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By

Salaheldin A. Mukhtar
Adam I. Adam
Abu Elhassan S. Ibrahim

Research Article

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Salaheldin A. Mukhtar*[1], Adam I. Adam[2] and Abu Elhassan S. Ibrahim[3]

[1]Sugarcane Research Center-Guneid, Sudan.
[2]Faculty of Agriculture and Natural Sciences, University of Sinnar, Sudan.
[3]Faculty of Agricultural Sciences, University of Gezira, WadMedani, Sudan.

*Corresponding Author's Email: salahabdulgadir@gmail.com

ABSTRACT

This study is based on two previously conducted experiments that were carried out to conserve urea-N. The first was planted October 2005, established for the first and second ratoon during seasons 2007 to 2009; and the second was planted in June 2006 and established for the first ratoon during the season 2007/2009. The treatments of the basic experiments were 357.1 and 535.7 kg urea /ha. Conserving treatments were splitting the dose of urea versus the full dose and burying the urea versus unburied urea treatments. Results of the basic experiments showed no significant differences between any of the used treatments.

The current study consisted of one treatment to all experimental units of the basic experiments. These treatments were application of 238.1 kg urea/ha for June planted cane basic experiment in the second ratoon (season 2009/2010). For both basic experiments, June and October plantings, no urea application in the third ratoon (seasons 2009/2010 and 2010/2011), and application of the normal rate of urea (usually given to the commercial cane fields i.e. 476.2 kg urea/ha) in the forth ratoons (seasons 010/2011 and 2011/2012). The objective of the current study was to investigate the response of the sugarcane crop to the residual N effect of previously conserved treatments of urea in the basic experiments after plant cane, first and second ratoons.

The results of the current study revealed that there were no significant differences in cane yield, yield components of the ratoon crops for the residual N effects of previous conserved urea-N treatments of the basic experiments. However, yield and yield components of no urea treatments showed very low values possibly due to effects of N deficiency on the sugarcane crop. Moreover, application of half the normal commercial crop urea rate, i.e. 238.1 kg /ha, gave moderate yield and yield components. Finally, in application of the common commercial urea rate, i.e. 476.2 kg/ha, the sugarcane crop attained satisfactory yields and yield components. The quality parameters, namely brix, pol and ERS percentages of cane, were not affected with treatments.

The current study confirmed the reported low residual effects of N fertilizers on subsequent crops even if it contained a conserving practice such as burying the urea or splitting the rate. It is thus recommended that at every growing season the sugarcane crop should receive the adequate rate of N fertilizer.

Keywords: N fertilizer, urea, residual effect, sugarcane, plant cane, ratoons, pol, brix, ERS.

INTRODUCTION

Nitrogen is the most used essential macronutrient in modern agriculture. However, in the soil, N is subjected to biological immobilization and chemical losses, and hence it has been regarded as an unpredictable nutrient element (Viets, 1965). In this respect, Havlin et al. (1999) reported that long-term residual benefits of N are usually not well recognized like those of P and K. However, Wood (1989) reported some residual behaviour of N fertilization to sugarcane: the first ratoon crop may get about 6% of the previously applied N from an ammonium source. Humbert (1968) reported that under N deficiency, sugarcane growth, cane and sugar yields will be greatly decreased. On the other hand, Dharmawardene and Keerthipala (2005) reported that excessive application of N fertilizers have ill-effects on sugarcane quality.

Cultivation of sugarcane usually proceeds for several ratoons. These ratoons with their relatively low cost and high sugar content have the importance and generally receive a great attention because over 75% of the annually harvested cane in Sudan comes from ratoons.

The current study was based on two previous experiments (2006-2009) carried out on sugarcane planted on the Sugarcane Research Center-Guneid farm, Sudan (Mukhtar et al., 2009, 2011). These experiments will be designated as the basic experiments throughout the current study. Treatments of the basic experiments targeted to conserve the applied urea-N and minimize losses through splitting the rate and burying urea with a thin layer of soil. Since there were no significant differences between treatments of the basic experiments, it is postulated that some urea-N is probably conserved in the soil. It is then assumed that the residual N per se with small additional N dose may be adequate for the coming ratoon crop.

Thus the objective of the current study was to investigate the effect of residual N from the previously mentioned treatments on the ratoon crops. For this purpose, no N will be applied in the first season in one experiment, half the recommended dose of N will be applied in the second experiment. After that the normal dose of N will be applied in the third season.

