Response of sugarcane ratoons to nitrogen rates and methods of application in Guneid Sugar Scheme, Sudan

Salaheldin A. Mukhtar
salahamukhtar@hotmail.com
Sugarcane Research Center-Guneid, Sudan.

ABSTRACT

Three experiments were conducted during the periods 2007 to 2013 at the farm of the Sugarcane Research Center-Guneid (SCRCG), Sudan. The objective was to investigate the response of sugarcane ratoon crops to different rates of nitrogen in the form of urea in addition to splitting the rate during the long season of sugarcane crop. The first experiment included 150, 200 and 250 kg urea/feddan (feddan, f=4200m^2). Treatments in the second experiment were zero, 50, 100, 150 and 200 kg urea/ f, while the third experiment consisted of zero, 100, 150, 175 and 200 kg urea/f, for the first, second and third ratoons. The treatments of the second experiment were coupled with splitting the dose of urea *versus* the full dose (two thirds at the age of 20 to 30 days; and one third at the age of three to four months). Treatments were laid out in a randomized complete block design with four replicates in experiment I and III and a factorial arrangement for experiment II with four replicates. The results revealed that there were no significant differences in yield components and total cane yield of the ratoon crop between the rates of nitrogen of the first experiment. In the second experiment, yield components and total cane yield increased significantly for rates of urea from zero to 100, 50 to 150 and 100 to 200 kg urea/ f. In the third experiment, only cane yield increased with the increase of N rate but significant only between zero and 150 to 200 kg urea/f in the first ratoon, zero and 100 to 200 kg urea /f in the second ratoon, and zero and 100; 100 and 150 to 200 kg urea/f in the third ratoon. Brix, pol% cane and ERS%, decreased significantly with the increased rate of N in all experiments. No significant differences in yield and quality parameters were found in response to splitting the rate of N. The rates of 150 and 200 kg urea/f seemed satisfactory for both cane and sugar yields for the ratoon crops. However, under field conditions where many factors interact it is seen as advisable to have some N reserves. In this sense, 200 kg urea /f is recommended as the dose to be endorsed as an official dose for the ratoon crops in the Guneid Sugar Scheme.

INTRODUCTION

In the Sudan, sugarcane is grown mainly in soils of the central clay plain (Vertisols) which are characterized by moderate chemical fertility, high contents of smectitic clays, high pH values, low N and organic matter. The N content of these soils ranges from 300-450 mg kg soil^{-1} (Idris, 2001).
In the cultivation of sugarcane, ratoons comprise more than 75% of the annually harvested crop. Moreover, ratoons have the advantages of lower cost, better cane quality and occupy the land for a shorter time compared to those of the plant cane crop; usually, 12 to 13 months compared to 14 to 18 months.

Urea is the main source of nitrogen fertilizer for sugarcane and other crops in the Sudan, therefore, determining the optimum rates of this fertilizer is justifiable because of its escalating prices, high cost of transport, storage and application. The application of urea for ratoons in Sudan is carried out as early as one to 30 days of cane age, followed by split ridging or ripping and, hence, automatically the urea is covered and mixed with the soil.

It is well known that nitrogen is vital for plant growth and is also necessary for development of primary shoots, tillers, and stalks. Thus increase in N fertilizer increases the number of millable stalks, plant height, cane and sugar yields until an optimum is reached, beyond which all these parameters are negatively affected (Dillewijn,1952; Sreewarmore *et al*., 2007). However, plant cane crop responds weakly response to the added nitrogen fertilizer (Mukhtar *et al.*, 2009).

Split application of N for sugarcane is practiced in areas with longer season crops such as Hawaii (Humbert, 1968). However, it has little advantage over a full dose. This is because sugarcane uptakes nitrogen during the first few months of age in amounts more than needed (luxury consumption) and is stored to be used lately during the "boom stage of growth" (Humbert, 1968). Moreover, split application has the disadvantages of increased cost and the ill effect of additional movements of machines in the fields (Barnes, 1974; Rao *et al*., 1975; Achieng *et al*., 2013).

