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OPTIMIZING USE OF ENHANCED EFFICIENCY N FERTILIZERS TO IMPROVE WHEAT- MAIZE CROPPING SEQUENCE UNDER ALLUVIAL SOILS

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ABSTRACT: Collectively, the challenges aim to accelerate the development of innovative fertilizer product technologies and to increase the use of existing enhanced efficiency fertilizers sources (EEFS) like slow release fertilizers (SRF) as an example for increasing crop yields and reducing environmental impacts to air, land and water. Two field experiments were carried out at Experimental Farm of Tag El-Ezz, Agricultural Research Station (30º 59\ N latitude, 31º 58\ E longitude´), Agriculture Research Center (ARC), Dakahlia Governorate, Egypt. Completely randomized blocks design (CRBD) with three replicates was used during the two winter and summer successive growing seasons 20٢٠/21 and 2021 to study the effect of three different slow release nitrogen fertilizer (SRNF) sources 1- sulfur coated urea (SCU), 2- urea formaldehyde (UF) and 3- cement coated urea (CCU) with different fertilization rates (100,125 and 150 % from the recommended dose) comparing with conventional urea (CU) under recommended fertilization rate for wheat and corn crops respectively (75 and 120 kg N fed^{-1}) on growth, yield and its components of wheat (*Triticum aestavium L.*) cv. Misr1 during the winter season. As well as studying the residual effect of (SRNFs) with half additional application does of conventional urea to each plot on maize (*Zea mays L.*) var. (Tri Cross 360) growth, yield and its components. Available soil N in the experimental plots was determined during the growing seasons along the two experiments.

The obtained results indicated the ability to use new age technologies as enhanced efficiency fertilizers (EEFS) like slow release fertilizers (SRFs) to sustain crops yield and maintain environment quality.

SRNFs applications gave the highest values of vegetative growth, yield and its components of wheat plant compared to conventional urea. Raising rate of N fertilizer caused an increase in all studied parameters.

SCU using at 100% fertilization rate was the superior SRNF using at the same rate where it increased ChlC a+b and BY by 31.23 and 19.95%, respectively, as well as it gave the highest grain nutrients concentration and protein content by 2.35% for N; 0.289% for P; 1.38% for K and 13.51% for protein comparing with CU using at 100% fertilization rate.

The highest residual N (mg kg^{-1}) in the soil after wheat harvesting was recorded with cement coated urea (CCU) and the same trend continuous to maize post harvesting. Thus the residual of CCU using at 100% fertilization rate + 50% CU increased maize ChlC a+b and BY by 36.40 % and 7.27%, respectively as well as it gave the highest values of maize grain content from N (2.09%), P (0.134%), K (1.46%) and oil content (5.20%) comparing with CU using at 100% fertilization rate.

Economically, we advised farmer using SCU at 100% fertilization rate for one crop and using CCU at 100% +50 % CU recommended fertilization rates for cropping sequence.

Key words: Slow release fertilizers, residual effect, cropping sequence, wheat and maize.

INTRODUCTION

The most reliable and effective way to make the availability of nutrients coincide with plant requirements is by controlling their release into the soil solution. Slow release fertilizers (SRFs) are considered as novel and revolutionary approaches in the field of fertilizer synthesis. SRFs are seen as economical and environment-friendly alternative to chemical fertilizers.

The most common nitrogen fertilizer product used all over the world is urea (CO_2NH_2). It has concentrated nitrogen content (46.5%) and also with a low cost (Glibert et al., 2006). Urea dissolved in soil water just applied through a short time ranging between minutes to hours releasing ammonia (NH^{4+}) and bicarbonate (HCO^{3-}), it losses by leaching, volatilization and decomposition causing environmental pollution (Al-Kanani et al., 1991).

Slow release fertilizers (SRFs) were produced to avoid or at least reduce losses of conventional fertilizers and also enhance the fertilizers efficiency. It can be defined as a fertilizer that supply nutrient to plants for a long time than conventional urea fertilizer (Trenkel, 2010). Slow release fertilizers (SRFs) are made of soluble fertilizers coated with inorganic materials such as sulfur or mineral-based coatings and fertilizers coated with an organic polymer that control water penetration and thus limit dissolution rate of nutrient which make it controls releasing of nutrient as plant need (Sartain et al., 2004).

Urea Formaldehyde (UF 38 %N) is the first developed group of slow release nitrogen fertilizers, it is formed by a reaction between formaldehyde and excess of urea under controlled conditions i.e. pH, temperature, mole proportion, reaction time, etc. (Watson, 2013). It's a good slow release nitrogen fertilizer (SRNF) for most crops where it has a low solubility. On the other hand, it's used widely in warmer climates as in the Mediterranean region where it's more effective in case of higher temperatures than cold one (Trenkel, 2010).

Sulfur coated urea (SCU 30-40%N and approximately 20%S) is produced through coating hot urea by molten sulfur which considered as a cheap cost coating. N releasing from SCU particles is positively affected by the thickness and quality of the coating (Shiva *et al*., 2016).

As well as plant growth required micronutrients in trace amounts. Cement is the less expensive coating example that release micronutrient as silicon, aluminum and iron where it contains 78 % $CaCO_3$, 14 % SiO_2, 2.5 % Al_2O_3 and 1.75 % Fe_2O_3. (Muller, 1974 and El-Ghamry *et al*., 2016).

Crop sequences are important for studying the productivity of a long-term rotation. Sequenced crops may enhance soil quality and crop production. (Hamd Alla *et al.,* 2015).

Wheat (*Triticum aestavium L.*) as well as corn (*Zea mays L.*) crops are required high amounts of nutrients especially N. Sequence of cereals in the same field in two successive growing seasons affects negatively on the soil fertility leading to a reduction in crops yield.

So that, this research was made to find out the performance of slow release fertilizers (SRFs) as enhanced efficiency fertilizers sources (EEFS). Studying effect of sources and rates of three SRNF forms on wheat and corn cropping sequence productivity as well as their residual effect on soil nitrogen content for the second growing season under alluvial soils condition.

MATERIALS AND METHODS

Experimental Field Location and Cropping Sequence

Two field experiments were conducted during consecutive seasons at the farm of Tag El-Ezz, Agricultural Research Station, Agricultural Research Center (ARC), Dakahlia governorate, Egypt, (located at 30º 59' N latitude, 31º 58' E longitude´) during the winter (wheat) and summer (maize) 20٢٠/21 and 202١ growing seasons to study the effect of different nitrogen fertilizer forms as enhanced efficiency fertilizers sources (EEFS) and rates on growth, yield and nutrients uptake of wheat, as well as the residual effect on the soil then on maize growth, yield and nutrients uptake through wheat- maize cropping sequence.

Random disturbed soil samples from the surface of the soil (0-30 cm) were collected before wheat planting. Some physical and chemical properties of the experimental soil were determined according to Page *et al*. (1982) and Klute (1986) as shown in Table 1.

Table 1. Physical and chemical soil properties of the experimental site at Tag El-Ezz during ٢٠٢٠/٢٠٢١ growing seasons.

