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Effect of Nitrogen and Potassium Fertilization on Vegetative Growth, Yield and Sugar Content of Two Sweet Sorghum (*Sorghum bicolor* L. Moench) Genotypes[1]

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Abstract: This experiment was conducted at the Demonstration Farm of the Faculty of Agriculture University of Khartoum at Shambat, Sudan, in 2016. The aim of the experiment was to study the effect of nitrogen and potassium fertilization on growth, yield and sugar content of two genotypes of sweet sorghum (*Sorghum bicolor* L. Moench). The treatments consisted of three levels of nitrogen (0; 50 and 100 kg N/Fed), potassium (0; 50 and 100 kg K/Fed) and two sweet sorghum genotypes;G1, RNF 1107 white colored seeds from El Gazira Aba and G2, El Banjadeed, black colored seeds from Kordofan. The experiment was arranged in a randomized complete block design with three replications. Studied parameters were plant height, number of leaves, leaf area, stem diameter, plant, leaf, stem and head fresh weights, baggasse and juice weights. The results showed that nitrogen application had a significant ($P \leq 0.05$) effect on plant height, number of leaves per plant, leaf area, stem diameter, plant and leaves' fresh weight, baggasse and juice weights. Potassium application affected plant height significantly ($P \leq 0.05$) but had no significant ($P \leq 0.05$) effect on number of leaves per plant, leaf area and stem diameter. Also potassium application had no

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significant effect on all studied yield parameters. The results indicated significant ($P \leq 0.05$) differences for most interactions. G2 showed better performance than G1 for plant height, leaf number, leaf area, stem diameter and yield parameters at N1K1.

Key words: sorghum; fertilization; nitrogen; potassium; Sudan.

INTRODUCTION

Sweet sorghum is mainly planted for sugar and ethanol production (Gnansounoua *et al*. 2005). In Sudan sweet sorghum, locally known as Ankoleeb; is grown in many areas such as Kosti; ELdewem; Sennar; ELsouki Gezira; Kordofan; ELgadarif; Blue Nile and Darfur and is mainly used for chewing as a sweet. Syrup is produced from condensed juice, also is used as forage and the grain is utilized as feed for livestock and birds (Sir Elkhatim 2003).Juice from stalks is used primarily for alcohol production; and can also be used for production of syrup. Sweet sorghum sugar accumulation levels can be similar to that in sugar cane (*Saccharum* spp.), though studies on enzymatic control and carbon transport suggest that the mechanism of accumulation is different (Tarpley and Victor 2007).It is estimated that under favourable conditions, sweet sorghum can produce around 43 tons per ha per year of juice, which contains 11.8 % of fermentable sugar (Kim and Day 2011).

Unfortunately, many challenges must be overcome before this plant can be sustainably and profitably used for bio-fuel production; for example the input versus the output yield of biomass. One way to lower the input cost, is through nitrogen fertilization management. Indeed, nitrogen appears to be the most applied and crucial fertilizer that greatly affects plant growth. Ibrahim (2004) reported that the plant height, number of leaves/ plant, stem diameter, leaf area index, fresh yield (ton ha^{-1}), dry yield (ton ha^{-1}), crude protein and juice sugar content increased with increased nitrogen fertilizer. Generally, few studies have been carried out to test how nitrogen fertilization really affects the production of sweet sorghum.

Potassium is one of the major elements required by plants for proper growth and optimum yields. It is absorbed by plants in large amounts than any other mineral element, except nitrogen. Unlike phosphorus, potassium is present in relatively large quantities in most soils. However, the nature and mode of weathering of potassium–bearing minerals depend to a large extent on their properties and environment (El Dessougi *et al.* 2002).

Again, few studies on potassium fertilization effect on sweet sorghum growth and yield are available.
The objective of this research was to study the effect of nitrogen and potassium fertilizers on growth and yield components of two early sown sweet sorghum genotypes.

MATERIALS AND METHODS

Experimental site

A field experiment was conducted at the Demonstration Farm, Faculty of Agriculture, University of Khartoum; Shambat, Sudan, to study the effect of nitrogen and potassium fertilizers on growth and yield components of early sown sweet sorghum genotypes. The farm is located in semi desert zone with latitude 15^{o}. $40^{'}$N, longitude $32^{.o}32^{'}$ E and altitude380 m above sea level; the soil of the experimental site is heavy clay with alkaline pH (Hassan 2008).

