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Nitrogen Management Effect on the Production of Two Sweet Sorghum Cultivars under Arid Regions Conditions

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ABSTRACT

A two years field study was conducted to evaluate the effect of response of two sweet sorghum cultivars to different sources and time of nitrogen application during 2009 and 2010 at experimental farm Faculty of Agriculture, South Valley University at Qena Governorate, Egypt. Two cultivars viz. Tracy and Honey and six combination of source and application time of nitrogen fertilizes viz. ammonium sulphate, 20.5% N in two equal doses (T_1) and in three equal doses (T_2), ammonium nitrate, 33.5% N in two equal doses (T_3) and in three equal doses (T_4), urea, 46.5% N in two equal doses (T_5) and in three equal doses (T_6) were tested in the study. The experiment was laid out in split plot design with cultivars in main plots and nitrogen fertilizers in sub-plots. Among sweet sorghum cultivars, cv Honey had the highest stalk height, stalk diameter, number of internodes per stalk, Brix value, sucrose content, apparent purity percentage and stalk and forage (leaves) yields and lowest reducing sugar content. Application of T_4 gave the highest value of the above measurements and lowest reducing sugar content. Cultivar and nitrogen treatments interaction was significant on stalk and forage yields as well as reducing sugar content. The highest stalk and forage yields and lowest reducing sugar content were obtained by planting cv Honey and application of ammonium nitrate in three equal doses (at planting , 4 leaf stage and booting). Plant height, stalk diameter, forage yield, brix and sucrose were positively and strongly correlated with stalk yield.

Key words: Sweet sorghum, nitrogen sources, application time, sucrose, correlation

INTRODUCTION

Sorghum (*Sorghum biocolor* L. Moench) is multipurpose cereal, contains grain, forage and sweet types. Sweet sorghum mainly is planted for a good source of syrup, forage and ethanol production. Sweet sorghum gave higher ethanol concentration than cassava (Nadir *et al.*, 2009). Furthermore, sweet sorghum has a lower water requirement and drought tolerant, meantime, its rapid growth rate early maturity high total energy value as well as adapted to sub-tropical and temperate region of the world (Rego *et al.*, 2003). Cane syrup (locally known as black honey) is a very popular product in Egypt, its manufacture consumes about 4.8% of the total sugar cane area and the continuous demand necessitated more attention towards sweet sorghum as an ancillary source of syrup (Besheit *et al.*, 1996).

Yield and quality of syrup are influenced by variety, fertilization, plant population, sowing date and soil type. However, variety and nitrogen fertilizers source are the most important especially under local conditions. Worth to mention, Mokadem *et al.* (1999) and El-Wafa and El-Hamd (2001) reported that not all sweet sorghum are equally good for syrup production but there is a good deal of variation from variety i.e., quantity of stalk per area and technological characters. Among sweet sorghum cultivars, Chohan *et al.* (2003) compared ten sorghum cultivars and reported cv F-9905 produced the highest green fodder yield (69.62 t ha^{-1}) followed by F-9904 (69.44 t ha^{-1}) and F-9909 (69.06 t ha^{-1}). Also add that, check varieties JS-88 and JS-263 produced 65.55 and 63.33 t ha^{-1} green fodder yields, respectively. Almodares *et al.* (2007a) found that differences between cultivars (Rio, Keller, Sofra and Soave) in germination and seedling fresh weight under salinity conditions.

