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**ORIGINAL ARTICLE** **OPEN ACCESS**

# Growth and Yield of Cowpea (*Vigna unguiculata* L.) cultivars under Water Deficit at different Growth Stages

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**ABSTRACT**
*A field experiment conducted in 2013 and 2014 at the Agriculture Experimental Station of King Abdulaziz University to study the effects of water deficit on growth, yield and irrigation water use efficiency (IWUE) of three cowpea cultivars. The deficit irrigation treatments were applied at vegetative (T1), flowering and bud setting (T2), bud filling (T3), vegetative and bud filling (T4) and flowering and bud filling (T5) stages. The plants of cowpea provided with the full water requirements were used as control treatment (T0). The experiments were laid out in split plot design using 3 replicates. The cultivar 'Balady' revealed significant increase in all assessed growth, yield component and yield parameters and irrigation water use efficiency (IWUE) in both seasons except no. of seeds/pods in 2013. Applying water deficit at vegetative growth stage significantly increased no. of branches/plant, no. of pods/plant, no. of seeds/pod, weight of seeds/plant (g), weight of 100 seeds(g), total yield of dry seeds (kg/ha) and IWUE (kg $mm^{-1}ha^{-1}$). Growing the plants under water deficit at the stage of flowering and pod filling (T5) caused significant reduction in all measured growth, yield component and yield parameters as well as irrigation water use efficiency (IWUE). Enhanced growth, yield and irrigation water use efficiency were observed for plants of the cultivar 'Balady' under water deficit stresses at vegetative stage (T1). Least performance was observed for plants of the cultivars 'Carem7' and 'TVu9443' under water deficit stresses at vegetative and flowering stage (T4) and flowering and pod filling stages (T5). The cowpea cultivar 'Balady' can be presented for cultivation under water deficit stresses particularly at vegetative stage.*
***Key words:*** *Cowpea, water use efficiency, yield, water deficit.*

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## INTRODUCTION

Water deficit was reported to be a major constraint to food production due to the losses of crops growth, yield and quality and the restriction of spread cultivation of crops and use of land previously uncultivated [1], [2], [3]. Therefore, increase the gap between food needs and production. Plant tolerance to water deficit is the ability to survive and preserve growth under water deficit. The tolerant/resistant plants utilize different mechanisms to grow and develop under the stresses of water deficit. For instance some plants tend to finish their life cycle as fast as the occurrence of water deficit [4], [5]. The other tolerant plants have the ability to conserve available water (maintain growth by retaining water content) through the reduction of water loss. These types of plants reducing their leaf sizes, number of stomatal pore and stomatal conductance under the water deficit [6], [7]. Another type of tolerant plants able to increase water use efficiency of limited available water [8], [9], [10]. Utilizing these mechanisms in breeding program as indicators for water deficit tolerances was reported to be effective tools to improve crops tolerance [6]. Plant biotechnology has enabled adding desired traits into crops by recombinant DNA technology. However, quantities traits (i.e. water deficit and salinity) which regulated by multiple genes, was reported to be difficult to transfer into some plant species to improve plant tolerance to abiotic stresses including water deficit [11], [12], [10]. Cowpea (*Vigna unguiculata* L.) is grown in arid and semi-arid regions of the world where it is considered as the most drought-tolerant food legumes [13], [5]. The economic importance of cowpea are high protein content of the seeds (20% to 40%), N fixed biologically ranged from 73 to 354 kg N/ha per year, and the consumption of its foliage and fresh and dry grain [1]. There were observed significant differences among cowpea genotypes with regard water deficit tolerance at the vegetative, flowering and pods filling stages [14], [15], [16]. Plant leaves are the most affected plant aspects by water deficit including leaf expansion, leaf area per plant and leaf production and promotes senescence and abscission [17], [18]. The present investigation aimed to study growth, yield and irrigation water use efficiency of three cowpea cultivars grown under stresses of different water deficit treatments.

## MATERIALS AND METHODS

*Experimental Site and climate:*

A field experiment was carried out in 2013 and 2014 cropping seasons at the Agriculture Experimental Station of King Abdulaziz University (KAU) which located at Hada Alsham village (110 km north east of Jeddah, Altitude 226m, Latitude 21◦ 48′ 3″ N and Longitude 39◦ 43′25″ E), KSA. The soil texture of the experimental sites was classified as sandy loam (Sand 84.21%: silt 14.05%: clay 1.74%). The physical prosperities of the soil were pH 7.8 unit, EC 1.79 $dsm^{-1}$, organic matter 0.453% and organic carbon 0.5%. The available macro nutrients N (0.09%), K (60mg/kg) and P (0.02%). The dominant climate of the area is arid, with high temperatures and long photoperiods during summer season (Table 1 and Table 2).

*Plant materials and experimental design:*

Three cowpea cultivars of different genetic backgrounds were evaluated at different growth stages under the effects of different water deficit treatments. The cultivars were Vigna unquculata cv (Balady) obtained from seed market of Makkah regions, Saudi Arabia, Vigna unquculata cv (Cream 7, no eye) and Vigna unquculata cv (TVu 9443, black eye) obtained from International Institute of Tropical Agriculture, Oya State, nigeria. Seeds of all cultivars were subjected to purity, germination and viability tests at the lab of horticulture, Department of Arid Land Agriculture, Faculty of Meteorology, Environment & Arid Land Agriculture, King Abdulaziz University Saudi Arabi. The water deficit field experiment was laid out in split plot design and the treatments were distributed over plots following the Randomized Complete Block design (RCBD) [19] using 3 replicates.

*Applied drip irrigation Systems*

The crop was grown using surface drip irrigation systems. For installing the drip irrigation systems, the experimental site was precisely leveled then the dripper lines were installed on soil surface. The distance between the dripper lines (rows spacing) was 50 cm and the distance between drippers (distance between each two plants in the same line) was 45 cm. The type of the dripper lines was RAIN BIRD LD- 06- 12-1000 Landscape drip 0.9 G/h (4L/h) @18"(obtained from the irrigation accessories market in Jeddah, Saudi Arabia). The downstream end of each dripper line was connected to a manifold for convenient flushing. Inlet pressure on each tape was about 1.5 bars. The system uses 125 micron disk filter. The water source was from two containers always full of water via main irrigation network installed in the location.

*Planting of cowpea Seeds and cultural practices*

Seeds of the tested cultivars were planted in 15 September 2013 and 2014 at the Agriculture Experimental Station of King Abdulaziz University (KAU). Two seeds were planted per dripper and thin to one plant after complete germination. The planting space was 45cm (between two plants in the same row) and the row spacing was 50cm (between two rows). The plant water requirements were added to the plants and controlled automatically through power supply (PSM) timer. The PSM timer was programmed to supply irrigation water for a period of 10 minutes twice a day (at 7:00 am and 6:00 pm) until germination accomplished (25 days from planting). The supplied irrigation water was extended gradually along the growing season to cover the required amount of water for cowpea. The quality of applied irrigation water was as recommended for cowpea including water EC (1.5 $dsm^{-1}$), Na (0.39 $meql^{-1}$), Mg (0.22 $meql^{-1}$) and Ca (5.15 $meql^{-1}$) [20] (Mohammed et al. (2007). The plants were fertigated by the recommended dose of 20:20:20 N-P-K combined fertilizer, which divided into 6 equal doses and injected with irrigation water [20] (Mohammed et al. (2007). The other culture practices required for cowpea cultivation were applied.

