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The effect of water deficiency on physiological growth parameters and yield of sorghum cultivars

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Abstract

In order to assess the effect of water deficiency stress on Physiological Growth Parameters and yield of sorghum cultivars, an experiment was performed in split plot in form of randomized complete block design, in three replications in 2012 summer. Irrigation treatments including complete irrigation based on the 60 mm from evaporation pan class (I0), no irrigation in the stage of booting (I1), no irrigation at flowering stage (I2) and no irrigation at grain filling stage (I3) were classified in the main plots and cultivars of sorghum (Payam(V1) and KGS36(V2)) also in the subplots. The results showed that dry material aggregation, crop growth rate, relative growth rate, net assimilation rate and grain yield on the effect of irrigation-cutback significantly will be reduced at booting stages. The reduction in the treatment of irrigation-cutback was more at flowering stages. Dry material aggregation and plant growth rate genotypes was more in KGS36 than Payam one and also there was a significant difference in yield between the two genotypes that KGS36 assigned the highest grain yield with 310.53 grams per square meter.

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Introduction

Iran, with an average rainfall of 240 mm is classified among the world's arid and semiarid regions (Khodabandeh *et al* 1997). On the other hand, aridness is one of the limiting factors and serious threats for successful production of crops in the world (Sarmodnia, 1995).

Among environment variables that affect plant growth, water stress is the most important factor. Therefore, adopting methods for proper utilization of the water using proper agricultural practices including cultivating tolerant plants, identifying the relationship between water inadequacy of soil and crops growth at each stage, providing genotypes that can produce considerable yield with limited irrigation, examining physiological responses and useful internal relationships of plant to cope with water inadequacy stress and transferring desirable physiological traits to high yielding genotypes and other things that provide more development of plants in dry areas will be beneficial in this regard (Heidari Sharif Abad 2000).

Sorghum, due to having characteristics like high osmotic adjustability, deep and extensive root system, wax coating on stem and leaves, increasing efficiency of water consumption using regulating leaves' trend, less losing of water in lieu of reducing per unit of leaves' water potential, high resistance to water absorption, daily adjustment and renewed transfer of photosynthetic stored matters in stem and leaves for filling seeds in drought stress conditions can continue its own growth and development and produce acceptable yield (Kochki 76). The plant has a high production potential is compatible with Iran weather especially in hot, dry and temperate areas (Ajirlo 1996; Karimi, 1997).

Growth is a series of specific biochemical and physiological processes that have interactions with each other are affected by various environmental factors such as drought stress (Latifi 1993). In general, the dry matter of the plant production of plants can be evaluated by indicators such as dry matter accumulation (DMA), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) (Karimi & Seyedik, 1991). Chapman and West Gate (1993) during some researches pointed out that the plant growth rate can be sharply reduced under the influence of stress. Shirazi Kharazi and colleagues (2008) in their investigation on grain sorghum genotypes under drought stress announced that most of the drought stress damage was related to grain yield. Ari (1989) reported that stress during vegetative growth period has led to the shrinking of leaves and decreases leaf area index during crop yield period and reduces plant absorbing light. Sayer (1994) stated that drought stress has effect on the leaf area index and growth rate, and has reduced 25 percent in maize and 20 percent of leaf area index in sorghum.

This research is intended to study water deficiency stress on Physiological Growth Parameters and yield of sorghum cultivars . Ultimately, we aim at introducing the most suitable cultivar in drought stress conditions.

Materials and methods

Field experiment

This experiment performed in summer 2012 in Ahvaz Shahid Salemi Research Center with geographical longitude of 48 degrees, 40 minutes east, 31 degrees of geographical latitude, 20 minutes north with 22.5 meters above sea level in split plot in form of randomized complete block design, in three replications. Factors in this experiment consisted of four irrigation (I0), no irrigation in the stage of booting (I1), no irrigation at flowering stage (I2) and no irrigation at grain filling stage (I3) were classified in the main plots and cultivare of sorghum (Payam(V1) and KGS36(V2)) in the subplots. Operation of land preparation performed in late July. Cultivation on July 6th was carried out in one-side along the beds. Spacing between shrubs was considered 12 cm. In each pit 2-3 seeds in 3-4 cm depth was planted. All plots were irrigated after planting, but the subsequent irrigations were applied fitting the related treatments. During experiment period, the weeds in the farm were weeded with hand.