Mohamed (1990), by applying N fertilizer rates of 0N to 8N on the ratoon cane, showed that cane yield significantly increased in response to rates of N fertilizer levels from 0N to 5N, with the highest yields were obtained at 4 N (72 kg N /f or 156 kg urea/f) and 5N (90 kg N/f or 195 kg urea/f). He recommended that the rate of 4 N is the optimum dose for the first ratoon.

Ali (2007) reported no significant differences in cane yields between rates from zero up to 115 kg N /feddan on the ratoon crop but numerically the cane yields recorded under 69, 92 and 115 kg N/feddan were the highest.

In contrast to cane yield, Ali (2007) stated that sugar yields were highest at the lower N rates (i.e. 46 and 69 kg N/f). Therefore, he recommended 69 N kg /f for ratoon cane which is equivalent to 150 kg urea /f at the Dinder clay of Kenana Sugar Estate. It is also reported that increase in N rate resulted in the decrease of each of pol % and ERS (%) cane and the quality of cane in general (Dillewijn,1952; Humbert,1968; Rattey and Hogarth, 2001; Kennedy *et al*., 2004 and Ali, 2007). However, field inspectors and cane growers believe that addition of more N always results in more cane yields. They observed that when they occasionally added extra doses of N fertilizer to their cane, i.e., above 200 kg urea per feddan, they got higher yields.

The present study was aimed to determine the optimum rate of nitrogen, (in the form of urea) and to investigate the effect of splitting the rate for the ratoon crops under the conditions of Guneid Sugar Scheme.

MATERIALS AND METHODS

The present research was conducted at the farm of the Sugarcane Research Centre-Guneid (SCRCG) which lies at the intersection of latitude 14° 52′ N and longitude 33° 19′ E. The soils belong to Remaitab soil series which has high clay content (about 40%), high pH values, low N and organic matter. Total N ranges from 300-450 mg kg soil^{-1} (Idris, 2001). These soils were classified as

Haplusterts, fine, smectitic, isohyperthermic (Soil Survey Staff, 1999). The land suitability subclass was S2v, i.e., moderately suitable land with vertisolic limitation (Van der Kevie, 1976).

Three field experiments, at three different sites of the farm of the SCRCG, each was performed in three consecutive seasons to include the first, second and third ratoons. The main objective was to find the optimum N rate for the ratoons of sugarcane in Guneid Sugar Scheme.:

1) Experiment I

This experiment was started after harvest of the plant cane crop (PC) at one site of the farm of the SCRCG and continued for three consecutive seasons (2007/08, 2008/09 and 2009/010). It included the first, second and third ratoons. The experiment was comprised of three rates of urea, i.e.150, 200 and 250 kg urea/f.

2) Experiment II

This experiment was also carried out at a second site of the farm of the SCRCG in seasons 2007/08, 2008/9 and 2009/010. It started from the first ratoon up to the third ratoon crops. The N rates were 0, 50, 100, 150 and 200 kg urea/f neglecting the 250 kg urea/f which was included in the first experiment. Each rate was split-applied; two thirds were applied after 20 to 30 days from the first irrigation and the remaining third of the dose was added at 4 to 5 months of cane age.

3) Experiment III

This experiment was conducted in seasons 2011/012, 2012/013 and 2013/014 at a third site in the farm of the SCRCG. It covered the first second and third ratoons. The idea was to verify the results of the two previous experiments and to separate the obtained similar responses between each of the 100 and 150kg urea/f and that between 150 and 200 kg urea/f. Therefore another dose was added, i.e.175 kg urea/f. The new rates of urea in this experiment were zero, 100, 150, 175 and 200 kg urea/f.

According to the number of factors in each experiment, treatments were laid out in a randomized complete block design for experiment I and III and two-factor factorial arrangement for experiment II with four replicates. The experimental plots were four rows; each row was 10 m long and 1.5 m apart. The test crop was the sugarcane variety Co 6806 which is dominating the sugar estates in the Sudan.

The adopted husbandry practices in the sugarcane estates for the ratoon cane crop were closely followed. Urea was applied at both sides of the row of cane plants, similar to machine application, when the cane was 20-30 days old as has been practiced in the commercial cane fields. In plots where splitting was assigned, ⅔rd of the dose was applied when the cane was 20 to 30 days old and the remainder was applied when the cane was three to four months old. The number of millable stalks, stalk height and yield of cane were recorded at harvest. All millable stalks in the two inner rows were counted, manually cut by cane knives, topped, cleaned from dead leaves and trash, weighed and the cane yield per feddan was calculated. Methods of measuring these parameters were according to those described by Clements (1980).

