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Research article

EFFECT OF WATER STRESS AT DIFFERENT PERIODS ON VEGETATIVE GROWTH OF GUAR GROWN UNDER IRRIGATION CONDITIONS

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ABSTRACT: A field experiment was conducted at the experimental farm of the Faculty of Agriculture, University of Khartoum, Shambat, Sudan, for two seasons (2005 and 2006) to study the effect of water stress imposed at 35, 50, 65 days after sowing (DAS) and a control treatment, on growth of three indeterminate guar (*Cyamopsis tetragonoloba (L.) Taub*.), lines (L_{12}, L_{18}, and L_{33}). The treatments were arranged in a split-plot design with three replications; with water regime treatments assigned to the main plots and guar lines to the sub– plots. Data were recorded on plant height, number of main branches per plant, shoot dry weight per plant and leaf area index. The results indicated that withholding irrigation water for three weeks at 35 DAS, significantly reduced plant height, number of main branches per plant and LAI. On the other hand there was no significant influence on shoot dry weight per plant. However, it was apparent that the damage caused by the water stress for three weeks was not permanent because plants re-watered at the end of the stress cycle recovered and had almost the same values at maturity as the control treatment. The three guar genotypes used in this study were not significantly different in their response to water stress. Nevertheless, line L_{12} proved to be slightly superior to the other two lines in terms of growth performance under water stress conditions.

Key words: Cluster bean; Genotype; Shoot dry weight; Leaf Area Index; Vegetative Growth; Drought Stress.

Abbreviations: DAS – days after sowing; L - guar line; LAI – leaf area index; WS – water stress.

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INTRODUCTION

Guar or Cluster bean (*Cyamopsis tetragonoloba (L.) Taub*.) is a drought-tolerant annual legume crop, grown widely in the semiarid tropics of India and Pakistan, mainly as a green manure, animal feed and as a vegetable and grain for human consumption (Whistler and Hymowitz, 1979). It improves the soil fertility, and its seed is also a rich source of agro-based industry to obtain galactomannan gum, which is used in food processing, paper manufacturing, textile printing and in pharmaceutical industries (Alexander et al., 1988).

Availability of water is one of the most important factors, which determine geographical distribution and productivity of plants (Kotchoni and Bartels, 2003). However, drought stress occurring at different crop developmental stages, in arid and semi-arid areas could potentially limits plant growth and productivity more than any other abiotic stress.

Several researchers have indicated that, the most influenced growth trait by water stress was stem length (Traore et al., 2000; Boutraa and Sanders, 2001; Gupta et al., 2001 and Cakir, 2004). However, in a field experiment on sesame, El Naim (2003) reported that the number of branches per plant increased with the increase in water quantities. This indicates that the number of branches per plant is directly proportional to consumptive use of water. Khanzada et al. (2003) in an experiment to study the photosynthetic efficiency of some guar genotypes under different water regimes found that leaf area was significantly influenced by water stress in all the genotypes. Nevertheless, they observed that there was a non-significant difference between pre and post-flowering treatments on leaf area, whereas the leaf area was reduced in terminal stress treatment. Leaf area index (LAI) which is defined as the ratio of leaf area to land area is widely considered as the main physiological determinant of crop yield. However, previous studies (Ashraf et al., 2002 and Siddique et al., 2000) have indicated that the possible causes of its reduction might be due to reduction in cell enlargement, stunted growth; reduced photosynthetic activity of leaves and increased abscission rate due to the decrease in water status of the plant under stress. Jama and Ottman (1993) have studied the effect of moisture stress during early growth stages of a corn plant including anthesis and found out that a delay in the irrigation during this stage decreased plant dry weight. Similar findings were reported by Xia (1994) on faba bean, Chandrasekar et al. (2000) on wheat, and Ahmed (2002) on maize.

In the Sudan, however and as guar crop is increasingly being grown in rain-fed and marginal areas where the average annual rainfall is less than 400 mm; where drought stress is a recurring problem and access to irrigation is limited, it is very important to put more efforts on research in order to thoroughly understand the reactions of growth stages of the crop against water deficit stress. The purpose of the present study was to examine the effect of water stress imposed at different periods on vegetative growth of three indeterminate guar lines grown under irrigation conditions.

