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The effect of nitrogen and potassium fertilizers on growth parameters and carbohydrate contents of sweet sorghum cultivars

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Abstract: *Sweet sorghum is tolerant to high temperature and drought and can be considered as an alternative crop to sugar beet and maize in Iran. In this study, the effects of nitrogen and potassium fertilizers on growth parameters including stem height, stem diameter, stem fresh weight, total fresh weight; carbohydrate contents including total sugar, brix value, sucrose content and purity; and juice extract of two sweet sorghum cultivars were determined. Three rates of N-fertilizer (0, 90, 180 kg urea ha^{-1}) and two rates of K fertilizer (0 and 50 kg potassium sulfate ha^{-1}) assigned as main plots and two sweet sorghum cultivars (Rio and Keller) as subplots. Growth parameters at soft dough and physiological maturity stages and carbohydrate contents at physiological maturity stage were determined. Results showed that application of 180 kg urea ha^{-1} as compared to control at physiological maturity significantly ($p<0.01$) increased stem height (12.65%), stem fresh weight (24.57%), total fresh weight (78.22%), total sugar (39.25%), sucrose content (9%) and juice extract (34.96%). Application of 50 kg potassium sulfate ha^{-1} increased ($p<0.05$) stem fresh weight (24.33%), total fresh weight (25.44%), total sugar (10.50%), and juice extract (9%) at physiological maturity. The highest growth parameters, carbohydrate contents and juice extract were obtained with the application of 180 kg urea ha^{-1} and 50 kg potassium sulfate ha^{-1} using cultivar (cv) Keller. The best results were taken with the application of both fertilizers.*

Key words: *N fertilizer, K fertilizer, Sweet sorghum, Growth parameters, Carbohydrate contents*
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Introduction

Sweet sorghum (*Sorghum bicolor* L. Moench) is one of the 5 major cultivated species in the world. It is consumed as food and feed (Almodares *et al.*, 2007) and used for sugar, ethanol and paper pulp production (Berenji and Dahlberg, 2004; Gnansounoua *et al*., 2005; Dolciotti *et al*., 1998; Legwaila *et al*., 2003; Almodares and Mostafafi, 2006). It can also be produced with cereals under marginal environmental conditions like dry and hot climatic also it requires low fertilizer (Kulkarni *et al.*, 1995; Legwaila *et al*., 2003). The biomass and sugar content of sweet sorghum are important factors for food and industrial productions. Balanced fertilization can increase yields (Rego *et al*., 2003; Johnston, 2000; Anderson and Ingram, 1993). Nitrogen fertilizer promotes sucrose content, protein percent and growth rate in sweet sorghum (Suksri, 1999; Tsialtas and Maslaris, 2005). Nitrogen has a significant role on plant growth through cell division (Stales and Inze, 2001; Duli Zhao *et al*., 2005; Saraswathy *et al.,* 2007). K fertilizers also increase yield of sorghum responses than increasing levels of nitrogen fertilizer alone (Pholsen and Sornsungnoen, 2004). K is required for efficient transformation of solar energy into chemical energy (Mengel and Kirkby, 2001). Accurate application of N and K fertilizers can stimulate biomass and carbohydrate of sweet sorghum which considered as an important factor in food and industrial usage. Although effect of K fertilizer on other plants is reported (Adeli and Varco, 2002) but there are few reports regarding the effect of K fertilizer on biomass of sweet sorghum. Therefore, it is of considerable value to carry out an experiment on biomass and carbohydrate content of sweet sorghum in relation to different rates of N and K fertilizers.

Materials and Methods

Field location: The experiment was carried out at the Isfahan University Research Station (31°, 31'N, 5°, 51' E, altitude 1550 m above sea level) Isfahan, Iran.

Experimental design: A split plot design in 3 replications. A factorial combination of 3 levels of N fertilizer (N1= 0, N2= 90 and N3= 180 kg urea ha^{-1}) and 2 levels of K fertilizer (K1=0 and K2=50 kg potassium sulfate ha^{-1}) were assigned to the main plots. Two sweet sorghum cultivars (Rio and Keller) were assigned to the subplots. Each plot consisted of four rows of 10 m long and 0.5 m a part. Seeds were planted in furrows and following establishments, the plants were thinned to 10 cm apart so that the final plant populations were 200,000 plants ha^{-1}.

Measurement of growth parameters and carbohydrate contents: At soft dough and physiological maturity stages three plants from two center row were randomly selected and growth parameters including stem height and stem diameter were determined. Then fresh stalk crushed in a sugarcane crusher to extract the juice. After filtration through a sieve to remove chaff, reducing sugars were measured according to Lane-Eynone (1970). The soluble solids (brix), sucrose (pol%) were measured according to Varma (1988). Hydrocarbons were determined using high performance liquid chromatography (HPLC) and the measuring of fructose and glucose was repeated by gas chromatography (GC).

