Bull. Fac. Agric., Cairo Univ., 57
(2006): 401-416.

EFFECT OF POTASSIUM FERTILIZATION ON THE YIELD AND QUALITY OF SWEET SORGHUM JUICE AND SYRUP

(Received: 12.3.2006)

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ABSTRACT

Two field experiments were conducted at Malawi Agric. Res., Station, El-Minia Governorate, Egypt, during 2003 and 2004 seasons to study the effect of different levels of potassium fertilizer *i.e.* 0, 24 and 48kg K_2O/fed.on stalk yield, physical properties and chemical compositions of the juice and syrup of two sweet sorghum cultivars *i.e.* Honey and Brandes. The tested cultivars differed significantly in their biomass yield, stripped stalk and syrup yield (ton / fed.) in both seasons and juice yield in the 2nd one. Brandes cultivar exhibited higher values of the most aforementioned traits.

Maximum stripped stalk and syrup yield of sweet sorghum were obtained using potassium fertilization at the rate of 24.0 kg K_2O/ fed. for both cultivars. Meantime, such treatment enhanced greatly juice and syrup quality.

Therefore, these results give evidence to the use of sweet sorghum for syrup production instead of sugar cane, to reduce the vast gab between sugar production and consumption which reached about 0.7 million tons (CCSC,2005).

Key words: *sweet sorghum, potassium fertilization, TSS %, juice, syrup and syrup extraction percentage (SEP).*

1. INTRODUCTION

Sweet sorghum (*Sorghum bicolor* L. Moench) is a native crop of Africa, and many of today's varieties originated there. Sorghum was also grown in India before recorded history and in Assyria as early as 700 BC. The name " sweet sorghum " is used to identify varieties of sorghum that are sweet and juicy. These sweet varieties also are called "sugar sorghum ". Sweet sorghum is a warm –season crop that matures earlier under high temperatures and short days. So, it is one of the most important and useful crops in the summer season (Freeman & Boadhead, 1973; Undersander *et al.,* 1990 and Abo - El.Wafa & Abo-El. Hamd, 2001 and Osman *et al.*, 2005) .

Sweet sorghum is cultivated mainly for its syrup, which is called Black honey. It will be one of the major sources for syrup production in the near future if the sorghum syrup quality improved. Good sorghum syrup is light colored and mild and has a characteristic flavor. Therefore, this leads to save cane yield for sugar production and reduce the vast gab between sugar production and consumption which reached about 0.7 million ton.It is still imported annually (Collins *et al.,* 1977; CSCC, 2003 and Imbaby, 2003).

Sweet sorghum productivity and quality are affected greatly by many factors. Variety selection is one of the most important decisions in the production of sweet sorghum syrup. There is a great variation among sorghum varieties grown under different regions in stalk diameter, height of stalk, number of internodes, yield and its components, syrup production and the other aspects (Nour 1963; Cowley & smith 1982, Miller & Creelman, 1982 and Chawdhury &Rahman, 1990).

In this respect, Taha *et al.* (1994) illustrated that stripped stalks yield is the effective parameter on yield of juice and syrup, in addition to the chemical characteristics which in turn affect syrup quality.

Potassium is known for its role in sucrose transloctaion and accumulation in storage tissues of plants. In this respect, potassium fertilizer increases the percentage of sucrose without significant reduction in purity %. In addition the standard NPK fertilizer for sweet sorghum is 1:1:1 ratio to supply approximately 40 pounds each of nitrogen (N), phosphorus (P_2O_5) and potash (K_2O) per acre balanced fertilization. Ample amounts of nitrogen and adequate phosphorus and potassium, are essential to get high yields. A 5 to 7 tons /acre sorghum crop will remove about 100 lb N, 40 lb P_2O_5 and 180 lb K_2O /acre (Undersander *et al.,* 1990).

This work was carried out to study the effect of different levels of potassium fertilizer on yield and yield components, physical properties and chemical composition of juice and syrup of two sweet sorghum cultivars.