For cane quality determination, 10 stalks from the two inner rows were randomly taken from each experimental plot at harvest and the following quality parameters were determined according to the International Commission for Uniform Methods of Sugar Analysis (ICUMSA, 1994):

1. Brix (%) cane (total soluble solids). 2. Pol (%) cane {sucrose (%) of cane}. 3. Fiber (%) cane. 4. Estimated recoverable sugar (ERS) (%).

Sugar yield in tons of sugar per feddan (TS/f) was calculated as follows: ERS (%) x yield of cane (ton cane /f).

RESULTS AND DISCUSSION

In experiment I, results showed insignificant increases in cane yield from 150 to 200 and from 200 to 250 kg urea/ f in the first ratoon of season 2007/08. Number of millable stalks and millable stalk height were inconsistent and insignificant (Table 1). For the second and third ratoon crops, cane yield, number of millable stalks and stalk height were relatively similar and inconsistent (Tables 2 and 3). In contrast, there was consistent and sometimes a significant decrease in the ratoon crops of experiment I in quality parameters such as brix (%) cane, pol (%) cane and ERS (%), with the increase of N rate from 150 to 200 and from 200 to 250 kg urea/ f. Sugar yield, a product of cane yield and ERS, showed similar results for the three rates of N in the ratoons for experiment I (Tables 1, 2 and 3).

In experiment II, results differed from those of the first experiment, probably because lower rates of urea were used (Tables 4, 5 and 6). Yield of cane, number of millable stalks and sometimes stalk height, increased with the increase of rate of urea from zero up to 200 kg urea/f in the first, second and third ratoon, but these increases were insignificant between zero and 50; 50 and 100; 100 and 150 and 150 and 200 kg urea/f. Experiments I and II complemented each other and denoted that the increase in N rates, increased yield parameters up to a certain level. This level that caused the maximum increase was 150 to 200 kg urea/f. It is well known that increase in N fertilizer increases the number of millable stalks, plant height, cane and sugar yields until an optimum is reached (Dillewijn, 1952; Sreewarmore *et al.*, 2007). However, the present results have refuted the beliefs of cane growers and field inspectors who opine that more N fertilizer results in more cane yield.

Table 1. Effect of rates of urea on yield, yield components and quality of sugarcane, 1st ratoon, season 2007/08.

Parameters	Rates of urea (kg/f)			S.E (±)	C.V. (%)
	150	200	250		
Stalk height (cm)	300.0	294.6	288.3	3.07	3.0
No. of millable stalks/f	58433	63875	62522	1583	7.3
Yield of cane (ton/f)	69.7	71.6	74.9	1.51	5.9
Brix (%) cane	17.7	17.3	17.0	0.16	2.7
Pol (%) cane	15.6	15.2	14.8	0.15	2.8
ERS (%) cane	12.2	11.7	11.4	0.22	5.3
Fiber (%) cane	18.3	17. 6	17.7	0.47	7.4
TS (ton/f)	8.5	8.4	8. 6	0.23	7.6

Table 2. Effect of rates of urea on yield, yield components and quality of sugarcane, 2nd ratoon, season 2008/09 (established in February 2008).

Parameters	Rates of urea (kg/f) 150	200	250	S.E (±)	C.V. (%)
Stalk height (cm)	224.0	216.0	213.5	4.21	5.47
No. of millable stalks/f	54040	56280	56753	1323	6.72
Yield of cane (ton/f)	51.5	52.5	51.o	1.37	7.51
Brix (%) cane	18.6	18.5	18.4	0.14	2.07
Pol (%) cane	14.5	14.4	14.1	0.13	2.65
ERS (%) cane	12.5	12.4	12.1	0.14	3.29
Fiber (%) cane	15.5	15.0	15.8	0.24	4.41
TS (ton/f)	6.4	6.5	6.2	0.20	8.72

Table 3. Effect of rates of urea on yield, yield components and quality of sugarcane, 3rd ratoon, season 09/2010 (established in March 2009).