Nitrogen has now been recognized as one of the most limiting nutrient. Its use and demand is continuously increasing day by day. Since it is highly mobile, it is subjected to greater loss from the soil plant system. Even under the best management practices 30-50% of the applied N is lost through different agencies (Stevenson, 1985) and hence the farmer is compelled to apply more than the actual need of the crop to meet the loss. The loss of N not only harasses the farmer but it has also hazardous impact on the environment (Kessel *et al.*, 1993; Gosh and Bhat, 1998). Thus it is the need of the time to search not only for the source N of a crop but also to find out appropriate time for its application to reduce the loss. Different approaches may be adopted for effective and efficient utilization of nitrogenous fertilizers. Zeidan and El-Kramany (2001) in wheat and Ahmed *et al.* (2007) in sorghum, reported that there were significant differences due to N sources in growth, yield and yield components. Nemeat (2001) reported that ammonium nitrate as a nitrogen fertilizer source surpassed other nitrogen fertilizer sources i.e., urea or ammonium sulphate in sugar beet and produced the highest values of root length and diameter, root and top fresh weight (kg/plant), root, top and sugar yields (tons/fed.) as well as TSS percentage. Fertilization sugar beet in the form of ammonium nitrate (33.5% N) and splitting nitrogen fertilizer dose at three equal portions significantly maximized root and sugar yields (Sharief *et al.*, 2004). Split application of N has been found more efficient method as compared with a sole doze at the time of application. Tripathi and Bhan (1995) found that application of 60 kg N ha^{-1} in two split (half at planting in furrows 2-3 cm below the seed and remaining half side dressed about 5 weeks after planting) significantly increased the sorghum yield and its attributes. Sidedress application of nitrogen fertilizer at eight-leaf growth stage is feasible and would be beneficial for sorghum (Khosla *et al.*, 2000).

There is a considerable interest in the source and time of nitrogen fertilization required to maximize the total yield and quality can be obtained. Thus, the main objective of this study was to evaluate the response of two cultivars of sweet sorghum to source and time of nitrogen application under arid conditions.

MATERIALS AND METHODS

The investigation was carried out at experimental farm Faculty of Agriculture, South Valley University at Qena Governorate, Egypt, for two years during summer 2009 and 2010. The farm is located at an altitude of 79 m above mean sea level and is intersected by 26°10' N latitude and 32°43' E longitude. The weather is very hot and dry from May to October where temperatures can reach up to 40°C. On the other hand, the weather is usually warm during winter months and rainfall is rare. The relative humidity averages about 55%. The soil of the experimental site is sandy-loam throughout its profile (74.2 sand, 16.4% silt and 9.4% clay). Its pH value of 7.82, 1.89 EC (dS m^{-1}), 0.48% organic matter content, 0.33% total N, 8.32, 198 ppm available P and K, respectively.

The treatments consisted two cultivars i.e., Tracy (V_1) and Honey (V_2) and six combination of source and application time of nitrogen fertilizes i.e., ammonium sulphate; $(NH_4)_2SO_4$ (20.5% N) in two equal doses; at planting and 4 leaf stage (T_1), ammonium sulphate; $(NH_4)_2SO_4$(20.5% N) in three equal doses; at planting, 4 leaf stage and booting (T_2), ammonium nitrate; NH_4NO_3 (33.5% N) in two equal doses; at planting and 4 leaf stage (T_3), ammonium nitrate; NH_4NO_3 (33.5% N) in three equal doses; at planting, 4 leaf stage and booting (T_4), urea; $(NH_2)_2$ CO (46.5% N) in two equal doses; at planting and 4 leaf stage (T_5) and urea; $(NH_2)_2$ CO (46.5% N) in three equal doses; at planting, 4 leaf stage and booting (T_6). The experiment was laid out in randomized complete block split plot design with three replications keeping cultivars in main plot and combination of source and application time of nitrogen fertilizes in sub plot. Individual sub plots measured 3.0 m in width and 7 m in length.

Seeds sweet sorghum cultivars "Tracy and Honey" (24 kg ha^{-1}) were hand sown at 5 and 8 May in the first and second years, respectively as the usual dry method of sowing on one side of ridges (60×20 cm). The preceding winter crop was wheat in both years. The N, P_2O_5 and K_2O fertilizes were applied at 170, 55 and 60 kg ha^{-1}, respectively. The other agronomic practices were kept normal and uniform for all the treatments.

The plants were harvested at hard dough stage in both years. At harvest time, the following traits were determined from a minimum of twenty five randomly sampled plants from each sub plot: 1-stalk height, 2-stalk diameter, 3-number of internodes per stalk, 4-brix value in the juice (using Brix Hydrometer), 5-sucrose content in 100 cm^3 of juice using Sacharemeter according to AOAC (1995), 6-apparent purity percentage (sucrose % *100/birx %) and 7-reducing sugar content according by Chemical Control Lab of Sugar and Integrated Industries Company, Anonymous (1981). Stalk and forage (leaves) yields (tons ha^{-1}) were also determined immediately after harvest in the field from the three central rows of each sub plot.

