International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.9, No.10, pp 188-196, 2016

Slow-release nitrogen fertilizers effects on plant growth and yield of sorghum

Mona E. El-Azab

Soil and water Dept., National Research Center, Dokki, Egypt

Abstract : The aim of this investigation was to study the efficiency of conventional nitrogen fertilizers compared with slow-release fertilizers as urea, ureaform and sulfur- coated urea (SCU) at different doses on sorghum plants. Field experiment was conducted at Al-Sharkia Governorate, Egypt in a private farm through a project of soil and water use Dept. of the National Research Center. This experiment design with three replicates. Sorghum seeds were sown on the 15th of December, 2015. Plants were fertilized by Seven treatments of nitrogen fertilizer from control (no fertilization), (urea 46%N), (ureaform 38%N) and (SCU 32%N) respectively, with two levels of nitrogen as 100 and 200 $Kgfed^{-1}$. Results showed that the use of slow-release nitrogen fertilizer gave the highest values of vegetative growth as plant height, number of leaves/plant, number of internodes/plant and dry weight and increase the yield and its components beside increase the concentrations of N, P and K and its uptake at all growth stages. The use of sulfur coated urea more effective than ureaform of the parameters under investigated.
Keywords : urea, slow-release fertilizers, nitrogen efficiency, sorghum.

Introduction

Sorghum (*Sorghum bicolor L.*) plant a cereal crops is very important for economically after corn, wheat and rice[1]. This plant can be grown under hard situations such as soil moisture, temperature and it responses to irrigation very good so it can grown in different zones of the world. For plant growth of sorghum, nitrogen is very necessary to improve the growth and yield[11]. Nitrogen is the major factor for increased or reduced yields [33]. Nitrogen is important as macronutrients for increase plant growth. Its main effect are use as the component of many important organic compounds and collaborate in many essential metabolic processes in plants such as building amino acids, proteins, carriers, enzymes, regulators, nucleic acids, pigments, alkaloids and many other metabolites [20,29]. More studies effects the nitrogen fertilization on plant growth such as[12] obtained that the use of nitrogen fertilizers increase the plant growth and yield. But the large use of nitrogen fertilizers increase the production costs and it causes the pollution of environment[25,19].

Nitrogen use efficiency is significance in crop production system because its effect on farmer economic outcomes and environmental influence. Also, may be decrease the crop production resulted to many factors as losses of soil nitrogen by volatilization, leaching and denitrification. Conducted numerous research to increase sorghum yield by increasing the efficiency of fertilizers use and increasing of nutrient absorption by plants through use the controlled- release fertilizers which can be reduce the nutrients loss by leaching and runoff[17]. Slow-release nitrogen fertilizers is very important to save nitrogen from loss by leaching from plant, it can be increase the level of nitrate (No_3) in ground and surface water [18]. Recently, slow-release nitrogen fertilizer has

been suggest as to increase N fertilizer for sandy soil that loss N leaching and increase N use efficiency [21]. Slow-release fertilizers are new technique to increase the nutrient availability to plant as well as loss the release of nutrients to soil compared to another conventional fertilizers[17]. [8]showed that the use of slow-release nitrogen fertilizer improved the plant growth and gave the highest yield of sorghum plants compared to other nitrogen sources. [26] suggested that the use of slow-release N fertilizers can be decrease N leaching and increase plant growth which increase nitrogen concentration in plant. [33] showed that after application of slow-release fertilizer up to 30% of N applied that can be leached compared to more 88% N leaching after application the soluble ammonium nitrate in sandy soils. In general, the major advantages for coating fertilizers are that they make an acidic environment from acidic materials used and inhibit ureolytic microorganism's activities which in effect slows down the release of NH_4^+ into the soil and indirectly decrease N loss[5].

Slow-release fertilizers showed that the release of the nutrient in a lower quantity than other fertilizers. However, slow-release fertilizers are different in rate, form and period of release. It will be strongly affected with storage, transportation and distribution in the field, or by soil conditions such as moisture content, wetting and drying, thawing and freezing, and biological activity [5,27,23].

