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Phosphorus and Potassium Fertilization Effects on Growth Attributes and Yield of Two Sugarcane Varieties Grown on Three Soil Series

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ABSTRACT

A two-year field trial was carried out in the seasons of 1997/98 and 1998/99 at Sennar Sugar Company (latitude 13° 33′N and longitude 33° 37′E), to investigate the effect of different levels of potassium (0, 72, and 144 kg K/ha) as K_2O and phosphorus (0, 29 and 58 kg P/ha) as P_2O_5 on the performance of two sugarcane (*Saccharum officinarum*) varieties (Co 6806, Co 527) and their first ratoon grown on three soil series (Hagu, Nasr, and Dinder). The layout was a randomized complete block design arrangement using three replications. The results indicated that potassium application affected plant density and stalk diameter significantly. The stalk height of the plant

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cane and its first ratoon was positively affected only late in the season. In the ratoon, the effect was significant early in the season on all growth parameters. The yields of cane and sugar on Dinder series were raised significantly in response to potassium addition in plant cane and ratoon. Potassium increased yield of cane and sugar on Nasr soil and yield of sugar on Hagu soil significantly. Phosphorus addition, on the other hand, reflected a significant effect on stalk height, number of internodes and plant density of plant cane and ratoon early in the season. However, the increase in stalk height and plant density of ratoon continued as the season proceeded. In plant cane, phosphorus application significantly affected sugar yield on Hagu soil. Application of phosphorus to ratoon grown on Dinder and Hagu series resulted in significant increase of cane and sugar yields. Variety Co 6806 gave the best growth and yield compared with Co 527. Soil analysis revealed a depletion of extractable potassium after plant cane harvest. The reverse was true after ratoon harvest from Nasr and Hagu soil series. Soil available phosphorus decreased after cane cropping and increased after ratoon harvest, but both were mostly less than the initial amount before cane planting.

Key Words: Sugarcane production; Fertilizers; Phosphorus; Potassium; Nitrogen; Cane yield.

INTRODUCTION

Sugarcane production and industry are of growing importance. The production of cane was known long time ago, but the industry of sugar came into effect only two hundreds year ago.[1] Sugarcane is the world's major source of sucrose sugar. It is grown mainly in tropics and subtropics between latitude 35°N and 35°S. Nevertheless, sugarcane production is mostly confined to the humid tropics, but it can be also grown under irrigation in the dry lower latitudes. The main growing sugarcane countries include India, Brazil, Cuba, Australia, and Mexico. The yield of cane obtained from these different fields varied tremendously. These variations in cane yield are due to many factors such as soil fertility, cultural practices and weather conditions.[2] In Sudan, trials on sugarcane production started since 1959 but on a large scale only in 1963 at EL Guneid, mainly to satisfy the local need. The suitability of weather conditions in the central clay plain with the availability of land and the good quality irrigation water, encouraged the concerned authorities in the Ministry of Agriculture and Industry to expand on sugar production by establishing schemes at New Halfa (1965/66), North West Sennar

(1976/77), Assalaya (1979/80), and Kenana (1980/81). Thereafter, sugar industry gained a considerable importance in Sudan national economy. However in spite of all this expansion of cane cultivation, yield per unit area is well below the potential yield obtained elsewhere. High yield and high sucrose content are the major objectives of sugarcane growers. These are controlled by the cultural practices that vary widely and must be adapted to local conditions. Efficient use of fertilizers in modern agriculture is considered as one of the main factors for high yields. The use of nitrogen, phosphorus and potassium fertilizer play an important role in increasing cane and sugar yield. Sugarcane known as a heavy feeder depletes the soil of essential nutrients, hence adequate nutrient addition is necessary.

Fertilization of cane fields in Northwest Sennar Scheme was almost limited to nitrogen fertilizer but part of the field received phosphorus in the form triple superphosphate.[3] However, very little work was assigned for the response of cane to phosphorus and potassium fertilizers. Therefore, field experiments were laid out to investigate the influence of soil series, cane varieties, phosphorus, and potassium fertilizers on: (1) the growth of cane and its ratoon at different stages of development to the senescence of the crop and (2) cane and sugar yields.

MATERIALS AND METHODS

A two-year field experiment was carried out in 1997/98 and 1998/99 seasons at Sennar Sugar Company (latitude 13° 33′N and longitude 33° 37′E). The area lies within the tropical hot semi-arid zone of central Sudan. The annual rainfall ranges between 437 and 481 mm, falling mostly during June to October. The mean annual temperature is about 28°C with a maximum of 32.2°C in May and a minimum of 23°C in January.[4] The experiment was conducted on three soil types using two most commonly grown sugarcane varieties (Co 6806, Co 527) and different levels of potassium and phosphorus fertilizers and their combinations. The soil types include: Dinder series classified as, very fine montmorillonitic, isohyperthermic, Typic Chromusterts (Dinder clay); Hagu series, fine kaolinitic, isohyperthermic, Ultic Haplustalfs (Hagu sandy clay), Nasr series occupying intermediate position between Dinder and Hagu series classified as fine, montmorillonitic, isohyperthermic, Vertic Ustorthents (Nasr sandy clay).[4] The experimental site was disc ploughed, finely harrowed, leveled and ridged at 1.5 m apart and divided into plots 1.5 m apart. The size of each plot was 7.5 × 5 m, with 5 rows. The plots were arranged in a randomized complete block design and the treatments were replicated thrice. Phosphorus fertilizer was applied in bands in the furrow at the time of planting at three levels (0, 29, and 58 kg P/ha) as P_2O_5 designated as P0, P1, and P2, respectively. The rate of potassium was 0, 72, and 144 kg K/ha, as K_2O designated as K0, K1, and K2. A basal dressing of nitrogen was applied as urea to all plots, at the rate of 219 kg N/ha as recommended by Yassin.[2] Both potassium and nitrogen fertilizers were mixed thoroughly, and broadcast by hand in the furrow two months from planting, buried and irrigated immediately. After four months from planting the ridges forming the furrow were split to cover the base of the growing stools (hilling up). Weeding was done by Gezapax and Gezaprim herbicides prior to the second irrigation. Thereafter, hand weeding was practiced when necessary. In the first year the effects of the treatments on the plant cane were examined and the ratoon was tested in the second year.

The growth parameters were measured at an interval of two months starting from the 4th month after planting and continued to the 10th month. Five stalks were selected randomly from the three inner rows in each plot and marked to follow their growth. The growth parameters measured were; stalk height, stalk diameter, number of internodes, plant density, millable cane and sugar yields. The latter was measured according to Humbert.[5]

In the ratoon all stools were cut to the ground level, plots were cleaned and irrigated, ridges were raised and the ratoon received similar doses of nitrogen, potassium and phosphorus fertilizers as the previous plant cane. Hand weeding was done when necessary but no herbicides were added. All measurements were made following the methods employed for the cane plant in the first year.

Chemical Analysis

Soil potassium, sodium, calcium, magnesium, and particle size distributions were determined according to the Methods of Soil Analysis.[6,7] The concentrations of these elements were measured using atomic absorption spectrophotometer, model 2380, Perkin Elmer, using air acetylene flame. Macro-Kjeldahl and the colorimetric method measured soil nitrogen and phosphorus respectively. The pH of the soil paste was measured by corning pH meter model 7. The electrical conductivity of the saturation extract was measured by conductivity TDS meter, model 44600 (Hach). Statistical analysis was performed and the means were separated using Duncan Multiple Range Test.

