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Assessment of the Effects of Drought Stress at Seedling and Flowering Stages of Cowpea Development on Yield and Yield Attributes

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Abstract

Cowpea is a food legume widely used in tropic and sub-tropic countries of Africa. Drought stress is one of the major constraints in cowpea production. Its damages on cowpea agronomic performance is function of plants developmental stage. The aim of the study was to assess the effects of seedling and flowering stages drought stress on cowpea production. Treatments consisted of drought stress at three levels (drought at seedling stage (DS), drought at flowering stage (DF) and the control) and four cowpea varieties (Gorom local, Moussa local, KVx396-4-5-2D and Tiligre). The trial was conducted using a split-plot design replicated three times. Growth and yield data were collected and submitted to an analysis of variance using JMP Pro 16 software. Means were separated using Student Newman Keuhl's test. The results show that during both seasons and combined, the control gave the highest number of pods per plant, weight of pods per plant, number of grains per pod and grain yield per hectare, except for above ground biomass for which higher averages were registered from the seedling stage drought stress conditions.The lowest yield and yield attributes were consistently recorded when plants subjected to drought stress at flowering stage. Drought at flowering stage of cowpea development drastically affects both grain and haulm yields. Drought at seedling stage of cowpea development when followed by a re-irrigation is without major negatives impact on cowpea agronomical performance.

Key words: Cowpea, drought stress, variety, yield.

1. Introduction

Agriculture is the main source of food and livelihood for many households over the world and particularly in Africa. Farming systems encounter key difficulties including the expansion of aggregate food for feeding the growing population and the scarcity of water resources (Bouman, 2007). Water is the pivotal element in crops production as it plays a major role in the initiation of growth and the development processes throughout the plant's life (Shakeel Ahmad *et al*., 2017). The rainfall which is the main source of water for crops production for most of rural farmers is gradually becoming erratic due mostly to global climate change (Belder *et al*., 2005; Bouman, 2007).

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The climate change characterized by an increasing world's surface average temperature and consequently an increasing precipitations, dissipations and overflow over the world led to an intensification of worldwide hydrological cycle and expansion of extreme events (Huntington, 2006). One of the most emerging extreme meteorological events affecting the agricultural sector is the gradual increase of drought spells during production seasons (FAOSTAT, 2015; Penalba & Rivera, 2013). Drought is one of the most dynamic and worse stress that severely hampers plants growth and development (Jaleel *et al.*, 2009). Drought stress affect seeds germination, seedling emergence, leaf, root, tiller and stem growth and development as well as dry matter production, flowering, pollination, fertilization, seed development, seed yield and seed quality (Jaleel *et al.*, 2009). Likewise, the reduction of water potential in plants alters plant physiological and biochemical processes such as cells division and elongation, the synthesis of new protoplasm and the productivity (Alves & Setter, 2004; Anjum *et al.*, 2011; Shao *et al.*, 2009). This harmful effects of water deficit on crops production is chiefly observed in the arid and semi-arid zones, where agriculture remains the main source of employment (Anjum *et al.*, 2011). The lowered amount of rainfall during the rainy season significantly hinders agricultural performance sowing to decreases of crops yields and the profitability of productions (Anjum *et al.*, 2011). The decrease of yield in these conditions concerns all crops species including legumes, such as cowpea. Ahmad & Ibrahim (2013), reported that pedoclimatic stresses are the main constraints in cowpea production. According to Ishiyaku & Aliyu (2013), in the arid and semi-arid tropics and sub-tropics, water deficit due to the erratic rainfall and the high temperatures are the major problems faced by cowpea producers. Drought negatively affects not only the grain yield of cowpea but also biomass production (Ahmad & Ibrahim, 2013). According to Toudou *et al.* (2018), the loss of cowpea grain yield and fodder yield due to drought stress was estimated at 62% and 56% respectively compared to normal conditions. The decline in cowpea grain productions due to drought spells during the rainy season contributes to decrease the food availability, which leads to a nutritional deficit of many people, as cowpea is the main source of vegetable protein in rural zones. In effect, drought stress is a major threat to food security over the world (Waleed, 2019). According to Anjum *et al.* (2011) and Shao *et al.* (2009), the decrease of yields due to drought depends on the crop genotype, the intensity and duration of the drought stress and the plant developmental stage. In these conditions, understanding the relative effects of drought stress on growth and yield of cowpea varieties at different developmental stages is important for guiding farmers in cowpea production, especially in adopting the adequate measures for mitigating drought negative effects on cowpea yields. The study is aimed at understanding the effects of seedling and flowering stages drought stress on cowpea production. Specifically, the objectives were (i) evaluating the effects of seedling stage drought stress on growth, yield components and yield of cowpea (ii) evaluating the effects of flowering stage drought stress on growth, yield components and yield of cowpea varieties.

