

Original Research Article

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## The Effect of Nitrogen and Potassium Fertilizers on Yield and Quality of Sweet Sorghum Varieties under Arid Regions Conditions

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### ABSTRACT

Two field experiments conducted during 2013 and 2014 seasons at the farm of the Faculty of Agriculture, Demo, Fayoum University, Egypt, to evaluate two sweet sorghum varieties under the effect of three nitrogen levels and three potassium levels on yield and its attributes. The experiment was set up according to three-factorial (Split-split plot) block design in three replications, the main plots were assigned to sweet sorghum varieties *viz.*, Honey ( $V_1$ ) and Brandes ( $V_2$ ). The sub plots were occupied with three levels of nitrogen at the level of 80 ( $N_1$ ), 100 ( $N_2$ ) and 120 ( $N_3$ ) Kg N/fed (fed= 4200 m<sup>2</sup> = 0.405 hectare) in three equal doses. Potassium sulphate (48% K<sub>2</sub>O) applied to the soil at the level of 25 ( $K_1$ ), 50 ( $K_2$ ) and 75 ( $K_3$ ) kg K<sub>2</sub>SO<sub>4</sub>/fed were arranged in the sub-sub plots treatments and applied in three equal doses. Results indicated that the effect of nitrogen levels as well as, potassium levels had a highly significant positive effect on yield, yield components and quality traits, varieties differed significantly in stem diameter, seed index and theoretical ethanol yield in both seasons, the highest former traits produced by Brandes variety ( $V_2$ ). The highest values of seed index in both seasons, as well as brix, juice extraction, juice yield and sugar yield in the first season, while stem length, leaf weight and leaves yield in the second season were obtained by Brandes ( $V_2$ ) variety with 120 kg N/fed ( $N_3$ ) with 75 ( $K_3$ ) kg K/fed. The highest yields of sugar and juice were 1.83 and 10.68 t/fed were obtained from the trilateral interaction among Brandes ( $V_2$ ) variety with 120 kg N/fed ( $N_3$ ) with 75 ( $K_3$ ) kg K/fed in the first season, respectively. According to, best-subsets regression the pest model for the stem height, stem diameter, stem weight, stem yield, brix%, sucrose % , purity % and juice extraction% showed that high adjusted  $R^2 = 99.80$  and  $99.90\%$ , in the 1<sup>st</sup> and 2<sup>nd</sup> seasons, respectively.

### Keywords

Sweet sorghum, varieties, nitrogen, potassium and stepwise regression.

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### Introduction

Sweet sorghum (*Sorghum bicolor* (L.) Moench) consider as a C<sub>4</sub> plant and characterized by high stalk and sugar yield (Antonopoulou *et al.*, 2008). The high sucrose rate of its stalk is not as much as sugarcane and sugar beet plants, however it

has a lower water requirement (40 – 50% less water than maize and four times less water than sugarcane), and drought tolerant, meanwhile, its speedy growth rate early ripeness high total energy value addition to, suitable to sub-tropical and temperate region

of the world (Martin *et al.*, 1990; Howell *et al.*, 1997 and Rego *et al.*, 2003).

In arid and semi-arid environments including Egypt, limited rainfall and low soil fertility have reduced crop productivity, particularly sugar cane crop that produces about 63% of sugar production worldwide, requiring high water availability (20000–24000 m<sup>3</sup> irrigation water/ha) and high soil fertility (Singh *et al.*, 2008). Appropriate soil, water administration, and choice of convenient varieties seriously influence crop productivity and soil sustainability the highly values (Benhabib *et al.*, 2014).

Productivity of sweet sorghum is influenced greatly by many factors. Varieties chosen were one of the most substantial decisions. There is a great difference among sorghum varieties in stalk dimension, yield and its components (Mohamed *et al.*, 2006). Aly *et al.*, (2008) reported that sweet sorghum varieties show significant differences in leaf area, plant height and diameter, percentages of sucrose, purity, juice and syrup extraction, as well as stripped stalk, juice and syrup yields.

The varieties with a high stalk yield, high extractable juice and brix content, connected with resistance to diseases and drought are surpass for biofuel production (Morris, 2006). So, this yield has brilliant prospects and endeavors are required for creating and identifying the varieties having higher sugar content and higher ethanol production potential.

Nitrogen is the element desired in the superior quantities in yield of crops, comprehensive sweet sorghum. Utilization of nitrogen enhanced sugar percentage, root and sugar yield for sugar beet plants (Tsiatas and Maslaris, 2005 and Mekdad and Rady, 2016). Increasing nitrogen

enhance significantly yield and quality of sugar beet plants Mekdad (2015). Almodares and Hoseini (2016) noted that the effect of nitrogen levels on stem dimension of sweet sorghum were significant at 1%, as well as produce the maximum values of stem fresh weight and percentage of brix, total sugar, sucrose, purity and ethanol yield of stem.