All measurements in this study were analyzed using an analysis of variance appropriate for a randomized complete block split plot design with cultivars as the main factor and nitrogen treatments as the split factor. Mean separation of treatment effects in this study was accomplished using Duncan's multiple test (Steel and Torrie, 1980). Probability levels lower than 0.05 were categorized as significant. All data analyses in this study were accomplished using the COSTAT system for windows, version 6.311 (CoHort software, Berkeley, CA, USA).

RESULTS AND DISCUSSION

Cultivars effect: Data in Table 1 shows analysis of variance for sweet sorghum cultivars and nitrogen treatments on stalk height, stalk diameter, number of internodes per stalk, brix value, sucrose content, apparent purity percentage, reducing sugar content and stalk and forage (leaves) yields. The results showed that effect cultivars on the above measurements were significant ($p<0.05$) except for apparent purity in the first and second seasons. Cv Honey had the highest stalk height (308.4 and 308.8 cm), stalk diameter (2.163 and 2.341 cm), number of internodes per stalk (16.22 and 15.93), stalk yield (37.844 and 35.078 tons ha^{-1}) and forage (leaves) yield (11.600 and 11.961 tons ha^{-1}) in 2 consequence years, respectively (Table 2). High stalk yield of cv Honey may be due to its long and thick stem. El-Shafai *et al.* (2005) found similar results. Also, Mokadem *et al.* (1999) compared thirteen sweet sorghum cultivars and reported cv Honey among those cultivars had the highest yield of stalk, juice quality and syrup production. Cv Honey had the highest sucrose content (10.80 and 10.27%) among sweet sorghum cultivars and this is because of the highest Brix value (15.39 and 14.66%) and lowest reducing sugar content (2.517 and

2.396%), (Table 2). This could be better explained by genetically differences rather than environmental. These results are in harmony with those obtained by El-Hoda *et al.* (1994). Almodares *et al.* (2007b) found that cv Rio had the highest stalk yield, brix value and sucrose content. Almodares and Dosti (2008) compared two sweet sorghum cultivars (Soave and Sofra) and found that the sucrose content of Soave was higher than Sofra but its glucose and fructose content was lower than Sofra.

Nitrogen fertilizers: The effect of nitrogen treatments on the previous measurements was significant ($p<0.01$) except for apparent purity and number of internodes per stalk in the first and second years (Table 1). Application of T_4(ammonium nitrate, NH_4NO_3, 33.5% N in three equal doses at, planting , 4 leaf stage and booting) gave the highest stalk height (317.2 and 315.8 cm), stalk diameter (2.350 and 2.330 cm), stalk yield (43.583 and 40.750 tons ha^{-1}) and forage (leaves) yield (13.683 and 14.767 tons ha^{-1}) in 2 consequence years, respectively (Table 2). Also, T_4 had the highest sucrose content (11.75 and 10.98%) among nitrogen treatments and this is because of the highest brix value (16.67 and 16.18%) and lowest reducing sugar content (2.433 and 2.227%). The lowest value of stalk height (285.3 and 297.8 cm), stalk diameter (1.897 and 2.050 cm), stalk yield (29.500 and 27.917 tons ha^{-1}) and forage (leaves) yield (6.900 and 7.300 tons ha^{-1}), were obtained from T_1 (ammonium sulphate $(NH_4)_2SO_4$, 20.5% N in two equal doses at planting and 4 leaf stage). Also T_1 had the lowest sucrose content (8.90 and 8.67%) among nitrogen treatments and this is because of the lowest Brix value (12.17 and 12.52%) and highest reducing sugar content (2.852 and 2.767%), (Table 2). The influence of nitrogen fertilizer as ammonium nitrate (33.5% N) on agronomic efficiency is mainly due to their effect on soil reaction and nutrient availability .These results are in good agreement with those reported by Nemeat (2001). Also the increases in the previous measurements due to splitting nitrogen fertilizer dose in three equal portions may be attributed to minimize the lose of nitrogen by leaching besides saving suitable amount of nitrogen as plant need during the different stages of life which increased growth and yield. These results are in good accordance with those reported by Sharief *et al.* (2004).

