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ALLEVIATING ADVERSE EFFECT OF WATER STRESS ON SOME GRAIN SORGHUM (*SORGHUM BICOLOR* L. MOENCH) CULTIVARS BY FOLIAR APPLICATION WITH AMINO CAT FERTILIZER

Ahmed, M.A., Amal G. Ahmed and El-Housini, Ebtesam A.

Field Crop Research Dept., Agricultural and Biological Research Division, National Research Centre, Dokki, Giza, Egypt

Abstract

Two field experiments were carried out to study alleviating adverse effect of water stress on some grain sorghum cultivars (Houras and Shandawell cultivars) by foliar application with the foliar fertilizer Amino cat in private farm at Kom Oshim, Fayoum Governorate during the summer season of 2017 and 2018 agricultural seasons. The main obtained results were:

1- Grain sorghum cultivars (Houras and Shandawell 2 cultivars) significantly differed in growth characters at the different stages of growth, as well as, yield and its components except ($RPP_{bio.}$ and $RPP_{veg.}$). In addition photosynthetic pigments content per green blades at 90 days age and each of total carbohydrate, also, crude protein percentages per dry grains were significantly differed between Houras as Shandawell cultivars. Moreover, the grain sorghum cultivars Shandawell-2 significantly out weight hours cultivar in growth characters at 90 and 105 days age, in photosynthetic pigments content per grain blades at 90 days, and yield and its components (except $RPP_{gr.}$). On the other hand Hours cultivar had the greatest values from RPP_{gr} and RPP_{bio} compared with Shandawell cultivar. Regarding's the percentages of total carbohydrates and crude protein per dry grains at harvest date, Shandawell-2 cultivars characterized by its greatest values from these two chemical constituents of dry grains compared with Hours cultivar.

2- Water stress was imposed by skipping one irrigation at vegetative growth (49 days after sowing), at flowering stage (63 days after sowing) and at grain filling stage (at 77 days after sowing). The most sensitive growth stage of grain sorghum was the vegetative growth, followed by flowering stage and the grain filling period in the end of the least. Generally, water stress treatments significantly decreased growth characters, photosynthetic pigments content per blades, total carbohydrates percentages per dry grain, and yield and its components of grain sorghum in comparison with normal irrigation. On the contrary, water defect treatments significantly increased crude protein per dry grains compared with normal irrigation (without skipping irrigation).

3- Foliar application of amino cat fertilizer increased growth characters, yield and its components, photosynthetic pigments contents per green blades, and total carbohydrates; crude protein percentages. Generally Amino cat fertilizer can alleviated the pervious water stress adverse effects on grain sorghum, and the most favorable concentration to alleviate the water defect effect on grain sorghum plants were 400 cm^3/fed from Amino-cat fertilizer.

4- The data were discussed in terms of interaction of cultivars; water stress, and amino cat fertilizer on grain sorghum plants. Generally, the most favorable treatment to alleviate water defect damage effect on grain sorghum cultivars were Shandawell cultivars sprayed with 400 cm^3/fed amino cat under skipping and irrigation at grain filling stage.

***Keywords*:** Sorghum –water stress- amino cat-chemical components-growth characters-yield.

Introduction

Grain sorghum (*Sorghum bicolor* L. Moench) is one of the most important crops in the world. It is considered the fourth cereal crops after maize, wheat and rice. This crop can yield reasonably well under adverse conditions of low irrigation. It is grown different part of the tropical and subtropical region in the world. In Egypt is concentrated in the middle and upper parts, (Ahmed *et al*., 2013). The introduction of the new semi-tallest cultivars (Shadauel-1, Shandawel-2, Shandawel-6, Hybrid-301, Hybrid-302, Hybrid-304, Hybrid-305, Hybrid-306 and Horus) and the shorted cultivars (Pioneer and Dorado) has resulted in an increases yielding ability when grown under modern production techniques. Moreover, grain sorghum cultivars differed significantly in growth characters and yield as well as its components (Ahmed *et al*., 2011 and Ahmed *et al* 2013 and Gebrekorkos *et al*., 2017). Most of the countries of the world are facing the problem of drought. The insufficiency of water is the principle environmental stress and to enter heavy damage in many parts of the world for agriculture products (Rashad *et al*., Amjad *et al*., 2011, Ahmodizaddah, 2013).

In addition, response of plants to water stress depends on several factors, such as development stage, intensity and duration of stress and cultivar genetics (Ahmodizaddah, 2013). The plant response is very complex because it reflects over space and time the integration of stress effects and response at all underlying levels of organization (Velikova *et al*., 2000). On the other hand, water stress inhibits the photosynthesis of plats, causes changes in chlorophyll content and components and demage to the photosynthetic apparatus (Nayyar and Cupta, 2006), also, it inhibits the photochemical activities and decrease the activities of enzyme in the Calvin cycle in photosynthesis (Abedi and Pakniyat, 2010). In addition, tolerance to biotic stress is very complex due to the interact of interactions between stress factors and various molecular, biochemical and physiological phenomena affecting plant growth and development (Jaleel *et al*., 2009 and Ahmodizaddah, 2013).

For saving irrigation, grain sorghum cultivars that produced high yield under water regime should be developed. A possible approach to minimize drought induced crop losses is the foliar spraying with the foliar fertilizer amino cat. Amino cat fertilizer contains (Free Amino Acids 10%, OM 18%, Total N3%, P_2O_5 1% and K_2O 1%). Approaches have been carried out to minimize the adverse effect of drought by using amino acids as foliar spray (Kasem, 2017)/

So the objectives of the present study were to assess the effectiveness of exogenously applied amino cat fertilizer as foliar spray treatment on grain sorghum plants in terms of improvement of growth characters, biomass production, grain yield, physiological and biochemical processes such as photosynthetic pigments, also, total carbohydrate and crude protein percentages per dry grains in drought stressed grain sorghum plants.

Materials and Methods

The present investigation was carried out during the two summer seasons of 2017 and 2018 at private form in newly cultivated sandy land at Kom Oshim Fayoum Governorate to study the effectiveness of exogenously applied Amino Cat. Fertilizer as foliar spray treatment on two grain sorghum cultivars (i.e. Shandawl-2 and Horus) in terms of improvement of growth characters, biomass production, grain yield, physiological and biochemical processes such as photosynthetic pigments, also, total carbohydrate and crude protein percentages per dry grains in drought stressed grain sorghum plants. Each experiment was laid out in split-splil plots design with four replications, where, the main plants included grain sorghum cultivars, the such plots included the water stress treatments, whereas Amino cat Fertilizer were allocated in sub-sub plots. The experimental unit consisted of seven ridges, five meter long and 60 cm a part planting was done at Mid. May in the two seasons in hills spaced 15 cm a part, where, three grains were added per hill. Thinning to plant per hill was done at 21 days after planting. Nitrogen fertilizer was applied at rate of 120 kg N/fed in four equal dosses at 21, 28 35 and 42 days after planting before irrigation in the form of urea (46% N). Irrigation, pest control and other cultural practices were carried out as recommended by Grain Sorghum Research Dept., Field Crops Research Institute, Agriculture Research Center, Giza, Egypt.

Each experiment included 24 treatments which were the combination of the following treatments:

A- Cultivars:

1- Shandawell-2.

2- Houras.

B- Irrigation treatments:

1- Irrigation every seven days as normal irrigation (I_1).

2- Skipping one irrigation at 49 days after planting (I_2), i.e. at vegetative growth stage.

3- Skipping one irrigation at 63 days after sowing (I_3), i.e. at stage.

4- Skipping on irrigation at 77 days after planting (T_4), i.e. at grain filling stage.

C- Amino Cat Fertilizer:

1- 200 cm^3/fed.

2- 300 cm^3/fed.