2. MATERIALS AND METHODS

Two field experiments were conducted at Mallawi Agric. Res. Station, El-Minia Governorate, Egypt, during the two successive seasons 2003 and 2004. A split- plot design with four replications was used. The two cultivars namely Honey and Brandes were arranged in the main plots and the three potassium levels, *i.e,*. 0, 24 and 48 kg K_2O /fed. were allocated to the sub plots. Plot size was 21 m^2 (1/200 fed.) (five rows, 6 m long and 70 cm apart). Sowing date was 18^{th} of June in both seasons. Nitrogen fertilizer was added at the recommended rate of 60 kg N /fed. in two equal doses (the first one was after 30 days from sowing and the second one 15 days later). Phosphorus fertilizer was added at the recommended rate of 15 P_2O_5 kg /fed. at planting. Some physical and chemical properties of the experimental site were analyzed according to the procedures outlined by Jackson (1967) and Olsen & Sommers (1982) and are shown in Table (1).

Table (1): Physical and chemical properties of the experimental soils.

Properties	Season 2003	Season 2004
Texture analysis		
Sand %	7.55	8.95
Silt %	54.5	54.2
Clay %	37.75	36.85
Soil texture	Silty clay loam	Silty clay loam
Organic matter%	1.19	1.16
PH (1:2.5) soil water ratio	8.2	8.25
Soluble cations :		
Ca^{++} meq/L.	6.25	6.10
Mg^{++} meq/L.	0.76	0.73
K^{+} meq/L.	0.20	0.19
Na^{+} meq/L.	2.85	2.78
Soluble anions:		
CO_3^{--} meq/L.	-	-
HCO_3 meq/L.	2.05	1.87
Cl^{-} meq/L.	2.25	2.10
SO_4^{--} meq/L.	5.85	5.63
Available N (ppm)	20.35	19.85
Available P (ppm)	8.15	7.65
Available K (ppm)	185	178
Ece mmohs/cm	1.35	1.30
Cl^{-} meq/100g soil	1.15	1.12

At the dough stage (content of seeds are firm and easily crushed between thumb and index fingers), the plants were harvested (after 115 days from sowing for Honey cultivar and 135 days for Brandes cultivar). A sample of twenty stalks from each subplot was taken at random to determine the following parameters:

1 -Stalk yield

Plants taken from the three middle rows of each sub-plot to avoid the border effect were used to determine gross yield/fed and stripped yield/fed. While, juice and syrup yields were determined by weighing the extracted juice and syrup produced according to Mohamed (1997).

2 - Physical properties

Brix % was determined by Brix hydrometer standardized at 20 C°, purity % was determined by the following equation:

Purity %= sucrose % x 100 / TSS%.

Juice and syrup extraction % = juice or syrup yield (ton /fed) x 100/stripped stalks yield (ton /fed.)

However, pH value was measured by a Beckman pH meter according to Collins *et al.* (1977).

3 - Chemical analysis

Juice and syrup were chemically analyzed for moisture %, sucrose %, reducing sugars % and titratable acidity per 10ml NaOH 0.1 N were determined according to the methods described by AOAC (1995).

All data were subjected to the proper statistical analysis according to the procedures outlined by Gomez & Gomez (1984). Means of the treatments were compared using the Least Significant Difference (LSD) at 5% level of probability (Waller & Duncan, 1969).

3. RESULTS AND DISCUSSION

3.1. Yield and its components

The results obtained (Table 2) revealed that the cultivars, significantly differed in biomass yield, stripped stalks yield, and syrup yield (ton / fed.) in both seasons. The higher values of aforementioned yields were scored for Brandes cultivar as compared with the other studied cultivar. This pronounced influence might be attributed to the differences in the growth parameters, which were reflected on yield and its components (Table, 2). Taha (1990) and Taha *et al.* (1994) published data which are in line with these findings. But, the present data contradicted those obtained by Mokadem *et al.* (1999) who found that Honey cultivar had the higher value of biomass and stripped stalk

Table (2): Effect of potassium fertilization levels on biomass, stripped stalk, juice and syrup yield of two studied sweet sorghum cultivars.

