Unit	Quantity	Remarks*
Physical characteristics			
Clay	%	28.43	
Silt	%	33.01	Sandy loam
Sand	%	48.59	
Chemical characteristics			
Soil pH(1:25) H2O	pH	5.30	Slightly acidic
CEC	cmol(+)/kg	15.41	High
K	cmol(+)/kg	0.12	Low
Ca	cmol(+)/kg	4.49	Medium

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Mg	cmol(+)/kg	2.14	Medium
TN	%	0.13	Low
OC	%	0.82	Low
P	mg/kg	15.30	Medium

*According to Landon (1991)

3.2 Weather condition

Weather data were collected in 2015, however there were no precipitations data since the experiments were conducted during off season. Non experimental data collected were mean monthly maximum temperatures, which ranged from 17.06°C in September to 27.23°C in October and minimum temperatures, ranged from 5.20°C in May to 14.05°C in November. The mean relative humidity was lowest in August (57.93%) and highest in July (72.7%). Solar radiation was lowest in June (17.72MJm^{-2}day^{-1}), and highest in September (18.73MJm^{-2}day^{-1}).

Table 2: Summarized mean monthly weather data collected during the experiment

Month	Rainfall (mm)	Temperature (°C) Maximum temperature	Minimum temperature	Relative humidity (%)	Radiation (MJm^{-2}d^{-1})
May	0	23.92	5.2	72.1	18.68
June	0	23.52	8.69	70.73	17.72
July	0	20.5	8.6	72.7	18.21
August	0	23.75	7.37	57.93	18.49
September	0	17.06	11.3	60.17	18.73
October	0	27.33	10.3	62.97	18.17
November	0	23.08	14.05	69.6	18.62

Source: Uyole Meteorological Station (2015)

3.3 Effects of moisture tress treatments and common bean genotypes on growth characters

3.3.1 Days to 50% flowering

There were highly significant (p≤0.001) differences between genotypes on number of days to reach 50% flowering among common bean genotypes (Table 3). The earliest genotype was KG104-72 (34.33) followed by SER82 (36.0), SER125 (36.67) and RCB266 (36.89). These were however, statistically similar. The latest genotypes were 41-EX-VAM (48.56), SER45 (47.56), CZ109-22 (43.56) and MR13905-6 (43.22). In this study, there were no significant differences between moisture treatments on 50% flowering (Table 3).

3.3.2 Days to 85% physiological maturity

There were highly significant (P≤0.001) differences between genotypes on number of days to reach 85% physiological maturity (Table 3). The earliest genotype to reach 85% maturity was SER82 (83) followed by KG104-72 (84.22), RCB266 (85.44) DAP and SER125 (85.67). However, the earliest genotype (SER82) was statistically similar to KG104-72 and RCB266. The latest genotype was PASS (94.1 days) followed by RCB233 (93.67 days). Genotypes with moderate days to reach 85% was KG25-21 (88.78) followed by CZ109-22 (88.67) and SER83 (88.56) and these were statistically similar. On the other hand longest days for maturity was recorded from PASS (94.11) DAP and RCB233 (93.67), however these two genotypes were statistically similar.

Table 3: Effects of moisture stress treatments and common bean genotypes on growth characteristics

Moisture treatments (a)	50% flowering	85% maturity
SP0	40.37a	94c
SPI	41.3a	84.43a
SPII	41.5a	88.15b
Mean	**41.06**	**88.86**
F.test0.05	**Ns**	**
CV%	**4.0**	**1.0**
Genotype (b)		
KG104-72	34.33a	84.22ab

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SER82	36.00ab	83.00a
SER125	36.67abc	85.67bc
RCB266	36.89a-d	85.44abc
SER16	37.78a-e	86.00bc
KG25-21	39.11b-f	88.78ef
PASS	40.89c-f	94.11i
SER124	40.89c-f	86.11bcd
BFS20	41.56def	92.11ghi
BFS60	41.89ef	89.44ef
CZ104-61	42.33ef	92.78hi
KG4-30	42.33ef	87.22cde
SER83	42.44ef	88.56def
RCB233	43.00fg	93.67i
MR13905-6	43.22fg	90.11fg
CZ109-22	43.56fg	88.67ef
SER45	47.56gh	92.78hi
41-EX-VAM	48.56h	90.78fgh
Mean	**41.6**	**88.86**
F.test$_{0.05}$	***	***
CV%	**2.0**	**1.5**

Means in the same column followed by the same letter(s) are not statistically different (P<0.05) by Duncan's New Multiple Range Test. *** = Significant at 0.001.SP0 = without moisture stress, SPI=Stress at flowering and SPII=Stress at mid-pod filling

There were statistical (P≤0.01) differences between moisture regimes in reaching 85% maturity (Table 3). The earliest to reach maturity was stressed at 50% flowering followed by stress at mid pod filling and the latest was unstressed condition.

