INHIBITORS, METHOD AND TIME OF NITROGEN APPLICATION FOR IMPROVED WINTER WHEAT PRODUCTION IN CENTRAL MONTANA

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ABSTRACT

The contribution of nitrogen (N) fertilizer to boost yield and improve quality is unquestionable. Inefficient use of applied N is economically significant and environmentally unsafe. Ammonia loss can exceed 40% of applied N. Nitrogen leaching is polluting wells. Use of urease and nitrification inhibitors along with appropriate timing and method of nitrogen application can reduce nitrogen loss, improve yield and quality of wheat. This experiment investigated the effect of timing and method of N fertilizer application and urease and nitrification inhibitors on grain yield, grain protein content and grain nitrogen uptake of winter wheat and residual soil nitrate content at Moccasin, Montana. The experiment was conducted in 2011 and 2012 in randomized complete block design (RCBD) with four replications. Treatments were application of urease and nitrification inhibitors, polymer coating (ESN), time and method of nitrogen application on winter wheat (cv Yellowstone). Results indicated that applying regular urea at higher rate together with the seed should be avoided since it will reduce seedling stand and later grain yield, unless using ESN. Spring broadcasting of regular urea resulted in 24% grain yield advantage over fall broadcasting when rainfall is relatively high in 2011. Fall broadcasted urea with Agrotain and N-serve (RUBANSF) resulted in 17% grain yield advantage over urea alone (RUBF) in 2011 (wet season). But this situation was reversed in 2012 (relatively dry season). This result revealed that the effect of N application and use of inhibitors for grain yield improvement varies with precipitation amount and distribution.

INTRODUCTION

The economic benefit of N fertilizer use has been well recognized. But worldwide N fertilizer recovery in cereals production has been calculated to be 33% (Raun and Johnson, 1999). A recent study in Montana indicated that ammonia volatilization can exceed 40% applied N (Engel et al., 2011). This is economically significant loss for producers. In some parts of this state, with shallow soil profile, nitrogen fertilizer has been identified as source of nitrate pollution for drinking water wells. These wells are important source of domestic water supply for 60-80% of the population in the area. In this connection, more than 26% of the wells have nitrate beyond the World Health Organization standard limit for human consumption (Schmidt and Mulder, 2010). The nitrate in drinking water beyond the standard limit can interfere with the ability of red blood cells to transport oxygen causing blue baby syndrome. This is a disease that can result in brain damage and even death (Shearer et al., 1972). These economic, environmental and health issues are of significant concern for the research community worldwide to improve nitrogen use efficiency to increase the economic benefits and reduce environmental and health problems associated with N fertilizer use.

Urea is the most widely used N fertilizer due to its relative ease of handling, high concentration and low price. Nitrogen loss begins when urea is applied to the soil and comes in contact with the enzyme urease and moisture. Urease is an enzyme that catalyzes hydrolysis of urea to NH_3 (Fenn and Hossner, 1985). Plant residues including wheat are known to have significant urease activity (Kissel et al., 2008). In the soil, hydrolysis of urea may result in loss of ammonia via volatilization after fertilization (Turner et al., 2010). Inhibiting the activity of urease will retard the formation of ammonia. This will give more time for applied urea to get moisture and infiltrate into the soil and minimize N loss. The use of urease inhibitors such as N-(n-butyl) thiophosphoric triamide (NBPT) has been found to reduce ammonia loss by 66% compared to applying urea alone (Engel et al., 2011).

Conversion of ammonium to nitrite and nitrate is facilitated by soil bacteria. Nitrate is very susceptible for N loss through leaching and denitrification. Therefore, inhibiting the activity of these bacteria will retard nitrate formation. This will reduce N loss and contribute to increase N use efficiency. Some chemicals have been developed to retard the nitrification process to minimize N loss. Additions of urease and nitrification inhibitors with urea will allow applied nitrogen fertilizer to stay in the soil close to the root zone for a longer period. This will create better opportunity for plant uptake than applying urea alone. However, the effectiveness of these inhibitors in increasing yield and improving grain protein content is affected by several soil and environmental factors. Moreover, the optimal application method and timing of nitrogen fertilizer was not well defined for farmers in central Montana. Therefore, we evaluated the effect of inhibitors, timing and method of nitrogen fertilizer application on grain yield, protein content, nitrogen uptake and residual soil mineral nitrogen content at Moccasin, MT.