DISCUSSION

Effect of Treatments on Growth Attributes

Stalk height in plant cane showed that the effect of phosphorus was significant early in the season (Table 1). However, phosphorus application to ratoon showed significant differences in stalk height (Table 2). This response to phosphorus might be due to the low level of available phosphorus in the soil series examined. In addition, the increase in stalk height can be attributed to the beneficial effect of phosphorus in metabolic process, root growth, cell division and elongation.[8,9] The differences between the phosphorus levels applied were not significant suggesting that addition of phosphorus at 29 kg P/ha was adequate.

Application of potassium fertilizer manifested, significant effect in stalk height of plant cane when the plant was 10 months old, and at all stages of growth for ratoon. Potassium application at the rate of 86 kg/ha appeared to be the recommended level. This could be due to the positive effect of potassium on the uptake of phosphorus and nitrogen and consequently the growth rate by ensuring appropriate balance of nutrients.[10,11] The significant difference among varieties in stalk height in both plant cane and ratoon reflected varietal differences in response to phosphorus and potassium application.[12] Variety Co 6806 was significantly taller than variety Co 527. Dinder soil type showed significantly shorter plants at all growth stages compared to plants grown on other soil types, which may be attributed to differences in soil characters (Table 3) that affect plant growth.[13]

Table 4 shows that phosphorus fertilization generally had no effect on stalk diameter in plant cane as well as in ratoon (Table 5). These results confirmed the findings of Ali.[14] On the other hand, potassium addition reflected a significant effect on stalk diameter at the sixth month and fourth to sixth month measurements in plant cane and ratoon, respectively. Plant cane developed a larger stalk diameter than ratoon. Variety Co 6806 differs significantly from Co 527 in stalk diameter at the sixth month measurement confirming the findings of Humbert[5] and Clements.[15] The soil types exhibited a significant difference in stalk diameter. The mean number of internodes in plant cane was slightly affected by potassium application (Table 6). However, significant effects were observed in ratoon experiment early in the season (Table 7). Phosphorus treatment increased the number of internodes at 6 and 10 months age of plant cane, and 4 months age of ratoon. The positive effect of phosphorus on the number of internodes was observed by Mohamed.[16] For plant cane, varieties had significant differences in the

Table 1. Mean stalk diameter (cm) of plant cane as affected by treatments.

	Fertilizer rate		4 months from planting				6 months from planting				8 months from planting				10 months from planting			
			Soil series				Soil series				Soil series				Soil series			
Variety	K	P	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE
		P0	38.3	37.1	49.9		82.5	131.5	90.7		184.0	229.7	185.9		248.1	268.0	264.4	
	K0	P1	41.4	42.2	53.7		86.5	138.9	95.1		186.8	226.3	190.1		258.3	263.1	266.4	
		P2	41.8	42.4	55.1		87.8	139.6	104.7		185.3	235.3	208.7		251.3	274.1	286.5	
		P0	37.5	39.2	47.9		85.3	135.7	87.7		190.5	238.9	192.1		263.2	277.3	269.7	
Co 6806	K1	P1	37.5	41.3	48.2	42.9b	93.3	139.8	97.7	107.9a	196.2	235.1	197.6	207.9a	266.5	273.1	272.9	269.5a
		P2	36.4	42.1	49.3		84.3	143.9	98.9		183.6	241.9	200.2		245.4	283.6	277.4	
		P0	35.7	40.9	45.8		83.6	139.1	89.3		190.0	237.0	195.4		261.5	279.4	272.5	
	K2	P1	37.2	40.2	47.0		91.3	140.3	102.2		195.6	231.0	201.9		263.9	271.3	279.1	
		P2	40.5	40.0	48.7		95.1	144.0	103.8		199.9	245.7	203.7		269.0	285.4	284.2	
		P0	40.3	42.0	37.6		92.1	126.5	87.16		169.8	219.8	173.1		238.4	270.1	258.1	
	K0	P1	40.8	49.5	41.3		95.0	137.7	89.13		170.7	221.9	174.1		244.6	271.0	260.2	
		P2	42.9	49.7	43.1		92.5	137.8	91.8		173.4	229.4	187.3		247.3	281.3	273.9	
		P0	40.5	45.9	37.2		89.5	128.7	87.5		170.6	223.7	178.3		239.3	275.5	267.8	
Co 527	K1	P1	43.4	49.7	42.4	44.1a	98.0	131.5	90.6	104.7b	178.8	234.5	174.6	186.0b	254.1	285.7	261.4	256.9b
		P2	41.5	50.5	44.3		93.6	121.1	89.2		168.6	204.3	167.6		232.0	265.5	254.4	
		P0	39.1	48.1	39.7		88.9	129.2	88.3		176.6	223.5	174.9		248.8	273.6	264.1	
	K2	P1	46.3	50.3	45.3		100.9	134.8	94.1		178.2	222.3	181.3		252.7	272.5	269.2	
		P2	41.6	51.3	46.2		93.6	135.4	88.8		177.6	212.3	169.2		251.0	266.3	257.4	
MSE			40.2c	44.5b	45.7a		90.8c	135.3a	93.2b		182.0c	228.5a	186.4a		252.0c	274.1a	268.9b	

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Main K effect	Main K effect	Main K effect	Main K effect
K0 K1 K2	K0 K1 K2	K0 K1 K2	K0 K1 K2
43.9a 43.1a 43.6a	106.0a 105.3a 107.6a	200.8a 198.7a 191.3a	263.0b 264.7a 267.9a
Main P effect	Main P effect	Main P effect	Main P effect
P0 P1 P2	P0 P1 P2	P0 P1 P2	P0 P1 P2
41.3b 44.3a 44.9a	102.4a 107.9a 108.1a	199.1a 201.9a 199.7a	263.3a 265.9a 265.9a
Variety SE = ±0.2	Variety SE = ±0.7	Variety SE = ±0.84	Variety SE = ±0.97
Soil, K and P SE = ±0.3	Soil, K and P SE = ±0.8	Soil, K and P SE = ±1.02	Soil, K and P SE = ±1.2
CV = 4.9%	CV = 5.7%	CV = 3.8%	CV = 3.3%

Symbols used in this table and the following tables are explained as follows:
K = Potassium; P = Phosphorus; MVE = Main variety effect; MSE = Main soil effect.
Means followed by the same letter do not differ significantly using Duncan's Multiple Range Test at 1 and 5%.

Table 2. Mean stalk height (cm) of ratoon as affected by treatments.