Potassium levels (kg/fed.)	Biomass yield (Ton /fed.)			Stripped yield (Ton /fed.)			Juice yield (Ton /fed.)			Syrup yield (Ton /fed.)		
	Honey	Brandes	Mean	Honey	Brandes	Mean	Honey	Brandes	Mean	Honey	Brandes	Mean
2003 season												
0	37.48	39.6	38.58	27.75	29.58	28.67	14.53	14.53	14.53	2.03	2.48	2.26
24	37.97	41.01	39.49	28.61	30.39	29.50	15.04	15.01	15.03	2.64	3.11	2.88
48	38.05	41.28	39.67	28.69	30.94	29.81	15.11	15.29	15.20	2.67	3.19	2.93
Mean	37.83	40.65	39.25	28.35	30.31	29.33	14.89	14.94	14.92	2.45	2.93	2.69
LSD .05:var. (A)	0.96			1.45			NS			0.19		
K level (B)	NS			0.68			0.5			0.11		
AB	NS			NS			NS			NS		
2004 season												
0	38.90	40.62	39.76	29.00	30.51	29.76	15.28	14.92	15.10	2.11	2.59	2.35
24	39.43	41.42	40.43	29.65	31.29	30.47	15.87	15.52	15.69	2.80	3.34	3.07
48	39.67	41.91	40.79	30.02	31.86	30.94	16.07	15.90	15.99	2.87	3.44	3.16
Mean	39.33	41.31	40.33	29.56	31.22	30.39	15.74	15.44	15.59	2.59	3.12	2.86
Average	38.58	40.98	39.79	28.96	30.77	29.86	15.32	15.19	15.26	2.52	3.03	2.78
LSD .05:var. (A)	0.25			0.34			0.21			0.21		
K level (B)	NS			0.41			0.25			0.08		
AB	NS			NS			NS			NS		

Table (3): Effect of potassium levels fertilization on the physical properties of juice extracted from the studied sweet sorghum cultivars.

2003 season									
	TSS%			Purity%			Juice extraction %		
Potassium levels (kg/fed).	Honey	Brandes	Mean	Honey	Brandes	Mean	Honey	Brandes	Mean
0	17.80	19.38	18.59	60.33	58.10	59.22	52.37	48.79	50.58
24	19.94	21.62	20.78	62.64	62.09	62.36	52.62	49.39	51.01
48	20.48	21.81	21.15	62.42	62.29	62.35	52.66	49.42	51.04
Mean	19.41	20.94	20.17	61.80	60.82	61.31	52.55	49.20	50.88
LSD .05:var. (A)	1.10			0.97			1.29		
K level (B)	0.57			0.89			NS		
AB	NS			NS			NS		
2004 season									
0	17.85	19.67	18.76	60.66	58.70	59.68	52.68	48.90	50.79
24	20.56	21.70	21.13	62.77	62.12	62.45	53.54	49.26	51.40
48	20.54	21.97	21.25	62.47	62.20	62.33	53.55	48.91	51.23
Mean	19.65	21.11	20.38	61.97	61.10	61.49	53.26	49.02	51.14
Average	19.53	21.03	20.28	61.89	60.92	61.40	52.91	49.11	51.01
LSD .05:var (A)	NS			NS			0.27		
K level (B)	0.37			0.74			NS		
AB	NS			NS			NS		

yields than Brandes cultivar. These differences might be due to the variations in the environmental conditions and soil type of the different experiments.

From the data in Table (2), it could be seen that there was a significant increase in stripped stalks yield, juice yield and syrup yield (ton/fed.) with potassium application at the rate of 24 or 48 kg K_2O / fed. as compared to 0 kg k_20/fed. in both growing seasons compared with the control. But, in the first season the increase did not reach the significant level between 24 or 48 kg K_2O / fed. This could be attributed to the positive effect of potassium on stalk weight, where the low fiber contents and high water contents with the application of potassium supports such explanation. The obtained results are in harmony with those reported by Ali (1985) who pointed out that the influence of potassium was not only on carbohydrate assimilation but the also on nitrogen metabolism.