*Water deficit treatments*

The water deficit treatments were applied after complete of seed germination (25 days of planting). The crop were subjected to the following water deficit treatments

1. Control treatment (T0: Full water requirements)
2. Water deficit after 25 days of sowing (T1: vegetative stage)
3. Water deficit after 50 days from sowing (T2: flowering and pods setting stages)
4. Water deficit after 75 days from sowing (T3: pods filling stage)
5. Water deficit after 25 days and 50 days from sowing (T4: vegetative and flowering and pods setting stages)
6. Water deficit after 50 days and 75 days from sowing (T5: flowering and pods filling stages)
7. *Calculated water requirements*

The required irrigation water was calculated based on crop water requirement (Evapotranspiration) and total available soil moisture. Evapotranspiration was calculated from reference evapotranspiration and crop coefficient as follows:

$ETc = Kc \times ET0$

Where:

ETc: crop evapotranspiration (mm/day)

ET0 : Reference evapotranspiration (mm/day)

Kc : Crop Coefficient.

Reference evapotranspiration were calculated using Penman-monteith equation as described by [21]. Also, crop coefficient values listed by [21] for cowpea crop were used. The calculated water requirements are presented in Table (3). Calculated water requirements of cowpea which presented in Table (3) was manually applied in the field from drip irrigation network for the required irrigation time calculated

from the dripper discharge, the distance between drippers, and number of drip lines as follows:-

Drip line discharge = 2.1 l/h * 33 dripper = 70 l/h.

Discharge of drip lines of each crop for each treatments = 70 * 6 = 420 l/h.

Discharge (mm/h) = (0.420 m3/ 37.5 m)*1000 = 9.33 mm/h = 0.15 mm/min

Total irrigation time /day = calculated water requirement per day/ discharge (mm).

The required irrigation time for fully and stress treatment during the whole growing season is presented in Table (4). Also, Average water supply ($m^3$/h) for fully and stress treatments during the growing seasons was presented in Table (5).

*Measurements*

The following growth, yield components and yield parameters were assessed during and at the end of each cropping season: Plant height (cm), no. of branches/plant, days to flowering, no. of pods/plant, no. of seeds/pod, weight of seeds/plant, weight of

100 seeds (g), total yield of dry seeds (ton/ha). The irrigation water use efficiency (IWUE kg $mm^{-1}ha^{-1}$) was estimated by dividing yield by depth of water applied in $mm^{-1}$ [22].

*Data Analysis*

Analysis of variance related to split plot design and RCBD experiments as described by [19] was conducted. The treatment means were compared by *F-test* and the Least Significant Differences test (LSD) at 5% probability level.

## RESULTS

*Growth Parameters*

*Plant height(cm)*

There were observed significant differences due to the effects of water deficit treatments on the plant height of tested cultivars in both seasons (Table 6). The control treatment (T0) produced the tallest plants in 2013 and 2014 with no significant differences from T1 (water deficit after 30 days from sowing), T2 (water deficit after 50 days from sowing) and T3 (water deficit after 70 days from sowing). Subjecting the crop to water deficit at two deferent growth stages (T4: water deficit after 25 and 50 days from sowing and T5: water deficit after 50 and 70 days from sowing) significantly restricted the heights of the crop in both seasons. The cultivar 'TVu9443' registered the tallest plants in 2013 (169.53 cm) and 2014 (169.83 cm), while the shortest plants were observed for the cultivar 'Cream 7' in 2013

(89.17 cm) and 2014 (92.35 cm) (Table 7). Regarding the interaction, the watering the crop with full water requirement ( T0) and water deficit treatments T1 and T2 enhanced the plant heights of the cultivar 'TVu9443' in both seasons. Contrary, the shortest plants were observed for the cultivar 'Cream 7' under water deficit treatments T4, but the differences were not significant from the treatments T5, T1 and T2 in both cropping seasons (Table 7).

*No. of branches/plant*

The no. of plant branches was significantly affected by the genotypic and applied water deficit treatments and their interaction in 2013 and 2014 cropping seasons. The crop plants grown under water deficit after 30 days from sowing (T1) formed the greatest no. of branches (8.98 and 7.14 in 2013 and 2014, respectively). Applying water deficit at two different growth stages (T4 and T5) significantly reduced the no. of branches/plant in both seasons (Table 6). With regard the genotypic effects, the cultivar 'Cream 7' registered the highest no. of branches/plant (7.60 in 2013 and 5.58 in 2014) followed by plants of the cultivar 'TVu9443' (7.16 in 2013 and 5.42 in 2014) where the differences were not significant. The least no. of branches was observed for the cultivar 'Balady' with 6.41 and 4.64 in 2013 and 2014, respectively. Concerning interaction the cultivar 'TVu9443' recorded the greatest no. of branches/plant with water deficit T1 (11.50 and 10.11 in 2013 and 2014, respectively). Lower no. of branches was obtained by plants of the cultivar 'Cream 7' (5.07 and 3.00 in 2013 and 2014, respectively) under water deficit T5 as compared to remain treatments (Table 7).

*Days to flowering*

The results of genotypic and water deficit treatments effects on days to flowering of cowpea were presented in Table (6). The differences between the cultivars, the water deficit treatments and their interaction were highly significant in both seasons (Table 6). The crop grown under water deficit treatments T3 and T4 was get into flowering after 65.22 and 64.67 days in 2013 and 61.67 and 63.00 days in 2014 for T3 and T4, respectively (Table 8). On the other hand, plants of the cultivars 'Balady' and 'Cream 7' were significantly delayed to get into flowering in both seasons (64.02 and 61.33 for 'Cream 7' and 63.80 and 60.83 for Balady' in 2013 and 2014, respectively) as compared to cultivar 'TVu9443'. A significant interaction was observed between the tested cultivars and the water deficit treatments with regard days to flowering (Table 8). The results revealed that watering the cultivar 'Cream 7' with full water requirements (T0) and water deficit treatments T1 and T4 significantly delayed the plants to get into flowering in both seasons (Table 8). The earliest flowers were observed for the cultivars 'TVu9443', 'Cream 7' and 'Baldy' under water deficit T5 in both seasons.

*Yield components and yield Parameters*

*No. of pods/plant*

The applied water deficit treatments were significantly affected average no. of pods per plants. The water deficit T1 (after 30 days from sowing) caused significant increase in no. of pods/plant in 2013 (69.64) and 2014 (72.47). The leas no. of pods/plant was produced under water deficit treatments T4 and T5 with no significant differences between the treatments (34.87 and 28.98 in 2013 and 38.30 and 32.01 in 2014 for T4 and T5, respectively). The differences between the three tested cultivars with regard no. of pods/plant were significant in both seasons. Greatest no. of pods/plant was observed for the cultivar 'Balady' with 51.15 and 54.23 pods in 2013 and 2014, respectively. The cultivar 'TVu9443' registered the least no. of pods/plant in 2013 (45.83) and 2014 (49.08). Concerning interaction 'TVu9443' under water deficit T1 attained the highest no. of pods/plant in 2013 (95.50) and 2014 (99.03) (Table 8). However, 'TVu9443' plants produced the least no. of pods/plant under water deficit treatments T5 (22.00 and 25.30) and T4 (23.80 and 27.05) in 2013 and 2014, respectively.

