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SOIL SCIENCE

NEEM AND SULFUR-COATED UREA ENHANCE GROWTH AND SUGAR YIELD OF SUGARCANE BY INCREASING NITROGEN USE EFFICINECY

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ABSTRACT

The use of nitrogen (N) fertilizers is important for improving agricultural productivity, especially in the cultivation of sugarcane. Traditional urea, generally used as N source, has several limitations, including high nutrient losses and environmental pollution. Alternative urea forms, such as neem coated urea (NCU) and sulfur coated urea (SCU) have been investigated by researchers to overcome these issues. The purpose of this field experiment is to evaluate how SCU and NCU affect sugarcane production and N agronomic efficiency. Field trial was conducted during the year 2020 to 2022 at sugarcane farm area to compare the performance of this coated urea with traditional urea in sugarcane farming. In SCU treated field 12% and 10% higher sugarcane yield noted in plant and ratoon crop, correspondingly over traditional urea treatments. Similarly 15% higher sugar yield was recorded in SCU treatments as compared to traditional urea. The results indicated that SCU exhibited 25% in plant and 16% in ratoon crop higher N agronomic efficiency than traditional urea. These results suggest that the use of SCU can be a viable strategy to enhance sugarcane yield and improve the economic sustainability of the sugar industry while minimizing environmental impacts.

KEYWORDS: *Saccharum officinarum;* coated urea; cane girth; cane height; nitrogen; sugarcane yield; sugar recovery; Pakistan

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) stands as one of the important cash crop worldwide, contributing significantly to the sugar industry and bioenergy sector. On the other hand, proper fertilizer management is crucial to ensuring high yields and high-quality sugarcane output. Due to its high nitrogen content and low cost, urea has traditionally been used as a primary source of N, a crucial nutrient for sugarcane growth and development. But regular urea applications frequently cause significant nutrient losses through to volatilization, leaching, and denitrification, which reduce fertilizer use effectiveness and causes environmental contamination (Garcia-Montiel *et al*., 2017 ;Sharma *et al*., 2018). Scholars have looked into using coated urea to minimize these problems and maximize N consumption. A controlled-release nitrogen fertilizer, sulfur-coated urea (SCU) progressively releases nitrogen through the microbial breakdown of the sulfur coating (Zheng *et al*., 2016). This coating significantly reduces N losses, increases nutrient use efficiency, and provides a sustained release of N over an prolonged period, thus enhancing crop yield (Yang *et al*., 2017). NCU on the other hand incorporates the bioactive components of neem in the coating, which not only delays the release of N but also exhibits insecticidal and nematicidal properties (Mishra *et al*., 2016). The neem coating acts as a natural pesticide, protecting the crop against pests and diseases (Kumar *et al*., 2021). Coated urea application considerably improved the growth, biomass accumulation, and yield of sugarcane compared to traditional urea (Reddy *et al*., 2019). NCU application enhanced the nutrient uptake efficiency and yield attributes of sugarcane while reducing the incidence of insect pests (Mishra *et al*., 2018). Coated urea fertilizer application resulted in higher sugar recovery and brix content leading to higher sucrose content compared to traditional urea (Gupta *et al*., 2017; Sharma *et al*., 2020). An objective of this trial is to compare the performance of SCU and NCU with conventional urea in terms of sugarcane yield and sugar recovery. The results of this study will shed important light on coated urea formulations, effectiveness as a sustainable strategy for increasing sugarcane productivity while maximizing nutrient use effectiveness and reducing environmental consequences.

MATERIALS AND METHODS

To determine the effectiveness of neem coated urea (NCU) and sulfur coated urea (SCU) on the growth and yield parameters of sugarcane variety CPF-253, the trial was conducted at the farm area of Sugarcane Research Institute, Ayub Agriculture Research Institute Faisalabad. The experiment spanned over two cropping seasons of 2020-21 (first plant) and 2021-22 (ratoon). GPS coordinates of the site were 31°23'31.2"N and 73°03'19.9"E. The regional climate ranges from semi-arid to arid. The research experiment constituted six levels of treatments. Randomized complete block design was used with three replications. RD (recommended doses) of Nitrogen (N), Potassium (K) and Phosphorous (P) were 168,112 and 112 Kg /ha^{-1}, respectively.