Treatments

Fertilizers

The treatments consisted of three nitrogen levels (0, 50 and100 kg N/fed) designated as 0N, 1N and 2N. Urea (46 %N) was used as the source of nitrogen; and three levels of potassium as potassium sulphate (0, 50 and 100 kg K/fed) designated as 0K, 1K and 2K, respectively.

Genotypes

The plant material consisted of two sweet sorghum genotypes; (G1, RNF 1107 from El Gazira Aba and G2, El Banjadeed, from North Kordofan State).

Experimental layout

A factorial arrangement laid in a randomized complete block design was used with three replications and each unit consisted of four ridges (3 meters in length).

Cultural practices

The field was disc ploughed, disc harrowed, levelled and ridged. Spacing was 70 cm between ridges and 20 cm between plants. The area of the experiment was divided into 54 plots each plot (3×3m).

The crop was sown in the summer season 2016, by sowing two seeds per hole on one side of the ridge (East side). The crop was irrigated at an interval of 7-12 days. A basal dose of phosphorus as (50 kg fed^{-1}) was applied to all plots before sowing; and the other 2 fertilizers (nitrogen and potassium) were applied 2 weeks after sowing. Manual weeding was carried out twice during the growing season and a pesticide (Folimat) was applied twice during the season to control the stem borers.

Data collection

Observations were taken on three randomly tagged plants in the inner ridges of each plot 83days from sowing. Data were recorded on vegetative and yield parameters as follows:

Plant height (cm)

The plant height was calculated as an average of the three selected plants measured manually from the soil surface to the tip of the flag leaf, using a ruler.

Number of leaves

The number of leaves for the three tagged plants was obtained and the average number per plant was recorded.

Leaf area per plant (cm^2)

Average leaf area was determined by taking three random plants. The length and width of leaf, in each plant was measured in (cm) and the average leaf area was recorded.

Stem diameter (cm)

Stem diameter was calculated as an average of the diameters of the third internodes from the soil surface of the three selected plants measured by a digital calliper.

Harvesting
At the milk stage, the 3 randomly selected plants were harvested, weighed and then separated into leaves and stems. Shoots were taken to the laboratory to determine the fresh weight per plant (g) and the average was recorded. Then the heads were separated, weighed and the average was calculated and recorded.

Extraction of juice
The juice was extracted from the stem using sugarcane presser (Model No ET-ZZJ180).The juice was then weighed and the average of the three plants was calculated and recorded per plant. The remaining of the stem tissue (Bagasse) was weighed and the average was determined.

Statistical analysis
Analysis of variance (ANOVA) was performed on the data according to the method described by Gomez and Gomez (1984) for randomized complete block design and the means separation was done using Least Significant Difference (LSD) procedure.

RESULTS

Plant height (cm): Fig. 1 a, b and c shows the mean effect of applying nitrogen and potassium and genotype difference on plant height. Nitrogen (N) application and genotypes showed significant ($P \leq 0.05$) differences on plant height where as potassium (K) had no significant effect ($P \leq 0.05$) at harvest.