*No. of seeds/pod*

The greatest no. of seeds/pod was produced under water deficit T1 and T3 in 2013 and T0 and T3 in 2014, whereas the water deficit T2 and T5 in 2013 and T2 in 2014 significantly reduced the no. of seeds/pods (Tale 9). Regarding genotypic effects on no. of seeds/pod the differences between the cultivars were significant in 2014 and not significant in 2013(Table 6). However, the cv. 'Balady' registered higher no. of seeds/pod (8.74 and 7.92) than cvs. 'Cream 7' (8.34 and 7.60) and 'TVu9443' (8.13 and 7.65) in 2013 and 2014, respectively (Table 9). The interaction between water deficit treatments and cultivars revealed inconsistent results regarding no. of seeds/pod in 2013 and 2014. Nevertheless, high no. of seeds/pod was observed for the cultivar 'Balady' under T1 (water deficit during vegetative growth) and T0 (full water requirements) in 2013 (10.49) and 2014 (10.01), respectively. Reduced no. of seeds/pod was registered by the cultivar 'Cream7' under the effects of applying water deficit at flowering and pod setting stage (T2) with 6.77 and 6.30 in 2013 and 2014, respectively.

*Weight of seeds/plant (g)*

Highly significant differences were observed between the water deficit treatments, cultivars and their interaction with regard weight of seeds/plant (g) in both seasons (Table 6). Water deficit at vegetative stage (T1) increased seeds weight/plant by 11.79%, 22.96%, 10.47%, 45.08% and 54.96% more than that were observed for T0, T2, T3, T4 and T5, respectively in 2013. Also, in 2014 the T1 water deficit increased seeds weight/plant by 10.24%, 21.14%, 8.94%, 42.87% and 50.21% more than T0, T2, T3, T4 and T5, respectively. The cultivar 'Balady' produced higher seeds weight/plant 'cream7' by 10.65% and 14.08% and 'TVu9443' by 3 9.09% and 35.75% in 2013 and 2014, respectively (Table 9). Regarding interaction enhanced seeds weight/plant (g) was observed when watering the plants of the cv. 'Balady' with full water requirements (T0) in both seasons (83.83 and 88.64 for T0in 2013 and 2014, respectively). The water deficit treatments T4 and T5 extremely reduced plant seeds weight (g) of all tested cultivars particularly the cultivar 'TVu 9443' in both cropping seasons. *Weight of 100 seeds (g)*

Seeds quality of cowpea crop represented by weight of 100 seed (g) was significantly affected by water deficit, genotypes and their interaction in both seasons (Table 6). Greatest weight of 100 seeds was observed for T1 (water deficit at vegetative growth) in 2013 (16.91g) and 2014 (12.39g). Applying water deficit during vegetative, flowering and pod setting stages (T4) significantly reduced weight of 100 seeds in both seasons (14.93g and 11.22g in 2013 and 2014, respectively). On the other hand, greatest weight of 100 seeds was observed for the cultivar 'TVu9443' in 2013 (16.47 g) and 2014 (11.81 g). Reduced weight of 100 seeds was observed for the cultivars 'Cream 7' and 'Balady' with no significant differences in both cropping seasons (Table 10). The weight of 100 seeds was extremely increased when 'TVu9443' plants received water deficit at vegetative growth (T1) in (18.50g and 13.57g in 2013 and 2014, respectively). The cultivar 'Cream7' registered smaller weight of 100 seeds when their plants received water deficit during vegetative, flowering and pod setting stages (T4) as compared to other cultivars in both seasons (Table 10).

*Total yield of dry seeds (kg/ha)*

The results of total yield of dry seeds revealed significant differences between the applied water deficit treatments, tested cultivars and their interaction in both season (Table 6). The water deficit T1 increased the total yield of dry seeds by 28.28%, 18.31%, 1.31%, 30.57% and 62.04% from T0, T2, T3, T4 and T5 in 2013, respectively. Also, in 2014 the increase percentages in total yield of dry seeds were 28.61%, 19.39%, 2.49%, 31.99% and 59.09% from T0, T2, T3, T4 and T5, respectively (Table 10). The cultivar 'Balady' registered higher total yield of dry seeds more than 'TVu 9443' by 48.71% and 47.69% and 'Cream7' by 39.48% and 38.43 in 2013 and 2014, respectively. Regarding interaction the cultivar 'Cream 7' registered highest total yield of dry seeds under T3 in 2013 (1226.40 kg/ha) and T1 in 2014 (1272.70 kg/ha) followed by 'Balady' under T2 with 1077.27ha and 1128.07 kg/ in 2013 and 2014, respectively. Contrary, reduced total yield of dry seeds was observed for the cultivar 'Cream7' under water deficit T5 in 2013 (158.87 kg/ha) and 2014 (210.60 kg/ha).

*Irrigation water use efficiency (IWUE kg mm-1ha-1)*

Results of IWUE revealed significant effects due to applied water deficit, tested cultivars and their interaction in 2013 and 2014 (Fig 1A-D). The highest IWUE was obtained for the cultivar 'Balady' in 2013 (0.273 kg $mm^{-1}ha^{-1}$) and 2014 (0.290 kg $mm^{-1}ha^{-1}$), while the cultivar 'TVu9443' registered the least IWUE in both seasons (0.153 and 0.135 kg $mm^{-1}ha^{-1}$ in 2013 and 2014, respectively) (Fig 1A). Watering the cowpea plants with deficit water at vegetative stage only (T1) result the highest IWUE in 2013 (0.345 kg $mm^{-1}ha^{-1}$), while in 2014 the highest IWUE (0.267 kg $mm^{-1}ha^{-1}$) was observed under water deficit T2 (deficit water was applied at flowering and pod setting stage). Moreover, applying water deficit at flowering and pod setting and at pod filling stages (T5) significantly restricted the IWUE in both seasons (Fig1B). Highly significant interaction between water deficit treatments and tested cultivar (cvs.*WD) was observed (Table 4). Applying water deficit at vegetative stage (T1) enhanced plants of the cultivar 'Cream7' to produce the highest IWUE in both cropping season (0.511 for 2013 and 0.370 kg $mm^{-1}ha^{-1}$ for 2014). However, the results of the second season were not significant from that observed for the cultivar 'Balady' with T2, T1 and T4 with 0.367, 0.365 and 0.320 kg $mm^{-1}ha^{-1}$, respectively (Fig 1C). The cultivars 'TVu9443' and 'Cream7' registered revealed lower IWUE under water deficit T4 and T5 in both cropping season (Fig 1D).

*Relationships between measured parameters*

The simple linear correlations between the growth, yield components and yield parameters during the cropping seasons 2013 and 2014 were presented in Table (11). The plant height revealed significant positive correlation with weight of 100 seeds (g) in 2013. Moreover, non-significant positive correlations were observed between the plant height and the other assessed parameters in both seasons except the traits days to flowering, weight of seeds/plant (g) and total yield (kg/ha) in 2013 and no. of branches and days to flowering in 2014. The no. of pods and weight of seeds/plant (g) was significantly increased as no. of branches/plant increased reflecting significant positive correlations between the traits. Also, as no. of branches increased the values of other assessed parameters non-significantly increased except no. of seeds/pod in the cropping season 2014 (Table 11). Increasing no. of days required to flowering subsequently increased no. of pods/plant, no. of seeds/pods, weight of seeds/plant (g) and total dry seeds yield (kg/ha), while decreased weight of 100 seeds (g) in both seasons. The weight of seeds/plant (g), weight of 100 seeds (g) and total yield of dry seeds (kg/ha) were significantly increased as the no. of pods/plant increased. Also, the no. of seeds/pod was positively associated with no. of pods/plant but the correlation was not significant. Positive linear correlations were observed between no. of seeds/pod and weight of seeds/plant (g) and weight of 100 seeds (g) in both seasons and total yield of dry seeds (kg/ha) in 2014. Highly significant positive correlation was observed between weight of seeds/plant (g) and total dry seeds yield (kg/ha) in both seasons, while the correlation was positive and non-significant with weight of 100 seeds (kg) in both seasons. Results of relationships between the cowpea growth and yield parameters and IWUE indicated positively non-significant correlations except days to flowering in both seasons and total yield of dry seeds( kg/ha) and plant height (cm) in 2014 where the correlations were negatively non-significant.