T_1 = RD of PK
T_2 = RD of NPK (100 % N through commercial urea)
T_3 = RD of NPK (100 % N through NCU)
T_4 = RD of NPK (90 % N through NCU)
T_5 = RD of NPK (100 % N through SCU)
T_6 = RD of NPK (90 % N through SCU)

Soil physicochemical properties and N use efficiency: A composite soil sample was collected from the field prior to sowing the sugarcane crop and analyzed for its physicochemical properties (Table1). Available phosphorus was estimated using sodium bicarbonate extraction method and a spectro photo meter and soil texture by the hydrometer method (Page *et al*., 1982). Organic matter content of soil was assessed as described by Ryan *et al*. (2001). Potassium was extracted with 1 N ammonium acetate at pH 7.0 and determined using a PFP-7 Janway Flame Photometer (Rowell, 1994). Nitrogen use efficiency (NUE) and nitrogen agronomic efficiency (NAE) were determined using equations given by Dobermann (2005) and Fageria *et al*. (1997).

$$\text{Nitrogen Use Efficiency} = \frac{\text{Yield (kg /ha)}}{\text{N applied (kg /ha)}}$$

$$\text{NAE} = \frac{[\text{Yield (kg /ha) in treated plot}] - [\text{Yield (kg /ha) in untreated plot}]}{\text{Nitrogen dosage applied (kg /ha)}}$$

Plant growth and yield parameters: For measurement of physical cane parameters including stripped single cane Height (cm), stripped single cane weight (kg) and cane girth (mm) were measured at the harvesting stage. For each parameter, ten stripped canes were taken from each plot and the averages were taken as representations of plots. Cane girth was measured by using a vernier caliper in the middle of the cane in millimeters. The cane height was measured in cm by using measuring tape. For Cane Yield (t /ha) determination, 4×9.6m^2 plot sizes were harvested to get yield in tons per hectare.

Table 1: Physiochemical Characteristics of Experimental Soil

Characteristics	Units	Value
Sand	%	48.54
Silt	%	21.18
Clay	%	30.28
Textural class		Sandy clay loam
pH_s	---	8.11
EC_e	dS /m	1.37
Organic matter	%	0.69
Total nitrogen	%	0.027
Available phosphorus	mg /kg	7.45
Extractable potassium	mg /kg	152

Furthermore, sugarcane juice quality parameters were also analyzed which were used to determine sugar yield (SY) and commercial cane sugar (CCS %) and sugar recovery (SR) %. CCS % was determined by utilizing the following equation:

$$\text{CCS \%} = \frac{3P}{2}\left(1 - F + \frac{5}{100}\right) - \frac{B}{2}\left(1 - F + \frac{3}{100}\right)$$

Where, F represents the fiber percentage of a cane sample and B represents the brix of sugarcane (Chen and Chou, 1993).

The Sugar Recovery Percentage (SR %) was determined by utilizing the equation developed by Spancer and Meade (1963):

$$\text{SR \%} = \text{CCS \%} \times 0.94$$

The sugar yield (t/ ha) was calculated by dividing the product of stripped can yield (t/ ha) and sugar recovery percentage (SR %) by following the equation used by Majeed *et al*. (2022).

$$\text{Sugar Yield} = \frac{\text{Cane Yield } (\text{t ha}^{-1}) \times \text{Sugar Recovery } (\%)}{100}$$

All the experimental data sets were evaluated by using the computer software Statistix 8.1 to evaluate the analysis of variance (ANOVA). The parameters were considered to be significant at a difference of $p<0.05$ between standard errors and mean values.

Mean values of replications were represented along with the standard deviation (Steel *et al*.,1997).

RESULTS AND DISCUSSION

Stripped single cane height (cm): The statistical analysis of cane height data sets revealed significant difference in the stripped single height (SSCH) under various treatments in both initially planted and ratoon canes. As demonstrated in the Fig. 1, the tallest canes were observed under the T_5 at 51.70 % and 65 % more than T_1 in both first planted and ratoon crop, respectively. Comparing with T_1, the second tallest canes were recorded under the T_3 application at 48.06 % increase in first planted and 54.76 % increase in ratoon crop. Both T_3 and T_5 constitute 100 % Urea fertilizer coated with Neem and Sulphur, respectively. However, in spite of neem coating, 90 % urea T_4 resulted in the shortest cane tillers at 18.6 % decrease in first planted and 11.2 % decrease in the ratoon cane when compared with T_2, where, only 100 % non-coated urea was applied. The results of current study coincide with the findings of Sharma *et al*. (2020), where SCU was experimented on sugarcane along with other grain crops.

