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Impact of UREA^{Stable} on Soil Property, Nitrogen Use Efficiency and Yield of Durum Wheat under Balanced Fertilizer Application

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Authors' contributions

This work was carried out in collaboration among all authors. Author TM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author ST and DB managed the analyses of the study. Author YA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Wheat requirement of nitrogen for plant growth, and crop yields and quality depends upon substantial N inputs. Therefore, a field experiment was carried out at Gimbichu district in 2017 and 2018 main cropping season with the objective of evaluating the overall performance of applying slow-release/UREA^{stable} fertilizer over the conventional urea fertilizer for durum wheat production, and to determine optimum rates of slow-release urea fertilizer for wheat productivity. The treatments consisted of Control, 90 kg N ha^{-1} from conventional urea applied in split, 90 kg N ha^{-1} from UREA^{stable} applied once at planting, 90 kg N ha^{-1} from UREA^{stable} applied in split, 45 kg N ha^{-1} from UREA^{stable} applied once at planting, 45 kg N ha^{-1} from UREA ^{stable} applied in split form, 135 kg N ha^{-1} from UREA ^{stable} applied in split form, 135 kg N ha^{-1} from conventional UREA applied in split form and 135 kg N ha^{-1} from UREA^{stable} applied once at planting. The results revealed that plant height, spike length, Tiller number, grain yield, biomass yield, harvest index and grain and straw

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uptake were significantly (P<0.05) affected by the application of slow release and conventional urea fertilizer. The highest spike length (3.8cm), Tiller number (2.1), grain yield (2205 kg ha^{-1}), biomass yield (6968 kg ha^{-1}) and nitrogen grain straw uptake (35.6 kg N ha^{-1}) were recorded from 135kg N ha^{-1} urea stable fertilizer applied in split form followed by application of 135 kg N ha^{-1} conventional urea fertilizer applied in split form. While, maximum straw nitrogen uptake was obtained from application of 135 kg N ha^{-1} conventional urea fertilizer applied in split form. Therefore, taking the findings of the present study consideration it may be concluding that farmers can use 135 kg N ha^{-1} UREA^{stable} fertilizer to improve nitrogen use efficiency and productivity of wheat in the study area in addition to conventional urea fertilizer. However, further research may be required at various locations to come up with an inclusive recommendation.

Keywords: Conventional urea; UREA^{stable}; yield and nutrient uptake.

1. INTRODUCTION

Wheat productivity in Ethiopia is low (2.8 t ha^{-1}) (CSA, 2019), as compared with the world average (3 t ha^{-1}). This is due to depleted soil fertility, low levels of chemical fertilizer usage, limited knowledge on time and rate of fertilizer application and unavailability of other modern crop management inputs. (Anderson and Schneider, 2010). Declining soil fertility has continued to be a major constraint for food production in many parts of the tropical region. Particularly, in sub-Saharan Africa, soil fertility depletion is the fundamental cause for declining per capital food production as crop lands have a negative nutrient balance, with annual losses ranging from 1.5 - 7.1 (t ha^{-1}) of nitrogen (N), phosphorus (P) and potassium (K) mainly due to crop harvest, leaching and low inputs applied to the soil [1,2]. Among these nutrients**,** nitrogen is the most critical and required for growth, grain yield and quality of wheat [3,4]. Thus, management of N for both grain quality and quantity should combine rate, timing, splitting and sources (Basso et al. 2012). Nitrogen (N) is an essential element for winter wheat (*Triticum aestivum* L.) growth and development , Global N fertilizer consumption has increased in recent years to meet the ever-growing need for food production , Meanwhile, only about 33% of the N fertilizer applied worldwide translates into grain in cereal production [5]; wheat remains the least efficient nitrogen user among major crops [5]. A high-quality standard could be guaranteed with an increase in N input at rates often double those required to maximize grain yield (Garrido-Lestache et al. 2005) On the other hand, higher nitrogen application rates decrease N use efficiency (NUE) through an increase of nitrogen losses, which cause increase of production costs and considerable environmental and health problems [6,7].