The separation was accomplished by using an aminopropyl column (4.6 x 250 mm) with a mobile phase of 80% acetonitrile/20% water (Biermann and Mcginnis, 1989). Quantitation was accomplished by use of three point calibration curve. Total sugar content per hectare on stem fresh weight basis was calculated as :

Stalk x moisture% x brix x specific gravity of juice x % juice (Wt/ha in stem value for the corresponding brix value purity)

Statistical analysis: Statistical analyses were performed using SAS program (SAS, 1997). The means were compared according to Duncan multiple rang test. Linear regression analyses were done by MS Excel.

Results and Discussion

Growth parameters: The effect of nitrogen fertilizer on stem height (SH), stem diameter (SD) stem fresh weight (SFW), and total fresh

Table - 1: Sum of squares of stem height, stem diameter, stem fresh weight and total fresh weight at different growth stages of two sweet sorghum cultivars

Source	d.f.	Stem height (cm)		Stem diameter (cm)		Stem fresh weight (t ha^{-1})		Total fresh weight (t ha^{-1})	
		Soft dough	Physiological maturity	Soft dough	Physiological maturity	Soft dough	Physiological maturity	Soft dough	Physiological maturity
Replication	2	3.69	1.39	2.52	4.96	24.25	43.11	25.86	51.19
N	2	3506**	2902**	18.02*	26.08**	2235**	2844**	49998**	6392**
K	1	18.78	21.78	10.67	11.33	1144**	124.8**	2384**	2652**
N*K	2	69.53*	84.03*	2.86	5.76	765.5**	912.5**	1658**	2017
Error	10	12.63	13.39	2.48	2.65	9.68	11.51	24.66	33.36
Cultivar	1	121**	152.10**	22.4**	29.88**	156.20**	196	140**	191.40**
N* cultivar	2	5.08*	1.36	0.01	0.14	8.08	20.58	17.69	38.53
K* cultivar	1	1.78	2.78	0.16	0.13	0.25	0.11	10.03	80.30
N*K* cultivar	2	1.03	0.53	1.05	0.36	1158	11.03	36.03	26.4
Error	12	1.03	0.94	3.52	4.49	7.05	8.22	16.42	16.28

** and * Significant at 1 and 5 percent respectively

Table - 2: Means * of stem height, stem diameter, stem fresh weight and total fresh weight at different growth stages of two sweet sorghum cultivars

Treatments	Stem height (cm)		Stem diameter (cm)		Stem fresh weight (t ha^{-1})		Total fresh weight (t ha^{-1})	
	Soft dough	Physiological maturity	Soft dough	Physiological maturity	Soft dough	Physiological maturity	Soft dough	Physiological maturity
Fertilizer (urea kg ha^{-1})								
0	232^{c}	245^{c}	15.4^{b}	16.6^{b}	39.9^{c}	41.1^{b}	56.1^{c}	57.7^{c}
90	211^{b}	261^{b}	15.7^{ab}	17.2^{ab}	47.8^{b}	50.8^{a}	66.0^{b}	69.9^{b}
180	266^{a}	276^{a}	17.6^{a}	19.4^{a}	66.5^{a}	51.2^{a}	95.3^{a}	102.3^{a}
Potassium sulfate (kg ha^{-1})								
0	249^{a}	260^{a}	15.7^{a}	17.2^{a}	45.7^{b}	48.5^{b}	64.3^{b}	68^{b}
50	251^{a}	261^{a}	16.8^{a}	18.3^{a}	57.1^{a}	60.3^{a}	80.6^{a}	85.3^{a}
Rio	248^{b}	258^{b}	15.4^{b}	16.9^{b}	49.3^{b}	52.1^{b}	70.5^{b}	74.3^{b}
Keller	252^{a}	262^{a}	17.0^{a}	18.9^{a}	53.5^{a}	56.7^{a}	74.4^{a}	78.9^{a}

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

Table - 3: Sum of squares of total sugar, brix value, sucrose content, sucrose content and juice extract at physiological maturity stage of two sweet sorghum cultivars

Treatments	d.f.	Total sugar (t ha^{-1})	Brix value (%)	Sucrose content (%)	Purity (%)	Juice extract (gm^{-2})
Replication	2	0.48	2.09	0.1	20.52	82152
N	2	2.19**	0.76	4.41**	3.16	525277**
K	1	0.58**	0.34	3.40*	0.42	122500*
N*K	2	0.02	0.05	0.92	61.09	10833
Error	10	0.1	0.41	0.43	57.59	23486
Cultivar	1	1.58**	14.06**	3.95**	181.08	160000**
N* cultivar	2	0.12	0.81	0.07	196.5	10000
K* cultivar	1	0.28*	0.34	0.05	3.75	46944*
N*K* cultivar	2	0.04	0.21	0.01	50.81	3611
Error	12	0.03	0.49	0.13	60.02	9236