3- 400 cm^3/fed.

Spraying amino cat fertilizer was done after skipping irrigation. It is worthy that physical and chemical analysis of experimental site at Kom Oshim, Fayom Governorate was done according to the method described by Chapman and Pratt (1978). The mechanical and chemical of the soil at the experimental site were reported in Table (1).

Table 1: Mechanical and chemical analysis of the soil at experimental site (Average of 2017 and 2018 seasons).

Sand %	Silt %	Clay %	$CaCO_3$ %	Organic matter %	E.C. m. mhos /cm^3	pH	Soluble N Ppm	Available P Ppm	Exchange. K ppm
91.17	3.71	4.12	1.4	0.29	0.31	7.3	8.09	3.4	20.1

Growth Characters

Samples of ten guarded plants were taken at random from each plot at 90 and 105 days age o measure growth characters of grain sorghum plant where, plant height cm, number of active leaves/plant, stem + sheets dry weight g/plant, bloods dry weight g/plant and panicle dry weight g. Furthermore, blades area in/plant were determined according to Bremner and Taha, (1966), whereas, leaf area index (LAI) were measured as recommended by Watson (1952).

Yield measurement

At harvest date, ten guarded plants were taken out at random from the middle two ridges of each plot to determine yield parameters, i.e. plant height, weight of panicle g, weight of grains g/parameter, straw yield g/plant and above ground biomass g/plant. In addition, grain; straw and above ground biomass yield Ten/fed were determined for the total plot area and then converted to yield per fed, then, migration coefficient, crop index and harvest index were determined according to Abdel-Gawad *et al*. (1987). Moreover, Relative Photosynthetic Potential (RPP) for grains, biological yield and vegetative organs were calculated according to the method described by Vidovic and Pokorny (1973).

Chemical Constituents

Photosynthetic pigments content in grain sorghum green (mg/g dry weight) were extracted by aqueous solution of 89% action and calculated using Wettestein formula (Wettestein, 1957) at 9 days after sowing date. Furthermore, the dried grains were finally ground and kept or carbohydrate and crude protein percentages determination, using phenol-sulphoric acid method (Dubois *et al*., 1956) in case of total carbohydrate percentage, while, case of crude protein determination the method described by A.O.A.C. (1980) was used, then crude protein was estimated by multiplying total nitrogen by the factor 5.75.

Statistical analysis

Combined analysis of the data for the two growing season was carried out as procedure outlined by Snedecor and Cochran (1990). For comparison between means L.S.D. test was used.

Results and Discussion

(1) Effect of cultivars

Data reported in Table (2) indicated that sorghum cultivars Houras and Shandawell-2 significantly differed in growth parameters at 90 and 105 days after sowing. Moreover, Shandawell-2 cultivars significantly out weighed on Houras cultivars in plant height, number of active leaves/plant, stem + sheets dry weight "g/plant", active blades dry weight g/plant, panicle dry weight g, blades area, plant and LAI at the two stages of measurement 90 and 105 days after sowing date. On the other hand, number of active leaves/plant, dry weight of stem + sheets and active blades/plant, blades area/plant and LAI of all cultivars tended to decreased with advance of plant age from 90 to 105 days after sowing date, bet plant height and panicle dry weight were increased after 90 days age. The cultivars differences in growth characters are in good harmony with results obtained by (Ahmed *et al*., 2007; Ahmed *et al*., 2013 and Gebrekorkos *et al*., 2017). In addition, cultivar differences in growth attributes in this study may be due to differences in genetic structure (Ahmed *et al*., 2013), to the widely differences between genotypes for mineral element concentrations (Clarek *et al*., 1997), also, to the cultivar differences in photosynthate partitioning and migration among sorghum plant organs (El-Gazzar, 2003 and Ahmed *et al*., 2013).

At 90 days age, photosynthetic pigments content per green sorghum blades were significantly varied between the two grain sorghum cultivars under this study hour as and Shandawel-2, where, Shandawel-2 significantly surpassed Hour as cultivar in Chl-a, Ch0b, Chl-a+b and carotenoids "mg/g dry weight of blades (Table 5). These significant cultivar differences in photosynthetic pigments content may be due to the cultivar differences in genetic structure (Ahmed *et al*., 2013).

At harvest data, plant height, weight of panicle g/plant; grain; straw and biological yields per plant and/or per fed., and RPP_{gr} g/LAI were significantly differed between hour as cultivar and Shandawel-2 cultivar (Table 8). Data illustrated in the same table (i.e. Table 8) indicate clearly that the cultivar differences in RPP_{bio} and RPP_{veg} failed to reach the significant level at 5% level. Furthermore, Table (5) indicates that the differences between grain sorghum cultivars in percentages of total carbohydrates and crude protein per dry grains were significant. Generally, Shandawel-2 cultivar significantly exceeded hour as cultivar in each of plant height, panicle dry weight g/plant, grain, straw and biological yields per plant and/or per fed (Table 8), also, total carbohydrate and crude protein percentages per dry grains (Table 5). On the contrary, hour as cultivars gave the highest significant value from RPP_{gr} compared with Shandawel-2 cultivars at harvest date (Table 8). It is worthy to mention that the differences between cultivars in genetic structure (Ahmed *et al*., 2013) to the differences in mineral element concentrations (Clarch *et al*., 1997), again, to the differences between grain sorghum cultivars in photosynthate partitioning and migration among plant organs (El-Gazzar, 2003 and Ahmed *et al*., 2013). Moreover, the superiority of Shandawel-2 cultivars on hour as cultivars in yield and its components may be due to its superiority in growth characters (Table. 2) and photosynthetic pigments content per green blades (Table 5) compared with hour as cultivar. Finally our results in cultivar differences between grain sorghum cultivars in yield and its components and chemical constituents of grain sorghum plant are in good agreement with previous results reported by El-Gazzar (2003) Ahmed *et al*., (2007), Ahmed *et al* (2013) and Gebrekorkos *et al*. (2017).

(2) Effect of drought stress treatments

Data illustrated in table (2) observed clearly that growth characters of grain sorghum plants were significantly affected by missing one irrigation a different growth stages. The plants received normal irrigation (I_1) gave the heights significant values from plant height, number of active leaves/plant, active blades/plant, panicle dry weight/plant, blades area/plant and LAI at 90 and 105 days after sowing, whereas, the plants exposed to water defect at vegetative growth (49 days after sowing date) res I_2 characterized by its significant smallest mean values from the previous growth characters under this study compared with plants received normal irrigation (S_1), Generally, data presented in Table (2) clearly show that skipping, and irrigation at different stages of growth for grain sorghum plants (i.e. at 49, 63 and 77 days after sowing) caused significant decrement in all growth parameters studied in this study compared with normal irrigation (without missing one irrigation). In addition, data indicated clearly that grain sorghum plants were more sensitive to water stress at vegetative growth stage (i.e. 49 days age), followed by drought stress at heading stage (i.e. 63 days) and skipping one irrigation at milk-rip stage (i.e. 77 days after sowing date, respectively). Furthermore, number of active leaves/plant, dry weight of stem + sheats as well as active blades/plant, blades area/plant and LAI tended to decreased with advancing of plant age from 90 to 105 days after sowing. On the contrary, each of plant height and dry weight of panicle/plant were increased with advancing plant age from 90 to 105 days after sowing date (Table 2). Generally, our results in the negative effect of water defect on growth characters of grain sorghum plants are in harmony with those reported by Ahmed *et al* (2009), Rashad *et al* (2010), Amjad *et al* (2011), Ahmodizaddah *et al* (2011), Ahmed *et al* (2015) El-Metwally *et al*., (2015); Abdel-Salam *et al* (2016).

