Nitrogen Management Strategies for Winter Wheat Yield and Grain Protein Improvement in Southeastern Colorado.

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Introduction

There is an increasing demand for high quality wheat as the baking industry requires adequate protein levels for their products. Frequently, wheat with higher grain protein is marketed at a premium and price deductions are incurred for low protein wheat. Protein premiums and penalties have increased the interest among wheat growers in producing high quality wheat that meets the market standard and increases profits.

The most important management practice affecting grain protein content and yield is the rate and timing of nitrogen (N) fertilizer application. Dryland winter wheat growers are often reluctant to invest in fertilizer before they assess the condition of the crop in the spring. Since efficient use of available N from soil and fertilizer is critical for economic wheat production, producers have two options for applying N fertilizer: (i) as a single application where all N is applied pre-plant or at planting or (ii) as a split application where a small amount of N is applied pre-plant or at planting, followed by a late-winter or early spring topdressing.

Since the availability of N mid-season is environmentally dependent, the common practice of soil testing before planting is not suitable for detecting N deficiencies late season. Field analysis procedures (tiller counts) and chemical analysis of soil and plant tissue are effective for monitoring N status during the growing season. The main problem with these methods is the time required for sampling, analysis, and recommendations of rates to meet the demands of the growing crop. Delaying N applications may reduce yield potential and protein responses. Using the sensor-based technology (GreenSeeker and Chlorophyll) producers have a better chance of maximizing their inputs rather than misjudging or guessing the correct fertilizer rate before the season even begins.

With the increasing adoption of higher-yielding varieties in Colorado, it is important to revise current N management practices and recommended rates to meet yield and protein goals. This research enables dryland wheat growers to produce high-yielding wheat with acceptable protein content and optimum marketability.

Objectives

1. Develop N management strategies for optimum yield and protein content for dryland wheat production.
2. Compare yield and grain protein responses of red and white wheat varieties to contrasting N rates and application timing.
3. Determine if flag leaf N content, chlorophyll readings and GreenSeeker sensor measurements are reliable predictors of yield and protein content in response to N rates and application timing.
4. Evaluate the agronomic and economic performance of predicted N rates using the chlorophyll meter and GreenSeeker relative to N rates chosen by wheat producers.
5. Develop a comprehensive dryland winter wheat best N management guide for producers, extension agents and agricultural consultants.

Summary 2014 - 2015

Experimental plots were established in three locations in eastern Colorado in late September and early October 2014. Two sites were located on private farms in Brandon and Bristol. The third site was located at the USDA-ARS Central Great Plains Research Station in Akron. The sites were managed as a

partnership between Colorado State University Extension, cooperating producers and research scientists from The USDA-ARS.

General Growing Conditions

The fall of 2014 was characterized by wet and warm conditions. In all three locations, precipitation was above the 30-year norm. Precipitation and warm temperatures were beneficial for wheat germination and emergence. October was unusually warm with day temperatures in the upper 70's. November started with frigid weather conditions, which created concerns about winterkill. During December and most of the winter months, winterkill was a still a concern, particularly in Bristol where advanced growth of the crop was observed. However, the weather patterns with cold temperatures also brought snow that helped insulate and protect the wheat crop from excessive winterkill.

Wheat began breaking dormancy in early March. As warm temperatures and dry conditions prevailed in March, moisture stress was observed. During April, dry conditions persisted and dry pockets in some plots became more pronounced, particularly in Brandon. Due to the dry conditions, an outbreak of army cutworms and pale western cutworms was observed. An insecticide (Warrior) was applied to successfully control the cutworms. Severity of the insect pressure was minor.

May was characterized by widespread precipitation events. May 2015 is considered to be the wettest month on record for eastern Colorado. Accumulated precipitation was 5.21 inches at Akron, 7.4 inches at Brandon and 6.47 inches at Bristol. Also, May was marked by cooler temperatures, which favored the development of stripe rust. Damage to wheat from stripe rust ranged from very mild to severe, depending on wheat variety.

