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The effects of deficit irrigation and auxin on the yield of forage sorghum

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Abstract

This research was carried out in Shahid Salemi of Ahvaz in 2012 in order to investigate the effects of deficit irrigation and auxin foliar spray on the yield of forage sorghum, speed feed cultivar (Sorghum bicolor L. Moench). The experiment was conducted as split plots in randomized complete block design with three replications. Experimental treatments included water stress in three levels of normal irrigation (I_0=90), mild stress (I_1=120), and severe stress (I_2=150) mm evaporation of class A evaporation pan as the main factor and the sub factor consisted of auxin foliar spray in four levels including the control (A_0=0ppm), (A_1=15 ppm), (A_2=20ppm), (A_3=25ppm).The studied traits included plant height, stem diameter, number of tillers, fresh forage yield, dry forage yield, and percentage of dry weight to wet weight. The ANOVA results showed that plant height, stem diameter, number of tillers, fresh forage yield, dry forage yield, and the percentage of dry weight to wet weight were affected by water stress. Moreover, the use of auxin hormone increased plant height, stem diameter, number of tillers, fresh forage yield, dry forage yield, and the percentage of dry weight to wet weight so that the highest increase was associated with the highest concentration of applied auxin, that is 25 ppm. Furthermore, the interactive effects of irrigation and auxin on studied traits were significantly different at 1% level. Comparison of means showed that as the stress increased, the mean of above mentioned traits decreased so that the decrease of the severe stress treatment (150mm evaporation) was more than the other ones and even the use of auxin could not prevent the dramatic decrease of yield. Therefore, in case of mild stress (120 mm evaporation) it is possible to have acceptable economic yield by using 20 ppm or 25 ppm auxin.

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Introduction

Drought is a serious threat to successful production of crops throughout the world. Approximately 90% of arid regions of the world are concentrated in 27 countries including Iran. Drought stress constrains agricultural productions and seriously reduces production efficiency in areas which are facing this phenomenon. Lack of adequate precipitation and its uneven distribution during growing season in arid and semiarid areas had made the cultivation of most crops possible only through irrigation. On the other hand, because of limited water resources, it is greatly important to use water correctly and accurately. Accordingly, determining an accurate schedule for irrigation gets a special priority so that the crop won't face water stress on one hand, and the excessive consumption of water by the plant will not lead to the waste of this vital resource or will not pollute surface and groundwater by means of nitrate, on the other hand. Besides, it won't leach the soil nutrients and won't reduce efficiency of water and fertilizer consumption, either (Anabi, Ajdar, 1997).

In the plains of Khuzestan, by the beginning of rainfall season and the increase of water flow, cultivation is done through irrigation, but in the spring and summer the lands are left without any cultivation due to lack of water. If we can save irrigation water by appropriate management of deficit irrigation and planting drought tolerant plants, it is possible to increase the area under cultivation and production (Rahnama and Absalan, 2008).

Due to its unique morphological and physiological characteristics, sorghum has been introduced as the indicator of dough resistant crops which is more resistant than other crops to difficult irrigation conditions and long irrigation intervals and needs less water. (Moaveni, 2003). Considering its photosynthetic system, stomata activity and root system, sorghum is both able to absorb water better and to reduce water loss in atmosphere and even after a long drought period of stomas it is able to resume its activity without any damage (Kouchaki, 1985). It has an adventitious root system which is very strong and widespread so that the roots penetrate the soil as deep as 2 meters. Of course, when there is sufficient moisture, the roots penetrate the soil just as deep as 60 cm and supply more than half of the plant's water need (Dehghani, 1996). Under water deficit conditions the roots spread less laterally and penetrate the soil more deeply. In comparison to maize, sorghum has a very wide adventitious root system and penetrates a large volume of the soil very deeply and absorbs moisture (House, 1985).

This plant tolerates drought but it needs irrigation to produce much forage. Its water requirement is at least 500 mm of rainfall during the growing season. During the drought period, its forage products are decreased and the poisonous prussic acid increases in it (Karimi, 1997).