Table (1): Metrological data recorded from Hada Alsham Meteorology Station[1] during the time of experiment.

| Year /Month | Min. temp.(C°) | Max. temp. (C°) | Mean | Min. Rh. (%) | Max. Rh. (%) | Mean |
|---|---|---|---|---|---|---|
| **Season 2013** | | | | | | |
| February | 20.73 | 31.60 | 26.16 | 37.82 | 56.30 | 47.06 |
| March | 22.86 | 33.10 | 27.98 | 38.64 | 57.40 | 48.02 |
| April | 23.00 | 33.30 | 28.15 | 33.20 | 52.80 | 43.00 |
| May | 26.22 | 36.80 | 31.51 | 36.22 | 56.00 | 46.11 |
| June | 26.64 | 39.70 | 33.17 | 24.97 | 45.20 | 35.08 |
| **Season 2014** | | | | | | |
| February | 13.25 | 35.90 | 24.77 | 16.49 | 60.00 | 58.24 |
| March | 14.99 | 36.90 | 26.98 | 11.94 | 68.70 | 55.32 |
| April | 14.40 | 38.02 | 27.89 | 9.47 | 56.70 | 53.08 |
| May | 20.43 | 44.49 | 32.20 | 16.35 | 68.60 | 57.47 |
| June | 21.03 | 45.17 | 33.71 | 11.40 | 55.60 | 53.50 |

[1]Meteorological Station at Hada Al-sham ((Excellency Centre for climatic change, King Abdulaziz university).

Table (2): Metrological data recorded from Hada Alsham Meteorology Station[1] during the time of experiment.

| Year/Month | Min. wind speed(km/h) | Max. wind speed(km/h) | Mean wind speed(km/h) | Sunshine (h) | Total Rain Full (mm) |
|---|---|---|---|---|---|
| **Season 2013** | | | | | |
| February | 17.21 | -2.00 | 12.53 | 8.13 | 0 |
| March | 16.35 | -2.41 | 11.19 | 7.74 | 0 |
| April | 16.97 | -1.43 | 12.33 | 8.39 | 0 |
| May | 16.00 | -2.38 | 10.87 | 9.78 | 0 |
| June | 17.03 | -0.90 | 12.76 | 10.67 | 0 |
| **Season 2014** | | | | | |
| February | 14.52 | 1.75 | 14.13 | 9.03 | -999 |
| March | 12.63 | 1.80 | 17.21 | 8.37 | 4.76 |
| April | 18.24 | 1.40 | 14.82 | 9.93 | 9.41 |
| May | 19.03 | 0.70 | 14.865 | 10.81 | -999 |
| June | 8.19 | 0.25 | 10.22 | 11.93 | -999 |

[1]Meteorological Station at Hada Al-sham ((Excellency Centre for climatic change, King Abdulaziz university).

Table (3): Calculated crop coefficient at 100% of field capacity and the calculatedvalue of crop evapotranspiration at the three levels of water deficit along the growing season of cowpea.

| Duration | Crop growth stages | Crop coefficient at 100% F.C (Kc) | ETc mm/day | ETc mm/dec | Eff rain mm/dec | Irr. Req. mm/dec |
|---|---|---|---|---|---|---|
| Feb | Initial | 0.70 | 3.26 | 32.60 | 0.10 | 32.50 |
| Feb | Initial | 0.70 | 3.54 | 35.40 | 0.00 | 35.40 |
| Feb | Development | 0.70 | 3.70 | 29.60 | 0.00 | 29.50 |
| Mar | Development | 0.70 | 3.85 | 38.50 | 1.50 | 37.00 |
| Mar | Development | 0.69 | 4.00 | 40.00 | 2.30 | 37.80 |
| Mar | Middle | 0.69 | 4.30 | 47.30 | 2.80 | 44.60 |
| Apr | Middle | 0.69 | 4.62 | 46.20 | 3.70 | 42.40 |
| Apr | Middle | 0.69 | 4.93 | 49.30 | 4.50 | 44.80 |
| Apr | Late | 0.69 | 5.16 | 51.60 | 3.00 | 48.60 |
| May | Late | 0.67 | 5.23 | 52.30 | 0.40 | 51.90 |
| May | Late | 0.65 | 5.36 | 5.40 | 0.00 | 5.40 |
| Total | | | | 428.1 | 18.3 | 409.8 |

Table (4): Average irrigation time min/day for fully and stress treatments during the growing seasons.

| Duration | Water deficit treatments | | | | | |
|---|---|---|---|---|---|---|
| | T0 | T1 | T2 | T3 | T4 | T5 |
| Feb | 22 | 22 | 22 | 22 | 22 | 22 |
| Feb | 24 | 24 | 24 | 24 | 24 | 24 |
| Feb | 25 | 10 | 25 | 25 | 10 | 10 |
| Mar | 25 | 10 | 25 | 25 | 10 | 10 |
| Mar | 25 | 10 | 25 | 25 | 10 | 10 |
| Mar | 27 | 27 | 10 | 27 | 10 | 27 |
| Apr | 28 | 28 | 10 | 28 | 10 | 28 |
| Apr | 30 | 30 | 10 | 30 | 10 | 30 |
| Apr | 32 | 32 | 32 | 10 | 32 | 10 |
| May | 35 | 35 | 35 | 10 | 35 | 10 |
| May | 36 | 36 | 36 | 10 | 36 | 10 |

Table (5): Average water supply ($m^3/h$) for fully and stress treatments during the growing seasons.

| Duration | Crop growth stages | Water deficit treatments | | | | | |
|---|---|---|---|---|---|---|---|
| | | T0 | T1 | T2 | T3 | T4 | T5 |
| Feb | Initial | 325 | 330 | 330 | 330 | 330 | 325 |
| Feb | Initial | 354 | 360 | 360 | 360 | 360 | 354 |
| Feb | Development | 295 | 120 | 300 | 300 | 120 | 120 |
| Mar | Development | 370 | 150 | 375 | 375 | 150 | 150 |
| Mar | Development | 378 | 150 | 375 | 375 | 150 | 150 |
| Mar | Middle | 446 | 445 | 165 | 445 | 165 | 446 |
| Apr | Middle | 424 | 420 | 150 | 420 | 150 | 424 |
| Apr | Middle | 448 | 450 | 150 | 450 | 150 | 448 |
| Apr | Late | 486 | 480 | 480 | 150 | 480 | 150 |
| May | Late | 519 | 525 | 525 | 150 | 525 | 150 |
| May | Late | 54 | 54 | 54 | 15 | 54 | 15 |
| Total | | 4098 | 3484 | 3264 | 3370 | 2634 | 2732 |

