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Effectiveness of silicon and irrigation scheduling for mitigating drought stress in sorghum (*Sorghum bicolor* L.) in arid region of Saudi Arabia

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Abstract

A field experiment with three treatments of irrigation and three treatments of silicon in triplicate was conducted at Hada Al-Sham research station of King Abdulaziz University Jeddah Saudi Arabia using multi-cut sorghum crop. The main objective of this study was to obtain the maximum crop yield at minimum water use under natural arid conditions. The crop was grown for fodder under natural drought condition of Hada Al-Sham until three cuts. Daily weather data was collected from Hada Al-Sham meteorological station to estimate the crop water requirement. Penmen-Monteith equation (PME) (FAO-56) was used to estimate reference evapotranspiration and then crop evapotranspiration was calculated by using crop coefficient (Kc) for sorghum. The irrigations (100%, 80% and 60% of ETc) were applied as main plot treatments and silicon (0, 1, and 2 kg ha^{-1}) were applied as sub-plot treatments. Three cuts were harvested at 50% spikes initiation to determine 1) the number of plants per square meter, 2) plant height, 3) fresh yield and 4) dry yield. The results revealed that drought during growing season severely affected the morphological characters of sorghum. The decrease in irrigation from 100% to 60% decreased the plant height, fresh and dry yields while the number of tillers during 2nd and 3rd cuts increased. Meanwhile the foliar application of silicon improved the number of tillers, plant height, fresh and dry yields under drought conditions.

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Introduction

Sorghum is the well-known food and fodder cereal crop belonging to Poaceae family cultivated in all over the world. Sorghum is single cut and multi cut crop with green fodder yield ranging 70-100 tons/ha. In Africa and Asia sorghum is used as staple food (Swathandran and Aslam, 2016). It is used for livestock feed in the farm of grains and green fodder. Sorghum is also a main component of poultry feed. It has the same nutritional values as corn, so it is gaining more importance for livestock feed also due to its drought resistance.

Drought is a well-known phenomenon that refer to a period of low water availability to the crop plants which ultimately affects its physiological and morphological parameters. It is a climatological term used by agriculturists, when the water availability in the soil is reduced due to continuous water losses (Hanson *et al.*, 1995; Singh *et al.*, 2012). When the rain fall is less than 25% of actual amount of evapotranspiration in a specific region, then it is also called as drought stress (Dracup *et al.*, 1980). The agricultural production is badly affected by drought because it depends upon soil moisture and rainfall (Narasimhan and Srinivasan, 2005). Agricultural drought affects plant growth and yield severely (Wilhite and Glantz, 1985). It is noted that due to severe drought stress the crop productivity of major crops reduces by 50% in arid regions as compared to humid and semi-arid regions (Zlatev and Lidon, 2012).

In arid and semi-arid regions, it has been noted that Silicon (Si) can reduce the adverse effects of drought stress (Afef *et al.*, 2016). The silicon is the 2nd richest part of the earth crust. Silicon is not compulsory element for crop production, but it considerably reduces the adverse effects of drought, salinity, heat stress and low temperature when plants are treated with it (Almutairi, 2016). For proper development and growth of plants, Si is considered as an advantageous element (Liang *et al.*, 2007; Ma and Yamaji, 2008). The functional form of Si which is present in nature is SiO_2 which is formed when one oxygen molecule is combined with Si (Bouzoubaa, 2005).

Silicon retains a balance in nutrients under water stress condition and in the presence of adequate water, chemical and physical nature of soil is improved in the presence of silicon therefore fertility and crop production is also increased (Shi *et al.*, 2014). The application of supplemental irrigation and development of modern irrigation scheduling can cope with the food demands of human and animals under deficit water conditions in arid areas under severe drought (Ahmad *et al.*, 2015). Proper agronomic practices and irrigation scheduling is necessary for crop production under water scarce condition because over irrigation and drought waste resources and reduce yield (Siddique *et al.*, 2007). Awise irrigation scheduling is necessary in arid areas to cope with drought conditions and utilize available water resources properly. Many researchers have revealed the beneficial effects of irrigation scheduling and silicon application on crop production. Many pot, and green house experiments has been conducted to check the effect of silicon under drought conditions.