The main role of slow-release nitrogen fertilizer that improving the efficiency of fertilizers and decrease the loss of nitrogen. This result obtained with [14] showed that the use of slow-release fertilizers improve the plant growth and the coating materials decrease or delaying the release of nitrogen from fertilizers granules to soil. [16] who obtained that the application of slow-release nitrogen fertilizer increasing yield of sorghum. [24,36]also indicated that the application of slow-release with urea increased wheat yields from 18.3 – 27.8 % and rice yields from 27.5 – 50.4 % than application of urea only. [21] found that the slow-release N can decrease N loss by leaching, increase plant growth and increase N concentration compared with ammonium nitrate. Slow-acting fertilizers are characterized by a delay between the time of application and nutrient availability, as well as a lower release of nutrients into soil compared to conventional fertilizers[17].

There is some information of use slow-release fertilizers on sorghum. Therefore the present study was conducted to evaluate the effect of nitrogen fertilizers with slow-release fertilizers on yield and some nutrients uptake of sorghum plants.

Materials and Methods

A field experiment was executed in Sharkia Governorate, Egypt, to effects the efficiency of nitrogen fertilizers with slow-release fertilizers with two levels on nutrient concentration and yield of sorghum plant (*Sorghum bicolor L.*). Sorghum seeds were sown on the 15th of December, 2015. Superphosphate (15.5% P O) was added at rate of 150 Kg/fed before sowing. Plants were fertilized with Seven treatments of nitrogen fertilizer as control, urea (46%N), ureaform (36%N), SCU (32%N) respectively, with two levels of nitrogen as 100 and 200 Kgfed^{-1}. The fertilizers were added before irrigation which applied at 15, 45 and 60 days from sowing. Treatments were as follows:

1. Control
2. Urea 100Kgfed^{-1}
3. Urea 200Kgfed^{-1}
4. Ureaform100 Kgfed^{-1}
5. Ureaform200 Kgfed^{-1}
6. SCU100 Kgfed^{-1}
7. SCU200 Kgfed^{-1}

The physical – chemical properties of the soil is presented in Table (1). Chemical formula and nitrogen percent of the applied slow-release fertilizers and conventional fertilizers is presented in Table (2). Treatments were arranged in a complete randomized block design with 3 replicates. Plant samples were taken at 60, 90 and 120 days after planting. Plant height (cm), number of leaves/plant, number of internodes, dry weight of plant, grain weight, shoot and grain yields as well as 100-grain weight were recorded and grains were also subjected to chemical analysis. Grain weight kg/plot were measured. Grain yield per feddan was obtained. Total of nitrogen, Phosphorus and potassium were determined.

Methods of Analysis

Mechanical analysis was determined according to the international Pipette method and calcium carbonate content of the soil was determined volumetrically using Calcimeter as described by [22].

The electrical conductivity (EC) of soil water extract was determined by using the bridge, [13].

Calcium carbonate content of the oil was determined volumetrically using Collins calcimeter as described by [22].

Soil pH was measured using a glass electrode pH meter in a 1: 2.5 soil water suspension [6].

Organic matter was determined by Walkley and Black's method as described by [13].

Soluble cations and anions were determined in (1:5) soil water extract according to [4].

Sodium and potassium were determined by using flame photometer as described by [6].

Calcium and magnesium were determined following the versenate method [13].

Total nitrogen in soil was determined using microKjeldahl method [13].

Total potassium in soil was determined by flame photometer according [13].

Total phosphorus in soil was determined colourmetrically using ascorbic acid method [32].

The data obtained was subjected to analysis variance procedure using Duncan's Multiple Range Test was adopted for the means comparison among treatments showing significant difference. Effect of N and P fertilizer was partitioned into linear and quadratic components and regressions were calculated for effects significant at 0.05 level of probability [7].