Table (6): Mean squares for the response of three cowpea cultivars to water deficit at different growth stages during 2013 and 2014 cropping seasons.

| Source of variance | df | Plant height (cm) | No. of branches | Days to flowering | No. of pods/plant | No. of seeds/pod | Weight of seeds/plant (g) | Weight of 100 seeds (g) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|
| **Cropping season 2013** | | | | | | | | | |
| Replications | 2 | 233.280 ns | 1.227 ns | 1.125 ns | 153.709 ns | 2.350 ns | 3.645 ns | 0.516 ns | 19578.907 ns |
| Cultivars (cvs) | 2 | 33821.34*** | 6.159*** | 44.291*** | 131.014* | 1.596 ns | 2247.114*** | 0.3.485*** | 816831.416*** |
| Water Deficit (WD) | 5 | 4660.438*** | 13.473*** | 45.941*** | 1980.506*** | 7.936*** | 1549.904*** | 3.221*** | 272616.758*** |
| cvs x WD | 10 | 1153.660*** | 4.381** | 9.941*** | 897.063** | 3.325* | 570.330*** | 1.926*** | 252523.298*** |
| Error | 30 | 385.310 | 1.080 | 1.536 | 53.913 | 0.060 | 36.056 | 0.225 | 15974.308 |
| **Cropping season 2014** | | | | | | | | | |
| Replications | 2 | 3.600 ns | 1.153 ns | 0.347 ns | 168.937 ns | 0.173 ns | 1.936 ns | 0.273 ns | 13268.208 ns |
| Cultivars (cvs) | 5 | 28512.100*** | 4.460* | 51.125*** | 126.025* | 2.227* | 2221.836*** | 0.664* | 913717.410*** |
| Water Deficit (WD) | 6 | 4470.540*** | 13.565*** | 50.975*** | 1972.608*** | 4.016*** | 1593.077** | 1.653*** | 295443.314*** |
| cvs x WD | 30 | 830.326*** | 5.193** | 9.925*** | 910.421*** | 1.685*** | 557.339*** | 0.702*** | 221061.435*** |
| Error | 82 | 242.404 | 1.061 | 1.602 | 55.670 | 0.734 | 34.615 | 0.165 | 15543.937 |

ns = non-significant, *, **, ***Significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$

## DISCUSSION

*Growth and yield parameters*

The irrigation water use efficiency (IWUE), growth and yield of three cowpea cultivars under water deficit at different growth stages were investigated. The applied water deficit treatments were designed to cover crop growth stages including vegetative, flowering and pods filling. Also, the duration of 20 days for each water deficit treatment allowed evaluating the consistency of performance of tested cultivars. Highest performance was observed for 'the local cultivar 'Balady' under all applied water deficit treatments. For instance, yield and yield components parameters were higher for 'Balady' than 'TVu9443' and 'Cream7'in both seasons. The reason perhaps due to extensive use of 'Balady' by Saudi framers in Western regions of Saudi Arabia, which increased the cultivar adaptability to dominant environment including soil, irrigation water and climate. The high values of yield and yield components of 'Balady' supported the above explanation. The less seed yield of 'TVu9443' attributed to cultivar sensitivity to drought treatments resulted in less no. of pods/plant, no. of seeds/pod and weight of seeds/plant. Genotypic differences of cowpea have been reported under drought stresses during different growth stages [14], [23], [17]. Water deficit at vegetative stage (T1: applying water deficit after 25 days from sowing) significantly increased yield and yield component parameters of tested cultivars. This may be attributed to decreased evaporation and increased water-use efficiency as compared to other water deficit treatments. Water deficit at vegetative stage reduced the rate of leaf expansion and inhibited the production of new leaves. The negative effects of water deficit at the vegetative stage were removed after re-watering the plants [24]. It was reported that flowering and bud filling were the most sensitive stage of cowpea to water deficit. Yield reduction was reported to be from 35 to 69 % depending on growth stage and duration of water deficit [25], [26]. Applying water deficit at two subsequent growth stages T4 (vegetative and pod filling stages) and T5(flowering and pod filling stages)significantly reduced growth, yield components and yield of cowpea plants. These results illustrated to the timing and length of the drought treatment. In our study, cowpea received water deficit for 40 days for each of T4 (20 days during vegetative and 20 days during pod filling) and T5 (20 days during flowering and 20 days during pod filling). The extended period of drought treatments increased evaporation and decreased water use efficiency resulted in losses of yield components and yield. Also, at flowering and pod filling stages water deficit caused the senescence and subsequently fall down of mature basal leaves. The detrimental effects of water deficit at the flowering and pod-filling stages were not improved by re-watering the plants. These findings were partially in line with the findings of [25], [26]. They reported that timing and length of the drought treatment were responsible for yield reduction from 35 to 69 % that was observed as water deficit applied at vegetative and pod filling stages.

Table (7): Effects of water deficit treatments at different growth stages on growth and yield of three cowpea cultivars: plant height (cm) and no. of branches at maturity.

| **Water deficit treatments (WDT)** | **Plant height (cm)** | | | | **No. of Branches** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Cowpea cultivars** | | | **Mean WDT** | **Cowpea cultivars** | | | **Mean WDT** |
| | **TVu9443**[1] | **Cream7**[1] | **Balady**[2] | | **TVu9443**[1] | **Cream7**[1] | **Balady**[2] | |
| **Cropping season 2013** | | | | | | | | |
| **Control (T0)** | 197.50 | 117.90 | 118.50 | 144.63a | 6.90 | 8.90 | 7.10 | 7.63b |
| **25 days from sowing (T1)** | 214.60 | 80.80 | 120.00 | 138.47a | 11.50 | 8.70 | 6.73 | 8.98a |
| **50 days from sowing (T2)** | 197.60 | 89.27 | 98.20 | 128.36a | 6.20 | 7.80 | 7.33 | 7.11b |
| **75 days from sowing (T3)** | 163.50 | 115.00 | 105.37 | 127.96a | 6.67 | 8.13 | 6.40 | 7.07b |
| **25 and 50 days (T4)** | 119.30 | 65.90 | 86.77 | 90.66b | 6.13 | 6.80 | 5.13 | 6.02c |
| **25 and 75 days (T5)** | 124.97 | 66.20 | 94.00 | 95.06b | 5.67 | 5.07 | 5.80 | 5.51c |
| **Mean cultivar (cvs.)** | 169.59a | 89.17c | 103.81b | | 7.18a | 7.60a | 6.41b | |
| **LSD(0.05) cultivar (cvs)** = 13.368 | | | | | = 0.707 | | | |
| **LSD(0.05) Water deficit (WDT)** = 18.905 | | | | | = 0.548 | | | |
| **LSD(0.05) ( cvs*WDT)** = 25.960 | | | | | = 1.726 | | | |
| **Cropping season 2014** | | | | | | | | |
| **Control (T0)** | 201.01 | 121.03 | 122.08 | 148.04a | 5.00 | 7.03 | 5.27 | 5.77b |
| **25 days from sowing (T1)** | 167.47 | 84.00 | 12310 | 124.87b | 10.11 | 6.52 | 4.80 | 7.14a |
| **50 days from sowing (T2)** | 200.44 | 92.50 | 101.50 | 131.48b | 4.63 | 5.87 | 5.50 | 5.33b |
| **75 days from sowing (T3)** | 172.50 | 118.50 | 158.50 | 149.83a | 4.77 | 6.27 | 4.77 | 5.27b |
| **25 and 50 days (T4)** | 122.05 | 69.04 | 90.04 | 93.71c | 4.27 | 4.80 | 3.51 | 4.19c |
| **25 and 75 days (T5)** | 155.50 | 69.00 | 97.06 | 107.19c | 3.77 | 3.00 | 4.00 | 3.59c |
| **Mean cultivar (cvs.)** | 169.83a | 92.35c | 115.38b | | 5.42a | 5.58a | 4.64b | |
| **LSD(0.05) Cowpea cultivar (cvs)** = 10.599 | | | | | = 0.701 | | | |
| **LSD(0.05) Water deficit treatments (WDT)** = 14.989 | | | | | = 0.543 | | | |
| **LSD(0.05) ( cvs*WDT)** = 32.741 | | | | | = 1.732 | | | |