With respect of the effect of drought stress on photosynthetic pigment content, Table (5) observed that Chl.a, Chl-b, Cha+b and carotenoids were significantly affected by drought stress treatments, in addition, the water stress treatments (i.e. skipping one irrigation at vegetative growth stage 49 days age; skipping one irrigation at flowering stage "63 days age" and skipping one irrigation at milk-ripe stage "77 days after sowing" caused significant decrement in photosynthetic pigments content per green blades of grain sorghum plants at 90 days after sowing in comparison with normal irrigation without missing one irrigation (Table 5). It is worthy that our collected date show clearly that grain sorghum plants were more sensitive to water stress at vegetative growth stage, followed by flowering stage, and milk-ripe stage if grains respectively. These results are in harmony with results obtained by Reddy (2004), Galmes *et al* (2007), Hussein and Khursheed (2014) and Shalaby *et al* (2018a & b). The reduction in photosynthetic pigments content caused by water stress effects may be due to the decreasing in the availability of nutrient to plant which are important to building the photosynthetic pigments under water defect condition especially N,P, Mg, Fe and Se on or may be related to decline the rate of some enzyme such as nitrate reeducates, also, other enzymes which are essential for construction the chlorophyll structure as reported by Galmes *et al.* (2007) and Hussein and Khursheed (2014).

Furthermore, Table (8) observed that skipping one irrigation at certain developmental stage of grain sorghum plant growth caused an significant decrement in yield and its components compared with normal irrigation plants, i.e. without missing an irrigation. In addition, skipping one irrigation at 49 days after sowing date (vegetative growth stage) caused an significant demage in each of plant height, panicle dry weight, grain; straw and biological yields per plant and/or per fed, RPP_{gr}, APP_{bio} and RPP_{veg} (Table 8); as well as; total carbohydrates percentage per dry grains at harvest date (Table 5). On the contrary, a positive effect was found with water stress treatment at vegetative growth on crude protein percentages compared with normal irrigation plants (Table 5). In addition, grain sorghum plant were more sensitive to drought stress treatments at vegetative growth stage (49 days age), followed by, flowering stage (i.e. 63 days age) and milk-ripe stage of grain filling and the end of the sensitivity to drought stress to grain sorghum plants (Table 5 and Table 8). It is worthy to mention that harmful effect of drouht stress on yield and its components of grain sorghum plants are in full agreement with previous results obtained by Ahmed *et al*. (2009), Rashad *et al.* (2010), Amjad *et al.* (2011), Ahmodizaddah *et al.* (2011), Amed *et al* (20-15), El-Metwally *et al.* (2015) and Abel-Salam *et al.* (2016). On the other hand, the negative effect of water stress condition on yield and its components of grain sorghum plants could be attributed to the significant decreament in growth parameters (Table 2), Photosynthetic pigments content per green leaves (Table 5) and RPP_{gr} and RPP_{bio} compared with normal irrigation plants. Furthermore, the harmful effect yield and yield components of grain sorghum plants caused by water defect conditions may be due to the water stress on chlorophyll synthesis, normal decrease and turgor loss (Kramer and Boyer, 1995). Also, regular irrigation after water defect did not recover the drought stress harmful effects on productivity reduction (Ahmed *et al*., 2015). Again, the retardation of photosynthetic enzyme caused by drought stress conditions could be cause such effects, since negative growth stage was affected by water defect, thus; water defect induced perturbation of physiological processes at late stage critical to yield production, consequentially; water defect will be avoided to growth stage (Ahmed *et al*., 2009). In addition, water stress inhibit the photochemical activities and caused decreament in the activities of enzyme in the calven cycle in photosynthesis (Abedi and Pakniyat 2010). Tolerance to biotic stress is very complex due to phenomena affecting plant growth and development (Jaleal *et al*., 2009 and Ahmodizaddeh, 2013). Generally, drought stress damaged might be due to lack of water absorbed, in adequate uptake of essential element, inhibition of meristimatic activity and/or reduction in photosynthetic capacity under unfavorable condition (Ahmed *et al*., 2005), where, assimilates translocate to new developing for premedical were reduced and which were not sufficient to mention or develop this organ.

(3) Effect of amino cat fertilizer

Foliar spraying with amino cat fertilizer on grain sorghum plant caused positive significant effect on growth characters of plants, where, data in Table (2) observed that application of 400 cm^3/fed amino cat fertilizer gave the greatest significant mean values of each of plant height, number of active leaves/plant, panicle dry weight, stem + sheets dry weight/plant, active blades dry weight/plant, panicle dry weight/plant, blades area/plant and LAI compared with 200 and 300 cm^3/fed amino cat fertilizer rates, respectively, and this was true at 90 and 105 days after sowing. In addition Table (5) indicate that the effect of amino cat fertilizer on photosynthetic pigments content per green blades caused significant increment effect according to concentration of amino cat used, where, foliar spraying with 400 cm^3/fed was the most favorable effect of collect the greatest mean values from Ch.a, Ch.b, Chl.a+b and carotenoids per green blades at 90 days age compared with the other two used rates under this study 200 and 300 cm^3/fed, respectively regarding yield and its components Table (8) show clearly that foliar application with 400 cm^3/fed amino-cat fertilizer, also; significantly exceeded the other to concentration from amino-cat fertilizer used in this scientific work, i.e. 200 and 300 cm^3/fed in yield and its components of grain sorghum plants (i.e.) plant height, weight of panicle, grain; straw and biological yield per plant and/or per fed RPP_{gr} and RPP_{bio}, as well as, total carbohydrates and crude protein percentages per dry grains at harvest date, respectively. On the other hand, foliar application with 300 cm^3/fed amino cat fertilizers gave greatest values from RPP_{veg} compared with 200 and 400 cm^3/fed, respectively (Table 8). It is worthy that, the superiority of 400 cm^3/fed over 200 and 300 cm^3/fed from amino cat fertilizer may be due to its greatest positive effect on growth parameters (Table 2), and photosynthetic pigments content per green blades (Table 5) in comparison with 200 and 300 cm^3/fed concentrations, respectively. Furthermore, amino cat fertilizer contains free amino acid 10%, DM 18%, total N_3%, $P\ _2O_5$% and K_2O 1%), where one of the essential amino acids (arginine) considered the main precursor of polyamines which produced by decarboxylation of arginine via arginine decarboxylase to form putrescine (Evans and Malmberg, 1989; Bouchereau *et al*., 1999 and Kasem, 2017), where L-arginine is one of the most functionally diverse amino acids in living cells, again, to serving a constituent of protein, arginine is a precursor for biosynthesis of polyamines, arginine, and protein, as ell as; the cell signaling molecules glutamine and nitrate oxide (Liu *et al*, 2006). Moreover, treatment with amino acids significantly increased content of Chl-a, Ch.b, Chl a+b, as well as carotenoids, carbohydrate, proteins, protein, growth and yield of wheat plants (Kasem *et al*., 2017). It is worthy that, our results herein are in good harmony with those obtained by Gamal El-Din *et al*., 1997; Tarraf and Zaki, 1999; Zaki *et al*., 2014) and Kasem, 2017).