Soil Characteristics	
I. Physical properties:	
Particle size distribution	
Sand	19.50
Silt	38.09
Clay	42.41
Soil Texture Class	Clay
II. Chemical properties:	
pH, [1:2.5 soil suspension]	8.00
EC, [soil past, dS m^{-1}]	2.97
Soluble cations, meq 100 g soil $^{-1}$)	
Ca^{2+}	5.61
Mg^{2+}	5.30
Na^{+}	16.21
K^{+}	2.62
Soluble anions, meq 100 g soil $^{-1}$)	
CO_3^{2-}	-
HCO_3^{-}	1.21
Cl^{-}	13.11
SO_4^{2-}	15.42
$CaCO_3$, %	4.79
OM, %	1.42
III. Nutritional properties:	
N, mg kg^{-1}	50.10
P, mg kg^{-1}	8.96
K, mg kg^{-1}	242.08

Slow Release Nitrogen Fertilizers (SRNFs)

Table 2 shows analysis of the samples from different nitrogen fertilizers sources according to methods described by Salman, (1988) and Vashishtha et al. (2010).

Experimental Treatments and Statistical Design.

The experiment was comprised of ten treatments including three slow release N fertilizers applied with three fertilization rates in addition to conventional urea with one application rate (recommended). Total ten treatments were distributed in a randomized complete blocks design with three replicates. Fertilizers were added to wheat plant at rates of 100%, 125% and 150% from recommended rate (75kgN fed^{-1}) in forms of sulfur coated urea (SCU, 41% N), urea formaldehyde (UF, 38.3% N) and cement coated urea (CCU, 37.2% N) comparing with conventional urea (46.5% N) at recommended dose. Slow release fertilizers were applied at sowing, while urea was applied in three splits after 0, 25 and 45 days after sowing. Maize received 50% N from recommended dose (120 kg N fed^{-1}) as conventional urea. P and K fertilizers were applied as recommended by the Ministry of Agriculture and land Reclamation (MARS).

Cultivation Practices:

Seeds of wheat (*Triticum aestavium* L.) cv. (Misr1) and of maize (*Zea mays L*) cv. (Tri Cross 360) were obtained from Field Crops Research Institutes (FCRI), MARS, Egypt . Wheat seeds were sown in 17 November 2020 and the harvest was in 28 April 2021. On the same field, maize seeds were sown in 3 Jun 2021 and the harvest was in 27 September 2021.

Plant Growth Stages Parameter Data:

1-Vegitateve Growth Parameters and Chemical Constituents.

Plant samples of each crop were collected from each plot at maximum vegetative growth stage for measurement of some growth parameters (shoot height (ShH), cm; shoot fresh weight (ShFW), g and shoot dry weight (ShDW), g as well as chlorophyll a and b (mg g^{-1} fresh weight of leaf) were determined using a method described by Nayek *et al.* (2014). Total N, P and K content were determined according to the methods described by Buresh et al. (1982) and Chapman and Pratt (1961), respectively.

Table 2. Analysis of the different nitrogen fertilizers sources used during the winter (wheat) 2020/2021 season.

N fertilizers	Coating material	Color	%		Dissolution rate, minute.gm^{-1}
			N concentration	coating Percentage	
Conventional Urea (CU)	-	White	46.5	-	0.118
Sulfur coated urea (SCU)	Sulfur	Yellow	41.0	10.3	0.252
Urea Formaldehyde (UF)	Formaldehyde	White	38.3	9.8	0.226
Cement coated urea (CCU)	Cement	Dark Gray	37.2	17.4	0.468

2-Harvestin Stage Parameters.

At harvest stage, yield attributes of each plant, seed yield (SY) and straw yield (StY), ton fed^{-1} were recorded from each plot. The yielded seeds were prepared to determine total N, P and K components. Nutrients uptake was determined according to the following formula:

Nutrients uptake (NutU), kg fed^{-1}=
Nutrient concentration, % × grain yield (GY) kg fed^{-1} /100

Protein content (%) of wheat seeds was estimated by multiplying nitrogen percentage by the factor (5.75) according to A.O.A.C. (1990), while, Grain maize oil % : was extracted by soxhelt apparatus using petroleum ether as a solvent A.O.A.C. (1995).

3-Residues N in the Soil.

Surface soil samples (0-30 cm) from each experimental plot were collected at maximum vegetative growth stage of wheat crop, after harvesting of wheat, before maize sowing and after maize harvesting to determine the available N in the soil (mg kg^{-1}). Mineral N was extracted using 2 M potassium chloride and determined according to Kenney and Nelson, (1982) by distillation method.

Economic Evaluation.

Total cost of cultivation as well as gross income was calculated on the basis of prevailing market for different practices and produces. The total cost of cultivation per feddan was subtracted from the gross income for computing net returns from each treatment (Jadon *et al.*, 2018).

Net return (£. fed^{-1})= Gross income (£. fed^{-1}) - Cost of cultivation (£. fed^{-1})

Benefit cost ratio (BCR) was calculated treatment wise as below.

Benefit Cost Ratio (BCR) = Gross income /Cost of cultivation

Statistical Analysis.

All data were subjected to statistical analysis according to Gomez and Gomez, (1984) and the means were compared using least significant difference at 5% level were carried out as described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Collectively, the challenges aim to accelerate the development of innovative fertilizer product technologies and to increase the use of existing enhanced efficiency fertilizers sources (EEFS) like slow release fertilizers (SRF) as example that maintain or increase crop yields and reduce environmental impacts to air, land and water. Cropping Sequences of Wheat and Maize under single fertilization using slow release N fertilizers (SRNFs) were investigated under alluvial soils conditions located in middle Nile delta.

A- First Growing Season Sequence

Wheat Vegetative Growth Parameters and Chlorophyll Content.

Data tabulated in Table 3 recorded the effect of different nitrogen fertilizer sources and rates on some vegetative growth parameters i.e. shoot height (ShH), cm, shoot fresh weight (ShFW), g^{-1}, shoot dry weight (ShDW), g^{-1} and chlorophyll content (ChllC), mg g^{-1} FW of wheat plants. A significant increase in all previous parameters by application of all nitrogen fertilizer sources and rates were recorded comparing with control treatment (Conventional urea fertilizer). The results showed positive response to SRNF in the order SCU > UF > CCU respectively under all evaluated rates (100%, 125% and 150%) with tremendous increase. It's clear that the ShH, ShFW, ShDW as well as ChllC rising with increasing N fertilization rate (Table 3). The results indicated that application of SRNF (SCU, UF and CCU) comparing with

urea using 100% fertilization rate increased ShH by 19.50, 11.24 and 4.46% respectively. Whereas ShFW and ShDW stimulated with the same types and fertilization rate by 20.77, 16.06 and 4.84% for ShFW and by 15.70, 10.54 and 6.88% for ShDW. The same trend of data noticed for ChlC (a+b) by increase 31.23, 27.61 and 9.78% respectively. The obtained data appeared the same trend when fertilization rate increased to 125 and 150% comparing with conventional urea using 100% fertilization rate wherever the nitrogen nutrient is a responsible nutrient for plant growth and chlorophyll formation (Bojović and Marković, 2009). In addition to the effective role of nitrogen in meristematic activity that increasing cells numbers as well as cell elongation (Zaman *et al*., 2008).

Slow release nitrogen fertilizers (SRNFs) i.e. SCU, UF and CCU were better than conventional urea (CU) in respect of previous vegetative parameters of wheat. This improving effect of SRNFs may be ascribed for their ability to regulate N releasing according to needs of plant (Haderlein et al., 2011).