Table (1): Physical and chemical properties of the studied soil

Soil characteristics	Soil content
Mechanical analysis:	
Fine sand%	12.36
Coarse sand%	66.42
Silt%	6.80
Clay%	14.42
Textural	Sandy
Chemical analysis:	
Organic matter%	1.04
pH	7.31
EC (dS m-1)	0.12
CaCO3 g kg^{-1}	2.25
Soluble ions ($mmol^{-1}$)	
Ca^{++}	0.34
Mg^{++}	0.56
Na^{+}	0.66
K^{+}	0.12
CO^{-3}	-
HCO^{-3}	0.37
Cl^{-}	0.48
SO^{-4}	0.29
Available-N (g kg^{-1})	2.47
Available-P (g kg^{-1})	1.22
Available-K (g kg^{-1})	0.63

*Soil- water suspension 1:2.5 ** Soil water extract 1:5

Table (2): Chemical formula and nitrogen percent of the applied slow-release fertilizers and conventional fertilizers.

Material	Formula	N%
Urea	O=C(NH2)2	46
Ureaform	HO-CH_2-CO-NH-CH_2-NH-C= O-H	36.2
Sulfur-coated urea "SCU"	O=C(NH_2)$_2$+S	32

Results and Discussion

Vegetative growth:

Results show that the effect of nitrogen fertilizers of sorghum plants with slow-release fertilizers at different concentrations on vegetative growth. Concerning the effect of nitrogen fertilizers with slow-release fertilizers on vegetative growth at 60 and 90 day after sowing, data presented in Table (3), showed that the slow-release fertilizers was generally more effective than the control plants and urea. These results may be due to the effect of coating materials on decrease of nitrogen loss from fertilizers. These results were in agreement with the results obtained by [17] and [8] who revealed that the application of slow-release nitrogen fertilizer increased the growth of sorghum plants compared to other nitrogen sources. Data obtained that the application of Slow- release N fertilizer as ureaform and sulfur coated urea gave the highest values of plant height, number of leaves/plant, number of internodes/plant and dry weight of plant compared with urea and control. This result may be attributed to the effect of coating materials on delaying the release of nitrogen from fertilizer granules as indicated by[14] and [31] who obtained that coating materials can decrease nitrogen loss through intermittent leaching by stalling the release of nitrogen. Data presented in the same Table showed that sorghum grown in soil fertilized with slow-release N fertilizer improved the plant growth at 60 and 90 day after sowing, than the other sources of N fertilizer as urea. Result may be due to the solubility of urea was greater than ureaform and sulfur coated urea so the application of urea increased the loss of nitrogen compared with slow-release fertilizer. These results are agreement with [31,17,26].

The maximum mean values of plant height, number of leaves/plant, number of internodes/plant and dry weight of plant at 60 and 90 day after sowing, were found with foliar slow-release fertilizer with 200Kgfed^{-1}. On the other hand, the minimum values of the vegetative growth were occurred with urea fertilizer with 100Kgfed^{-1}. These results may be due to the effect of slow-release fertilizers in plant physiology which it increase the nitrogen uptake from plant that nitrogen plays a important role in several vital processes in plant such as photosynthesis consequently affecting plant growth which was effect on vegetative growth plant. Improving effect of slow-release fertilizers on vegetative growth might be attributed to their positive role on nitrogen loss and it was increase the rate of photosynthesis, biosynthesis of proteins and carbohydrate assimilation. This result in coincidence with the findings of [26]. Data in the same Table, illustrate that slow-release fertilizers treatments with 200Kgfed^{-1} increased significantly the dry weight compared with urea and control. The positive effect of slow-release fertilizers was greater than urea. These result may be due to the solubility of urea was greater than urea form and sulfur coated urea. These results are agreement with [31]. Data in the same Table showed that the maximum mean values of vegetative growth at 60 and 90 day after sowing, were obtained with sulfur coated urea at 200Kgfed^{-1} than urea form. This result may be attributed to the low activity index of urea form as recorded by [3].