2. Materials And Methods

2.1 Experimental site

The experiments were conducted in 2020 and 2021 during dry seasons in Burkina Faso at the Centre of Environmental and Agricultural Research and Training (CREAF), one of the Regional Centres of the Institute of Environment and Agricultural Research (INERA). It is located in the northeast part of the capital city Ouagadougou, at 12°28' north and 01°33' west at 300 m above sea level. The climate is of north-soudanian type characterized by a long dry season from November to May and a rainy season from June to October, the rainfall varying from a year to another.

2.2 Treatments and experimental design

The experiment consisted of two factors: drought stress at three levels of treatments (control (good watering); drought at seedling stage (DS); drought at flowering stage (DF)) and the variety at four levels (Gorom local, Moussa local, KVx396-4-5-2D and Tiligre). The experimental design was a split-plot design with the drought stress stage as main factor in the main plot and the variety as sub-factor in the sub-plot, replicated three times.

2.3 Cultural practices

2.3.1 Land preparation and sowing

The land preparation consisted of a ploughing using a tractor. A day before sowing, all the plots were well irrigated. Sowing was done in lines of 3 m length. The inter-row and intra-row spacing were respectively of 0.8 m and 0.4 m.

2.3.2 Crop maintenance practices

Irrigation and drought stress induction

A day before the sowing, the plots were irrigated up to the field capacity. After sowing, the irrigation was uniformly done at 4 days interval to field capacity. The impositions of drought stress at seedling and flowering stages were done by suspending irrigation for two weeks.

Weeding

The weed management within each experimental field was done by manual hoe at two weeks and 6 weeks after sowing in all the plots.

Fertilization

The NPK (14-23-14) at the rate of 100 kg per hectare as recommended by the Alliance for a Green Revolution in Africa (2018), was applied as fertilizer one week after sowing to favour a good development of plants.

Pesticide application

The plants protection against crops pests during their growing and reproductive stages was done by applying the Delta cal insecticide at the rate of 0.02 kg a.i ha^{-1} at the beginning flowering and the beginning of pods formation using Knapsack sprayer.

2.4 Data collection

The following data were recorded:

- Growth data: pod length, above ground biomass
- Yield and yield components data: number of pods per plant, weight of pods per plant, number of grains per pod, grain weight per plant, hundred grain weight, grain yield per hectare and harvest index.

The grain yields were calculated using the following formula:

$$\text{Grain yield ha}^{-1} = \frac{\text{Grain yield of net plot (kg)}}{\text{Harvested area of net plot (m}^2\text{)}} * 10000\ \text{m}^2$$

The harvest index (HI) was calculated as the ratio of the grain weight to the above ground dry matter including the grain and the straw weights through the following formula.

$$\text{HI} = \frac{\text{Grain yield (kg } ha^{-1}\text{)}}{\text{(Biomass + Grain yield) (kg ha}^{-1}\text{)}}$$

3. RESULTS

3.1 Effects of Drought Stress Stage and Cowpea Variety on Yield Components and Yield

Table 1 and Table 2 respectively present the effects of drought stress stage and cowpea variety on yield components and yield in 2020, 2021 seasons and combined.

Above ground biomass

Significant effects of the drought stress stage and variety on above ground biomass was observed during both seasons and combined. Imposing drought stress at seedling stage consistently resulted in the highest above ground biomass, while the lowest was registered when plants subjected to drought stress at flowering stage. In combined, Moussa local was significantly the high above ground biomass productive variety, while Gorom local was the low.

