

IMPACT OF UREASE INHIBITOR (NBPT) AND HERBICIDE ON WHEAT YIELD AND QUALITY

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ABSTRACT

A field experiment was conducted to investigate the impact of urease inhibitor N-(n-butyl) thiophosphoric triamide (NBPT - "Agrotain") and herbicide on wheat (Triticum aestivum L.) grain yield and protein contents. The application of both urea with herbicide and urea with urease inhibitor significantly increased grain protein contents compared with urea treatment ALONE. Similarly NBPT treated urea with herbicide increased grain yield by 20%. Similarly, NBPT treated urea with herbicide produced significantly higher protein contents by 15% compared with urea alone or other treatments. These results suggested that both NBPT and herbicide together executed better than urea alone, probably by increasing fertilizer use-efficiency through controlled urea hydrolysis and weeds competition. A delay in urea hydrolysis by NBPT and reduced weeds competition by herbicides provided a maximum opportunity for direct plant uptake of an increased proportion of the applied urea-N than in the case of urea alone. Treating urea with NBPT and herbicide has the potential to improve urea efficiency by increasing productivity as well as improving quality.

Key words: Urea, urease inhibitor, maize, weeds, herbicide.

INTRODUCTION

The global population has risen substantially in recent decades. Between 1980 and 2000 it rose from 4.4bn to 6.1bn and food production increased 50%. By 2050 the population is expected to reach 9bn. According to the United Nation's food and agriculture programme, 854 million people do not have sufficient food for an active and healthy life. Providing food to the growing population is only possible, if we can improve agricultural practices such as (crop rotation, sowing at the right time of year and basic weed control etc)

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and use efficient and modern agricultural technologies such as higher yielding crop varieties, improving fertilizer, water use-efficiency and effective pest and disease control management. Among the different management options, an improvement in fertilizer use-efficiency of inorganic fertilizers and weed control may have the potential to increase productivity and also minimize environmental damage.

Nitrogen (N) is the primary nutrient and is commonly found in inorganic fertilizers such as urea, ammonium nitrate, ammonium sulphate, di-ammonium phosphate and potassium nitrate. Primary nutrients are utilized in the largest amounts by crops, and therefore, are applied at higher rates than secondary nutrients and micronutrients. Nitrogen is an essential nutrient for plant growth and development (Simpson, 1987) as it plays a key role in the synthesis of protein and chlorophyll, which are essential to improved the quality and quantity of dry matter and protein in grain crops. Urea not only accounts for 50 % of the total world N-consumption (IFIA, 2007), but it is also the predominant form (80%) of the chemical fertilizer applied to both arable crops and pasture in New Zealand.

Wheat production world-wide is under threat from climate change and an increase in demand from a growing human population. Wheat is the most commonly grown cereal crop in the world in developed countries. In New Zealand, wheat is grown in the Canterbury plains in winter and spring and the crops receives about 200-300 kg N ha⁻¹ which is applied in split applications mainly as urea at different growth stages to meet crop demand and increase productivity. However, a major disadvantage associated with the use of urea is gaseous loss of N via ammonia (NH₃) emission, which depend on soil moisture, temperature, pH, wind velocity, soil organic C and N fertilizer type (Cabrera *et al.*, 2001; Gioacchini *et al.*, 2002; Khalil *et al.*, 2002; Kissel *et al.*, 2004; Ahmed *et al.*, 2006; Pacholski *et al.*, 2006; Zaman *et al.*, 2008; Rochette *et al.*, 2009).

Among the different management options (e.g. avoiding heavy N application rates, applying N fertilizer at appropriate time, splitting N applications, using slow release fertilizer, or coating N fertilizers with polymers or elemental S), adding urease inhibitors to urea may have the greatest potential to reduce N losses and enhance its N efficiency (Carmona *et al.*, 1990; Chai and Bremner, 1987; Blennerhassett *et al.*, 2006; Zaman *et al.*, 2008). Of the various urease inhibitors [including hydroxyl urea, phosphoroamides, and phenyl phosphorodiamidate (PPDA)], N- (n-butyl) thiophosphoric triamide (NBPT - "Agrotain") has the potential to reduce N losses at low concentration and improved crop productivity (Watson *et al.*, 2008; Zaman *et al.*, 2008; Dawar *et al.*, 2010; 2011). Weeds can reduce yield further by competing with wheat for available N. Therefore, weed control is pre-requisite for

higher yield and quality crops. This experiment was established to test the hypothesis that coating urea fertilizer with NBPT would result in enhance fertilizer use-efficiency and herbicides would reduce competition with wheat for available N.

MATERIALS AND METHODS

A field experiment was established on irrigated (spray irrigation) arable farm in central Canterbury, New Zealand. The experiment received the same crop management applied by the farmers. The soil used was Paparua silt loam, Typic Haplustepts (Soil Survey Staff 1998). About 20 plots each of 3 x 7 m with a buffer zone of 2 m were set up on April 2009. Before the application of treatments, 4 composite soil samples (0–10 cm depth), each composite soil sample comprised of 10 randomly collected soil cores, were collected from the experimental site and passed through a 2 mm sieve to remove visible plant litter and roots. Sieved soil samples were analyzed for key soil properties (Table-1). Each plot received phosphorus (P) using triple superphosphate (TSP) and sulphur (S) at 60 kg ha⁻¹ using potassium sulphate before sowing the wheat crop.