Table 1: Mean squares of some traits of sweet sorghum year (2009, 2010)

Source of variance	df	Plant height	Stalk diameter	No. Internodes stalk^{-1}	Brix	Sucrose	Reducing sugar	Apparent purity	Stalk yield	Forage yield
2009										
Replication	2	158.10	0.040	1.333	2.507	2.084	0.0036	64.74	13.745	0.042
Cultivars (V)	1	1456.70*	0.096*	23.361*	41.17*	11.000*	1.068*	66.48	211.70*	64.27*
Error a	2	21.19	0.003	0.778	0.924	0.375	0.035	51.55	8.711	2.799
Nitrogen (T)	5	733.80**	0.127**	0.383	13.14**	5.970**	0.183**	20.26	171.9**	30.42**
V×T	5	54.63	0.006	1.894	2.540	0.410	0.074**	111.27	50.56**	13.54**
Error b	20	40.07	0.008	1.389	1.207	0.409	0.010	67.96	7.100	3.119
2010										
Replication	2	74.30	0.0004	0.422	0.272	1.986	0.0451	94.82	2.043	3.309
Cultivars (V)	1	1534.00*	0.043*	24.50*	13.73*	10.912*	0.518*	24.88	115.92*	60.84*
Error a	2	38.78	0.014	1.111	0.535	0.581	0.0038	7.39	5.052	2.181
Nitrogen (T)	5	529.5**	0.059**	0.527	9.940**	3.269**	0.263**	49.48	129.4**	37.48**
V×T	5	31.56	0.012	2.156	0.969	0.593	0.118**	37.23	50.79**	9.050**
Error b	20	16.76	0.009	0.906	0.600	0.481	0.007	50.34	10.815	1.835

* and ** significant at 5 and 1% level, respectively

Table 2: The effect of cultivars and nitrogen treatments on some traits of sweet sorghum year (2009, 2010)

Treatments	Plant height (cm)	Stalk diameter (cm)	No. of internodes stalk^{-1}	Brix (%)	Sucrose (%)	Reducing sugar (%)	Apparent purity	Stalk yield (t ha^{-1})	Forage yield (t ha^{-1})
Cultivars (V) (2009)									
Tracy (V1)	295.7^{b}	2.059^{b}	14.61^{b}	13.25^{b}	9.69^{b}	2.860^{a}	73.54^{a}	32.994^{b}	8.928^{b}
Honey (V2)	308.4^{a}	2.163^{a}	16.22^{a}	15.39^{a}	10.80^{a}	2.517^{b}	70.82^{a}	37.844^{a}	11.600^{a}
Nitrogeu (T)									
T1	285.3^{d}	1.897^{c}	15.50^{a}	12.17^{c}	8.90^{d}	2.852^{a}	74.06^{a}	28.300^{e}	6.900^{c}
T2	293.8^{c}	2.062^{b}	15.33^{a}	13.50^{b}	9.50^{cd}	2.850^{a}	70.51^{a}	31.683^{d}	9.500^{b}
T3	306.1^{b}	2.108^{b}	15.67^{a}	14.50^{b}	10.50^{b}	2.733^{a}	73.04^{a}	35.250^{c}	11.217^{b}
T4	317.2^{a}	2.350^{a}	15.33^{a}	16.67^{a}	11.75^{a}	2.433^{b}	71.51^{a}	43.583^{a}	13.683^{a}
T5	305.0^{b}	2.133^{b}	15.00^{a}	14.58^{b}	10.75^{b}	2.517^{b}	74.13^{a}	34.867^{cd}	9.500^{b}
T6	304.5^{b}	2.117^{b}	15.67^{a}	14.50^{b}	10.08^{bc}	2.750^{a}	69.82^{a}	38.833^{b}	10.783^{b}
Cultivars (V) (2010)									
Tracy (V1)	295.7^{b}	2.001^{b}	14.28^{b}	13.42^{b}	9.17^{b}	2.636^{a}	68.71^{a}	31.489^{b}	9.361^{b}
Honey (V2)	308.8^{a}	2.341^{a}	15.93^{a}	14.66^{a}	10.27^{a}	2.396^{b}	70.73^{a}	35.078^{a}	11.961^{a}
Nitrogeu (T)									
T1	297.8^{d}	2.050^{c}	14.95^{a}	12.52^{d}	8.67^{c}	2.808^{a}	69.54^{a}	27.917^{d}	7.300^{d}
T2	297.3^{c}	2.080^{bc}	15.50^{a}	13.17^{cd}	9.65^{b}	2.642^{b}	73.70^{a}	29.900^{cd}	9.300^{c}
T3	306.0^{b}	2.188^{b}	14.67^{a}	13.70^{c}	9.67^{b}	2.455^{c}	70.80^{a}	32.200^{c}	10.100^{bc}
T4	315.8^{a}	2.330^{a}	15.33^{a}	16.18^{a}	10.98^{a}	2.227^{d}	68.02^{a}	40.750^{a}	14.767^{a}
T5	301.2^{bc}	2.177^{b}	15.00^{a}	13.93^{bc}	9.75^{b}	2.600^{b}	70.08^{a}	32.483^{c}	10.917^{bc}
T6	305.3^{b}	2.200^{b}	15.17^{a}	14.73^{b}	9.62^{b}	2.362^{c}	65.09^{a}	36.450^{b}	11.583^{b}