Pod length

During both seasons and combined, drought stress stage and variety significantly influenced the variable pod length. The control consistently gave longer pods. Stressing plants at flowering-stage produced shorter pods. At variety level, KVx396-4-5-2D significantly exhibited longer pods, while Moussa local presented the shortest.

Number of pods per plant, pod weight per plant, number of grains per pod, grains weight per plant and hundred grains weight

Drought stress stage and variety had significant effect on yield components. During both seasons and combined, the highest number of pods per plant, pod weight per plant, number of grains per pod and grain weight per plant were registered from the control. Stressing plants at seedling stage resulted in intermediate average values, while the lowest were registered when drought was imposed to plants at flowering stage of development.

In contrary to the other yield components, the control consistently resulted in the highest 100 grains weight, while the lowest was registered in seedling-stage drought stress plot.

During both seasons and combined, the highest number of pods per plant, pods weight per plantand grains weight per plant were significantly and consistently exhibited by KVx396-4-5-2D, while Moussa local recorded the least.

The highest number of grains per pod was exhibited by KVx396-4-5-2D, while the lowest was showed by Tiligre. However, Tiligre significantly and consistently recorded the highest 100 seeds weight than the other varieties, while Moussa local consistently supported the least.

Grain yield per hectare

Drought stress stage and cowpea variety significantly affected grain yield per hectare during both seasons and combined. Similarly, to most of the yield components, the unstressed plot consistently and significantly resulted in the highest grain yield than the other drought stress treatments during both seasons and combined. The lowest grain yield was registered when drought stress was imposed to plants at flowering stage.

KVx396-4-5-2D significantly and steadily showed the highest grain yield. Lower grain yield was registered with the variety Moussa local during both seasons and combined.

Harvest index

The drought stress stage and variety had significant effect on harvest index. The control gave higher harvest index during both seasons and combined. Applying drought stress at flowering stage consistently resulted in the lowest harvest index. At variety scale, KVx396-4-5-2D and Moussa local recorded the highest and the lowest harvest index respectively in 2020. In 2021, Gorom local presented the highest harvest index, while Moussa local supported the lowest.

Cowpea varieties significantly influenced the grain yield per hectare during both and across seasons. The variety KVx396-4-5-2D consistently recorded the highest grain yield. Moussa local consistently registered the lowest grain yield during both seasons and combined.

3.2 Interaction between drought stress stage and variety on yield characters

Table 3 shows the interaction between drought stress stage and varieties on number of pods per plant in 2020 and 2021, number of grain per pod and grain yield per hectare in combined.

In 2020, number of pods per plant of Gorom local, Moussa local and Tiligre did not significantly change with changes of drought stress stage. However, for KVx396-4-5-2D, imposing drought stress at seedling stage resulted in a greater number of pods per plant than the control and the flowering stage drought stress treatment.

In 2021, Gorom local and KVx396-4-5-2D significantly exhibited higher number of pods per plant in unstressed control. Moussa local and Tiligre respectively presented greater number of pods per plant when drought was imposed at seedling stage and in the control. For all the varieties, the lowest number of pods per plant was consistently registered when drought stress was imposed at flowering stage.

The number of grains per pod of Moussa local did not change with change of drought stress application period. However, Gorom local exhibited the highest number of grains per pod in the control, while the lowest was registered when drought occurred at flowering stage. Similar trend was observed for KVx396-4-5-2D. Stressing Tiligre at seedling stage resulted in higher number of grains per pod, while smaller number of grains per pod was recorded in the control. In combined seasons, for all the varieties, the control significantly resulted in the highest grain yield per hectare. The lowest grain yield was registered when plants were stressed at flowering stage.

Likewise, the interaction between drought stress stage and cowpea variety had significant effects on above ground biomass, grains weight per plant and harvest index. All the varieties (Gorom local, Moussa local, KVx396-4-5-2D and Tiligre) significantly presented the highest above ground biomass when drought was imposed at seedling stage (Figure 1). Drought at flowering stage consistently resulted in lower above ground biomass, except for Tiligre, for which lower average was registered from the control.

The highest grains weight per plant was constantly registered in the control, while lower grains weight per plant was recorded when drought was applied at flowering stage (Figure 2).