Saudi Arabia is a country situated in south-west of Asia with abundant land resources (230 Mha) and very small water resources. The prevailing climatic condition of the Kingdom is Arid. The overall climate of the country is hot, dry desert. Due to aridity, the precipitation is very unusual and erratic. Despite of very low rainfall, the temperature and evapotranspiration rates are very high which make rainfall useless and lowers the soil moister contents below the required level for crop production in most parts of the country during the whole year. The crop production particularly in Makkah Al-Mukarmah region requires proper irrigation and other management to mitigate drought stress for proper crop production. In this research sorghum fodder crop was grown under natural drought condition of arid region of Hada Al-Sham (a small town) during hot summer season to see the positive effects of silicon and irrigation scheduling on Sorghum fodder yield.

Material and methods

Experimental site and design

A field experiment was conducted at the Agricultural Research Station of King Abdul-Aziz University located at Hada Al-Sham area from March 2017 to September 2017.

The Hada Sham village is located 110 km North East of Jeddah with 100 hectares total area. The coordinates of research stations are 21°47'5''N and 39°42'E. The elevation from sea level is 235 meters. The prevailing environment of research area is arid with average daily temperature 33.41C° and average daily net solar radiation 12.86 MJ/m² day) during summer. The experiment was conducted using randomized complete block design (RCBD) with split-plot arrangement with three replications. Each experimental plot was divided into (4m × 2m) with one-meters pace between each plot to prevent inter-plot water flow. The plots (2m × 4m) were planned as basins and surface irrigation (bubbler irrigation) was applied to each plot.

Irrigation and silicon treatments

The irrigation was applied as main-plot factor and silicon was applied (foliar application) as sub-plot factor to check the influence of irrigation scheduling and silicon in mitigating drought stress in sorghum fodder crop as under

T1 = Full irrigation (100% ETc)

T2 = Level one irrigation (80% ETc)

T3 = Level two irrigation (60% ETc)

Si0 = Control treatment (no Si application)

Si1= 1 kg Si ha^{-1}

Si2= 2 kg Si ha^{-1}

Since each main plot was applied with three different Si treatments having same irrigation treatment. The source of silicon was potassium silicate powder (K_2SiO_3). Three cuts of sorghum were taken. Every time crop was harvested at the end of development stage at 50% spikes. The harvested crop was fed to the dairy cows at Hada Al-Sham.

Irrigation system

The bubbler irrigation system was used to irrigate sorghum fodder crop. Each plot was provided with eight (8) number of pressure compensating full circle bubblers (Rain Bird) having 0.50 GPM discharge with trickle pattern. Pressure control valve was used with pump to deliver even pressure and prevent damage to the pump or lines. Irrigation scheduling was applied after proper germination and crop establishment period.

The irrigation scheduling was made after five leaves stage on the base of evapotranspiration. The daily reference Evapotranspiration (ETo) was calculated using Penman-Monteith method (FAO-56) (Allen *et al.*, 1998) using daily average weather data recorded from Hada Al Sham weather station and then crop evapotranspiration (ETc) for sorghum was calculated by multiplying the reference evapotranspiration with crop coefficient (Kc) (FAO-56) for sorghum as under

ETc = (ETo) x (Kc).

The daily average weather data collected from research station during crop season is presented in Table 1.

Cultural practices

The experimental soil was ploughed twice using disc plough at 30 cm depth. The land was leveled using laser land leveler. Then seedbed was prepared using chisel plough. After complete preparation the experimental area was divided into 27 sub-plots (basins) for the experiment. Sorghum crop was sown manually, the seed was placed at 5cm depth and it was covered manually. The row to row distance was kept 30cm. Each plot was sown with six rows of crops. The plant population was kept same for all the plots. The seed rate of 60 kg ha^{-1} was used. Recommended doses of NPK were applied during all cuts.

Measurements of crop parameters

To check the effect of different irrigation scheduling and silicon treatments on the yield of sorghum, the following parameters were measured during the experiment. All the data was collected from central rows.