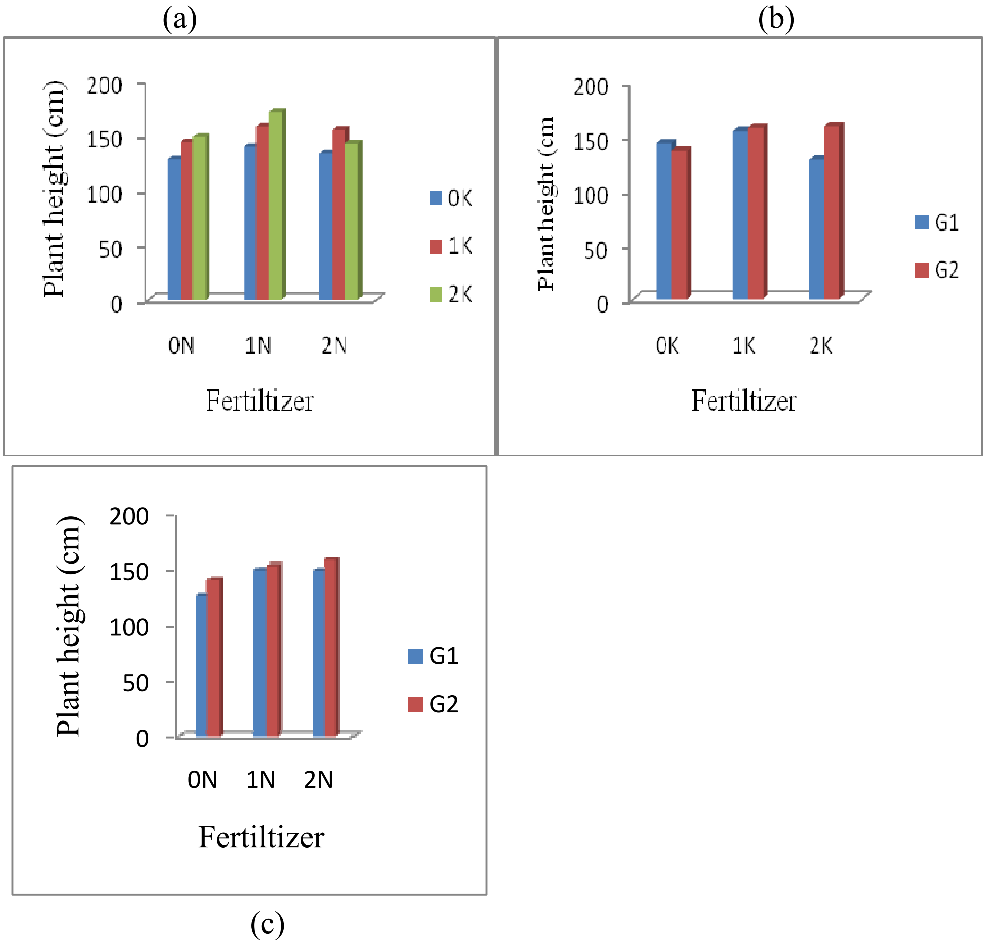


Fig. 1 Mean values of the effect of (a) nitrogen and potassium fertilization; (b) potassium fertilization and genotypes and (c) nitrogen fertilization and genotypes on plant height of two sweet sorghum genotypes.

Number of leaves: Significant ($P \leq 0.05$) differences for the number of leaves were recorded for application of nitrogen (N) fertilizer, genotype and the interactions between NxG and NxKxG. On the other hand neither K fertilization nor KxG and NxK interactions were significant ($P \leq 0.05$). The treatment N1K1 and genotype G2 recorded the highest number of leaves (Fig. 2 a, b and c).