(4) Effect of the interaction:

(a) The interaction cultivars & drought stress treatments:

Table (3) show that plant height, number of active leaves (plant, stem + sheets dry weight/plant, active blades dry weight/plant, panicle dry weight, plant, blades area/plant and LAI were significantly responses to the interaction between grain sorghum cultivars and water stress treatments at 90 and 105 days after sowing. Moreover number of active leaves/plant, stem + sheets dry weight/plants active blades dry weight/plant, blades area/plant and AI tended to decreased with advancing plant age from 90 to 105 days after sowing, whereas, plant height and panicle dry weight were increased with advancing plant age from 90 to 105 days after sowing. In addition Shandaweel-2 cultivars under the normal irrigation (without skipping one irrigation) have the greast mean values from all growth characters studied. On the contrary, Houras cultivars under skipping one irrigation treatment at 49 days are characterized by its smallest values from growth parameter studied at 90 and 105 days age compared with other interaction treatments (Table 3). With respect of photosynthetic pigment content per green blades at 90 days; data illustrated in Table (6) indicated that the interaction cultivars x drought stress treatment was significant on Chl-a, Chl. b, Chl a+b and carotenoids per green blades, Generally, Shandawell-2 cultivars grown under normal irrigation has the greaset mean values from photosynthetic pigment content, but, Houras cultivars gave the smallest mean values from Ch.la, Ch.b, Chl.a+b and carotenoids per green blades compared with other interactions cultivars x water defect treatments under study. Furthermore, Table (8) also, indicate that grain sorghum cultivars were more sensitive to skipping one irrigation at growth stage (49 days age), followed by flowering stage (63 days age) and milk-ripe stage to grains (77 days after sowing), respectively.

Regarding, cultivars x water defect interaction, also, its effects on yield and its components, i.e. plant height, weight of panicle, grain; straw and biological yield per plant and/or per fed., RPP_{gr}, RPP_{bio} and RPP_{veg} were significant (Table 9)< as well as, total carbohydrates and crude protein percentages per dry grains at harvest date (Table 6). Moreover, normal irrigation for Shandawell-2 cultivar gave plants characterized by it greatest out yielded from all yield components studied except RPP_{bio} and RPP_{veg} that found it highest values in Houras cultivar plant under normal irrigation and under skipping one irrigation milk ripe grain stage conditions, respectively. On the other hand, Houras cultivar plants under missing one irrigation at vegetative growth stage characterized by harvesting the little values from yield and its component, herein in comparison with other seven interaction treatments under study (Table 9). Furthermore Table (6) observed that Shandawell-2 cultivars hat the greatest percentage from total carbohydrates per dry grains at normal irrigation, whereas, gave the highest crude protein x per dry grains under skipping one irrigation at vegetative growth stage. On the other hand, Houras cultivar plant-characterized by its inferiority from total carbohydrate and crude protein % under skipping one irrigation at vegetative growth and normal irrigation respectively.

(b) The interaction cultivars x amino fertilizer rates:

Concerning the effect of the interaction cultivars x amino cat fertilize concentration on growth parameters of grain sorghum plants, Table (3) show that the interaction was significant, where Shandawell cultivars plants sprayed with 400 con/fed out yielded the greatest mean values from growth character at 90 and 105 day as, whereas, when Houras cultivar plants sprayed with 200 cm^3/fed amino cat fertilizer produced the lowest values from plant height, number of active blades/plant, stem + sheets dry weight/plant, active blades dry weight/plant, panicle dry weight plant, blades area/plant and LAI at different growth stages studied. Data reported in Table (6) indicate that the effect of the interaction cultivars x amino cat fertilizer concentration reflect a significant effect on Chl-a, Chl.b, Chl.a+b and carotenoids per green blades at 90 days age, in addition, Shandawell-2 cultivar under foliar application with 400 cm^3/fed amino cat fertilizer harvested the greatest values from the previous photosynthetic pigment content, whreas, Houras cultivar plants under foliar spraying with 200cm^3/fed amino cat fertilizer gave the smallest values from photosynthetic pigments content studied (Table 6). Furthermore, yield and its components were significantly responses to the interaction grain sorghum cultivars x amino cat fertilizer rates where, Shandawell cultivar treated with 400 cm^3/fed amino cat characterize by its superiority from plant height, weight of panicle, grains straw and biological yield/plant, RPP_{gr} and RPP_{bio} whereas, Houras cultivars, gave the lowest values from yield and its components under foliar spraying with 200 cm^3/fed except RPP_{ve}, where this cultivar gave the greatest value from RPP_{veg} under foliar application with 300 cm^3/fed amino cat fertilizer, compared with other treatments (Table 6). It is worthy that Shandawell-2 cultivar + 400 cm^3/fed amino cat was the most effective treatments to increase total carbohydrate and crude protein percentage, on the contrary, Houras cultivar + 200 cm^3/fed amino cat fertilizer treatment had the lowest values from total carbohydrates and crude protein percentages per dry grains, compared with other treatments under study.

The interaction water stress treatments x amino cat fertilizer concentrations was significant on growth parameters at 30 and 105 days after sowing (Table 3), chemical constituents of grain sorghum plants (Table 6), as well as, yield and its attributes (Table 9), grain sorghum plants under normal irrigation -40 cm^3/fed amino cat fertilizer gave the greatest values from growth parameters at 90 and 105 days after sowing (Table 3), chemical constituents of grain sorghum plants (Table 6), and consequently, yield and its components (except RPP_{veg}), while, growing grain sorghum plants under foliar spraying with 200 cm^3/fed characterized by its inferiority from the collected plant height, panicle dry weight, grain; straw and above ground biomass per plant/or per fed., RPP_{gr}/ RPP_{bio} and RPP_{veg} compared with other treatments; (Table 9). In addition, normal irrigation treatment + 400 cm^3/fed amino cat fertilizer gave the highest mean values from photosynthetic pigments values per green blades at 90 days age and total carbohydrates/per dry grains, whereas, skipping one irrigation + 400 cm^3/fed amino cat fertilizer treatment gave the greatest crude protein/value per dry grains at harvest date, compared with other treatments. On the contrary, skipping one irrigation + 200 cm^3/fed treatment harvested the lowest values from Chl.a, Chl.b, Chl.a+b, and carotenoids per green blades, as well a, total carbohydrate % per dry grains compared with other treatments, it is worthy that, normal irrigation 200 cm^3/fed amino cat fertilizer gave the lowest crude protein % per dry grains, compared with other eleven treatments (Table 6).

(c) Effect of the three way interaction cultivars x water stress x amino cat fertilizer:

The three way interaction between grain sorghum cultivars, drought stress treatments and foliar spraying with amino cat fertilizer concentrations had an significant effects on growth parameters at 90 and 105 days after sowing (Table 4), photosynthetic pigments content per green blades at 90 days age (Chl.a, Chl.b, Chl.a+b and carotenoids, as well as, total carbohydrate and crude protein percentages per dry grains (Table 7), consequently, yield and its components of grain sorghum plants (Table 10). Generally, Shandaweel-2 cultivar exposed to normal irrigation with skipping any irrigation and treated with 400 cm^3/fed as foliar spraying was the most favorable treatment to collecting the greatest value from growth characters at 90 and 105 days after sowing (Table 4), photosynthetic pigments content per green blades at 90 days, and total carbohydrate% per grain seeds (Table 7), as well as, yield and its components except RPP_{bio} and RPP_{veg} (Table 10) at harvest date. On the other hand, Shandawell-2 cultivar exposed to skipping one irrigation at vegetative growth stage under foliar application with 400 cm^3/fed. Amino cat fertilizer was the most favorable treatment to gave the greatest mean value from crude protein % per dry grains at harvest, whereas, RPP_{bio} and RPP_{veg} gave its greatest values under the treatment Shandaweel-2 under skipping one irrigation at flowering stage (63 cays age) and foliar spraying to grain sorghum plant foliage with 300 cm^3/fed amino cat fertilizer.

Table 2 : Effect of cultivars, water stress at certain development stages and amino cat fertilizer on growth characters of grain sorghum plant (Average of 2017 and 2018 seasons).