			4 months from planting				6 months from planting				8 months from planting				10 months from planting			
	Fertilizer rate		Soil series				Soil series				Soil series				Soil series			
Variety	K	P	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE
		P0	72.2	41.7	46.0		116.5	207.7	114.4		217.2	219.6	218.9		235.9	243.8	246.7	
	K0	P1	83.5	45.2	56.7		124.0	211.8	117.5		222.5	221.3	222.5		242.8	246.1	250.3	
		P2	83.1	46.9	60.4		118.1	214.3	124.2		216.9	227.2	231.1		238.2	253.1	268.6	
		P0	77.4	44.9	48.1		119.2	210.5	115.1		221.2	231.0	224.1		241.1	252.3	254.2	
Co 6806	K1	P1	82.6	51.9	58.0	59.9a	120.9	214.3	118.3	147.2a	225.6	236.1	224.3	223.5a	250.2	259.7	256.2	246.4a
		P2	79.9	50.3	59.5		117.8	217.1	121.2		220.0	233.6	227.7		241.0	256.7	260.1	
		P0	75.4	51.8	60.9		118.1	215.2	123.7		224.3	232.2	219.3		243.8	254.7	252.6	
	K2	P1	80.7	48.9	58.0		119.3	213.4	120.9		229.8	224.1	228.1		246.3	250.2	261.1	
		P2	79.2	53.3	57.7		119.6	218.1	118.3		232.2	238.8	229.3		254.2	261.2	264.4	
		P0	66.2	36.9	52.4		111.1	178.3	105.7		213.0	210.0	213.5		222.2	230.3	236.1	
	K0	P1	70.1	40.9	57.6		116.1	183.8	114.8		215.7	217.1	215.6		227.4	235.2	237.9	
		P2	72.4	44.7	63.3		117.2	184.1	115.9		219.5	223.4	224.6		231.0	244.9	255.6	
		P0	70.3	43.5	52.9		115.6	184.5	114.5		215.0	214.8	217.5		224.9	233.6	238.5	
Co 527	K1	P1	72.9	44.3	57.9	58.5b	116.8	186.4	119.8	143.0b	225.1	219.8	218.6	220.9b	235.1	241.0	243.4	241.2b
		P2	83.8	38.7	49.6		119.5	183.8	113.2		214.8	210.0	212.3		223.2	232.1	231.9	
		P0	70.7	48.9	58.1		120.3	191.5	119.1		221.8	226.3	220.7		231.7	242.2	245.2	
	K2	P1	74.0	44.3	53.7		123.6	189.2	117.2		229.1	222.2	223.8		237.2	241.0	252.9	
		P2	86.6	39.2	48.5		125.7	186.1	113.1		224.5	216.5	211.7		234.2	236.6	233.2	
MSE			76.7a	45.4c	55.5b		118.9b	199.4a	117.1b		221.7a	223.6a	221.3a		236.7c	245.3b	249.4a	

Main K effect	Main K effect	Main K effect	Main K effect
K0 K1 K2	K0 K1 K2	K0 K1 K2	K0 K1 K2
57.8b 59.3a 60.6a	143.1b 144.9a 147.4a	219.5b 221.8b 225.3a	241.5b 243.1b 246.8a
Main P effect	Main P effect	Main P effect	Main P effect
P0 P1 P2	P0 P1 P2	P0 P1 P2	P0 P1 P2
55.6b 60.1a 61.0a	142.0b 146.8a 146.0a	220.1b 223.4a 223.0a	240.6b 245.2a 245.6a
Variety SE = ±0.5	Variety SE = ±1.1	Variety SE = ±0.7	Variety SE = ±1.29
Soil, K and P SE = ±0.6	Soil, K and P SE = ±1.3	Soil, K and P SE = ±0.8	Soil, K and P SE = ±1.1
CV = 7.3%	CV = 6.8%	CV = 2.7%	CV = 3.9%

Symbols as defined in Table 1.

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Table 3. Physical and chemical properties of examined soil series.

Soil series	Depth (cm)	PH (paste)	ECe (dS/m)	CEC ($mmol_c$/kg soil)	$CaCO_3$ (%)	O.C. (%)	N (%)	P (ug/g)
Dinder	0–30	8.00	0.40	640	0.80	0.91	0.05	2.2
	30–50	8.10	0.43	650	0.80	0.62	0.04	2.6
Nasr	0–30	7.44	0.34	540	2.2	0.94	0.04	1.8
	30–50	7.50	0.50	580	2.4	0.58	0.05	3.8
Hagu	0–30	7.05	0.56	460	1.4	0.94	0.04	3.6
	30–50	7.08	0.55	430	1.7	0.55	0.03	3.0

		Soluble cations and anions ($mmol_c$/L)					Exchangeable cations ($mmol_c$/kg soil)		
Soil series	Depth (cm)	Na	Ca	Mg	Cl	HCO_3	Exch. Na	Exch. K	Mobile K reserve
Dinder	0–30	3.20	1.00	0.20	2.40	3.00	0.92	0.58	1.28
	30–50	3.50	1.20	0.40	2.40	4.50	1.87	0.44	1.11

Nasr	0–30	1.25	2.10	1.00	2.80	5.00	0.34	0.66	1.38
	30–50	1.40	3.50	1.00	2.60	3.50	0.48	0.50	0.87
Hagu	0–30	1.30	4.00	2.00	2.70	4.70	0.30	0.54	1.65
	30–50	1.20	3.20	1.70	2.50	5.10	0.70	0.41	1.42

		Particle size distribution (%)				
Soil series	Depth (cm)	Coarse sand	Fine sand	Silt	Clay	Bulk Density
Dinder	0–30	17	6	25	52	1.66
	30–50	17	5	24	54	1.78
Nasr	0–30	29	6	17	48	1.89
	30–50	28	7	17	49	1.87
Hagu	0–30	41	8	14	37	1.88
	30–50	39	6	16	39	1.86

Table 4. Mean stalk diameter (cm) of plant cane as affected by treatments.

	Fertilizer rate		4 months from planting				6 months from planting				8 months from planting				10 months from planting			
			Soil series				Soil series				Soil series				Soil series			
Variety	K	P	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE
		P0	1.706	2.07	2.25		2.56	2.49	2.49		2.65	2.62	2.72		2.63	2.48	2.66	
	K0	P1	1.69	2.05	2.16		2.44	2.49	2.38		2.75	2.50	2.62		2.66	2.55	2.72	
		P2	1.81	2.10	2.24		2.55	2.40	2.36		2.67	2.64	2.65		2.58	2.65	2.72	
		P0	1.85	2.29	2.18		2.50	2.54	2.31		2.66	2.64	2.48		2.47	2.49	2.56	
Co 6806	K1	P1	1.86	2.08	2.24	2.03b	2.63	2.50	2.53	2.48b	2.71	2.58	2.65		2.59	2.54	2.63	2.59a
		P2	1.58	2.12	2.05		2.51	2.45	2.38		2.67	2.66	2.56		2.62	2.56	2.44	
		P0	1.76	2.30	2.14		2.51	2.58	2.45		2.73	2.74	2.64		2.56	2.53	2.58	
	K2	P1	1.74	2.22	2.03		2.53	2.53	2.41		2.66	2.58	2.77		2.52	2.58	2.73	
		P2	1.90	2.22	2.19		2.43	2.74	2.42		2.72	2.72	2.72		2.62	2.67	2.69	
		P0	2.01	2.34	2.16		2.54	2.52	2.62		2.58	2.53	2.87		2.34	2.65	2.74	
	K0	P1	2.18	2.44	2.32		2.42	2.50	2.52		2.62	2.72	2.70		2.60	2.61	2.68	
		P2	2.09	2.38	2.24		2.52	2.57	2.58		2.72	2.61	2.72		2.56	2.60	2.67	
		P0	2.02	2.39	2.14		2.43	2.58	2.50		2.62	2.58	2.76		2.50	2.66	2.73	
Co 527	K1	P1	2.05	2.36	2.18	2.19a	2.52	2.47	2.62	2.53a	2.65	2.51	2.70		2.51	2.67	2.66	2.59a
		P2	2.00	2.40	2.12		2.44	2.58	2.36		2.56	2.72	2.50		2.27	2.69	2.57	
		P0	1.80	2.37	2.20		2.55	2.44	2.62		2.60	2.64	2.74		2.51	2.63	2.60	
	K2	P1	2.02	2.24	2.28		2.59	2.55	2.57		2.60	2.60	2.58		2.52	2.64	2.70	
		P2	1.87	2.50	2.11		2.53	2.54	2.55		2.59	2.74	2.80		2.44	2.58	2.57	
MSE			1.89c	2.27a	2.18b		2.51b	2.53a	2.48c		2.65a	2.63a	2.68a		2.52b	2.60a	2.64a	