Total amount of irrigation applied (mm) Number of plants per square meter Plant height (cm)Fresh yield (t/ha) Dry yield (t/ha).

Soil physical properties

Before the experiment soil samples were collected with auger from 15 cm and 45 cm depths to determine the soil physical properties. Sieve analysis and other soil physical properties were determined in soil and water relation laboratory department of Hydrology and water resources management at King Abdul-Aziz University Jeddah according to standard procedure. The soil physical properties are shown in Table 2.

Statistical analysis of data

The data collected from all three cuts was statistically analyzed after applying the analysis of variance using (statistics 8.1) software. The mean values were compared using LSD (P≤ 0.05; steel *et al.*, 1997).

Results

Irrigation application during growing season

The treatment of irrigation was started after the crop establishment while before that was same irrigation (100% of ETc).

Table 1. Daily average data of temperature, wind speed, relative humidity, solar radiation, total rainfall and reference evapotranspiration during 2017 crop seasons.

Month	Daily Average temp C°	Daily Average wind speed (m/sec)	Daily Average Relative Humidity (%)	Daily Average Solar Radiation (MJ/m² day)	Total rainfall mm	Daily ETo (mm/day)
March	26.59	1.30	41.19	10.61	0.00	4.70
April	31.54	1.26	31.54	12.12	3.70	5.76
May	34.25	1.47	27.49	14.32	4.50	7.18
June	35.12	1.24	26.97	14.58	0.60	7.02
July	35.50	1.61	24.33	14.16	0.00	7.61
August	35.67	1.44	37.73	12.60	23.40	6.34
September	35.22	1.46	35.85	11.66	0.00	6.15

The bubbler irrigation system was used for irrigation. The details of irrigation amount applied during all the cuts is shown in Table 3.

Number of plants per square meter of Sorghum

The analysis Table 4 showed that irrigation and silicon treatments did not show any significance (P≤ 0.05) effect on number of plants per square meter during 1stcut. The interaction of irrigation and silicon also was non-significant.

Table 2. Soil physical properties of experimental soil.

Properties Soil depth	FC volumetric	PWP volumetric	Bulk density (g/cm3)	Particle density (g/cm3)	Porosity	Texture
15cm	0.22	0.18	1.72	2.67	0.35	Sandy
45cm	0.27	0.20	1.70	2.68	0.36	Sandy

During 2nd and 3rdcuts the irrigation and silicon showed significant (P≤ 0.05) effect on tillering and the number of tillers were increased as compared to 1stcut. The interaction of irrigation and silicon also showed significant (P≤ 0.05) effect on tillering (Table 4). During 2nd cut irrigation level one (100% ETc) and silicon level two (2 kgha^{-1}) gave the maximum number of plants per square meter (122.33) followed by irrigation level one (100% ETc) and silicon level one (1 kg ha^{-1}) (115.00) while irrigation level three (60% ETc) and zero level of silicon foliar application gave minimum number of plants per square meter (100.67) (Table 4).

During 3rd cut the tillers started decreasing as compared to 2ndcut and remained more than 1stcut. Irrigation level one (100% ETc) and silicon level two (2 kg ha^{-1}) gave the maximum number of plants per square meter (104.00) followed by irrigation level one (100% ETc) and silicon level one (1 kg ha^{-1}) (98.00) while irrigation level three (60% ETc) and zero level of silicon foliar application gave minimum number of plants per square meter (85.67). The table of means comparisons (Table 4) shows that during 2nd and 3rdcuts the number of plants per square meter increased within the same irrigation level with increasing the silicon level. Irrigation and silicon treatments applied during 1stcut showed positive effect during 2ndcut tillering and irrigation and silicon treatments applied during 2ndcut showed positive effect during 3rdcut tillering, but the trend started decreasing from 3rdcut.

Table 3. The details of irrigation applied during all cuts.