MATERIALS AND METHODS

The two basic experiments were conducted at the Sugarcane Research Centre, Guneid farm, Gezira State, Sudan, within the intersection of latitude 14º 52′ N and longitude 33º 19′ E during 2005-2008. The site is located in the central clay plain of Sudan. Soils of this plain are mostly Vertisols whose salient properties are moderate chemical fertility, high contents of smectitic clays, alkaline soil reaction (pH values from 7.5 to 8.5), low organic matter (< 1%), low N and phosphorus. Available N ranged from 0.03 to 0.045% (Idris, 2001).

In the basic experiments, sugarcane was planted in two different planting dates:

1- The first experiment was planted in October 2005 (October planting), proceeded for two ratoons, the first ratoon was cropped in the season 2007/2008 and the second ratoon was cropped in the season 2008/2009.
2- In the other experiment sugarcane was planted in June 2006 (June planting), and proceeded for the first ratoon which was cropped in the season 2008/2009.

For both October and June plantings plant cane and ratoons the following treatments were given:

1- Urea rates: 358.6, 538kg/ha;
2- Splitting the rate, in half of the experimental units, applying 2/3rd of the rate at 50 to 60 days after planting and applying the last part at five months of cane age. In the other half of the experimental units, the rate of urea was applied in a full single application.
3- Burying the urea with a thin layer of soil and leaving half of the plots unburied (buried and unburied treatments). The above treatments with their interactions comprised 8 treatments, i.e., 2 X 2 X 2. The treatments were laid out in a randomized factorial complete block design with four replicates.

The current experiments were conducted as a continuation of the crop cycles of both basic experiments, immediately after harvesting of the second ratoon of October planting and harvesting the first ratoon of June planting. Moreover, it is noteworthy to say that the current study consisted of one treatment to all experimental units of every basic experiment.

A. October planting (February 2009- March 2011): Applications of treatments were done in the 3rd and 4th ratoons after the PC, 1st and 2nd ratoons of the first basic experiments as follows:

1. For the 3rd ratoon crop (season 2009/2010): No application of urea was performed, i.e., the experiment was just left to use the expected residual effects of urea-N of the first basic experiments.
2. For the forth ratoon crop (season 2010/2011): A single rate of 478.2 kg/ha (the normal dose for the commercial cane fields) was applied.

B. June planting (January 2009 - March 2012): Urea was applied to the 2nd, 3rd and 4th ratoons after the plant cane and the first ratoon of the second basic experiment as follows:

1. Application of a 239.1 kg urea/ha (half of the normal commercial dose) (Mukhtar: personal communication) to the 2nd ratoon (season 2009/2010) followed by:
2. No application of urea-N to the third ratoon (season 2010/2011), followed by:
3. Application of the common commercial rate of 478.2 kg/ha to the fourth ratoon (season 2011/2012).

Table 1: Crop categories, planting dates, ratoon establishment dates, harvesting dates and treatments of the basic and the current experiments.

	Crop category	Experiment I (November planting)			Experiment I (June planting)		
Basic Experiments		Planting date	Harvesting date	Treatments	Planting date	Harvesting date	Treatments
	P. C.	Nov. 2005	Jan. 2007	Urea Rates: 358.6, 538kg/ha; Splitting and burying	June 2006	Nov. 2007	Urea Rates: 358.6, 538kg/ha; Splitting and burying
	R1	Jan. 2007	Feb. 2008	Urea Rates: 358.6, 538kg/ha; Splitting	Nov. 2007	Dec. 2008	Urea Rates: 358.6, 538kg/ha; Splitting
	R2	Feb. 2008	March 2009	Urea Rates: 358.6, 538kg/ha; Splitting and			
Current Experiments	R2				Jan. 2009	Feb. 2010	239.1 kg/ha for all units
	R3	Feb. 2009	March 2010	No application of urea (residual effects)	Feb. 2010	March 2011	No application of urea (residual effects)
	R4	March 2010	April 2011	Application of normal rate of urea: 478.2 kg/ha.	March 2o11	April 2012	Application of normal rate of urea: 478.2 kg/ha..

P.C.: Plant cane crop. R1: First ratoon crop. R2: Second ratoon crop. R3: Third ratoon crop. R4: Fourth ratoon crop

Table 1 specifies the crop categories, planting dates, ratoon establishment dates, harvesting dates and treatments of the basic and the current study experiments.

The experimental unit was chosen to be four rows; each was 1.5 m apart and 10 m long. The sugarcane variety Co 6806 which is dominating the sugar estates in Sudan (> 90% of the cultivated area) was selected as a test crop. The normal cane husbandry was carried out throughout the growing seasons such as ripping, irrigation and weeding. The number of millable stalks, stalk height and yield of cane were taken as quantitative yield components. Methods for sampling were those described by Clements (1980). Qualitative yield components comprised of brix% cane (total soluble solids), pol% cane (sugar content of cane), ERS% (estimated recoverable sugar) and TS/ha (ton sugar/ha). Quality of the cane was determined according to the International Commission for Uniform Methods of Sugar Analysis (ICUMSA) (1979).