For the last three decades, the use of N in cereal crops has increased in Ethiopia, but its use efficiency has declined tremendously due to the leaching of its available forms below, particularly, the shallow rooted like wheat, tef and barley. In order to improve urea-N recovery and reduce its loss, many forms of slow-release urea fertilizers have been developed and applied to different plant species under a range of environmental conditions. The products may be coated, chemically and biochemically modified, or are granular [8]. Such slow-release urea fertilizers can increase the efficiency of applied urea-N and are environmentally friendly because their N release is in synchrony with plant N uptake, and in a single application, can provide sufficient N to satisfy plant N requirements while maintaining very low concentrations of mineral N in soil throughout the growing season [9].

The use of slow-release urea fertilizer sources is a common strategy to reduce N losses in horticultural crops, but its agronomic performance and cost-effectiveness for field crops like has not been well established particularly durum wheat in Ethiopia. Therefore, this study was conducted to evaluate the overall performance of applying slow-release/UREA ^{stable} fertilizer over the conventional urea fertilizer for wheat production, and to determine optimum rates of slow-release urea fertilizer for wheat productivity.

2. MATERIALS AND METHODS

2.1 Site Description

The experiment was conducted at Gimbichu districts on farmers' field, East Showa Zone of Oromia Region. The gimbichu filed is located around 25 km south east of Addis Ababa (08° 16.7 N latitude and 38°57.7 E longitude) at an altitude of 2,423 meter above sea level (m.a.s.l.). The area receives a mean annual rainfall of 736.2 mm, and a mean annual minimum and maximum temperature of 13.4 and 25.7°C, respectively (Table 1).

2.2 Experimental Design and Treatments

The experiment was carried out on Farmers' fields during the main rainy cropping season (2018 up to 2019). The field experiment consisted of nine treatments1. Control, 2. 90 kg N ha^{-1} from conventional urea applied in split, 3. 90 kg N ha^{-1} from $UREA^{stable}$ applied once at planting, 4. 90 kg N ha^{-1} from $UREA^{stable}$ applied in split, 5. 45 kg N ha^{-1} from $UREA^{stable}$ applied once at planting, 6. 45 kg N ha^{-1} from $UREA^{stable}$ applied in split form, 7. 135 kg N ha^{-1} from $UREA^{stable}$ applied in split form, 8. 135 kg N ha^{-1} from conventional UREA applied in split form, 9. 135 kg N ha^{-1} from $UREA^{stable}$ applied once at planting). The balanced nutrients (P, S, B and Zn) were uniformly applied based on the recommended rates for all plots. The experiments were laid out in a randomized complete block design with three replicate plots. Unit plot size was 3m x 4m ($12m^2$). Treatments were assigned to each experimental plot by using SAS Software to randomize within a replication.

2.3 Soil Sampling, Preparation and Analysis

Soil samples were taken in a zigzag pattern from the entire experimental field at 0-20cm depth using an auger before sowing. The composite soil samples were prepared by quartering and air-drying at room temperature, ground using a pestle and a mortar and allow passing through a 2mm sieve. Working samples were obtained from bulk sample and was analyzed to determine the soil physico-chemical properties: soil texture, organic matter, and soil pH, CEC, Av. P and TN.

Table 1. Climate data of Chefedonsa area in the 2018 and 2019 cropping season

Location	Chefedonsa		
	2018	**2019**	**Mean**
Total annual rainfall (mm)	777.7	694.6	736.2
Mean annual maximum temperature (°C)	26.2	25.1	25.7
Mean annual minimum temperature (°C)	13.6	13.1	13.4