Table (3): Effect of different sources of nitrogen fertilizers on vegetative growth of sorghum plant.

Treatments		plant height (cm)		number of leaves/plant		number of internodes/plant		dry weight (g)	
fertilizers	**Rate of N Kg/fed**	**60**	**90**	**60**	**90**	**60**	**90**	**60**	**90**
Control	0	98.24	110.28	4.33	4.00	5.00	5.00	94.12	115.36
Urea	100	104.24	129.34	5.67	5.33	6.00	6.00	127.45	133.54
	200	114.36	138.55	6.00	5.50	6.00	6.00	128.23	142.58
Ureaform	100	126.22	135.39	7.00	6.50	7.00	7.00	145.22	154.23
	200	131.25	144.21	7.50	7.00	7.00	7.00	151.14	156.91
SCU	100	132.69	146.11	7.31	7.00	8.00	8.00	156.35	163.41
	200	134.41	148.57	7.66	7.50	8.00	8.00	158.14	164.54
LSD at 0.05		1.26	1.44	0.11	0.24	0.25	0.16	1.48	1.23

Yield and its components:

Data in Table (4) obtained that the grain weight, shoot and grain yields as well as 100-grain weight as affected by nitrogen fertilizer with slow-release fertilizers under experimental conditions. The maximum values of this characteristics were produced from slow-release fertilizers application. While, the minimum values of aforementioned attribute were obtained with control. These results are in harmony with those obtained by[8] who suggested that there are several potential benefits of providing nitrogen to slow-release fertilizer. These include: reduced nitrogen losses through denitrification and leaching compared with nitrogen fertilizer application as urea. The superior of slow-release than urea can be attributed to the slow-release of N to meet plants requirement, where it has a low dissolution rate than the others which reduces nitrogen loss from soil profile and gives a chance for more nitrogen uptake by plant root. Similar finding were reported by [16] who found that slow-release nitrogen fertilizer gave the highest yield of sorghum. [24]also showed that slow-release urea increased wheat yields by 18.3 – 27.8 % and rice yields by 27.5 – 50.4 % as compared with common urea. [21] showed that amending sandy soils with slow-release N can reduced leaching, increase plant growth and increase N concentration compared with sweet corn grown in soil amended with ammonium nitrate. [28] told that, slow-release N fertilizer overcame soluble N fertilizer.

Sorghum grown in soil fertilized with slow-release N fertilizer as ureaform and sulfur coated urea gave significantly more yield and its components. These result due to effect of slow-release fertilizers on nitrogen loss which increase the plant growth and effect on photosynthesis rate. These results are agreement with [31,17,26]. Although sorghum uses nitrogen more efficiently than most plants with the C3 cycle, nitrogen is the main factor responsible for reduced yield[34].

Data showed that all slow-release fertilizers treatments with 200Kgfed^{-1} greatly improved the yield and its components of sorghum plants compared with control, grain weight, shoot and grain yields as well as 100-grain weight were significantly improved with increasing of slow-release fertilizers with rate from 100Kgfed^{-1} up to 200Kgfed^{-1}. These results may be due to the effect of these slow-release fertilizers on nitrogen loss so it effect on plant physiology such as photosynthesis consequently affecting plant growth, important for ^{14}C fixed in the primary photosynthetic process. These increases of the grain weight, shoot and grain yields and 100-grain weight may be due to the amount of metabolites synthesized by plants as a result of increasing nitrogen levels. This may be attributed to the favorable effect of nitrogen fertilizer levels on the metabolic processes and physiological activates of meristimatic tissues, which are responsible for cell division and elongation in addition to formation of plant organs this lead to more vigorous growth and consequently accumulation of more photosynthesis assimilates. Similar results were reported by[10,9].

