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The effects of ethephon on biomass and carbohydrate content in two sweet sorghum cultivars

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Abstract

In this study, the effects of concentration and application time of ethephon on growth parameters; stem height, stem diameter, biomass, carbohydrate content; sucrose content, invert sugar, brix value, and juice volume of two sweet sorghum cultivars were determined. Three ethephon application time (8 leaves, booting, and flowering) and five ethephon concentrations (0, 200, 400, 600, and 800 ppm) on two sweet sorghum cultivars (Sofra and Keller), were deigned in a split-split plot with three replications. Hormone application time assessed as main plot, cultivars as sub plot and ethephon concentrations as sub-sub plots. Brix was shown the maximum amount (16.7%) at booting stage while it was not significant at the other two stages of hormone application time (15%). The lowest biomass was (21.5 t ha^{-1}) at 8 leaves stage and the highest (46 t ha^{-1}) at flowering stage. Similar to biomass the lowest juice volume was (3650 L ha^{-1}) at the 8 leaves stage of the hormone application time and highest (8000 L ha^{-1}) at the flowering. Sucrose content was significantly affected ($P<0.01$) by the treatment. It was higher at booting stage (11.84%) than both 8 leaves stage and flowering stage (10.7%). cv. Keller had higher stem height, brix, and sucrose content than Sofra while its invert sugar was lower than Keller. Based on these results, to have the highest brix value it may be suggested to apply ethephon at 800 ppm at flowering stage in both sweet sorghum Keller and sofra cultivars.

Keywords: Ethephon; Sweet sorghum; Biomass; Carbohydrates.

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is one of the 5 major cultivated species in the world and can be used as feed, food, sugar or ethanol production (Almodares et al., 2007). Biomass and carbohydrate contents are among the most parameters for above products so increasing and improvement of these characteristics should be considered. In *Arabidopsis thaliana*, Plant growth regulators serve as biomass and sugar accumulation, and carbohydrate improvement (Kieber, 1997). Ethephon (2-chloroethylphosphonic acid), is an ethylene-generating compound that has a profound effect on plant growth and developmental processes. The response of ethephon is depends on the species, cultivar, rate and time of application (Foster et al., 1991). They also reported ethephon significantly increased biomass and tillering of barley while its plant height was reduced. Ma and Smith, 1992 examined the effects of ethephon timing on yield components, grain yield, and agronomic traits in barley and reported that, ethephon application increased tiller-derived spikes per square meter up to 265% compared to the unsprayed control. Ethephon also hastens the cane maturation process which favours early milling, suppresses flowering and sustains quality during late-milling (Li and Solomon, 2003). The inhibition of flowering in sugarcane by ethephon was reported by Moore and Osgood, 1989. They also demonstrated an 87% reduction in tasseling, 7.5% increasing in yield, and 10% increasing in the sugar yield. Sorghum has been indicated as one of the difficult plant species for genetic manipulation (Pola et al., 2008) so using of other methods for increasing carbohydrates and biomass can be considered. In this study the effect of ethephon on biomass and sugar content in sweet sorghum was investigated.

Materials and Methods

Field experiment was conducted at the University of Isfahan Experimental Station in 2008. Three stages of hormone application (8 leaves, booting, and flowering), two sweet sorghum cultivars (Sofra and Keller), and five ethephon concentrations (0, 200, 400, 600, and 800 ppm) were deigned in a split-split plot with three replications. Stages of hormone application assessed as main plot, cultivars as sub plot and concentration as sub-sub plots. Plots consisted of 8 rows, 5 m long and 0.80 cm apart. Plots received 300 kg/ha of diammonium phosphate and 100 kg/ha of urea disced into the soil before planting. Plots were side-dressed with 100 kg/ha of urea subsurface banded 30 days after planting. Ethephon with the mentioned concentrations was sprayed at above stages. Three meters from two centre rows were harvested when the plants reached at physiological maturity. The plants were harvested and growth parameters including plant height, plant diameter, and biomass were determined. After removing the panicles and leaves, the stems crushed in a sugarcane crusher to extract the juice and its volume was measured. The juice was transferred to the laboratory for measuring sucrose content and invert sugar. Invert sugars were determined according to Lane-Eynon, 1970. The soluble solids (brix) and sucrose were measured according to Varma, 1988.