Source: - nasapower:-2019

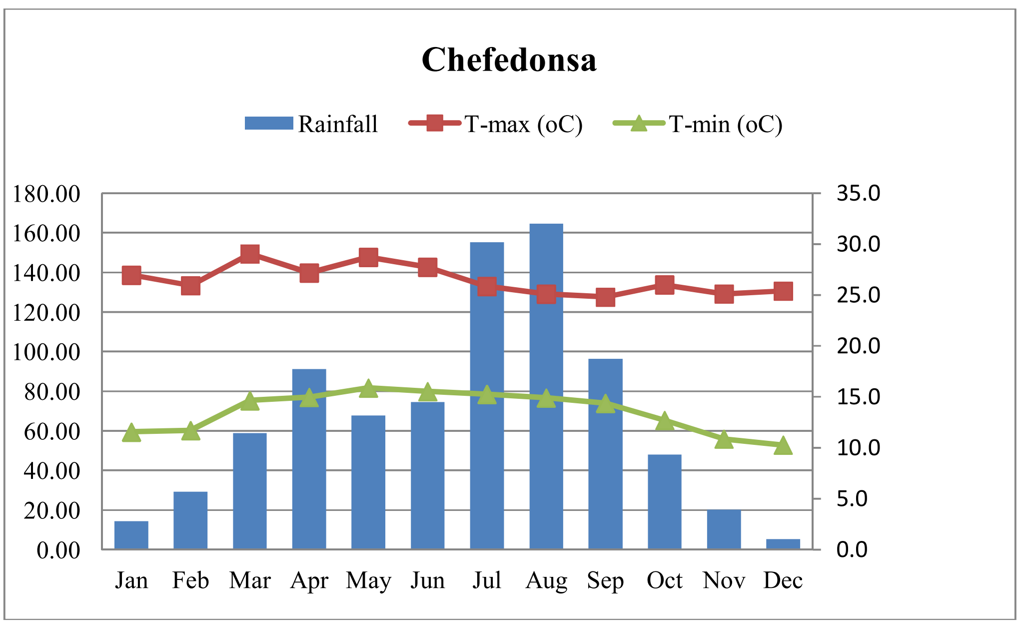

Fig. 1. Average rainfall of (1990-2019) and mean maximum and minimum daily temperature of Chefedonsa area

Source: nasapower:-2019

A physical soil characteristic (particle size distribution) was determined following Bouyoucous hydrometer method (Bouyoucous, 1962). The pH of the soil was measured using pH-water method by making soil to water suspension of 1: 2.5 ratios and measured using a pH meter, the Kjeldahl method for total N, the Olsen method for available P, the Walkley Black [10] method for organic C, and the ammonium acetate method for CEC.

2.4 Determination of N Content in Grain and Straw of Wheat

Plants sampled for yield components at harvest were partitioned into vegetative and grains for the determination of total nitrogen in straw and grains using standard procedures. Both the grain and vegetative plant parts were air dried to a constant weight.

Total N in grain and straw was quantitatively determined by a Kjeldahl procedure (Bremner and Mulvarey, 1982).

N uptake in the grain was determined after multiplying nitrogen content of the grain by grain yield, and straw nitrogen uptake was also determined by multiplying nitrogen concentration of the straw by the straw yield [11].

GNU (kg ha^{-1}) =GNC (%) x GY (kg ha^{-1})
Where, GNU = Grain nitrogen uptake
GNC = Grain nitrogen concentration
GY= Grain yield

SNU (kg ha^{-1}) = STNC (%) X STDW (kg $ha^{-1\ -1}$)
Where, STNU = Straw nitrogen uptake
STNC = Straw nitrogen concentration
STDW = Straw dry weight

Nitrogen agronomic efficiencies (NAE) estimates were based on the relative crop performance in treated plots as compared to plots without N fertilization (Fageria et al., 2008).

$$\text{NAE(kg grain/kg N)} = \frac{\text{YN} - \text{YO}}{\text{FN}}$$

where, AE = Agronomic efficiency, YN and YO are the grain yield with and without N applied, respectively and FN is the amount of nitrogen fertilizer applied.

Apparent fertilizer N use (recovery) efficiency (ANRE) was obtained by dividing the amount of fertilizer N taken up by the plant to the kg of N applied as fertilizer as it was described by [12].

$$\text{ARE } \left(\frac{\text{Kg N}}{\text{kg N}}\right) = \frac{\text{UN} - \text{UO}}{\text{FN}}$$

Where ARE = Apparent recovery efficiency, UN and Uo are nutrient uptake in fertilized and control plot respectively; FN is the amount of N fertilizer applied.