Main K effect			Main K effect			Main K effect			Main K effect		
K0	K1	K2	K0	K1	K2	K0	K1	K2	K0	K1	K2
2.13a	2.11a	2.11a	2.44c	2.49a	2.53a	2.66a	2.62a	2.68a	2.61a	2.57a	2.59a
Main P effect			Main P effect			Main P effect			Main P effect		
P0	P1	P2	P0	P1	P2	P0	P1	P2	P0	P1	P2
2.11a	2.12a	2.11a	2.51a	2.51a	2.50a	2.66a	2.64a	2.67a	2.57a	2.61a	2.58a
Variety SE = ±0.02			Variety SE = ±0.005			Variety SE = ±0.02			Variety SE = ±0.01		
Soil, K and P SE = ±0.03			Soil, K and P SE = ±0.006			Soil, K and P SE = ±0.02			Soil, K and P SE = ±0.02		
CV = 8.69%			CV = 1.71%			CV = 6.55%			CV = 4.72%		

Symbols as defined in Table 1.

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Table 5. Mean stalk diameter (cm) of plant cane as affected by treatments.

			4 months from planting				6 months from planting				8 months from planting				10 months from planting			
	Fertilizer rate		Soil series				Soil series				Soil series				Soil series			
Variety	K	P	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE
		P0	2.14	1.43	1.89		2.19	2.28	2.26		2.53	2.55	2.48		2.48	2.45	2.43	
	K0	P1	2.17	1.37	1.79		2.27	2.27	2.21		2.53	2.60	2.46		2.50	2.52	2.40	
		P2	2.09	1.34	1.83		2.18	2.29	2.21		2.54	2.61	2.49		2.47	2.54	2.45	
		P0	2.13	1.47	1.88		2.27	2.30	2.17		2.57	2.59	2.45		2.50	2.47	2.41	
Co 6806	K1	P1	2.15	1.46	1.83	1.81a	2.25	2.29	2.18	2.23a	2.59	2.58	2.52	2.53a	2.53	2.52	2.49	2.48a
		P2	2.19	1.51	1.77		2.21	2.31	2.21		2.57	2.57	2.49		2.51	2.49	2.46	
		P0	2.15	1.41	1.88		2.24	2.24	2.21		2.55	2.67	2.52		2.47	2.62	2.48	
	K2	P1	2.20	1.40	1.96		2.24	2.23	2.19		2.48	2.61	2.49		2.41	2.56	2.45	
		P2	2.19	1.40	1.73		2.23	2.27	2.23		2.53	2.63	2.49		2.46	2.59	2.44	
		P0	2.10	1.37	1.67		2.15	2.23	2.17		2.52	2.50	2.41		2.47	2.47	2.36	
	K0	P1	2.13	1.36	1.75		2.15	2.19	2.20		2.53	2.61	2.42		2.49	2.56	2.39	
		P2	2.15	1.34	1.77		2.19	2.22	2.14		2.49	2.60	2.49		2.43	2.57	2.44	
		P0	2.22	1.43	1.83		2.27	2.30	2.16		2.47	2.54	2.49		2.41	2.50	2.45	
Co 527	K1	P1	2.17	1.40	1.82	1.77b	2.24	2.25	2.16	2.21b	2.51	2.52	2.48	2.52b	2.47	2.46	2.42	2.46a
		P2	2.15	1.42	1.63		2.17	2.28	2.19		2.45	2.54	2.47		2.40	2.47	2.40	
		P0	2.07	1.43	1.84		2.18	2.23	2.19		2.52	2.60	2.50		2.48	2.57	2.43	
	K2	P1	2.09	1.39	1.80		2.15	2.17	2.17		2.47	2.57	2.46		2.43	2.51	2.40	
		P2	2.19	1.38	1.75		2.21	2.21	2.16		2.57	2.54	2.42		2.54	2.55	2.37	
MSE			2.15a	1.41c	1.80b		2.21b	2.25a	2.19c		2.52b	2.58a	2.47c		2.47b	2.52a	2.43c	

Main K effect			Main K effect			Main K effect			Main K effect		
K0	K1	K2	K0	K1	K2	K0	K1	K2	K0	K1	K2
1.76b	1.80a	1.79a	2.21b	2.23a	2.21b	2.52a	2.52a	2.53a	2.47a	2.46a	2.48a
Main P effect			Main P effect			Main P effect			Main P effect		
P0	P1	P2	P0	P1	P2	P0	P1	P2	P0	P1	P2
1.80a	1.79a	1.77b	2.22a	2.21a	2.22a	2.53a	2.52a	2.53a	2.47a	2.47a	2.48a
Variety SE = ±0.005			Variety SE = ±0.005			Variety SE = ±0.005			Variety SE = ±0.008		
Soil, K and P SE = ±0.007			Soil, K and P SE = ±0.006			Soil, K and P SE = ±0.006			Soil, K and P SE = ±0.01		
CV = 2.67%			CV = 1.83%			CV = 1.78%			CV = 2.85%		

Symbols as defined in Table 1.

Table 6. Mean number of internodes of plant cane as affected by treatments.

	Fertilizer rate		4 months from planting				6 months from planting				8 months from planting				10 months from planting			
			Soil series				Soil series				Soil series				Soil series			
Variety	K	P	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE
		P0	2.80	2.07	3.40		8.60	10.46	10.20		15.80	17.53	18.53		24.46	24.06	24.66	
	K0	P1	2.60	2.05	3.53		8.26	10.73	11.40		16.46	18.08	18.66		24.66	24.60	24.80	
		P2	2.80	2.10	3.73		8.53	11.20	10.93		17.13	18.73	18.93		24.86	24.80	25.06	
		P0	3.13	2.29	3.06		7.63	10.53	9.66		15.53	18.00	16.83		21.33	23.10	23.06	
Co 6806	K1	P1	3.06	2.08	3.00	2.76a	9.18	10.86	10.40	9.81b	16.86	18.26	18.33	17.83a	23.66	23.26	25.20	24.34a
		P2	2.60	2.12	3.46		7.93	11.33	9.73		16.93	18.60	18.66		24.40	24.06	25.73	
		P0	2.46	2.30	3.06		8.00	10.73	9.00		17.30	18.73	17.46		23.26	24.40	23.93	
	K2	P1	3.06	2.22	3.33		7.80	10.26	9.66		17.53	18.90	18.26		23.87	24.63	25.00	
		P2	2.86	2.22	3.26		9.21	11.73	9.93		17.80	19.03	18.80		24.20	25.60	26.26	
		P0	3.40	2.34	2.86		9.66	11.00	9.13		16.13	18.86	16.86		23.15	23.73	24.39	
	K0	P1	2.93	2.44	3.13		9.66	12.13	9.40		16.86	19.66	15.93		24.40	24.20	24.53	
		P2	3.26	2.38	3.13		9.33	11.46	9.46		16.20	19.40	17.03		23.93	24.80	24.61	
		P0	3.00	2.39	2.60		9.40	11.20	8.66		17.53	20.20	16.53		23.35	23.20	24.40	
Co 527	K1	P1	3.26	2.36	3.33	2.88a	10.80	11.73	9.43	10.13a	17.00	18.73	18.36	17.50b	24.66	23.73	25.33	24.04a
		P2	2.86	2.40	3.53		9.20	10.73	9.53		16.20	17.73	16.70		22.93	24.00	25.46	
		P0	3.26	2.37	3.00		8.93	11.60	8.63		17.13	18.70	17.40		23.35	22.06	24.44	
	K2	P1	3.60	2.24	3.53		10.63	11.86	9.30		16.86	18.26	16.80		24.06	22.86	24.73	
		P2	3.06	2.50	3.13		9.00	12.26	9.53		17.25	18.26	16.40		23.73	23.06	26.06	
MSE			3.00b	2.27c	3.22a		8.98c	11.26a	9.66b		16.80c	18.64a	17.58b		23.79b	23.89b	24.88a	