Table 1. Effects of drought stress stage and cowpea variety on growth and yield attributes in 2020, 2021 and combined

Treatments	AGB (g)			PL (cm)			NPP			PWP (g)			NGP		
	2020	2021	Comb	2020	2021	Comb	2020	2021	Comb	2020	2021	Comb	2020	2021	Comb
DROUGHT STRESS STAGE (DSS)															
Control	38.22b	40.61b	39.41b	13.39a	13.68a	13.53a	22.25a	35.58a	28.91a	55.86a	80.99a	68.42a	7.75	7.86	7.80a
Drought at flowering	29.77c	31.50c	30.64c	10.81c	11.85b	11.33c	15.41b	17.88b	16.65b	38.13c	33.52c	35.82c	7.25	7.27	7.26b
Drought at seedling	59.05a	65.89a	62.47a	12.50b	13.44a	12.97b	22.16a	31.36a	26.76a	44.58b	66.31b	55.44b	7.58	7.50	7.54ab
P-value	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	0.0004	‹.0001	‹.0001	0.14	0.20	0.035
SE±	2.613	2.641	1.857	0.196	0.211	0.139	1.352	2.030	0.992	3.132	5.726	2.864	0.206	0.222	0.146
VARIETY (V)															
Gorom local	39.90c	41.62b	40.76c	11.25b	12.02b	11.64b	16.63bc	33.18a	24.90b	39.82b	76.80a	58.31b	7.66b	7.40b	7.53b
Moussa local	49.94a	53.59a	51.76a	11.23b	11.98b	11.60b	15.74c	20.96b	18.35d	28.46c	35.88b	32.17d	6.85c	6.59c	6.72c
KVx396-4-5-2D	43.95b	45.80b	44.88b	13.25a	14.03a	13.64a	29.48a	33.48a	31.48a	68.68a	87.17a	77.93a	8.96a	9.48a	9.22a
Tiligre	42.60b	46.64ab	44.62bc	13.20a	13.94a	13.57a	19.25b	24.14b	21.70c	39.79b	49.23b	44.51c	6.63c	6.70bc	6.66c
P-value	0.007	0.010	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001
SE±	3.017	3.050	2.145	0.227	0.244	0.161	1.561	2.344	1.145	3.617	6.612	3.307	0.238	0.256	0.169
DSS*V	0.08	0.005	0.0001	0.49	0.96	0.70	‹.0001	0.041	0.07	‹.0001	0.015	0.05	0.0004	0.54	0.05

AGB: above ground biomass; PL: pod length;NPP: number of pods per plant; PWP: pods weight per plant; NGP: number of grains per plant; DSS: drought stress stage; V: variety; SE±: standard error.

Table 2. Effects of drought stress stage and cowpea variety on grain weight per plant, 100 seeds weight, grain yield, above ground biomass and harvest indexin 2020, 2021 and combined

Treatments	GWP (g)			100GW (g)			GYH (kg ha^{-1})			HI		
	2020	2021	Comb	2020	2021	Comb	2021	2020	Comb	2020	2021	Comb
DROUGHT STRESS STAGE (DSS)												
Control	36.30a	59.49a	47.89a	20.94a	20.38a	20.94a	1610.28a	3059.88a	2335.08a	0.49a	0.54a	0.52a
Drought at flowering	25.29a	24.86b	25.07c	20.90a	20.10a	20.90a	1680.08b	2601.49b	2140.78b	0.46a	0.42b	0.44b
Drought at seedling	31.21b	46.36a	38.67b	18.45b	19.04b	18.45b	1240.91b	1214.17c	1227.54c	0.32b	0.40b	0.36c
P-value	0.0004	‹.0001	‹.0001	‹.0001	0.006	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001
SE±	2.192	4.004	2.010	0.252	0.252	0.252	134.599	251.665	123.511	0.016	0.019	0.012
VARIETY (V)												
Gorom local	27.87b	55.38a	41.62b	21.26b	21.06a	21.26b	1451.79b	3001.97a	2226.88b	0.45b	0.55a	0.50a
Moussa local	19.92c	25.12b	22.52d	18.42c	17.93c	18.42c	1079.50c	1149.28b	1114.39d	0.28c	0.30c	0.29c
KVx396-4-5-2D	48.08a	61.02a	54.55a	18.31c	18.56b	18.31c	2280.58a	3155.32a	2717.95a	0.51a	0.54a	0.53a