Plant nitrogen use efficiency / physiological efficiency was calculated by dividing the total dry matter produced to a unit of N absorbed as indicated below:

$$\text{PE kg grain/ kgN} = \frac{\text{Yn} - \text{Yo}}{\text{Un} - \text{Uo}}$$

Where, PE = physiological efficiency, Yn and Yo are the grain yield in fertilized and control plot respectively. UN and Uo are nutrient uptake in fertilized and control plot, respectively.

Nitrogen harvest index $= grain\ N \frac{uptake}{total}\ N\ uptake$

2.5 Data Collection and Measurements

2.5.1 Growth parameters, yield and yield components

Plant height (PH): Plant height was measured at heading and physiological maturity from the ground level to the tip of panicle from ten randomly selected plants in each plot.
Panicle length (PL): is length of the panicle from the node where the first panicle branches start to the tip of the panicle as the average of ten selected plants per plot.
Total number of tillers: It was determined by counting the total number of tillers from ten randomly selected plants in each plot.
Biomass yield (BY): At maturity, the whole plant biomass including, leaves, stems, seeds etc. were harvested from the net plot area and air-dried, after which the weight was recorded.
Grain yield (GY): Grain yield was measured by harvesting the crop from the net middle plot area of 2m x 2m to avoid edge effects
Harvest index (HI) Harvest index was calculated by dividing grain yield by the total above ground biomass yield.

Table 2. Pre-planting physical and chemical properties of soil of experimental site

Soil parameters	Values	Rate	References
Soil Physical properties			
Texture (clay %)	67.6		
Silt (%)	14.4		
Sand	18		
Textural class	Clay		Rowell, [13]
Soil Chemical properties			
PH	7.04	Neutral	Murphy [16]
OM (%)	1.05	Low	[16]
CEC (Cmol (+)/kg)	66.8	Very high	[14]
Total N (%)	0.08	Low	(Tekalign 1991)
Av.P (mg kg $^{-1}$)	7.93	Low	[15]
Av.K (Cmol (+)/kg)	0.8	High	(FAO, 2006)

2.6 Physico-Chemical Properties of Soil before Planting

The soil of the field experiment belongs to clay textural class based on soil textural class determination triangle of International Soil Science Society (ISSS) system [13]. The reactions of soils as revealed by their pH are neutral, and low in organic matter (%) and total nitrogen content according to rating of Tekalign (1991), and very high in cation exchange capacity (CEC) and exchangeable potassium according to [14] and [3,4] , respectively. The available soil phosphorus was in the low range [15] (Table 2).

3. RESULTS AND DISCUSSION

3.1 Effect of UREA^{stable} Fertilizer on Chemical Properties of soil at Harvest

The surface soil (0–20 cm) analysis result showed that, the experimental soils had a PH value of 7.2-7.5 (slightly to moderately alkaline), which is typical for Ethiopian Vertisols (Debele, 1985; Kebede and Charles, 2009). The soil organic matter contents were in lower ranges. According to the ratings of Cottenie (1980), the available P (Olsen extractable) ranges from (7.6-14.8 mg kg$^{-1)}$ low to medium range (Table 3). Total nitrogen value of the experimental soil after harvest was in the low range (0.07-0.11).

Generally, the soil chemical properties of the field experiment site after harvesting were not altered due to application of the slow release urea, fertilizer, this may be due to high volatile nature of the nitrogen and nature of the soil (Table 3).

3.2 Yield and Yield Component Parameters

3.2.1 Plant height

Wheat plant height o was significantly affected by the application of different rates of urea stable fertilizer. The highest plant height (73 cm) was obtained from half more than recommended N from normal UREA in split application, while the lowest (52 cm) was from the control plot (Table 3).

3.2.2 Spike length

Application of different rates of normal and urea stable fertilizer under balanced nutrient showed significant ($P<0.05$) difference among treatments (Table 3).

The highest spike length (3.8 cm) was obtained from application of 150% of the recommended N from UREA ^{stable} applied in split form, which is statistically at par with most of the treatments. While, the lowest (2.7 cm) was obtained from the control plots.

3.2.3 Total tiller

The number of total tiller was significantly influenced by application of different source and rates of Urea fertilizer. Maximum tiller number (2.1) was obtained from application of 135 kg N ha^{-1} UREA ^{stable} applied in split form (Table 3).

