Research Article

Influence of Slow Release Urea Fertilizer on Growth, Yield and N Uptake on Maize under Calcareous Soil Conditions

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Abstract

Heavy N losses are always associated with urea fertilizer application therefore, improving its efficiency is crucial to reduce economic and environmental losses related with its application. The viable approach to reduce the N losses from the surface applied urea is to coat it with sulfur, urease inhibitor and other biodegradable materials. Field experiment were conducted to investigate the impact of super and urease coated urea on growth, yield, yield components and N uptake in maize under calcareous soil conditions of Khyber Pakhtunkhwa (KPK) during 2011-12. The experiment was conducted in a randomized complete block design (RCBD) with 4 replications each. Urea coated with urease (agrotain) and nitrification inhibitors (super urea) were applied at 90 kg and 120 kg N ha⁻¹ in 2 or 3 splits. The fertilizer treatments were applied at sowing, after 30 and 60 days of sowing (DAS), respectively. The results showed that inhibitors treated urea significantly improved the growth, yield and yield components of maize crop over granular urea and control treatment. Super urea shows its superiority over agrotain in terms of increased yield. Inhibitors application at 90 kg N ha⁻¹ has pronounced effect than 120 kg N ha⁻¹. Three splits of coated urea performed better than 2 splits. The highest improvement of 38.06% in grain yield and 45.13% in total N uptake was obtained in treatment receiving super urea at 90 kg N ha⁻¹ compared with granular urea at 90 kg N ha⁻¹. Agrotain treated urea at 90 kg N ha⁻¹ gave the next highest improvement of 30.55% in grain yield and 38.87% in total N uptake than granular urea and control plots at 90 kg N ha⁻¹. These results suggest that the combined use of urease + nitrification inhibitors (super urea) was better than urease alone. It was concluded that both agrotain and super coated urea delayed the urea hydrolysis and made the maximum N availability to plants and increase the yield of maize crop.

Key words: Agrotain; nitrification inhibitor; NUE; super-urea; wheat yield.

Introduction

Urea has been shown to have lower N use efficiency in many cropping systems compared to other N fertilizers, meaning that a large percentage of the applied fertilizer N is not being used for productive purposes and is essentially lost [1]. After surface application, urea is

quickly hydrolyzed within 1 to 2 days by soil urease to NH₄⁺, hydroxyl (OH⁻) and carbonate (CO₃²⁻) ions, leading to a high pH and very high concentrations of NH₄⁺ around the urea. This NH₄⁺ reaches equilibrium with dissolved NH₃. The sharp rise in soil pH increases the likelihood of gaseous NH₃ losses to the atmosphere. A

wide range of gaseous NH_3 losses from 1.7% to 56% of the applied N have been reported which depend on soil moisture, temperature and pH, wind velocity, soil organic C and N fertilizer type [2]. The temporary rise in soil pH and production of high NH_4^+ due to fast urea hydrolysis, or after application of NH_4^+ based fertilizers such as DAP, lower the activity of *Nitrobacter*, the genus of bacteria responsible for the oxidation of NO_2^- to NO_3^- . This results in an accumulation of NO_2^- in the soil around the fertilizer granules, which can have harmful effects on germinating seeds and young plants, and increase the risk of N being lost as N_2O , a greenhouse and ozone (O_3 -) depleting gas, via nitrification [3]. Similarly, nitrate is repelled from soil exchange sites because of its negative charge and is prone to both leaching losses if drainage occurs, and emission to the atmosphere as N_2O via denitrification. Because of its very dynamic nature, the efficient use and management of N is always a challenging task in agricultural systems. Where there is substantial water input through irrigation or rainfall, total N losses can be very high up to 80%. Nitrogen losses through NO_3^- leaching, NH_3 volatilization and N_2O emissions have both economic and environmental implications. It is very important therefore to minimize such losses by synchronizing plant N uptake with the available soil N (NH_4^+ and NO_3^-) to optimize fertilizer N efficiency. Therefore, various attempts have been made to coat or treat N fertilizers with urease inhibitors, nitrification inhibitors, polymers and elemental S to reduce N losses and enhance fertilizer N efficiency. Among the urease inhibitors, N-(n-butyl) thiophosphoric triamide (NBPT), trade name “Agrotain” is one of the most efficient and widely available commercially [4]. After application, Agrotain is quickly converted in soil to its more effective oxygen analogue N-(n-butyl) phosphoric triamide (NBPT), which then forms a tridentate ligand with the