MATERIALS AND METHODS

A field experiment was conducted under irrigation for two consecutive seasons (2005 and 2006), at the experimental farm of the Faculty of Agriculture, University of Khartoum, Shambat, Sudan, located at latitude (15º 40′) N, longitude (32º 32′) E, and altitude 380 m above sea level.

The experiment was laid out in split – plot design with three replications with a net sub-plot size of 4 m × 3 m. The water regime treatments and guar genotypes were randomized in the main and sub-plots, respectively.

The experimental material comprised of three indeterminate guar lines coded L_{12}, L_{18}, and L_{33} and four different water regime treatments namely, WS_1 (stressed at 35 days after sowing), WS_2 (stressed at. 50 DAS), WS_3 (stressed at 65 DAS), and WS_0 (control treatment) which was never stressed but irrigated every two weeks.

Sowing was on the third of July in both seasons, at a seed rate of 11 kg ha^{-1}, and at a spacing of 0.70 m between rows and 0.40 m between plants within rows. Water stress was imposed at a specific period by withholding irrigation for three weeks. Two hand weeding, at 21 and 33 DAS were carried out to keep the crop free from weeds in both seasons.

Five destructive sample plants were randomly taken from each sub-plot every two weeks at 35, 50, 65, 80 and 95 DAS to study progressive growth development on plant height, number of main branches, shoot dry weight (g) and leaf area index. LI-COR 3000 Area meter was used for measurement of leaf area.

The data collected were subjected to analysis of variance based on the general linear model procedures of the Statistical Analysis System (SAS), and the least significant difference (LSD) at 0.05 probability level was used to compare the differences among treatment means.

RESULTS AND DISCUSSION

Plant height

Significant differences were observed in plant height between the different water regime treatments in the first season (Table 1).Withholding irrigation for three weeks at 35 DAS (WS_1) significantly (P= 0.05) reduced plant height by about 21 % as observed in the second sampling occasion at 50 DAS compared with control treatment in the first season. Although it (treatment WS_1) didn't significantly influenced plant height at the same age in the second season, the tendency of reducing plant height was also observed. Similar findings of the decreased shoot growth during water stress have been reported by many research workers in guar (Khanzada et al., 2002a) and in other plants (Srinivasan and Arjunan, 1987). However, in the present study it was observed that, plants recovered and attained almost the same heights as those in the control treatment, after re-watering at the end of the stress cycle. Similar supporting explanation was reported by Bates and Hall (1981) that cowpeas exhibited extreme drought avoidance to the extent that water conservation by the remaining vegetative tissues ensures plant survival under field conditions.

On the other hand the non-significant effect of treatments WS_2 and WS_3 on plant height could explain the fact that developmental priorities were shifted to translocation of assimilates to the developing pods rather than growth needs. Similar finding was reported by El Nadi (1969) on faba bean, that plant height was less affected by the longer irrigation intervals during pod development phase.
The three guar (L_{12}, L_{18} and L_{33}) lines used in this experiment showed no significant differences (P= 0.05) between them for plant height under different water regime treatments. However, line L_{12} seems to have slight tendency to give greater average plant heights than the other two lines. On the other hand, line L_{18} exhibited lower average plant heights than the other two lines (L_{12} and L_{33}) in both seasons. This observation may suggest that line L_{12} is tolerant to water stress at the vegetative growth stage and had the ability to rapidly recover from the stress. While, L_{18} exhibited sensitivity to water stress at the early growing period than the other two lines.