1st cut	Irrigation levels	Irrigation applied (mm)		
		Before treatment	After treatment	Total
Duration	100% ETc	112.39	187.48	299.87
61 Days	80% ETc	112.39	149.98	262.37
(March, April And May)	60% ETc	112.39	112.48	224.87
2nd cut	Irrigation levels	Irrigation applied (mm)		
		Before treatment	After treatment	Total
Duration	100% ETc	247.00	171.40	418.40
76 days	80% ETc	247.00	137.12	384.12
(May, June and July)	60% ETc	247.00	102.84	350.00
3rd cut	Irrigation levels	Irrigation applied (mm)		
		Before treatment	After treatment	Total
Duration	100% ETc	76.99	181.83	258.82
64 days	80% ETc	76.99	145.46	222.45
(July, Aug, Sep)	60% ETc	76.99	109.09	186.00

Effect of irrigation and silicon on plant height

During all three cuts the effect of irrigation and silicon was highly significant (P≤ 0.05) on plant height also the combination of irrigation and silicon was significant (P≤ 0.05) (Table 5). During 1st cut the irrigation level one (100% ETc) and silicon level two (2 kg ha^{-1}) gave the maximum plants height (122.67cm), followed by irrigation level one (100%ETc) and silicon level one (1 kg ha^{-1}) (116.67cm) while irrigation level three (60% ETc) and zero level of silicon foliar application gave minimum plant height (88.33cm) (Table 5).

Table 4. Effect of irrigation and silicon on number of plant per square meter of Sorghum.

1st Cut	Irrigation levels	Silicon levels			
		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	73.33	69.33	79.33	74.00a
	80% ETc	67.68	70.33	77.00	71.67a
	60% ETc	73.00	76.00	84.00	77.67a
	Mean	71.33a	71.89a	80.11a	
2nd Cut	Irrigation levels	Silicon levels			
		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	112.00	115.00	122.33	116.44a
	80% ETc	109.00	112.00	113.67	111.56b
	60% ETc	100.67	104.33	109.00	104.67c
	Mean	107.22c	110.44b	115.00a	
3rd Cut	Irrigation levels	Silicon levels			
		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	95.33	98.00	104.00	99.11a
	80% ETc	93.00	95.00	96.67	94.89b
	60% ETc	85.67	85.67	93.00	89.11c
	Mean	91.33c	93.89b	97.89a	

Mean sharing similar letters are not significantly different at P < 0.05 according to LSD.

During 2nd cut the irrigation level one (100% ETc) and silicon level two (2 kg ha^{-1}) gave the maximum plants height (110.47 cm) followed by irrigation level one (100%ETc) and silicon level one (1 kg ha^{-1}) (104.43cm), while irrigation level three (60% ETc) and zero level of silicon application gave minimum plant height (80.10 cm) (Table5).

Table 5. Effect of irrigation and siliconon Plant height of Sorghum (cm).

1st Cut	Irrigation levels	Silicon levels			
		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	105.00	116.67	122.67	114.78a
	80% ETc	97.67	101.67	110.00	103.11b
	60% ETc	88.33	96.00	104.33	96.22c
	Mean	97.00c	104.78b	112.33a	
2nd Cut	Irrigation levels	Silicon levels			
		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	94.53	104.43	110.47	103.14a
	80% ETc	88.33	91.60	99.60	93.18b
	60% ETc	80.10	86.10	94.17	86.79c
	Mean	87.66c	94.04b	101.41a	
3rd cut	Irrigation levels	Silicon levels			
		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	111.00	122.00	127.67	120.22a
	80% ETc	103.33	107.00	116.67	109.00b
	60% ETc	94.00	101.00	110.00	101.67c
	Mean	102.78c	110.00b	118.11a	

Mean sharing similar letters are not significantly different at $P < 0.05$ according to LSD.

During 3rd cut the irrigation level one (100% ETc) and silicon level two (2 kg ha^{-1}) gave the maximum plants height (127.67 cm) followed by irrigation level one (100%ETc) and silicon level one (1kg ha^{-1}) (122.00cm), while irrigation level three (60% ETc) and zero level of silicon application gave minimum plant height (94.00 cm) (Table 5).