urease enzyme, slowing urea hydrolysis, reducing NH_3 volatilization from surface applied urea, and increasing N uptake and yield in a range of crops. Treating urea with Agrotain enables plants to take up more N in either urea or NH_4^+ forms, both of which require less energy to metabolize and covert N into plant protein [5]. Nitrification inhibitors such as dicyandiamide (DCD) and (DMPP) slow the activity of *Nitrosomonas*, the genus of nitrifying bacteria responsible for the oxidation of NH_4^+ to NO_2^- and can thereby reduce NO_3^- leaching and N_2O emissions. DCD is more widely used nitrification inhibitor because it is cheaper, less volatile and relatively soluble in water [6]. However, the persistence of excess NH_4^+ in soil as a result of reduced activity of *Nitrosomonas* may lead to increased N losses via NH_3 volatilization. Therefore, urea in combination with NBPT and NBPT + DCD can increase N recovery by crops by minimizing ammonia volatilization and thus increases nitrogen use efficiency.

The soils of Pakistan are mostly alkaline and calcareous in nature and are favorable to N losses via NH_3 volatilization. Limited work has been done in Pakistan to assess the impact of urease and nitrification inhibitors with urea fertilizer on minimizing N losses and increasing crop yields. This study was therefore undertaken to investigate the impact of urease and nitrification inhibitors with urea fertilizer on yield and N use efficiency and also to compare the effect of two and three split applications of urea on N recovery and yield of maize crop.

Materials and Methods

Field experiment was conducted at the Agronomy Research Farm, University of Agriculture, K.P.K Peshawar to study the effect of urease and nitrification inhibitors on maize yield and nitrogen use efficiency during 2011-12. Soil of the experimental site was silt loam, alkaline in reaction (pH 8.06), non-saline (EC 0.16 dSm^{-1}),

strongly calcareous (lime 16.0%) and low in organic matter (Table 1).

There were a total of 10 treatments were viz., (1) control (no urea), (2) urea at the rate of 90 kg N ha⁻¹ (in two splits), (3) urea at the rate of 120 kg N ha⁻¹ (in two splits), (4) urease inhibitor (agrotain) coated urea at the rate of 90 kg N ha⁻¹ (in two splits), (5) urease inhibitor (agrotain) coated urea at the rate of 120 kg N ha⁻¹ (in two splits), (6) urease plus nitrification inhibitor coated urea (super urea) at the rate of 90 kg N ha⁻¹ (in two splits), (7) urease and nitrification inhibitors coated urea (super urea) at the rate of 120 kg N ha⁻¹ (in two splits), (8) urea at the rate of 120 kg N ha⁻¹ (in three splits), (9) urease inhibitor (agrotain) coated urea at the rate of 120 kg N ha⁻¹ (in three splits) and (10) urease and nitrification inhibitors coated urea (super urea) at the rate of 120 kg N ha⁻¹ (in three splits). Agrotain product was used as urease inhibitor while super-urea was used as urease and nitrification inhibitors. Experimental design was randomized complete block (RCBD) and each treatment was replicated four times. Net plot size of 5 m wide and 3 m long with 0.5 m distance between the treatments and 1 m distance between the blocks was used. All treatment plots received P₂O₅ at 90 kg ha⁻¹ and K₂O at 60 kg ha⁻¹ as basal dose at sowing time. Urea was applied with and without inhibitors at sowing, 2nd and 3rd dose after 30 and 60 days of sowing (DAS) as per experimental plan. Maize hybrid cultivar “Baber” was sown in July and harvested in October. Recommended cultural practices were followed throughout the growing period. The crop was irrigated with canal water when needed. The crop was harvested at maturity and data was recorded on various agronomical traits (viz., plant height, ear length, number of ears plant⁻¹, number of rows ear⁻¹, number of grains row⁻¹, number of grains ear⁻¹, biological yield, grain yield, 100-grain weight) and total N uptake in crop.

Laboratory Analysis: Total mineral N in soil samples was determined by the steam distillation method as given in Mulvaney [6]. Total N in soil and plant samples was determined by Kjeldhal method as described in Bremner [7]. Soil pH and EC were determined in the saturated soil extract. Soil extract was read for pH on pH meter [8] and for EC on EC meter [9]. Organic matter in soil samples was determined by the Walkley-Black procedure as described by [10]. The amount of lime in soil samples was determined by the acid neutralization method as described by [11]. Texture of soil sample was determined by the Bouyoucos hydrometer method [12].