[1] obtained from the International Institute for Tropical Agriculture (IITA), Nigeria, [2] obtained from the seeds market in Makkah regions, Saudi Arabia.

*Irrigation water use efficiency (IWUE kg mm-1ha-1 )*

Increasing IWUE (kg $mm^{-1}ha^{-1}$) of the cowpea cultivar 'Balady' in both cropping seasons as compared to the other tested cultivars reflected the capability of the cultivar to grow and produce yield under water deficit at different growth stages. Moreover, the increased IWUE of the cultivar 'Balady' can be attributed to the high yield production in relation to the total water supply. In the present study, the cultivar 'Balady' produced shorter plants with lower number of branches as compared to 'Cream7' and 'TVu9443'. Also, the cultivat 'Balady' produced highest no. of pods/plant, no. of seeds/pod, weight of seeds/plant and total yield of dry seeds. These findings can be explained the greater IWUE of 'Balady' as compared to 'Cream 7' and 'TVu9443'. These results were in line with that observed by [17], [27], [28]. They reported that the erect cowpea cultivars maintain higher WUE under water deficit conditions. On the other hand, applying water deficit at vegetative stage (T1) and at flowering and pod setting stage increased significantly IWUE in 2013 and 2014, respectively. Extreme decrease in IWUE was observed when water deficit applied at pod filling (T3), vegetative and flowering (T4) and flowering and pod filling stages (T5) (Fig 1B). This reduction can be attributed to the sensitivity of the reproductive stages of cowpea including flowering and pod setting (T2) and pod filling (T3, T4 and T5) stages to the water deficit. Also, the long period of water deficit during T4 and T5 which was a twice of 20 days during two different growth stages. It was reported that the most sensitive plant growth stages to drought effects were the reproductive stages including flowering and pods/fruits setting and pod filling/fruit development [27], [28], [17], [22] Contrary, the water deficit at vegetative stage revealed the least negative effects on flowering, yield component and yield [29].

Table (8): Effects of water deficit treatments at different growth stages on growth and yield of three cowpea cultivars: days to flowering and no. of pods/plant.

| Water deficit treatments (WDT) | Days to flowering | | | | No. of pods/plant | | | |
|---|---|---|---|---|---|---|---|---|
| | Cowpea cultivars | | | Mean WDT | Cowpea cultivars | | | Mean WDT |
| | TVu9443[1] | Cream7[1] | Balady[2] | | TVu9443[1] | Cream7[1] | Balady[2] | |
| **Cropping season 2013** | | | | | | | | |
| **Control (T0)** | 60.50 | 66.11 | 63.00 | 63.20b | 40.50 | 47.50 | 49.00 | 45.67c |
| **25 days from sowing (T1)** | 62.00 | 65.00 | 62.51 | 63.17b | 95.50 | 48.03 | 64.50 | 69.34a |
| **50 days from sowing (T2)** | 59.03 | 62.01 | 66.04 | 62.36b | 63.00 | 45.03 | 58.41 | 55.48b |
| **75 days from sowing (T3)** | 63.50 | 63.51 | 67.00 | 64.67a | 30.21 | 82.11 | 52.77 | 55.03b |
| **25 and 50 days (T4)** | 63.05 | 67.00 | 66.50 | 65.52a | 23.80 | 35.10 | 45.70 | 34.87d |
| **25 and 75 days (T5)** | 59.00 | 59.12 | 59.08 | 59.07c | 22.00 | 28.42 | 36.53 | 28.98d |
| **Mean cultivar (cvs.)** | 61.18b | 63.80a | 64.02a | | 45.83b | 47.70ab | 51.15a | |
| **LSD(0.05) cultivar (cvs)** = 0.843 | | | | | = 4.990 | | | |
| **LSD(0.05) Water deficit (WDT)** = 1.193 | | | | | = 7.069 | | | |
| **LSD(0.05) ( cvs*WDT)** = 2.112 | | | | | = 12.443 | | | |
| **Cropping season 2014** | | | | | | | | |
| **Control (T0)** | 57.50 | 63.50 | 60.50 | 60.50c | 43.51 | 50.80 | 52.50 | 48.94c |
| **25 days from sowing (T1)** | 59.00 | 62.00 | 59.50 | 60.17c | 99.03 | 51.03 | 67.37 | 72.47a |
| **50 days from sowing (T2)** | 56.00 | 59.00 | 63.00 | 59.33c | 66.52 | 48.00 | 61.00 | 58.51b |
| **75 days from sowing (T3)** | 60.50 | 60.50 | 64.00 | 61.67b | 33.05 | 85.00 | 56.00 | 58.02b |
| **25 and 50 days (T4)** | 60.00 | 64.00 | 65.00 | 63.00a | 27.05 | 38.05 | 49.00 | 38.03d |
| **25 and 75 days (T5)** | 56.00 | 56.00 | 56.00 | 56.00d | 25.30 | 31.50 | 39.50 | 32.10d |
| **Mean cultivar (cvs.)** | 58.17b | 60.83a | 61.33a | | 49.08b | 50.73ab | 54.23a | |
| **LSD(0.05) Cowpea cultivar (cvs)**= 0.862 | | | | | = 5.079 | | | |
| **LSD(0.05) Water deficit treatments (WDT)**= 1.218 | | | | | = 7.183 | | | |
| **LSD(0.05) ( cvs*WDT)** = 2.064 | | | | | = 11.224 | | | |

[1] obtained from the International Institute for Tropical Agriculture (IITA), Nigeria, [2] obtained from the seeds market in Makkah regions, Saudi Arabia.

