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The Effect of Different Rates of Urea with or without Urease Inhibitor (NBPT) on Wheat Yield and Quality

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Abstract: The application of urea fertilizer has always been associated with heavy N losses therefore, improving its efficiency is critical to minimize economic and environmental losses associated with its application. A field experiment was conducted on an arable site using Mayfield silt loam soil near Methven Canterbury, New Zealand to investigate the effect of different rates of granular urea applied with or without urease inhibitors, N-(n-butyl) thiophosphoric triamide (NBPT) or Agrotain on wheat (*Triticum aestivum* L.), grain yield and protein contents. About 21 field plots each plot of 3×7 m, separated by a 2 m buffer zone were set up on April 20, 2005. Three replicates of 6 fertilizer treatments (urea alone; urea + Agrotain each applied at 120, 200 and 300 kg N ha^{-1} in 3 split applications at Growth Stage (GS) (GS32, GS39 and GS59) were randomly applied to those plots in a randomized block design. The control plots receive no Nitrogen (N). Urea applied with Agrotain at different rates performed better and produced more grain yield compared to their corresponding urea treatments. Agrotain treated urea applied at 300 kg N ha^{-1} produced 11% more grain yield than that of urea alone. Protein contents of wheat grain significantly increased with N application rates and were optimum (15.7%) at the high rate of Agrotain treated urea. These results showed that applying urea with Agrotain has the potential to improve efficiency of urea by increasing productivity as well as improving quality and can thus results in a greater economic return.

Key words: Urea, Agrotain, wheat, protein, application rate, New Zealand

INTRODUCTION

World population is predicted to increase by 50% by 2050 and this will put further pressure on limited land resources to grow sufficient food for the world's growing population. Providing food to the growing population is only possible through improved agricultural technologies such as higher yielding crop varieties, improving fertilizer and water use efficiency and effective pest and disease control management. Among these technologies, an improvement in fertilizer use efficiency of inorganic fertilizers through the use of N inhibitors may play a key role in increasing productivity as well as minimizing environmental damage (Chen *et al*., 2008).

Among the major essential plant nutrients required for cereal crops worldwide, N supply to wheat is critical for grain yield and quality. Urea is not only the major form of N fertilizer worldwide (Watson, 2000) but it is also the predominant form (80%) of the chemical fertilizer applied to both arable crops and pastures in New Zealand. In New Zealand, wheat is mostly grown in the Canterbury plains in winter and spring and the crops receive about 200-300 kg N ha^{-1} which is applied in split applications (typically 70-100 kg N/ha/application) mainly as urea at different growth stage to meet crop N demand and increase productivity. However, urea has been reported to have lower N use efficiency in many cropping systems compared to other types of N fertilizers because of the heavy N losses associated with its fast hydrolysis by urease enzymes. Soil urease enzymes in the presence of sufficient moisture contents hydrolyze the applied urea within 1-2 days and produce ammonium (NH_4^+) (Zaman *et al*., 2008) and hydroxyl (OH^-) ions.

The OH^- produced raises soil pH around the urea granule and thus, increases the likelihood of N losses via gaseous emission of ammonia (NH_3) to the atmosphere (Zaman *et al*., 2008). A wide range (0-50% of the applied N) of NH_3 loss has been reported in the literature mainly depending on climatic and soil conditions (soil pH, temperature, moisture, wind velocity), agronomic

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practices and management of fertilizer application (Sommer *et al*., 2004; Malhi *et al*., 2001; Gioacchini *et al*., 2002; Zaman *et al*., 2008, 2009; Zaman and Blennerhassett, 2010). Apart from the economic loss to the farmer (Van der Stelt *et al*., 2005), NH_3 lost to the atmosphere from applied urea is likely to be deposited on land or water, causing eutrophication and acidification of natural ecosystems on a regional scale (Sommer and Hutchings, 2001). Therefore, enhancing N use efficiency of urea is critical from both an agronomic and environmental viewpoint.

Among the different options to improve urea efficiency, coating urea with urease inhibitors like N-(n-butyl) thiophosphoric triamide (NBPT) or (Agrotain) has the most potential to reduce urea hydrolysis at relatively low concentrations, minimize N losses and improve crop productivity (Watson *et al*., 1994; Blennerhassett *et al*., 2006; Zaman *et al*., 2008). A number of studies using different types and rates of N fertilizers on wheat productivity have been reported (Malhi *et al*., 2001; Salvagiotti and Miralle, 2007). However, no information is available on the effect of Agrotain treated urea on grain yield and quality of wheat in the southern hemisphere. The objective of the study was to evaluate the agronomic efficiency (grain yield and quality) of different rates of urea alone or with Agrotain applied to winter wheat under a spray irrigation system.