The experiment site had clay loam soil with ph=7.8 and Ec=5mmoh/cm and the rate of nitrogen=5.7 ppm.

All the basic fertilizers based on soil test (Phosphorus and Potash) before planting were used with the amount of 250 kg triple phosphate, 150 kg potassium and 180 kg net nitrogen from urea fertilizer source at one stage at the beginning of cultivation and a stage as a surplus. To determine the total plant dry matter (TDW) at each sampling, shoots were chopped and located in the oven in the temperature of 72°C for 48 hours. Leaf area index was determined by leaf area meter (LP-80 Accupar PAR/LAI Ceptometer).

Estimate growth indices

To estimate growth indices, obtained dry weight values of aerial organs per square meter for each treatment in each sampling. Finally, using Fajeria proposed relationships (1995) the crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were calculated from the following equations.

$$\mathrm{CGR}\ (\mathrm{g.\ m^{-2}.\ d^{-1}}) = \frac{\mathrm{TDM_2 - TDM_1}}{(\mathrm{T_2 - T_1}) \times \mathrm{GA}}$$

$$\mathrm{RGR}\ (\mathrm{g.\ g^{-1}.\ d^{-1}}) = \frac{[\mathrm{Ln}\ (\mathrm{TDM_2}) - \mathrm{Ln}\ (\mathrm{TDM_1})]}{(\mathrm{T2 - T1})}$$

$$\mathrm{NAR}\ (\mathrm{g\ .\ m^{-2}\ .\ d^{-1}}) = \frac{[\mathrm{Ln}\ (\mathrm{LAI_2}) - \mathrm{Ln}\ (\mathrm{LAI_1})]}{(\mathrm{LAI_2 - LAI_1})} \times \mathrm{CGR}$$

TDM total dry matter plant in each stage of sampling (g m^{-2})

T1- T2 = interval between the two samplings (day)

GA = occupied level by the plant (m^{-2})

LAI = leaf area index.

Data analysis

The data analysis of the research components was conducted using advanced statistical software. At the end of the research in order to analyze combined variance of the data after conducting Bartlett test, split plot statistical model in place and year was used. The statistical analysis of the data was carried out using MSTATC and MINITAB software and comparison of means was done using Duncan's multiple range test at the level of five percent. Excel 2003 software was used for drawing the diagrams.

Results and discussion

Total Dry Matter (TDM)

The change procedure of total dry matter is initially low and has an upward trend that the procedure lasts about 74 days until the flowering stage after planting and from this stage to the end of the growth period has a constant trend. On the other hand, it is seen at flowering stage with giving irrigation-cutback treatment (I2) that the downward trend of total dry weight changes in this treatment is more than the three other treatments and this trend continues until the late growth period. The full irrigation treatment (I0) and irrigation-cutback during grain filling stage (I3) has a similar trend until about 86 days after planting, but on day 86 with the irrigation-cutback treatments on grain filling stage (I3), this treatment has a more decline than control treatment. It can be concluded that the no irrigation treatment at the flowering stage (I2) caused the greatest decline and after it the no irrigation at pregnancy stage (I_1) has the greatest decline as compared to no irrigation at grain filling stage (I3) and control one (Fig. 1). Applying irrigation-cutback treatment, dry matter accumulation reduced (Fig. 1). It seems that one of the important reasons for the reduction in total dry matter accumulation is irrigation-cutback as Ferryman (1978) and Greenwey and Munns (1980) stated that the effect of the stress on reduction of leaf area index is increasing ostium and mesophyll resistance and thus current photosynthesis is reduced. Trend of dry weight changes in G1 and G2 Genotypes initially is low and an upward trend until the dry matter weight reaches its maximum about 74 days after planting. Highest total dry matter accumulation in KGS36 (G2) genotype is 1098 g and the lowest dry matter accumulation in Payam genotype was 923 g per square meter. It was seen that the rate of dry weight increased with time, and it seems that the reason of the slow increasing trend at the beginning of growth was due to the non-use of environmental resources, particularly light, because in this period plants were small, did not produce enough leaf area, did not absorb enough light and hit the ground. Rapid increase in dry matter accumulation after this stage is due to fact that in this period the leaf area index has increased, the entered radiation into the plant community is absorbed and regarding that dry matter accumulation is dependent on the absorption of solar radiation, dry matter accumulation reaches its maximum when leaf area index reaches its maximum and reducing dry matter accumulation after its peak is due to its decreased photosynthetic active level activity and abscission part of plant organs such as leaves. These results were consistent with Derini and colleagues' (2008).

