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Nitrogen use efficiency and yield of maize crop as affected by agrotain coated urea in arid calcareous soils

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Abstract

It is reported that about 50% of nitrogen applied to soil as urea is lost through volatilization and leaching. A study was, therefore, conducted to assess the impact of two rates of urea fertilizer coated with 2 L and 3 L Agrotain ton^{-1} , applied in 2 and 3 splits, on growth and yield and nitrogen use efficiency of maize crop at farm area of the Gomal University Dera Ismail Khan, Pakistan. The experiment was laid out in RCBD with nine treatments of 3x5 m^2 plots with four replicates. The fertilizer treatments were applied at sowing, after 25 and 55 days of sowing, respectively. Data showed that maximum grain yield (3.56 t ha^{-1}) was obtained in those plots fertilized with 115 kg N ha^{-1} as urea, coated with 3L ton^{-1} Agrotain applied in two splits as compared to other treatments. Minimum grains yield (3.17 t ha^{-1}) were obtained where no nitrogen was applied. Other yield parameters also showed significant increase in the plots where Agrotain treated urea was applied. It was concluded that Agrotain coating of urea delayed the urea hydrolysis and made the maximum N availability to plants and increased yield of maize crop.

Keywords: *Agrotain inhibitor, slow release, nitrogen use efficiency, maize yield*

Introduction

Nitrogen (N) is one of the major nutrients that is taken by the plants comparatively in large quantity and is generally deficient in most soils of Pakistan. Urea fertilizer is most commonly used to supply N due to high percentage of N content (46%). Urea is inexpensive, safe to handle and it has a high percentage of nitrogen (46%). But the major problem associated with the urea fertilizer is the low N efficiency (30-40%). There are many factors that affect the NUE. Among these factors, denitrification (conversion of NO_3–N to N_2O, NO and N_2 gases) causing global warming and major threat to the safe environment (Snyder *et al*., 2007). Studies have also revealed excessive ammonia volatilization and nitrate leaching from urea in arid and semi-arid zone with alkaline pH (Pacholski *et al*., 2006; Rochette *et al*., 2009). The researchers are busy to find ways how to control its losses and get maximum benefits from its efficient use. Presently intensive agricultural systems are quite fertilizer based demanding high inputs with more chances of N losses resulting into huge economic loss (Boyer *et al*., 2002). To utilize the maximum N content of commercial urea fertilizer by application of inhibitors is considered best strategy.

There are many compounds known as urease inhibitors. Among those, N-(n butyl) thiophosphoric triamide (NBTPT) (trade name ‘‘Agrotain’’) is widely used by researchers. Agrotain is readily changed in soil to N-(n-butyl) phosphoric triamide (NBPTO) and converted into ligand with the urease that is responsible of slowing urea hydrolysis (Manunza *et al*., 1999). Many other workers also proved that coated urea performed better than commercial fertilizers by increasing grain yield and N uptake in maize in Japan, peanuts in Japan (Wen *et al*., 2001), rice in Spain (Carreres *et al*., 2003), winter wheat in China (Fan *et al*., 2004), potatoes in the USA (Munoz *et al*., 2005). Results of more than 400 field experiments with and without NBTPT were compared and proved that maize grain yield increases of 0.89 and 0.56 t ha^{-1} (Trenkle, 1997).

Maize (*Zea mays* L.) is one of the most important cereal crops of the world largely grown in irrigated and rain fed areas (Irshad *et al*., 2002). In Pakistan, maize crop ranks third in number after wheat and rice. Out of total cultivated area, 98% of the maize crop is grown in Khyber Pukhtoon Khwa and Punjab. It occupies the area about 1.11 million hectares with annual production of 4.04 million tons of grain with average yield of 3.62 t ha^{-1} (GOP, 2009).

To minimize the nitrogen losses and improve its use efficiency with the help of urease inhibitor (Agrotain) the proposed research project was designed to study the effect of various doses of Agrotain coated urea to assess the effect of Agrotain on N use efficiency and the yield of maize crop

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in arid calcareous soils of Dera Ismail Khan, KPK. Pakistan.