The increase of silicon dose increased the plant height as compared to control treatment of silicon and 100% irrigation gave good results. The overall plant height was more during 1st cut and decreased during 2nd cut due to very hot weather during June July. Again, the plant height increased during 3rd cut due to decrease in temperature and solar radiation. Five numbers of plants were measured at the center of each plot and average value was taken for plant height. The analysis of variance table (Table 5) shows the combined effect of irrigation and silicon decreased from 1st cut ($P<0.016$) to 2nd cut ($P<0.032$) and again increased during 3rd cut ($P<0.028$) as compared to 1st cut but remained less as compared to 2nd cut.

Effect of irrigation and silicon on fresh yield (t/ha) of Sorghum fodder

The analysis table (Table 6) shows that during all three cuts the effect of irrigation and silicon treatments was highly significant ($P\leq 0.05$) on fresh yield. The combined effect of irrigation and silicon was also significant ($P\leq 0.05$) (Table 6). During 1st cut the irrigation level one (100% ETc) and silicon level two (2 kg ha^{-1}) gave the maximum fresh yield (52.33 t/ha) followed by the irrigation level two (80% ETc) and silicon level two (2 kg ha^{-1}) (44.87 t/ha) while irrigation level three (60% ETc) and zero level of silicon application gave minimum fresh yield (31.37 t/ha) (Table 6).

During 2ndcut the irrigation level one (100% ETc) and silicon level two (2 kg ha^{-1}) gave the maximum fresh yield (47.10 t/ha) followed by the irrigation level two (80% ETc) and silicon level two (2 kg ha^{-1}) (40.38 t/ha) while irrigation level three (60% ETc) and zero level of silicon application gave minimum fresh yield (28.25 t/ha) (Table 6).

Table 6. Effect of irrigation and siliconon fresh yield (t/ha) of Sorghum.

	Irrigation levels	Silicon levels			
1st Cut		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	40.33	44.73	52.33	45.80a
	80% ETc	36.10	39.17	44.87	40.04b
	60% ETc	31.37	36.57	44.40	37.44c
	Mean	35.93c	40.16b	47.20a	
2nd Cut	Irrigation levels	Silicon levels			
		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	36.47	40.26	47.10	41.28a
	80% ETc	32.49	35.25	40.38	36.04b
	60% ETc	28.25	33.08	39.94	33.76c
	Mean	32.40c	36.20b	42.47a	
3rd cut	Irrigation levels	Silicon levels			
		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	39.77	43.87	51.33	44.99a
	80% ETc	35.40	38.43	44.03	39.29b
	60% ETc	30.80	43.53	43.53	36.79c
	Mean	35.32c	39.44b	46.30a	

Mean sharing similar letters are not significantly different at $P < 0.05$ according to LSD.

During 3rdcut the irrigation level one (100% ETc) and silicon level two (2 kg ha^{-1}) gave the maximum fresh yield (51.33 t/ha) followed by the irrigation level two (80% ETc) and silicon level two (2 kg ha^{-1}) (44.03 t/ha) while irrigation level three (60% ETc) and zero level of silicon application gave minimum fresh yield (30.80 t/ha) (Table 6).

After harvesting the sorghum fodder crop, immediately it was weighted and the fresh yield in kg/m^2 was measured and then it was converted into tons/ha. The analysis table (Table 6) shows that the overall trend in fresh yield was observed as, it was more during 1stcut and decreased during 2ndcut due to very hot weather and heat stress and again it increased during 3rd cut but it was still less than 1stcut. During 1stand 3rdcuts the weather was mild as compared to 2ndcut.

It was also noted that during 1stand 3rdcuts the stems had more thickness as compared to 2nd cut.

Effect of irrigation and silicon on dry yield (t/ha) of Sorghum fodder

After taking fresh yield of the crop, from each plot crop samples were collected for dry yield analysis. The collected samples were packaged in envelops with sample ID and weighted immediately so that there is no evaporation (moister) losses of plant moister content.

The plant samples were putted in oven at 65 centigrade for 3 days to get constant dry weight. The weight of samples was taken in grams and then it was converted also in kg/m^2 and then into t/ha.