Main K effect			Main K effect			Main K effect			Main K effect		
K0	K1	K2	K0	K1	K2	K0	K1	K2	K0	K1	K2
2.83a	2.80a	2.85a	10.08a	9.88a	9.94a	17.59a	17.61a	17.82a	24.42a	23.95a	24.19a
Main P effect			Main P effect			Main P effect			Main P effect		
P0	P1	P2	P0	P1	P2	P0	P1	P2	P0	P1	P2
2.76a	2.87a	2.86a	9.61b	10.24a	10.05a	17.50a	17.76a	17.76a	23.59b	24.34a	24.64a
Variety SE = ±0.05			Variety SE = ±0.10			Variety SE = ±0.12			Variety SE = ±0.15		
Soil, K and P SE = ±0.06			Soil, K and P SE = ±0.12			Soil, K and P SE = ±0.15			Soil, K and P SE = ±0.19		
CV = 15.37%			CV = 8.8%			CV = 6.12%			CV = 5.65%		

Symbols as defined in Table 1.

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Table 7. Mean number of internodes of ratoon as affected by treatments.

			4 months from planting				6 months from planting				8 months from planting				10 months from planting			
	Fertilizer rate		Soil series				Soil series				Soil series				Soil series			
Variety	K	P	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE
		P0	5.20	2.33	3.87		9.87	12.20	9.87		20.47	18.20	16.93		22.52	22.84	20.32	
	K0	P1	5.87	2.43	3.66		9.87	12.50	9.80		20.60	18.30	16.87		22.66	22.96	20.24	
		P2	5.93	2.60	3.98		10.00	11.50	10.13		21.27	18.66	17.73		23.40	22.39	21.28	
		P0	6.40	2.58	3.40		10.20	12.15	10.40		21.00	19.07	16.87		23.10	21.88	20.24	
Co 6806	K1	P1	6.40	2.43	3.80	3.94a	9.73	12.60	10.47	10.91a	20.80	18.27	17.07	18.96a	22.88	21.92	20.48	21.35a
		P2	6.47	2.40	4.00		10.13	12.88	10.60		20.73	18.93	16.93		22.80	22.71	20.32	
		P0	5.66	2.82	4.03		9.87	11.87	9.80		20.70	18.27	16.73		22.77	21.92	20.08	
	K2	P1	6.07	3.00	4.07		9.53	12.07	10.53		20.07	18.37	17.60		22.07	22.04	21.12	
		P2	6.80	2.47	3.60		9.67	11.80	10.33		20.67	18.80	17.20		22.74	22.56	20.64	
		P0	5.00	2.00	3.05		9.70	11.50	9.80		20.20	18.07	16.73		21.22	20.08	18.40	
	K0	P1	5.66	2.46	3.60		9.73	11.73	9.73		20.73	18.27	16.85		22.08	20.10	18.54	
		P2	5.47	2.47	3.87		9.80	11.40	9.93		20.29	18.53	17.13		21.52	20.38	19.84	
		P0	5.53	2.67	3.33		10.13	12.13	10.20		20.73	18.93	16.80		21.80	20.82	18.48	
Co 527	K1	P1	5.66	2.36	3.47	4.00a	9.60	12.07	9.80	10.32b	20.07	18.20	17.00	18.38b	21.28	20.02	19.07	20.71b
		P2	6.40	2.38	3.00		10.33	11.73	10.07		20.40	18.80	16.90		21.64	20.68	18.59	
		P0	5.60	2.62	2.90		9.87	11.87	9.73		20.80	17.93	16.73		21.98	19.72	18.40	
	K2	P1	5.00	2.53	3.47		9.47	10.66	10.07		20.13	18.12	17.47		21.41	19.93	19.22	
		P2	6.70	2.40	3.50		9.77	11.73	10.23		20.60	17.73	17.07		21.66	19.50	19.10	
MSE			5.82a	2.50c	3.59b		9.85c	11.91a	10.08b		20.56a	18.41b	17.03c		22.16a	21.25b	19.69c	

Main K effect			Main K effect			Main K effect			Main K effect		
K0	K1	K2	K0	K1	K2	K0	K1	K2	K0	K1	K2
3.80b	4.04a	4.07a	10.49b	10.85a	10.49b	18.66a	18.74a	18.61a	21.15a	21.00a	20.94a
Main P effect			Main P effect			Main P effect			Main P effect		
P0	P1	P2	P0	P1	P2	P0	P1	P2	P0	P1	P2
3.78b	4.00a	4.14a	10.62a	10.55a	10.67a	18.62a	18.62a	18.80a	20.88a	21.00a	21.21a
Variety SE = ±0.058			Variety SE = ±0.066			Variety SE = ±0.08			Variety SE = ±0.14		
Soil, K and P SE = ±0.071			Soil, K and P SE = ±0.081			Soil, K and P SE = ±0.10			Soil, K and P SE = ±0.17		
CV = 13.05%			CV = 5.61%			CV = 3.8%			CV = 6.01%		

Symbols as defined in Table 1.

number of internodes from 6 to 8 months age and ratoon from 6 to 10 months age. Significant differences between varieties had been reported by Ali[14] concluding that the best yielding variety had more internodes.

There was a high population density in plant cane and ratoon experiments at the early stages of growth (Tables 8 and 9), which decreased with age. The high mortality rate of the stalks observed in this study coincided with the findings of El-Negay[17] who found that the number of stalks decreased steadily by almost one third 9 months after planting and, thereafter, stalk mortality rate was very small. Mortality of shoots occurred mainly due to the cane competition for light, water and nutrients at advanced stages. Phosphorus and potassium fertilization significantly increased plant density in both plant cane and ratoon because adequate supply of these elements increased both the number of tillers and mass of each tiller.[18] The significantly high plant density recorded by variety Co 6806 was due to its high tillering ability. The soil type affected the population density significantly.

Effect of Treatments on Cane and Sugar Yield

Plant cane and ratoon showed significantly high cane tonnage due to potassium application (Tables 10 and 11). It has been found that application of potassium progressively increased cane yield.[19,20] Sugarcane was known to require high levels of potassium because potassium is involved in important physiological processes of the plant, and thereby, determines the rate of growth and yield directly.[1] The obtained cane yield range was more than that reported in some of the classical sugar production areas[21] and the sugar content was in the range of the international figures.