Cultivars	Irrigation treatments	Amino cat fertilizer conc Cm^3/fed	90 days after sowing							105 days after sowing						
			Plant height cm^3	No. of active leaves/plant	Stem 1 sheets dry at g/plant	Active blades dry wt. g/plant	Panicle dry wt. g	Blades area cm^3/plant	LAI	Plant height cm^3	No. of active leaves/plant	Stem + sheets dry wt. g/plant	Active blades dry wt. g/plant	Panicle dry wt. g/plant	Blades area cm^3/plant	LAI
Houras			88.45	16.28	9.14	9.37	70.46	878.92	0.98	90.90	15.01	7.91	8.85	120.76	849.39	0.94
Shandawell-2			92.67	17.22	9.31	9.59	74.26	973.94	1.08	96.96	16.21	8.20	9.02	124.05	877.80	0.98
L.S.D at 5% level			2.18	0.26	0.11	0.14	1.44	12.47	0.06	1.68	0.16	0.21	0.10	1.89	11.74	0.02
	I_1		101.15	17.86	9.80	10.32	82.74	842.42	1.09	102.75	16.13	8.50	9.74	141.47	923.59	1.03
	I_2		82.05	15.75	8.66	8.77	64.8	942.42	0.99	82.47	14.78	7.56	8.19	109.14	823.36	0.91
	I_3		87.72	16.32	8.99	9.17	68.9	905.10	1.01	91.49	15.36	7.86	8.55	114.67	839.46	0.93
	I_4		91.33	17.07	9.47	9.66	73.00	925.26	1.03	99.0	16.17	8.31	9.28	124.34	867.98	0.96
L.S.D at 5% level			8.11	0.44	0.15	0.29	1.58	11.11	0.05	1.07	0.02	0.15	0.21	10.27	11.26	0.04
		200cm^3/fed	87.07	16.11	8.74	8.85	66.98	893.04	0.99	91.25	15.06	7.69	8.16	116.70	835.62	0.93
		300cm^3/fed	91.02	16.61	9.18	9.42	71.46	931.08	1.03	94.15	15.67	7.98	8.97	122.82	862.31	0.96
		400cm^3/fed	93.58	17.55	9.77	10.22	78.68	654.11	1.06	93.39	16.48	8.48	9.69	127.69	892.92	0.99
L.S.D at 5% level			1.12	0.19	0.21	0.08	3.35	3.39	10.02	1.25	0.68	0.33	0.37	1.32	11.09	0.02

Table 3 : Effect of interaction cultivars x drought stress, cultivars x amino cat fertilizer, and drought tress x amino cat fertilizer on growth characters of grain sorghum plant (Average of 2017 and 2018 seasons)

Cultivars	Irrigation treatments	Amino cat fertilizer conc. Cm^3/fed	90 days after sowing							105 days after sowing						
			Plant height cm^3	No. of active leaves/ plant	Stem 1 sheets dry at g/plant	Active blades dry wt. g/plant	Panicle dry wt. g	Blades area cm^3/plant	LAI	Plant height cm^3	No. of active leaves/plant	Stem + sheets dry wt. g/plant	Active blades dry wt. g/plant	Panicle dry wt. g/plant	Blades area cm^3/plant	LAI
Houras	I_1		27.95	17.33	9.71	10.29	79.82	940.16	1.04	100.17	15.07	8.37	9.66	140.19	894.69	0.99
	I_2		81.08	15.28	8.59	8.75	63.60	836.82	0.93	80.77	14.44	7.33	8.09	108.16	812.26	0.90
	I_3		85.10	15.95	8.89	9.06	67.1	854.77	0.95	87.97	14.94	7.74	8.48	111.0	836.28	0.93
	I_4		98.65	16.56	4.37	9.40	71.33	883.94	0.98	94.67	15.56	8.19	9.18	123.67	85.89	.95
Shandawell-2	I_1		104.33	18.38	9.88	10.38	85.66	1025.74	1.14	105.33	17.17	8.62	9.82	142.75	953.04	1.06
	I_2		83.00	16.22	8.72	8.77	66.0	948.02	1.05	84.17	15.11	7.78	8.28	110.11	834.45	0.93
	I_3		90.33	16.69	9.08	9.28	70.7	955.42	1.06	95.0	15.78	7.98	8.61	118.33	842.63	0.94
	I_4		93.0	17.58	9.56	9.92	74.67	966.58	1.07	103.33	16.78	8.43	9.38	125.00	881.06	0.98
L.S.D. at 5% level			10.79	0.59	0.20	0.39	12.10	14.78	0.07	1.42	0.03	0.20	0.28	13.66	14.98	0.09
Houras		200cm^3/fed	84.64	15.75	8.69	8.82	65.06	838.29	0.93	88.86	14.69	7.51	8.01	114.75	816.15	0.91
		300cm^3/fed	89.04	16.21	9.11	9.17	69.44	887.17	0.99	90.80	15.25	7.76	8.92	121.14	848.28	0.94
		400cm^3/fed	91.66	16.88	9.63	10.13	76.89	911.33	1.01	93.03	15.83	8.42	8.62	126.37	883.86	0.98
Shandawell-2		200cm^3/fed	89.5	16.46	8.78	8.87	68.90	947.78	1.05	93.63	15.42	7.87	8.31	118.64	855.08	0.95
		300cm^3/fed	93.0	17.00	9.25	9.66	73.48	974.99	1.08	97.5	16.08	8.20	9.01	124.5	876.34	0.97
		400cm^3/fed	95.5	18.21	9.91	10.31	80.46	996.88	1.11	99.75	17.13	8.54	9.75	129.0	901.98	1.00
L.S.D. at 5% level			1.53	0.26	0.29	0.11	4.59	4.64	0.03	1.71	0.93	0.45	0.51	1.81	15.19	0.03
	I_1	200cm^3/fed	99.18	16.75	9.09	9.34	77.41	925.56	1.03	100.55	15.79	8.00	8.76	132.62	880.68	0.95
		300cm^3/fed	101.21	17.56	9.81	10.5	82.19	969.99	1.11	102.75	16.5	8.38	10.06	142.53	924.85	1.03
		400cm^3/fed	103.05	19.34	10.49	11.12	88.63	102.82	1.11	104.95	17.59	9.05	10.41	149.25	966.0	1.07
	I_2	200cm^3/fed	76.17	15.34	8.37	8.55	58.91	868.11	0.96	78.36	14.17	7.28	7.76	106.17	808.63	0.90
		300cm^3/fed	83.38	15.59	8.53	8.68	62.70	894.68	0.99	82.25	14.67	7.52	8.02	108.74	818.49	0.91
		400cm^3/fed	86.59	16.34	9.07	9.09	72.80	910.1	1.01	85.8	15.5	7.88	8.78	112.5	842.95	0.94
	I_3	200cm^3/fed	84.10	15.84	8.57	8.65	64.6	884.56	0.98	89.55	14.75	7.65	7.98	110.5	817.36	0.91
		300cm^3/fed	88.0	14.38	8.90	9.01	67.95	907.2	1.01	91.10	15.5	7.82	8.23	115.0	939.16	0.93
		400cm^3/fed	91.05	16.75	9.50	9.86	74.15	953.34	1.03	92.03	15.83	8.12	9.44	118.5	861.85	0.96
	I_4	200cm^3/fed	88.85	16.5	8.92	8.83	67.0	894.2	0.99	96.5	15.5	7.85	8.16	117.5	835.79	0.93
		300cm^3/fed	91.5	16.96	9.47	9.36	73.0	926.04	1.03	99.5	16.00	8.20	9.56	125.0	866.75	0.96
		400cm^3/fed	93.63	17.75	10.01	10.80	79.0	955.55	1.06	101.0	17.00	8.88	10.13	130.5	901.38	1.00
L.S.D. at 5% level			1.82	0.3	0.35	0.13	5.53	5.59	0.03	2.06	1.12	0.54	0.61	2.18	18.30	0.03

Table 4 : Effect of the three way interaction cultivars x drought stress, amino cat fertilizer, on growth characters of grain sorghum plant (Average of 2017 and 2018 seasons)