Application of potassium fertilizers increment yield of (*Sorghum bicolor* (L.) Moench) especially with increasing levels of nitrogen (Pholsen and Sornsungnoen, 2004). Potassium fertilizer is required for effective transformation of solar energy into chemical energy (Mengel and Kirkby, 2001). Exact use of N and K fertilizers can invigorate biomass and starch of sweet sorghum which considered a vital element in food and modern use.

In spite of the fact that the impact of K fertilizer on different plants is appeared (Adeli and Varco, 2002) however there are few works concerning the impact of K fertilizer on biomass of sweet sorghum. Therefore, it is of large value to conduct an experiment on yield and sugar content of sweet sorghum in connection to different levels of N and K fertilizers as well as the influences of varieties.

Thus, the primary goal of this study was to evaluate the response of two varieties of sweet sorghum to nitrogen and potassium fertilization under arid conditions.

## **Materials and Methods**

The present investigation was carried out at the farm of the Faculty of Agriculture, Demo (29°17' N; 30°53' E), Fayoum University, Egypt, during the two successive summer seasons of 2013 and 2014. The objective of this work was to evaluate two

sweet sorghum varieties viz., Honey (V<sub>1</sub>) and Brandes (V<sub>2</sub>) under the effect of three nitrogen and potassium fertilizer levels on plant characteristics, quality and yield traits of sweet sorghum.

The experiment was set up according to three-factorial (Split-plot plot) block design in three replications, with the basic plot size of 10.5 m<sup>2</sup>, each experimental basic unit included 5 ridges, 60 cm apart and 3.5 m long, (1/400 fed., fed= 4200 m<sup>2</sup>= 0.405 hectare).

The main plots were assigned to sweet sorghum varieties viz., Honey (V<sub>1</sub>) and Brandes (V<sub>2</sub>). The sub plots were occupied with three levels of nitrogen (ammonium nitrate, NH<sub>4</sub>NO<sub>3</sub> (33.5% N) at the level of 80 (N<sub>1</sub>), 100 (N<sub>2</sub>) and 120 (N<sub>3</sub>) in three equal doses i.e., at planting, 4 leaf stage after 21 days from planting and booting stage after 35 days from planting. Potassium sulphate (48% K<sub>2</sub>O) applied to the soil in granular form at the level of 25 (K<sub>1</sub>), 50 (K<sub>2</sub>) and 75 (K<sub>3</sub>) kg K<sub>2</sub>SO<sub>4</sub>/fed (fed= 4200 m<sup>2</sup> = 0.405 hectare) were arranged in the sub-sub plots treatments and applied in three equal doses i.e., after thinning, before the second and the third irrigation (surface irrigation as recommended). Calcium super phosphate (15.5% P<sub>2</sub> O<sub>5</sub>) at the rate of 200 kg/fed was applied during land. Seedlings were thinned at two plants/hill after 21 days from sowing. Other cultural practices such as hoeing, irrigation, etc., were maintained aimed at levels to assure optimum production.

The preceding winter crop was sugar beet (*Beta vulgaris*, L) in both seasons. After sterilization using 1% (v/v) sodium hypochlorite, experiments were sown on May 7<sup>th</sup> and 5<sup>th</sup> in the first and second season and harvest was at dough to ripe stage (on August 29<sup>th</sup> and 26<sup>st</sup>) in 2013 and 2014 seasons, respectively. Physical and chemical

analysis of soil at the experimental site in both seasons of study are presented in Table (1). The soil is a sandy clay loam in 2013 and sandy loam in 2014, and defined as Typic Torripsamments, siliceous, hyperthermic (Soil Survey Staff, USDA, 1999)

### **Climatic conditions**

Considering average data for the two experimental seasons, average maximum daily temperature was ≈38.98°C and the air relative humidity was usually ≈43.88%. Table (2) shows the variations of maximum daily temperatures during growth season as average.

At harvest time a random sample of twenty plants from each sub-sub plot was taken to determine the flowing traits. Growth traits: Stem length, stem diameter, stem weight, leaf weight, seed index. Juice quality traits: Stems was taken from each sub-sub plot stripped, cleaned and squeezed by electric roller pilot mill. Brix%: estimated by using digital refractometer, sucrose % determined by using direct polarization method as described by A.O.A.C (1995), purity%: calculated by dividing sucrose%/T.S.S% x100, juice extraction %: determined by dividing juice weight/stem weight x 100. Yield and its components: Net stripped stem, leaves, grain, sugar and juice yield, the theoretical ethanol yield (1 fed<sup>-1</sup>, fed= 4200 m<sup>2</sup> = 0.405 hectare) was calculated according to a method described by Lipinski (1978), the ethanol yield = sugar content (brix%) × 6.5 (converting index) × 0.85 (producing index) × fresh biomass (t fed<sup>-1</sup>(fed= 4200 m<sup>2</sup> = 0.405 hectare).

Where: converting index is constant (6.5) to explain the efficiency of converting sugar and biomass of stem yield of sweet sorghum to ethanol. Producing index is constant (0.85) to explain the efficiency of

manufacturing sugar and biomass of stem yield of sweet sorghum to ethanol.