On the other hand, the effect of SCU on studied vegetative parameters and chlorophyll content was the best SRNFs. SCU recorded the highest values where it act as a source of both major macronutrients (N and S) that are needed for plant growth and cell elongation as well as their effective role in chlorophyll synthesis (Mishra *et al*., 2001 and Ning et al., 2012). This results are in agreement with that obtained by (Shiva *et al*., 2016 and Hatifield and Parkin (2014).

Table 3. Effect of different sources and rates of SRNFs on some vegetative growth parameters and chlorophyll content (mg g^{-1} FW) of wheat.

Treatments	Shoot height (ShH), cm	Shoot weight (ShW), g m^{-2}		Chlorophyll content (ChlC), mg g^{-1}FW		
		Fresh	Dry	a	b	a+b
CU100% (control)	80.89	4188.33	622.38	0.510	0.236	0.746
SCU100%	96.67	5058.06	720.10	0.714	0.265	0.979
SCU125%	97.33	5067.00	728.12	0.717	0.269	0.986
SCU150%	99.83	5076.25	730.24	0.718	0.270	0.988
UF100%	89.98	4860.80	688.00	0.702	0.250	0.952
UF125%	92.97	4916.15	690.06	0.705	0.254	0.959
UF150%	95.17	4933.23	699.32	0.710	0.256	0.966
CCU100%	84.50	4391.25	652.10	0.577	0.242	0.819
CCU125%	86.67	4464.30	665.20	0.645	0.244	0.889
CCU150%	87.01	4490.66	678.14	0.650	0.248	0.898
F test	***	***	***	***	***	***
LSD at 0.05%	1.72	8.51	8.50	0.008	0.009	0.014

Nutrients Concentration in Wheat Shoot.

Data presented in Table 4 displayed the effect of different nitrogen sources and rates on NPK content of wheat shoot at maximum vegetative growth stage (75 days after planting). The results revealed that, increasing nitrogen fertilization rate to 125 and 150% over the recommended rate caused an increase in NPK content. The results presented that fertilizing using conventional urea with recommended rate (100%) gave NPK shoot concentration 2.61, 0.371 and 3.13% respectively, whereas fertilizing using SRNFs (SCU, UF and CCU) enhanced concentration of the nutrients by 11.11, 7.28 and 3.83% for N and 15.09, 6.46 and 1.62 for P and finally increased with 6.37, 3.83 and 1.28% for K. the same trend of data were located when SRNF (SCU, UF and CCU) fertilization rate raised up to 150% from recommended rate. These results are in matching with that recorded by Shiva *et al.* (2016).

N,P and K nutrients content were affected significantly by SRNFs especially SCU , the same result achieved by Malakouti *et al*., (2008). Hassanein *et al*. (2013) reported that application of slow release fertilizers (SRNFs) increased absorption of phosphorus and potassium where sulfur oxidation in soil reducing pH and increasing availability of nutrients leading to increase nutrient uptake by plant.

Wheat Yield and Yield Attribute.

Data presented in Table 5 indicated that biological yield (BY), (grain (GY) and straw (StY)) and yield attributes i.e. shoot height (ShH), spike length (SpL) and 1000 grain weight (1000 GW) were affected significantly by increasing rates of all N fertilizer treatments sources (SCU, UF, CCU). The results displayed that there were highly significant differences located due to treatments on ShH, SpL, 1000GW, BY, GY and StY. The results presented that fertilizing using conventional urea with recommended rate (100%) gives ShH, 98.21 cm; SpL 12.92 cm; 1000GW 50.82 g; BY 8.27 ton fed $^{-1}$; GY 3.47 ton fed $^{-1}$ and StY 4.8 ton fed $^{-1}$. Application of different SRNFs of the first rate enhanced wheat yield and yield attributes by 10.19, 7.63, 3.89% for ShH; 15.56, 7.97, 3.87% for SpL; 12.59, 6.49, 1.53% for 1000GW; 19.95, 14.15, 7.26% for BY; 37.46, 28.24, 13.83% for GY; and 7.29, 3.96, 2.5o% for StY. The results are in conformity with those of Abdel Nour and Fateh (2011) who indicated a significant increase in yield and yield parameters of wheat plant as nitrogen level was increased up to the recommended rate in two growing seasons, where increasing nitrogen rates caused an increase in number of fertile tillers plant^{-1} which resulted in higher number of spikes m^{-2}, and this may be due to the effective role of nitrogen in building up new tissues leading to increasing grain and straw yield (Hamd Alla *et al.*, 2015). These results are also in matching with that recorded by Abd El-Razek and El-Sheshtawy (2013).

SRNFs recorded a significant values in all studied parameters comparing with conventional urea (CU), the highest values of 1000 GW and yield were indicated by (SCU) followed by (UF), then (CCU) and lately (CU). These results may be due to the regulation of nutrient release which makes nutrient more efficiency for plant than conventional urea as well as reducing N losses by leaching and providing roots by a constant supply of required nutrient (Trenkel, 2010).

Table 4. Effect of different sources and rates of SRNFs on nutrients concentration (%) of wheat shoot at maximum vegetative growth stage.

Treatments	Nutrients concentration (%)		
	N	P	K
CU100%(control)	2.61	0.371	3.13
SCU100%	2.90	0.427	3.33
SCU125%	2.92	0.434	3.35
SCU150%	2.95	0.440	3.38
UF100%	2.80	0.395	3.25
UF125%	2.84	0.410	3.29
UF150%	2.87	0.416	3.31
CCU100%	2.71	0.377	3.17
CCU125%	2.75	0.382	3.20
CCU150%	2.77	0.391	3.22
F test	***	***	***
LSD at 0.05%	0.085	0.008	0.085

Table 5. Effect of different sources and rates of SRNFs on yield and yield attributes of wheat plant.

Treatments	Shoot height (ShH), cm	Spike length (SpL), cm	1000 GW, g	Bio Yield (BY)	Grain Yield (GY)	Straw Yield (StY)
				ton fed^{-1}		
CU100% (control)	98.21	12.92	50.82	8.27	3.47	4.80
SCU100%	108.22	14.93	57.22	9.92	4.77	5.15
SCU125%	108.88	15.25	57.64	9.98	4.80	5.18
SCU150%	109.71	15.90	58.30	10.1	4.88	5.22
UF100%	105.71	13.95	54.12	9.44	4.45	4.99
UF125%	106.54	14.15	54.63	9.56	4.54	5.02
UF150%	107.88	14.40	55.00	9.69	4.64	5.05
CCU100%	102.04	13.42	51.60	8.87	3.95	4.92
CCU125%	102.21	13.66	52.91	8.93	3.99	4.94
CCU150%	103.71	13.78	53.33	9.25	4.29	4.96
F test	***	***	***	***	***	***
LSD at 0.05%	0.170	0.85	0.08	0.085	0.16	0.08

In addition to sulfur coated urea (SCU) act as a source of S which a responsible macronutrient for plant growth and yield production as well as an enhanced efficiency of nitrogen fertilizer (Shiva *et al.*, 2016).

NPK and Protein Content and Nutrients Uptake in Grains.