3.2.4 Grain yield

Grain yield of durum wheat was significantly influenced by application of two source of N fertilizer. The highest mean grain yield (2205 kg ha^{-1}) was obtained at the rate of 135 kg N ha^{-1} or

150% of the recommended N from UREA ^{stable} applied in split form which is statistically at par from application of 135 kg N ha^{-1} conventional UREA applied in split form (Table 4). This may be attributed to the asynchrony in the time of availability of sufficient amounts of the nutrient in the soil proportionate with the demand of the plant for uptake. High response to N is understandable because total N in most Vertisols area is deficient. Therefore, UREA ^{stable} fertilizer minimizes the problem of rapid nitrification, most of the N added as fertilizer containing NH_4 or NH_2 is subject to leaching or denitrification soon after application. In conformity with this finding, Okubay et al. [17] reported that the addition of slow release urea fertilizer significantly increased grain yield of tef compared to conventional urea. Similarly, Howard and Oosterhuis [18] reported that N fertilizer application rates on cotton have reduced by 40% if controlled release rather than conventional fertilizers are used. Research finding by, Okubay [19] showed also that, the lowest grain yield of wheat was obtained from the control plot, which have comparable yield obtained from application of conventional and urea ^{stable} fertilizer applied at once (Table 4). Therefore, application of urea stable fertilizer in split form gave maximum grain yield than applying at once.

3.2.5 Above ground biomass yield

The analysis of variance revealed that the effects of urea stable and conventional urea fertilizer rates significantly ($P < 0.05$) influenced the biomass yield of wheat.

The maximum biomass yield (6968 kg ha^{-1}) was obtained at the highest rate of N source from UREA ^{stable} applied in split application (135 kg N ha^{-1}) and it was at par with biomass yield recorded from conventional urea applied in split application at the rate of 135 kg N ha^{-1} (6296 kg ha^{-1}). This shows that slow release urea fertilizer can reduce N losses by leaching in the form of NO_3-, fixation as NH_4, volatilization as NH_3 and atmospheric emission in the form of N_2O or N_2. Okubay [19] finding also indicated that, biomass yield showed a sharp increase with increasing the rates with super granular urea fertilizer application. The lowest biomass yield (2411 kg ha^{-1}) was recorded in unfertilized plot (Table 4).

3.2.6 Harvest index

The analysis of variance showed that application of urea stable and conventional urea fertilizer significantly influenced harvest index of wheat. However, there were no significant differences in harvest index due to the application of urea stable and conventional urea fertilizer; it is only significantly different from the unfertilized plot (Table 4).

3.3 Effects of UREA ^{stable} Fertilizer on Nitrogen Straw and Grain Uptake of Wheat

3.3.1 Nitrogen uptake by grains

Nitrogen uptake in grain was significantly affected by the application of urea stable fertilizer on durum wheat.

The uptake of N into wheat plant and subsequent contents in grain and straw were affected by the application of different sources (fertilizers) and application rates. The highest Nitrogen uptake in grain (35.6 kg ha^{-1}) was obtained from UREA ^{stable} (135 kg N ha^{-1}) in split form, while the lowest (12.5 kg ha^{-1}) was from the control plot (Table 4).While, the maximum nitrogen straw uptake (31.3 kg N ha^{-1}) was obtained from application of 135 kg N ha^{-1} from conventional urea applied in split form followed by 135 kg N ha^{-1} from UREA ^{stable} applied in split form (Table 5). Similarly, Genene (2003) reported a positive correlation between nitrogen fertilization and grain and straw nitrogen contents in wheat.