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the split-split plot design as published by Gomez and Gomez (1984), using GenStat 12<sup>th</sup> edition. Least Significant Difference (LSD) method was used to test the differences between treatment means at 5% level of probability. The data of sugar yield and its components of the study were analyzed by two statistical procedures; stepwise regression was used in order to determine the most important variables contributed to sugar yield variability (Draper and Smith, 1981) and best subsets regression to assess all possible models and displays a subset along with their adjusted R-squared and Mallows'  $C_p$  values. For this purpose computer software MINITAB (version 16) was used. Where: Mallows'  $C_p$ -statistic, recall that an underspecified model is a model in which important predictors are missing. And, an underspecified model yields biased regression coefficients and biased predictions of the response. Well, in short, Mallows'  $C_p$ -statistic estimates the size of the bias that is introduced into the predicted responses by having an underspecified model.

## **Results and Discussion**

### **Effect of sweet sorghum varieties**

The results obtained in Tables (3 and 4) revealed that varieties significantly differed in stem diameter, seed index and theoretical ethanol yield in 2013 and 2014 seasons, stem length, stem and leaf weight in the 1<sup>th</sup> season, as well as sucrose, purity, juice extraction, stem yield, juice and sugar yield in the 2<sup>nd</sup>. The highest values of former studied traits were recorded by variety

Brandes ( $V_2$ ) as compared with the anther variety Honey ( $V_1$ ). The differences in these traits between varieties might be due to the differences in their genetic the make-up. Such data in the same trend with Mohamed *et al.*, (2006), Almodares *et al.*, (2008) and EL-Sheikh *et al.*, (2011). The superiority of cv. Brandes in theoretical ethanol yield (l/fed) in both season and sugar yield (ton/fed, fed= 4200 m<sup>2</sup> = 0.405 hectare) in the second season might be due to its high records of mean sucrose, brix, juice extraction and stem yield.

It was noticed that planting Brandes variety ( $V_2$ ) caused significant increases in stem length (cm) by 10.63 and 7.73 %, stem diameter (cm) by 18.99 and 15.68 %, stem weight (kg/plant) by 20.00 and 20.69, leaf weight (kg/plant) by 10.00 and 5.00, seed index (g) by 4.53 and 3.81, sucrose by 2.73 and 3.88 %, purity by 0.61 and 2.78 %, juice extraction from fresh stems by 0.44 and 2.52%, stem yield (t/fed) by 5.63 and 6.68 , juice yield (t/fed) by 6.23 and 9.50, also sugar yield (t/fed) by 8.21 and 10.08 as well as theoretical ethanol yield (l/fed) by 8.71 and 10.90 % in the first and second season respectively, compared planting with Honey variety ( $V_1$ ) of sweet sorghum. Our results indicated that taller, thicker and heavier sweet sorghum varieties stems could have higher stem, juice and sugar yield and consequently higher theoretical ethanol yield. Theoretical ethanol yield ranged between 1089.60 and 1038.40 l/fed for Honey variety ( $V_1$ ) and 1184.50 and 1151.60 l/fed for Brandes variety ( $V_2$ ) in the first and second season, respectively. Meantime, the variation among sweet sorghum ability in theoretical ethanol production detected herein was affirmed previously by Abd El-Razek and Besheit (2009), Almodares and Goli (2013) and Rutto *et al.*, (2013). In general, among the tested varieties of sorghum the most

productive was Brandes ( $V_2$ ), while the Honey ( $V_1$ ) was characterized by the lowest productivity.

### **Effect of nitrogen fertilization**

The results showed that the effect of nitrogen fertilizer was significant at 1% level on all studied traits in both seasons. The trait means comparison showed that stem length (cm) by 8.92 and 17.88 %, diameter (cm) by 10.53 and 29.41 %, stem weight by 48.98 and 41.51 %, leaf weight by 47.06 and 23.53 %, seed index by 11.23 and 8.66 %, brix by 7.58 and 7.06 %, sucrose by 13.92 and 13.47 %, purity by 6.02 and 5.98 %, juice extraction from fresh stems by 5.99 and 5.60 % as well as, stems yield by 14.01 and 16.59 %, leaves yield by 29.51 and 37.55 %, juice yield by 20.84 and 23.17 %, also sugar yield by 29.51 and 31.62 % were significantly increased with increasing in nitrogen fertilizer levels from 80 to 120 kg N/fed in the first and second season respectively. The mean comparison of the nitrogen fertilizer levels on the above measurements is presented in Tables(3 and 4). Results showed that all former traits were increased significantly by increasing nitrogen fertilizer levels from 80 to 120 kg N/fed. The remained measurements were highest under nitrogen level 120 kg N/fed. Our results indicated that taller, thicker and heavier sweet sorghum stems could have higher stem, juice and sugar yield and, consequently, higher theoretical ethanol yield. The results for stem height and diameter are quite in line with those of Almodares *et al.*, (2008) and Usofzadeh *et al.*, (2013), reported that nitrogen fertilization increased stem height and stem diameter, as well as stem, sugar, juice and theoretical ethanol yield. Nitrogen may affect plant growth through cell division and cell enlargement which consequently increase stem height and diameter,

consequently, higher yield. These results indicate that N input of 120 kg N fed<sup>1</sup> is sufficient to obtain maximum stems, leaves, sugar and theoretical ethanol yields, while the further application of N fertilizer poses a risk of having negative effects on sweet sorghum production. Uchino *et al.* (2013) observed similar results and reported that the yield of sweet sorghum increased at up to 150 kg N ha<sup>-1</sup>. Root and sugar yield in sugar beet plants were increased with increasing nitrogen level (Mekdad, 2015).