3.4 Effects of moisture stress and common bean genotypes on yields and yield components

3.4.1 Yield

There were highly significant (P≤0.001) differences between genotypes on yields (Table 4). Genotype with highest yield was SER16 (1419 kg/ha) followed by KG104-72 (1375 kg/ha) and KG4-30 (1374 kg/ha), however KG104-72 and KG4-30 were statistically similar (Table 4). Genotype with lowest seed yield was 41-EX-VAM (763 kg/ha) followed by PASS (824 kg/ha), BFS20 (935 kg/ha), SER45 (1062 kg/ha) and MR 13905-6 (1123 kg/ha). The remaining genotypes had moderate seed yields and were statistically similar. There were highly significant (P≤0.001) differences between moisture regimes on yield. The unstressed treatment produced highest yield (1759 kg/ha) followed by stress at mid pod filling (977 kg/ha) and lowest yield was from stress at 50% flowering (824 kg/ha); however, yields under stress at mid pod filling and 50% flowering were statistically the same.

Table 4: Effects of moisture treatments and common bean genotypes on yield and yield components

Moisture treatments (a)	Yield (kg/ha)	Number of pods per plant	Weight of pods per plant (g)	Number of seeds per pod	weight of seed per plant (g)	100 seed weight (g)
SP0	1759b	17.48c	21.0c	5.12b	14.9c	23.72b
SPI	824a	9.9a	10.23a	4.71a	6.49a	23.43b
SPII	977a	11.44b	16.3b	5.01b	10.99b	20.00a
Mean	**1187**	**12.94**	**15.75**	**5.011**	**10.79**	**22.38**
F.test$_{0.05}$	**	***	***	ns	***	**
CV%	**6.8**	**1.9**	**10**	**1.4**	**10.5**	**1.3**
Genotype (b)						
41-EX-VAM	763a	12.42abc	11.90a	5.156bc	7.90a	17.49a
PASS	824ab	9.49a	14.40a-d	3.933a	9.29abc	30.21g
BFS20	935abc	12.71abc	16.55c-f	4.689b	10.97b-f	25.00f
SER45	1062bcd	19.16d	19.89f	5.244bc	13.68f	20.31b

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MR13905-6	1123cde	12.31abc	14.71a-d	4.711bc	10.03a-e	24.29ef
CZ104-61	1152c-f	12.58abc	14.75a-d	4.978bc	9.82a-e	23.50ef
SER82	1184c-f	13.02bc	14.07abc	4.822bc	9.10ab	20.56bc
SER83	1211def	12.82abc	15.88b-e	5.178bc	11.01b-f	21.33bcd
KG25-21	1232def	13.07bc	14.51a-d	4.889bc	10.65a-e	21.32bcd
SER125	1233def	12.75abc	13.96abc	5.328bc	9.74a-d	23.33ef
SER124	1254def	14.49bc	17.76def	5.200bc	12.09c-f	21.15bcd
RCB233	1258def	14.58c	18.40ef	5.156bc	12.69ef	20.64bc
BFS60	1300def	12.44abc	17.80def	4.867bc	12.35def	23.30ef
RCB266	1322def	11.40abc	12.83ab	5.356c	8.96ab	21.07bcd
CZ109-22	1335def	12.64abc	15.87b-e	5.244bc	10.80b-e	22.44cde
KG4-30	1374ef	11.09ab	17.77def	5.178bc	12.74ef	22.85de
KG104-72	1375ef	11.29abc	15.00a-e	5.200bc	10.18a-e	23.34ef
SER16	1419f	14.67c	17.47c-f	5.078bc	12.30def	20.77bc
Mean	**1187**	**12.94**	**15.75**	**5.011**	**10.79**	**22.38**
F.test0.05	***	***	***	***	***	***
CV%	**9.7**	**6**	**4.4**	**4.5**	**7.6**	**3**

Means in the same column followed by the same letter(s) are not statistically different (P<0.05) by Duncan's New Multiple Range Test. ns = Non significant, ** = Significant at 0.01, *** = Significant at 0.001. SP0 = Without moisture stress, SPI=Stress at flowering and SPII=Stress at mid-pod filling