Stripped single cane weight (Kg): As shown in Figure 2, the highest significant stripped single cane weight (SSCW) was observed under T_5 treatment with a 45.9 % increase noted in the initial planted crop and a 48.5 % increase in per cane weight was also recorded in ratoon crop, as compared to T_2, containing only non-coated 100 % urea. The ratoon crop resulted in significantly higher SSCW corresponding to the first planted crop against all treatments. The second overall highest SSCW was observed in the T_6 ratoon crop at 7.9% per cent more than T_2. The SSCW results of the current study correlate with the research of

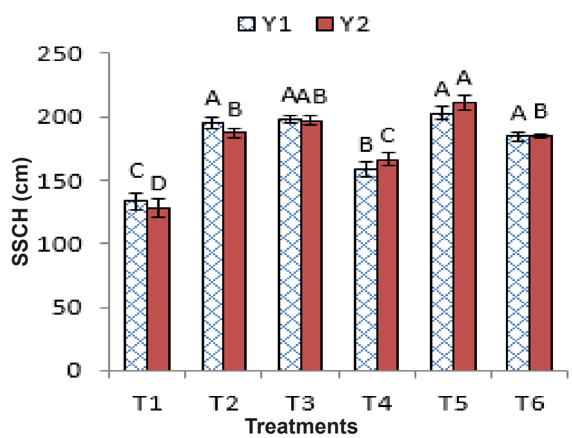

Fig. 1. Effect of NCU and SCU on single stripped cane height

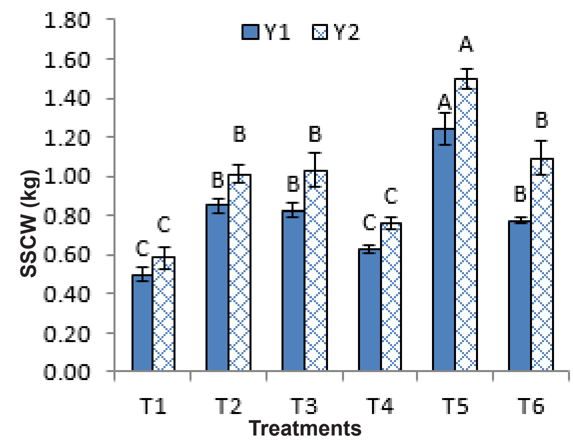

Fig. 2. Effect of NCU and SCU on single stripped cane weight

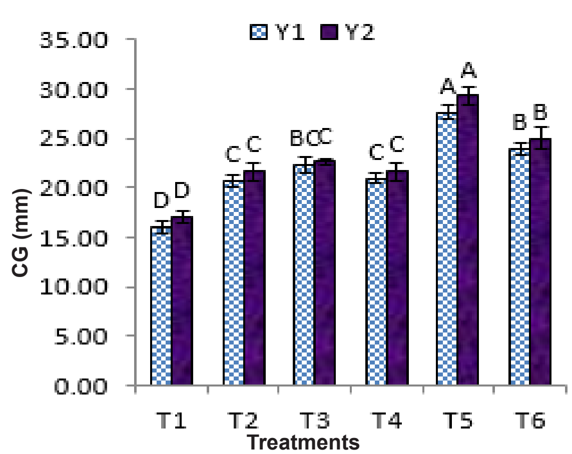

Fig. 3. Effect of NCU and SCU on cane girth

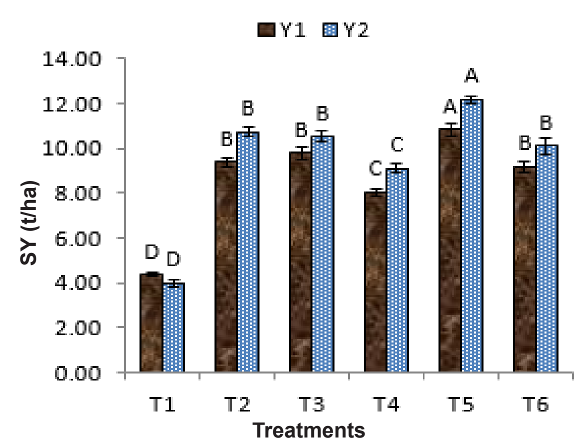

Fig. 4. Effect of NCU and SCU on sugar yield

Sharma *et al*. (2020) as per cane weight increased by increasing nitrogen fertilization.