Application of N tested fertilizers were significantly increased NPK concentration and uptake in wheat grains as well as grain content of protein as shown in Table 6 and Figs. 1 (a, b and c). Fertilizing with N recommended rate (100%) using SRNFs especially SCU induced higher NPK and protein content in grain (2.35, 0.289, 1.38 and 13.51% respectively) than conventional urea (2.08, 0.265, 1.19 and 11.96% respectively) with slight response to the other two SRNFs (UF and CCU). The recorded data denoted that raising N fertilizer up to 125 and 150% over the recommended rate had a positive significant effect on N concentration and uptake. The highest values were recorded with 150% fertilization rate using SCU fertilizer (2.39, 0.293, 1.43 and 13.74% for NPK and protein content). Shiva et al. (2016) found that more nitrogen applied produces a linear increase in nitrogen uptake. The poor N uptake associated with conventional urea treatment in alkaline soil may be due to the loss of nutrient through large volatilization and leaching (Shavive and Mikkelsen, 1993 and Nasima *et al*., 2010).

SRNFs also enhanced P and K uptake as well as N as a result of the natural of coated material which helps in obtaining nutrients, and thus increase yield production and nutrients content (Trenkel, 2010).

SRNFs achieved higher protein concentration than conventional urea and this result may be due to supply of sufficient N that led to increase protein concentration (Shiva *et al*., 2016).

Table 6. Effect of different sources and rates of SRNFs on protein and nutrient concentration (%) in grains of wheat plant.

Treatments	Nutrients and protein concentration (%)			
	N	P	K	Protein
CU100%(control)	2.08	0.265	1.19	11.96
SCU100%	2.35	0.289	1.38	13.51
SCU125%	2.37	0.291	1.40	13.63
SCU150%	2.39	0.293	1.43	13.74
UF100%	2.27	0.280	1.30	13.05
UF125%	2.29	0.285	1.33	13.17
UF150%	2.33	0.287	1.35	13.40
CCU100%	2.18	0.269	1.22	12.54
CCU125%	2.21	0.273	1.24	12.71
CCU150%	2.23	0.277	1.27	12.82
F test	***	***	***	***
LSD at 0.05%	0.085	0.009	0.086	0.048

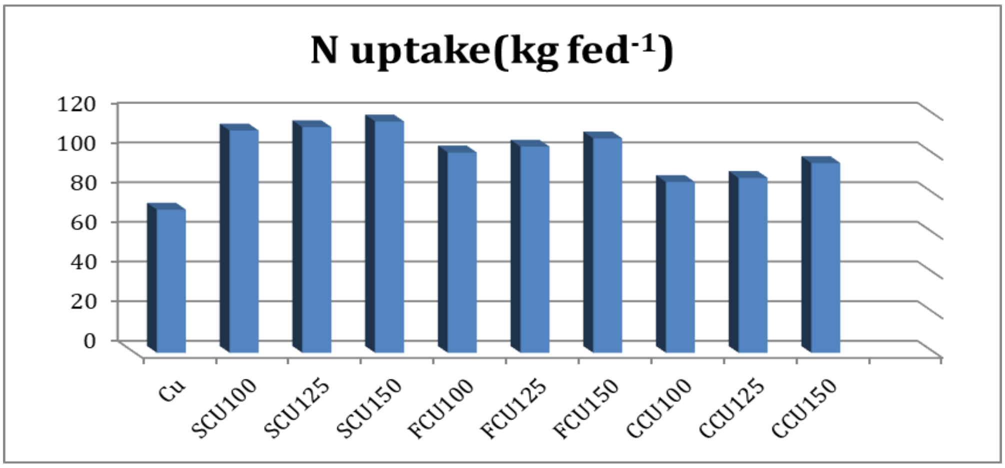

Fig (1a): Effect of different sources and rates of SRNFs on N uptake (kg fed^{-1}) in grains of wheat plant.

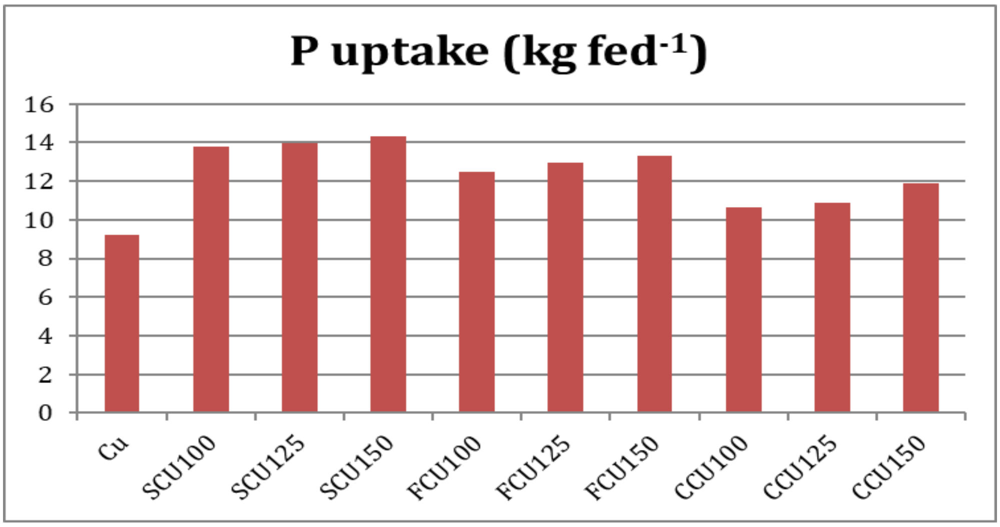

Fig (1b): Effect of different sources and rates of SRNFs on P uptake (kg fed^{-1}) in grains of wheat plant.

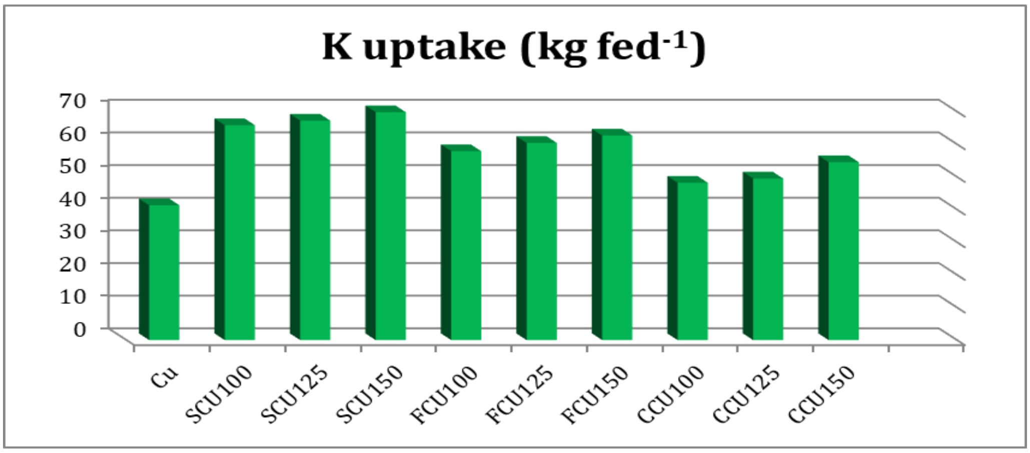

Fig (1c): Effect of different sources and rates of SRNFs on K uptake (kg fed^{-1}) in grains of wheat plant.