The obtained results are in harmony with those of[2] and [15] where they found that yield and its components increased markedly by slow-release fertilizers with 200Kgfed^{-1} compared with the untreated plants.

Although sorghum uses nitrogen more efficiently than most plants with the C_3 cycle, nitrogen is the main factor responsible for reduced yields [34]. So, the uses of slow-release fertilizers decrease of nitrogen loss and increase the nitrogen uptake from plant.

It is clear from Table (4) that slow-release N fertilizer as sulfur coated urea at 200kgfed^{-1} was the best treatment in all characters under study especially grain yield and straw yield/plant compared with urea. This result may be attributed to the loss nitrogen from urea. The positive effect of slow-release fertilizers was greater than urea. These result may be due to the solubility of urea was greater than ureaform and sulfur coated urea. This result are agreement with [31]. Data in the same Table showed that the maximum mean values of yield were obtained with sulfur coated urea at 200Kgfed^{-1} compared with ureaform. This result may be attributed to the low activity index of ureaform as recorded by [3]. On the other hand, the minimum mean values of grain yield were obtained with control. Similar finding were obtained by [28,8]. Slow-release N fertilizer may help positively in plant growth, which was increased of N, P and K content in plant because it saved the nutrients from loss. Similar results were reported by [10,9].

Table (4): Effect of different sources of nitrogen fertilizers on yield and its components of sorghum plant at harvest.

Treatments		grain weight/ plant(g)	shoot yield /plant(g)	grain yields (ton/fed)	shoot yield (ton/fed)	100-grain (g)
fertilizers	**Rate of N Kg/fed**					
Control	0	24.11	114.24	0.87	4.24	22.47
Urea	100	34.58	186.24	1.46	8.74	25.14
	200	38.22	195.23	1.51	8.94	26.32
Ureaform	100	41.26	214.56	2.47	9.35	28.59
	200	44.59	232..14	2.63	9.47	28.45
SCU	100	48.26	241.58	2.57	9.66	30.18
	200	51.23	249.36	2.78	9.71	30.53
LSD at 0.05		1.22	1.24	0.45	0.33	1.29

Nutrient concentration:

Results showed that the application of slow-release fertilizer with different levels on nitrogen, phosphorus and potassium concentration (%) and its uptake (g plant-1) in sorghum grains. The results in Table (5) show that application of slow-release fertilizer with 200Kgfed^{-1} significantly increased nutrient concentration of sorghum plant compared to control treatment or urea application. This result may be due to effect of slow-release fertilizers on nutrients loss which decrease the loss by leaching so effect on translocation rate of photosynthesis. These results are in agreement with those obtained by [30] who showed that the application of slow-release fertilizers increased the N, P and K concentration in plant.

The results indicate that the highest concentration of nitrogen and it is uptake with slow-release fertilizers as urea form and sulfur coated urea at 200K gfed^{-1} compared with the application of urea, but the lowest concentration of nitrogen at control. Also, the results show that the highest concentration of phosphorus and potassium and it is uptake absorbed with ureaform and sulfur coated urea at 200K gfed^{-1} compared with treatment urea. And the lowest concentration of phosphorus and potassium and it is uptake absorbed with control. These results may be attributed to effect of slow-release fertilizers to reduce N leaching and increases the yield of sorghum in such sandy soil. Also the effect of slow-release fertilizers is positive effect from nutrients availability for plant. This result obtained by [21] showed that amending sandy soils with slow-release N can reduced leaching, increase plant growth and increase N,P and K concentration compared with sweet corn grown in soil amended with ammonium nitrate. [28] showed that, the slow-release fertilizer increase the nutrients availability to plant which decrease the nutrient loss by leaching. It might be due to participation of slow-

release fertilizers with 200Kgfed^{-1} which reduce the nitrogen loss so, its plays important roles in plant growth and production, including chlorophyll synthesis, protein synthesis and chloroplast development.