Cane Girth (mm): The maximum cane growth (Figure 3) in terms of CG was recorded under the T_5 treatment at 27.7 mm in initially planted and 28.7 mm in ratoon cane, with a 33.8 % and 32.3 % increase compared to T_2. This increase in the CG complements the effectiveness of SCU against the non-coated urea application (T_2). The minimum CG was recorded in T_1 with no urea application. A subsequent increase in the CG from T_2 to T_6 treatment signifies the importance of nitrogen in cane development and growth. Alike results have been shared by Kabiraj *et al*., (2017), suggesting the importance of available plant nutrients in the enhancement of sugarcane girth.

Sugar recovery percentage (SR %): The SR% is one of the most crucial quality attributes for commercial sugarcane production as it directly influences the cane markets. As shown in Table 2 and 3, the SR% was significantly inclined to the varying urea fertilization. The highest sugar recovery was observed in the T_5 treatment at 11.88 % and 12.35 % for both initially planted and ratoon crops. This indicated the effectiveness of SCU on the long-term phyto-availability of nitrogen consequently enhancing the SR percentages. As shown in Table 2 and 3, a trivial difference in the SR was recorded between T_2 and T_3 in ratoon and the first planted sugarcane crop. Sharma *et al*., (2020) found that SCU treatments caused in significantly higher SR% compared to traditional urea-treated crops. The increased SR% can be endorsed to the improved nutrient use efficiency and sustained release of nitrogen provided by the coated urea formulations.

Sugar yield (t /ha): The sugar yield (SY) was directly influenced by the sugarcane yield (t /ha) and SR percentage. As demonstrated in Figure 4, the highest SY (t /ha) was noted in T_5 treatment at 10.84 (t /ha) and 12.18 (t /ha) in both first planted and ratoon crops, respectively. Janke *et al*., (2016) also observed the difference between the SY against varying levels of nitrogen fertilization from urea. SCU perform better than NCU in terms of sugar yield. The maximum SY was observed with the application of T_5 treatment 10.84 (t /ha) and 12.18 (t /ha) for the first planted and ratoon crop which was 15 % and 13 % more than T_2 treatment. The lowest SY was observed in the T_1 treatment at 4.4 (t /ha) and 3.9 (t /ha) for first planted and ratoon sugarcane. Alimohammadi *et al*., (2020) noted similar trends that signifying the importance of nitrogen fertilization in the enhancement of cane sugar yield.

Sugarcane yield (t/ ha): The maximum sugarcane yield was observed with the application of T_5 treatment, at 91 (t /ha) and 99 (t/ ha) for the first planted and ratoon crop which was 12.8 % and 9.6 % more than T_2 treatment (Table 2 and 3). The second highest per hectare cane yield was demonstrated by 100 % NCU treatment (T_3), at 84 (t/ ha) and 89 (t/ ha) with an increment of 3.9 % and 1.3 % compared to T_2 treatment for first planted and ratoon sugarcane crop, respectively. A subsequent decrease in the cane yield was recorded under 90 % NCU (T_4) and SCU (T_6) treatments, in both first planted and ratoon crops at 70 (t/ ha) and 78 (t/ ha) against T_4 and 79 (t /ha) and 86 (t /ha) against T_6, respectively. The results of current research correlate with the findings of (Lagos, 2022), where a significant increase in the sugarcane yield was recorded under coated urea treatments. Reddy *et al*. (2019) reported a significant yield increment of 12.5% with SCU application. Mishra *et al*. (2018) also observed an improvement in yield up to 18.7% with NCU treatment. These results suggest that the slow-release properties of coated urea formulations ensure a sustained supply of nitrogen, leading to better nutrient utilization by the crop and