Statistical Analysis: The analysis of variance procedure was used to test differences among the means of the basic treatments in each ratoon separately.

RESULTS AND DISCUSSION

Some agronomic and quality parameters are presented in Tables 2, 3, 4, 5 and 6 and Figures 1 and 2. It is noteworthy that the tables are presenting the main effects of the treatments only because interactions are not significant. Table 2 and 3, where no urea was applied in the two experiments, showed that there were neither significant differences between agronomic nor between quality parameters as a result of the residual effect of urea-N applied to the basic experiments; neither for urea rates, for splitting versus the full single dose, or for burying of the urea versus no burying. However, all yield components showed very low values (e.g. cane yield was 60.5 to 71.2 ton cane/ha respectively) compared to the basic experiments (Figure 1 and 2). This was presumably denoting the probable effect of nitrogen deficiency on cane growth and yield caused by the treatment of no urea application of the current experiments. This N deficiency was reflected in poor cane growth and low yield that has been documented by Humbert (1968). The present data also confirmed the statement of Havlin et al. (1999) who has reported that N fertilizers have low residual effect on succeeding crops. Moreover, this study added that this residual effect of N fertilizer will be low even if it contained a conserving treatment.

However, quality parameters were not affected by non application of urea-N. Surprisingly enough, they showed adequate measurements. It is reported that N fertilizers negatively affect sugar content of sugarcane specially when applied at high rates or when applied late in the growing season (Dharmawardene and Keerthipala, 2005). In the light of this statement, the ineffectiveness of the low N on quality parameters in this study can be understood.

Table 4 also showed that there were neither significant differences between agronomic nor between quality parameters for the previous treatments of the second basic experiment (plant cane of June planting) currently treated with 239.1 kg urea-N/ha. No significant differences showed between treatments of either urea doses, splitting the dose versus the full application of the dose or for burying the urea versus the unburied urea treatments. However, all yield components showed moderate values (e.g., yield was 95 to 105 ton cane/ha) compared to no urea application (Tables 2 and 3). This was presumably due to the application of the half of the common commercial dose rather than residual effect of urea-N of the basic experiments.

Table 2: Effect of no urea (residual urea-N) following urea application to the first basic experiments (October planting), on yield and quality components of sugarcane. Guneid 3rd ratoon, February 2009-March 2010[1].

Character	Urea (kg/ha)		Split	Full	Buried	Unburied	S.E. (±)	C.V. (%)
	358.6	538						
Stalk height (cm)	173.4	171.5	174.2	170.8	172.0	172.9	3.46	8.0
No. of millable stalks	112833	111250	111229	112855	110583	113500	552	4.7
Cane yield (ton/ha)	60.7	62.6	62.4	61.0	60.5	62.9	0.6	9.3
Brix% cane	17.4	17.4	17.4	17.5	17.4	17.5	0.12	2.8
Pol% cane	15.1	14.8	14.9	14.9	15.0	14.9	0.12	3.1
Fiber% cane	16.8	16.7	16.8	16.6	17.2	16.2	0.41	9.8
ERS%	12.1	11.8	11.9	11.9	12.0	11.9	0.12	3.9
Sugar yield (ton/ha)	7.34	7.39	7.43	7.26	7.26	7.49	0.02	9.5

[1] The named treatments were for basic experiments of PC, 1st and 2ndratoons application.

Table3: Effect of no urea (residual urea-N) following urea application to the second basic experiment (June planting), on sugarcane yield and quality components, 3rd ratoon, Guneid, Season: February 2010-March 2011[1].

Character	Urea (kg/ha)		Split	Full	Buried	Unburied	S.E (±)	C.V. (%)
	358.6	538						
Stalk height (cm)	183.3	187.2	186.7	183.8	187.3	183.2	2.19	9.0
No. of millable stalks	120710	116960	113917	123750	118376	119293	1059	10.2
Cane yield (ton/ha)	69.8	71.0	70.2	70.5	71.2	69.5	0.72	15.7
Brix% cane	17.2	17.2	17.1	17.3	17.2	17.1	0.09	2.9
Pol% cane	14.7	14.61	14.64	14.63	14.62	14.65	0.06	2.7
Fiber% cane	17.51	17.43	17.55	17.19	17.37	17.38	0.29	9.6
ERS%	11.62	11.61	11.60	11.63	11.58	11.65	0.06	3.4
Sugar yield (ton/ha)	8.11	8.24	8.14	8.2	8.24	8.1	0.09	16.9

[1] The named treatments were for basic experiments of PC, 1st and 2ndratoons application.