Table 1. Variance analysis results of grain in sorghum yield.

S.O.V	df	Yield
Replication (R)	2	3003.9
Irrigation (I)	3	36549.5 **
Ea	6	1908.5
cultivar (v)	1	8584 **
Irrigation × cultivar (I × v)	3	4832 *
Eb	8	788.3
% (CV)	-	9.49

Ns, * and ** indicate non-significant and significant difference sat the five and one percent levels.

Table 2. The mean comparison of interaction of sorghum yield at different levels of irrigation-cutback and genotypes.

	Squares mean	
Genotype	Irrigation-cutback	grain yield (g per square meter)
V1	I0	347.92b
	I1	268.24e
	I2	205.94f
	I3	297.98d
V2	I0	440.98a
	I1	264.38e
	I2	213.05f
	I3	323.71c

Leaf area index

Leaf area index (LAI) in different irrigation treatments initially is low and with a rising number of days after planting, it had an upward trend so that the greatest rate of leaf area index was seen at the flowering stage and then to the end of the growing period, it had a downward trend. About 74 days after planting, it was found that I2 treatment (irrigation-cutback at flowering stage) decreased more than three treatments (I0, I1, I3), but I0 treatment (control) and I3 (no irrigation at grain filling stage) approximately followed a similar trend and then by applying no irrigation at grain filling stage (I3), the treatment decreased after about 86 days after planting and this decrease continued until late growing period. The greatest level of leaf area index at flowering stage was related to the full irrigation (I0) was 03, 4. The least level of leaf area was related to the applying stress at flowering stages and grain filling. In fact, moisture inadequacy decreased leaves' production and growth and increased leaves' aging that finally it decreases LAI. The results of this experiment section were consistent with Babazadeh and colleagues' (2010) based on the matter that with the increase in water stress, the LAI decreases. The LAI changes trend in the genotypes used in this experiment at the beginning of has an upward trend that this upwardness will continue until flowering stage about

74 days after planting and from this stage to the end of the growth period, will decline. The highest LAI of KGS36 (G2) within 74 days after planting reached 4.22 and in the Payam it was 3.51. Therefore it was seen that the KGS36 (G2), due to its more leaf area, more light absorption will occur, which ultimately leads to increased crop growth rate. The reason for decreasing in LAI after flowering stage can be related to the increase of leaves' casting shadow on each other and decrease of light penetration to the lower part of plant community.

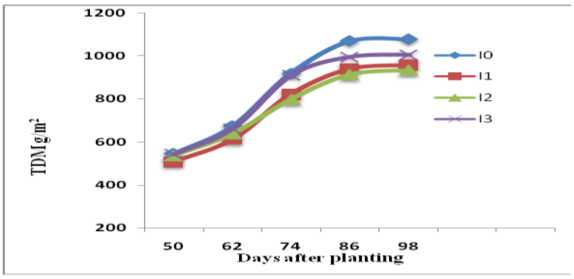

Fig. 1. Trend of total dry weight changes at different stages of irrigation-cutback.

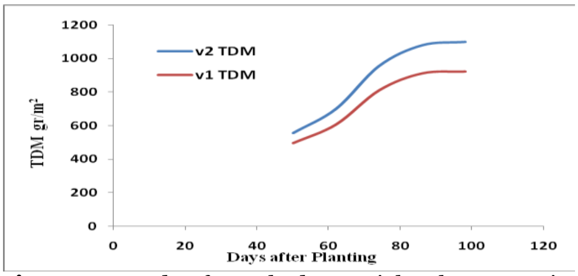

Fig. 2. Trend of total dry weigh changes in genotypes.

Corp growth rate (CGR)

The CGR in different irrigation-cutback treatments had an upward trend until 74 days after planting and after flowering stage, the trend continued its downward trend. Applying I2 treatment (no irrigation at flowering stage) caused that decreasing trend in this treatment be more than the two other treatments (I1 and I3). On the other hand, until 8 days after planting, I0 treatment (control) and I3 treatment (no irrigation at grain filling stage) had a similar trend and after applying I3 treatments, this trend indicated further decrease as compared to the control treatment (I0). Overall, it was seen that the highest CGR at flowering stage related to control treatment was 20.44 g per square meter (Fig. 5).