Statistical Analysis

Data were statistically analyzed according to randomized complete block design (RCBD). Least significant difference (LSD) at 5% probability level was employed upon obtaining significant F-values between treatment means.

Results and Discussion

The results obtained on the effect of urease and nitrification inhibitors on yield and N uptake of maize are presented and discussed as under:

Yield Components: The results obtained on plant height, ear length, number of ears plant⁻¹, number of rows ear⁻¹, number of grains rows⁻¹, number of grains ear⁻¹ and 100 grain (wt) as influenced by N inhibitors and split application of urea are reported in Table 2 and 3. It is revealed that N inhibitors and split application of coated urea significantly improved the growth, yield and yield components of maize. Maximum plant height of 136.70 (cm) was obtained for treatment receiving super-urea (urease + nitrification inhibitor treated urea) at 120 kg N ha⁻¹ in three splits (Table 2). This was however statistically at par with that (135 cm) obtained with agrotain treated urea at 120 kg N ha⁻¹ in three splits. Maximum ear length of 24 cm were obtained from plots receiving super-urea (urease + nitrification inhibitor treated urea) at 120 kg N ha⁻¹ in

three splits (Table 2) followed by agrotain coated urea at 120 kg N ha⁻¹ in three splits. The next highest number of ears plant⁻¹ (2.53) was obtained from plots receiving super urea at 120 kg N ha⁻¹ in three splits. The lowest number of ears plant⁻¹ (1.17) was obtained in the control treatment and this was significantly lowest in all fertilizer treatments. The minimum number of rows ears⁻¹ (17.33) was obtained in control treatment. The results showed that number of ears plant⁻¹ of maize hybrid cultivar increased with increasing level of N. Furthermore, number of ears plant⁻¹ of maize was generally greater for three than for two splits of coated urea application. Moreover, the number of grains row⁻¹ increased with increasing level and splits of urea application. The significantly highest number of grains row⁻¹ (36 grains row⁻¹) were obtained for treatment receiving super urea (urease + nitrification inhibitor treated urea) at 120 kg N ha⁻¹ in three splits. This was however statistically at par with that (34.21 grains row⁻¹) obtained with agrotain treated urea at 120 kg N ha⁻¹ in three splits. The lowest number of grains row⁻¹ (27.67) were obtained in the control treatment and this was significantly lowest than all fertilizer treatments. The results obtained on number of grains ear⁻¹ of maize revealed that maximum number of grains ear⁻¹ of 636.30 was obtained in the treatment receiving super urea (urease + nitrification inhibitors treated urea) at 120 kg N ha⁻¹ in three splits and this was statistically at par with those obtained with super urea at 90 kg N ha⁻¹ in two splits (585.70) or agrotain (urease inhibitor treated urea) at 90 kg N ha⁻¹ (557.30¹) (Table 3). As with other yield components, the significantly highest 100-grain weight of 42 g was obtained for treatment receiving super urea (urease + nitrification inhibitors treated urea) at 120 kg N ha⁻¹ in three splits (Table 3). The lowest 100-grain weight of 30 g was obtained in the control treatment and this was significantly ($p < 0.05$) lowest than all

fertilizer treatments. It was however noticed that 100-grain weight was generally increased with increasing level and number of split application of urea. Almost similar results have been reported for the influence of urease and nitrification inhibitors on yield and yield components of wheat and other crops [1, 13].

Biological Yield: The results obtained on biological yield of maize as influenced by N inhibitors treated and untreated urea treatments are presented in Table 4. The results showed that on average the maximum biological yield of 13744 kg ha⁻¹ was obtained in the treatment which had received super-urea (urease + nitrification inhibitors treated urea) at 120 kg N ha⁻¹. The super-urea improved the biological yield by 21.30% with 90 kg N and 17.73% with 120 kg N ha⁻¹, whereas agrotain (urease treated urea) improved biological yield by 16.59% with 90 kg N and 10.67% with 120 kg N ha⁻¹ (Table 4). Zaman *et al.* [1, 14-16] also reported that agrotain and dicyandiamide (DCD) in combination were more effective in minimizing NH₃ losses and N₂O emission, and in controlling urea hydrolysis, improving pasture production and retaining N in NH₄⁺ form. Other researchers had also observed similar results whereas the combined use of nitrification and urease inhibitors gave better results in terms of increasing crop yields than their use alone [2, 14].