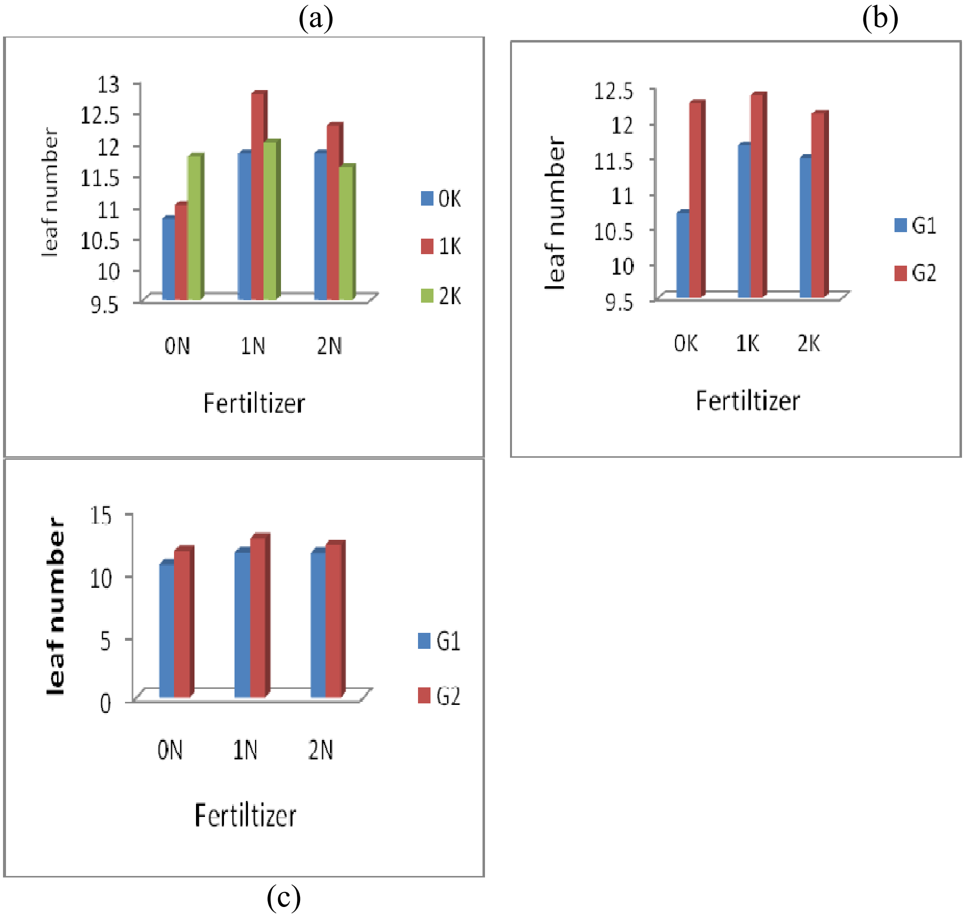


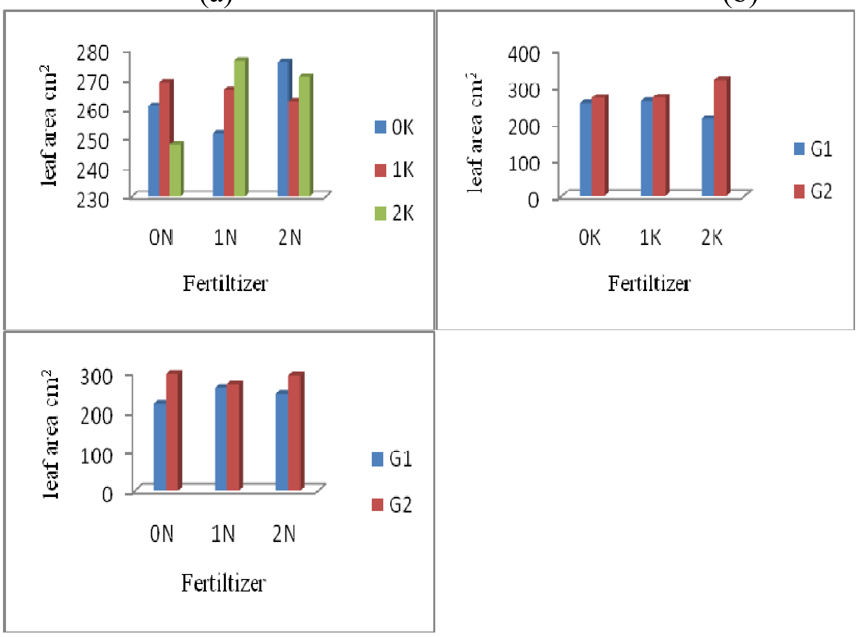
Fig. 2 Mean values of the effect of (a) nitrogen and potassium fertilization; (b) potassium fertilization and genotypes and (c) nitrogen fertilization and genotypes on number of leaves per plant of two sweet sorghum genotypes.

Leaf area (cm^2): Application of nitrogen did not result in significant ($P \leq 0.05$) differences on leaf area; although genotypes affected leaf area significantly ($P \leq 0.05$), the interaction NxG was not significant. No

significant ($P \leq 0.05$) differences on leaf area were recorded with potassium fertilizer (Fig. 3 a, b and c).

Stem diameter (cm): No significant (P≤ 0.05) effects on stem diameter were found for nitrogen or potassium application or for genotypes.

(a) (b)



(c)

Fig. 3 Mean values of the effect of (a) nitrogen and potassium fertilization; (b) potassium fertilization and genotypes and (c) nitrogen fertilization and genotypes on leaf area per plant of two sweet sorghum genotypes.