### **Effect of potassium fertilization**

A significant effect at 1% level was detected due to potassium levels on stem length and diameter, stem and leaf weight, seed index, percentage of brix, sucrose purity and juice extraction, as well as yields in terms of stems, leaves, juice, sugar and theoretical ethanol in 2013 and 2014 seasons. Increasing potassium up to 75 kg K<sub>2</sub>O /fed from 0 kg K<sub>2</sub>O/fed ( $K_1$ ) increased all studied traits. The mean comparison of the potassium fertilizer levels on the above measurements is presented in Table (3 and 4). It was noticed that applying 75 kg K<sub>2</sub>O/fed ( $K_3$ ) caused significant increases in stem length (cm<sup>2</sup>) 8.92 and 7.18 %, stem diameter (cm) 10.53 and 9.47 %, stem weight (kg/plant) 12.28 and 15.00 %, leaf weight (kg/plant) 15.00 and 15.79 %, seed index 4.32 and 2.74 %, brix 2.51 and 2.32 %, sucrose 5.08 and 4.23 %, purity 2.59 and 1.86 %, juice extraction 1.76 and 1.63 %, stem yield (t/fed, fed= 4200 m<sup>2</sup> = 0.405 hectare) 5.96 and 5.35 %, leaves yield (t/fed) 9.45 and 12.25 %, juice yield (t/fed) 7.96 and 7.16 %, sugar yield (t/fed) 10.53 and 9.23 % and theoretical ethanol yield (l/fed) 11.56 and 9.82 % in the first and second season respectively compared with 0 kg K<sub>2</sub>O/fed ( $K_1$ ). Overall, potassium fertilizer application of 75 kg K/fed ( $K_3$ ) recorded the highest values for all studied traits. Such

increase in stem yield obtained from using potassium with level of 75 kg K<sub>2</sub>O/fed can be attributed to enhance sweet sorghum growth, in terms of longer, thicker and heavier stems weight, whereas K plays a major role in many physiological and biochemical processes such as cell division and elongation. These results are in accordance with those reported by Almodares *et al.*, (2008) and EL-Sheikh *et al.*, (2011).

The positive effect of K fertilizer which improved chemical components may be due to the vital role of K in building up metabolites and activating starch synthetase enzymes and carbohydrates accumulation (Nitoses and Evans, 1969).

#### **D- Interaction effects**

D-1. Effect of the bilateral interaction between the two sweet sorghum varieties and nitrogen levels: Data illustrated in Tables (3 and 4) revealed that the mean sugar yield (t/fed, fed= 4200 m<sup>2</sup> = 0.405 hectare) and theoretical ethanol yield (l/fed) in both seasons, while juice extraction % and juice yield (t/fed) in the first season, as well as stem weight (kg/plant) and sucrose % in the second season were significantly affected by the interaction between application of the two sweet sorghum varieties and nitrogen levels. The highest values of former studied traits were recorded by variety Brandes (V<sub>2</sub>) with higher level of nitrogen 120 kg N/fed. Reddy *et al.*, (2008), found that the interaction between nitrogen fertilizer and varieties were significant for juice extract (gm<sup>-2</sup>) and sugar yield (t ha<sup>-1</sup>).

D-2. Effect of the bilateral interaction between the two sweet sorghum varieties and potassium levels: Results in Tables (3 and 4) indicated that sugar yield (t/fed) in

both seasons, while seed index, stem yield (t/fed, fed= 4200 m<sup>2</sup> = 0.405 hectare), juice yield (t/fed) and theoretical ethanol yield (l/fed) in the first season, as well stem weight (kg/plant) in the second season were significantly affected by the interaction between application of the two sweet sorghum varieties and potassium fertilizer levels. The highest amounts of aforementioned characters were obtained with the application of variety Brandes (V<sub>2</sub>) with higher level of potassium 75 kg K/fed. Almodares *et al.* (2008), reported that the interaction between potassium fertilizer and varieties was significant for sugar yield (t ha<sup>-1</sup>).

D-3. Effect of the bilateral interaction between levels of nitrogen and potassium fertilizer: Data illustrated in Tables (3 and 4) reveal that the mean of stem yield (t/fed, fed= 4200 m<sup>2</sup> = 0.405 hectare), sucrose %, sugar and juice yield (t/fed) and theoretical ethanol yield (l/fed) in both seasons, besides seed index and juice extraction % in the first season, in addition to, stem weight (kg/plant) and leaves yield (t/fed) in the second one were significantly affected by the interaction between application of nitrogen and potassium levels. The highest amounts of aforementioned characters were obtained with higher level of nitrogen 120 kg N/fed and potassium 75 kg K/fed. Almodares *et al.*, (2008), noted that the interaction between nitrogen and potassium fertilizer level was significant for stem height (cm) and stem fresh weight (t ha<sup>-1</sup>).