3.4.2 Number of pods per plant

There were highly significant (P≤0.001) differences between genotypes on number of pods per plant (Table 4). Genotype with significantly highest number of pods was SER45 (19.16). This was followed by SER16 (14.67) and RCB233 (14.58); however, these were statistically similar. Lowest number of pods per plant was recorded from PASS (9.49) followed by KG4-30 (11.09), KG104-72 (11.29) and RCB266 (11.40); however, KG4-30 and RCB266 were statistically not different. There were also statistical (P<0.01) differences between moisture regimes on number of pods per plant. The largest number of pods was from unstressed treatment (17.48) followed by stress at mid-pod filling (11.44) and the lowest was from stress at 50% flowering (9.9). All these regimes differed significantly from each other. Although, these two treatments (SPI and SPII) were statistically similar (Table 4).

3.4.3 Weight of pods per plants

There were highly significant (P≤0.001) differences between genotypes on weight of pods per plant (Table 4). Genotype with highest weight of pods per plant was SERF45 (19.89 g) followed by RCB233 (18.40 g), BFS60 (17.80 g), KG4-30 (17.77 g), SER124 (17.76 g), SER16 (17.47 g) and BFS20 (16.55g). However, BFS60, KG4-30 and SER124 were statistically not different. Genotypes with lowest weights of pods was 41-EX-VAM (11.9 g) followed by RCB266 (12.83 g), SER125 (13.96 g) and SER82 (14.07 g), although genotypes SER125 and SER82 were statistically the same. The rest of genotypes had moderate weights of pods per plant. Results across moisture treatments were significant (P≤0.001). Significantly highest weight (21 g) of pods per plant was under unstressed treatment (21 g) followed by those stressed at mid pod fill (16.3 g) and the least weight (10.23 g) was found in stress at flowering.

3.4.4 Number of seeds per pod

There were highly significant (P≤0.001) difference between bean genotypes on number of seeds per pod (Table 4). Genotype with significantly highest number of seeds per pod was RCB266 (5.36). This was followed by SER125 (5.33), while genotype with lowest number (3.93) of seeds per pod was PASS. The remaining genotypes had moderate number of seeds per pod and they were statistically similar. The effect of moisture treatments on number of seeds per pod was significant (Table 4). The highest number of seeds per pod was recorded from those with unstressed treatment (5.12) followed by those stressed at mid pod filling (5.01). The lowest was from those stressed at flowering (4.71)

3.4.5 Weight of seeds per plant

Common bean genotypes showed significant (P≤0.001) differences between genotypes on seeds weight per plant (Table 4). Genotype with significantly highest weight (13.68 g) of seeds per plant was SER45 and this was followed by KG 4-30 (12.74 g) and RCB233 (12.69 g); however, these two genotypes were statistically similar. Genotype with lowest weight of seeds per plant was 41-EX-VAM (7.90g) followed by RCB266 (8.969), SER82 (9.10g) and PASS (9.29). There were statistical (p≤0.001) differences between moisture treatments on weight of seeds per plant. The weight of seeds per plant under unstressed treatment was highest (14.9 g) followed by those stressed at mid pod filling (10.96 g) and least weight (6.52 g) of seeds per plant was from those stressed at 50% flowering.

3.4.6 Weight of 100 seeds

Common bean genotypes differed significantly (P≤0.001) on 100 seed weight (Table 4). Genotype with statistically highest 100 seed weight (30.21 g) was PASS. The latter was followed by BFS20 (25.09 g). Genotypes that followed BFS20 were MR.13905-6 (24.29 g), CZ104-61 (23.50 g), KG104-72 (23.34g), SER125 (23.33g) and BFS60 (23.30 g) and these were not statistically different. Genotype with statistically lowest 100 seed weight was 41-EX-VAM (17.49 g). There were significant (P≤0.01) differences between moisture regimes on 100 seed weight. The highest 100 seed weight was from unstressed treatment (23.72 g) followed by stress at flowering (23.4 g) and these were statistically similar. The least 100 seed weight was from stress at mid-pod filling (20.62 g).