Materials and Methods

Soil analysis

Soil samples were collected, dried at room temperature and sieved through a 2 mm sieve. The samples were analyzed for pH and ECe (Ryan *et al*., 2001), bulk density (Blake 1965), total porosity (Vomocil, 1965), Na (Ryan *et al*., 2001), Ca^{++} and Mg^{++} along with CO_3^{-}, HCO_3^{-} and Cl^{-} (Ryan *et al*., 2001) and SO_4 (Williams and Steinbergs, 1959). Organic matter and Total N content were determined by MAFF (1986) and by Kjeldahl procedure (Jackson, 1964). Available K and P were determined according to Black (1965) and Lennox (1979). The micronutrients analysis (Zn, Cu, Fe, Mn) was done by using methods described by Lindsay and Norvell (1978). The results of soil analysis are given in Table 1.

Table 1: Physico-chemical characteristic of the soil

Property	Unit	Value
Textural class	----	Sandy clay loam
Dry bulk density	g cm^{-3}	1.32
Total porosity	%	51
pH (1:5)	---	8.1
ECe	dS m^{-1}	0.39
Organic matter	%	0.81
Available K	mg kg^{-1}	170
Total N	%	0.03
Available P	mg kg^{-1}	7.2
HCO_3^{-1}	meq L^{-1}	98
$Ca^{++} + Mg^{++}$	meq L^{-1}	12
Cl^{-1}	meq L^{-1}	12
Soluble Na	meq L^{-1}	15
SO_4	meq L^{-1}	39
DTPA Ext: Zn	mg kg^{-1}	1.1
DTPA Ext: Cu	mg kg^{-1}	5.4
DTPA Ext: Fe	mg kg^{-1}	5.21
DTPA Ext: Mn	mg kg^{-1}	8.5

Field experiment

A field experiment was conducted to study the effect of slow release compounds (Agrotain coating) on urea fertilizer efficiency by minimizing the nitrate leaching and ammonium volatilization and on the yield of hybrid maize variety "Pioneer 7067", at farm area of Faculty of Agriculture, Gomal University, Dera Ismail Khan (KPK). Different doses of nitrogen were applied as urea coated with or without Agrotain. The P and K were applied to all treatments at 90 and 60 kg ha^{-1} . The detail of treatments is as under:

T_1: Control (no urea)
T_2: N at 115 kg ha^{-1} as simple urea (100%) in two splits
T_3: N at 87 kg ha^{-1} as simple urea (75%) in two splits
T_4: N at 115 kg ha^{-1} as 2 L Agrotain treated urea (100%) in two splits
T_5: N at 87 kg ha^{-1} as 2 L Agrotain treated urea (75%) in two splits
T_6: N at 115 kg ha^{-1} as 3 L Agrotain treated urea (100%) in two splits
T_7: N at 87 kg ha^{-1} as 3 L Agrotain treated urea (75%) in two splits
T_8: N at 115 kg ha^{-1} as 3 L Agrotain treated urea (100%) in three splits
T_9: N at 87 kg ha^{-1} as 3 L Agrotain treated urea (75%) in three splits

The doses of Agrotain at 2 L and 3 L were used for one ton of urea. The 1st fertilizer dose was applied at sowing time, 2nd and 3rd dose after 25 and 55 days of sowing, respectively. The statistical design was RCBD with nine treatments. Each treatment was replicated four times with plot area of 3x5 m^2.

Statistical analysis

The data recorded was subjected to the analysis of variance technique using MSTATC software. The mean values were compared using Least Significance Difference (LSD) test (Steel *et al.,* 1997).

Results

Effect of agrotain coated urea on growth and yield of maize crop

The plant height of maize was significantly affected by different levels of Agrotain coated urea (Table 2). Plots treated with N at115 kg ha^{-1} as 3L Agrotain treated urea in three splits, produced maximum plant height (136.70 cm) as compared to other treatments. Minimum plant height (112.70 cm) was obtained in the plants where no urea was applied.