Table (9): Effects of water deficit treatments at different growth stages on growth and yield of three cowpea cultivars: no. of seeds/pod and weight of seeds/plant(g).

| Water deficit treatments (WDT) | No. of seeds/pod | | | | Weight of seeds/plant(g) | | | |
|---|---|---|---|---|---|---|---|---|
| | Cowpea cultivars | | | Mean WDT | Cowpea cultivars | | | Mean WDT |
| | TVu9443[1] | Cream7[1] | Balady[2] | | TVu9443[1] | Cream7[1] | Balady[2] | |
| **Cropping season 2013** | | | | | | | | |
| **Control (T0)** | 8.50 | 9.50 | 8.27 | 8.76ba | 41.07 | 37.63 | 83.33 | 54.01b |
| **25 days from sowing (T1)** | 8.50 | 10.00 | 10.49 | 9.66a | 59.30 | 50.10 | 74.30 | 61.23a |
| **50 days from sowing (T2)** | 8.00 | 6.77 | 6.80 | 7.19c | 26.50 | 63.10 | 51.90 | 47.17c |
| **75 days from sowing (T3)** | 9.77 | 7.76 | 9.49 | 9.01ba | 35.23 | 73.77 | 55.47 | 54.82b |
| **25 and 50 days (T4)** | 7.00 | 7.76 | 9.98 | 8.25bc | 20.53 | 33.43 | 46.87 | 33.61d |
| **25 and 75 days (T5)** | 7.00 | 8.27 | 7.44 | 7.57c | 24.93 | 29.40 | 28.90 | 27.74e |
| **Mean cultivar (cvs.)** | 8.13a | 8.34a | 8.74a | | 34.59c | 47.90b | 56.79a | |
| **LSD(0.05) cultivar (cvs)** = NS | | | | | = 4.087 | | | |
| **LSD(0.05) Water deficit (WDT)** = 1.106 | | | | | = 5.781 | | | |
| **LSD(0.05) ( cvs*WDT)** = 1.430 | | | | | = 9.812 | | | |
| **Cropping season 2014** | | | | | | | | |
| **Control (T0)** | 8.00 | 8.00 | 10.01 | 8.84a | 46.37 | 43.00 | 88.46 | 59.28b |
| **25 days from sowing (T1)** | 7.26 | 8.00 | 9.05 | 8.01ba | 64.37 | 55.17 | 79.00 | 66.18a |
| **50 days from sowing (T2)** | 7.77 | 6.30 | 7.51 | 7.07c | 31.20 | 68.20 | 57.17 | 52.19c |
| **75 days from sowing (T3)** | 9.00 | 7.77 | 8.27 | 8.35a | 40.10 | 78.77 | 61.90 | 60.26b |
| **25 and 50 days (T4)** | 7.40 | 7.77 | 7.00 | 7.34bc | 25.60 | 38.50 | 49.33 | 37.81d |
| **25 and 75 days (T5)** | 6.50 | 7.77 | 7.77 | 7.37bc | 30.17 | 34.37 | 34.30 | 32.95d |
| **Mean cultivar (cvs.)** | 7.65ba | 7.60b | 7.92a | | 39.63c | 53.00b | 61.69a | |
| **LSD(0.05) Cowpea cultivar (cvs)**= 0.583 | | | | | = 4.005 | | | |
| **LSD(0.05) Water deficit treatments (WDT)**= 0.825 | | | | | = 5.664 | | | |
| **LSD(0.05) ( cvs*WDT)** = 1.921 | | | | | = 10.013 | | | |

[1] obtained from the International Institute for Tropical Agriculture (IITA), Nigeria, [2] obtained from the seeds market in Makkah regions, Saudi Arabia.

Table (10): Effects of water deficit treatments at different growth stages on growth and yield of three cowpea cultivars: weight of 100 seeds (g) and total yield of dry seeds(kg/ha).

| Water deficit treatments (WDT) | Weight of 100 seeds (g) | | | | Total yield of dry seeds(kg/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | Cowpea cultivars | | | Mean WDT | Cowpea cultivars | | | Mean WDT |
| | TVu9443[1] | Cream7[1] | Balady[2] | | TVu9443[1] | Cream7[1] | Balady[2] | |
| **Cropping season 2013** | | | | | | | | |
| **Control (T0)** | 17.00 | 15.80 | 16.00 | 16.27b | 362.27 | 264.57 | 1006.10 | 544.31b |
| **25 days from sowing (T1)** | 18.50 | 15.07 | 17.17 | 16.91a | 504.00 | 707.77 | 1065.10 | 758.97a |
| **50 days from sowing (T2)** | 16.30 | 16.50 | 15.43 | 16.08b | 536.57 | 246.23 | 1077.27 | 620.02b |
| **75 days from sowing (T3)** | 15.60 | 16.63 | 15.97 | 16.07b | 558.00 | 1226.40 | 462.70 | 749.03a |
| **25 and 50 days (T4)** | 15.00 | 14.80 | 15.00 | 14.93c | 403.47 | 385.63 | 791.83 | 526.98b |
| **25 and 75 days (T5)** | 16.43 | 15.40 | 15.77 | 15.87b | 169.10 | 158.87 | 536.43 | 288.13c |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Mean cultivar (cvs.)** | 16.47a | 15.70b | 15.89b | | 422.23b | 498.24b | 823.24a | |
| **LSD(0.05) cultivar (cvs)** = 0.323 | | | | | = 86.041 | | | |
| **LSD(0.05) Water deficit (WDT)** = 0.457 | | | | | = 121.68 | | | |
| **LSD(0.05) ( cvs*WDT)** = 0.682 | | | | | = 207.870 | | | |
| **Cropping season 2014** | | | | | | | | |
| **Control (T0)** | 12.00 | 11.57 | 11.50 | 11.69b | 410.40 | 313.10 | 1056.70 | 593.40b |
| **25 days from sowing (T1)** | 13.57 | 11.40 | 12.20 | 12.39a | 608.30 | 1272.70 | 612.60 | 831.20a |
| **50 days from sowing (T2)** | 11.20 | 11.80 | 11.20 | 11.40cb | 586.47 | 295.47 | 1128.07 | 670.00b |
| **75 days from sowing (T3)** | 11.30 | 11.30 | 11.50 | 11.36cb | 554.80 | 760.67 | 1115.97 | 810.48a |
| **25 and 50 days (T4)** | 11.30 | 11.17 | 11.20 | 11.22c | 415.07 | 438.10 | 842.67 | 565.28b |
| **25 and 75 days (T5)** | 11.50 | 11.37 | 11.37 | 11.41cb | 220.47 | 210.60 | 588.90 | 339.99c |
| **Mean cultivar (cvs.)** | 11.81a | 11.43b | 11.49b | | 465.92b | 548.44b | 890.82a | |
| **LSD(0.05) Cowpea cultivar (cvs)**= 0.276 | | | | | = 84.874 | | | |
| **LSD(0.05) Water deficit treatments (WDT)**= 0.391 | | | | | = 120.030 | | | |
| **LSD(0.05) ( cvs*WDT)** = 0.791 | | | | | = 210.736 | | | |

[1] obtained from the International Institute for Tropical Agriculture (IITA), Nigeria, [2] obtained from the seeds market in Makkah regions, Saudi Arabia.