D-4. Effect of the trilateral interaction among the two sweet sorghum varieties, nitrogen and potassium levels: The data presented in Tables (3 and 4) show the differences seed index in 2013 and 2014 seasons, besides brix, juice extraction %, sugar and juice yield (t/fed, fed= 4200 m<sup>2</sup> = 0.405 hectare) in the first season, while stem

length (cm), leaf weight (kg/plant), leaves yield (t/fed) in the second season due to the interaction among the three factors were significant. The highest yields of sugar and juice were 1.83 and 10.68 t/fed in the first season, respectively which are presented in Fig.(1&2) were obtained by Brandes ( $V_2$ ) variety with higher level of nitrogen 120 kg N/fed and potassium 75 kg K/fed.(fed= 4200  $m^2 = 0.405$  hectare).

**Stepwise regression and best-subsets regression**

Stepwise regression and best-subsets regression are both automatic tools that help you identify useful predictors during the exploratory stages of model building for

linear regression. These two procedures use different methods and present you with different output. In stepwise regression analysis, sugar yield (Y) as dependent variable and other traits as independent variables were considered.

The results showed that stem yield ( $X_5$ ), juice extraction% ( $X_{10}$ ), brix% ( $X_7$ ), stem weight ( $X_4$ ), leaves weight ( $X_3$ ) and leaves yield ( $X_6$ ) with  $R^2 = 99.87\%$  in the 1<sup>st</sup> season, and stem yield ( $X_5$ ), brix% ( $X_7$ ), juice extraction ( $X_{10}$ ), stem weight ( $X_4$ ), stem diameter ( $X_2$ ) and leaves weight ( $X_3$ ) with  $R^2 = 99.88\%$  in the 2<sup>nd</sup> season, had justified the maximum of sugar yield changes.

**Table.1** Particle size distribution and some chemical properties of the experimental soil in 2013 and 2014 seasons

Season		2013	2014	
Sand%		65.9	79.4	
Silt%		6.9	8.7	
Clay%		27.2	11.9	
Soil texture class		Sandy clay Loam	Sandy Loam	
CaCO <sub>3</sub> %		10.11	8.64	
Cations	MeqL <sup>-1</sup>	Na <sup>+</sup>	13.8	12.4
		K <sup>+</sup>	3.9	2.57
		Mg <sup>+2</sup>	30.4	27.61
		Ca <sup>+2</sup>	58.6	63.11
Anions	MeqL <sup>-1</sup>	SO <sub>4</sub> <sup>-2</sup>	62	37.99
		CL <sup>-</sup>	159	167
		HCO <sub>3</sub> <sup>-</sup>	9.9	12.3
		CO <sub>3</sub> <sup>-2</sup>	-	-
Organic Matter %		0.82	0.54	
ECe, dSm <sup>-1</sup> at 25 C <sup>o</sup>		14.8	13.2	
pH at 25 C <sup>o</sup>		7.60	7.93	
Micronutrients (ppm)	Fe	12.51	9.47	
	Mn	3.41	1.76	
	Cu	0.52	0.24	
	Zn	0.94	0.38	

**Table.2** Monthly weather data at Fayoum, Egypt as average during 2013–2014

Month	<sup>a</sup> T <sub>min</sub> (°C)	T <sub>max</sub> (°C)	T <sub>avg</sub> (°C)	RH <sub>avg</sub> (%)
May	21.1	38.0	29.55	41.8
June	23.4	39.1	31.25	43.8
July	25.2	39.0	32.10	45.3
August	25.3	39.8	32.55	44.6

<sup>a</sup>T<sub>avg</sub>, T<sub>max</sub> and T<sub>min</sub> are average, maximum and minimum temperatures, respectively, RH<sub>avg</sub> is average relative humidity.

**Table.3** Effects of cultivars, nitrogen and potassium levels and their interactions on sweet sorghum growth and yields in two seasons