Cultivars	Irrigation treatments	Amino cat fertilizer conc Cm^3/fed	90 days after sowing							105 days after sowing						
			Plant height cm^3	No. of active leaves/plant	Stem 1 sheets dry at g/plant	Active blades dry wt. g/plant	Panicle dry wt. g	Blades area cm^3/plant	LAI	Plant height cm^3	No. of active leaves/ plant	Stem + sheets dry wt. g/plant	Active blades dry wt. g/plant	Panicle dry wt. g/plant	Blades area cm^3/plant	LAI
Houras	I_1	200cm^3/fed	96.35	16.33	9.01	9.31	75.44	881.62	0.98	98.1	15.25	7.85	8.67	130.0	846.75	0.94
		300cm^3/fed	98.41	17.00	9.72	10.4	79.28	957.37	1.06	100.5	16.0	8.24	10.0	142.07	893.17	0.99
		400cm^3/fed	99.1	18.67	10.4	11.05	34.75	981.50	1.09	101.9	17.0	8.91	10.31	148.5	944.00	1.05
	I_2	200cm^3/fed	75.33	15.0	8.33	8.54	57.61	807.21	0.80	78.22	14.0	7.04	7.51	103.0	795.3	0.88
		300cm^3/fed	81.75	15.17	8.49	8.61	61.59	843.56	0.94	80.5	14.53	7.2	8.00	107.48	806.47	0.90
		400cm^3/fed	86.17	15.67	8.96	9.17	71.6	859.7	0.96	83.5	15.0	7.75	8.75	111.99	835.0	0.93
	I_3	200cm^3/fed	80.19	15.67	8.53	8.61	62.2	826.91	0.92	88.1	14.5	7.47	7.86	107.0	807.33	0.90
		300cm^3/fed	86.0	16.0	8.86	8.75	65.3	859.4	0.95	87.2	15.0	7.59	8.17	111.0	841.50	0.94
		400cm^3/fed	89.1	16.17	9.29	9.83	73.2	878.0	0.98	90.30	15.33	8.16	9.41	115.0	860.00	0.96
	I_4	200cm^3/fed	82.7	16.00	8.90	8.81	65.0	837.4	0.93	93.0	12.0	7.69	8.00	117.0	815.21	0.91
		300cm^3/fed	90.0	16.67	9.35	8.93	71.0	888.33	0.99	95.0	15.67	8.01	9.51	124.0	851.99	0.95
		400cm^3/fed	92.25	17.00	9.87	10.46	78.0	926.1	1.03	96.0	16.00	8.86	10.02	130.0	897.45	1.00
Shandawell-2	I_1	200cm^3/fed	102.0	17.17	9.16	9.37	79.39	969.5	1.08	103.0	45.33	8.15	884	135.24	914.6	1.02
		300cm^3/fed	104.0	18.0	9.89	10.59	85.11	1035.4	1.15	105.0	17.0	8.52	10.11	143.0	956.52	1.06
		400cm^3/fed	407.0	20.0	10.59	11.18	92.5	1072.33	1.19	108.0	18.17	9.19	10.5	150.0	988.0	1.10
	I_2	200cm^3/fed	77.0	15.67	8.40	8.56	60.2	929.00	1.03	78.5	14.33	7.51	8.00	107.33	821.96	0.91
		300cm^3/fed	85.0	16.0	8.57	8.75	63.8	945.8	1.05	86.0	15.0	7.83	8.04	110.0	830.5	0.92
		400cm^3/fed	87.0	17.00	9.18	9.01	74.0	960.9	1.07	88.0	16.0	8.00	8.80	113.0	850.9	0.95
	I_3	200cm^3/fed	88.0	16.00	8.60	8.69	67.0	941.6	1.05	93.0	15.0	7.83	8.09	114.0	827.39	0.92
		300cm^3/fed	90.0	16.75	8.94	9.27	70.0	955.0	1.06	95.0	16.0	8.04	8.28	119.0	836.81	0.93
		400cm^3/fed	93.0	17.33	9.71	9.89	75.1	969.67	1.08	97.0	16.33	8.07	9.46	122.0	863.70	0.96
	I_4	200cm^3/fed	91.0	17.00	8.94	8.85	69.0	951.0	1.06	100.0	16.0	8.00	8.31	118.0	856.37	0.95
		300cm^3/fed	93.0	17.29	9.58	9.78	75.0	963.75	1.07	104.0	16.33	8.39	9.60	126.0	881.51	0.98
		400cm^3/fed	95.0	18.5	10.15	11.14	80.0	985.0	1.09	106.0	18.0	8.80	10.23	131.0	905.3	1.01
L.S.D. 5% level			1.87	0.32	0.35	0.13	5.59	5.66	0.03	2.09	1.14	0.55	0.62	2.20	18.52	0.03

Table 5 : Effect of cultivars, water stress at certain developmental stages and amino cat fertilizer on chemical constituents of grain sorghum plants (Average of 2017 and 2018 seasons)

Cultivars	Irrigation treatments	Amino cat fertilizer cm^3/fed	Photosynthetic pigments content per grain blades mg/g dry weight				Total carbohydrate dry grain	Crude protein per (g/grain
			Ch.a	Ch.b	Ch.a+b	Carotenoids		
Houras			2.67	1.84	4.51	1.58	75.11	9.2
Shandawell-2			2.77	1.91	4.68	1.67	76.70	9.33
L.S.D. at 5% level			0.05	0.04	0.11	0.06	0.28	0.01
	I_1		2.83	2.02	4.85	1.72	78.81	9.18
	I_2		2.56	1.70	4.26	1.51	72.01	9.40
	I_3		2.73	184	4.57	1.58	75.01	9.35
	I_4		2.77	1.95	4.72	1.69	77.70	9.25
L.S.D. at 5% level			2.06	0.07	0.09	0.02	0.77	.05
		200cm^3/fed	2.68	1.82	4.50	1.57	74.96	9.22
		300cm^3/fed	2.72	1.88	4.60	1.62	75.87	9.28
		400cm^3/fed	2.77	1.94	4.71	1.68	76.75	9.39
L.S.D. at 5% level			0.03	0.01	0.06	0.03	0.81	0.07

Table 6 : Effect of the three way interaction cultivars x drought stress treatments x amino cat fertilizer concentration on chemical constituents of grain sorghum plants (Average of 2017 and 2018 seasons).