Table 4: Effect of application of 238.1 kg urea/ha following application of urea-N to the second basic experiments (June planting) on sugarcane yield and quality. 2nd ratoon, Guneid, Season: Jan. 2009-Feb. 2010[1].

Character	Urea (kg/ha)		Split	Full	Buried	Unburied	S.E (±)	C.V. (%)
	358.6	538						
Stalk height (cm)	183.1	185.1	184.6	183.6	186.1	182.1	4.84	10.5
No. of millable stalks	144543	139188	142083	141645	142479	141250	1335	9.0
Cane yield (ton/ha)	97.9	97.6	94.8	100.7	97.6	97.9	0.93	9.1
Brix% cane	16.7	17.0	16.8	16.8	16.9	16.8	0.15	2.5
Pol% cane	13.2	13.3	13.2	13.2	13.2	13.3	0.11	4.5
Fiber% cane	16.9	16.4	16.2	17.1	16.2	17.1	0.29	6.9
ERS%	11.1	11.2	11.2	11.2	11.1	11.2	0.16	5.6
Sugar yield (ton /ha)	10.87	10.93	10.62	11.28	10.83	10.96	0.11	9.7

[1] The named treatments were for basic experiments of PC, 1st and 2ndratoons application.

Table 5: Effect of application of 476.2 kg urea/ ha over the previous seasons' residual effect on sugarcane yield and quality. 4th ratoon, Guneid, Season: March 2010-April 2011[1, 2].

Character	Urea (kg/ha)		Split	Full	Buried	Unburied
	358.6	538				
Stalk height (cm)	215.3	213.4	214.2	214.4	214.1	214.5
No. of millable stalks	161279	159229	165667	154840	158862	161645
Cane yield (ton/ha)	123.1	120.2	121.4	121.9	123.3	120.0
Brix% cane	18.63	18.28	18.41	18.50	18.44	18.46
Pol% cane	15.33	15.03	15.20	15.15	15.14	15.21
Fiber% cane	16.13	16.36	16.61	15.88	16.36	16.13
ERS%	12.32	12.03	12.20	12.15	12.14	12.21
Sugar yield (ton /ha)	15.17	14.46	14.81	14.81	14.97	14.65

[1]The values represent means of 2-4 readings but without statistical analysis.
[2] The named treatments were for basic experiments of PC, 1st and 2ndratoons application.

Table 6: Effect of 476.2 kg urea/ ha over the previous seasons' residual effect on sugarcane yield and quality. 4th ratoon, Guneid, Season: March 2011-March 2012[1, 2].

Character	Urea (kg/ha)		Split	Full	Buried	Unburied
	358.6	538				
Stalk height (cm)	222.0	217.9	220.9	219.0	231.7	208.2
No. of millable stalks	150062	159229	145598	142098	149562	143464
Cane yield (ton/ha)	121.7	106.9	107.6	121.2	114.8	113.8
Brix% cane	18.16	18.41	18.36	18.21	18.29	18.21
Pol% cane	15.86	15.88	16.03	15.71	15.73	16.01
Fiber% cane	17.56	17.04	17.4	17.19	16.69	17.9
ERS%	12.88	12.88	13.03	12.73	12.75	13.01
Sugar yield (ton /ha)	15.67	13.77	14.02	15.43	14.64	14.81

[1]The values represent means of 2-4 readings but without statistical analysis.
[2]The named treatments were for basic experiments of PC and 1st ratoons application.

Figure 1: Stalk height, No. of millable stalks, cane and sugar yield of sugarcane crop categories of October planting cycle