Parameters	Rates of urea (kg/f) 150	200	250	S.E (±)	C.V. (%)
Stalk height (cm)	185.2	186.1	183.0	2.13	3.3
No. of millable stalks/f	62388	60393	58503	908	4.3
Yield of cane (ton/f)	48.0	48.7	48.8	0.72	4.2
Brix (%) cane	18.1	17.7	17.7	0.15	2.4
Pol (%) cane	15.2	15.0	14.8	0.07	1.3
ERS (%) cane	12.2	12.0	11.8	0.07	1.7
Fiber (%) cane	16.6	17.0	16.8	0.30	5.1
TS (ton/f)	5.9	5.8	5.7	0.10	4.6

The data in each of Tables 4,5 and 6 did not show any significant differences in each of number of millable stalks, stalk height, yield of cane and in any of the tested quality parameters between

applying N in a single application or applied in a split dose. This result was in conformity with that of Barnes (1974), Rao *et al*. (1975) and Achieng *et al.* (2013) who stated that split application of N fertilizer has little advantage over a full dose. They added that split application has the disadvantages of increased cost and the damage caused by additional movements of machines in the field.

Quality parameters of experiment II have the same trend as recorded for the previous experiment, i.e., decreasing consistently and more often significantly with increasing rate of urea up to 200 kg urea/f. Sugar yield (TS), was significantly higher only at the rate of 200 kg urea /f for the three studied ratoons (Tables 4, 5 and 6). However, responses to 100 and 150 kg urea/f and those of 150 to 200 kg urea/f were similar. That is why the third experiment was conducted, in which a rate of 175 kg urea /f was introduced. However, the results matched those of the forecited two experiments, i.e. experiment I and II (Tables 7, 8 and 9). Number of millable stalks and cane yield which were significantly different only from 0.0 N rate but they were fluctuating, for higher N rates. This was also the case for sugar yield. however, quality characters showed inconsistent numerical values.

Table 4. Effect of rates of urea, split or full dose, on yield, yield components and quality of sugarcane , 1st ratoon, season 2007/08.

Parameter	Rates of urea (kg/f)					S.E. (±)	Split	Full	S.E. (±)	C.V. (%)
	00	50	100	150	200					
Stalk ht (cm)	224.5	226.1	224	230.9	232.6	6.9	227.8	227.4	4.4	8.6
No. of stalks/f	56228	57429	61618	62983	66188	1397	61549	60221	883	6.5
Yield (ton /f)	44.7	45.99	49.24	52.9	55.4	1.73	49.6	49.7	1.1	9.9
Brix (%)	17.2	17.3	16.7	16.6	17.2	0.12	17.06	17.0	0.08	2.1
Pol (%)	15.3	15.1	14.2	14.3	14.8	0.15	14.78	14.7	0.10	2.4
ERS (%)	11.7	11.4	10.7	10.6	11.0	0.16	11.13	11.0	0.10	4.0
Fiber (%)	16.7	16.5	17.0	16.6	15.7	0.41	16.55	16.5	0.26	7.0
TS (ton/f)	5.2	5.2	5.3	5.6	6.1	0.22	5.5	5.5	0.14	11.1

Parameter	Rates of urea (kg/f) 00	50	100	150	200	S.E. (±)	Split	Full	S.E. (±)	C.V. (%)
Stalk ht (cm)	178.3	180.9	100	1179.5	186.9	5.2	183.7	178.2	3.29	8.1
No. of stalks/f	44555	50978	179.7	54635	59395	1980	53046	53074	1253	10.6
Yield (ton /f)	28.4	34.1	55738	42.9	46.5	1.6	38.2	38.1	1.03	12.1
Brix (%)	18.6	18.9	38.8	18.5	18.3	0.09	18.6	18.6	0.06	1.3
Pol (%)	14.3	14.5	18.8	14.3	14.0	0.12	14.2	14.2	0.08	2.4
ERS (%)	12.3	12.5	14.2	12.3	12.0	0.13	12.3	12.2	0.08	3.0
Fiber (%)	14.9	14.4	12.2	15.0	14.9	0.24	14.7	14.7	0.15	4.6
TS (ton/f)	3.5	4.3	14.2	5.3	5.6	0.20	4.7	4.7	0.12	11.9

Table 5. of rates of urea, split or full dose, on yield, yield components and quality of sugarcane, 2nd ratoon, season 2008/09, (established January 2008

Table 6. Effect of rates of urea, split or full dose, on yield, yield components and quality of sugarcane 3rd ratoon, season 09/2010,(established February 2009).