Grain Yield: The results obtained on grain yield of maize showed that on average the highest grain yield of 4517 kg ha⁻¹ was obtained in the treatment receiving super-urea (urease + nitrification inhibitor treated urea) at 120 kg N ha⁻¹ followed by 4201 kg N ha⁻¹ obtained in the treatment receiving agrotain (urease inhibitor treated urea) at 120 kg N ha⁻¹ (Table 5). Super urea improved the grain yield of maize by 38.06% with 90 kg N and 25.23% with 120 kg N ha⁻¹, whereas agrotain improved the grain yield by 30.55% with 90 kg N and 19.61% with 120 kg N ha⁻¹ as compared to treatments

Table-1. Some important soil characteristics of the experimental site

Property	Value (Unit)
Clay	9.10 (%)
Sand	14.22(%)
Silt	76.68(%)
Textural class	Silt loam
pH(se)	8.06
EC(se)	0.16(dSm ⁻¹)
Lime	16.00(%)
Organic matter	0.89(%)

Table -2. Effect of urease inhibitor (Agrotain) and urease plus nitrification inhibitor (Super-urea) on yield and yield components of maize.

Treatments	N rate (kg ha ⁻¹)	Plant height (cm)	Ear length (cm)	No. ears plant ⁻¹	No. rows ear ⁻¹
Control	0	112.70f	18.67c	1.17 g	17.33de
Simple urea (2 splits)	90	125.30d	19.33c	1.70 ef	20.33cd
Simple urea (2 splits)	120	119.0e	18.67c	1.50 f	18.33de
Agrotain treated urea (2 splits)	90	133.0bc	22.00 ab	2.00cd	24.67b
Agrotain treated urea (2 splits)	120	130.0c	20.67bc	1.83de	20.33bc
Super Urea (2 splits)	90	134.00ab	23.33a	2.13d	24.33b
Super Urea (2 splits)	120	133.30bc	22.67ab	2.18d	21.67bc
Simple urea (3 splits)	120	132.00c	22.00ab	2.25c	25.45b
Agrotain treated urea (3 splits)	120	135.00ab	24.00a	2.32b	26.33ab
Super Urea (3 splits)	120	136.70a	24.00a	2.53a	27.67a
LSD (0.05)		2.42	2.57	0.29	2.14

*Means followed by same letter(s) within columns are statistically non-significant (P<0.05).

Agrotain contain urease inhibitor; *Super urea contain both urease and nitrification inhibitor

Table-3, Effect of urease inhibitor (Agrotain) and urease plus nitrification inhibitor (Super-urea) on yield and yield components of maize.

Treatments	N rate (kg ha ⁻¹)	No. of grains row ⁻¹	No. of grains ear ⁻¹	100 grain wt (g)
Control	0	27.67d	316.70f	30.00f
Simple urea (2 splits)	90	31.67bc	419.30e	33.00de
Simple urea (2 splits)	120	31.33bc	397.30e	31.67ef
Agrotain treated urea (2 splits)	90	29.33cd	557.30bc	34.00cd
Agrotain treated urea (2 splits)	120	30.33bcd	508.00cd	33.33de
Super Urea (2 splits)	90	32.33bc	585.70ab	36.00bc
Super Urea (2 splits)	120	33.67b	465.30de	37.33b
Simple urea (3 splits)	120	33.00 b	467.00de	38.67ab
Agrotain treated urea (3 splits)	120	34.21 a	524.00d	40.00a
Super Urea (3 splits)	120	36.00a	636.30a	42.00a
LSD (0.05)		2.40	74.47	2.28

*Means followed by same letter(s) within columns are statistically non-significant (P<0.05).

Table -4, Percent increase in biological yield of maize by urease (Agrotain) or urease plus nitrification (Super-urea) inhibitors treatments over non-inhibitors treatments.

Treatments	Biological Yield (kg ha ⁻¹)	Increase by inhibitors (kg ha ⁻¹)	% Increase by inhibitors	% increase by super urea over agrotain
Commercial urea @ 90 kg N ha ⁻¹	9732	-	--	--
Agrotain treated urea @ 90 kg N ha ⁻¹	11669	1937	16.59	
Super urea @ 90 kg N ha ⁻¹	12366	2634	21.30	5.63
Commercial urea @ 120 kg N ha ⁻¹	11307	-	-	-
Agrotain treated urea @ 120 kg N ha ⁻¹	12658	1351	10.67	-
Super urea @ 120 kg N ha ⁻¹	13744	2437	17.73	7.90

Table -5, Percent increase in grain yield of maize by urease (Agrotain) or urease plus nitrification (Super-urea) inhibitors treatments over non-inhibitors treatments.