Table 2: Effect of SCU and NCU on plant cane yield, sugar recovery, N use and agronomic efficiency

Treatments	SCY(t/ha)	NUE kg/kg N	NAE kg/kg N	SR (%)
T1	39 ± 1.01 d	0	0	11.15 ± 0.09 c
T2	81 ± 1.63 b	481 ± 9.73 cd	248 ± 12.13 b	11.6 ± 0.06 ab
T3	84 ± 2.16 b	500 ± 12.85 bc	267 ± 18.48 b	11.65 ± 0.08 ab
T4	70 ± 1.89 c	466 ± 12.50 d	207± 10.23 c	11.42 ± 0.06 bc
T5	91 ± 1.53 a	543 ± 9.12 a	310 ± 15.07 a	11.88 ± 0.17 a
T6	79 ± 1.40 b	524± 9.28 ab	265 ± 15.59 b	11.6 ± 0.12 ab
LSD	5.43	31	33	0.3

Values having different letters are statistically significant, LSD (0.05).

Table 3: Effect of SCU and NCU on ratoon cane yield, sugar recovery, N use and agronomic efficiency

Treatments	SCY(t/ha)	NUE kg/kg N	NAE kg/kg N	SR (%)
T1	36 ± 1.53 d	0	0	10.93 ± 0.09 c
T2	90 ± 1.23 b	535 ± 7.35 bc	318 ± 16.32 b	11.93 ± 0.09 b
T3	89 ± 2.21 b	528 ± 13.18 c	311 ± 11.01 bc	11.87 ± 0.04 b
T4	78 ± 2.23 c	513 ± 14.75 c	272 ± 22.15 c	11.78 ± 0.04 b
T5	99 ± 0.99 a	587 ± 5.86 a	370 ± 14.98 a	12.35 ± 0.08 a
T6	86 ± 2.55 b	567 ± 16.87 ab	325 ± 15.80 b	11.82 ± 0.07 b
LSD	6.4	38	41	0.23

Values having different letters are statistically significant, LSD (0.05).

enhanced productivity (Rathnappriya, 2022).

N use and agronomic efficiency: The maximum NUE (543 and 587 kg/ kg N) was found by application of SCU at the rate of 168 kg (100%) N/ha in first (Table 2) and ratoon crop (Table 3) respectively. Likewise results presented (Table 1 and 2) that higher NAE (310 and 370 kg/ kg) noted by 168 kg/ ha sulfur coated N application in both first and ratoon crop plant. The comparison of coated urea and traditional urea showed that higher NUE and NAE were recorded where nitrogen fertilizer was applied in coated form as contrast to conventional urea at equivalent amount of N application. SCU is a slow release N fertilizer that gradually releases N through the microbial degradation of the sulfur coating (Zhang *et al*., 2016). This coating significantly reduces nitrogen losses, improves nutrient use efficiency, and provides a sustained release of N over an extended period, thereby enhancing crop productivity (Yang *et al*., 2017).

CONCLUSION

In conclusion, the adoption of slow-release nitrogenous fertilizers presents a viable solution to improve sugarcane yield and mitigate the adverse environmental impacts associated with conventional fertilizer practices. By applying SCU, 10% nitrogen fertilizer can be saved without any loss in sugarcane yield as compared to traditional urea fertilizer. Therefore, based on the findings of current research, to efficiently utilize nitrogen fertilizers and achieve maximum sugarcane growth and yield, it is recommended to consider the application of SCU in the sugarcane crop. Further research and implementation of slow-release fertilizers in sugarcane cultivation are warranted to fully realize their potential and pave the way towards a more sustainable future for sugarcane production systems.

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2.	Naeem Iqbal	Wrote-up the manuscript	
3.	Muhammad Shahzad Afzal	Assisted in research	
4.	Muhammad Akhlaq Mudassar	Edited the manuscript	
5.	Abdul Khaliq	Assested in research	
6.	Mahmood-UL- Hassan	Collected the data	
7.	Muhammad Shafique	Edited the manuscript	
8.	Babar Hussain Babar	Reviewed the manuscript	
9.	Syed Saqlain Hussain	Collected data and analysed statistically	
10.	Naeem Fiaz	Analysed the data statistically