IV. DISCUSSION

4.1 Response of Bean Genotypes to Different moisture Stress Periods on Growth Characteristics

Days to attain 50% flowering among the common bean genotypes differed significantly (P≤0.05) as summarized in Table 3. These results indicate that, there is genetic variability among the common bean genotypes tested on number of days to reach 50% flowering and these results are in agreement with the findings of Yoshinda (1981). The latter revealed genetic variation among genotypes of common bean on days to attain 50% flowering. Similarly, Das (2005) reported considerable variability of traits including number of days to 50% flowering of snap beans. Among the 18 common bean genotypes, there were significant differences among tested genotypes on days to 85% maturity. The variation among genotypes is influenced by the genetic constitution of the individuals. The stress treatments influenced the time taken to attain flowering and maturity in such a way that, beans flowered and matured earlier in a stressed than in non-stressed environments. This situation could be enhanced by a harsh condition (moisture deficit) that faced plants, as a result plants accelerate senescence. Further, in that plants tend to attain reproduction hence propagation before they die giving it a life survival strategy under stressful conditions, the C/N ratio is reached faster where incipient to flowering occurs hence earlier maturity and hence the life circle of the plant is shortened. This act enables the reserved food in leaves to be partitioned to harvestable parts in order to maintain its generation. This type of adjustment mechanism to moisture stress condition was reported by Sabaghpour *et al*. (2003) who found that early phenology, such as early maturity was the most important mechanism for genotypes to escape terminal drought stress as associated with high initial growth vigour. Guar *et al*. (2008) associated the early maturing of the chickpea in the dry areas of India to their drought mechanism. The genotype with early maturity would be less vulnerable to terminal drought and hence suited as drought tolerant genotype. The genotypes with such traits could be selected for better performance and as source of genes for improvement. Similar result was found by Beaver and Rosas (1998) in their study for drought tolerance of common beans, where selection for earlier flowering in red beans permitted the identification of the bean genotypes with a shorter life cycle without affecting its yield potential and with greater rate of partitioning assimilates.

4.2 Effects of moisture stress on yield and yield components

Subjecting genotypes to moisture stress during the reproductive stage reduced grain yields in this study. Moisture regimes affected significantly seed yields. SER16 yielded the highest (2183 kg/ha) under unstressed condition (Table 4). Other genotypes that yielded better were RCB266, BFS 60, kg104-72 with average of 2071 kg/ha, 1999 kg/ha and 1939 kg/ha respectively. The overall difference of yields per hectare across moisture treatments was 44.5% from non-stressed treatment to stress at mid pod filling and 53.2% from unstressed treatment to stress at flowering. Emam et al. (2010) reported that drought stress is one of the limiting factor in crop growth and yield which reduces dry matter production, grain yield, and yield components through decreasing leaf area and accelerating leaf senescence and plant death. Albert, drought stress during all developmental stages significantly reduce the number of pods per plant, seeds per pods, 100 seed weight and consequently yield (Beshir et al., 2016). However, Emam, (1985) and Emam and Seghatoleslami (2005) stated that common bean grain yield is significantly reduced when moisture stress occurs during the reproductive phase. Reduction in grain yield was caused by reduction in the yield components because the grain yield is the product of several yield components and these components are generally the product of sequential development processes. Any reduction in these yield components directly reduces grain yield (Ardakani et al., 2013). Therefore, a reduction in yield is largely due to reduction in number of pods/plant and seeds/pod. The reduction in grain yield is attributed to lower percentage of pod production when the moisture stress occurs during flowering (Emam, 1985) and from embryos abortion when the moisture stress occurs during pod filling stage (Robins and Domingo, 1956). In this study, higher percentage of yield loss occurred with stress at flowering though it did not differ significantly with stress at pod filling. Thus pod production was affected as shown by lowest number of pods formed at stress during flowering. Ardakani et al. (2013) noted that water stress at flowering reduces yield through increased flower failure or abortion and consequently number of pods is reduced by aborted seeds. Barrios *et al*. (2005) reported that seed yield reduction of up to 60 % observed in common beans under drought stress was attributed to losses of 63.3 % in pods per plant, 28.9 % in seed per pod and 22.3 % in seed weight per plant. In this study, the number of pods per plant was significantly influenced by moisture stress treatments. The introduction of moisture stress lowered the number of pods per plant and seed number per pod. This finding is in agreement with that obtained by Castañeda *et al*. (2009) that high moisture stress during the reproductive stage exposed the plant to floral abortion and resulted in low seed yield. Other authors (Singh 1995; Sponchiado *et al*. 1989) reported that moisture stress imposed during flowering and pod setting caused flower and pod abortion. Generally, the reproductive stage is the most sensitive to drought stress (Nielsen and Nelson, 1998). This phase includes flower formation (Pedroza and Muñoz, 1993), full flowering (Pimentel *et al*., 1999), pod formation (Castañeda *et al*., 200), or grain filling (Nielsen and Nelson, 1998). Moisture deficit caused falling or abortion of reproductive structures in soybeans (Beshir *et al*., 2016) and reduced pollen formation and pollination in common bean (Boutra and Sanders, 2001). The need to maintain high pod number under moisture stress condition in common bean is vital, since it constitutes an important yield component that determines final yield. Confalone *et al*. (1991) reported that the number of pods per plant constitute the main yield component which is mostly affected by moisture deficit during flowering stage and can reduce seed yield up to 70 % depending on the duration and severity of the moisture stress. Lopez *et al*. (1996) reported that total number of flowers in some susceptible varieties may be reduced up to 47 % under drought conditions thereby influencing the number of pods per plant; though pod setting may also vary among different common bean varieties in response to drought.