B-Second Growing Season Sequence:

Maize Vegetative Growth Parameters and Chlorophyll Content

Data recorded in Table 7 elucidated a significant effect of all tested treatments on studied vegetative growth parameters such as shoot height (ShH), cm, shoot fresh weight (ShFW), g^{-1}, shoot dry weight (ShDW), g^{-1} and leaf area (LA) cm^{-2} as well as chlorophyll content (ChlC), mg g^{-1} FW of maize plant. On the other hand, there were a significant differences between the different residual SRNFs were observed. Similar results were reported by Jadon *et al. (*2018). The results showed a positive response to different residual SRNFs in the order CCU > SCU >UF respectively under all evaluated rates (100%, 125% and 150%) over CU. This result may be due to their ability to regulate N releasing according to needs of plant (Mikkelsen *et al*., 1994).

The results exhibited that the residual of SRNFs (CCU, SCU and UF) achieved the highest values of ShH (305.0, 285.5 and 267.84) respectively. Whereas ShFW, ShDW and LA respond to the same type and fertilization rate with values 378.30, 344.66 and 297.80 for ShFW, 46.38, 42.25 and 36.51 for ShDW and 562.51, 532.55 and 491.50 for LA. The same trend of data noticed by ChlC (a+b) where the values were 0.311, 0,290 and 0.246 respectively comparing with urea using 100 % fertilization rate.

It's clear that ShH, ShFW, ShDW, LA and ChlC raising with residual effect of SRNFs at rates over the recommended rate i.e. 125 and 150%. This result is in harmony with that recorded by Shehzad *et al., (*2012) who found that by increasing nitrogen levels, fresh weight per plant, dry weight per plant and chlorophyll content of maize were increased. As well as there was a close link between nitrogen plant growth and chlorophyll formation (Bojović and Marković, 2009). These results are in matching with that recorded by Hassan *et al*., (2010).

Table 7. Effect of different sources and rates of residual SRNFs and additional CU on some vegetative growth parameters and chlorophyll content (mg g FW^{-1}) of Maize.

Treatments	Shoot height (ShH), cm	Shoot weight (ShW), g^{-1}		Leaf area (LA), cm^2	Chlorophyll content (ChlC), mg .g FW^{-1}		
		Fresh	Dry		a	b	a+b
CU100%(control)	253.65	276.32	33.87	475.81	0.172	0.056	0.228
SCU100+50%CU	285.50	344.66	42.25	532.55	0.220	0.070	0.290
SCU125+50%CU	290.66	356.32	43.68	548.27	0.226	0.073	0.299
SCU150 +50%CU	300.80	366.50	44.93	553.26	0.230	0.076	0.306
UF100+50%CU	267.84	297.80	36.51	491.50	0.186	0.060	0.246
UF125+50%CU	275.12	316.05	38.74	508.12	0.192	0.064	0.256
UF150+50%CU	281.32	332.12	40.71	525.92	0.205	0.066	0.271
CCU100+50%CU	305.00	378.30	46.38	562.51	0.236	0.075	0.311
CCU125+50%CU	315.60	386.15	47.34	575.55	0.242	0.078	0.320
CCU150+50%CU	321.32	392.62	48.13	583.38	0.248	0.082	0.330
F test	***	***	***	***	***	***	***
LSD 5%	1.62	8.51	0.080	3.42	0.0085	0.002	0.004

Nutrients Concentration in Maize Shoot.

Data presented in Table 8 showed the effect of residual different SRNFs on NPK concentration in maize shoot plant at maximum vegetative stage growth. The results showed that, the residual of SRNFs recorded the highest effect in NPK content in maize shoot. The superior treatments were all CCU applications followed by SCU treatments, where residual of CCU, SCU and UF using at 100 % fertilization rate enhanced NPK shoot concentration by 16.54, 12.23 and 3.23% for N; 31.61, 16.77 and 3.87% for P and 18.11, 10.24 and 1.97% for K. Abou – Zied *et al*., (2014) revealed that different SRNFs affected significantly NPK content of maize comparing with conventional urea (CU). Similar results were recorded by Signor and Barbiani (2013) and El-Ghamry *et al*., (2016). The same trend of data was observed by residual of SRNFs using 125 and 150% fertilization rate. These results are in harmony with Almodares *et al*., (2009); Mello *et al*., (2017) and EL-Metwally *et al.,* (2019).

Maize Yield and Yield Attributes.

Data presented in Table 9 indicated that a significant increases in yield and yield attributes i.e., shoot height (ShH), ear length (EL), ear diameter (ED), 100-grain weight (100 GW), biological (BY), grain (GY) and straw yield (StY) by residual of all SRNFs.

Tabulated data indicated that conventional urea (CU) treatment application at recommended rate (100%) recorded ShH, 278.40 cm; EL ,16.55 cm; ED,3.80 cm; 100GW, 31.30 g; BY, 8.53 ton fed^{-1}; GY,3.20 ton fed^{-1} and StY 5.33 ton fed^{-1} . Residual of CCU, SCU and UF using at 100% fertilization rate increased maize yield and yield attributes by 19.32, 12.18 and 4.45% for ShH; 36.25, 24.60 and 14.80 % for EL; 13.68, 7.89 and 3.94% for ED; 16.96, 11.15 and 0.575% for 100GW; 7.26, 4.45 and 0.47% for BY; 9.38, 3.75 and 0% for GY; and 6.00, 4.88 and 0.75% for StY.

Table 8. Effect of different sources and rates of residual SRNFs and additional CU on nutrient concentration at maximum vegetative growth stage of maize shoot.

Treatments	Nutrients concentration (%)		
	N	P	K
CU100% (control)	2.78	0.155	2.54
SCU100+50%CU	3.12	0.181	2.80
SCU125+50%CU	3.16	0.187	2.85
SCU150 +50%CU	3.19	0.195	2.90
UF100+50%CU	2.87	0.161	2.59
UF125+50%CU	2.99	0.167	2.66
UF150+50%CU	3.04	0.175	2.74
CCU100+50%CU	3.24	0.204	3.00
CCU125+50%CU	3.31	0.213	3.02
CCU150+50%CU	3.36	0.207	3.10
F test1	***	***	***
LSD5%	0.038	0.006	0.065

Table 9. Effect of different sources and rates of residual SRNFs and additional CU on yield and yield attributes of maize.