Tiligre	27.85b	34.46b	31.16c	22.39a	21.80a	22.39a	1330.73b	1761.73b	1546.23c	0.45b	0.43b	0.44b
P-value	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001	‹.0001
SE±	2.532	4. 624	2.321	0.291	0.33	0.291	155.422	290.598	142.618	0.019	0.022	0.014
DSS*V	‹.0001	0.016	‹.0001	‹.0001	0.19	‹.0001	‹.0001	0.013	0.001	0.032	0.048	0.004

GWP: grain weight per plant; 100GW: hundred grain weight; GYH: grain yield per hectare; HI: harvest index; DSS: drought stress stage; V: variety; SE±: standard error.

All the varieties significantly showed higher harvest index in the unstressed plots (the control) and lower harvest index when drought was imposed at seedling-stage of development (Figure 3).

Table 3. Interaction between drought stress stage and cowpea variety on number of pods per plant in 2020 and 2021 and number of grains per pod in 2020, grain weight per plant (g) and grain yield per hectare (kg ha^{-1}) in combined seasons

Variety	Drought stress stage					
	Control	DS	DF	Control	DS	DF
	Number of pods per plant in 2020 season			Number of pods per plant in 2021 season		
Gorom local	18.46gh	13.77ij	17.66hij	44.11ab	33.33bcd	19.11g-j
Moussa local	20.88f-i	12.00j	14.33ij	22.33fgh	26.33efg	14.22ij
KVx396-4-5-2D	31.55de	41.55abc	15.33hij	47.22a	36.22cd	17.00hij
Tiligre	18.11hij	21.33f-i	18.33hij	28.66def	24.55efg	17.22hij
SE±		1.761			3.556	
	Number of grain per pod in 2020 season			Grain weight per plant across seasons		
Gorom local	8.44cde	7.66c-h	6.88g-j	54.58bc	39.46de	27.83gh
Moussa local	6.66g-j	7.33e-i	6.55hij	27.55gh	22.42hi	17.58i
KVx396-4-5-2D	10.00a	8.11c-f	8.77bc	72.95a	63.51ab	27.18gh
Tiligre	5.88j	7.22f-i	6.77g-j	3v.49efg	29.73fgh	27.70gh
SE±		0.362			4.777	
	Grain yield per hectare across seasons					
Gorom local	2911.50bc	2329.20ef	1439.95g-j			
Moussa local	1422.39hij	1121.66kl	799.12m			
KVx396-4-5-2D	3025.24a	3606.12b	1519.8ijk			
Tiligre	1981.22e-h	1506.15jkl	1151.32hij			
SE±		293.415				

Means followed by same letter (s) within and across columns of a treatment group are not significantly different at 5% level of threshold using Student-Newman Keuls test. DF: Drought at flowering stage; DS: Drought at seedling stage. SE: Standard error.

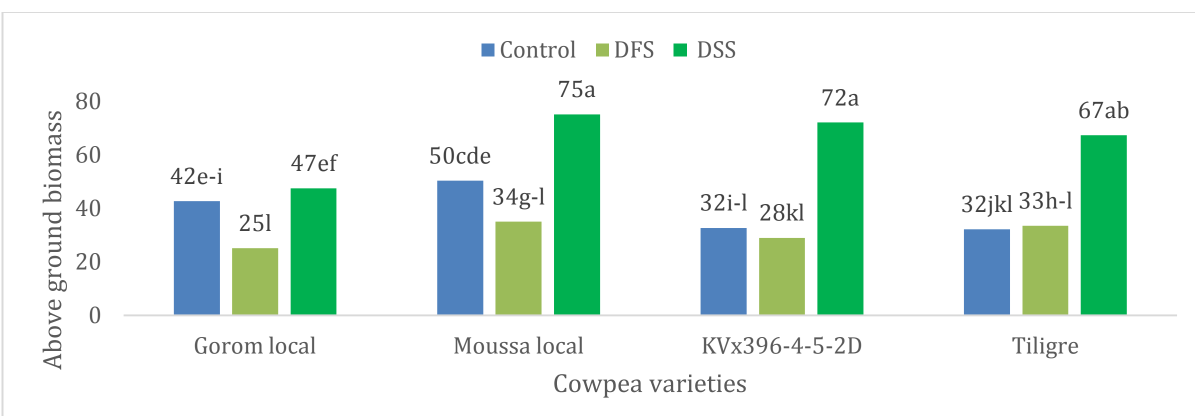

Figure 1. Interaction between drought stress stage and cowpea variety on above ground biomass in combined seasons