Treatment	Stem length	Stem diameter	Stem weight	Leaf weight	Seed index	Stem yield	Leaves yield	
	(m)	(cm)	(kg/plant)		(g)	(t/fed)		
2013								
Varieties	<b>Honey (V<sub>1</sub>)</b>	3.67	2.37	0.55	0.20	24.97	21.50	6.37
	<b>Brandes (V<sub>2</sub>)</b>	4.06	2.82	0.66	0.22	26.10	22.71	6.91
	<b>LSD (5%)</b>	0.31*	0.21*	0.07*	0.01**	0.89*	ns	ns
Nitrogen	<b>80 Kg N/fed (N<sub>1</sub>)</b>	3.55	2.27	0.49	0.17	24.22	20.70	5.76
	<b>100 Kg N/fed (N<sub>2</sub>)</b>	3.88	2.59	0.60	0.21	25.45	22.00	6.70
	<b>120 Kg N/fed (N<sub>3</sub>)</b>	4.17	2.93	0.73	0.25	26.94	23.60	7.46
	<b>LSD (5%)</b>	0.18*	0.14**	0.03**	0.01**	0.22**	0.41**	0.23**
Potassium	<b>25 Kg K/fed (K1)</b>	3.70	2.47	0.57	0.20	25.01	21.49	6.35
	<b>50 Kg K/fed (K2)</b>	3.87	2.59	0.61	0.21	25.50	22.05	6.63
	<b>75 Kg K/fed (K3)</b>	4.03	2.73	0.64	0.23	26.09	22.77	6.95
	<b>LSD (5%)</b>	0.10*	0.04**	0.01**	0.01**	0.13**	0.21**	0.18**
Interactions	<b>V*N</b>	ns	ns	ns	ns	ns	ns	ns
	<b>V*K</b>	ns	ns	ns	ns	**	**	ns
	<b>N*K</b>	ns	ns	ns	ns	**	*	ns
	<b>V*N*K</b>	ns	ns	ns	ns	**	ns	ns
2014								
Varieties	<b>Honey (V<sub>1</sub>)</b>	3.75	2.36	0.58	0.20	24.40	20.80	6.08
	<b>Brandes (V<sub>2</sub>)</b>	4.04	2.73	0.70	0.21	25.33	22.19	6.89
	<b>LSD (5%)</b>	ns	0.37*	ns	ns	0.83*	0.19**	Ns
Nitrogen	<b>80 Kg N/fed (N<sub>1</sub>)</b>	3.58	2.21	0.53	0.17	23.80	19.83	5.46
	<b>100 Kg N/fed (N<sub>2</sub>)</b>	3.88	2.56	0.64	0.21	24.93	21.53	6.48
	<b>120 Kg N/fed (N<sub>3</sub>)</b>	4.22	2.86	0.75	0.21	25.86	23.12	7.51
	<b>LSD (5%)</b>	0.14**	0.06**	0.02**	0.01**	0.18**	0.30**	0.16**
Potassium	<b>25 Kg K/fed (K1)</b>	3.76	2.43	0.60	0.19	24.49	20.95	6.12
	<b>50 Kg K/fed (K2)</b>	3.89	2.54	0.64	0.21	24.93	21.45	6.47
	<b>75 Kg K/fed (K3)</b>	4.03	2.66	0.69	0.22	25.16	22.07	6.87
	<b>LSD (5%)</b>	0.04**	0.04**	0.01**	0.01**	0.13**	0.11**	0.07**
Interaction s	<b>V*N</b>	ns	ns	**	ns	ns	ns	ns
	<b>V*K</b>	ns	ns	**	ns	ns	ns	ns
	<b>N*K</b>	ns	ns	**	ns	ns	**	**
	<b>V*N*K</b>	**	ns	ns	*	*	ns	**

\* P < 0.05; \*\*P < 0.01; ns – non-significant



**Table.4** Effects of cultivars, nitrogen and potassium levels and their interactions on sweet sorghum growth and yields in two seasons

Treatment		Brix	Sucrose	Purity	Juice extraction	Sugar yield	Juice yield	Ethanol yield
		%			(t/fed)		(l/fed.)	
<b>2013</b>								
Varieties	Honey (V <sub>1</sub> )	15.97	9.15	57.24	38.80	1.34	8.35	1089.60
	Brandes (V <sub>2</sub> )	16.31	9.40	57.59	38.97	1.45	8.87	1184.50
	LSD (5%)	ns	ns	ns	ns	ns	ns	80.32*
Nitrogen	80 Kg N/fed (N <sub>1</sub> )	15.57	8.69	55.78	37.76	1.22	7.82	994.00
	100 Kg N/fed (N <sub>2</sub> )	16.11	9.24	57.33	38.86	1.38	8.55	1123.90
	120 Kg N/fed (N <sub>3</sub> )	16.75	9.90	59.14	40.02	1.58	9.45	1293.20
	LSD (5%)	0.06* *	0.07**	0.52**	0.24**	0.03**	0.18**	23.51**
Potassium	25 Kg K/fed (K1)	15.94	9.06	56.78	38.55	1.33	8.29	1078.50
	50 Kg K/fed (K2)	16.15	9.25	57.21	38.86	1.39	8.58	1129.30
	75 Kg K/fed (K3)	16.34	9.52	58.25	39.23	1.47	8.95	1203.20
	LSD (5%)	0.05* *	0.07**	0.48**	0.16**	0.02**	0.10**	16.19**
Interactions	V*N	ns	ns	ns	*	**	*	*
	V*K	ns	ns	ns	ns	**	**	*
	N*K	ns	**	ns	**	**	**	**
	V*N*K	*	ns	ns	**	**	*	ns
<b>2014</b>								
Varieties	Honey (V <sub>1</sub> )	16.03	9.01	56.16	38.43	1.29	8.00	1038.40
	Brandes (V <sub>2</sub> )	16.21	9.36	57.72	39.40	1.42	8.76	1151.60
	LSD (5%)	N.S.	0.29*	0.09**	0.12**	0.04**	0.04**	30.16**
Nitrogen	80 Kg N/fed (N <sub>1</sub> )	15.57	8.61	55.31	37.87	1.17	7.51	944.00
	100 Kg N/fed (N <sub>2</sub> )	16.11	9.17	56.89	38.90	1.35	8.38	1091.80
	120 Kg N/fed (N <sub>3</sub> )	16.67	9.77	58.62	39.99	1.54	9.25	1249.20
	LSD (5%)	0.10* *	0.08**	0.70**	0.20**	0.02**	0.13**	20.83**
Potassium	25 Kg K/fed (K1)	15.94	8.99	56.37	38.61	1.30	8.10	1044.90
	50 Kg K/fed (K2)	16.10	9.19	57.02	38.90	1.35	8.36	1092.60
	75 Kg K/fed (K3)	16.31	9.37	57.42	39.24	1.42	8.68	1147.50
	LSD (5%)	0.05* *	0.04**	0.35**	0.12**	0.01**	0.05**	8.51**
Interactions	V*N	ns	*	ns	ns	*	ns	*
	V*K	ns	ns	ns	ns	*	ns	ns
	N*K	ns	*	ns	ns	**	**	**
	V*N*K	ns	ns	ns	ns	ns	ns	ns

