ENVIRONMENTALLY SMART NITROGEN PERFORMANCE IN NORTHERN GREAT PLAINS' SPRING WHEAT PRODUCTION SYSTEMS

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ABSTRACT

Field trials were conducted at three locations in Montana to evaluate the efficacy of Environmentally Smart Nitrogen (ESN) (44-0-0) as a nitrogen (N) source for spring wheat. The ESN, urea (46-0-0), and a 50%-50% urea-ESN blend was applied at seeding at three rate levels - low, medium, and high - with actual rated dependent on the yield goal at each location, followed by urea application of 0 or 40 lb N/a at Feekes 5. Grain yield (GY) varied from 265 to 815 lb/a and grain protein (GP) content ranged between 9.1 and 17.3% among the site-years. Spring wheat GY and GP responded to at-seeding N application. Urea, ESN, and the blend resulted in higher yields at 3, 2, and 2 site-years out of 8 evaluated site-years, respectively. No apparent trend in GP content associated with N source was observed. Results showed that ESN and urea-ESN blend performed as well, but not better than urea alone. With ESN costing consistently more than urea per unit of N, we concluded that the investment in ESN product is not justified for spring wheat production.

INTRODUCTION

The awareness and interest to enhanced-efficiency fertilizer technologies among the Northern Great Plains producers is apparent. This trend is mainly due to steady efforts to improve the efficiency of fertilizer use and to minimize the negative impact of intensive agricultural production on the environment. Environmentally Smart Nitrogen, a common enhanced-efficiency fertilizer, is produced by coating urea granules with a polymer shell that allows for a slow-release of N to the soil. Literature review points to numerous studies showing that higher yields and better crop quality could be achieved with ESN compared to conventional urea providing crop producers with a higher return on their fertilizer investment (Gordon, 2008). Furthermore, due to the slow-release technology, the increase in NUE is achieved by reduction of N losses through denitrification, leaching, and volatilization. Some consider the ESN as a controlled-release N fertilizer (www.agriumwholesale.com, 2014; Keller, 2010) that supplies the crop with N all through the growing season. Moreover, the manufacturer affirms that ESN offers a predictable release of N due to the coating characteristics. The polymer coating represents a semi-permeable membrane that allows water to diffuse into the granule and dissolve N; encapsulated N remains inside and is released over time at a controlled rate (www.agriumwholesale.com, 2014). The N release rate is controlled by soil temperature - N release rate increases as the soils temperatures rise in the spring. This methodology aims to match crop need for N by "spoon-feeding" it with gradual N release from the ESN capsules. However, others tend to classify ESN simply as a slow-release product (Franzen, 2010; Ruark, 2012) due to uncertainty in the level of control provided by the polymer coating. In fact, as water diffuses through a flexible, micro-thin polymer coating, the liquefied N is allowed to disperse out through the membrane and into the soil. The common variations in soil characteristics and temperatures must be also considered. Soil and air temperatures, as well as crop development rate, do not increase linearly throughout the growing season. In most cropping systems, warmer/colder periods are likely; the speed of crop growth is known to vary considerably depending on the developmental growth stage. For instance, stem elongation (Feekes 4–9) is the most rapid stage of wheat crop growth (Alley et al, 2009). Studies have shown that, as all N has been dissolved within the ESN casing, and the soil temperatures reach 68°F, between 65 and 90% of N is released into the soil within a 30 day period (Golden, 2009). In addition, the rate of N release is highly dependent on the soil type. A more rapid release of N was observed in clay soils compared with silt- and sandy-loam soils (Golden, 2009). To meet a producers' yield and quality targets for specific crops and growing conditions, ESN can be used as a sole N source or as a blend with other fertilizers such as traditional urea. The ESN recommendations for a wide variety of field crops such as corn, canola, cotton, and wheat have been developed by the manufacturer. The manufacturer's guidelines for ESN use in spring wheat in the Great Plains area is application of N as 100% ESN in the fall prior to seeding. Alternatively, spring wheat can be fertilized with a blend (40–75% ESN + 25–60% urea) (www.agriumwholesale.com, 2014). This three year-long study has assessed the efficacy of ESN, compared with urea, for spring wheat production in the Northern Great Plains. The specific objectives of the study were: (i) to evaluate ESN as an N fertilizer source for spring wheat production in Montana compared with conventional urea and (ii) to evaluate N use efficiency (NUE) and grain yield and protein response to these two fertilizer materials, alone and in a blend.