The data regarding ear length of maize as affected by different levels of Agrotain coated Urea is presented in Table 2. The plots fertilized with 115 kg ha^{-1} N dose with Agrotain coating of 3L ton^{-1} in tow splits produced maximum length of ear (24 cm) as compared to other treatments. Minimum ear length (18.67 cm) was recorded in those plants where no urea was applied.

The data regarding number of ears plant^{-1} of maize as affected by different levels of Agrotain coated urea is presented in Table 2. The number of ears plant^{-1} was significantly affected by different levels of Agrotain coated urea and the frequency of fertilizer splits. The plots treated with 115 kg ha^{-1} N as urea with 3 L ton^{-1} Agrotain coating in two splits gave maximum number of ears plant^{-1} (2.53) as compared to other treatments. Minimum number of ears plant^{-1} (1.16) was obtained in those plants where no urea was applied.

Table 2: Plant height, ear length, no. of ears plant^{-1} and no of rows ear^{-1} as influenced by different levels of Agrotain coated urea

Treatment	Fertilizer splits	Plant height (cm)	Ear length	No. of ears plant^{-1}	No. of rows ear^{-1}
T_1	-	112.70 f	18.67 c	1.17 g	17.33 e
T_2	3	125.30 d	19.33 c	1.70 ef	20.33 cd
T_3	3	119.00 e	18.67 c	1.50 f	18.33 de
T_4	3	133.00 bc	22.00 ab	2.33 ab	24.67 b
T_5	3	130.00 c	20.67 bc	1.83 de	20.33 cd
T_6	3	136.70 a	23.33 a	2.16 bc	24.33 b
T_7	3	133.30 abc	22.67 ab	2.00 cd	21.67 d
T_8	2	136.00 ab	24.00 a	2.533 a	27.67 a
T_9	2	133.00 bc	24.00 a	2.06 bcd	26.33 ab
LSD	-	3.42	2.57	0.29	2.14

Means not sharing common letters are statistically different at 5% level of probability

Table 3: Number of grains row^{-1}, no of grains ear^{-1}, 100 grain weight and grain yield of maize as influenced by different levels of Agrotain coated Urea

Treatment	Fertilizer splits	No. of grains Row^{-1}	No. of grains ear^{-1}	100 grain weight (g)	Grain yield (T ha^{-1})
T_1	-	31.33 bc	316.70 f	30.00 f	3.177 f
T_2	3	27.67 d	419.30 e	31.67 ef	3.270 e
T_3	3	31.67 bc	397.30 e	33.00 de	3.270 e
T_4	3	29.33 cd	557.30 bc	34.00 cd	3.280 de
T_5	3	30.33 bcd	508.00 cd	33.33 de	3.303 d
T_6	3	32.67 bc	585.70 ab	36.00 bc	3.467 b
T_7	3	33.00 b	465.30 de	37.33 b	3.430 c
T_8	2	37.33 a	636.30 a	42.00 a	3.567 a
T_9	2	33.67 b	467.00 de	40.00 a	3.487 a
LSD	-	3.405	74.47	2.289	0.0316

Means not sharing common letters are statistically different at 5% level of probability

This parameter was also significantly affected by various levels of N applied as Agrotain coated urea (Table 2). The more number of rows ear^{-1} (27.67) was found in the treatments which got N at 115 kg ha^{-1} with 3 L ton^{-1} Agrotain coating of urea in 2 splits as compared to other treatments. The number of rows ear^{-1} was minimum (17.33) in control treatment where no urea or Agrotain was applied.

The data pertaining to the no. of grains row^{-1} showed highly significant differences among different levels of Agrotain coated urea (Table 3). The data showed that maximum no. of grains row^{-1} (37.33) was obtained in the plots which were treated with 115 kg ha^{-1} nitrogen with 3 L ton^{-1} Agrotain mixed urea and the fertilizer applied in two splits as compared to other treatments. Minimum no. of grains row^{-1} (27.67) was obtained where no Agrotain coated urea was applied.