3.2. Physical properties of juice and syrup

Data of the physical properties of juice and syrup presented in Tables (3 &4) indicated that TSS and purity percentage traits significantly differed between the two cultivars in the first season only. While, this trend for juice extraction percentage (JEP%) was true in both seasons. With regard to syrup properties it is clear that pH and purity were insignificantly affected by sorghum varieties in both seasons. Brandes cultivar showed the higher values of TSS% of juice and SEP than Honey. This might be mainly due to surplus sugars formed by photosynthesis for Brandes than Honey cultivar. Generally, there was a positive relationship between TSS% and sucrose% of sorghum juice as well as SEP in sorghum syrup. These results agree with those obtained by Taha (1990), Taha *et al.* (1994) and Mohamed (1997). But these findings conflict with those obtained by Mokadem *et al.* (1999) who found that Honey cultivar had the higher value of TSS% than Brandes cultivar. This variation in the results might be due to the variations in the environmental conditions and soil type among different experiments. However, Honey cultivar had the higher value of purity% of juice and juice extraction percentage (JEP) as compared with Brandes cultivar. This result might be mainly due to the fact that the non-sugar substances% (NSS%) of juice and fiber content were lower for Honey cultivar. Similar findings were obtained by Taha *et al.* (1994), Mohamed (1997) and Mokadem *et al.*(1999). In general, the higher values of TSS% and purity% of sorghum juice are the preferable

Table (4): Effect of potassium levels fertilization on the physical properties of syrup produced from the studied sweet sorghum cultivars.

	Purity%			PH value			Syrup extraction %		
2003 season									
Potassium levels (Kg/fed).	**Honey**	**Brandes**	**Mean**	**Honey**	**Brandes**	**Mean**	**Honey**	**Brandes**	**Mean**
0	39.30	38.57	38.94	4.70	4.60	4.65	7.34	8.39	7.86
24	40.97	40.29	40.63	4.90	4.80	4.85	9.24	10.36	9.80
48	40.73	40.33	40.53	4.90	4.80	4.85	9.32	10.32	9.82
Mean	40.33	39.73	40.03	4.83	4.73	4.78	8.63	9.69	9.16
LSD .05:var. (A)	NS			NS			0.10		
K level (B)	0.89			0.12			0.30		
AB	NS			NS			NS		
2004 season									
0	39.43	38.61	39.02	4.70	4.60	4.65	7.26	8.48	7.87
24	41.03	40.33	40.68	4.90	4.80	4.85	9.44	10.68	10.06
48	40.78	40.37	40.57	4.90	4.80	4.85	9.56	10.82	10.19
Mean	40.41	39.77	40.09	4.83	4.73	4.78	8.75	9.99	9.37
Average	40.37	39.75	40.06	4.83	4.73	4.78	8.69	9.84	9.27
LSD .05:var. (A)	NS			NS			0.75		
K level (B)	0.90			0.14			0.28		
AB	NS			NS			NS		

Table (5): Effect of potassium fertilization levels on the chemical composition of the juice extracted from the studied sweet sorghum cultivars.