Treatments	Grain yield (kg ha ⁻¹)	Increase by inhibitors (kg ha ⁻¹)	% Increase by inhibitors	% increase by super urea over agrotain
Commercial urea @ 90 kg N ha ⁻¹	2445	-	--	--
Agrotain treated urea @ 90 kg N ha ⁻¹	3521	1076	30.55	--
Super urea @ 90 kg N ha ⁻¹	3948	1503	38.06	10.81
Commercial urea @ 120 kg N ha ⁻¹	3377	-	-	-
Agrotain treated urea @ 120 kg N ha ⁻¹	4201	824	19.61	-
Super urea @ 120 kg N ha ⁻¹	4517	1140	25.23	5.02

Table-6, Percent increase in N uptake of maize by urease (Agrotain) or urease plus nitrification inhibitors (Superurea) treatments over non-inhibitors

Treatments	Total N uptake (kg ha ⁻¹)	Increase by inhibitors (kg ha ⁻¹)	% Increase by inhibitors	% increase by super urea over agrotain
90 kg N without inhibitors (2 splits)	54.1	-	--	--
90 kg N with agrotain inhibitors (2 splits)	88.5	34.4	38.87	--
90 kg N with super urea inhibitors(2 splits)	98.6	44.5	45.13	10.24
120 kg N without inhibitors(2 splits)	63.7	-	-	-
120 kg N with agrotain inhibitors (2 splits)	94.3	30.6	32.44	-
120 kg N with super urea inhibitors(2 splits)	101.2	37.05	32.6	6.81

receiving untreated urea at 90 or 120 kg N ha⁻¹ (Table 5). These results are consistent with those of [17, 18] who reported that combination of urea with urease inhibitors, N-(n-butyl) thiophos phorictriamide (NBPT), and a nitrification inhibitor, dicyandiamide (DCD), significantly reduced urea hydrolysis and in turn increase the grain yield of wheat by 27.8%.

Nitrogen Uptake: On average, the highest N uptake of 101.2 kg ha⁻¹ was obtained in treatment receiving super-urea (urease + nitrification inhibitor treated urea) at 120 kg N ha⁻¹ followed by 98.6 kg ha⁻¹ in treatment receiving super urea at 90 kg N ha⁻¹ (Table 6). Super-urea increased the N uptake of maize by 45.13% with 90 kg N and 32.6 with 120 kg N ha⁻¹. However, agrotain (urease treated urea) increased N uptake of maize by 38.87 % with 90 kg N and 32.44% with 120 kg N ha⁻¹. The results also showed that N uptake increased with increasing the number of split application of urea both at 90 and 120 kg N ha⁻¹ (data not shown). [18] reported that urea in combination with dicyandiamide plus hydroquinone (U + DCD + HQ) recovered 69% of urea-N in plant and 73% of the recovered N was transformed into grain protein by spring wheat. Other workers also reported that the use of urease and nitrification inhibitors reduced N losses and increased N use efficiency by various crops [18, 19]. These results revealed that the use of nitrification inhibitors with urea did improve the yield and yield components of maize planted on a calcareous alkaline soil. Using both urease and nitrification inhibitors with urea performed much better than the use of urease inhibitor alone [19, 20]. Thus it could be concluded that strongly calcareous alkaline soils are highly conducive to rapid urea hydrolysis and nitrification processes which lead to N losses. Curtailing such processes with urease or nitrification inhibitors prolong the existence of nitrogen in soil giving greater opportunity to plants for its

utilization and hence reducing chances of its volatilization. These results therefore suggest that the use of urea on highly calcareous alkaline soils need special management to reduce its loss and maximize its efficiency or plant utilization. The use of nitrogen inhibitors seems one of the promising strategies to reduce N losses from urea on calcareous alkaline soils provided other conditions are favorable such as soil organic matter and temperature.

Conclusions

Three split applications of controlled release urea fertilizers are fruitful for improving growth, yield and soil fertility as compared to single or pre-plant application. Moreover, coated urea fertilizers are less susceptible to various N losses which occur in coarse textured soils. Combined application of urease + nitrification inhibitors (super-urea) was superior to urease inhibitor alone (agrotain) in increasing the yield and yield components of maize. The superiority of these controlled release urea fertilizer can be affirmed by giving significantly higher dry matter yield and N uptake by maize crop.

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