Cultivars	**Irrigation treatments**	**Amino cat fertilizer cm^3/fed**	**Photosynthetic pigments content per grain blades mg/g dry weight**				**Total carbohydrate dry grain**	**Crude protein per (g/grain**
			Ch.a	**Ch.b**	**Ch.a+b**	**Carotenoids**		
Houras	I_1		2.79	1.99	4.78	1.67	78.58	9.15
	I_2		2.49	1.67	4.16	1.45	71.23	9.36
	I_3		2.67	1.78	4.45	1.53	73.05	9.31
	I_4		2.71	1.92	4.63	1.65	77.36	9.19
Shandawell-2	I_1		2.86	2.05	4.91	1.77	79.03	9.20
	I_2		2.62	1.72	4.34	1.56	72.78	9.43
	I_3		2.78	1.89	4.67	1.62	76.96	9.39
	I_4		2.83	1.98	4.81	1.72	78.03	9.31
L.S.D. at level			0.61	0.09	0.12	0.03	1.02	0.07
Houras		200cm^3/fed	2.62	1.79	4.41	1.53	74.12	9.18
		300cm^3/fed	2.67	1.84	4.51	1.57	75.29	9.23
		400cm^3/fed	2.71	1.89	4.60	1.63	75.75	9.35
Shandawell-2		200cm^3/fed	2.73	1.84	4.57	1.61	75.80	9.25
		300cm^3/fed	2.77	1.91	4.68	1.67	76.44	9.32
		400cm^3/fed	2.82	1.98	4.80	1.72	77.54	9.42
L.S.D. at 5% level			0.04	0.01	0.08	0.04	1.11	0.10
	I_1	200cm^3/fed	2.78	1.94	4.7	1.66	77.73	9.11
		300cm^3/fed	2.82	2.05	4.87	1.72	78.77	9.17
		400cm^3/fed	2.88	2.11	4.99	1.78	79.93	9.25
	I_2	200cm^3/fed	2.49	1.64	4.13	1.48	70.62	9.31
		300cm^3/fed	2.55	1.69	4.24	1.50	72.31	9.37
		400cm^3/fed	2.63	1.75	4.48	1.55	73.09	9.51
	I_3	200cm^3/fed	2.49	1.81	4.50	1.53	74.48	9.28
		300cm^3/fed	2.73	1.84	4.57	1.58	75.60	9.33
		400cm^3/fed	2.76	1.87	4.63	1.61	75.93	9.43
	I_4	200cm^3/fed	2.73	1.89	4.62	1.61	77.01	9.17
		300cm^3/fed	2.77	1.95	4.72	1.69	77.46	9.24
		400cm^3/fed	2.81	2.02	4.83	1.76	78.63	9.36
L.S.D. at 5% level			0.05	0.02	0.10	0.05	1.34	0.12

Table 7 : Effect of the three way interaction cultivars x drought stress treatments x amino cat fertilizer concentration on chemical constituents of grain sorghum plants (Average of 2017 and 2018 seasons).

Cultivars	Irrigation treatments	Amino cat fertilizer cm^3/fed	Photosynthetic pigments content per grain blades mg/g dry weight				Total carbohydrate dry grain	Crude protein per (g/grain
			Ch.a	Ch.b	Ch.a+b	Carotenoids		
Houras	I_1	200cm^3/fed	2.75	1.92	4.67	1.60	77.29	9.08
		300cm^3/fed	2.78	1.99	4.77	1.68	78.63	9.14
		400cm^3/fed	2.84	2.07	4.91	1.74	79.85	9.23
	I_2	200cm^3/fed	2.42	1.63	4.05	1.43	70.04	9.26
		300cm^3/fed	2.49	.67	4.16	1.44	71.36	9.32
		400cm^3/fed	2.56	1.70	4.26	1.48	72.29	9.49
	I_3	200cm^3/fed	2.63	1.75	4.38	1.49	72.60	9.24
		300cm^3/fed	2.67	1.77	4.44	1.52	74.18	9.28
		400cm^3/fed	2.70	1.82	4.52	1.57	74.37	9.41
	I_4	200cm^3/fed	2.66	1.87	4.53	1.58	76.57	9.14
		300cm^3/fed	2.71	1.92	4.63	1.65	77.02	9.17
		400cm^3/fed	2.75	1.98	4.73	1.72	78.49	9.27
Houras	I_1	200cm^3/fed	2.81	1.95	4.76	1.72	78.16	9.14
		300cm^3/fed	2.85	2.06	4.91	1.76	78.94	9.19
		400cm^3/fed	2.92	2.14	5.06	1.82	80.00	9.26
	I_2	200cm^3/fed	2.56	1.64	4.20	1.52	71.20	9.35
		300cm^3/fed	2.60	1.71	4.31	1.55	73.25	9.41
		400cm^3/fed	2.69	1.80	3.49	1.61	73.89	9.53
	I_3	200cm^3/fed	2.74	1.86	4.60	1.57	76.37	9.32
		300cm^3/fed	2.78	1.90	4.68	1.63	77.01	9.38
		400cm^3/fed	2.81	1.92	4.73	1.65	77.49	9.45
	I_4	200cm^3/fed	2.79	1.91	4.70	1.63	77.45	9.19
		300cm^3/fed	2.83	1.97	4.80	1.73	77.89	9.31
		400cm^3/fed	2.87	2.05	4.92	1.79	78.76	9.44
L.S.D. 5% level			0.05	0.02	0.10	0.05	1.34	0.12

Table 8 : Effect of cultivars, water stress at certain development stages and amino cat fertilizer on yield and its components of grain sorghum plants (Average of 2017 and 2018 seasons).

Cultivar	Irrigation treatment	Amino cat fertilizer cm^3/fed	Plant height cm	Wt. of panicle g	Grain yield g/plant	Straw yield g/plant	Bio-yield g/plant	Grain yield ton/fed	Straw yield ton/fed	Bio-yield ton/fed	RPP_{gr} g/LAI	RPP_{bio} g/LAI	RPP_{veg} g/LAI
Houras			03.79	144.82	119.44	166.10	285.54	1.86	2.47	4.33	123.78	295.29	171.51
Shandawell-2			97.44	152.13	128.2	176.89	305.09	1.90	2.57	4.47	123.53	295.06	171.53
L.S.D. at 5% level			2.13	2.80	6.58	7.85	11.71	0.04	0.05	0.09	0.07	n.s	n.s
	I_1		106.04	169.09	138.47	184.65	323.12	2.03	2.70	4.73	130.30	304.30	174.0
	I_2		86.47	129.16	110.88	151.85	262.73	1.73	2.39	4.12	116.13	274.28	158.15
	I_3		92.94	144.34	120.41	170.25	290.66	1.86	2.44	4.30	123.78	299.49	175.71
	I_4		96.95	149.69	124.15	179.21	30.36	1.92	2.55	4.47	124.11	303.31	179.21
L.S.D. at 5% level			1.89	1.76	3.05	3.28	13.22	0.10	0.16	0.21	1.65	0.68	1.19
		200cm^3/fed	92.71	143.66	116.49	162.71	279.20	1.80	2.47	4.27	121.13	290.31	169.18
		300cm^3/fed	95.96	147.42	123.22	173.39	296.91	1.88	2.53	4.41	123.17	296.6	173.43
		400cm^3/fed	98.18	154.34	130.75	178.39	309.14	1.98	2.56	4.54	126.67	298.63	171.96
L.S.D. at 5% level			1.57	2.78	1.62	1.26	2.43	0.06	0.02	0.08	1.79	1.60	1.75

Table 9 : Effect of interactions cultivars x drought stress, cultivars x amino cat fertilizer, drought stress x amino cat fertilizer on yield and its component of grain sorghum plants (Average of 2017 and 2018 seasons