Number of main branches per plant

The yield and yield components of guar crop like in many other plants are reduced under water deficit conditions, even in tolerant genotypes. The seed yield depends on number of main branches produced per plant and/ or survived the water shortage among others. In the present study, withholding irrigation at 35 DAS (WS_1) exhibited lower average number of main branches per plant (7.3 and 3.4) at 50 DAS, in the first and second seasons, respectively (Table 2). This result is in line with that of Misra et al., (2012) who reported that holding irrigation water up to 15 and 30 days on mulberry plant imposed slow leaf primordial growth causing less number of branches per plant. Similar result on sesame was also reported by El Naim (2003).The significant differences observed in number of main branches in the first season at plant age of 80 DAS in this experiment could probably be attributed to sampling error (destructive samples).
However, the insignificant effect of treatments WS_2 and WS_3 on number of main branches per plant was probably due to the fact that imposing stress at 50 and 65 DAS coincided with advanced reproductive stage at which the ability of plants to produce new branches was either slowed down or stopped. This may suggests that pre-flowering period is more susceptible to water deficit than post-flowering period. This finding is in disagreement with that of Boutraa and Sanders (2001) who found that water stress during flowering and pod-filling stages reduced number of main branches of two cultivars of bean.
The three lines were significantly different in number of main branches per plant in the second season. Greater number of main branches per plant was given by the line L_{12} in both seasons. However, line L_{33} though not significantly different from L_{18}, it produced the least number of branches per plant. Thus, it could be graded as more susceptible to water stress than the other two lines (L_{12} and L_{18}).

Table 1: Average plant height (cm) as affected by water stress and guar lines during the two seasons (2005 and 2006).

Treatment	Season (2005)						Season (2006)				
	Plant height (cm)						Plant height (cm)				
	35	50	65 (DAS)	80	95		35	50	65 (DAS)	80	95
WS_0	50.0[A]	81.5[A]	96.2[A]	104.8[A]	114.1[A]		63.6[A]	87.6[A]	96.4[A]	112.9[A]	121.8[A]
WS_1	51.3[A]	64.4[B]	80.3[B]	92.9[A]	105.6[A]		68.8[A]	74.5[A]	85.2[A]	101.5[A]	108.0[A]
WS_2	53.3[A]	86.2[A]	90.9[A]	103.1[A]	111.3[A]		58.4[A]	84.7[A]	86.9[A]	89.9[A]	97.9[A]
WS_3	50.9[A]	80.9[A]	96.9[A]	102.9[A]	110.2[A]		61.5[A]	81.5[A]	90.8[A]	96.3[A]	105.4[A]
LSD(0.05)	n.s	5.929	10.302	n.s	n.s		n.s	n.s	n.s	n.s	n.s
L_{12}	53.6[a]	77.7[a]	87.4[a]	100.1[a]	108.1[a]		67.9[a]	85.2[a]	91.8[a]	101.9[a]	112.8[a]
L_{18}	50.6[a]	75.9[a]	89.7[a]	99.4[a]	108.5[a]		62.5[a]	80.3[a]	88.4[a]	97.8[a]	104.6[a]
L_{33}	50.0[a]	81.2[a]	96.1[a]	103.3[a]	114.3[a]		58.8[a]	80.7[a]	88.6[a]	100.8[a]	107.6[a]
LSD(0.05)	n.s	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s	n.s

Means with the same letter(s) in each column are not significantly different at 5% level.
WS_0 = control treatment, WS_1 = water stressed at 35 days after sowing, WS_2 = water stressed at 50 (DAS), WS_3 = water stressed at 65 (DAS), L = guar line.

Table 2: Average number of main branches per plant as affected by water stress and guar lines during the two seasons (2005 and 2006) .

	Season (2005)						Season (2006)				
Treatment	Number of main branches per plant						Number of main branches per plant				
	35	50	65 (DAS)	80	95		35	50	65 (DAS)	80	95
WS_0	5.4^{A}	8.4^{A}	9.3^{A}	8.0^{A}	8.6^{A}		3.4^{AB}	6.0^{A}	6.2^{A}	8.1^{A}	10.5^{A}
WS_1	6.5^{A}	7.3^{A}	7.4^{A}	6.6^{B}	7.8^{A}		4.8^{A}	3.4^{B}	5.5^{A}	7.1^{A}	7.6^{A}
WS_2	4.4^{A}	9.3^{A}	8.9^{A}	7.6^{AB}	8.1^{A}		3.1^{B}	6.4^{A}	6.4^{A}	6.1^{A}	9.4^{A}
WS_3	6.2^{A}	8.7^{A}	8.8^{A}	8.3^{A}	8.5^{A}		2.4^{B}	6.0^{A}	6.3^{A}	6.5^{A}	8.3^{A}
LSD(0.05)	n.s	n.s	n.s	1.209	n.s		1.544	1.746	n.s	n.s	n.s
L_{12}	6.6^{a}	9.4^{a}	9.1^{a}	8.5^{a}	8.5^{a}		4.9^{a}	6.2^{a}	7.4^{a}	8.5^{a}	10.2^{a}
L_{18}	5.4^{a}	7.5^{a}	8.2^{a}	7.6^{a}	8.4^{a}		3.0^{b}	5.3^{a}	6.1^{ab}	6.1^{b}	9.0^{ab}
L_{33}	4.9^{a}	8.4^{a}	8.5^{a}	6.8^{a}	7.8^{a}		2.3^{b}	4.8^{a}	4.8^{b}	6.4^{b}	7.7^{b}
LSD(0.05)	n.s	n.s	n.s	n.s	n.s		1.349	n.s	1.704	2.079	1.768