Parameter	Rates of urea (kg/f) 00	50	100	150	200	S.E. (±)	Split	Full	S.E. (±)	C.V. (%)
Stalk ht (cm)	164.8	169.9	182.2	183.4	184	5.17	180.0	173.7	3.27	8.3
No. of stalks/f	46760	52658	57698	58835	66465	1917	57259	55671	1212	9.6
Yield (ton /f)	28.5	32.5	40.2	43.7	47.0	1.79	38.5	38.2	1.13	13.2
Brix (%)	18.2	18.3	18.3	18.4	18.3	0.14	18.4	18.2	0.09	2.2
Pol (%)	15.2	15.2	15.2	15.2	15.2	0.12	15.2	15.2	0.07	2.2
ERS (%)	12.2	12.2	12.2	12.2	12.2	0.12	12.2	12.2	0.07	6.2
Fiber (%)	16.1	15.7	15.6	15.3	15.8	0.34	15.4	16.0	0.22	2.7
TS (ton/f)	3.5	4.0	4.9	5.3	5.7	0.21	4.7	4.7	0.13	12.8

The results of the three experiments indicated that the response of the ratoon cane to N rate in terms of cane yield and number of millable stalks was higher than those reported for plant cane to N fertilizer (Mukhtar *et al.*, 2009), a finding that was in conformity with that of Mohamed (1990) and Wiedenfeld (1997).

The results also indicated a decrease of each of pol (%) and ERS (%) cane with the increase of N rate in the three experiments similar to the reported trend of the decreased quality of cane in response to increased N fertilizer (Dillewijn, 1952; Humbert, 1968; Rattey and Hogarth, 2001; Kennedy *et al*., 2004 and Ali, 2007).

In conclusion, all the three experiments of this study, showed that cane and sugar yields were best and stable at 150 to 200 kg urea/f. It is thus recommended that under field conditions, where many factors interact, the 200 kg urea/f is suitable for the ratoon crop of sugarcane.

Table 7. Effect of rates of urea on yield, yield components and quality of sugarcane, first ratoon, season 2011/012.

Parameter	Rates of urea (kg/f) 0.0	100	150	175	200	S.E. (±)	C.V. (%)
Stalk ht (cm)	241.1	252.8	256.5	250.2	239.2	9.04	7.3
No. of stalks/f	52974	57472	5628	51728	59125	4211	15.2
Yield (ton /f)	48.6	59.1	63.5	61.7	66.0	4.23	14.2
Brix (%)	17.2	16.8	16.8	16.6	16.9	0.24	2.9
Pol (%)	14.4	14.0	14.3	13.8	14.1	0.23	3.2
ERS (%)	11.4	11.0	11.3	10.8	11.1	0.23	4.1
Fiber (%)	16.9	16.5	16.8	16.7	16.3	0.63	7.6
TS (ton/f)	5.6	6.5	7.2	6.7	7.3	0.48	14.4

Table 8. Effect of rates of urea on yield, yield components and quality of sugarcane, 2nd ratoon, season 2012/013.

Parameter	Urea rates (kg/fed.) 0.0	100	150	175	200	S.E. (±)	C.V. (%)
Stalk ht (cm)	213.0	239.6	238.5	232.2	238.0	7.2	6.3
No. of stalks/f	56063	65412	63705	68257	65412	2642	10.3
Yield (ton/f)	29.5	45.1	43.1	44.7	46.9	2.14	9.3
Brix (%)	17.7	17.7	17.7	17.9	17.6	0.25	4.2
Pol (%)	15.1	15.6	15.4	15.9	15.0	0.19	3.6
ERS (%)	12.1	12.6	12.4	12.9	12.0	0.19	4.5
Fiber (%)	17.1	17.7	18.2	17.4	16.8	0.82	12.0
TS (ton/f)	3.6	5.7	5.3	5.8	5.64	0.28	10.3

Table 9. Effect of rates of urea on yield, yield components and quality of sugarcane, 3rd ratoon, season 2013/014.