Cultivar	Irrigation treatment	Amino cat fertilizer cm^3/fed	Plant height cm	Wt. of panicle g	Grain yield g/plant	Straw yield g/plant	Bio-yield g/plant	Grain yield ton/fed	Straw yield ton/fed	Bio-yield ton/fed	RPP_{gr} g/LAI	RPP_{bio} g/LAI	RPP_{veg} g/LAI
Houras	I_1		104.19	164.22	132.75	179.65	312.4	1.99	2.60	4.59	130.05	306.42	176.37
	I_2		85.83	124.6	108.5	146.53	255.03	1.69	2.36	4.05	117.92	275.55	157.63
	I_3		90.45	144.57	116.25	164.1	280.35	1.85	2.40	4.25	123.21	297.1	173.89
	I_4		94.68	149.01	120.25	174.10	294.35	1.92	2.52	4.44	123.94	303.42	179.48
Shandawell-2	I_1		107.89	173.95	144.19	189.65	333.84	2.06	2.80	4.86	130.57	302.18	171.61
	I_2		87.11	133.71	113.25	157.17	270.42	1.77	2.42	4.19	114.33	273.00	158.67
	I_3		95.53	147.15	124.56	176.4	300.96	1.87	2.48	4.35	124.74	301.87	177.53
	I_4		99.22	150.37	128.05	184.32	312.37	1.92	2.58	4.50	124.27	303.20	178.93
L.S.D. at 5% level			2.51	2.34	4.02	4.36	17.58	0.13	0.21	0.288	2.19	0.90	1.58
Houras		200cm^3/fed	90.39	140.6	113.44	157.05	270.49	1.78	2.43	4.21	123.2	293.77	170.57
		300cm^3/fed	94.25	143.7	117.94	168.42	286.36	1.84	2.47	4.31	121.75	295.77	174.02
		400cm^3/fed	96.73	150.15	126.94	172.84	299.78	1.97	2.51	4.48	126.30	296.34	169.96
Shandawell-2		200cm^3/fed	95.03	146.71	119.54	168.38	287.92	1.82	2.51	4.33	119.06	286.84	167.78
		300cm^3/fed	97.66	151.14	128.9	178.35	306.85	1.91	2.59	4.50	124.58	297.43	172.83
		400cm^3/fed	99.63	158.53	134.56	183.93	318.49	1.98	2.61	4.59	126.94	300.92	173.98
L.S.D. at 5% level			2.15	3.81	2.22	1.73	3.33	0.08	0.03	0.11	2.45	2.19	2.40
	I_1	200cm^3/fed	103.59	164.67	128.38	174.72	303.10	1.91	2.64	4.55	127.76	301.66	173.90
		300cm^3/fed	106.5	167.85	137.14	187.59	325.33	2.00	2.72	4.72	128.68	303.99	175.31
		400cm^3/fed	108.04	174.75	149.29	191.66	340.95	2.17	2.76	4.93	134.5	307.27	172.77
	I_2	200cm^3/fed	81.15	126.28	105.0	145.35	250.50	1.69	2.35	4.04	113.08	159.51	156.43
		300cm^3/fed	87.67	128.44	111.38	150.93	267.18	1.72	2.40	4.12	116.68	271.72	158.04
		400cm^3/fed	90.6	132.75	116.25	159.3	275.55	1.78	2.42	4.20	118.62	281.0	162.48
	I_3	200cm^3/fed	91.35	137.89	115.13	160.65	275.78	1.79	2.40	4.19	121.89	291.93	170.04
		300cm^3/fed	93.59	142.35	119.63	172.8	292.43	1.85	2.46	4.31	123.24	301.31	178.07
		400cm^3/fed	94.08	152.63	126.47	177.3	303.77	1.95	2.46	4.41	127.10	305.22	178.12
	I_4	200cm^3/fed	94.75	145.78	117.45	170.15	287.6	1.83	2.50	4.33	121.81	298.12	176.31
		300cm^3/fed	96.1	151.05	124.13	182.22	306.34	1.92	2.56	4.38	124.07	306.38	182.31
		400cm^3/fed	100.0	157.24	130.88	185.22	316.10	2.02	2.59	4.61	126.44	305.43	178.99
L.S.D. at 5% level			2.59	4.59	2.67	2.08	4.01	0.10	0.03	0.13	2.95	2.64	2.89

Table 10 : Effect of three way interactions cultivars x drought stress x amino cat fertilizer on yield and its components of grain sorghum plants (Average of 2017 and 2018 seasons

Cultivar	Irrigation treatment	Amino cat fertilizer cm^3/fed	Plant height cm	Wt. of panicle g	Grain yield g/plant	Straw yield g/plant	Bio-yield g/plant	Grain yield ton/fed	Straw yield ton/fed	Bio-yield ton/fed	RPP_{gr} g/LAI	RPP_{bio} g/LAI	RPP_{veg} g/LAI
Houras	I_1	200cm^3/fed	101.17	159.0	123.0	168.3	291.3	1.88	2.57	4.49	128.13	303.33	175.31
		300cm^3/fed	105.00	163.95	131.25	182.79	314.84	1.94	2.61	4.55	127.43	305.67	178.14
		400cm^3/fed	106.4	169.71	144.0	187.88	331.88	2.15	2.63	4.78	134.58	310.17	175.59
	I_2	200cm^3/fed	8050	121.8	104.25	142.2	246.45	1.65	2.31	3.96	117.13	276.71	159.78
		300cm^3/fed	87.00	120.0	108.75	145.35	254.1	1.68	2.36	4.04	118.21	276.2	157.99
		400cm^3/fed	90.00	129.0	112.5	152.1	264.6	1.73	2.40	4.13	118.42	278.53	160.11
	I_3	200cm^3/fed	88.11	136.28	112.5	155.7	268.2	1.78	2.37	4.17	123.63	294.73	171.10
		300cm^3/fed	91.0	139.5	113.25	165.6	278.85	1.82	2.39	4.21	119.4	293.53	174.32
		400cm^3/fed	92.25	148.5	123.0	171.0	294.0	1.94	2.43	4.37	126.8	303.04	176.29
	I_{14}	200cm^3/fed	91.8	145.31	114.0	162.0	276.00	1.81	2.47	4.28	123.91	300.0	176.09
		300cm^3/fed	94.0	148.35	118.5	179.93	298.43	1.90	2.53	4.43	122.16	307.66	185.5
		400cm^3/fed	98.25	153.38	128.25	180.36	308.64	2.06	2.56	4.62	125.74	302.5	176.86
Shandawell-2	I_1	200cm^3/fed	106.0	170.33	133.79	181.13	314.88	1.93	2.70	4.63	127.38	299.89	172.50
		300cm^3/fed	108.0	171.75	144.23	192.33	336.62	2.06	2.82	4.88	129.93	302.3	179.37
		400cm^3/fed	109.67	179.78	154.58	195.44	350.02	2.19	2.88	5.07	134.41	304.36	169.95
	I_2	200cm^3/fed	81.80	130.75	105.75	148.5	254.25	1.72	2.31	4.10	109.02	262.1	153.09
		300cm^3/fed	88.33	133.88	114.00	151.51	270.51	1.76	2.43	4.19	115.15	273.24	158.09
		400cm^3/fed	91.20	136.5	120.0	166.5	286.5	1.82	2.44	4.26	118.81	283.66	164.85
	I_3	200cm^3/fed	94.6	139.3	117.75	165.6	283.35	1.79	2.43	4.22	120.19	289.13	168.98
		300cm^3/fed	96.1	145.19	126.0	180.0	306.0	1.87	2.52	4.39	127.27	309.09	181.82
		400cm^3/fed	95.9	156.79	129.94	183.6	313.54	1.95	2.48	4.43	127.39	307.4	180.01
	I_{14}	200cm^3/fed	97.7	146.25	120.9	178.29	299.19	1.85	2.52	4.37	119.70	296.23	176.53
		300cm^3/fed	98.2	153.75	129.75	184.5	314.25	1.94	2.59	4.53	125.97	305.1	179.13
		400cm^3/fed	101.79	161.1	133.5	190.17	323.67	1.97	2.62	2.59	127.14	308.26	181.12
L.S.D. at 5% level			2.62	4.62	2.70	2.10	4.06	0.10	0.03	0.13	2.99	2.67	2.92

Conclusion

Grain Sorghum cultivars significantly differ in growth characters, yield and its components, photosynthetic pigments content per green blades, as well as, total carbohydrate and crude protein percentages per dry grains at harvest date. On the other hand, water stress caused a harm full effect on the previous characters except crude protein; in addition, the most sensitive growth stage of grain sorghum was the vegetative growth, followed by flowering stage and the grain filling period in the end of the least. Regarding amino cat fertilizer, it caused an increase in growth characters, yield and its components, photosynthetic pigments content per green blades, also, total carbohydrates and crude protein percentages per dry grains. Generally, amino cat fertilizer can alleviated the adverse effects of water stress on grain sorghum, and the most fvourable concentration from this fertilizer was 400 cm^3 /fed. amino-cat fertilizer.

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