METHODS

The experiment was conducted at the Central Agricultural Research Center, Moccasin, MT, during the 2010-2011 and 2011-2012 crop seasons using a winter wheat (cv Yellowstone). Three N products (urea, SuperU, and ESN) were applied at 80 lb N/ac in the fall or spring using three methods (broadcast, middle row banding, and with seed). Additional treatments include adding Agrotain or Agrotain with N-Serve to regular urea and broadcasted in fall and spring. The details of these treatments are shown in Table 1. The experiment was a RCBD with four replications. Grain nitrogen content was determined using dry combustion method. The soil nitrate content in the top 24 inches was measured in 2012 after harvesting. Analysis of variance and mean comparison were performed using PROC GLM of SAS computer software (SAS Institute, 2011). Treatment comparisons were made using Fisher's LSD with probability value of 0.05 when ANOVA showed significant difference.

RESULTS AND DISCUSSION

Precipitation was significantly higher in 2011 (21.6 inches) than 2012 (11.0 inches) (Fig. 1). This high rainfall in 2011, particularly in the months of May and June, critical time for flowering and grain filling, might have accounted for the higher recorded grain yield in 2011 than 2012. The effect of different inhibitors, method and timing of N application and on the different parameters of winter wheat are presented and discussed in separate paragraph as follows.

Application Method:

In 2011, as shown in Fig. 2a, significantly higher grain yield (32.5 bu/ac) was recorded from the fall application of ESN than broadcast (RUBF) and with seed (RUSF); Applying regular urea together with the seed (RUSF) reduced grain yield by 50% compared to ESNF. This might be due to immediate hydrolysis of urea producing excess of ammonia toxic to germinating seed. This could have been the reason for reduced seedling number and later decreased grain yield. This is in agreement with the lower seedling count for RUSF than other treatments (Table 2). The grain protein content was lower in RUBF and RUDF than in RUSF treatment likely due to dilution effect. But grain N uptake was greater for ESNF due to higher grain yield than other treatments.

In 2012, regular urea broadcasted in fall (RUBF) resulted in significantly higher grain yield (31.9 bu/ac) compared to ESN and RUSF. Similar to 2011, applying urea together with the seed (RUSF) resulted in the lowest grain yield compared to other treatments (Fig. 2a). However, the decrease in seedling count and grain yield due to RUSF was relatively smaller in 2012 compared to 2011. This might suggest the importance of high precipitation in facilitating the activity of urease for ammonia formation that is toxic to the germinating seedling. Regular urea broadcasted in fall (RUBF) resulted in higher grain nitrogen uptake (47.14 lb N/ac) than urea applied with seed.

Table 1. Description of treatments

No.	Treatment	Urea type	N application method	Time	Type of inhibitors
1	RUBF	Regular	Broadcast	Fall	--
2	RUBS	Regular	Broadcast	Spring	--
3	RUABF	Regular	Broadcast	Fall	Urease
4	RUANSBF	Regular	Broadcast	Fall	Urease and nitrification
5	SUBF	Super U	Broadcast	Fall	Urease and nitrification
6	RUDF	Regular	Banded in middle row	Fall	--
7	RUSF	Regular	Applied with seed	Fall	--
8	ESNF	ESN	Applied with seed	Fall	--
9	RUABS	Regular	Broadcast	Spring	Urease
10	RUANSBS	Regular	Broadcast	Spring	Urease and nitrification
11	RUBS	Regular	Broadcast	Spring	--
12	SUBS	Super U	Broadcast	Spring	Urease and nitrification
13	Check	--	--	--	--

Application Timing:

In 2011, when we had relatively higher rainfall, regular urea broadcasted in spring (RUBS) resulted in significantly higher grain yield (36.5 bu/ac) (24% yield advantage) compared to fall application (RUBF) (27.7 bu/ac) (Fig. 2b). In 2012 when precipitation was low, however, RUBF resulted in significantly higher grain yield (31.9 bu/ac) than RUBS (26.9 bu/ac) (Fig. 2b). Grain protein content was improved with spring application of nitrogen both in 2011 and 2012 (Table 2). Spring nitrogen application in 2011 significantly increased grain nitrogen uptake by 47% compared to fall application (Table 2). This higher N uptake means lower residual N as observed in 2012 (Table 2).