Treatments	(cm)			100 Grain weight (100GW), g	Bio. yield (BY)	Grain yield (GY)	Straw yield (StY)
	Shoot Height (ShH)	Ear length (EL)	Ear diameter (ED)		Ton fed^{-1}		
CU100%(control)	278.40	16.55	3.80	31.30	8.53	3.20	5.33
SCU100+50%CU	312.30	20.62	4.10	34.79	8.91	3.32	5.59
SCU125+50%CU	321.26	20.75	4.12	35.34	8.99	3.37	5.62
SCU150 +50%CU	325.55	21.25	4.32	35.20	9.08	3.43	5.65
UF100+50%CU	290.80	19.0	3.95	31.48	8.57	3.20	5.37
UF125+50%CU	298.22	19.66	3.99	32.57	8.69	3.26	5.43
UF150+50%CU	303.59	20.25	4.05	33.74	8.82	3.29	5.53
CCU100+50%CU	332.22	22.55	4.32	36.61	9.15	3.50	5.65
CCU125+50%CU	343.33	23.75	4.50	37.43	9.22	3.53	5.69
CCU150+50%CU	355.10	24.0	4.62	38.84	9.29	3.57	5.72
F test	***	***	***	***	***	***	***
LSD5%	1.62	0.740	0.032	0.080	0.085	0.085	0.085

It's clear that residual of SRNFs treatments application causes a gradual increase in most studied parameters as a result of availability of needed N for a long time as plant need (Gagnon *et al*., 2012); the superior effect of treatments were obtained with residual of CCU. Jadon *et al*., (2018) recorded that SRNFs increasing yield and yield attributes of maize comparing with conventional urea. It could be explained by the low solubility of CCU than other SRNFs, controlling of nutrient release and providing more efficient nutrients to the roots.

Application of CU using additional 50% fertilization rate with residual of CCU (150%) achieved highest values of all yield parameters. These results may be due to the effective role of nitrogen on the meristmatic activity of plant tissues, as well as its role in proteins, nucleic acid and many other important substances of plant cell formation that lead to the highest yield producing. These results are in matching with that reported by Mukhtar *et al*. (2011).

NPK, Oil Content and Nutrients Uptake in Grains.

Results in Table 10 and Figs 2 (a, b and c) revealed that all applied treatments had a positive effects on grains NPK and oil content of maize.

The residual amounts from SRNFs application caused a significant increase in NPK content in maize grains. Residual effect of CCU using 100% fertilization rate recorded the highest NPK and oil content in grains (2.09, 0.134, 1.46 and 5.20% respectively) than that of CU (1.74, 0.101, 1.11 and 4.57% respectively). Tabulated data recorded that residual influence of SRNFs at fertilization rate 125 and 150% over recommended fertilization rates significantly increased NPK and oil content of maize grains comparing with CU using fertilization rate at 100% recommended dose (control). Abou-Zied *et al*., (2014) concluded that increasing rate of nitrogen increasing content of NPK. On the other hand residual effect of SRNFs increased oil content in maize grains, this result is in matching with that obtained by Signor and Barbiani (2013).

Table 10. Effect of different sources and rates of residual SRNFs and additional CU on oil and nutrient concentration (%) in maize grains.

Treatments	Nutrients and oil concentration (%)			
	N	P	K	Oil
CU100% (control)	1.74	0.101	1.11	4.57
SCU100+50%CU	1.92	0.121	1.29	4.90
SCU125+50%CU	2.01	0.126	1.35	4.85
SCU150 +50%CU	2.04	0.125	1.40	4.78
UF100+50%CU	1.79	0.106	1.16	4.73
UF125+50%CU	1.83	0.111	1.20	4.67
UF150+50%CU	1.88	0.116	1.23	4.60
CCU100+50%CU	2.09	0.134	1.46	5.20
CCU125+50%CU	2.13	0.138	1.49	5.17
CCU150+50%CU	2.17	0.141	1.54	5.08
F test	***	***	***	**
LSD5%	0.076	0.002	0.038	0.045

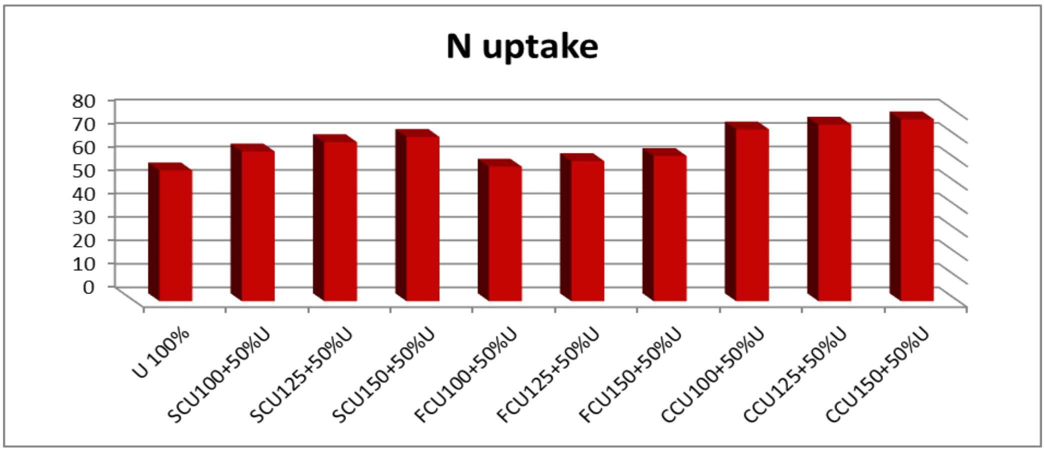

Fig. (2a): Residual effect of SRNFs and additional CU on N uptake (Kg fed^{-1}) of maize grains.

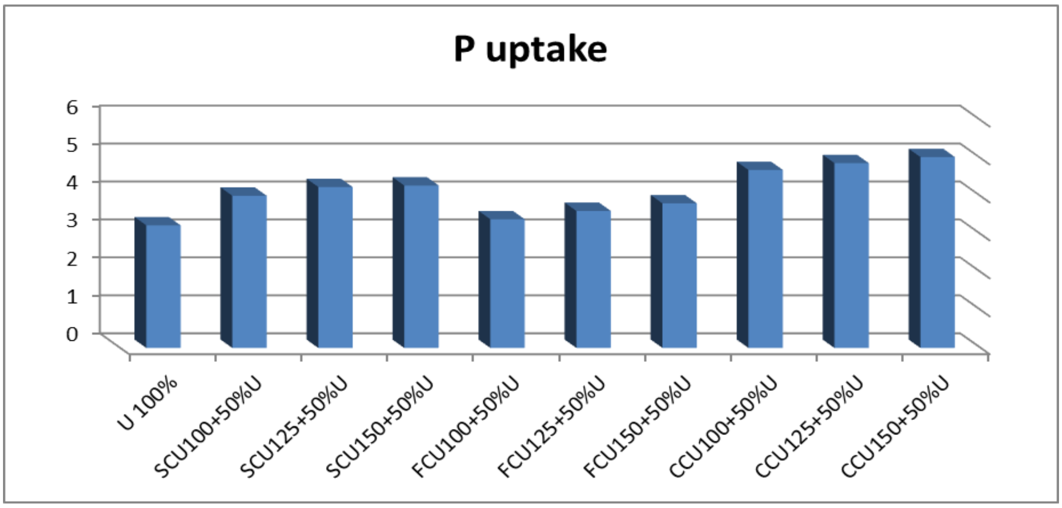

Fig. (2b): Residual effect of SRNFs and additional CU on P uptake (Kg fed^{-1}) of maize grains.