Potassium levels (Kg/fed).	Moisture %			Sucrose%			Reducing sugars %			Titratable acidity*		
	Honey	Brandes	Mean	Honey	Brandes	Mean	Honey	Brandes	Mean	Honey	Brandes	Mean
2003 season												
0	82.03	81.20	81.62	10.74	11.26	11.00	2.18	2.34	2.26	34.33	44.67	39.50
24	80.36	79.64	80.00	12.49	13.42	12.96	2.99	2.98	2.98	26.67	39.33	33.00
48	79.91	79.00	79.46	12.45	13.58	13.02	3.00	2.99	2.99	27.33	37.00	32.17
Mean	80.77	79.95	80.36	11.90	12.76	12.33	2.72	2.77	2.74	29.44	40.33	34.89
LSD .05:var. (A)	0.52			0.48			NS			8.04		
K level (B)	0.50			0.39			0.13			3.07		
AB	NS			NS			NS			NS		
season 2004												
0	82.11	79.62	80.86	10.83	11.55	11.19	2.25	2.38	2.31	34.33	44.00	39.17
24	80.17	78.91	79.54	12.91	13.48	13.20	2.99	3.06	3.03	26.00	37.33	31.67
48	79.44	78.28	78.86	12.83	13.67	13.25	3.03	3.01	3.02	26.00	36.00	31.00
Mean	80.57	78.94	79.75	12.19	12.90	12.55	2.76	2.81	2.79	28.78	39.11	33.95
Average	80.67	79.45	80.06	12.05	12.83	12.44	2.74	2.79	2.77	29.11	39.72	34.42
LSD .05:var. (A)	1.23			NS			NS			2.99		
K level (B)	0.61			0.31			0.12			3.91		
AB	NS			NS			NS			NS		

Titratable acidity* determined as ml Na OH 0.1 N characters for syrup production. Concerning potassium fertilization (Tables 3&4) there was a significant increase in juice TSS% and purity% as well as syrup purity%, pH value and SEP as potassium fertilization increased from 0 to 24or 48 kg K_2O/ fed. Meantime these differences did not reach the level of significance between 24or 48 kg K_2O/ fed.The increase in juice TSS% and purity% might be mainly due to the increase in sucrose % and the decrease in non-sugar substances% (NSS%) of sorghum juice with potassium fertilization, consequently the increase in purity% of sorghum juice and SEP of sorghum syrup as compared with the control treatment. Ali (1985) and Abou-Salama (1995) reviewed similar findings.

3.3. Chemical composition of juice and syrup

Data presented in Tables (5&6) clarify that sweet sorghum cultivars exhibited significant effect on moisture% of juice and syrup titratable acidity for sorghum juice and syrup in both growing seasons. While, sucrose% juice was significantly affected by sorghum cultivars in the first season only. Brandes exhibited higher values of sucrose% juice, reducing sugars and titratable acidity of juice and syrup than Hone cultivar. This might be mainly due to more sugars, *i.e.*. sucrose% and reducing sugars% in the juice, formed during the photosynthesis process for Brandes than Honey cultivar. In general, the high total sugars, *i.e.* sucrose%, reducing sugars % and low value of titratable acidity for sorghum juice and for sorghum syrup were desirable characters for high quality in final sorghum syrup. Such data are in the same trend with the findings of several investigators (Taha 1990 Taha *et al*. 1994 and Mohamed *et al.*, 1999). Meantime these results are in harmony with those of Mokadem *et al.*, (1999) who found that Honey cultivar had the higher value of sucrose % for juice and syrup than Brandes cultivar. This variation may be due to the variations in the studied environmental conditions and soil type of different experiments.

The data in Tables (5&6) indicated that potassium application at the rate of 24.0 or 48.0 kg K_2 O/fed. significantly increased sucrose % juice and syrup as well as juice reducing sugars. However, moisture% juice, reducing sugars %s syrup and titratable acidity in the juice and the syrup were significantly decreased as compared with 0 kg KO20/fed.

Such results are in agreement with those of Ali (1985) and Abou-Salama (1995).

Table (6): Effect of potassium fertilization levels on the chemical composition of the syrup extracted from the studied sweet sorghum cultivars.