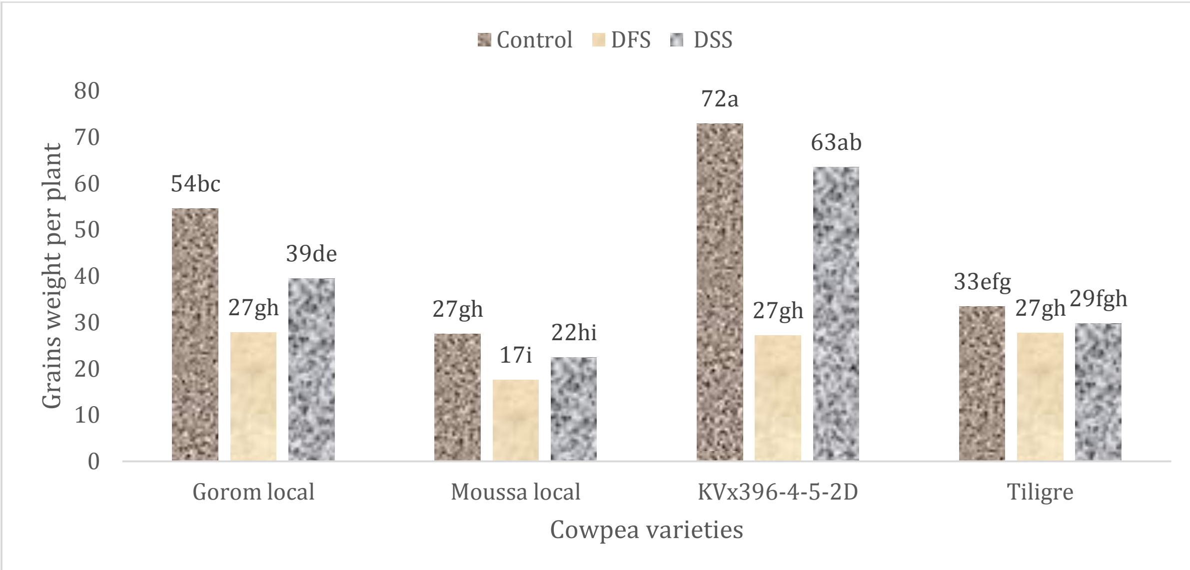

Figure 2. Interaction between drought stress stage and cowpea variety on grain weight per plant in combined seasons