MATERIALS AND METHODS

A field experiment was set up on irrigated (spray irrigation) arable site using Mayfield silt loam (Typic argillic palic) soil near Methven Canterbury, New Zealand. Daily average soil temperature in 0-10 cm soil depth was <6°C in June and July and was above 18°C during December to February. Previous crop grown on the site was barley and barley straw was burnt after harvesting grain yield.

About 21 plots each of 3×7 m with a buffer zone of 2 m were set up on April 20, 2005. Before the application of treatments, 4 composite soil samples (0-100 mm) were collected to determine the key soil properties. Each plot received phosphorus (P) and sulphur (S) at a rate equivalent to 60 kg ha^{-1} before sowing the wheat crop.

Wheat crop c.v. Aquila was sown at a seed rate of 100 kg ha^{-1} in rows (row to row distance of 150 mm). The 6 treatments (urea alone; urea + Agrotain each applied at 120, 200 and 300 kg N ha^{-1}) were applied in 3 split doses to appropriate plots in a 3×7 randomized block design. Each treatment had 3 replicates.

The first fertilizer application was broadcast at Growth Stage (GS) GS-32 on September 29, followed by the 2nd and 3rd application at GS-39 and GS-59 on October 20 and 28 November, respectively. Spray irrigation of 50 mm was applied within 1 day of fertilizer application to wash away added urea from surface soil. The control plots receive no N. The wheat crop was harvested on January 31 to determine grain yield and grain quality (protein).

Statistical analyses: Analysis of Variance (ANOVA) was carried out to determine if the different treatments had any significant effect on wheat grain yield and protein contents using Minitab (Version 12, Minitab Inc. USA). Least Significant Differences (LSD) were calculated only when the treatment effect was significant at $p<0.05$.

RESULTS AND DISCUSSION

Initial soil properties: Different soil chemical properties analysed prior to treatment application are shown in Table 1. All these chemical properties are within the adequate range required for arable cropping because of the mixed cropping rotation in New Zealand. Ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) are usually grown for 2-5 years for grazing followed by arable cropping.

Such pasture/arable rotation helps to maintain high soil fertility level during pasture growth through fixation of atmospheric N by white clover and deposition of dung and urine from grazing animals (Haynes and Williams, 1993; Saggar, 2004).

Wheat grain yield was significantly influenced by different N rates of urea applied with or without Agrotain (Table 2). Agrotain treated urea applied at different rates performed better and produced more grain yield compared to those of urea alone. At 120 and 200 kg N ha^{-1} rates, Agrotain treated urea produced 5 and 3% more grain yield, respectively compared to their corresponding rates of urea alone treatments.

Table 1: Key soil properties

Soil properties	Values
pH	6.00
Olsen P	24.00
Potassium (me/100g)	0.63
Calcium (me/100g)	9.90
Magnesium (me/100g)	0.71
Sodium (me/100g)	0.18
CEC (me/100g)	17.00
Base saturation (%)	66.00
Available N (kg ha^{-1})	101.00
Organic matter (%)	4.40
Total carbon (%)	2.60
Total nitrogen (%)	0.27
C/N ratio	9.50
Ammonium-N to total N ratio	2.70
Anaerobically mineralizable N (μg g^{-1})	72.00

Table 2: Wheat grain yield and protein contents as affected by different rates of urea with or without Agrotain

Treatments	Grain wt. (kg ha^{-1})	Protein (%)	Protein (kg ha^{-1})
Control	5130	11.40	583
Urea 120	6414	13.50	865
Urea 200	7204	14.60	1051
Urea 300	6799	15.40	1044
SustaiN120	6705	13.50	908
SustaiN200	7410	15.00	1114
SustaiN 300	7546	15.70	1183
LSD	431	0.47	74

Such increases in grain yield were not statistically significant at $p<0.05$. However, when applied at the highest rates (300 kg N ha^{-1}), Agrotain treated urea produced significantly higher grain yield (7,546 kg ha^{-1}) compared with that of urea alone (6,799 kg ha^{-1}) (Table 2). This represents 11% more grain yield than that of urea alone (Table 3).

The fertilizer response curve showed that the increase in grain yield was nearly linear up to 200 kg N ha^{-1} for both Agrotain treated urea and urea alone treatments (Fig. 1). However, at 300 kg N ha^{-1} rates, grain yield increased in Agrotain treated urea while urea alone treatment exhibited depressed grain yield and resulted in parabolic shaped. Like the grain yield, protein contents also varied with N application rates of urea with or without Agrotain (Table 2). Protein contents of wheat grain significantly increased with N rates and were optimum (15.7%) at 300 kg N ha^{-1} of Agrotain treated urea.