** and * Significant at 1 and 5 percent respectively

Table - 4: Means* of total sugar, purity, brix value and sucrose content in physiological maturity stage of two sweet sorghum cultivars

Treatments	Total sugar (t ha^{-1})	Brix value(%)	Sucrose content (%)	Juice extract (g m^{-2})
Fertilizer (urea kg ha^{-1})				
0	2.14^{c}	18.3^{a}	13.3^{b}	1167^{b}
90	2.41^{b}	18.5^{a}	14.1^{ab}	1292^{b}
180	2.98^{a}	18.8^{a}	14.5^{a}	1575^{a}
Potassium sulfate (kg ha^{-1})				
0	2.38^{b}	18.5^{a}	13.7^{b}	1286^{b}
50	2.63^{a}	18.7^{a}	14.3^{a}	1403^{a}
Cultivar				
Rio	2.30^{b}	17.9^{b}	13.6^{b}	1278^{b}
Keller	2.72^{a}	19.2^{a}	14.3^{a}	1411^{a}

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

weight (TFW) at soft dough and physiological maturity were significant (Table 1). The above measurements exhibited the highest with the application of 180 kg urea ha^{-1} and the lowest at control (Table 2). The effect of potassium fertilizer on SFW and TFW at both soft dough and physiological maturity were significant ($p<0.01$; Table 1). The highest SFW and TFW were obtained with the application of 50 kg sulfate potassium ha^{-1} (Table 2). The interactions between N and K on SH and SFW at both soft dough and physiological maturity stages, and TFW only at soft dough stage were significant (Table 1). Interaction between nitrogen and potassium on stem height, stem fresh weight and total fresh weight was significant at physiological maturity stage and presented in Fig. 1, Fig. 2 and Fig. 3, respectively. The highest amounts of aforementioned characters were obtained with the application of 180 kg urea ha^{-1} and 50 kg potassium sulfate ha^{-1}. Fig. 1 shows that nitrogen fertilizer increased stem height regardless of the amount of potassium fertilizer. The effect of potassium fertilizer on the above characters was significant only when the amount of nitrogen fertilizer was more than control. As a result, the combination of N and K fertilizers could have the highest effect on these characters. The effect of cultivars on SH, SD, SFW and TFW were significant ($p<0.01$, Table 1). Mean comparison between cultivars is presented in Table 2. In all the above measurements cv Keller was higher than cv Rio. Nitrogen fertilizer increases SH, SD, SFW and TFW. Johnston (2000) reported application of nitrogen fertilizer increases sweet sorghum stalk yield. Sainju *et al*. (2005) reported nitrogen fertilization increases both sorghum yield and biomass production. Nitrogen may effect on plant growth through cell division and cell enlargement which consequently increase SH and SD (Stales and Inze, 2001). Also nitrogen has significant role on protein biosynthesis (Taize and Ziger, 2000). SFW and TFW had positive relation with amount of potassium fertilizer. Potassium is an essential nutrient for plant growth and if it is deficient or not supplied in adequate amounts, growth is stunted and yields are reduced (Leigh and Jones, 1984; Bourke, 1985). The elevated accumulation of dry weight (DW) in various plant parts resulted due to adequate supply of K^{+} to the crop during the season. Michael and Beringer (1980) reported that K^{+} stimulates the formation of high storage (sink) capacity through higher photosynthesis. Stanley (2005) reported that relatively high levels of potassium are utilized

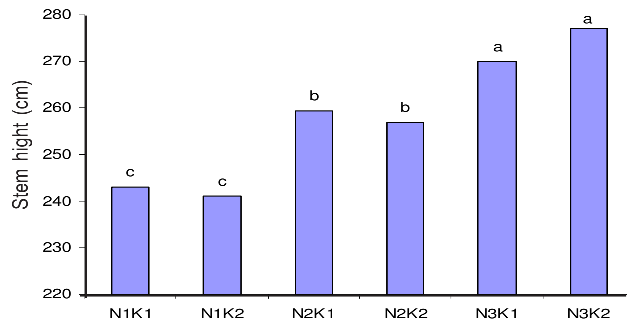

Fig. 1: Interaction between levels of nitrogen and potassium on stem height at physiological maturity stage. N1, N2, N3 (0, 90, 180 kg urea ha^{-1}) and K1, K2 (0 and 50 kg potassium sulfate ha^{-1})