Boyer (1970) reported that the leaf growth is the first process which responds to water deficit and reduces. Keramer (1969) found that water deficit decreases the plant growth and increases the cell wall thickness and amount of cutin and lignin. It also increases the leaf thickness, but decreases the leaf area.

One of the effects of water deficit is the reduction of cell development due to reduction of cell inflammation which leads to the decrease of plant height (Mojadam, 2006). (Cox and Jolliff, 1987) concluded that the decrease of net photosynthesis under drought conditions, which is an indicator of the decrease of dry matter production, shows that the leaf area efficiency has decreased due to drought stress.
The results of the research on the effect of deficit irrigation on the yield of forage sorghum cultivars in Ahvaz showed that 45% decrease of irrigation reduced the yield of fresh and dry forage as 39.4 and 8.5 Ton per hectare respectively, in comparison to complete irrigation (Rahnama *et al.,* 2007).

In their researches on sorghum, Rosenthal *et al.* (1987) concluded that water deficit during the vegetative growth of sorghum decreased the dry weight of shoots up to about 15%. Water stress in crops is made when the transpiration rate is more than water absorption and the water stress is measured by considering the dry matter accumulation in the plant.

Saki Nejad (2003) stated that the harvest index had a descending trend due to water stress which was resulted from both the decrease of biological yield and the attribution of dry matter to the grain, so that the photosynthetic power reduced due to the restriction of the leaf expansion and also the restriction of dry matter attribution to the grain.

All biological activities of plants are controlled by different chemicals. These chemicals are purely isolated from plant tissues by scientists and their features and formulae are gradually determined. Many scientists have applied the term "hormone", which was used since a long time ago for addressing the substances controlling animals' physiological activities, for plants as well. Auxin is a generic term for the growth substances which sort of stimulate the cell elongation; however, auxins cause a wide range of growth responses (Kouchaki, Sarmadnia, 2008). Auxin contributes to cell division, cell elongation, and regulation of plant tissues distinction. Its low concentration stimulates the plant's growth, but its high concentration could be poisonous to plants (Saki Nejad *et al.,* 2011).

Srivastava (2002) stated that auxin prevents the leaves loss and delays the falling of ripe fruits. The results of the experiments carried out on Japanica rice have shown that the application of auxin leads to the external activity of some genes (Exogenous) and the production of proteins in early hours of low temperature stress and ultimately it causes stress tolerance by the plant (Cheng *et al.,* 2007).

Gadallah (2000) reported that the rate of chlorophyll a and b decreased as the water stress increased and in plants treated by Zn and IAA they were less affected by water stress. They also reported that the effect of Zn and IAA solutions was increasing.

Devlin and Withan (1993) have remarked that with regard to the basic role of auxin in plants, it directly affects the substances biosynthesis. Therefore, they can produce more plant cells and consequently more dry matters and store them in grains as reservoirs. Consequently, the yield is unexpectedly increased.

Materials and methods

This research was carried out as split plots in randomized complete block design with three replications in Shahid Salemi of Ahvaz at longitude 48°40´ east and at latitude 31° 20´ north and 22.5 meters above the sea level in July 2012.

And the average annual temperature is 28°C. The maximum relative humidity in the region is 100 and the minimum is 8 and the average of maximum crop year is 64 and the average of minimum crop year is 25. The total annual evaporation is 3098.5 mm, and the average of crop year evaporation is 261.12mm. The soil of experiment site has syllith-clay texture with Ph=7.81 and EC=2.8 d S/m.

The studied factors included three levels of irrigation including (I_0=90), (I_1=120), (I_2=150) mm evaporation of class A evaporation pan as the main factor and the sub factor consisted of auxin foliar spray in four levels including the control (A_0=0ppm), (A_1=15ppm), (A_2=20ppm), (A_3=25ppm). Auxin foliar spraying was done at 8-leaf stage. The amount of auxin to be consumed in each plot was measured to be concentration of auxin. and was sprayed to the field with a special 20-liter spraying pump. Each plot contained 5 cultivations lines and each line was 5 meters long and 75 cm away from the other one. The seeds were planted manually and additional plants were cut at 2-4-leaf stages. Experimental plots were irrigated in July 26th for the first time and until the 8-leaf stage, irrigation was done normally and then water stress treatments were applied. During the growth stage the weeds were removed manually. The final harvest was done manually, too. Before that and after eliminating the margins, 18 plants from the two middle lines which represented the desired plot were marked. During the experiment, the plant height, stem diameter, number of tillers, fresh forage yield, and percentage of dry weight to wet weight were measured. The ANNOVA was analyzed by SAS statistical software and the means were compared by Duncan's multiple range tests at 1% probability level.