METHODS

The field study was initiated in the spring of 2011, continued in 2012, and completed in the 2013 growing season. Field trials were conducted at three locations in Montana: an irrigated site at the Western Agricultural Research Center (Corvallis), and two dryland sites - one at the North Western Agricultural Research Center (Kalispell) and one at the Western Triangle Agricultural Research Center (Conrad). Plots were arranged in a split-plot design with N source as the main plot factor, and the topdress – as the subplot factor. Three N sources - urea, ESN, and a 50:50 blend of urea and ESN and for N fertilizer rates (0, 50, 100, and 150 lb N/ac at Conrad and 0, 100, 200, and 300 lb N/ac at Kalispell and Corvallis, based on the area's yield goal and current Montana State University's N fertilization guidelines for spring wheat) were evaluated. Hard red spring wheat (cv. Choteau) was direct seeded into plots measuring 5 by 25 feet at the seeding rate of 17 plants per sq foot. At-seeding N fertilizer was applied with the seed. At all locations, each plot was split into two subplots at Feekes 5 (late tillering/ beginning of stem elongation) growth stage; the topdress N was applied at 0 or 40 lb N/a as granular broadcasted urea. At maturity, spring wheat was harvested with Wintersteiger classic plot combine (Wintersteiger Ag, Ried, Austria). The harvested grain was dried in the drying room for 14 days at the temperature of 95 F°; then, the by-plot grain yield was determined. The by-plot subsamples were analyzed by the Agvise Laboratories (Northwood, ND) for total N content utilizing near infrared reflectance spectroscopy (NIR) with a Perten DA 7250 NIR analyzer (Perten Instruments, Inc., Springfield, IL). The effects of N source and application rate on NDVI, N uptake, NUE, spring wheat grain yield, and grain protein content were assessed. Grain N uptake was calculated by multiplying yield by total N concentration. Nitrogen use efficiency was determined using the difference method (12) by deducting the total N uptake in wheat from the N unfertilized treatment (check plot) from total N uptake (NUp) in wheat from fertilized plots and then dividing by the rate of N fertilizer applied. The relationship between NDVI and grain yield, grain protein content, N uptake, and NUE were evaluated. The analysis of variance was conducted using the PROC GLM procedure in SAS v9.3 (SAS Institute, Inc., Cary, NC). Mean separation was performed using the Orthogonal Contrasts method at a significance level of 0.05.

RESULTS AND DISCUSSION

This study has enabled us to evaluate the N source effect on GY and GP in a wide range of growing environments. In all Tables, means within each effect group in the same column followed by the same letter are not significantly different ($p<0.05$). Spring wheat GY has varied from 265 to 815 lb/a and GP content ranged 9.1 to 17.3% among the site-years (Tables 1, 2, and 5). Spring wheat GY responded to N applied at the time of seeding at 7 of 8 site-years, also higher GP content was achieved with at-seeding N application (Tables 1, 2, and 5). Grain yield was increased with topdress N fertilization at 4 of 8 site-years; grain protein content was increased with topdress application of N only in 3 of 8 site-years (Tables 1, 2, and 5). No consistent trend in grain yield associated with N source was observed in this study: out of 8 site-years, urea resulted in higher yields at 3 site-years, ESN produced higher yields at 3 site-years, and the blend – at 2 site-years (with 1 site year having no data available for the urea/ESN blend) (Tables 1, 2 and 5). These results are in agreement with Weber and Mengel (2009) and Randal and Vetsch (2009), who observed that ESN and urea/ESN blend have outperformed urea in some years but resulted in lower crop grain yields in other years. No significant differences in grain protein content associated with N source were observed at most site-years, ESN and urea/ESN blend resulted in higher grain protein compared to urea alone at 3 of 8 site-years (Tables 1, 2, and 5). Nitrogen uptake was similar for all N sources, except for 1 site-year where slight increase in N uptake was observed with urea/ESN blend application and for 1 site-year where the blend resulted in significantly greater N uptake (Tables 3, 4, and 5). It is possible, that similar grain yield results achieved with urea, ESN, and urea/ESN blend, were obtained because similar N losses (predominantly due to ammonia volatilization) have occurred from urea and ESN. As the soil temperatures increased, the rate of urea hydrolysis from the urea treatments increased. At the same time, the dissolution of urea and its release from the ESN capsules has also increased with higher soil temperatures. This is where the controlled release vs delayed release discussion comes in – as an example, with an average soil temperatures in Montana being approximately 68°F for June and July (USDA-NRCS, 2014), it is expected that most of the urea has been released into the soil. In reality, we can expect comparable losses of N to occur from both urea and ESN treatments via ammonia volatilization. Thus, similar N amounts were available to wheat crop from all N sources applied. Nitrogen uptake increased with increase in preplant N rates at 7 of 8 site-years; topdress N application increased N uptake in 5 of 8 site-years (Tables 3, 4, and 5). There were no significant differences in NUE associated with N source at any of site-years, except 1, where urea resulted in higher NUE compared to ESN and urea/ESN blend (Tables 3, 4, and 5).

SUMMARY

The manufacturer's general recommendation for utilization of ESN for spring wheat in Great Plains region is application of N as 100% ESN in the fall prior to seeding wheat the next spring. Another commonly recommended application scenario is a spring application as a blend (40-75% ESN + 25-60% urea). Results showed that ESN and urea/ESN blend performed as well, but not better than urea alone. With ESN costing consistently more than urea per unit of N, we concluded that the investment in ESN product is not justified for spring wheat production.