Highly significant differences were observed for the number of grains ear^{-1} among various treatments where different levels of urea coated with Agrotain and without Agrotain were applied (Table 3). Maximum no. of grains ear^{-1} (636.3) was found in those treatments which were fertilized at 115 kg N ha^{-1} coated with Agrotain at the rate of 3 L ton^{-1} and applied in two splits. Minimum number of grains ear^{-1} (316.7) was observed in no urea receiving plots.

Highly significant differences were observed among different levels of Agrotain coated urea regarding 100 grain weight (Table 3). Those treatments getting 115 kg ha^{-1} N as urea treated with 3L ton^{-1} Agrotain in two splits yielded the

highest 100 grain weight (42 g) as compared to other treatments. Minimum 100 grain weight was found in those plots where no urea was applied.

The data given in Table 3 showed that grain yield per unit area was highly significant among different treatments getting levels of Agrotain coated urea. The highest grain yield (3.567 t ha^{-1}) was obtained in those treatments having N at the rate of 115 kg ha^{-1} coated with agrotain at the rate of 3 L ton^{-1} and the fertilizer applied in two splits as compared to the treatments getting lower levels of N. Minimum grain yield (3.177 t ha^{-1}) was obtained from control.

Discussion

The Agrotain coated urea increased N use efficiency and ultimately increased plant heights and length of ear. Similar to these results, Watson *et al*. (1998) and Zaman *et al*. (2009) also reported that encapsulating of urea with inhibitors improved N availability and increased the crop yield. Enhanced crop yield by Agrotain coated urea was also reported by few other scientists during conducting trials on application of Agrotain coated urea (Yang *et al*., 2006; Mattain *et al*., 2008).

Significant increase in other important yield parameters like number of rows ear^{-1}, number of grains row^{-1}, number of grains ear^{-1}, 100 grain weight and the grain yield per unit area were also recorded due to the application of Agrotain coated urea. These results are also supported by Quin *et al*. (2005) and Dawar *et al*. (2010) who applied Agrotain coated urea to crops and found improved crop productivity and reduced N losses. Urea fertilizer coated with urease Inhibitor (Agrotain) improved bioavailability of N, resulting in increased crop biomass and yield. This increase may be due to the delayed urea hydrolysis by inhibiting compounds and reduced losses of N.

Grant *et al*. (1996) and Dawar *et al*. (2011a,b,c) used nitrogen inhibitors and coated N and found better crop growth and yield during their research. Significant results of urease activity and inhibition was also reported on crops and nitrogen availability by various other scientists (Watson 2000; Zaman *et al*., 2010). Dawar *et al*. (2011a,b,c) also applied urea treated with urease or nitrification inhibitors and reported control on N losses to air and ground along with improvement in crop yield. These findings can also be supported by Ramakrishnan *et al*. (2006) and Chen *et al*. (2008) who found enhanced nitrogen availability from fertilizers due to the use of inhibitors which ultimately improved the crop yield. Increase in grain yield of maize crop was also recorded by Dawar *et al*. (2011b) who conducted research on the use of inhibitor (NBPT) coated urea and found significant impact on maize yield. Reduced losses of nitrogen due to the application of urease inhibitors was also reported by Sanz-Cobena *et al*. (2008) during their research which ultimately contributed to the positive effect on crop yield. Faizan *et al.* (2012) studied the effects of salicylic acid (SA) and putrescine on growth and oil quality of canola (*Brassica napus* L.) when exposed to drought stress and found that SA was economical and environment friendly that can improve the plant growth and oil quality of canola in current scenario of drought and climate change.

The data of present study showed that coating of urea fertilizer with Agrotain at 3 L ton^{-1}, increased the growth and yield of maize crop in the arid and semi-arid climatic region.

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