During all three cuts the irrigation and silicon showed highly significant ($P \leq 0.05$) effect on dry yield of sorghum and the interaction of irrigation and silicon also showed positive effect (P≤0.05) (Table 7). During 1st cut irrigation level one (100% ETc) and silicon level two (2 kg ha-1) gave the maximum dry yield (17.03 t/ha) followed by irrigation level one (100%ETc) and silicon level one (1kg ha-1) (15.13 t/ha) while irrigation level three (60% ETc) and zero level of silicon application gave minimum dry yield (10.53 t/ha) (Table 7).

During 2ndcut the irrigation level one (100% ETc) and silicon level two (2 kg ha-1) gave the maximum dry yield (15.31 t/ha) followed by irrigation level one (100%ETc) and silicon level one (1kg ha-1) (13.62 t/ha) while irrigation level three (60% ETc) and zero level of silicon application gave minimum dry yield (9.68 t/ha) (Table 7).

Table 7. Effect of irrigation and siliconon dry yield (t/ha) of Sorghum.

1st Cut	Irrigation levels	Silicon levels			
		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	13.83	15.13	17.03	15.33a
	80% ETc	12.27	13.07	14.57	13.30b
	60% ETc	10.53	12.20	14.77	12.50c
	Mean	12.21c	13.47b	15.46a	
2nd Cut	Irrigation levels	Silicon levels			
		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	12.45	13.62	15.31	13.79a
	80% ETc	11.06	11.76	13.11	11.98b
	60% ETc	9.68	13.28	13.28	11.31c
	Mean	11.06c	12.12b	13.90a	
3rd cut	Irrigation levels	Silicon levels			
		0 kg/ha	1 kg/ha	2 kg/ha	Mean
	100% ETc	13.53	14.83	16.70	15.02a
	80% ETc	12.07	12.83	14.27	13.05b
	60% ETc	10.53	11.97	14.47	12.32c
	Mean	12.04c	13.21b	15.14a	

Mean sharing similar letters are not significantly different at P < 0.05 according to LSD.

During 3rdcut the irrigation level one (100% ETc) and silicon level two (2 kg ha-1) gave the maximum dry yield (16.70 t/ha) followed by irrigation level one (100%ETc) and silicon level one (1 kg ha-1) (14.83 t/ha) while irrigation level three (60% ETc) and zero level of silicon application gave minimum dry yield (10.53 t/ha) (Table 7).

The overall trend in dry yield was also same as fresh yield, it was more during 1stcut then decreased during 2ndcut and increased during 3rdcut. There was great effect of weather on sorghum crop during 2ndcut. Except number of plants per meter square, all the morphological characters were decreased.

But during 2ndcut under severe drought stress the dry yield increased as compared to mild drought stress.

Discussion

Effect of drought stress on crop production

Plant growth and bio systems are greatly damaged by drought stress and the drought stress is one of the most important abiotic stress factors of arid and semi-arid regions in all over the world (Zalibekov, 2011; Hossain *et al.*, 2013; Lipiec *et al.*, 2013). Great reduction was seen in morphological, physiological and metabolic parameters in plants under drought stress (Maqsood *et al.*, 2012).

In present study sorghum fodder crop was grown under natural drought conditions of Hada Sham Saudi Arabia. Three levels of irrigation (100%, 80% and 60%ETc) were applied. Silicon was applied as foliar application (0, 1 and 2kg ha^{-1}) having 0 kg ha^{-1} as control treatment. The results indicated that severe drought conditions particularly during 2^{nd}cut decreased plant height, fresh and dry yields of sorghum. The supplemental irrigation and silicon application increased number of tillers, plant height, fresh and dry yield as compared to control treatment of silicon. During 1^{st}cut irrigation and silicon treatments did not affect the number of plants per square meter because no treatment was applied immediately before and after sowing. Irrigation and silicon treatments were applied after 20 days of crop sowing date at five leave stage.