June started with strong thunderstorms and localized hail associated with several storm systems. The abundance of heat and moisture generally improved wheat conditions in Brandon. However, persisting stripe rust and other fungal diseases on wheat were still observed where surplus soil moisture and cool temperatures occurred in greater frequency.

Akron Site

Wheat was planted at a seeding rate of 62 lb/acre. Treatments included a combination of six N rates (0, 25, 50, 75, 100 and 125 lb/ac), two application timings (fall and spring) and two winter wheat varieties (Byrd and Antero). The complete list and arrangement of treatments is included in Figure 1. Treatments were replicated 3 times in a split-split-split plot design with timing of application as the main plot, N rate as the sub-plot and variety as sub-sub plot. Plot size was 30 ft. x 10 ft. Urea ammonium nitrate was used as the source of N in the fall (October 17) and spring (March 28, Feekes 5, jointing) applications. At planting, phosphorus and potassium fertilizers were applied based on soil test results using triple super phosphate and potassium chloride respectively.

Chlorophyll meter (SPAD) readings were taken from 5 randomly selected fully-extended leaves in each plot on May 1. Sensor readings (NDVI) were also taken with a GreenSeeker hand-held from 5 half meter areas at the same time.

At maturity, a net plot of 20 ft x 5 ft. was harvested on July 27. Grain yield (bu/ac) was calculated after adjusting moisture content to 12%. Grain sub-samples (15 g) were taken to determine grain protein content using near infrared spectroscopy (Foss NIR System Model #6500, Silver Spring, MD). Also a sub-sample of 100 grains per treatment was selected for single kernel attributes (hardness, kernel weight, kernel diameter) determination using a Perten SKCS 4100.

Brandon and Bristol On-Farm Sites

Two wheat varieties (Antero and Byrd) were planted at a seeding rate of 50lb/acre. Nitrogen treatments included a combination of 4 N rates (0, 30, 60, and 120 lb/ac) and two application strategies, (1) full rate at planting and (2) split rate. The split application consisted of 1/3 of the full N rate (0, 30, 60, and 120 lb/ac) applied in the fall (October 17 at Brandon and October 7 at Bristol) and the remaining 2/3 in the spring (April 24 at Brandon and April 26 at Bristol, Feekes 10/boot). The complete arrangement and list of treatments is included in Figure 2 and 3. Treatments were replicated 3 times in a split-split-split plot design with variety as the main plot, application strategies as sub-plot and N rate as the sub-sub plot. The plot size was 800 ft. x 72 ft. Urea ammonium nitrate was used as the source of N for both applications. At planting, phosphorus, potassium and other nutrients were applied based on soil test results.

Chlorophyll meter (SPAD) readings and sensor readings (NDVI) were taken as previously described for the Akron site.

At maturity, a net plot of 600 ft. x 36 ft. was harvested (July 10 at Bristol and July 24 at Brandon). Grain yield (bu/ac) was calculated after adjusting moisture content to 12%. Grain sub-samples were taken to determine grain protein and kernel attributes as described for the Akron samples.

Preliminary Results

Akron

The growing conditions were characterized by a significantly higher precipitation than the 107-year average precipitation for the same period. Total precipitation was recorded at 14.12 in from October 1 2014 to July 31, 2015. About 84% (11.84 in) of the total precipitation occurred from April to July 2015 (Figure 4a).

Grain yield of Antero and Byrd significantly responded to both fall and spring applied nitrogen. Spring applied N resulted in greater grain yield than fall applied N. Spring applied N was more efficiently used by both wheat varieties for grain production. The analysis of variance also showed a significant effect of wheat variety. Byrd yielded significantly less than Antero regardless of timing of application and N rate. The lower yield of Byrd could be attributed to its high susceptibility to stripe rust. On average, Antero had a 22.9 bu/ac advantage over Byrd. Antero yielded an average of 78.3 bu/ac, while Byrd yielded only 55.4 bu/ac (Table 1).