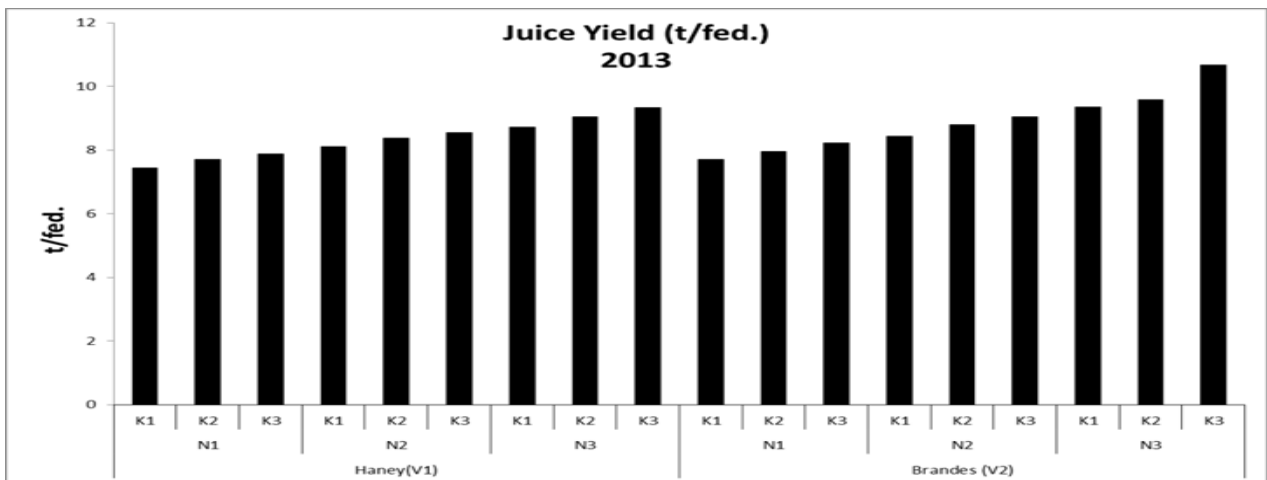
\* P < 0.05; \*\*P < 0.01; ns – non-significant

**Table.5** The best-subset regression models by adjusted coefficient of determination, Mallows Cp and standard error estimated of ten traits in sweet corn