Results and discussion

The ANOVA results showed that water stress in 8-leaf stage affected some traits of forage sorghum such as the plant height, stem diameter, number of tillers, fresh forage yield, dry forage yield, and percentage of dry weight to wet weight. Also, auxin foliar spraying significantly affected such traits as the plant height, stem diameter, number of tillers, fresh forage yield, dry forage yield, and percentage of dry weight to wet weight.

Table 1. Analysis of variance of studied traits of forage sorghum, Speed feed cultiva.

Squares mean							
Dry / Fresh weight	dry forage yield	Fresh forage yield	Tiller No.	Stem diameter	Stem height	d.f	S.O.V
2.57 ns	0.61 ns	4.73 ns	0.19 ns	0.015 ns	47.23 ns	2	Replication
195.39 **	221.37 **	1349.57 **	15.13 **	0.8 **	8001.33 **	2	Irrigation (A)
1.58 ns	0.53 ns	4.32 ns	0.13 ns	0.01 ns	26.93 ns	4	Error of(a)
82.87 **	19.95 **	102.34 **	0.84 **	0.17 **	1221.59 **	3	Auxin Hormone (B)
10.36 **	2.32 **	17.61 **	0.32 **	0.05 **	198.83 **	6	Auxin*Irrigation
1.99	0.4	3.74	0.07	0.01	47.08	18	Error of(b)
4.3	4	4.3	10.8	4.8	2.6	***	CV (%)

ns , *, ** respectively mean non-significant difference, and significant difference at 5% and 1% probability levels.

Stem Height

According to the ANOVA results (Table 1), the effects of different levels of irrigation, auxin, and the interactive effect of irrigation and auxin on studied traits of forage sorghum were significant at 1% probability level. Table (2) shows that the irrigation after 90 mm of evaporation had the tallest stem height by the average of 279.7 cm and the irrigation after 150 mm evaporation had the shortest stem height by the average of 231.3 cm. One of the effects of water deficit on maize is the reduction of cell development due to the reduction of cell inflammation which results in the decrease of plant height (Mojadam, 2006). Razmi and Gasemi (2007) reported the decrease of sorghum stem height during the drought stress and stated that the decrease of height in the mid stress had resulted from the decrease of internodes length. Morgan (1984) remarked that the growth, yield, and height of forage sorghum remarkably decreased due to delayed irrigation.

As the dosage of auxin increased, the plant height increased too. The tallest plant height belonged to 25 ppm treatment by 273.1.cm and the shortest one belonged to control treatment (0 ppm) by 246.1 cm which were placed in groups a and c respectively (Table 2). The role of auxin in the increase of plant height has been proved via the increase of the cell expansibility and also the increase of apical dominance (Evans, 1985).

Considering the interactive effects of irrigation levels and auxin hormone on the height of forage sorghum, the tallest height by 287 cm belonged to the treatment with 90 mm evaporation and the use of 25 ppm auxin and the shortest height by 204.4 cm belonged to the irrigation treatment with 150 mm evaporation and 0 ppm auxin (control) (table 2).

Stem Diameter

According to the ANOVA results (Table 1), the effects of different levels of irrigation, auxin, and interactive effect of irrigation and auxin on stem diameter were significant at 1% probability level. Table (2) shows that the irrigation after 90 mm evaporation got the highest stem diameter by 1.97 cm and the irrigation after 150 mm evaporation got the lowest stem diameter by 1.47 cm. Water increases cell inflammation and inflammation increases the size and volume of cells and consequently the diameter of plant organs will increase.