In this investigation, the heaviest pods per plant were recorded measured from unstressed treatment. The mean difference of pods weight per plant between unstressed treatment and stressed at mid pod filling was 24% and when stressed at flowering, the difference was 52% (Table 4) for the field experiment. Results indicated that moisture stress exerted at flowering and mid pod filling growth stages affected plants by reducing weight of pods, as drought affects formation of pods and development of reproductive parts of the plant. Due to this reason, beans may from empty pods and hence are lighter compared to beans grown under unstressed treatments and not affected by early abortion of seed embryos. In determination of seed weight per plant, results showed that trend of seed weight per plant among genotypes was significant different (Table 4). The highest quantity of seed weight per plant was measured from unstressed treatment followed by stress at mid pod filling and these did not differ significantly from each other. The least was recorded from stress at flowering. The latter differed significantly from the rest. Seed weight per plant under unstressed treatment differed by 32.9% from those stressed at mid pod filling and 56% from those stressed at flowering. This implies that stress at flowering reduce photosynthesis and consequently translocation and portioning of photosynthetic materials decreases. Our results are supported by the findings of Mohammadzadeh et al., (2011).

Number of seeds per pod varied from 4 to 5 among genotypes, however, PASS was observed to contain an average of less than four seeds. Moisture treatments affected number of seeds per pod especially for beans stressed at flowering. This observation corresponds with the findings of Nuñez *et al*. (2005) who also identified number of pods per plant as the principal cause of yield losses of bean subjected to drought stress, followed by the number of seeds per pod and seed weight.

In this study, 100 seed weight obtained under unstressed treatment was statistically the same with those plots stressed at flowering and was significantly different from those plots stressed at mid pod filling (Table 4). 100 seed weight at mid pod filling was the lowest and highly affected by moisture deficit. This observation signifies that, 100 seed weight stressed at flowering was less because when irrigation was resumed after 20 days it was the period of pod filling for most of genotypes. This phenomenon enabled these genotypes to maximize translocation of assimilates to the seeds and finally the seeds size and dry matter weight. However for those stressed at mid pod filling, stress was experienced when the seed size and weight were at critical stage of development. This shortage of soil moisture, lead to under development of seeds and finally, 100 seed weight decrease. Teran and Singh (2002) reported that drought stress, on the average reduced common bean 100 seed weight by 13 %. Singh (1995) observed a decrease in grain yield and mean weight of a hundred seeds along with accelerated maturity among these characteristics.

V. CONCLUSION

Common bean genotypes differed significantly in their growth characteristics, yield and yield components, when evaluated in different moisture stress treatments and across genotypes. Some genotypes yielded better while others were moderate and few yielded poorly. Highest yields among genotypes stressed at flowering were; BFS60, KG104-72, SER16, MR13905-6, CZ109-22, and SER125. Highest yields among genotypes stressed at mid-pod filling were; KG4-30, RCB266, KG25-21, KG104-72 and SER125. Despite the fact that results demonstrated no significant effect of interactions of the drought treatments and common bean genotypes, genotypes that yielded relatively better under both stresses (stress at flowering and mid pod filling) were SER16, KG104-72 and SER125. Genotypes that yielded better under all conditions (non stress, stress at flowering and mid pod filling) were SER16, KG104-72, KG4-30, and CZ109-22. Since the study was based on the observations of morphological response of bean genotypes treated with different moisture stress periods, therefore there is need to investigate the presence of any physiological mechanisms involved in providing tolerance under limited moisture. This knowledge will help to improve selection criteria for drought tolerance of common bean. Genotypes SER16, BFS60 and KG104-72 were observed to be superior in yield under moisture stress conditions; therefore, it is recommended that, those genotypes could be used as a source of breeding materials for drought resistance in areas which are affected by drought at flowering. In areas where droughts occur during mid-pod filling, it is recommend that genotypes KG4-30, RCB266, KG104-72 and SER125 could be used as a source of breeding materials for drought resistance. Since the selection was based on morphological characterization, it is recommended that, marker assisted selection could be deployed to confirm the findings.

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