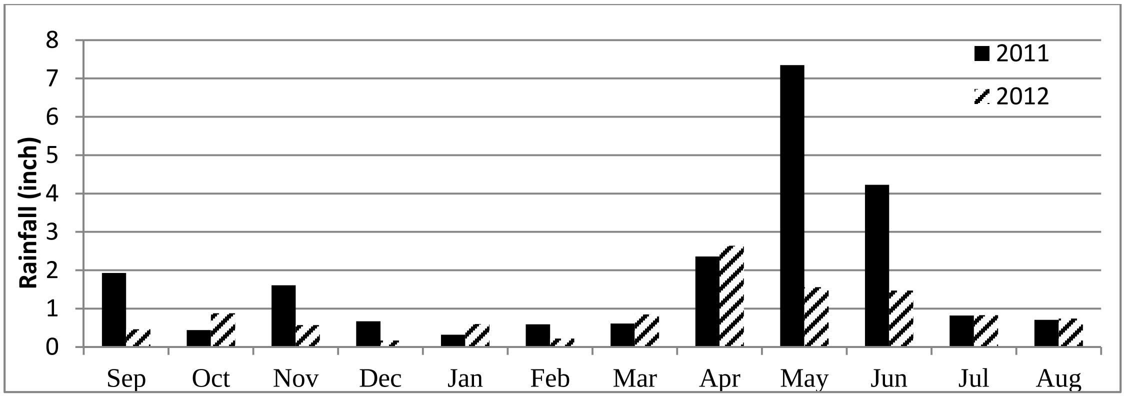

Fig. 1 Monthly rainfall distribution at Moccasin, MT, in 2010-2011 and 2011-2012 crop year. Crop year at Moccasin, Montana, is from September to August.