Wheat crop (cv. Aquila) was sown at a seed rate of 100 kg ha⁻¹ in rows (row to row distance of 20 cm). The 5 treatments (urea only, urea + herbicide, urea with NBPT, urea with NBPT + herbicide) were applied at 200 kg N ha⁻¹ in three split doses to appropriate plots in a 4x5 randomized block design. Each treatment had four replicates. The control treatment received no N and no herbicide.

Table-1. Physical and chemical properties of the soil used in experiments.

Soil properties	Values
pH	5.65
Total N (%)	0.38
Organic matter (%)	7.0
Olsen P (µg/ml)	20
CEC (me/100g)	14
Ca ₂ ⁺ (me/100g)	6.7
K ⁺ (me/100g)	0.45
Mg ⁺⁺ (me/100g)	1.74

The 1st fertilizer application was broadcast at Growth Stage (GS)-32, followed by 2nd GS-39 and 3rd GS 59, respectively. A commercial mixture (Combine) containing 200 g l⁻¹ bromoxynil + 200

g l⁻¹ ioxynil (both as octanoate ester in an emulsifiable concentrate formulation) was applied three times in 4 days before each fertilizer application to ensure broadleaf weeds did not become competitive. The wheat crop was harvested at maturity to determine grain yield and grain quality. Analysis of Variance (ANOVA) was carried out to determine if the different treatments had any significant effect on wheat grain yield and plant biomass 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

Wheat grain yield in response to urea (applied with or without NBPT and herbicide) were significantly ($P < 0.05$) higher than that of the control treatments. Urea with added herbicide produced significantly ($P < 0.05$) higher grain yield 5399 kg ha⁻¹ compared with urea alone (5923 kg ha⁻¹) (Table-2). This represents 11% more grain yield than that of urea alone (Table-2). These results are in line with those of (Azad *et al.*, 1997; Singh and Singh, 1996; Subhan *et al.*, 2003) who also observed that herbicide application and hand weeding increased grain yield of wheat. In the experiment, herbicide were applied 4 days before fertilizer application which would have reduced weeds growing in competition with wheat for available N and other nutrients in the field and may result in improved N bioavailability by providing wheat plant an extra-opportunity for uptake of more N.

Grain yield of wheat was even greater when urea applied with NBPT + herbicide (6511 kg ha⁻¹) compared with urea alone, Urea + herbicide and urea + NBPT treatments (Table-2). Urea with NBPT + herbicide increased grain yield by 20% compared with urea alone. Like the grain yield, protein contents also varied with N application of urea with or without NBPT and herbicide (Table-2). Protein contents of wheat grain significantly ($P < 0.05$) increased with NBPT and herbicide and were optimum (26%) at NBPT treated urea + herbicide.

These results suggested that the NBPT along with herbicide boosted the plant growth which ultimately increased the grain yield of crop. NBPT delayed the hydrolysis of urea up to one to two weeks (Sanz-Cobena *et al.*, 2008; Dawar *et al.*, 2011) by inhibiting the activity of urease enzyme in the soil (Gill *et al.*, 1997). Slowing urea hydrolysis allowed more time for irrigation or rain fall to come and to diffuse urea onto the soil from the application point and hence reduce the concentration of NH₄⁺ present in the surface soil layer and the potential for NH₃ volatilization (Grant *et al.*, 1996; Dawar *et al.*, 2011).

Apart from NH₃ losses such increases in grain yield could be related to other benefits of NBPT like delayed urea hydrolysis (Watson 2000; Chen *et al.*, 2008; Dawar *et al.*, 2011) and boost the

bioavailability (i.e., easier N uptake and metabolism) of applied urea (Blennerhassett *et al.*, 2006; Zaman *et al.*, 2008; Dawar *et al.*, 2010). Slow urea hydrolysis by NBPT enable wheat crop to take up N in urea form by the plant roots as an intact molecule which may be incorporated into organic compounds and eventually deposited as a plant protein at less energy cost compared to NO_3^- or NH_4^+ .

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 without 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 NBPT in different environmental conditions (Yang *et al.*, 2006; Watson *et al.*, 1994; Blennerhassett *et al.*, 2006; Dawar *et al.*, 2010). Urea with NBPT and herbicide also increased protein contents of wheat grain (Table-2).

Table-2. Wheat grain yield and protein contents as affected by urea with or without urease inhibitor and herbicide.

Treatments	Grain yield (kg ha ⁻¹)	% difference to urea-only	Protein (kg ha ⁻¹)	% difference to urea-only
Control	5112 ^a		683a	
Urea-only	5399 ^b		985 ^b	
Urea+Herbicide	5923 ^c	9	1051 ^c	6
Urea+NBPT	6229 ^d	15	1084 ^d	10
Urea+NBPT+ Herbicide	6511 ^e	20	1114 ^e	15

Within columns, means with the same letters are not significantly different at the $P < 0.05$ level where $n = 4$.

Protein content of wheat is influenced by N supply and the grain yield through which the N is disseminated. Therefore, any factors which influence N supply or grain yield will influence the protein concentration. Such increase in protein contents is due to the fact that N is a primary building block of protein. 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 of the cereal can help to optimize protein content while avoiding adverse effects on crop production and the rhizospheric environment. It is important that we ensure that the management practices we use in crop production not only optimize wheat yield and protein content, but also maintain or improve the quality of our wheat for its final intended use. This will help to maintain or improve our competitive position on international markets.

CONCLUSION

This field study has provided us significant insights into how wheat productivity and quality are influenced by urea with NBPT and herbicide. Despite less conducive soil conditions for NH_3 losses, NBPT improved bio availability of the applied urea and resulted in higher grain yield than those of urea alone suggesting that applying urea with NBPT has great potential to improve productivity as well as quality of the wheat crop.

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