2003 season												
	Moisture %			Sucrose%			Reducing sugars %			Titratable acidity*		
Potassium levels (K/fed).	Honey	Brandes	Mean	Honey	Brandes	Mean	Honey	Brandes	Mean	Honey	Brandes	Mean
0	74.03	74.48	74.26	29.55	28.93	29.24	30.74	30.52	30.63	182.7	191.3	187.0
24	74.12	74.22	74.17	30.74	30.22	30.48	29.72	29.40	29.56	176.7	181.3	179.0
48	74.12	74.05	74.09	30.55	30.25	30.40	28.90	29.61	29.25	178.0	181.0	179.5
Mean	74.09	74.25	74.17	30.27	29.80	30.04	29.78	29.84	29.81	179.1	184.6	181.8
LSD .05:var. (A)	NS			NS			NS			2.23		
K level (B)	NS			0.61			0.31			3.49		
AB	NS			NS			NS			NS		
2004 season												
0	74.08	74.13	74.11	29.57	28.96	29.27	30.92	30.90	30.91	183.3	189.7	186.5
24	74.00	73.75	73.88	30.77	30.25	30.51	29.29	29.39	29.34	175.7	181.3	178.5
48	74.15	73.85	74.00	30.25	30.28	30.27	29.22	29.24	29.23	173.0	180.0	176.5
Mean	74.08	73.91	74.00	30.20	29.83	30.02	29.81	29.84	29.83	177.3	183.7	180.5
Average	74.09	74.08	74.09	30.24	29.82	30.03	29.80	29.84	29.82	178.2	184.1	181.2
LSD .05:var. (A)	NS			NS			NS			4.30		
K level (B)	NS			0.55			0.65			4.77		
AB	NS			NS			NS			NS		

Titratable acidity* determined as ml Na OH 0.1 N

Increasing sucrose% and reducing sugars% juice besides decreasing titratable acidity in the juice accompanied potassium application at the rate of 24 kg K_2O/fed. improved sorghum syrup due to the increase in sucrose% and decreasing titratable acidity in the produced syrup.

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تأثير التسميد البوتاسى على انتاج وجودة العصير والعسل فى الذرة الرفيعة السكرية

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قسم بحوث الفسيولوجي، * قسم بحوث تكنولوجيا السكر ، معهد بحوث المحاصيل السكرية مركز البحوث الزراعية ،جمهورية مصر العربية

ملخص

أقيمت تجربتين حقليتين بمحطة البحوث الزراعية بملوى ،محافظة المنيا ،فى صيف ٢٠٠٣ و ٢٠٠٤ بتصميم القطع المنشقة مرة واحدة لدراسة تأثير ثلاثة مستويات من التسميد البوتاسى هى صفر ، ٢٤ و ٤٨ كجم بوتاسيوم بو٢ا / للفدان على محصول العيدان والعصير والعسل والصفات الطبيعية والكيمائية للعصير والعسل المنتج من صنفي سورجم السكر هني و براندز. اوضحت النتائج المتحصل عليها :اختلاف صنفى سورجم السكر معنويا فى الصفات المحصولية وهى المحصول الكلى ,العيدان النظيفة والشراب (طن/فدان) فى كلا الموسمين الزراعيين وناتج العصير فى الموسم الثانى فقط. هذا وقد تفوق صنف الذرة السكرية براندز عن صنف هنى فى جميع الصفات السابقة اضافة الى تفوقه فى نسبة المواد الصلبة الذائبة الكلية للعصير ونسبة ناتج العسل.

كذلك اشارت النتائج الى ان استخدام السماد البوتاسى بمعدل ٢٤كجم بو٢١/فدان ادى الى زيادة مئوية فى محصول العيدان النظيفة , العصير والشراب (طن/فدان), نسبة المواد الصلبة الذائبة الكلية للعصير ونسبة النقاوة للعصير, قيمة الـ pH ونسبة ناتج العسل فى كلا الموسمين الزراعيين.

وعليه ينصح بتسميد الذرة السكرية بالبوتاسيوم بمعدل ٢٤كجم بو٢١/فدان لتحسين خواص العصير والشراب الناتج عن طريق زيادة محتواهما من السكروز مع انخفاض الحموضة وبالتالى يتزايد استخدامها فى انتاج العسل ذو المواصفات الجيدة وتوفير كميات قصب السكر المستخدم فى انتاج العسل الاسود.

المجلة العلمية لكلية الزراعة – جامعة القاهرة – المجلد (٥٧) العدد الثالث (يوليو ٢٠٠٦):٤٠١-٤١٦.