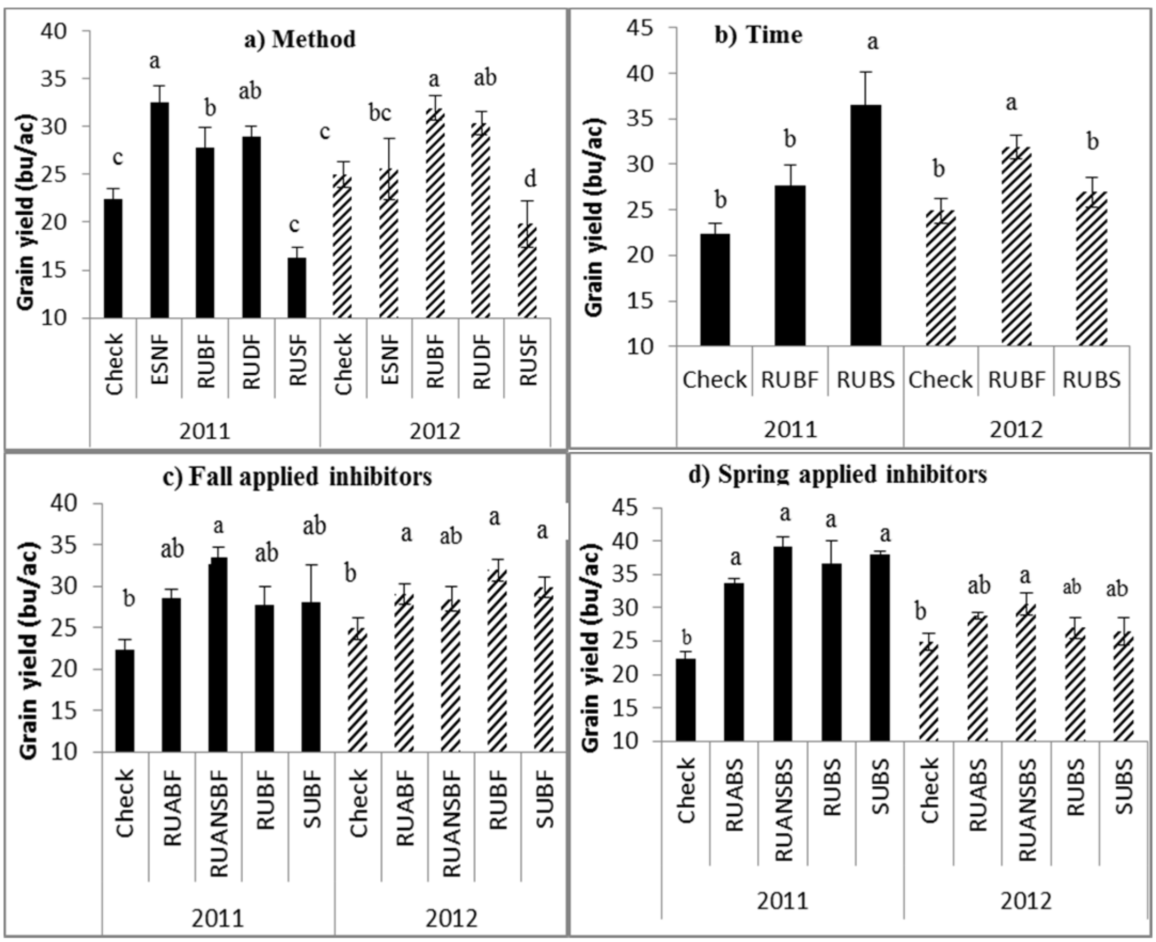

Fig. 2 The effect of method and time of N application, and enhanced N fertilizer (N with inhibitors or coating) on grain yield of winter wheat at Central Agricultural Research Center, Moccasin, MT, in 2011 and 2012. Means with a common letter for the same year and of same treatment group are not statistically different from each other according to Fisher's LSD at P <0.05 level. Error bars are standard error of the mean (n = 4).

Urease and Nitrification Inhibitors:

Timing of nitrogen application with inhibitors has been split into fall and spring applications and presented as follows.

Urea fall application with inhibitors:

In 2011, regular urea broadcasted with Agrotain and N-Serve in the fall (RUBANSF) resulted in higher grain yield (33.5 bu/ac) compared to RUBF and SUBF at P<0.10 (Fig. 2c). This increase in grain yield due to RUBANSF was 17% over regular urea broadcasted without inhibitor in the fall (RUBF). But in 2012, when there was low rainfall, RUBF resulted in similar yield as RUANSBF but better than ESNF (P<0.10). This suggests that the combined effect of urease and nitrification inhibitors will help to increase grain yield in areas and times with relatively high rainfall.

Table 2. The effect of method and time of N application and enhanced N fertilizer on grain protein content, seedling count, grain nitrogen uptake of winter wheat and soil nitrate content (0-6 inches soil depth) in 2011 and 2012 at Moccasin, Montana.

Main factor	Treatment	Grain protein (%)		Seedling/ft^2		Grain nitrogen uptake (lb/ac)		Soil N (lb/ac)
		2011	2012	2011	2012	2011	2012	2012
Method	RUBF	8.90b	14.03b	8a	12a	26b	47a	9.5a
	RUDF	8.90b	14.78ab	7a	14a	27b	47a	10.2a
	RUSF	10.02a	15.38a	4b	7b	17c	32b	10.8a
	ESNF	9.58ab	15.08a	7ab	13a	33a	40ab	8.9a
Time	RUBF	8.90b	14.03a	8a	12a	26b	47a	9.5a
	RUBS	12.88a	14.85a	7a	14a	49a	42a	11.0a
N applied with inhibitors in fall	RUABF	8.75b	14.65ab	8a	13a	30ab	45a	10.0a
	RUANSBF	9.38ab	14.40ab	8a	11a	33a	43a	12.1a
	RUBF	8.90b	14.03b	8a	12a	264b	47a	9.5a
	SUBF	10.50a	14.15b	7a	13a	26b	45a	11.3a
N applied with inhibitors in spring	RUABS	12.95a	14.80a	6a	14a	46b	45a	19.0a
	RUANSBS	13.05a	14.45a	8a	14a	54a	46a	13.0a
	RUBS	12.88a	14.85a	7a	14a	49ab	42a	10.0a
	SUBS	12.70a	14.45a	8a	14a	51ab	402a	16.2a
Check		9.27	10.43	8	12	22	27	7.5

Means followed by a common letter in a column, for the same main factor, are not statistically different form each other at LSD0.05.

Urea spring application with inhibitors:

In 2011, regular urea broadcasted with Agrotain and N-Serve in the spring (RUANSBS) resulted in similar grain yield (39.2 bu/ac) as RUBS and SUBS (Fig. 2d). In 2012, this same treatment (RUANSBS) resulted in more grain yield (30.5 bu/ac) than RUBS and SUBS (P<0.10). No significant difference in grain protein content and grain nitrogen uptake were recorded both in 2011 and 2012 due to spring application of different inhibitors (Table 2).

SUMMARY

This study finds out that applying regular urea at higher rate together with the seed will reduce seedling count and later grain yield. The effect of nitrogen application timing for grain yield increase depends on the amount and distribution of precipitation in the growing season. Similarly, the benefit of using inhibitors in the fall to increase grain yield depends on rainfall amount. When fall rainfall is high, urea applied with urease and nitrification inhibitors in the fall increased grain yield than urea alone.

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