Table 1. Effect of preplant N source, preplant N rate and topdress N rate on spring wheat grain yield and protein content, Kalispell, Corvallis, and Conrad, 2011.

Growing Season 2011						
Effects	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %
	Kalispell		Corvallis		Conrad	
Preplant N Source						
Urea	55	12.6	47	14.8	37	9.2
ESN	58	12.4	40	14.9	38	9.5
Blend	60	12.4	41	14.9	-	-
F test	*	ns	**	ns	ns	*
Preplant N rate						
0	43	11.2	39	13.9	37	9.1
low	63	11.7	41	14.4	38	9.1
med	63	13.1	44	15.6	43	9.3
high	61	13.8	45	15.6	47	9.9
F test	**	**	*	**	**	**
Topdress N rate						
0	55	12.1	40	14.4	37	9.4
40	60	12.9	45	15.3	38	9.5
F test	**	**	**	**	ns	ns

Table 2. Effect of preplant N source, preplant N rate and topdress N rate on spring wheat grain yield and protein content, Kalispell, Corvallis, and Conrad, 2012.

Growing Season 2012						
Effects	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %
	Kalispell		Corvallis		Conrad	
Preplant N Source						
Urea	67	13.8	69	13.4	76	12.9
ESN	64	14.2	72	12.9	82	12.0
Blend	65	14.4	69	12.7	81	12.5
F test	ns	**	**	ns	**	ns
Preplant N rate						
0	57	12.8	57	13.1	60	9.6
low	65	13.9	64	12.7	77	11.1
med	65	13.9	75	13.4	81	12.7
high	65	14.6	69	13.0	83	13.6
F test	ns	***	**	ns	***	***
Topdress N rate						
0	65	14.4	67	13.0	80	12.1
40	66	13.9	74	13.0	81	12.9
F test	ns	ns	**	ns	ns	**

Table 3. Effect of preplant N source, preplant N rate and topdress N rate on spring wheat N uptake and NUE, NWARC, WARC, and WTARC, 2011.

Growing Season 2011						
Effects	N Uptake, lb/a	NUE, %	N Uptake, lb/a	NUE, %	N Uptake, lb/a	NUE, %
	Kalispell		Corvallis		Conrad	
Preplant N Source						
Urea	89	18.9	86	12.8	46	15.6
ESN	93	19.3	70	4.8	49	16.9
Blend	96	22.2	73	6.1	49	19.6
F test	***	ns	ns	***	ns	ns
Preplant N rate						
0	48	n/a	58	n/a	40	n/a
low	86	27.8	69	8.6	39	0.4
med	95	18.9	79	6.7	48	17.2
high	97	13.6	82	6.5	56	34.5
F test	***	***	***	ns	***	***
Topdress N rate						
0	88	19.7	71	6.3	45	11.8
40	98	20.5	82	9.5	51	22.9
F test	***	ns	**	*	ns	**

Table 4. Effect of preplant N source, preplant N rate and topdress N rate on spring wheat N uptake and NUE, NWARC, WARC, and WTARC, 2012.

Growing Season 2012						
Effects	N Uptake, lb/a	NUE, %	N Uptake, lb/a	NUE, %	N Uptake, lb/a	NUE, %
	Kalispell		Corvallis		Conrad	
Preplant N Source						
Urea	95	9.6	95	8.7	105	40.2
ESN	94	9.6	96	8.9	102	36.8
Blend	96	12.0	91	6.6	104	39.5
F test	ns	ns	ns	ns	ns	ns
Preplant N rate						
0	76	n/a	77	n/a	77	n/a
low	93	15.6	84	6.4	88	41.5
med	93	8.2	104	12.4	106	39.8
high	98	7.3	94	5.4	117	34.0
F test	***	***	**	ns	***	**
Topdress N rate						
0	96	12.4	89	6.4	100	42.7
40	94	8.4	99	9.8	107	35.0
F test	ns	*	**	ns	**	**

Table 5. Effect of preplant N source, preplant N rate and topdress N rate on spring wheat grain yield and protein content, N uptake and NUE Corvallis and Conrad, 2013.

Effects	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %	N Uptake, lb/a	NUE, %	N Uptake, lb/a	NUE, %
	Corvallis		Conrad		Corvallis		Conrad	
Preplant N Source								
Urea	39	16.7	67	13.8	65	20.2	95	25.0
ESN	37	16.8	66	14.1	64	19.0	96	25.5
Blend	32	16.8	70	13.6	60	16.4	98	27.0
F test	**	*	**	*	ns	ns	***	ns
Preplant N rate								
0	27	14.7	55	11.0	41	n/a	61	n/a
low	38	16.4	69	13.0	64	19.4	93	23.2
med	38	16.6	68	14.1	69	23.0	99	27.7
high	32	17.3	66	14.4	56	13.2	97	26.7
F test	**	***	***	***	ns	ns	***	ns
Topdress N rate								
0	35	16.9	68	13.6	63	18.3	95	25.1
40	37	16.6	67	14.1	63	18.7	97	26.5
F test	**	ns	ns	**	ns	ns	*	ns

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