Brandon

Total precipitation for the period of October 2014 to July 2015 was 21.02 in. This accumulated precipitation is significantly higher than the 28-year average precipitation (12.89 in) for the same period. Most of this precipitation (15.15 in or 72.1%) occurred from April to July (Figure 4b).

Grain yield did not significantly respond to both full and split applied N. Also, yield was not responsive to N rates. This result could be attributed to a combination of high residual soil NO_3 (43.6 ppm to 24 in depth), early season drought stress, and insect damage. The analysis of variance also showed a significant wheat variety effect. Regardless of N rate and application strategy, Antero had a significant higher grain yield than Byrd. Yield advantage of Antero was estimate at 23.2 bu/ac. Byrd is highly susceptible to stripe rust. The development of the disease at the grain fill period (Feekes 11) could have significantly affected yield.

Bristol

Accumulated precipitation was significantly higher than the 30-year average. Accumulated precipitation for the period of October 2014 to July 2015 was recorded at 14.5 inches. About 71% (11.18 inches) of total precipitation occurred between April and July 2015 (Fig. 4c).

At present grain yield data is being processed. Data was collected using the John Deer's Green Start 2 yield monitor and Apex 3.4.2 software.

Greenseeker Data

Currently, the Greenseeker readings from the three sites are being used to evaluate the performance of existing algorithms (developed by Kansas State University and Oklahoma State University) in eastern Colorado. Also, the algorithms are used to evaluate their ability to predict the economic optimum N rate (EONR) for each field. Preliminary results indicate that the algorithms developed by both universities can be used in eastern Colorado once input parameters are calibrated for location growing conditions (soil moisture and growing degree day). The calibration also includes the development of an exponential model to predict yield potential using the NDVI and the adjustment of the Response Index (RI) used to calculate the maximum yield that can be achieved.

Fall and Current Activities

In late September 2015, two sites were planted (Brandon and Bristol) to Antero and Byrd following the same N rates and timing of applications treatments as on 2014 and 2015. The N fertilizer treatments were applied in mid-November. All sites had excellent stands and excellent soil moisture. Spring N applications and first field measurements are scheduled for early March, depending on wheat condition (breaking of dormancy).

Currently, we are processing grain samples for protein content. Also samples are undergoing further analyses to determine single kernel attributes such hardness, kernel weight and diameter.

Figure 1. Field arrangement of treatments at Akron, CO

Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Application	Preplant application in fall												Application in spring when dormancy breaks in March												
Rate	0		25		50		75		100		125		0		25		50		75		100		125		
Variety	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Rep I

30 ft.

10 ft.

15 ft.

Plot	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	
Application	Application in spring when dormancy breaks in March												Preplant application in fall												
Rate	125		50		0		25		100		75		100		25		125		75		0		50		
Variety	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Rep II

Plot	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	
Application	Preplant application in fall												Application in spring when dormancy breaks in March												
Rate	50		125		75		0		25		100		50		75		100		25		125		0		
Variety	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Antero	Byrd	Rep III

240 ft. wide

Figure 2. Field arrangement of treatments at Brandon, CO

Byrd								Antero								
Full (Fall)			Split (Fall + Spring)						Full (Fall)		Split (Fall + Spring)					
120*	60	30	40 + 80	20 + 40	10 + 20	0	0	120	60	30	40 + 80	20 + 40	10 + 20	Rep I
120	60	30	40 + 80	20 + 40	10 + 20	0	0	120	60	30	40 + 80	20 + 40	10 + 20	Rep II
120	60	30	40 + 80	20 + 40	10 + 20	0	0	120	60	30	40 + 80	20 + 40	10 + 20	Rep III

* N Rate lb/ac)

Figure 3. Field arrangement of treatments at Bristol, CO

Antero							Byrd							
Full (Fall)			Split (Fall + Spring)					Full (Fall)			Split (Fall + Spring)			
120*	60	30	40 + 80	20 + 40	10 + 20	0	0	10 + 20	20 + 40	40 + 80	30	60	120	Rep I
120	60	30	40 + 80	20 + 40	10 + 20	0	0	10 + 20	20 + 40	40 + 80	30	60	120	Rep II
120	60	30	40 + 80	20 + 40	10 + 20	0	0	10 + 20	20 + 40	40 + 80	30	60	120	Rep III