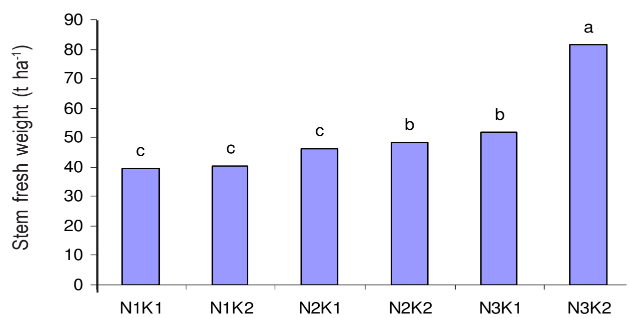

Fig. 2: Interaction between levels of nitrogen and potassium fertilizers on stem fresh weight at physiological maturity stage. N1, N2, N3 (0, 90, 180 kg urea ha^{-1}) and K1, K2 (0 and 50 kg potassium sulfate ha^{-1})

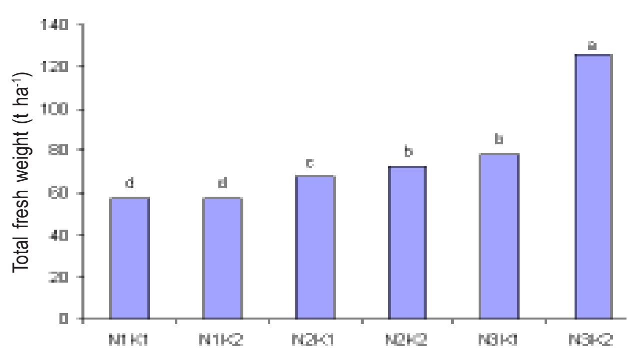

Fig. 3: Interaction between levels of nitrogen and potassium fertilizers on total fresh weight at physiological maturity stage. N1, N2, N3 (0, 90, 180 kg urea ha^{-1}) and K1, K2 (0 and 50 kg potassium sulfate ha^{-1})

by growing plants. Potassium activates some enzymes and plays a role in water balancing plants. It is also essential for some carbohydrate transformations. Generally, crop yields are greatly reduced in potassium deficient soils. The interaction between N and K on most growth parameters was significant. Pholsen and Sornsungnoen (2004) revealed that the growth parameters increased up to certain rates of N-K_2O but higher rates did not increase those parameters. In all the above measurements cv Keller was higher than cv Rio. Genotype differences may explain higher plant height and more nodes in cv Keller than cv Rio (Dolciotti *et al*., 1998).

Carbohydrate content and juice extract: The effect of nitrogen fertilizer on total sugar, sucrose content and juice extract was significant at 1 percent level (Table 3). Mean comparisons for these parameters are presented in Table 4. Total sugar, sucrose content and juice extract were highest with the application of 180 kg urea $ha^{-1.}$ While total sugar at 90 kg urea ha^{-1} was higher than control. The sucrose content and juice extract were not significant between 90 kg urea ha^{-1} and the control. Effect of potassium on total sugar, sucrose content and juice extract was significant (Table 3). The aforementioned measurements at 50 kg potassium ha^{-1} were higher than control. The effect of cultivars on total sugar, brix value and sucrose content was significant at 1 percent level (Table 3). cv Keller in all the above measurements was higher than cv Rio. The effect of nitrogen fertilizer on total sugar, sucrose content and juice extract was significant. Tallat (2002) reported that nitrogen fertilization had site-specific effects on quantitative (fresh root and sugar yields) and qualitative (sucrose content, K, Na, α–amino N) traits. Combined data over years and sites resulted that fresh roots and sugar yields were maximized at high N rates (Ayoub *et al*., 2003). Sucrose in the cane juice obtained from control plots was 14.6 percent against the significantly higher sucrose content of 16.5 percent found in plots treated with 200 kg K_2O ha^{-1} (Tallat, 2002). Potassium is required for efficient transformation of solar energy into chemical energy that could increase carbohydrate content (Taize and Ziger, 2000). Also potassium has a significant role in the translocation of assimilates to sinks by influence electron transport in the transport chain of crops (Reddy and Zhao, 2005; Suksri, 1999). Mengal and Kirkby (2001) reported the presence of potassium inhibits the formation of starch which may increase sucrose content. Potassium deficiency exerts a negative effect on photosynthesis and carbohydrate transport in sugarcane and high rates of K are required for maximum economic cane yield (Tallat, 2002). Same growth parameters, cv Keller had higher amount of carbohydrates than cv Rio. It seems that difference in genotype causes this effect.

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