Phosphorus fertilizer effect on cane yield in plant and ratoon was not significant as reported by Ali[14] and El-Tahir.[22] However, the increase in cane yield due to phosphorus application was mainly due to the positive effect of phosphorus application on stalk height. The significant differences among varieties in cane yield suggested that varieties can affect yield and yield parameters differently, and this can mostly be attributed to their differences in tillering capacities. Variety Co 6806 surpassed Co 527 in cane yield came in confirmation for the tonnage recorded by El-Tahir.[22] Moreover, Yassin[2] concluded that variety Co 527 is a heavy flowering variety which leads to low yield, high fiber and low sugar contents during the last 3 months of harvest. As expected plant cane out-yielded ratoon and this was recorded in all sugar estates. The low yield of ratoon recorded in this study could also be attributed to the

Table 8. Mean plant density (1000's/ha) of plant cane as affected by treatments.

	Fertilizer rate		4 months from planting				6 months from planting				8 months from planting				10 months from planting			
			Soil series				Soil series				Soil series				Soil series			
Variety	K	P	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE
		P0	142.5	153.7	164.0		124.4	145.6	155.8		117.6	139.8	144.0		113.0	126.0	131.3	
	K0	P1	138.6	135.8	170.0		130.0	128.4	141.6		129.6	125.3	140.3		124.1	124.8	132.0	
		P2	142.6	155.8	215.3		137.1	145.0	164.0		131.6	128.9	149.3		128.5	120.6	142.6	
		P0	141.4	161.2	152.1		144.8	146.6	157.3		131.2	135.2	139.3		124.1	129.4	135.3	
Co 6806	K1	P1	153.3	161.8	169.3	160.3a	147.0	153.4	166.6	148.7a	142.5	132.3	141.8	136.5a	140.6	129.6	141.3	130.5a
		P2	136.0	150.7	190.0		134.2	162.4	168.4		117.6	128.3	140.3		113.9	127.7	138.3	
		P0	142.2	162.4	159.9		129.2	150.5	151.6		130.0	142.0	144.2		121.0	127.7	146.5	
	K2	P1	156.1	167.6	172.0		131.0	151.4	157.4		127.4	126.6	143.3		124.4	122.5	141.0	
		P2	153.8	186.6	194.6		149.6	168.1	174.0		147.0	148.5	162.3		140.8	133.8	142.9	
		P0	120.0	128.1	140.0		116.0	126.6	133.7		109.3	113.3	126.9		108.4	112.2	116.8	
	K0	P1	128.0	134.6	148.1		125.3	096.7	139.7		113.8	124.6	128.0		111.0	112.9	119.7	
		P2	146.9	151.2	158.0		132.2	132.0	139.2		128.9	134.0	138.9		118.8	122.0	127.7	
		P0	140.4	157.3	160.4		132.2	132.4	135.7		122.5	132.1	135.5		114.5	118.0	122.5	
Co 527	K1	P1	150.6	157.4	161.9	146.1b	142.8	138.0	146.6	133.7b	136.9	133.7	136.7	127.0b	133.0	114.6	119.6	117.7b
		P2	131.7	137.3	169.6		128.0	129.6	140.1		113.7	131.1	137.3		109.6	112.0	129.7	
		P0	139.1	142.9	150.6		132.5	132.8	134.6		120.5	126.8	131.7		117.6	106.7	126.1	
	K2	P1	145.7	150.7	155.7		140.8	123.3	129.0		135.0	108.9	128.0		129.5	104.9	118.2	
		P2	132.0	141.6	165.3		129.3	138.2	153.3		126.5	120.4	134.9		124.5	106.2	121.6	
MSE			141.2c	152.0b	166.5a		126.5c	133.9b	149.4a		126.8b	129.5b	139.0a		122.1b	119.5b	130.7a	

(*continued*)

Table 8. Continued.

	4 months from planting			6 months from planting			8 months from planting			10 months from planting		
	Main K effect			Main K effect			Main K effect			Main K effect		
	K0	K1	K2	K0	K1	K2	K0	K1	K2	K0	K1	K2
	146.5b	154.6a	156.6a	135.8b	144.8a	143.1a	129.1a	132.7a	133.6a	121.8a	125.2a	125.3a
	Main P effect			Main P effect			Main P effect			Main P effect		
	P0	P1	P2	P0	P1	P2	P0	P1	P2	P0	P1	P2
	147.7c	153.9b	158.8a	137.9b	140.0b	145.8a	130.1a	130.8a	133.1a	122.0a	124.7a	125.6a
	Variety SE = ±1.4			Variety SE = ±1.7			Variety SE = ±1.8			Variety SE = ±1.9		
	Soil, K and P SE = ±1.8			Soil, K and P SE = ±2.1			Soil, K and P SE = ±2.2			Soil, K and P SE = ±2.4		
	CV = 11.2%			CV = 14.2%			CV = 16.6%			CV = 18.8%		

Symbols as defined in Table 1.

Table 9. Mean plant density (1000's/ha) of ratoon as affected by treatments.

Variety	Fertilizer rate K	Fertilizer rate P	4 months from planting: Dinder	Nasr	Hagu	MVE	6 months from planting: Dinder	Nasr	Hagu	MVE	8 months from planting: Dinder	Nasr	Hagu	MVE	10 months from planting: Dinder	Nasr	Hagu	MVE
	K0	P0	160.8	168.8	185.0		145.3	157.4	168.6		128.8	141.6	150.9		121.7	133.2	142.3	
		P1	197.7	189.1	222.1		171.7	175.1	188.3		156.7	148.5	170.0		129.0	142.0	155.3	
		P2	192.8	186.0	234.9		168.8	170.1	206.5		149.3	145.0	176.4		140.5	136.4	160.2	
		P0	184.0	192.4	194.5		163.6	179.1	173.0		143.9	153.6	155.0		133.5	140.8	143.0	
Co 6806	K1	P1	224.2	229.4	197.5	193.5a	200.5	205.6	166.8	173.2a	160.2	167.5	152.9	151.3a	138.5	145.6	140.7	140.0a
		P2	208.8	221.7	203.2		176.5	198.8	172.4		144.2	163.0	160.5		127.5	141.0	154.9	
		P0	195.1	189.0	213.5		168.1	178.2	182.5		148.1	153.7	163.5		135.0	138.7	155.4	
	K2	P1	183.3	180.0	202.2		166.6	165.5	170.7		149.3	145.9	161.2		144.6	132.9	147.7	
		P2	196.5	216.3	225.7		177.7	208.3	191.8		156.5	171.0	170.4		143.7	144.5	148.5	
		P0	150.1	156.8	165.4		134.0	145.6	155.2		119.6	129.7	133.5		114.3	121.6	127.3	
	K0	P1	170.2	174.9	187.6		149.6	161.2	167.7		133.0	140.2	139.4		122.4	128.2	144.5	
		P2	180.6	188.2	182.4		165.5	171.2	166.2		149.9	148.7	149.7		138.2	135.1	140.2	
		P0	168.6	178.2	178.1		152.8	160.7	161.5		136.2	144.7	144.9		124.3	127.7	135.6	
Co527	K1	P1	192.8	181.3	189.2	183.4b	169.9	164.4	174.9	164.7b	147.1	146.8	153.8	145.7b	132.3	131.0	148.8	133.1b
		P2	175.7	170.0	186.0		157.5	149.4	170.5		127.8	132.7	151.8		120.6	118.9	145.6	
		P0	180.1	173.1	184.3		161.8	157.8	166.1		144.0	139.5	153.2		131.8	130.3	141.9	
	K2	P1	180.8	169.6	180.2		159.1	156.7	164.7		142.3	134.9	147.2		136.6	124.1	138.5	
		P2	184.4	169.6	183.1		160.0	150.2	171.0		147.3	131.7	154.3		129.6	121.4	145.2	
MSE			184.8b	185.2b	195.3a		163.8b	169.7a	173.3a		144.0b	146.6b	154.9a		131.4b	133.0b	145.3a	

(*continued*)

Table 9. Continued.