Agrotain treated urea applied at different rates produced more wheat grain yield than those of urea alone (Table 2). In the experiment, spray irrigation (50 mm) was applied within 1 day of fertilizer application which could have enabled the applied urea from surface soils to move to sub-surface soil layers which would have precluded the main effect of Agrotain to reduce NH_3 volatilization losses.

Apart from minimizing NH_3 losses such increases in grain yield could be related to other benefits of Agrotain like delayed urea hydrolysis (Watson, 2000; Chen *et al*., 2008; Zaman *et al*., 2009) and improvement of bioavailability (i.e., easier N uptake and metabolism) of applied urea (Blennerhassett *et al*., 2006; Zaman *et al*., 2008; Dawar *et al*., 2010).

Delaying urea hydrolysis by Agrotain increases the chance of rain/irrigation to move the applied urea from surface soil into sub-surface soil layers where volatilization cannot occur. Generally plants take up the majority of their N in nitrate (NO_3^-) form as enforced on them by the ubiquitous urease enzymes and nitrifying bacteria. But plants need extra energy to convert NO_3^- to NH_4^+ via nitrate reductase followed by amide and protein conversion each of these steps occurs at the expense of energy. However urea, an un-charged particle can be taken up by plant roots as an intact molecule relatively faster as well as with out releasing any charge (H^+ or OH^-) into the root rhizosphere and can thus, be converted into plant protein at less energy cost compared with NH_4^+ or NO_3^-. This means that plants have less energy expenditure when utilizing urea/NH_4^+ as opposed to NO_3^-. Other researchers also found an improvement in crop productivity after applying urea with Agrotain in different environmental conditions (Yang *et al*., 2006; Watson *et al*, 1994; Blennerhassett *et al*., 2006; Zaman *et al*., 2008).

Table 3: Percent changes in grain weight and protein contents relative to urea alone

Change (%)	Grain wt (kg ha^{-1})	Protein (%)	Protein (kg ha^{-1})
SustaiN120	5	0.6	5.0
SustaiN 200	3	3.0	6.0
SustaiN 300	11	2.1	13.3

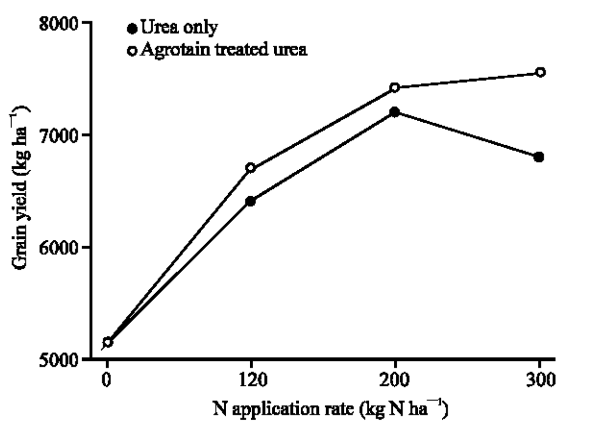

Fig. 1: Relationship between grain yield and added N

Agrotain treated urea also increased protein contents of wheat grain (Table 2). Such increase in protein contents is due to the fact that N is a primary building block of protein. A high grain protein content is important for milling and baking quality of wheat and results in higher economic returns as customers pay premiums for the higher protein content. These premiums are passed on to the producer, creating interest in managing for high protein content. Proper N management like applying the right amount of N at the right growth stage can help to optimize protein content while avoiding adverse effects on crop production and the environment. Environmental conditions are very important in determining the magnitude of NH_3 volatilization losses after urea application.

In Canterbury regions where the majority of wheat is grown, weather conditions normally become warmer and drier later in the summer so the risk of volatilization losses after urea application increases during that time.

Therefore, there is likely to be increasingly greater benefits of using urea with Agrotain when the associated volatilization losses would have a larger impact on N status in the soil. Similarly, in areas with warmer and drier weather conditions the use of Agrotain may be beneficial with in-crop applications of fertilizer to increase fertilizer rates to enhance grain protein content of wheat in anticipation of a protein premium added to grain price. Apart from the agronomic benefits, applying urea with Agrotain is likely to reduce the footprints of Green House Gas emission (GHG) as urease inhibitors have been recently included in New Zealand national inventory for GHG.

CONCLUSION

This field study has provided us significant insights into how wheat productivity and quality are influenced by different rates of urea with or without Agrotain. Despite less conducive soil conditions for NH_3 losses, Agrotain improved bio availability of the applied urea and resulted in higher grain yield than those of urea alone suggesting that applying urea with Agrotain has the potential to improve productivity as well as quality of the wheat crop.

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