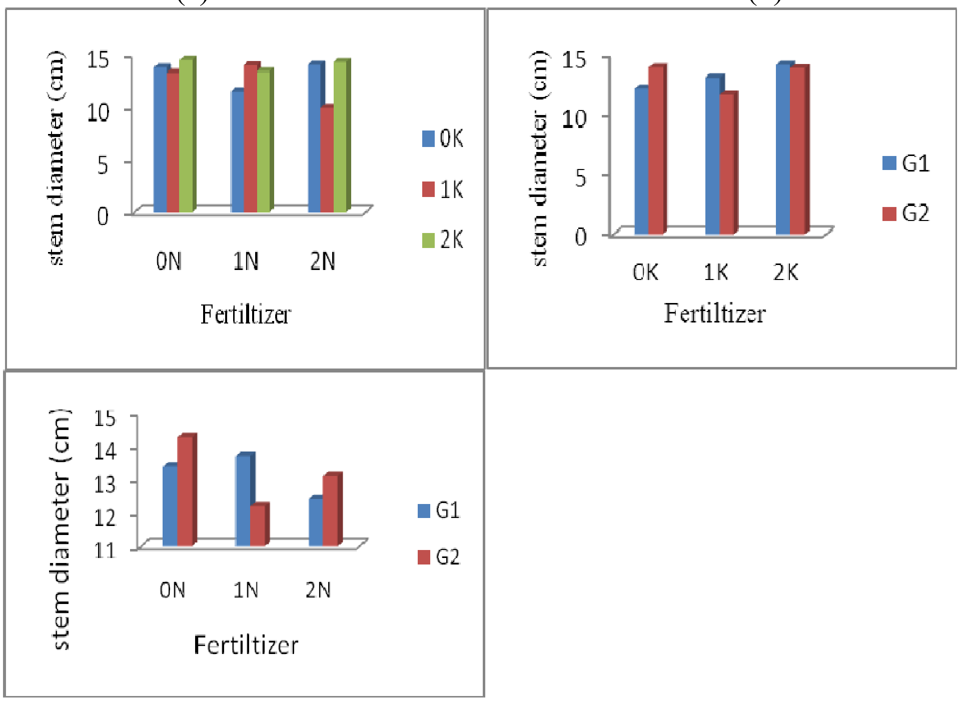
Yield parameters

Nitrogen fertilization resulted in significant (P≤ 0.05) increases in plant fresh weight, leaves' fresh weight, baggase and juice weights. N1 produced higher yields compared to N2 (Table 1). However, nitrogen did not have a significant (P≤0.05) effect on stem and head fresh weights. The

NxG interaction had a significant (P≤ 0.05) effect on head fresh weight but not on baggasse and juice weights (Table3).

On the other hand, application of potassium had no significant effects on all measured parameters and even the interaction NxK was not significant (Table 1). The genotypic difference significantly ($P \leq 0.05$) affected all measured parameters except the

(a) (b)



(c)

Fig. 4 Mean values of the effect of (a) nitrogen and potassium fertilization; (b) potassium fertilization and genotypes and (c) nitrogen fertilization and genotypes on stem diameter of two sweet sorghum genotypes.

juice weight (Table 3). The interaction KxG showed a significant ($P \leq 0.05$) effect on plant fresh, leaves and head and weight and baggasse weight but not on stem fresh and juice weights (Table 2).

Table 1. Effect of nitrogen and potassium fertilization on yield parameters of two sweet sorghum genotypes

Treatment		83 Days after sowing					
		PF wt	SF wt	LF wt	H wt	B wt	J wt
	OK	266.01	185.62	89.41	24.51	78.15	62.99
ON	1K	299.50	212.53	97.94	29.01	92.23	61.76
	2K	231.42	180.41	97.68	11.77	72.33	35.24
Mean		265.65	192.58	95.01	21.76	80.90	53.33
1N	OK	341.15	225.47	116.34	18.45	130.90	71.12
	1K	371.94	222.00	127.17	13.21	134.84	68.88
	2K	394.45	237.24	122.78	25.55	141.29	78.71
Mean		369.18	228.24	122.10	19.07	135.68	72.90
2N	OK	381.35	223.57	134.63	18.57	137.56	71.30
	1K	369.44	218.28	120.92	25.31	133.25	73.78
	2K	314.88	186.56	105.91	17.74	113.47	54.78
Mean		342.16	202.42	113.42	21.53	123.36	64.28
CV%		28.84	32.98	30.79	95.00	35.76	37.02
LSD N ($P\leq0.05$)		64.46*	46.95^{ns}	23.47*	13.17^{ns}	27.83*	16.12*
LSD K ($P\leq0.05$)		64.46 ^{ns}	46.95^{ns}	23.47^{ns}	13.17^{ns}	27.82 ^{ns}	16.12 ^{ns}
LSD NxK ($P\leq0.05$)		111.66^{ns}	81.32^{ns}	40.65^{ns}	22.80^{ns}	48.19^{ns}	27.92^{ns}

*= significantly different; ns= not significantly different

In this table and tables 2 and 3, PF wt, SF wt, H wt, LF wt, B wt and J wt mean respectively plant fresh weight, stem fresh weight, head weight, leaves fresh weight bagasse weight and juice weight.