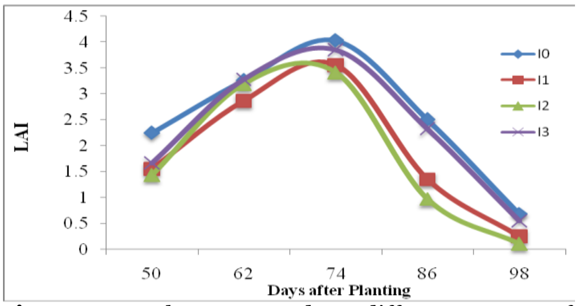

Fig. 3. LAI changes trend at different stages of irrigation-cutback.

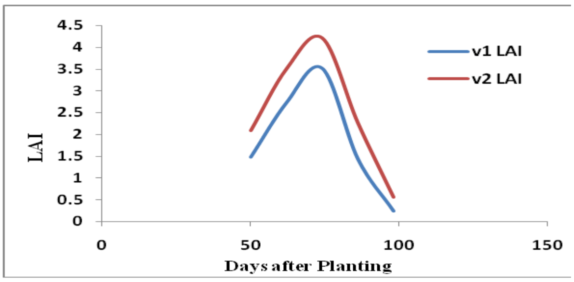

Fig. 4. LAI changes trend in genotypes.

CGR represents the amount of dry matter accumulation per unit of surface per unit of time. The CGR amount in full irrigation condition was more than the one in irrigation-cutback condition (Fig. 5). The decrease of CGR changes in irrigation-cutback conditions can be attributed to total photosynthesis rate decrease. This is because of the initial effect of drought stress on leaf, in other words it mean closuring of ostiums and inhibiting the biochemical process of absorption of CO_2 (Sowder *et al.*, 1997). Schussler and Westgate (1991) also reported that drought stress reduced leaf photosynthesis. On the other hand, the decrease of CGR can be attributed to more loss and more rapid aging of leaves under drought stress than under full irrigation. These results were consistent with Lorens and colleagues (1987). According to this (Fig. 6) KGS36 genotype as compared to Payam one initially had faster growth rate. Changes in crop growth rate at the beginning of the growth was relatively slow until about 62 days after planting and from this stage on, the CGR increased extraordinary until 74 days after the planting, it reached its maximum and suddenly it took a downward trend until late growing period. In the KGS36 (G2) genotype, the maximum use of water resources and nutritive sources were taken per unit area and dry matter accumulation was also significant, but in Payam (G1) due to less leaf area, leaf numbers could not take advantage of available resources and thus showed lower CGR than KGS36 genotype (Fig. 6).

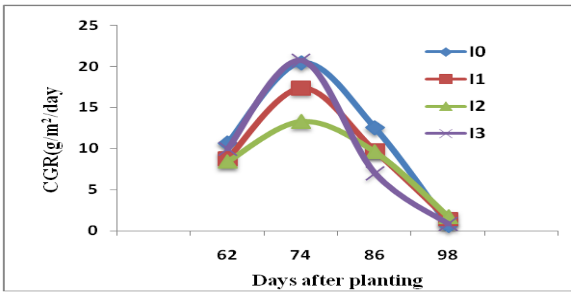

Fig. 5. CGR changes trend at different stages of irrigation-cutback.

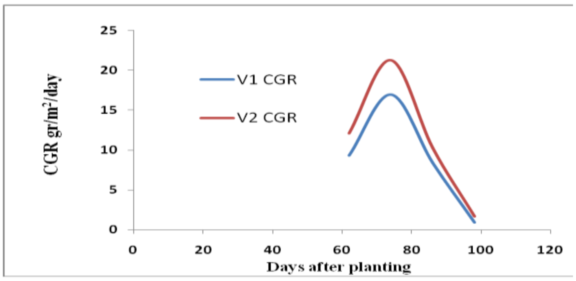

Fig. 6. CGR changes trends in genotypes.