	4 months from planting			6 months from planting			8 months from planting			10 months from planting		
	Main K effect			Main K effect			Main K effect			Main K effect		
	K0	K1	K2	K0	K1	K2	K0	K1	K2	K0	K1	K2
	182.3b	192.7a	188.8a	164.9b	172.1a	169.8a	145.0b	149.7a	150.8a	135.2a	136.1a	138.4a
	Main P effect			Main P effect			Main P effect			Main P effect		
	P0	P1	P2	P0	P1	P2	P0	P1	P2	P0	P1	P2
	178.4b	191.3a	194.3a	161.8b	171.1a	174.0a	143.6b	149.8a	15.1a	133.3b	137.9a	138.4a
	Variety SE = ±1.9			Variety SE = ±1.6			Variety SE = ±1.3			Variety SE = ±0.94		
	Soil, K and P SE = ±2.3			Soil, K and P SE = ±2.0			Soil, K and P SE = ±1.6			Soil, K and P SE = ±1.1		
	CV = 11.8%			CV = 11.4%			CV = 10.8%			CV = 8.2%		

Symbols as defined in Table 1.

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Table 10. Cane and estimated sugar yields (tons/ha) as affected by treatments in plant cane.

	Fertilizer rate		Cane yield				Estimated sugar			
			Soil series				Soil series			
Variety	K	P	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE
		P0	95.5	124.0	129.3		10.7	13.6	13.9	
	K0	P1	97.3	122.6	132.9		10.5	14.6	14.6	
		P2	96.0	134.2	142.6		10.6	14.5	15.3	
		P0	110.6	134.2	133.3		12.0	15.7	14.4	
Co 6806	K1	P1	112.0	129.3	136.6	124.3a	11.8	14.1	15.0	13.7a
		P2	94.6	136.6	139.1		10.4	15.4	15.4	
		P0	109.3	134.6	135.1		12.1	15.3	14.7	
	K2	P1	111.3	128.0	140.4		12.5	14.0	14.9	
		P2	115.5	139.5	141.3		13.0	15.9	15.9	
		P0	78.6	107.5	109.3		8.6	11.7	11.7	
	K0	P1	84.0	115.5	110.2		8.9	12.7	12.0	
		P2	85.3	126.6	120.4		9.2	13.8	12.3	
		P0	79.3	125.3	117.7		8.7	13.2	12.1	
Co 527	K1	P1	92.4	130.2	112.9	105.0b	9.8	14.3	12.2	11.3b
		P2	77.3	104.0	102.6		8.5	11.5	11.3	
		P0	86.6	123.5	117.3		9.1	14.0	12.3	
	K2	P1	90.6	119.1	119.1		9.6	13.1	12.3	
		P2	87.3	105.3	106.5		9.5	11.7	11.5	
MSE			94.7b	124.5a	124.8a		10.3c	13.8a	13.4b	

(*continued*)

Table 10. Continued.

	Cane yield			Estimated sugar		
	Main K effect			Main K effect		
	K0	K1	K2	K0	K1	K2
	111.8b	115.0a	117.2a	12.2b	12.5a	12.9a
	Main P effect			Main P effect		
	P0	P1	P2	P0	P1	P2
	114.0a	115.8a	114.2a	12.4a	12.6a	12.5a
	Variety SE = ±1.2			Variety SE = ±0.1		
	Soil, K and P SE = ±1.5			Soil, K and P SE = ±0.1		
	CV = 9.3%			CV = 6.9%		

Symbols as defined in Table 1.

Table 11. Cane and estimated sugar yields (tons/ha) as affected by treatments in ratoon.

	Fertilizer rate		Cane yield				Estimated sugar			
			Soil series				Soil series			
Variety	K	P	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE
		P0	91.7	111.25	110.3		10.7	12.4	12.4	
	K0	P1	95.0	109.25	112.5		11.3	13.2	12.6	
		P2	90.0	119.25	132.5		10.7	14.5	16.5	
		P0	98.3	122.5	115.9		11.5	14.6	13.0	
Co 6806	K1	P1	106.7	125.90	121.7	109.7a	12.8	14.8	14.3	12.5a
		P2	92.7	124.22	123.1		11.2	14.7	14.0	
		P0	103.0	120.51	114.2		12.1	14.1	13.4	
	K2	P1	105.0	116.25	128.3		12.7	13.4	15.4	
		P2	108.3	126.50	130.9		12.6	14.7	15.4	
		P0	70.0	100.34	103.3		8.1	11.1	11.5	
	K0	P1	73.0	104.33	105.5		8.6	11.8	11.8	
		P2	74.7	112.33	115.3		8.8	12.7	12.6	
		P0	72.3	104.31	106.7		8.6	12.2	12.0	
Co 527	K1	P1	87.2	108.44	108.9	100.0b	10.4	12.3	13.0	11.8b
		P2	65.9	103.24	95.6		7.8	11.6	10.9	
		P0	78.7	113.89	108.9		8.8	13.5	12.4	
	K2	P1	84.0	112.30	114.4		10.0	12.5	13.0	
		P2	79.7	106.22	96.7		9.2	12.1	10.8	
MSE			87.5b	113.4a	113.6a		10.3b	13.1a	13.0a	

(*continued*)

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Table 11. Continued.

	Cane yield			Estimated sugar		
	Main K effect			Main K effect		
	K0	K1	K2	K0	K1	K2
	101.69b	104.64a	108.15a	11.73b	12.19a	12.56a
	Main P effect			Main P effect		
	P0	P1	P2	P0	P1	P2
	102.56a	106.53a	105.39a	11.79b	12.43a	12.27a
	Variety SE = ±1.27			Variety SE = ±0.16		
	Soil, K and P SE = ±1.55			Soil, K and P SE = ±10.20		
	CV = 10.9%			CV = 12.05%		

Symbols as defined in Table 1.

late sowing date. El-Hag[23] recommended the period from July to October as the best planting date for Co 6806 but in this experiment plant cane was planted in January. The soil type significantly affected cane yield[21] and Hagu series was superior compared to Dinder and Nasr. The low yield of Dinder soil compared to Hagu soil may be due to Vertisolic character of Dinder series, which involves some physical (texture, aeration) and chemical (nutrient availability and uptake) limitations.

The sugar recovery percentage did not increase significantly with phosphorus fertilization in plant cane whereas, the ratoon yield was significantly affected by phosphorus treatments, demonstrating the importance of maintaining adequate soil phosphorus levels in the fertilizer application zone each year.[24] The added potassium significantly improved the sugar recovery percentage. Sugar recovery percentage was affected by variety since this character was mainly varietal. Variety Co 6806 gave higher recovery percentage compared with Co 527 (Tables 10 and 11). Dinder soil series gave significantly lower sugar recovery percentage compared to Hagu and Nasr in plant cane and ratoon.