Table 3. Physico-chemical properties of soils at harvest

Treatments	pH	OM (%)	TN (%)	Av. P (mg kg^{-1})
Control	7.4	2.4	0.07	7.6
90 kg N ha^{-1} from conventional UREA in split	7.4	1.3	0.08	11.4
90 kg N ha^{-1} from UREA stable at planting	7.4	0.6	0.09	14.8
90 kg N ha^{-1} from UREA stable in split form	7.4	1.5	0.09	12.4
45kg N ha^{-1} from UREA stable at once	7.2	1.4	0.11	11.0
45kg N ha^{-1} from UREA stable in split form	7.4	1.7	0.10	12.1
135 kg N ha^{-1} from UREA stable in split	7.2	1.4	0.08	13.0
135 kg N ha^{-1} from conventional UREA in split	7.5	1.7	0.08	7.7
135 kg N ha^{-1} from UREA stable at once	7.5	1.7	0.08	13.7

Table 4. Effects of UREA stable and conventional urea fertilizer on growth yield, and yield components of wheat at 2018/19 cropping season

Treatments	PH (cm)	SL (cm)	TL No.	GY (kg/ha)	AGB (kg/ha)	HI
Control	52e	2.7d	1.1d	513e	2411d	0.22b
90 kg N ha^{-1} from conventional UREA in split	69abc	3.4abc	1.6bc	1667c	5803b	0.29a
90 kg N ha^{-1} from UREA stable at planting	67cd	3.5abc	1.8abc	1524c	5444b	0.28a
90 kg N ha^{-1} from UREA stable in split form	67bcd	3.4abc	1.9abc	1771bc	5903b	0.30a
45kg N ha^{-1} from UREA stable at once	63d	3.4c	1.4cd	1087d	3850c	0.31a
45kg N ha^{-1} from UREA stable in split form	65cd	3.2c	1.6bc	1127d	3785c	0.32a
135 kg N ha^{-1} from UREA stable in split	72ab	3.8a	2.1a	2205a	6968a	0.32a
135 kg N ha^{-1} from conventional UREA in split	73a	3.7ab	2.0ab	1946ab	6296ab	0.31a
135 kg N ha^{-1} from UREA stable at once	68a-d	3.4abc	1.7abc	1492c	5513b	0.27ab
LSD (<0.05)	2.5	0.22	0.21	138.3	439	0.03
C.V (%)	6.5	11.6	21.9	16.2	14.9	16.7

Where, PH=Plant height, SL=Spike length, TL=total tiller number, GY= Grain yield, AGB= above ground biomass yield, HI=harvest index, Means with the same letter in the columns are not significantly different at P>0.05 probability level. Where; CV= Coefficient of variation and LSD=least significant difference

3.4 Effects of UREA^{Stable} on Nutrient Use Efficiency of Wheat

3.4.1 Agronomic efficiency

Agronomic nitrogen efficiency of durum wheat was significantly influenced by different rates of conventional and UREA ^{stable} fertilizers (Table 5). The highest (14 kg grain kg N^{-1}) agronomic efficiency was obtained from application of 90 kg N ha^{-1} stable and conventional urea applied in split form which is statistically similar value with most of the treatments, except plots that received nitrogen at planting time only. While, the lowest (3.4 kg grain kg N^{-1}) agronomic efficiency was obtained from application of 135 kg N ha^{-1} UREA ^{stable} applied at once. Agronomic nitrogen efficiency was higher in split application and this indicates efficient use of nutrient by plants when applied in split application than applied at once (Table 5). In contrast with this result, Okubay [19] reported that maximum agronomic efficiency was obtained from the lowest N fertilizer rates.

3.4.2 Apparent nitrogen recovery efficiency

Nitrogen apparent recovery (NAR) efficiency depends on the congruence between plant N demand and the quantity of N released from applied Nitrogen [15]. The mean value of wheat apparent nitrogen recovery efficiency was significantly influenced by application of different rates of stable and conventional urea. The maximum ANRE (29.6%) was obtained from 90 kg N ha^{-1} UREA ^{stable} applied in split form. While, the lowest (4.6%) was recorded from 135 kg N ha^{-1} UREA stable applied at once (Table 5).

3.4.3 Physiological nitrogen efficiency

Combined analysis of variance over the years revealed that the effect of UREA stable and conventional urea fertilizer rates significantly affected the physiological nitrogen efficiency.