Net assimilation rate (NAR)

NAR generally is affected by photosynthetic irradiance, uniformity of light distribution on the area of the leaves and the plant's respiration. The three no irrigation treatments had a high NAR initially and at the end due to the lower relation of photosynthetic organs (low LAI) to the respiration organs, NAR decreased. Applying the no irrigation treatment at pregnancy stage (I1), no irrigation at flowering stage (I_2) and no irrigation treatment at grain filling stage (I3), the two treatments (I1 and I2) showed greater reduction than the control treatment (I_0) Showed (Fig. 7).

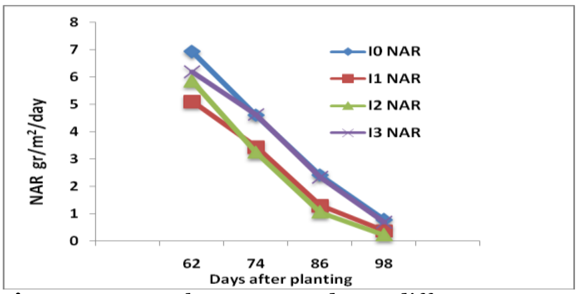

Fig. 7. NAR changes trend at different stages ofirrigation-cutback.

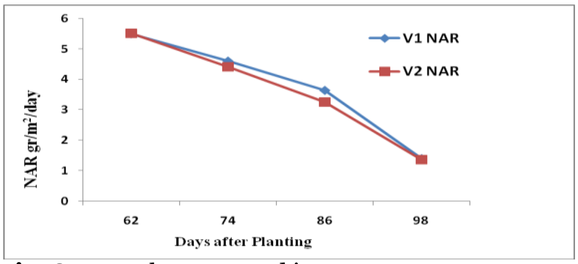

Fig. 8. NAR changes trend in genotypes.

Considering that LAI had significant difference among irrigation-cutback treatments, therefore, NAR of materials was related to changes in leaf area and plant dry weight and generally plant growth rate. The NAR includes a net amount of the made matters per unit of time and its rate is obtained by dividing CGR by LAI (Fajerya 1995). In this research, irrigation-cutback decreased CGR trend. As it was quoted from Saki (2003) according to Hunt's opinion (1987) the higher environmental conditions are more unfavorable for plants, acceleration in the NAR is higher. In this research, irrigation-cutback treatments especially no irrigation at flowering stage (I_2) the NAR decreased since drought stress close ostiums (Sowder *et al.*, 1997). Accordingly, photosynthesis rate has become lower than LAI as well as NAR decreases. Since the Payam genotype (G1) has smaller leaf area therefore leaves' casting shadow becomes less and more light penetrates. Thus the photosynthetic efficiency of the plant community is greater. KGS36 (G2) genotype due to its abundant aerial organs and leaves has more casting shadow and the role of lower leaves in photosynthesis becomes minor, consequently the photosynthetic efficiency of the plant community becomes low and the NAR places at a lower level. The results of this part of the experiment was consistent with Doreen and colleagues' (2008), which expressed increased number of leaves decreased solar radiation reaching the plant canopy and reduced the NAR (Fig. 8).

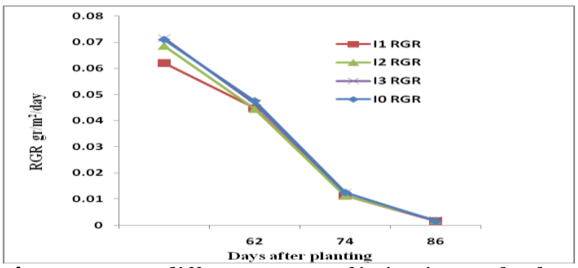

Fig. 9. RGR at different stages of irrigation-cutback.

Relative growth rate (RGR)

RGR in different irrigation-cutback treatments had a similar and upward trend until 74 days after planting. The trend at flowering stage had a downward trend. Applying I2 treatment (irrigation-cutback at flowering stage) caused the decrease trend in the treatment be greater than the other three treatments. On the other hand, until 86 days after planting, I_0 (Control) and I_3 (irrigation-cutback at grain filling stage) had a similar trend and after applying I3 treatment, this trend was also more decreased in relation to the control treatment and generally it was observed that the highest RGR at flowering stage was related to the control treatment with 20.44 g per square meter. Increasing inadequacy of water and relative decrease of leaf water content, reduced growth and increased leaves' area that decreased photosynthesis and matter making and finally reduced RGR. On the other hand, RGR decreased after the flowering stage due to aging, turning leaves yellow and reduction of matter making in the plant. The results of this part of the experiment was consistent with Saffroni Moatar and colleagues (2011) based on that in dry stress conditions and reduction of water potential in the plant, plant growth rate due to increased respiration and photosynthesis decline, reduces. RGR regularly increases until pollination stage and then tended to decline after this stage and RGR reaches zero at ripeness stage and becomes negative in some cases.