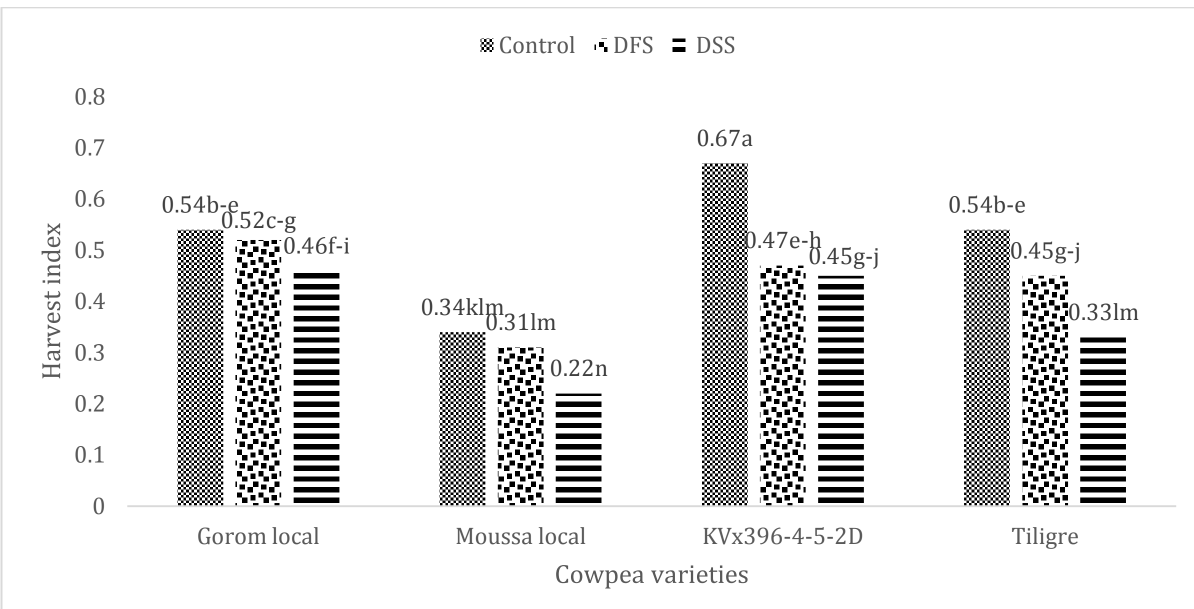

Figure 3. Interaction between drought stress stage and cowpea variety on harvest index in combined seasons

4. DISCUSSION

4.1 Effects of drought stress stage on cowpea growth characters

During both experimental seasons and combined, drought stress stage had significant effect on plants' above ground biomass. Imposing drought stress at seedling-stage recorded the highest above ground biomass, while drought at flowering stage supported the lowest during both seasons and combined. These results indicate that water deficit results in morphological and physiological changes and are in concordance with the findings of Hamidou *et al.*(2007), reporting that drought stress leads to a decreased tissue water content, an increased canopy temperature, a decreased leaves chlorophyll content and consequent photosynthesis.

In addition, the highest mean values observed in seedling stage drought stress treatment shows that drought occurring at seedling stage of cowpea development followed by re-irrigation is without negative influence on cowpea plants, while, that at flowering stage drastically affects their growth and biomass production. The results of the interaction between drought stress stage and varieties showed that for 75% of the varieties, the highest above ground biomass was registered when drought was applied at seedling stage, followed by the control, while lower averages values were recorded in flowering stage drought stress conditions. This could be due to the ability of the crop to recover from the initial drought stress. The resumption of water supply after the water deficit at early stage of cowpea development would rather serve as precursor in activating the plant growth mechanism in a speedy way than in normal conditions in the purpose of filling in the stunting caused by water deficit, hence the favourable effects of seedling stage drought stress on plants growth. Elsewhere, at seedling stage, plants' aerial biomass being usually reduced, irrigating regularly could create cells obstruction and subsequently a disturbance of plants optimum growth and development. The application of drought stress would mitigate the water logging negative effects on plants, facilitating a good aerial development. This could explain the high tall of plants and the high above ground biomass registered when drought stress was induced to plants at seedling stage. This disproportionate production of aerial biomass in seedling-stage drought stress conditions could be also explained by the fact that when water becomes non-limiting, some varieties tend to favour biomass production to grain production (Halilou, 2016). In effect, the lowest harvest index was recorded when drought was imposed at seedling stage testifying that plants were more aerial biomass productive than grain productive in seedling-stage drought stress conditions. The increase of above ground biomass in seedling stage drought stress conditions is in contrast with works of Farooq *et al.* (2009) and Ahmad & Ibrahim (2013), who depicted that drought stress decreases plant height and aerial biomass production. The reduction of the plant growth and biomass production under drought stress effects could be therefore depending on the environmental conditions, especially the crop species or variety, the period of drought stress occurrence during the developmental stage and the intensity and duration of the stress. However, the results corroborates with the findings of Toudou *et al.* (2018), who reported that water deficit at the vegetative stage of cowpea development has minimal effects on plant growth, while, that at flowering stage is more devastating as this stage is the most critical stage of cowpea development. Ishiyaku & Aliyu (2013) concordantly reported from a study on cowpea genotypes that root biomass/aerial biomass ratio was greatly higher when water deficit was occurred at the beginning of flowering stage, showing the extend of the impacts of flowering-stage drought stress on fodder loss in cowpea production.