Table (2) Effect of potassium fertilization and genotypes on yield parameters of sweet sorghum

Treatment		83 Days after sowing					
		PF wt	Sf wt	LF wt	H wt	B wt	J wt
OK	G1	392.56	258.45	153.05	11.14	136.44	72.28
	G2	266.45	164.65	73.86	29.88	94.63	64.66
Mean		329.50	211.55	113.46	20.51	115.53	68.47
1K	G1	297.98	231.85	165.73	16.89	141.73	72.85
	G2	313.74	203.35	64.95	28.14	98.48	63.42
Mean		305.86	217.60	115.34	22.51	120.10	68.14
2K	G1	309.80	209.49	138.50	1.53	103.26	56.46
	G2	307.83	193.32	79.09	35.17	114.80	56.02
Mean		308.82	201.40	108.79	18.35	109.03	56.24
LSD (P≤0.05) KxG		91.16*	66.40ns	33.19*	18.61*	39.35*	22.80ns

*= significantly (P≤0.05) different; ns= not significantly different

Table (3) Effect of genotypes and nitrogen fertilization on yield components of sweet sorghum

Treatment		83 Days after sowing					
		PF wt	Sf wt	LF wt	H wt	B wt	J wt
G1	ON	305.29	228.79	89.41	124.70	95.46	50.05
	1N	418.75	250.17	116.34	169.60	149.27	83.36
	2N	404.23	220.84	134.63	162.98	136.70	68.18
Mean		376.09	233.26	113.46	152.43	127.14	67.20
G2	ON	399.69	156.92	97.94	65.32	66.35	56.60
	1N	393.33	206.30	127.17	74.59	122.08	62.44
	2N	389.70	198.11	120.92	77.99	119.48	65.06
Mean		394.24	187.11	115.34	72.63	102.64	61.37
LSDG (P≤0.05)		52.63*	38.34*	19.65*	19.16*	22.72*	13.16ns
LSD (P≤0.05) GxN		91.16*	66.40ns	33.19*	33.19*	39.35ns	22.80ns

*= significantly (P≤0.05) different; ns= not significantly different

DISSCUSION

In this study, application of nitrogen increased plant height, and there were significant differences among genotypes in response to nitrogen fertilization.The increase in plant height might be due to the positive effect of nitrogen application on plant growth that led to progressive increase in internodes length and consequently plant height. Similar results were reported by Abusuwar (1981) who mentioned that plant height was positively and significantly affected by nitrogen fertilizer; also Ibrahim (2004) showed that plant height was significantly affected by levels of nitrogen fertilizers. Koul (1997) found that nitrogen application significantly increased plant height in maize.

Stem diameter in this study was increased significantly. This might have been due to the positive effect of nitrogen on plant growth. This result is in conformity with that of Abusuwar (1981) Koul (1997) and Gasim (2002). Ibrahim (2004) found that increasing levels of nitrogen increased stem diameter. Similar results were also reported by EItahir (1998) who showed that nitrogen application increased stem thickness of maize plant. The fact that stem diameter was less affected by nitrogen fertilization at later growth stages, might be because all plant parts were able to make use of available nitrogen, which might explain why, at late growth stages, the effect of nitrogen on stem diameter became non-significant.

The results showed a significant effect of N and GxN interaction on number of leaves per plant. These results are, however, in contrast with Abusuwar and Mohammed (1997) who found that no significant differences were manifested in leaf numbers. The effect of nitrogen on leaf area was significant at flowering and anthesis stages but not at harvest. This might be due to availability of nitrogen at early stages of growth, since the fertilizer was applied at early stages. Stals and Inoze (2001) reported that nitrogen might have an effect on cell division and cell enlargement which consequently increased leaf area. The genotypic effect observed in this study on leaf area is supported by the findings of

Ismail *et al*. (2007) and Aly *et al.* (2008). The authors reported that sweet sorghum varieties show significant differences in leaf area and leaf area index.