From data in the same Table, the results indicate that the highest concentration of nitrogen, phosphorus and potassium and it is uptake in sorghum grains were obtained with sulfur coated urea than urea form. This result may be attributed to the low activity index of urea form as recorded by[3].

Nitrogen Efficiency Ratio (NER) and Nitrogen Recovery (NR

Data in the Table (6) showed that the effect of nitrogen fertilizers and slow-release fertilizers on nitrogen efficiency ratio (NER) and nitrogen recovery (NR). The results of Table obtained that there are significantly differences between nitrogen efficiency ratio and nitrogen recovery in sorghum grains. Also, in the same Table, the highest mean value of (NER) obtained with slow-release fertilizers as ureaform and sulfur coated urea compared with urea and control. The lowest mean value of NER observed with control. Data of nitrogen recovery (NR) which presented in Table (6) show that the highest (NR) values has been obtained from slow-release fertilizers. While, the lowest values of (NR) has been obtained with control and urea. This result may be due to effect of slow-release fertilizers on nitrogen loss which decrease the loss by leaching. These results are in agreement with those obtained by[30]. Regarding with the effect of slow-release fertilizers rates, data in the same Table noticed that there are significantly differences between nitrogen efficiency ratio and nitrogen recovery as affected by slow-release fertilizers rates. Also, the highest mean value of NER was observed with sulfur coated urea at 200Kgfed^{-}. Meanwhile, the lowest mean value of (NER) obtained with urea fertilizer at 100Kgfed^{-1}. These results are in harmony with those obtained by[30]. Also, the highest mean values of NR was observed with sulfur coated urea at 200Kg. And the lowest values of NR was obtained with urea at 100Kgfed^{-1}. This result may be attributed to the loss nitrogen from urea. The positive effect of slow-release fertilizers was greater than urea. These result may be due to the solubility of urea was greater than urea form and sulfur coated urea. This result are agreement with [31]. Similar results were reported by [10,9].

Data in the same Table showed that the maximum mean values of (NER) and (NR) were obtained with sulfur coated urea at 200Kgfed^{-1} compared with ureaform. This result may be attributed to the low activity index of ureaform as recorded by [3]. On the other hand, the minimum mean values of (NER) and (NR) were obtained with urea. Similar finding were obtained by [28,8].

Table (5): Effect of different sources of nitrogen fertilizers on N, P and K concentration and its uptake of sorghum grains.

Treatments		%			Uptake (g plant^{-1})			NER	NR
fertilizers	Rate of Kg/fed	N	P	K	N	P	K		
Control	0	1.46	0.12	0.34	0.35	0.03	0.08	8.44	14.23
Urea	100	1.68	0.23	1.33	0.58	0.08	0.46	20.06	18.67
	200	1.87	0.25	1.42	0.71	0.09	0.54	27.14	19.47
Ureaform	100	2.14	0.34	1.75	0.88	0.14	0.72	36.31	21.65
	200	2.21	0.41	1.88	0.98	0.18	0.83	43.70	22.14
SCU	100	2.32	0.42	1.89	1.12	0.20	0.91	54.05	22.35
	200	2.54	0.45	1.91	1.30	0.23	0.97	66.59	24.57
LSD at 0.05		0.15	--	0.24	2.13	0.39	1.58	1.22	0.12

Conclusions:

There were significant differences between nitrogen fertilizers and slow-release fertilizers. For sandy soil, the use of slow-release nitrogen fertilizers was very important to reduces N leaching and increases the yield of sorghum. Also the use of slow-release N is more effective than another nitrogen fertilizers generally resulted in increased the growth and nutrients uptake by sorghum plants grown in sandy soil. Using slow-

release fertilizers reduces production costs, eliminates the need for multiple applications of soluble nitrogen fertilizers. Also slow release nitrogen fertilizers were able to increase nitrogen use efficiency by reduce nitrogen by leashing and volatilization from soils.

Acknowledgment

Many thanks to the staff members of soil and water use Department National Research Center for great help During This Study.

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