Table 2. Mean comparison of studied traits of forage sorghum, Speed feed cultivar.

Treatment traits mean						
DryFresh weight (%)	dry forage yield (t/ha)	Fresh forage yield (t/ha)	Number of tillers	Stem diameter (cm)	Stem height (cm)	
						Irrigation levels
36.4 a	19.74 a	54.57 a	3.36 a	1.97 a	279.7 a	I_0= 90 mm
34.12 b	16.75 b	46.53 b	2.65 b	1.84 b	270.9 b	I_1=120 mm
28.56 c	11.27 c	33.55 c	1.16 c	1.47 c	231.3 c	I_2=150 mm
						Auxin concentration
30.32 c	14.52 c	41.59 c	2.04 c	1.63 c	246.1 c	A_0 = 0 ppm
30.69 c	15.05 c	43.33 bc	2.28 bc	1.68 bc	257.4 b	A_1=15 ppm
34.48 b	16.23 b	45.18 b	2.48 ab	1.78 b	266 ab	A_2=20 ppm
36.6 a	17.88 a	49.44 a	2.76 a	1.95 a	273.1 a	A_3=25 ppm
						Interactive effect of irrigation*auxin
33 bcd	18.22 bc	50.14 bc	2.63 cd	1.77 d	273.9 abc	I_0A_0
33.2 bc	18.53 bc	52.96 b	3.1 bc	1.81 cd	276.2 abc	I_0A_1
39 a	19.75 b	54.15 b	3.53 b	1.98 bc	282 ab	I_0A_2
40.35 a	22.45 a	61.04 a	4.2 a	2.34 a	287 a	I_0A_3
30.39 cdef	15.22 d	42.01 e	2.36 d	1.69 d	259.9 cd	I_1A_0
31.26 cde	15.25 d	43.67 de	2.6 cd	1.76 d	269 bc	I_1A_1
34.97 b	17.17 c	47.41 cd	2.76 cd	1.87 bcd	275.4 abc	I_1A_2
39.84 a	19.36 b	53.04 b	2.9 bcd	2 b	279.4 ab	I_1A_3
27.58 f	10.10 f	32.61 f	1.13 e	1.44 e	204.4 g	I_2A_0
27.62 f	11.38 ef	33.37 f	1.16 e	1.48 e	227.2 f	I_2A_1
29.41 ef	11.77 e	34 f	1.16 e	1.49 e	240.5 ef	I_2A_2
29.62 def	11.82 e	34.24 f	1.2 e	1.49 e	253.1 de	I_2A_3

Means with the same letter in each column are not significantly different in Duncan's multiple range tests at 1% level of probability.

When the plant faces lack of water inflammation occurs less or it never occurs which finally results in the decrease of stem diameter. In an experiment, Nadervar *et al.* (2005) reported the direct relationship between the consumption of less water and the decrease of stem diameter.

In terms of auxin foliar spraying, the highest stem diameter was related to the treatment with 25 ppm auxin by 1.95 cm and the lowest stem diameter was related to the control treatment (0 ppm auxin) by 1.63 cm which were respectively placed in groups a and c (Table 2).

Considering the interactive effect of irrigation and auxin on the stem diameter of forage sorghum, the tallest height by 2.34 cm belonged to the treatment with 90 mm evaporation and the use of 25 ppm auxin and the shortest height by 1.44 cm belonged to the irrigation treatment with 150 mm evaporation and 0 ppm auxin (control). In other words, one of the most sensitive physiological stages to drought is the cell growth and development which is due to the decrease of turgor pressure. Cell development occurs only when the turgor pressure is more than the cell wall threshold (Makersie and Lethem, 2007).

Number of Tillers

According to the ANOVA results (table 1), the effects of different levels of irrigation, auxin, and interactive effect of irrigation and auxin on number of tillers were significant at 1% probability level. Table (2) shows that the irrigation after 90 mm of evaporation had the highest number of tillers by the average of 3.3 and the irrigation after 150 mm evaporation had the lowest number of tillers by the average of 1.1. Rahnama *et al.* (2008) stated that the highest number of tillers was produced at the highest level of irrigation that is the perfect irrigation treatment. Buxton (1996) reported that water stress prevents the forages to generate branches or tillers and leads to the faster death of tillers and the removal of protein from old leaves.