Physiological nitrogen efficiency (23.1 kg grain kg N^{-1}) was obtained at the highest rate of UREA^{stable} application in split form (135 kg N ha^{-1}) and it was statistically similar with PE recorded in plots from UREA ^{stable} application in split form at rates of 135 (21 kg grain kg N$^{-1)}$ and 90 (18.8 kg grain kg N^{-1}) kg N ha^{-1} (Table 5). Similarly, Fresew et al. [20] reported a decreasing trend in nitrogen use efficiency with increasing N rates. Likewise, Gauer et al. [21] reported the variation in nitrogen uptake efficiency of wheat, which was ascribed to differences in climate, cultivar and nitrogen rates.

Table 5. Effects of stable and conventional urea fertilizer on grain and straw nitrogen uptake and use efficiency of durum wheat

Treatments	NGU(kg ha^{-1})	SGU(kg ha^{-1})	AE(kg grain kg N^{-1})	ANRE (%)	PE kg grain kg N^{-1}	NHI (%)
Control	12.5f	18.8e	-	-	-	53.1
90 kg N ha^{-1} from conventional UREA in split	29.3bc	25.8bcd	14.0a	24.4ab	16.9bc	50.2
90 kg N ha^{-1} from UREA stable at planting	26.1cd	26.1abc	9.6b	21.1ab	13.6cd	52.3
90 kg N ha^{-1} from UREA stable in split form	31.3abc	28.6ab	14.0a	29.6a	18.8abc	49.1
45kg N ha^{-1} from UREA stable at once	20.1e	21.0cde	10.7ab	17.7b	7.7e	48.6
45kg N ha^{-1} from UREA stable in split form	20.8de	22.1cde	13.4ab	21.4ab	8.3de	55.7
135 kg N ha^{-1} from UREA stable in split	35.6a	28.5ab	12.3ab	22.8ab	23.1a	51.6
135 kg N ha^{-1} from conventional UREA in split	33.5ab	31.3a	10.5ab	23.4ab	21.0ab	47.7
135 kg N ha^{-1} from UREA stable at once	18.9e	20.5de	3.4c	4.6c	6.4e	53.1
LSD (<0.05)	5.5	5.5	4.2	10.4	5.6	NS
C.V (%)	12.5	12.8	21	28	22	8.9

Where, NGU= nitrogen grain uptake, SGU= straw grain uptake, AE= Agronomic efficiency, ANRE= Apparent nitrogen recovery efficiency, PE=Physiological efficiency, NHI= Nitrogen harvest index. Means with the same letter in the columns are not significantly different at P>0.05 probability level. Where; CV= Coefficient of variation and LSD=least significant difference

3.4.4 Nitrogen harvest index

Nitrogen harvest index (NHI) is defined as the amount of N accumulated in grain divided by the amount of N accumulated in grain plus straw. Nitrogen harvest index indicates the level of efficiency of plants to use acquired nitrogen for grain formation [22]. A high NHI indicates efficient utilization of N. Nitrogen harvest index was not significantly influenced by application of urea stable and conventional urea. However, numerically maximum nitrogen harvest index was obtained from application of 45kg N ha^{-1} UREA ^{stable} in split form (Table 5).

4. CONCLUSION AND RECOMMENDATION

In order to improve urea-N recovery and reduce its loss of nitrogen, slow-release and normal urea fertilizers types under balanced fertilizer were applied to durum wheat under Vertisols conditions. The agronomic parameters of wheat were significantly improved with the application of different source and rates of urea fertilizer. Maximum grain yield, above ground biomass yield and grain nitrogen uptake of wheat was obtained at the rate of 135 kg N ha^{-1} from UREA^{stable} applied in split form. This may be due to low total nitrogen and organic matter content of the soil.

Generally, the over year analysis results showed that at Gimbichu district, application of 135 kg N ha^{-1} from UREA ^{stable} in split form gave maximum spike length, tiller number, grain yield, biomass yield and grain nitrogen uptake of wheat followed by 135 kg N ha^{-1} from conventional urea applied in split form. The highest spike length and tiller number obtained also from this treatment.

As a general conclusive remark, the results of the current study provide a significant indication as the application of slow release urea can influence yield and yield components of wheat. Despite the need for verification of this study results over several locations and soil types, direct application of the findings by farmers at the study area will remain beneficial in addition to the application of conventional fertilizer provided that UREA ^{stable} fertilizer is available.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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