Application of nitrogen had a significantly positive effect on yield attributes except for stem and head fresh weights. This is to be expected

due to the enhancing effect of nitrogen on plant growth. Nitrogen supply limits crop productivity directly and indirectly. Growth in particular and the formation of new cells are affected directly by shortage of nitrogenous compounds needed for structural roles and enzymes and as a constituent of cell walls and membranes. Indirect effects follow, for example, less leaf area resulting in less light interception and modified metabolic rates. Mengel and Kirkby (2001) mentioned that, without nitrogen fertilizer application, corn and sorghum yield have dropped by 41 % and 19 %, respectively.The genotypic difference significantly affected all measured parameters except juice weight, and the interaction NxKxG significantly increased leaves' fresh weight and head weight. Results of Ismail *et al.* (2007) and Aly *et al.* (2008) support the findings of this study on genotypic effect on yield parameters.

Potassium application had a significant effect on plant height but no significant effects on other parameters (stem diameter, number of leaves, leaf area, and yield parameters).Potassium has a significant role in the translocation of assimilates to sinks by influencing electron transport in the transport chain of crops which increases panicle dry weight (Raja Reddy and Zhao 2005). Interaction of nitrogen (N) and potassium (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.

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. In this respect, Mohamed *et al*. (2006) illustrated that stripped stalk yield, was the effective parameter in juice and syrup yield, in addition to the chemical characteristics which in turn affect syrup quality of sweet sorghum varieties.

There is great variation among sorghum varieties in stalk height, diameter, number of internodes, syrup production and yield and its components (Mohamed *et al*. 2006.). The results in this study showed

significant effects for the variety, as recorded for number of leaves; leaf area and yield parameters except juice fresh weight. The interaction between fertilizers and genotype was significant for leaves and head fresh weights. This genotypic variation is supported by the findings of Ismail *et al.* (2007) and Aly *et al*. (2008), who reported that sweet sorghum varieties show significant differences in leaf area, leaf area index, plant height and diameter, TSS %, sucrose %, purity %, juice and syrup extraction%, stripped stalk, juice and syrup yields.
From the results of this study it can be concluded that application of nitrogen had significant effects on all vegetative parameters and a significantly positive effect on yield attributes except for stem and head fresh weights, and the interaction NxKxG significantly increased leaves' fresh weight and head weight. Potassium application had a significant effect on plant height only at some growth stages, but no significant difference on other parameters, however, the interaction of nitrogen (N) and potassium (K) on most growth parameters was significant. Significant effects for the genotype were recorded for number of leaves; leaf area and yield parameters except juice fresh weight. G2 showed better performance for plant height; leaf number; leaf area, stem diameter and yield parameters at N1K1level.

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تأثير التسميد بالنايتروجين والبوتاسيوم على الإنتاجية ونسبة السكر فى صنفين من الذرة السكرية (*Sorghum bicolor* L. Moench)[2]

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المستخلص: أُجريت هذه التجربة في المزرعة الايضاحية بكلية الزراعة جامعة الخرطوم بشمبات في 2016، بهدف دراسة تأثيرسمادي النتروجين والبوتاسيوم علي النمو والإنتاج وإنتاج السكر فى صنفين من الذرة السكرية (*Sorghum bicolor* L Moench) . نُفذت التجربة بتصميم القطاعات الكاملة العشوائية بثلاثة مكررات. إستُخدمت ثلاثة مستويات من الأسمدة كانت للنيروجين 0، 50، 100 كجم/ فدان، البوتاسيوم 0، 50، 100كجم/ فدان الأصناف المحسنة:G1 (RNF 1107) ذو بذور بيضاء من الجزيرة ابا، و G2 البان جديد ذو بذور سوداء من كردفان. شملت الدراسة طول النبات، عدد الأوراق، مساحة سطح الورقة، سمك الساق، وزن النبات الكلي، وزن الساق، وزن الأوراق، وزن القندول، وزن البقاس، ووزن العصير .أوضحت النتائج أن التسميد بالنيتروجين كان له أثر معنوي ($P\leq0.05$) على طول النبات، عدد الاوراق في النبات، مساحة الورقة، سمك الساق، وزن البقاس ووزن العصير. التسميد بالبوتاسيوم أثر تاثيراً معنوياً على طول النبات ولكن لم يحدث أثراً معنوياً على بقية القياسات. أوضحت النتائج فروق معنوية لاغلب التفاعلات. الصنف G2 كان الافضل لطول النبات، عدد الاوراق، مساحة سطح الورقة. سمك الساق وقياسات الإنتاجية في المعاملة N1K1.

[2] مستلة من اطروحة الماجستير للمؤلف الثاني، جامعة الخرطوم