In auxin treatments, the highest number of tillers belonged to the treatment with 25 ppm use of auxin by 2.7 and the lowest one (2) belonged to the control treatment (0 ppm auxin). (Table 2).

According to table (2), in terms of the interactive effects of irrigation and auxin on the number of forage sorghum tillers, the highest number of tillers by 4.2 was obtained in the treatment with 90 mm evaporation and the use of 25 ppm auxin and the lowest number of tillers by 1.1 was related to the irrigation treatment with 150 mm evaporation and 0 ppm auxin (control).

Fresh Forage Yield

According to the ANOVA results (Table 1), the effects of different levels of irrigation, auxin, and interactive effect of irrigation and auxin on the yield of fresh forage were significant at 1% probability level. Table (2) shows that the irrigation level after 90 mm of evaporation had the highest yield of fresh forage by the average of 54.57 Tha^{-1} and the irrigation level after 150 mm evaporation had the lowest yield of fresh forage by the average of 33.55 Tha^{-1}. Gardner *et al.* (2007) stated that stress during the vegetative growth stage led to the shrinking of leaves and decreased the leaf area index during the ripening stage and also decreased the light absorption by the plant. In severe drought stress the stomata got closed, which decreased the absorption of co_2 and the production of dry matter and the continuation of severe stress resulted in sharp photosynthesis decrease. The increase of plants biomass in optimal irrigation conditions was due to more expansion and better continuity of leaf area which led to the creation of strong physiological sources for more efficient use of received light and production of dry matter. Razmi and Ghasemi (2007) reported that drought stress reduced the yield of forage sorghum due to its negative effect on leaf area index, height, and other vegetative traits.

As the dosage of auxin increased the yield of fresh forage increased too. The highest yield of fresh forage belonged to the treatment with 25 ppm auxin by 49.44 Tha^{-1} and the lowest yield belonged to the control treatment (Auxin=0 ppm) by 41.59 Tha^{-1}(Table 2). Since the growth and development of the root is affected by the auxin hormone and the elongation of main axis and the growth of lateral roots are first of all impressed by the auxin which is derived from the plant shoots, by supplying this hormone the growth and development of plant root and particularly the growth of lateral roots will be stimulated by the auxin of plant shoots; therefore, by the development of the root system, the plant is able to optimally absorb assimilates which were faced with mobility reduction during the shortage of water. On the other hand, it is able to access more soil moisture reserves and prevent the decrease of forage yield (Marschner, 1995).

According to table (2), in terms of the interactive effects of irrigation and auxin on the yield of fresh forage, the highest yield by 61 Tha^{-1} was obtained in the treatment with 90 mm evaporation and the use of 25 ppm auxin and the lowest yield by 32.61 Tha^{-1} was related to the irrigation treatment with 150 mm evaporation and 0 ppm auxin (control). In irrigation treatment with 120 mm evaporation, the increase of auxin, increased the yield of fresh forage so that there was not a significant difference between the fresh forage yield of the irrigation treatment with 120 evaporation and 25 ppm auxin and that of the water treatment with 90 mm evaporation and 20 ppm and 15 ppm auxin and it seems like that in 120 mm irrigation treatment the use of 25 ppm auxin remarkably compensates for the yield reduction so that the yield could be economic and within the expected production level.

Dry Forage Yield

According to the ANOVA results (Table 1), the effects of different levels of irrigation, auxin, and interactive effect of irrigation and auxin on the yield of dry forage were significant at 1% probability level. Table (2) shows that the irrigation level after 90 mm of evaporation had the highest yield of dry forage by the average of 19.74Tha^{-1} and the irrigation level after 150 mm evaporation had the lowest yield of dry forage by the average of 11.27 Tha^{-1}. The increase of total production of dry matter in the plants under optimal irrigation treatment was due to more expansion and better continuity of leaf area which led to the creation of strong physiological sources for more efficient use of received light and production of dry matter, so that through the increase of water deficit stress, the yield of dry matter significantly decreased which was consistent with the reports released by Osborne *et al.* (2002) and Sepehri *et al.* (2002).