Results and Discussion

The effect of the hormone application time was significant at 1 percent level on stem height, brix, biomass, sucrose content, invert sugars and 5 percent on Juice volume (Table 1). The mean comparison of the hormone application time on the above measurements is presented in Table 2. Stem height was lowest (1.6 m) at 8 leaves stage of the hormone application time and highest (2.1 m) when hormone was applied at flowering (Table 2). Foster et al., 1991 tested ethephon at 0.3 and 0.6 kg ha^{-1} on barely (*Hordeuvmul gate* L.) and reported that plant height was reduced by ethephon application. In contrast, sweet sorghum height was not reduced by ethephon application however it has a positive relation with growth stage. The irresponsibility of sweet sorghum plant height to ethephon application could be due to low ethephon concentration in our experiment active ingredient (a.i.) 38%. Brix was shown the maximum amount (16.7%) when ethephon was applied at booting stage. Biomass was significantly different at all growth stages. The lowest (21.5 t ha^{-1}) at 8 leaves stage and the highest (46 t ha^{-1}) at flowering. Ockerby et al., 2001 reported that the application of ethephon delayed anthesis ingrain sorghum. Since vegetative growth could be ended by anthesis so ethephon is useful for prolong vegetative growth period and more biomass production. Therefore ethephon application is favor for bioethanol production from sweet sorghum. Our results could be due to improvement of the photosynthesis which is agreeable with Wei et al., 2006 who reported that ethephon causes photosynthesis improvement. Foster et al., 1991 tested ethephon at 0.3 and 0.6 kg ha^{-1} on barely (*Hordeuvmul gate* L.) and reported that biomass was increased 9 to 16 fold, respectively. They also reported that plant height was reduced by ethephon application. In contrast sweet sorghum height was not reduced by ethephon application. Li and Solomon, 2003 reported that biomass productivity per unit area increases in sugarcane following ethephon treatment. The inhibition of flowering in sugarcane by ethephon was studied. Moore and Osgood, 1989 results showed an 87% reduction in tasseling in the ethephon-treated blocks. The yield of sugarcane was increased by 7.5%, and the yield of sugar by 10%. The correlation (r^2) between the decrease in flowering and increase in cane and sugar yield was only 0.02 and 0.08%, respectively, indicating that the yield increase attributed to ethephon was not adequately explained by its effect on flowering (Moore and Osgood, 1989). Similar to biomass the lowest juice volume was (3650 L ha^{-1}) at the 8 leaves stage of the hormone application time and highest (8000 L ha^{-1}) at flowering. This increase in juice volume could be due to growth stages from 8 leave to flowering regardless of ethephon application. Sucrose content was significantly affected ($P<0.01$) by hormone application time. It was higher at booting stage (11.84%) than both 8 leaves stage and flowering stage (10.7%). A similar finding was reported by Liao et al., 2003, indicating that aerial spray of ethephon, 6-10 weeks prior to sugar can harvest consistently increase sucrose content in sugarcane juice with no adverse effect on stalk density, height and cane yield of the succeeding ratoon crop. He reported that ethephon increased sugar content per fruit more rapidly than control. He explained that such results may be due to ethylene effect on sugar accumulation in fruit tissues. This is in agreeable with other reports indicating that sucrose content increases linearly along with plant growth stages from 8 leaves stage to flowering (Almodares et al., 2007). Li and Solomon, 2003 reported that ethephon application promoted sugarcane quality and sugar accumulation, which lead to increase both cane yield and sucrose content. Invert sugar in contrast to sucrose content was higher (2.1%) when hormone was used in flowering than 8 leaves (1.8%) and booting stages (1.7%). The effect of two sweet sorghum cultivars on stem height, brix, sucrose content, and invert sugars was significant at 1% level (Table 1). The mean comparison is presented in Table 3. cv. Keller had higher Stem height, brix, and sucrose content than Sofra. It seems that these observations may be related to cultivars genotype. Sofra cv due to higher invert sugar than Keller is more suitable for ethanol production (Almodares and Hadi, 2009). The effect of ethephon concentration on brix is shown in Figure 1. The lowest (14.1%) was obtained in 200 ppm of ethephon concentration. Based on the results, although hormone concentrations didn't show effect measured characteristics but to have the highest sugar contents it is suggested to plant cv Keller and apply ethephon at flowering stage. It also recommended that more research is needed to find out the effect of ethephon concentration on mentioned characteristic such as biomass, sucrose content and juice volume.