Means with the same letter(s) in each column are not significantly different at 5% level.

Shoot dry weight

The effect of water regime treatments on shoot dry weight per plant was not significantly different (P= 0.05) in both seasons (Table 3). However, treatment WS_1 (stressed at 35 DAS) showed tendency to reduce shoot dry weight per plant compared to the rest of treatments in both seasons. Several researchers on different crop plants have reported that reduced biomass due to water stress was observed in sunflower (Tahir & Mehid, 2001), and soybean (Specht et al., 2001). However, in the present study, imposing stress at 50 and 65 DAS didn't show this tendency of reduced shoot dry weight per plant in both seasons. This could be attributed to the fact that vegetative growth at those periods had no sensitivity to water stress of such magnitudes, as the priority might have been shifted to reproductive growth and translocation process (partitioning of assimilate). Similar results were reported by Jama and Ottman (1993); Xia (1994); Ahmed (2002). However, a contrasting result was reported by Cakir (2004) that moisture stress during the ear formation and milk stage in maize, causes early loss of lower leaves and decreases dry matter weight and grain yield as a result of reduced intercepted radiation.

Shoot dry weight per plant was not significantly affected by the three guar lines used in this experiment in both seasons. However, lower average shoot dry weights (79.1 and 65.7 g) were recorded for L_{18} than the other two lines (L_{12} and L_{33}). This may suggest that line L_{18} is more likely susceptible to water stress than the other two lines.

Table 3: Average shoot dry weight (g) per plant as affected by water stress and guar lines during the two seasons (2005 and 2006) .

	Season (2005)					Season(2006)				
Treatment	Shoot dry weight (g) per plant					Shoot dry weight (g) per plant				
	35	50	65 (DAS)	80	95	35	50	65 (DAS)	80	95
WS_0	16.6^{A}	36.0^{A}	44.0^{A}	56.3^{A}	86.4^{A}	19.8^{A}	39.1^{A}	44.2^{A}	69.3^{A}	97.8^{A}
WS_1	17.6^{A}	28.3^{A}	35.7^{A}	47.6^{A}	91.6^{A}	21.0^{A}	25.3^{A}	38.8^{A}	53.2^{A}	56.1^{A}
WS_2	18.5^{A}	39.4^{A}	41.4^{A}	44.7^{A}	82.7^{A}	16.3^{A}	40.3^{A}	41.3^{A}	44.6^{A}	72.4^{A}
WS_3	15.7^{A}	37.4^{A}	44.3^{A}	50.4^{A}	78.6^{A}	15.9^{A}	36.1^{A}	45.4^{A}	50.6^{A}	61.8^{A}
LSD(0.05)	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
L_{12}	17.4^{a}	39.0^{a}	39.0^{a}	50.1^{a}	86.9^{a}	21.0^{a}	37.9^{a}	45.4^{a}	60.0^{a}	73.8^{a}
L_{18}	17.0^{a}	30.8^{a}	41.5^{a}	48.1^{a}	79.1^{a}	16.7^{a}	34.4^{a}	43.6^{a}	46.8^{a}	65.7^{a}
L_{33}	17.0^{a}	36.0^{a}	43.5^{a}	51.1^{a}	88.5^{a}	17.0^{a}	33.3^{a}	38.3^{a}	56.5^{a}	76.6^{a}
LSD(0.05)	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s

Means with the same letter(s) in each column are not significantly different at 5% level.