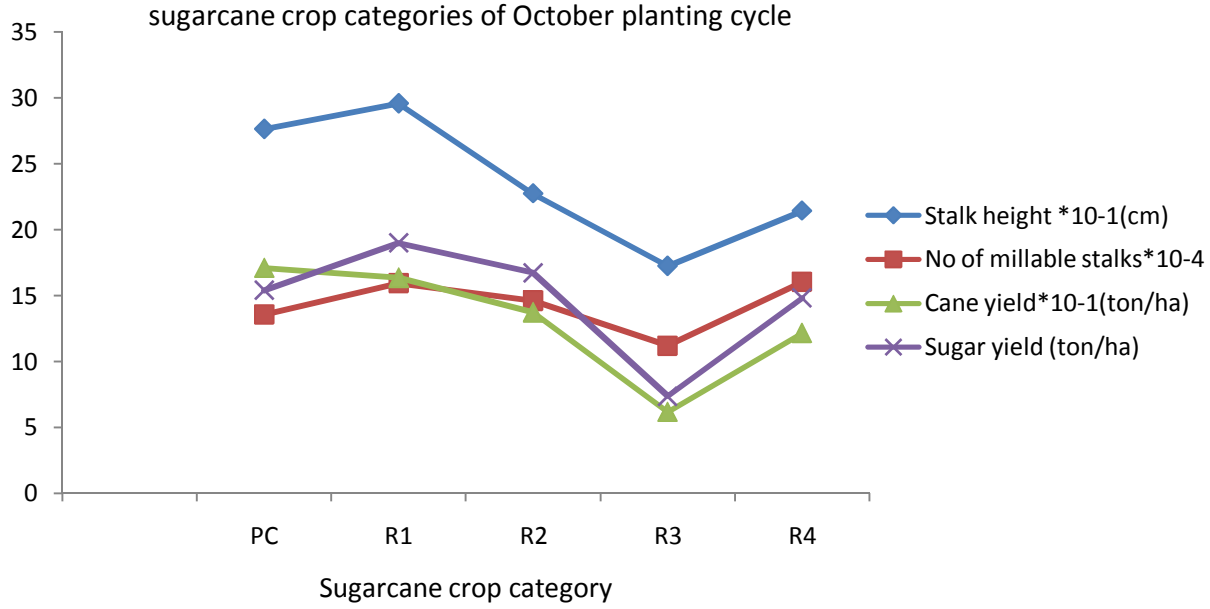
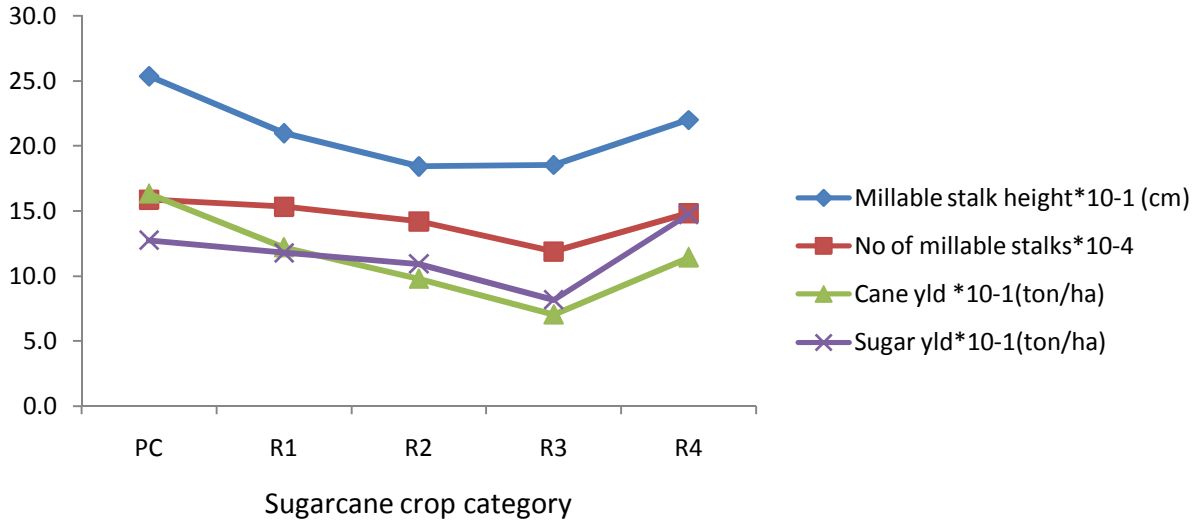


Figure2: Millable stalk heigt, No. of millable stalks, cane and sugar yield of cane catigories of June planting cycle



As for the common commercial dose of urea-N (i.e. 478.2 kg/ha.), the data showed that the cane regained satisfactory yields and better agronomic parameters (Tables 5, 6 and Figures 1 and 2). It is noteworthy that Figure 1 and 2 summarize the results of all experiments, the basic and the current ones and clearly showing the response of sugarcane ratoons in correspondence to the dose of applied urea. Based on these results it can be stated that sugarcane crop should be adequately fertilized with nitrogen.

CONCLUSION

In the cultivation of sugarcane and any other crop, no dependence on the residual effects of the previously applied N fertilizers is advised. Adequate amount of N should be applied to soils as the research recommended for sustainable production of crops. Moreover, more research is needed in this subject such as the fate of the added N fertilizers in the soil.

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