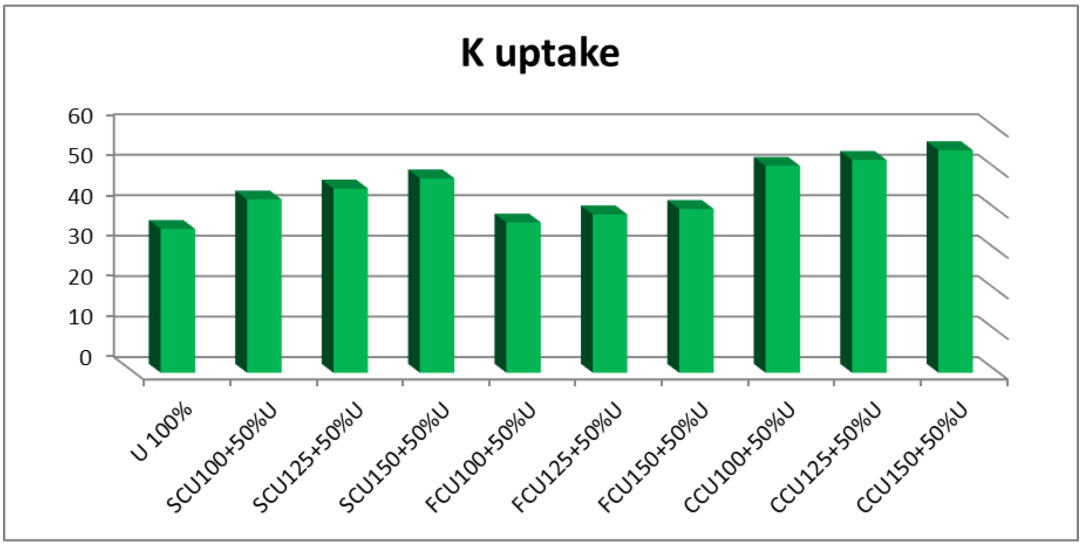

Fig. (2c): Residual effect of SRNFs and additional CU on K uptake (Kg fed^{-1}) of maize grains.

Residual N in Soil.

Soil samples were collected during the two successive growing seasons of wheat and maize (winter and summer growing seasons) to monitors available soil N content. Data tabulated in Table 11 showed the available soil nitrogen content in the soil surface layer (0-30cm) during maximum vegetative growth stage (75 days after planting) of wheat, after wheat harvesting, before maize sowing and finally after maize harvesting. From tabulated data it's clear that all treatments positively affected the availability of nitrogen content in the soil during all studied periods comparing with conventional urea (CU).

Firstly, during maximum wheat vegetative growth (75 days after planting) available nitrogen increased gradually, due to release of the SRNFs which recorded the highest values of available soil N comparing with conventional urea (CU) under 100% fertilization rate where UF, SCU and CCU induced 101.35, 98.85 and 90.65 mg kg^{-1} respectively. After harvesting we noticed that the highest values of available soil N was recorded by CCU (87.55 mg Kg^{-1}) followed by SCU (86.85 mg Kg^{-1}), UF (85.35 mg Kg^{-1}) and lately CU (80.55 mg Kg^{-1}) using 100% fertilization rate. The same trend was occurred before maize sowing with decrease in N content due to voltalization.

Secondly, after maize harvesting results of N concentration elucidated that the highest individual effect of SRNFs residual values recorded in case of CCU fertilizer, where CCU using at 100% fertilization rate recorded 80.20 mg Kg $^{-1}$ while SCU and UF using at the same fertilization rate showed 69.65 and 57.50 mg Kg^{-1} respectively, and the lowest available soil N (65.35 mg Kg $^{-1}$) achieved by CU. These results may be due to the low solubility of coating layer for CCU comparing with the other three urea types. Mello *et al.* (2017) indicated that losses of nitrogen through voltalization reduced by approximately 50% in case of coated urea application.

When applied conventional urea (CU) to the soil, urea hydrolyzed through a series of biological, chemical and physical reactions urease enzyme to NH^{4+} which oxidized to NO_3^- that loss by leached or denitrified (El-Ghamery *et al.*, 2016).

Ladha *et al*., (2005) and Galloway *et al*., (2004) indicated that crops used

approximately 30-50% from the applied N and this may be due to losses of N through leaching, volatilization, nitrification, denitrification and decomposition. On the other hand, the least remaining amount from N fertilizer after crop recovery and losses still in soil causing residual N effect and are available for subsequent crops (Krupnik *et al.,* 2004).

In a wheat/maize cropping sequence experiment the residual N recovery of applied fertilizer to wheat was 5–10% in the later maize crop and 1.7–3.5% in the subsequent wheat crop and this recovery act as a source of N in cropping sequence (Jia *et al*., 2011).

Releasing nutrients from slow release fertilizers ranging between (3-12 months) where it depends on different factors i.e.: coating solubility, rate of hydrolysis, moisture, temperature of the soil, coating thickness, micro cracks number in coating surface and granule size of fertilizer (Pereira, 2009).

SRNFs can be classified according to solubility into different types; in this research SCU and CCU are examples of fertilizers in which the release is controlled by some physical, chemical and microbial processes (Trenkel, 2010).

While, UF is example of fertilizers that has a low solubility with organic-N compounds that decomposed biologically or chemically and it's widely used in warmer climates where it be more effective at higher temperatures (Wilson *et al*., 2009).

Economic Analysis:

Gross income is an indicator to the benefit that farmers can obtain. While, net return determines farmers' actual income. On the other hand, benefit cost ratio (BCR) is the overall relationship between the relative costs and benefits. Economically if a BCR greater than 1.0, the project is expected to deliver a positive net present value to a firm and its investors (Jadon et al., 2018).

Table 11. Effect of different SRNFs on available N content in soil (mg kg^{-1}) at different stages during wheat–maize cropping sequence system.

Treatments	Available N in soil (mg kg^{-1})			
	At vegetative stage of wheat	After wheat harvesting	Before maize sowing	After maize harvesting +50 % CU
CU	89.55	80.55	54.25	65.35
SCU100%	98.85	86.85	68.95	69.65
SCU125%	99.50	88.95	70.65	73.40
SCU150%	100.88	90.65	72.06	77.65
UF100%	101.35	85.35	67.60	57.50
UF125%	102.65	88.55	69.40	62.45
UF150%	106.20	89.45	70.75	65.92
CCU100%	90.65	87.55	74.55	80.20
CCU125%	96.95	89.75	76.45	84.00
CCU150%	99.65	91.55	79.05	85.88
F test	***	***	***	***
LSD at 0.05%	0.085	0.084	0.085	0.085

Data tabulated in Table 12 declared that there was a differences in gross income, net return and benefit cost ratio between all treatments in wheat and maize crops, respectively. The highest cost of cultivation in wheat crop recorded by SRNFs comparing with conventional urea (CU). CCU using at 100% fertilization rate gave the highest costs of wheat cultivation (9524.00 £.fed^{-1}) followed by UF with (8852 £.fed^{-1}) and SCU with (8320£.fed^{-1}) at the same rate of application. The cost of wheat cultivation increased by increasing rate of applied nitrogen where CCU using at 150% fertilization rate achieved the highest cultivation cost (11036 £.fed^{-1}) in the wheat season. It's clear that coated urea showed more costs of cultivation than that of un coated urea and this may be due to high price of coating and production. SCU is the lowest cost of wheat cultivation comparing with other coated urea where sulfur is the cheapest coating.

In case of maize conventional urea (CU) using at 100% fertilization rate recorded the highest cost of cultivation (7875 £.fed^{-1}) comparing with the other treatments.