In terms of auxin, the highest rate of dry forage was related to the treatment with 25 ppm auxin by 17.88 Tha^{-1} and the lowest rate was related to the control treatment (auxin=0 ppm) by 14.52 Tha^{-1}. There was no significant difference between the treatments with 0 ppm and 15 ppm auxin and they were placed in the same group (Table 2). Saki Nejad *et al.* (2011) stated that auxin increased the biological yield. Saki Nejad (2011), Devlin and Witan (1993) reported that axuins in plant is directly involved in material biosynthesis therefore they could produce more plant cells and consequently more dry matter. Therefore they increase the yield more than what is expected.

According to table (2), due to the interactive effects of irrigation and auxin on the yield of dry forage, the highest yield by 22.45 Tha^{-1} was obtained in the treatment with 90 mm evaporation and the use of 25 ppm auxin and the lowest yield by 10. 1 Tha^{-1} was related to the irrigation treatment with 150 mm evaporation and 0 ppm auxin (control). Saki Nejad and Shokoohfar (2011) reported that by applying auxin the dry weight increased.

Dry Weight/Wet Weight Ratio

According to the ANOVA results (Table 1), the effects of different levels of irrigation, auxin, and interactive effect of irrigation and auxin on the wet weight/dry weight ratio were significant at 1% probability level. Table (2) shows that the irrigation level after 90 mm of evaporation had the highest ratio of dry weight/wet weight by the average of 36.3% and the irrigation level after 150 mm evaporation had the lowest ratio of dry weight/ wet weight by the average of 28.5%. It seems like that water stress has reduced biomass production in plant by having negative effect on cells elongation and massiveness and decreasing assimilates produced by the plant. Goldani *et al.* (2006) stated that the decrease of carbohydrates and dry mater production are deterministic effects of drought increase. Shahrajabian *et al.* (2010) reported that by increasing the irrigation intervals the ratio of dry weight/wet weight would decrease.

The ratio of dry weight/wet weight increased through the increase of auxin dosage. The highest ratio of dry weight/wet weight was related to the treatment with 25 ppm auxin by 36.6% and the lowest ratio was related to treatment with 0 ppm auxin (control) by 30.3%. There was no significant difference between the treatments with 0 ppm and 15 ppm auxin and they were placed in the same group. The decrease of biomass production due to drought stress is definitely associated with the decrease of cells elongation because according to acid growth hypothesis, the plan cells in response to auxin release hydrogen ion, which is a cell wall softening agent, into the cell wall and thus due to the decrease of ph, cell wall softening enzymes get activated the cell wall connections are broken. Then the water inflow and cell inflammation lead to the release of cell wall from stress and cell growth occurred (Taiz and Zeiger, 1991).

Among the interactive effect treatments, the highest ratio of dry weight/wet weight was related to the irrigation after 90 mm evaporation and 25 ppm auxin by the average of 40.3% and the lowest ratio was related to the irrigation after 150 mm evaporation and control treatment (auxin=0 ppm) by the average of 27.5 % (table 2).

Conclusion

Generally, the results of the experiment showed that as the stress increased the yield of forage sorghum decreased while the decrease under mild stress conditions (iirigation with 120 mm evaporation) was less through proper management and application of appropriate concentration of auxin and within the concentration of 25 ppm auxin, it had an economic and acceptable yield. With regard to dramatic decrease of yield at sever stress level (in this experiment, irrigation level with 150 mm evaporation) and little effect of auxinon sorghum growth and functional recovery, irrigation at this level is not recommended. Finally, considering the results of the experiment if water is a restrictive factor in the region and we are facing water deficit, it is possible to have irrigation periods after 120 mm evaporation with the use of 25 mm auxin which results in an acceptable yield; however, the highest yield is achieve by the use of 25 ppm auxin and irrigation after 90 mm evapoation.

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