Means followed by the same letter are not significantly different from one another based on Duncan's multiple test at $p \le 0.05$. T_1 (ammonium sulphate, 20.5% N in two equal doses at planting and 4 leaf stage), T_2 (ammonium sulphate, 20.5% N in three equal doses at planting, 4 leaf stage and booting), T_3 (ammonium nitrate, 33.5% N in two equal doses at planting and 4 leaf stage), T_4 (ammonium nitrate, 33.5% N in three equal doses at planting, 4 leaf stage and booting), T_5 (urea, 46.5% N in two equal doses at planting and 4 leaf stage) and T_6 (urea, 46.5% N in three equal doses at planting, 4 leaf stage and booting)

Interaction effect: In both years, the interaction between cultivars and nitrogen treatments was significant ($p<0.01$) on stalk yield, forage yield and reducing sugar content (Table 1, Fig. 1). Cv Honey significantly increased stalk yield and forage yield under all nitrogen treatments except under T_6 (urea, $(NH_2)_2$ CO, 46.5% N in three equal doses at planting, 4 leaf stage and booting) in both years (Fig. 1a, b). Honey surpassed Tracy in stalk yield by 23.7, 28.8, 11.9, 20.1 and 31.7% in the first season and by 3.7, 9.8, 14.0, 33.7 and 18.5 in the second season for T_1, T_2, T_3, T_4 and T_5, respectively. The highest stalk yield (47.570 and 46.63 tons ha^{-1}) and forage yield (14.87 and 17.13 tons ha^{-1}) in 2009 and 2010, respectively were obtained from V_2T_4. The lowest stalk yield (25.300 and 26.130 tons ha^{-1}) and forage yield (6.100 and 6.900 tons ha^{-1}) were obtained from V_1T_1 (Fig. 1a,b). In contrast, the highest reducing sugar content (3.200 and 2.850%) was obtained from interaction with V_1T_1 and the lowest (2.200 and 1.900%) from V_2T_4 (Fig. 1c).

Correlation coefficient: The results of correlations analysis between stalk yield and all studied parameters are shown in Table 3. It was observed that there was a high and positive correlation between stalk yield and plant height (r = 0.768 and r = 0. 0.671), stalk diameter (r = 0.758 and r = 0.534), forage yield (r = 0.747 and r = 0.769), brix (r = 0.630 and r = 0.697) and sucrose (r = 0.712 and r = 0.471) in 2009 and 2010, respectively. These results showed that any positive increase in such characters will suffice the boast in stalk yield. These findings are in agreement with Makanda *et al*. (2009) who found that plant height (r = 0.641) and stem diameter (r = 0.487)