The maximum gross return of wheat crop as well as maize increase by increasing nitrogen rate, SCU at100% fertilization rate gave the highest gross income of wheat (19840 £.fed^{-1}) comparing with UF, CCU and CU at the same rate. On the other hand residual of CCU using at 100% fertilization rate achieved the highest gross income of maize (18025 £.fed^{-1}) in comparison with SCU (17552 £.fed^{-1}), UF (16882 £.fed^{-1}). SRNFs i.e. SCU, UF and CCU at 100 % fertilization rate application as well as their residual enhanced wheat and maize grain yield more than that of conventional urea (CU) at 100% fertilization rate.

The highest net return of 11520 and 10800 £.fed^{-1} were obtained by SCU for wheat plant and CCU for maize plant, respectively at 100 % fertilization rate. The lowest net return in both seasons were indicated by CU at 100% fertilization rate with net return 9230 and 8929 £.fed^{-1} for wheat and maize , respectively.

Table 12: Economic criteria for the different treatments at the wheat – maize cropping sequence.

Treatments	Total costs (£.fed^{-1})		Gross income (£.fed^{-1})		Net return (£.fed^{-1})		BCR	
	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize
CU100% (control)	7310	7875	16540	16804	9230	8929	2.26	2.13
SCU100%	8320	7225	19840	17552	11520	10327	2.38	2.42
SCU125%	8787	7225	19960	17710	11173	10485	2.27	2.45
SCU150%	9244	7225	20200	17887	10956	10662	2.18	2.47
UF100%	8852	7225	18880	16882	10028	9657	2.13	2.33
UF125%	9437	7225	19120	17119	9683	9894	2.02	2.36
UF150%	10024	7225	19380	17375	9356	10150	1.93	2.40
CCU100%	9524	7225	17740	18025	8216	10800	1.86	2.49
CCU125%	10280	7225	17860	18163	7580	10938	1.73	2.51
CCU150%	11036	7225	18500	18301	7464	11076	1.67	2.53

The highest BCR (2.38) in wheat was achieved by SCU at 100% fertilization rate and (2.49) in maize was obtained by residual of CCU using at 100% fertilization rate.

From the economical point of view, it's clear that SCU at 100% fertilization rate applied treatment for wheat and residual of CCU at 100% fertilization rate for maize recorded the highest net return as well as BCR and both could be a good alternative to CU for enhancing yield and farmer income.

Conclusion:

Slow release nitrogen fertilizers (SRNFs) were more effective in enhancing growth, yield and yield components of plants as well as reducing N losses through volatilization, leaching and decomposition. So, it can be concluded that using of SRNFs especially SCU with 100% recommended dose achieved the highest growth, yield and yield component of wheat plants. Also, it was recorded that the residual of SRNFs were higher than conventional urea and we concluded that residual with the lower addition rates of conventional urea recorded the highest values of growth, yield and yield component of maize in wheat–maize cropping system.

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تقنين إستخدام الأسمدة الآزوتية ذات الكفاءة المحسنة لتحسين إنتاجية محصولى القمح والذرة فى تعاقب محصولى تحت ظروف الأراضى الطينية

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الملخص العربى

تستدعى التحديات الراهنة الي تطوير تكنولوجيات تصنيع الاسمدة و زيادة التوجه لاستخدام الاسمدة ذات الكفاءة المحسنة مثل الاسمدة البطيئة الذوبان (الإنسياب) بغرض زيادة انتاجية وحدة المساحة من المحاصيل و تقليل التلوث البيئي للماء و الهواء و التربة.

لذلك أجريت تجربتان حقليتان فى محطة البحوث الزراعية بتاج العز بمحافظة الدقهلية فى وسط دلتا نهر النيل – مركز البحوث الزراعية– مصر في تصميم قطع كاملة العشوائية فى ثلاث مكررات فى تعاقب محصولى خلال الموسمين الزراعيين الشتوي و الصيفي لعام ٢٠٢٠ و ٢٠٢١ بهدف دراسة تأثير ثلاثة مصادر مختلفة من الأسمدة بطيئة الذوبان (يوريا مغلفة بالكبريت و يوريا فورمالدهيد ويوريا مغلفة بالإسمنت) بثلاث معدلات مختلفة (١٠٠– ١٢٥ –١٥٠٪) من الموصي به ومقارنتها باليوريا العادية على نبات القمح صنف مصر ١ في الموسم الشتوي، وكذلك دراسة النيتروجين المتبقي من الاسمدة بطيئة الذوبان مع إضافة يوريا عادية بمعدل (٥٠٪) من الموصي به على نمو وانتاجية نبات الذرة صنف هجين ثلاثي ٣٦٠ أثناء الموسم الصيفي التالى . بالإضافة لدراسة النيتروجين الميسر في التربة اثناء مراحل النمو في التجربتين.

ويمكن تلخيص أهم النتائج المتحصل عليها من استخدام التكنولوجيا الحديثة التي تساعد علي رفع كفاءة الاسمدة مثل استخدام الاسمدة بطيئة الذوبان فيما يلى:

١. اعطت الاسمدة بطيئة الذوبان اعلي قيم للنمو الخضري و المحصول و مكوناته في القمح مقارنة باليوريا العادية و بزيادة معدل النيتروجين تزداد قيم الصفات محل الدراسة.

٢. كانت اليوريا المغلفة بالكبريت بمعدل تسميد ١٠٠٪ من الموصي به هي افضل الأسمدة بطيئة الذوبان المستخدمة تحت نفس المعدل، واعطت معدل زيادة في محتوي الكلوروفيل (أ+ب) بنسبه ٣١.٢٣٪ ،وكذلك زيادة في محصول القمح البيولوجي بمعدل ١٩.٩٥٪. كما حققت اعلي تركيزات من محتوي الحبوب من العناصر كالنيتروجين (٢.٣٥٪) والفوسفور (٠.٢٨٩٪) والبوتاسيوم (١.٣٨٪) وكذلك أعلي محتوي من البروتين بنسبة (١٣.٥١٪).

٣. أعلي قيمة للمتبقي من النيتروجين في التربة بعد حصاد القمح تحققت من خلال معاملة اليوريا المغلفة بالإسمنت، واستمر بنفس الاتجاه حتي بعد حصاد الذرة.

٤. حققت معاملة المتبقي من اليوريا المغلفة بالإسمنت بمعدل ١٠٠٪ مع اضافة ٥٠٪ من الموصي به في صورة يوريا عادية أعلي النتائج في محتوي الذرة من الكلوروفيل (أ+ب) بزيادة ٣٦.٤٪ و كذلك المحصول البيولوجي بزيادة ٧.٢٧٪. كما حققت نفس المعاملة أعلي القيم لمحتوي حبوب الذرة من النيتروجين (٢.٠٩٪) و الفوسفور (٠.١٣٤٪) و البوتاسيوم (١.٤٦٪) والزيت (٥.٢٠٪) مقارنة باليوريا العادية بالمعدل الموصي به.

٥– اقتصاديا ننصح المزارع باستخدام اليوريا المغلفة بالكبريت بمعدل ١٠٠٪ من الموصي به في حالة المحصول الواحد. واستخدام اليوريا المغلفة بالإسمنت بمعدل ١٠٠٪ في حالة التعاقب مع اضافة يوريا عادية لها في الموسم الثاني بمعدل ٥٠٪ من الموصي به.

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