Likewise, drought stress stage differently affected pod length. Drought at flowering stage recorded shorter pods, indicating a critical stage of water need by plants. This implies that the water availability plays a significant role during cowpea pods formation. Drought at flowering stage reduces pod growth speed more than that at seedling stage and in control conditions. The substantial decrease of pod length in flowering-stage drought stress conditions could be attributed to a general growth deceleration of plants parts including the pods under drought effect. The results concur with Sofield *et al.* (1977) and Toudou *et al.* (2018), who reported that the terminal drought stress reduces drastically the transfer of leaf assimilates to seeds, hampering the pods formation and pods length.

4.2 Effects of drought stress stage on cowpea yield and yield attributes

The stage of drought stress imposition had significant effects on most of the yield components and yield. During both seasons and combined, the unstressed control exhibited the highest average values of number of pods per plant, pod weight per plant, number of grains per pod, pod yield per hectare and grain yield per hectare. The interaction between drought stress stage and variety showed similar trend of drought effects on most of the studied varieties. Imposing drought stress at seedling stage resulted in intermediate average values, while the lowest were registered when plants subjected to drought stress at flowering stage. These variations of mean values traduce all the importance of water supply for the effectiveness of cowpea pods production and pod filling and the different impact of drought stress on cowpea depending on the developmental stage. Sufficient moisture leads to a production of greater number of pods per plant with an increase in number of grains per pod and subsequently in pod weight per plant, pod yield and grain yield per hectare. Drought at seedling stage of cowpea development has fewer negative impacts on cowpea yield. This corroborates with the findings of Hall (2012), who depicted that drought at the vegetative stage of cowpea followed by a re-irrigation has minimal influence on yield and yield attributes. However, drought at flowering stage negatively affects pod yield, grain yield as well as their components due to the deterrence of the photosynthesis and the overall plant's physiological and biochemical processes.

This corroborates with Jaleel *et al.* (2009), who highlighted that seed yield is reduced when plants are subjected to drought stress during seed development. Drought stress occurring at the reproductive phase shortens the seed filling period, which lessens the seed size and the number of seed per plant (Pervez *et al.*, 2009). The mean gap in grain yield and its components observed between the seedling-stage and the flowering-stage drought stress conditions, shows that the effects of drought at seedling stage of cowpea are minim when followed by a re-irrigation, while that at flowering stage can drastically reduce the final yield. One of the studied varieties (Gorom local) is drought tolerant (Batieno, 2014), but as for the other varieties, the lowest grain yield for that variety was observed when drought was imposed at flowering stage. This suggests that the drought stress occurring at flowering stage drastically hinders cowpea grain yield independently of the susceptibility or the tolerance status to drought of the genotype. This severity of the damages of water deficit occurring at flowering stage of cowpea is in concordance with findings ofToudou *et al.* (2018), who suggested that water deficit at flowering stage and at beginning of pod formation leads to a significant decrease in seed yield and yield attributes and the reduction of yield is severe when drought occurs at flowering stage than at early pod formation. According to Turk *et al.* (1980), the application of water stress during flowering and pod filling stages hugely reduces the number of pods per plant and grain size, which could elucidate the low yield recorded in flowering-stage drought stress conditions in the present study. Davies *et al.* (1999) and Fang *et al.* (2010) in the same line reported that in legumes, drought can dramatically reduce the seed yield by limiting flower and pod production, increasing flower and pod abortion and reducing seed size. These damages significantly result in low number of pods per plant, number of grains per pod, pod weight per plant as well as grain weight per plant in water deficit conditions comparatively to the control. All concurs with Waleed (2019), who reported that drought stress is one of the major agricultural productions constraints reducing crops yields and particularly grain crops. However, the negative effects of drought on cowpea varies depending on the period of its occurrence during plants developmental stage.

5. Conclusion

Drought stress differently affects cowpea growth and yield depending on the plants developmental stage. Drought at seedling stage positively influences cowpea aerial biomass production with minimal negative effects on yield and yield components. Drought at flowering stage drastically reduces cowpea agronomical performance by decreasing both grain and fodder yield. These two-year experiments results can serve in strengthening knowledge in drought stress effects on cowpea production for growers and help to enhance seasonal productions by taking adequate measures for mitigating the damages of drought stress on final yield. However, further investigations of drought stress impacts on cowpea taking into account more growing stages of drought stress application could be necessary.

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Conflict of interest

The authors declare that there is no conflict of interest.

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