The smaller cane yield of the ratoon crop was compensated by high recovery percentage, which resulted in good sugar yield. Variety Co 6806 out-yielded variety Co 527 in ton sugar/ha due to its high juice quality and high yields. This was in line with the findings of many workers.[21,25,26]

Effect of Treatments on Soil Extractable Potassium and Phosphorus After Harvest

Soil analysis revealed lower soil extractable potassium after harvest of plant cane compared with the values prior to cane cropping demonstrating the removal of soil potassium by sugarcane. Increasing potassium fertilizer rate increased extractable potassium.[27] After ratoon harvest, soil extractable potassium increased in the three soils compared with that after plant cane harvest. This increase in potassium can be, partly, explained by the expected less potassium fixation and/or the ratoon generally took less potassium than plant cane (Table 12). Furthermore, Mackenzie et al.[28] concluded that added urea increased extractable potassium, either through reduced potassium fixation through competition for fixation sites with NH_4 or through acidification, both resulting in increased potassium availability. The added phosphorus increased the soil extractable potassium.

Table 12. Soil extractable potassium ($mmol_c$/100g) at the end of plant cane experiment as affected by treatments.

			Plant cane				Ratoon			
	Fertilizer rate		Soil series				Soil series			
Variety	K	P	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE
		P0	0.46	0.54	0.42		0.46	0.64	0.51	
	K0	P1	0.53	0.53	0.43		0.53	0.66	0.53	
		P2	0.48	0.51	0.40		0.49	0.65	0.52	
		P0	0.47	0.56	0.43		0.54	0.65	0.58	
Co 6806	K1	P1	0.54	0.57	0.42	0.51a	0.55	0.67	0.58	0.58a
		P2	0.48	0.53	0.47		0.49	0.65	0.53	
		P0	0.54	0.59	0.44		0.54	0.78	0.62	
	K2	P1	0.55	0.59	0.39		0.55	0.67	0.59	
		P2	0.49	0.57	0.50		0.53	0.66	0.59	
		P0	0.48	0.55	0.47		0.49	0.56	0.48	
	K0	P1	0.50	0.56	0.48		0.52	0.70	0.54	
		P2	0.50	0.54	0.42		0.53	0.70	0.51	
		P0	0.48	0.59	0.47		0.50	0.65	0.49	
Co 527	K1	P1	0.51	0.57	0.48	0.51a	0.53	0.73	0.54	0.59a
		P2	0.56	0.54	0.43		0.55	0.74	0.57	
		P0	0.49	0.59	0.48		0.61	0.72	0.50	
	K2	P1	0.52	0.55	0.50		0.55	0.86	0.56	
		P2	0.52	0.55	0.43		0.59	0.78	0.54	
MSE			0.51b	0.56a	0.45c		0.53c	0.69a	0.55b	

Main K effect			Main K effect		
K0	K1	K2	K0	K1	K2
0.49b	0.51a	0.52a	0.56c	0.58b	0.63a
Main P effect			Main P effect		
P0	P1	P2	P0	P1	P2
0.50a	0.51a	0.49a	0.57b	0.60a	0.59a
Variety SE = ±0.003			Variety SE = ±0.005		
Soil, K and P SE = ±0.004			Soil, K and P SE = ±0.006		
CV = 5.8%			CV = 7.3%		

Symbols as defined in Table 1.

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Table 13. Soil available phosphorus (ug/g) at the end of plant cane experiment as affected by treatments.

			Plant cane				Ratoon			
	Fertilizer rate		Soil series				Soil series			
Variety	K	P	Dinder	Nasr	Hagu	MVE	Dinder	Nasr	Hagu	MVE
		P0	1.78	1.88	1.42		1.95	2.09	1.92	
	K0	P1	1.86	2.64	2.33		2.07	2.70	2.89	
		P2	1.91	2.67	2.40		2.15	2.87	3.25	
		P0	1.85	2.95	2.33		2.17	3.01	3.25	
Co 6806	K1	P1	2.04	3.17	2.75	2.42a	2.20	3.17	2.79	2.79a
		P2	2.34	3.22	2.86		2.50	3.41	3.34	
		P0	1.86	3.19	2.02		2.10	3.22	2.64	
	K2	P1	1.86	3.27	2.79		2.31	3.35	3.10	
		P2	1.90	3.33	2.89		2.34	3.49	3.47	
		P0	1.17	2.79	1.64		1.35	2.85	2.48	
	K0	P1	1.33	2.84	2.02		1.54	2.96	3.13	
		P2	1.60	3.26	3.50		1.86	3.33	3.35	
		P0	1.58	3.41	2.17		1.67	3.52	3.25	
Co 527	K1	P1	1.86	3.10	3.10	2.41a	2.30	3.49	3.32	2.76a
		P2	2.02	2.48	3.36		2.37	3.61	3.50	
		P0	1.24	2.48	2.33		1.55	3.25	3.03	
	K2	P1	1.55	3.20	2.71		2.48	3.41	2.78	
		P2	2.05	3.37	2.83		2.67	3.50	3.45	
MSE			1.77c	2.96a	2.53b		2.09c	3.18a	3.05b	

Main K effect			Main K effect		
K0	K1	K2	K0	K1	K2
2.17b	2.59a	2.49a	2.49b	2.94a	2.90a
Main P effect			Main P effect		
P0	P1	P2	P0	P1	P2
2.12c	2.47b	2.67a	2.52c	2.78b	3.03a
Variety SE = ±0.032			Variety SE = ±0.025		
Soil, K and P SE = ±0.039			Soil, K and P SE = ±0.031		
CV = 11.83%			CV = 8.9%		

Symbols as defined in Table 1.

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The available soil phosphorus decreased after the harvest of plant cane (Table 13). However, these low values of available phosphorus may be due to the uptake of the crop, and/or to the phosphorus retention by hydrous iron oxides or adsorption by clay particles.[29] It has been reported that most of the Sudan soils are poor in available phosphorus and have a high fixing capacity for phosphorus.[30] Addition of potassium fertilizer increased the available phosphorus significantly because potassium application increased the mobile P_2O_5 and the exchangeable potassium.[31] However, the available phosphorus in the soil solution at the higher rate of potassium decreased but it was higher than that of the control. Increasing the rate of phosphorus increased the available phosphorus significantly.[32] The available soil phosphorus after harvest of ratoon increased compared with those after plant cane, but they were less than the initial amount before planting of cane. Zhang and Mackenzie[33] reported that successive annual application of phosphorus increased its availability in the soil. The effect of potassium and phosphorus fertilizers on available soil phosphorus for the ratoon followed the same trend as that after harvest of plant cane. It is worth mentioning that although they were differences between the soils examined, no micronutrients deficiency symptoms were observed during the course of the experiment.

CONCLUSIONS AND RECOMMENDATIONS

Field trials were conducted to investigate the response of sugarcane plant and its first ratoon to potassium and phosphorus fertilizers. The attained results revealed the following:

1. Application of potassium and phosphorus fertilizers affected growth parameters of both plant cane and ratoon positively, particularly early in the growing season but slightly as the growing season proceeded.
2. Cane yield of plant cane and ratoon grown on Dinder series was increased significantly due to potassium and phosphorus fertilizers. Differential effects were observed on plants grown on Nasr and Hagu series where the plant cane was insignificantly affected while the ratoon responded well, particularly, to the added potassium and phosphorus. However, Dinder series showed the highest response to fertilization treatments.
3. It was evident that variety Co 6806 gave better response to treatments.

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