Table 1. Sum of squares of stem height, stem diameter, brix, juice volume, biomass, sucrose content and reduction sugars at different hormone concentrations and time of hormone application of two sweet sorghum cultivars.

source	df	Stem height	Stem diameter	Brix	Juice volume	Biomass	Sucrose content	Invert sugars
HAT	2	42.77**	1.28	14.46**	10.9*	12.6**	82**	23.38**
cultivars	1	29.1**	2.2	177.11**	4.8	6.6	4.3**	419.44**
HAT * cultivars	2	1.5	3.55*	0.38	7.88**	5.38**	0.35	23.44**
HC	4	1.12	1.06	4.04*	1.41	0.89	0.2	1.49
HAT * HC	8	1.37	0.75	0.46	0.85	0.92	1.05	1.1
HC *cultivars	4	1.39	1.2	0.86	0.99	1.41	3.08	23.44
Cultivars * HAT	2	1.5	3.55*	0.38	8.06	1.74	0.35	33.77
HC * cultivars * HAT	8	0.5	0.24	1.04	0.66	0.95	0.95	1

** and * Significant at 1 and 5 percent respectively.
Abbreviation: HAT, hormone application time; HC, hormone concentration.

Table 2. Means * of stem height, stem diameter, brix, juice volume, biomass, sucrose content and invert sugars at hormone application times.

hormone application time	Stem height (m)	Stem diameter (cm)	Biomass (t ha $^{-1}$)	Juice volume (l ha $^{-1}$)	Brix (%)	Sucrose content (%)	Invert sugars (%)
8 leaves	1.6c	1.6a	21.5c	3650c	15.3b	10.3b	1.8b
Booting	1.9b	1.6a	34b	5300b	16.7a	11.84a	1.7b
flowering	2.1a	1.5a	46a	8000a	14.6b	11.2b	2.1a

* Values within a column followed by the same letter are not significantly different at P<0.05 using Duncan multiple range test.

Table 3. Means * of stem height, stem diameter, brix, juice volume, biomass, sucrose content and reduction sugars at sweet sorghum cultivars.

cultivars	Stem height (m)	Brix (%)	Sucrose content (%)	Invert sugars (%)
Sofra	1.8b	13b	9.6b	2.05a
Keller	2a	17a	11.7a	1.7b

* Values within a column followed by the same letter are not significantly different at p<0.05 using Duncan multiple range test.

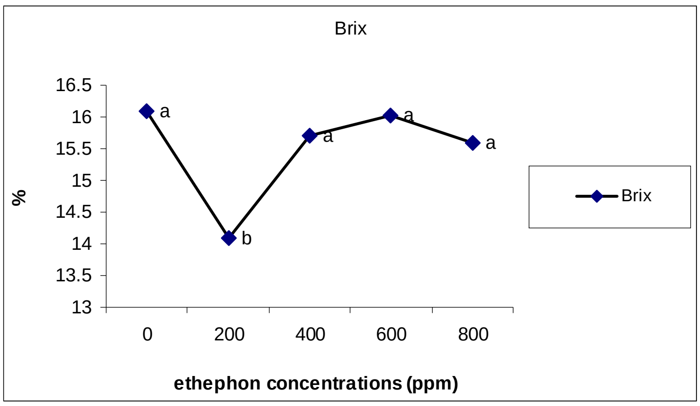

Figure 1. The effect of ethephon concentrations on Brix. Values within by the same letter are not significantly different at P<0.05 using Duncan multiple range test.

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