Effect of irrigation and silicon on tilering

During 2^{nd}cut number of tillers were increased as compared with 1^{st}cut and the trend started decreasing during 3^{rd}cut, the probable reason for this could be the nature of ratoon crops as supported by some previous researches (Cossani and Reynolds, 2012; Tabassam *et al.*, 2014).

Effect of irrigation and silicon on plant height, fresh and dry yields

In present study the drought stress significantly reduced the plant height, fresh and dry yield. The 2^{nd}cut was most affected by drought stress as compared to 1^{st}and3^{rd}cuts because of extreme weather conditions during May and June 2017. The probable reason of reduction in height and yield may be the extreme weather and low moister due to no rainfall. The effect of drought stress on crop height was also observed by previous researchers (Anjum *et al.*, 2003a; Bhatt and Srinivasa Rao, 2005; Kusaka *et al.*, 2005; Shao *et al.*, 2008). The drought stress reduces plant height as observed in many crops like on potato (Heuer and Nadler, 1995), soybean (Specht *et al.*, 2001), soybean (Zhang *et al.*, 2004), *Vigna unguiculata* (Manivannan *et al.*, 2007a), *Abelmoschus esculentus* (Sankar *et al.*, 2007 and 2008), citrus (Wu *et al.*, 2008), and parsley (*Petroselinum crispum*) which ultimately reduced the fresh and dry yields (Farooq *et al.*, 2009).

The decrease in fresh and dry yield was observed by some previous researches under drought conditions like sunflower (Tahir and Mehid, 2001), in sugar beet genotypes (Mohammadian *et al.*, 2005), common bean and green gram (Webber *et al.*, 2006), in rice (Lafitte *et al.*, 2007) and *Petroselinum crispum* (Petropoulos *et al.*, 2008).

Silicon and irrigation scheduling mitigates drought stress

In present study under severe drought stress the foliar application of silicon increased the morphological characters and growth of sorghum. The beneficial effect of silicon on sorghum production has been observed by previous researches (Lux *et al.*, 2002; Guntzer *et al.*, 2012). Application of silicon improves crop yield and crop quality under adverse environmental conditions (Rafi *et al.*, 1997; Kaya *et al.*, 2006; Pei *et al.*, 2010; Shen *et al.*, 2010; Pei *et al.*, 2010). The positive effect of silicon under drought has been investigated by some previous researches (Jones and Handreck 1967; Savant *et al.*, 1997b; Epstein 1999; Korndorfer and Lepsch, 2001; Datnoff *et al.*, 2001; Datnoff and Rodrigues 2005; Pei *et al.*, 2010; Shen *et al.*, 2010; Meena *et al.*, 2014). The plant height, dry matter, chlorophyll content, relative water content, stomatal conductance was increased in wheat and leaves were also larger and thicker (Gong *et al.*, 2003; Hattori *et al.*, 2005; Eneji *et al.*, 2005) and Sorghum (Ahmed *et al.*, 2011b). Plant height, number of tillers and dry weight was increased in barley, wheat, corn, sugarcane, cucumber, citrus and tomato plants (Epstein, 1994; Kaya *et al.*, 2006), in rice (Singh *et al.*, 2006; Gerami *et al.*, 2012). The application of silicon increases light receiving poster in rice plants (Savant *et al.*, 1997a), increases mass and volume of roots ultimately adsorbing surfaces of roots (Matichenkov *et al.*, 1999), increases roots respiration rate (Yamaguchi *et al.*, 1995).

Conclusion

The obtained results from this study indicated significant effect of drought on sorghum forage production, and the foliar application of silicon enhanced crop production by mitigating drought stress.

The decrease in irrigation application from optimum level (100%ETc) severely decreased the stem height, fresh fodder yield and dry yield but increased the number of tillers in 2nd and 3rd cuts. Meanwhile the foliar application of silicon increased the above morphological parameters of sorghum fodder crop. The increase in silicon dose directly increased the yield components. In conclusion, according to the present study 80% irrigation and 2 kg ha^{-1} silicon seems reasonable option for sorghum production which gives similar yield as 100% irrigation in control under severe drought in arid region of Saudi Arabia.

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