* N Rate lb/ac)

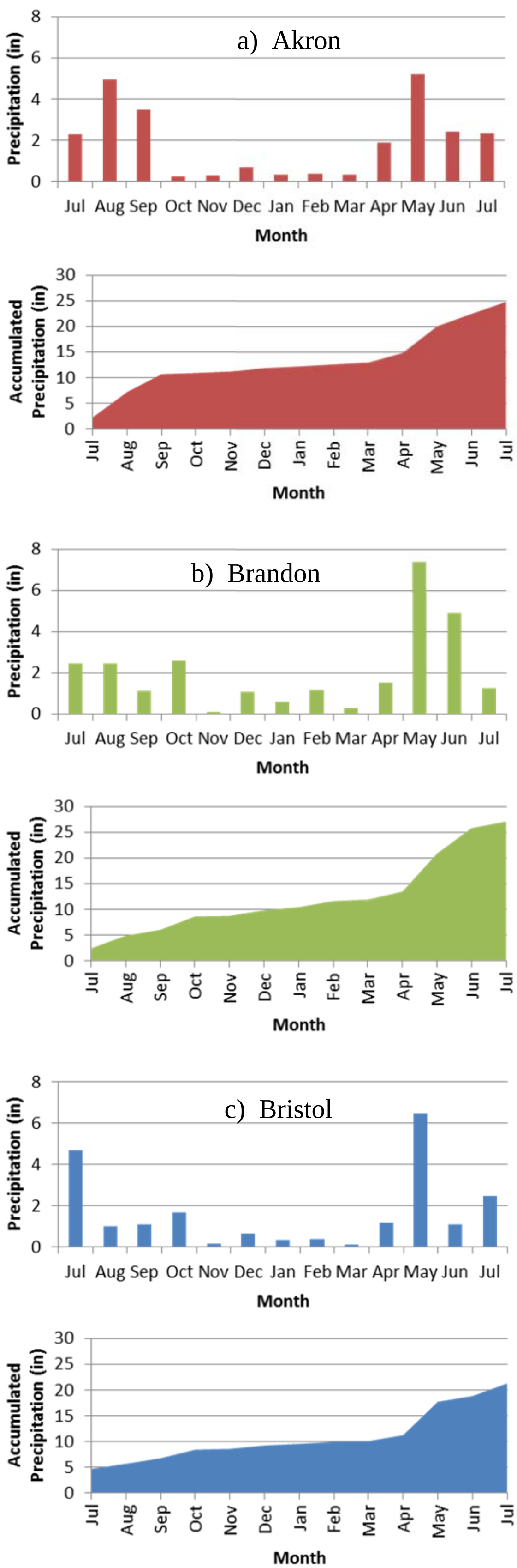

Figure 4. Monthly and accumulated precipitation from July 1 2014 to July 31 2015 at a) Akron, b) Brandon and c) Bristol.

Table 1. Grain Yield response to N rates and timing of application at Akron, CO.

N Rate (lb/ac)	Antero		Byrd	
	Fall	Spring	Fall	Spring
	bu/ac)			
0	58.3	58.3	43.5	43.5
25	66.9	79.6	46.2	57.9
50	69.8	69.4	46.1	63.4
75	75.4	81.2	47.5	70.8
100	91.9	95.1	57.9	66.0
125	91.6	102.5	58.5	63.8

Table 2. Grain Yield response to N rates and timing of application at Brandon, CO.

N Rate (lb/ac)	Antero		Byrd	
	Full	Split	Full	Split
	bu/ac			
0	55.3	53.5	31.5	31.5
30	56.2	55.9	31.6	32.4
60	56.9	56.9	34.1	32.4
120	60.9	59.7	40.0	33.7