Parameter	Rates of urea (kg/f) 0.0	100	150	175	200	S.E. (±)	C.V. (%)
Stalk ht (cm)	161.2	168.7	165.8	167.9	170.6	4.68	6.3
No. of stalks/f	60047	60534	57474	62133	59613	2765	10.3
Yield (ton/f)	31.6	33.6	35.1	36.6	38.7	1.4	9.3
Brix (%)	17.3	18.0	17.7	17.4	17.3	0.33	4.2
Pol (%)	15.0	15.1	14.9	14.8	15.0	0.24	3.6
ERS (%)	12.0	12.1	11.9	11.8	12.0	0.24	4.5
Fiber (%)	17.9	16.3	16.6	17.9	17.9	0.93	12.0
TS (ton/f)	3.8	4.1	4.2	4.3	4.6	0.19	10.3

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إستجابة خلف قصب السكر لجرعات من النيتروجين وطرق الإضافة في مشروع سكر الجنيد، السودان

صلاح الدين عبدالقادر مختار
مركز بحوث قصب السكر-الجنيد، السودان

الخلاصة

أجريت ثلاث تجارب (I و II و III) بمزرعة مركز بحوث قصب السكر- الجنيد، السودان خلال المواسم 2007 إلى 2013. هدفت الدراسة لبحث إستجابة محاصيل خلف قصب السكر لجرعات مختلفة من السماد الآزوتى (النيتروجين) في شكل يوريا، إضافة لتقسيم الجرعات خلال الموسم الطويل لقصب السكر. تضمنت التجربة الأولى الجرعات150 و200 و250 كجم يوريا للفدان (الفدان=4200م^2). وكانت معاملات التجربة الثانية صفر و50 و100 و150 و200 كجم يوريا للفدان. بينما كانت معاملات التجربة الثالثة 100 و150 و175 و200 كجم يوريا للفدان. أجريت كل التجارب للخلفة الأولى والثانية والثالثة. أضيفت معاملة تقسيم الجرعة إلى معاملات التجربة الثانية حيث أضيفت ثلثا الجرعة في عمر خلفة القصب من 20 إلى 30 يوم و أضيف الجزء الأخير من الجرعة في عمر 3 إلى 4 شهور. وقد أستخدم تصميم القطاعات العشوائية الكاملة مع أربعة مكررات في التجربة I وIII وتصميم عاملين بأربعة مكررات للتجربة II. أبانت النتائج عدم وجود إختلافات معنوية في إنتاجية القصب ومكوناتها لجرعات اليوريا 150 و200 و250 كجم للفدان للخلفة الأولى والثانية والثالثة للتجربة الأولى. وفي التجربة الثانية، زادت إنتاجية القصب ومكوناتها معنويا بزيادة الجرعة من صفر إلى 50 و100 و150 و200 كجم يوريا للفدان. بينما زادت فقط إنتاجية القصب في التجربة الثالثة بزيادة جرعة اليوريا ولكن كانت الزيادة معنوية فقط بين جرعة صفر و150 إلى 200 كجم للفدان في الخلفة الأولى، وبين صفر و100 إلى 200 كجم للفدان في الخلفة الثانية، وبين صفر و100 كجم للفدان، وبين 100 و150 و200 كجم للفدان في الخلفة الثالثة. نقصت مؤشرات جودة قصب السكر بصورة معنوية و أحيانا بصورة غير معنوية، بزيادة جرعة اليوريا بصورة عامة في كل الدراسة. لم تحدث فروقات معنوية في مكونات جودة وإنتاجية القصب في معاملة تقسيم الجرعة مقارنة مع إضافتها كاملة. في هذه الدراسة بدت الجرعتان 150 و 200 كجم يوريا للفدان مناسبتان لإنتاجية القصب والسكر لخلفات قصب السكر. إلا أنه في ظروف الحقل تتداخل عوامل كثيرة و يعتقد أنه من الأوفق أن يكون هنالك زيادة إحتياطية من عنصر السماد النيتروجيني. وعليه يوصى بتبني جرعة 200 كجم يوريا للفدان لتطبق أساساً على محاصيل خلفات قصب السكر في مشروع سكر الجنيد بالسودان.