Leaf area index (LAI)

On average, the leaf area index was significantly(P= 0.05) affected by different water regime treatments at 50 DAS in both seasons (Table 4).The lowest LAI (1.6 and 1.4) at 50 DAS were observed under treatment WS_1 in the first and second seasons, respectively.

This reduction in LAI could probably be attributed to reduction in total leaf area and leaf expansion as a result of low internal plant water status rather than leaf senescence. Similar conclusion was reported by Farah (1981) who stated that leaf area was reduced by water shortage, which was attributed to the effect on cell division, lamina expansion and leaf production. Nielson and Nelson (1998) observed significant LAI reductions in black bean (*Phaseolus vulgaris L.*) under drought stress condition. Therefore, this reduction in LAI during the active vegetative growing periods could generally be considered as a mechanism to withstand the effect of soil water shortage at that particular growing period. On a similar study, Qadir et al. (1999) concluded that water stress during vegetative growth caused reduction in LAI of wheat.
In the present investigation it was apparent that the negative effect of water stress under treatment WS_1 on LAI was alleviated after re-watering of the plants and LAI values became not significantly different from that of the control treatment (Table 4). This indicates that the compensation mechanisms of the growth attributes, especially leaf area, did operate under stress conditions, assuming that the stress at that period (35 DAS) did not limit the plant ability to recover from water stress. In contrast, there was no significant effect of treatments WS_2 and WS_3 on LAI compared to the control treatment. This observation could be attributed in away to insensitivity of growth at those periods to water stress, because re-watering the plants after the stress period did not induce remarkable increases in LAI values as observed in the second season.

Table 4: Average leaf area index (LAI) as affected by water stress and guar lines during the two seasons (2005 and 2006).

	Season (2005)					Season (2006)			
Treatment	Leaf area index (LAI)					Leaf area index (LAI)			
	35	50	65 (DAS)	80	95	35	50	80 (DAS)	95
WS_0	1.2^{A}	2.0^{B}	1.2^{A}	1.0^{A}	1.2^{A}	1.1^{A}	2.6^{AB}	1.7^{A}	1.4^{A}
WS_1	1.3^{A}	1.6^{C}	1.2^{A}	1.4^{A}	1.6^{A}	1.5^{A}	1.4^{C}	1.3^{A}	1.4^{A}
WS_2	1.2^{A}	2.3^{A}	1.0^{A}	1.1^{A}	1.4^{A}	1.3^{A}	2.9^{A}	0.9^{A}	1.1^{A}
WS_3	1.0^{A}	2.1^{AB}	1.3^{A}	0.9^{A}	1.3^{A}	1.1^{A}	2.0^{BC}	1.0^{A}	0.9^{A}
LSD(0.05)	n.s	0.27	n.s	n.s	n.s	n.s	0.766	n.s	n.s
L_{12}	1.2^{a}	2.1^{a}	1.0^{a}	1.0^{a}	1.1^{a}	1.4^{a}	2.4^{a}	1.3^{a}	1.1^{ab}
L_{18}	1.2^{a}	1.7^{a}	1.1^{a}	1.1^{a}	1.6^{a}	1.1^{a}	2.2^{a}	1.0^{a}	1.0^{b}
L_{33}	1.2^{a}	2.2^{a}	1.3^{a}	1.2^{a}	1.4^{a}	1.1^{a}	2.3^{a}	1.4^{a}	1.5^{a}
LSD(0.05)	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	0.346

Means with the same letter(s) in each column are not significantly different at 5% level.

The LAI was not significantly affected by the three guar lines used in this experiment in the first season, but was significantly affected in the second season. Line L_{18} had the lowest LAI values (1.7 and 2.2) at the age of 50 DAS, and may therefore, be graded as more susceptible to water stress than the other two (L_{12} and L_{33}) lines which on the other hand could be considered as relatively tolerant.

CONCLUSIONS

Based on the results of this study, it was concluded that guar can be subjected to water stress for three weeks at 35 DAS without affecting its ability to resume growth, after being re-watered at the end of the stress cycle. Among all the three guar genotypes used in this study, line L_{12} proved to be slightly tolerant to water shortage than the other two lines, thus it may be considered suitable for the areas of rain-fed agriculture in the Sudan, where drought stress is a recurring problem and access to irrigation is limited.

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