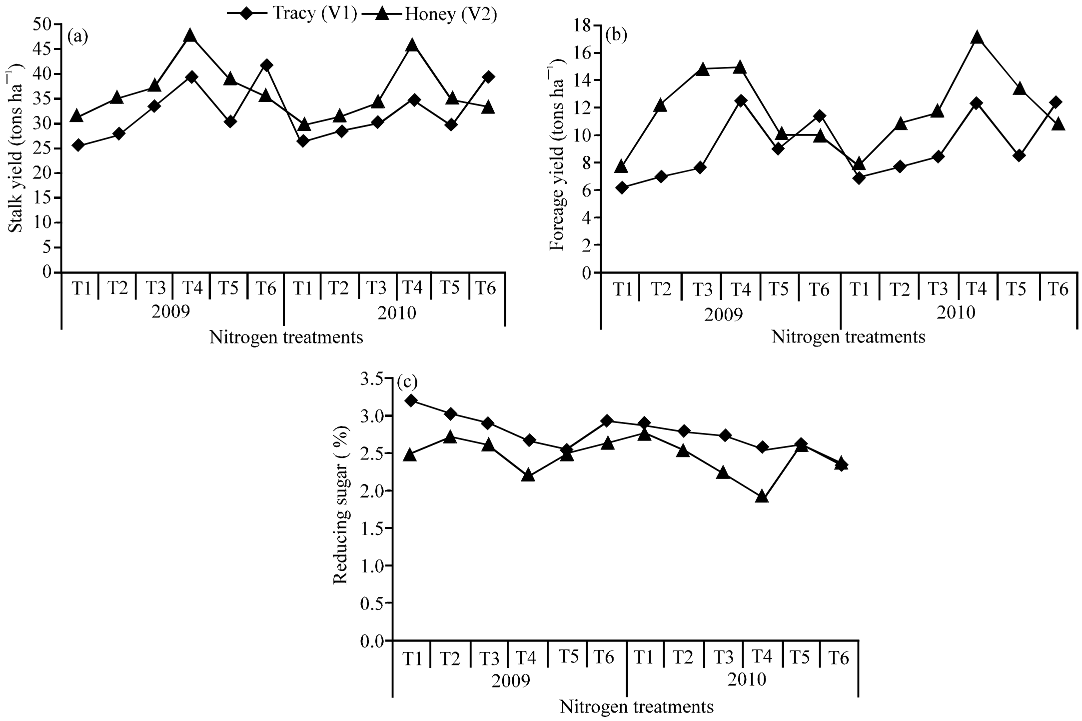

Fig. 1 (a-c): Interaction between cultivars (V1, V2) and nitrogen treatments (T1, T2, T3, T4, T5, T6) on stalk and forage yields (tons ha^{-1}) as well as reducing sugar (%) of sweet sorghum in 2009-2010 years

Table 3: Correlation coefficient between stalk yield and all studied traits of sweet sorghum year (2009, 2010)

	Y: Salk yield (tons ha^{-1})	
Traits	2009	2010
Plant height (cm)	0.768**	0.671**
Stalk diameter (cm)	0.758**	0.534**
Internodes $plant^{-1}$	0.292 ns	0.397*
Brix (%)	0.630**	0.697**
Sucrose (%)	0.712**	0.471**
Reducing sugar (%)	-0.568**	-0.755**
Apparent Purity (%)	-0.006 ns	-0.218 ns
Forage yield (tons ha^{-1})	0.747**	0.769**

**Significant 1 % level, ns: indicate that not significant

were positively and highly significantly ($p<0.01$) correlated to biomass weight. On the other hand, there were a negative and highly significant ($p<0.01$) correlation ($r = -0.568$ and $r = -0.755$ in the first and second years, respectively) observed between stalk yield and reducing sugar. The correlation between stalk yield and internodes $plant^{-1}$ is weak ($r = 0.292$ and $r = 0.397$) in 2009 and 2010, respectively. Interestingly, no significant correlation was observed between stalk yield and apparent purity in both years.

CONCLUSIONS

There were significant differences ($p<0.05$) between sweet sorghum cultivars except purity percentage in both years. In addition, significant differences ($p<0.01$) between nitrogen treatments expect internodes plant^{-1} and purity percentage. The interaction between cultivars and nitrogen treatments was significant on stalk yield, forage yield and reducing sugar content. The highest stalk and forage yields as well as lowest reducing sugar content were obtained from V_2T_4. Based on these results to obtain the highest stalk and forage yields as well as lowest reducing sugar content, it is recommended to planting sweet sorghum cv Honey and application of nitrogen as form ammonium nitrate (NH_4NO_3, 33.5% N) in three equal doses (at planting, 4 leaf stage and booting) under similar soil and climatic conditions.

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