Table (11): Simple linear relationships between the measured growth, yield components and yield parameters in the experiment during the two cropping seasons.

| Treatments | Plant height (cm) | No. of branches | Days to flowering | No. of pods/plant | No. of seeds/pod | Weight of seeds/plant (g) | Weight of 100 seeds (g) | Total yield dry seeds (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| **Cropping season 2013** | | | | | | | | |
| Plant height (cm) | | | | | | | | |
| No. of branches | 0.376$^{ns}$ | | | | | | | |
| Days to flowering | -0.370 $^{ns}$ | 0.221 $^{ns}$ | | | | | | |
| No. of pods/plant | 0.405 $^{ns}$ | 0.690* | 0.137 $^{ns}$ | | | | | |
| No. of seeds/pod | 0.067 $^{ns}$ | 0.093 $^{ns}$ | 0.360 $^{ns}$ | 0.170 $^{ns}$ | | | | |
| Weight of seeds/plant (g) | -0.024 $^{ns}$ | 0.426 $^{ns}$ | 0.285 $^{ns}$ | 0.635* | 0.244 $^{ns}$ | | | |
| Weight of 100 seeds (g) | 0.694* | 0.549* | -0.405 $^{ns}$ | 0.656* | 0.019 $^{ns}$ | 0.419 $^{ns}$ | | |
| Total yield of dry seeds (kg/ha) | -0.022 $^{ns}$ | 0.104 $^{ns}$ | 0.225 $^{ns}$ | 0.549* | -0.010 $^{ns}$ | 0.769** | 0.210 $^{ns}$ | |
| IWUE (kg mm$^{-1}$ha$^{-1}$) | 0.344 $^{ns}$ | 0.453 $^{ns}$ | -0.0431 $^{ns}$ | 0.396 $^{ns}$ | 0.012 $^{ns}$ | 0.087 $^{ns}$ | 0.237 $^{ns}$ | -0.028 $^{ns}$ |
| **Cropping season 2014** | | | | | | | | |
| Plant height (cm) | | | | | | | | |
| No. of branches | -0.062 $^{ns}$ | | | | | | | |
| Days to flowering | -0.055 $^{ns}$ | 0.184 $^{ns}$ | | | | | | |
| No. of pods/plant | 0.209 $^{ns}$ | 0.733 ** | 0.126 $^{ns}$ | | | | | |
| No. of seeds/pod | 0.343 $^{ns}$ | -0.023 $^{ns}$ | 0.387 $^{ns}$ | 0.146 $^{ns}$ | | | | |
| Weight of seeds/plant (g) | 0.365 $^{ns}$ | 0.422 $^{ns}$ | 0.290 $^{ns}$ | 0.632* | 0.399 $^{ns}$ | | | |
| Weight of 100 seeds (g) | 0.275 $^{ns}$ | 0.716** | -0.196 $^{ns}$ | 0.576* | 0.053 $^{ns}$ | 0.3475 $^{ns}$ | | |
| Total yield of dry seeds (kg/ha) | 0.373 $^{ns}$ | 0.122 $^{ns}$ | 0.261 $^{ns}$ | 0.555* | 0.301 $^{ns}$ | 0.760** | 0.015 $^{ns}$ | |
| IWUE (kg mm$^{-1}$ha$^{-1}$) | -0.034 $^{ns}$ | 0.313 $^{ns}$ | -0.259 $^{ns}$ | 0.471 $^{ns}$ | -0.351 $^{ns}$ | 0.033 $^{ns}$ | 0.340 $^{ns}$ | 0.198 $^{ns}$ |

ns= non-significant, *,**,*** significant at $p \leq 0.05$, 01 and 0.001

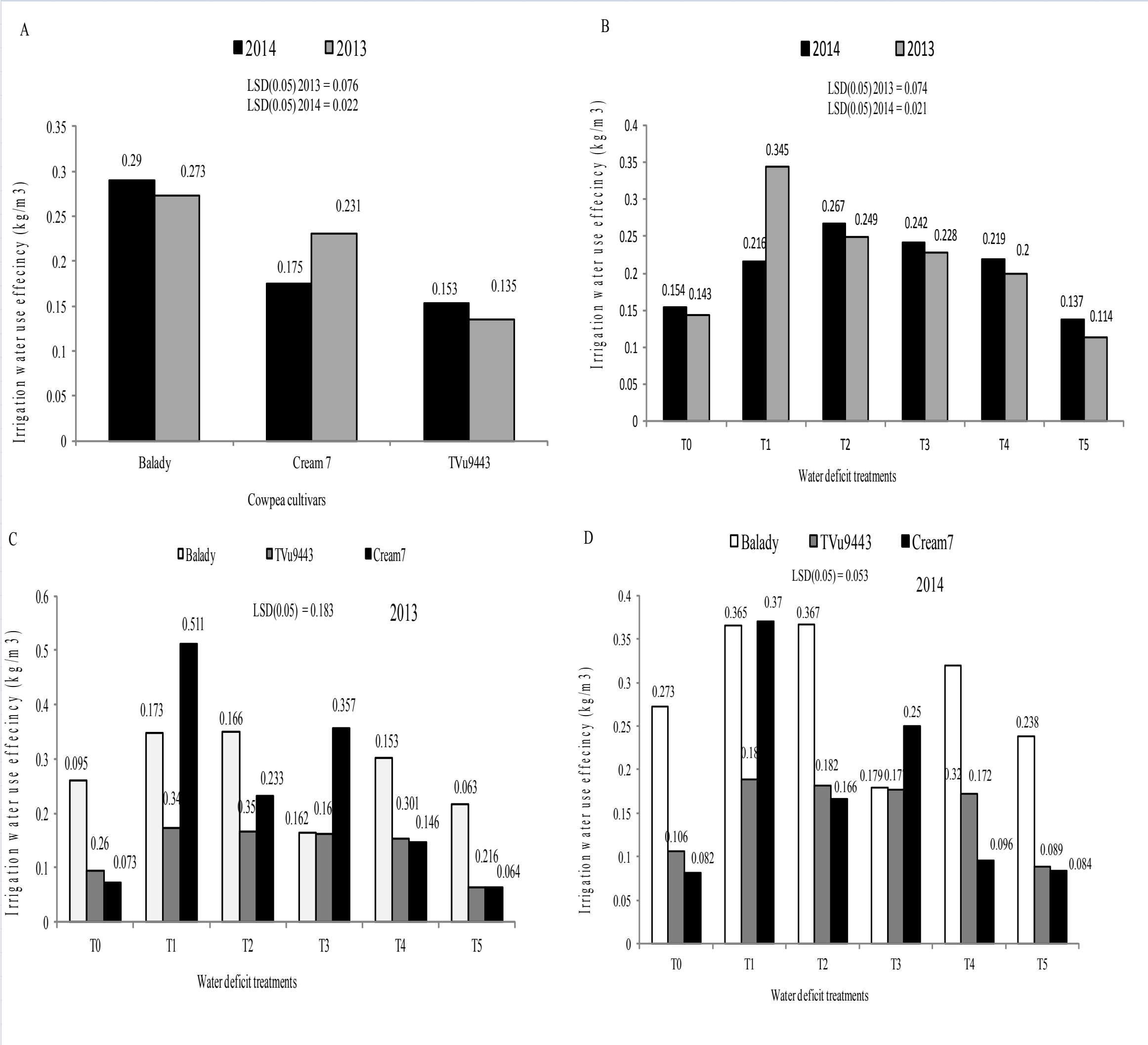


Figure 1: Irrigation water use efficiency (IWUE kg/m³) as affected by applied water deficit treatments and cowpea cultivars: a) genotypic effects in 2013 and 2014, b) water deficit treatments effects in 2013 and 2014, C and D) interaction effects between cowpea cultivars and water deficit treatments in 2013 and 2014, respectively.

## CONCLUSIONS

Good dry seeds yield of cowpea can be obtained under water deficit at vegetative stage for 20 days and 10min irrigation/day (T1). Genetic variability was observed under water stress for growth and yield. Adaptability of the local cultivar 'Balady' to dominant environments of western region of Saudi Arabia enhanced water use efficiency, growth yield under water stress. Subjecting cowpea to water stress twice each of 20 days for 10min/day at vegetative and pod filling (T4) and flowering and pod filling (T5) caused detrimental effects on cowpea growth and seeds yield.

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