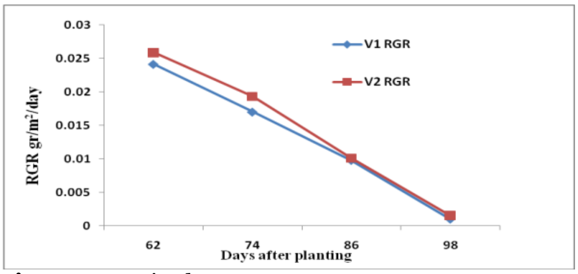

Fig. 10. RGR in the genotypes.

According to Figure 10, KGS36 genotype had faster growth rate in relation to Payam one from the beginning. The RGR at the beginning of the growth was and until about 62 days after planting was relatively slow and from this stage on RGR increased dramatically until 74 days after the planting reached its maximum and this trend suddenly took a downward trend until late of the growing period. In KGS36 (G2) genotype, the maximum use of water resources and nutrients had taken per area unit and dry matter accumulation was also significant, but in Payam (G1) genotype due to less leaf area and leaf number, it could not be able to take advantage of available resources maximally and thus lower CGR is shown in relation to the KGS36 genotype.

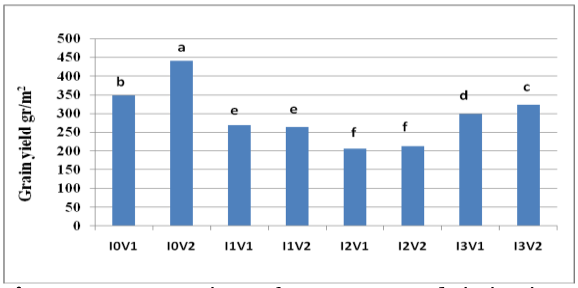

Fig. 11. Interaction of genotype and irrigation-cutback on the grain yield.

Grain yield

According to the results of the variance analysis table, irrigation-cutback and genotype showed a significant effect at one percent level whereas the interaction of irrigation-cutback and genotype was significant at five percent level (Table 1).

In the analysis of means comparison based on the Duncan test, a significant differences among irrigation-cutback treatments was found. The highest grain yield 395.45 g per square meter was attributed to the full irrigation (I_0) and the lowest one of 209.50 g per square meter was also related to the no irrigation treatment at the flowering stage (Table 2). It can be inferred that no irrigation at the flowering stage both on the grain number (due to the loss of the fetus) and on the grain weight through decreasing filing period and transferring storage matters due to the decreasing amount of water and photosynthesis and finally it reduced grain weight and also grain yield. It appears that moderate use of water during the control different stages (I0) improved grain yield as well as environmental benefit in the control with more care period can play a crucial role in improving the crop quantity (Roshdi & Rezadust 2005). Mazaheri Laghab and colleagues (2001) pointed out that during drought stress not only reduce leaf area and premature aging bot also decrease grain yield.

Accelerating in flowering and shortening of growth period are of factors in decreasing plant yield. The analysis of mean comparison of the genotype and sorghum yield indicated a significant differences in the level of five percent based on the Duncan test so that the highest grain yield of 310.53 g per square meter and the least one of 280.02 g per square meter were attributed to KGS36 (G2) and Payam (G1) respectively. Sorghum genotypes yield decrease under drought stress reduced the reproductive stage, can reduce the accumulation of dry matter per unit area crop growth rate and relative growth rate is related. Generally it can be said that drought stress in reproductive stages can be related to the decrease of DMA per area unit of CGR and RGR. Generally it can be stated that drought stress in the reproductive stages reduces DMA, CGR, RGR and sorghum yield. The decrease of sorghum grain yield was due to decline in growth indices and production of smaller grains. Decline in sorghum yield under drought conditions in the reproductive stages especially at the flowering and grain filing stages makes clear that an adequate water supply especially at the flowering and grain filing stages is essential so as to ensure the transmission of sufficient photosynthetic matters to the grains through establishment of wider leaf area and an adequate and long-term green leaf area.

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