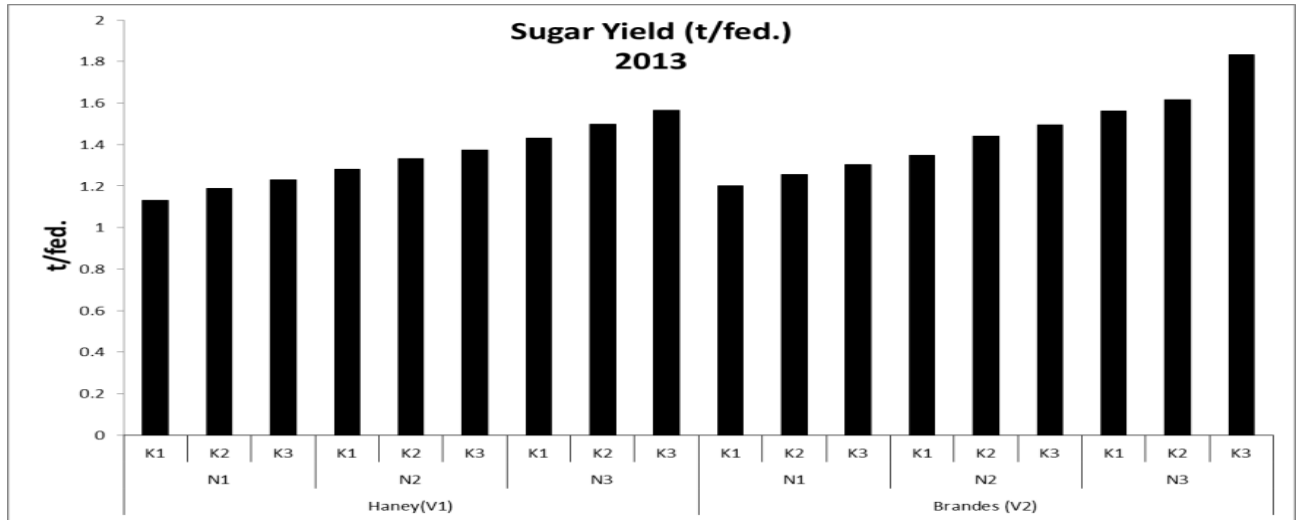
Vars	Adj. R-Sq	Mallows C-p	Standard error	Stem height (cm)	Stem diameter (cm)	Leaves weight (kg/plant)	Stem weight (kg/plant)	Stem yield (t/fed)	Leaves yield (t/fed)	Brix %	Sucrose %	Purity%	Juice extraction %
<b>1<sup>st</sup> season (2013)</b>													
1	96.90	2800.50	0.0314					X					
2	99.40	432.60	0.0130					X					X
3	99.70	136.90	0.0081					X		X			X
4	99.70	106.20	0.0074					X			X	X	X
5	99.80	26.30	0.0051					X		X	X	X	X
6	99.80	13.40	0.0045				X	X		X	X	X	X
7	99.80	10.20	0.0043		X		X	X		X	X	X	X
8	99.80	7.20	0.0041	X	X		X	X		X	X	X	X
9	99.80	9.00	0.0042	X	X	X	X	X		X	X	X	X
10	99.80	11.00	0.0042	X	X	X	X	X	X	X	X	X	X
<b>2<sup>nd</sup> season (2014)</b>													
1	97.80	2234.10	0.0259					X					
2	99.00	887.80	0.0167					X		X			
3	99.70	184.40	0.0084					X		X			X
4	99.70	132.30	0.0074					X			X	X	X
5	99.80	14.40	0.0042					X		X	X	X	X
6	99.80	12.10	0.0041	X				X		X	X	X	X
7	99.90	6.50	0.0038		X		X	X		X	X	X	X
8	99.90	7.60	0.0038	X	X		X	X		X	X	X	X
9	99.90	9.20	0.0039	X	X	X	X	X		X	X	X	X
10	99.90	11.00	0.0039	X	X	X	X	X	X	X	X	X	X

Vars: refer to how many predictors are in the model

**Fig.1** Effect of interactions between varieties, nitrogen and potassium levels on juice yield (t/fed.) in 2013 seasons. Haney V1, Brandes V2, 80 N1, 100 N2, 120 N3 kg N/fed, 25 K1, 50 K2, 75 K3 kg K2SO4/fed.



**Fig.2** Effect of interactions between varieties, nitrogen and potassium levels on sugar yield (t/fed.) in 2013 seasons. Haney V1, Brandes V2, 80 N1, 100 N2, 120 N3 kg N/fed, 25 K1, 50 K2, 75 K3 kg K2SO4/fed.



Due to their low relative contributions, the other variables were not included in the model. Consequently, based on the final step of stepwise regression analyses, the equation for prediction of sugar yield (Y) can be obtained:

$$Y = - 2.9 + 0.07 X_5 + 0.045 X_{10} + 0.07 X_7 + 0.0001 X_4 - 0.0003 X_3 - 0.008 X_6$$

In the 1<sup>st</sup> season

$$Y = - 2.7 + 0.07 X_5 + 0.1 X_7 + 0.03 X_{10} + 0.0002 X_4 - 0.05 X_2 - 0.0002 X_3$$

In the 2<sup>nd</sup> season

Best subsets regression assesses all possible models and displays a subset along with their adjusted R-squared and Mallows' Cp values (Table 5). The results of the first model for the stem height, stem diameter, stem weight, stem yield, brix%, sucrose % , purity % and juice extraction% showed that high adjusted R<sup>2</sup> = 99.80 and 99.90%, low Mallows Cp = 7.20 and 6.50 and low standard error = 0.0041 and 0.0038 in the 1<sup>st</sup>

and 2<sup>nd</sup> seasons, respectively. However, the second model for the stem height, stem diameter, leaves weight, stem weight, stem yield, brix%, sucrose % , purity % and juice extraction% showed that high adjusted R<sup>2</sup> = 99.80 and 99.90%, low Mallows Cp = 9.00 and 7.60 and low standard error = 0.0042 and 0.0038 in the 1<sup>st</sup> and 2<sup>nd</sup> seasons, respectively.

In conclusion, this study evaluated the effects of nitrogen and potassium fertilization levels on yield and quality of two sweet sorghum varieties Honey and Brandes. Two years of study indicated that the highest yield of sugar and juice and quality were obtained by Brandes variety with higher level of nitrogen 120 kg N/fed and potassium 75 kg K/fed.

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