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 2013 – 2014

General Growing Conditions in Eastern Colorado

Initially, this research project was set up to start in the fall of 2012. However, the project was delayed to the fall of 2013 due to the drought conditions and high temperatures experienced before planting the 2012-2013 wheat crop.

As the environmental conditions and soil moisture improved during the summer 2013 (Figure 2 and 4), experimental plots were established in three locations in eastern Colorado in late September and early October 2013. Two sites were located on private farms in Lamar and Brandon, CO. The third site was located at the USDA-ARS Central Great Plains Research Station in Akron, CO. The sites were managed as a partnership between Colorado State University Extension, cooperating producers and research scientists from The USDA-ARS.

During the winter months, temperatures were colder than normal. The majority of eastern Colorado was still under severe and extreme drought conditions. Lack of moisture combined with high wind conditions (gusts reaching 60 miles-per-hour) produced dust storms and blow-out of the wheat fields, especially in Lamar.

As wheat fields started to green up in the spring, there were concerns regarding possible winterkill due to extremely cold temperatures. Cool temperatures experienced in March and April delayed crop development to about one to two weeks behind normal. Record low temperatures with little or no snow cover caused some damage to the wheat crop in mid-April. Fortunately, the wheat was in the tillering growth stage and only minor freeze damage with yellowing of leaf tips was found upon inspection of the fields. In mid-May, temperatures were in the mid- to low-20s, which was low enough to damage wheat in more advanced growth stages. At this time, fields were in the jointing and pre-boot stage. Soil moisture conditions were still short. In mid- to late-May, rain and the return of more seasonably warm weather helped wheat survive, with the exception of the field in Lamar.

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 at Feekes 5. Sensor readings (NDVI) were taken with a GreenSeeker hand-held from 5-half meter areas in each plot at the same physiological growth stage. Fifty fully extended flag leaves were randomly collected from each plot for N analysis. Also, two one-meter rows were randomly cut from each plot to determine biomass (lb/ac) and N uptake.

At maturity, a net plot of 20 ft x 7.5 ft. was harvested (July 23, 2014). 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.

Lamar and Brandon On-Farm Sites

Wheat was planted at a seeding rate of 45lb/acre. Nitrogen treatments included a combination of 4 N rates (0, 30, 60, and 120 lb/ac), two application timings (full and split) and two winter wheat varieties (Byrd and Antero). The split application consisted of 1/3 of the full N rate (0, 30, 60, and 120 lb/ac) applied in the fall (November 18) and the remaining 2/3 in the spring (May 16, Feekes 10/boot). The complete arrangement and list of treatments is included in Figure 2. Treatments were replicated 3 times in a split-split-split plot design with variety as the main plot, timing of application 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 and potassium fertilizers were applied based on soil test results using triple super phosphate and potassium chloride, respectively.

The Lamar site was abandoned due to lack of soil moisture and high wind conditions (gusts reaching 60 miles-per-hour) that produced dust storms and blow-out of the wheat field from late December to early April. The second N application was not applied and no measurements were taken.

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

At maturity, a net plot of 600 ft. x 36 ft. was harvested (July 19, 2014). 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 14.51 in from October 1 2013 to July 31, 2014. About 75% (10. 84 in) of the total precipitation occurred from April to July 2014 (Figure 3).

Nitrogen rates and timing of application did not have significant effects on wheat yield, biomass production and chlorophyll and NDVI readings (Tables 1a, b, c, and e)

The analysis of variance showed a significant effect of variety. Byrd yielded significantly higher than Antero regardless of timing of application and N rate. On average, Byrd had an 8.0 bu/ac advantage over Antero. Byrd yielded an average of 69.5 bu/ac, while Antero yielded only 61.4 bu/ac (Table 1a). The lack of response to N rate and timing of application could be attributed to the high soil residual NO_3-N at planting (152 lb/ac to 24 in depth). The excess N in the soil resulted from a failure crop due to the drought in 2012. In addition, some significant mineralization could have taken place during the spring and summer of 2013 as wells as during the growing season when precipitation returned to normal.

Also, the analysis of variance showed a significant N rate x timing of application interaction for grain protein content. The significant interaction means that the effect of N rate was different depending on the timing of application. When N fertilizer was applied in the spring, the grain protein content was significantly higher when N rates were higher than 50 lb N/ac. In contrast, when N fertilizer was applied in the fall, the grain protein content did not significantly respond to increasing N rates (Table 2).

Brandon

Total precipitation for the period of October 2013 to July 2014 was 8.51 in. This accumulated precipitation is significantly lower than the 27-year average precipitation (12.70 in) for the same period. Most of this precipitation (6.53 in) occurred from April to July (Figure 4).

Means for yield, biomass, chlorophyll and NDVI readings and grain protein content are shown in Table 3a, b, c, d and e, respectively. The analysis of variance showed a significant three way interaction (N rates x varieties x timing of application) for yield, biomass and protein content. There was no significant effect of N rate, timing of application and variety on Chlorophyll and NDVI readings.

Regardless of the N rate and timing of application, Antero had a significant higher yield and biomass production than Byrd. However, splitting the N fertilizer significantly decreased Antero yield and biomass much more than those of Byrd. Splitting N reduced Antero yield and biomass on an average of 7.6 bu/ac and 489.0 lb/ac, respectively. In contrast, Byrd yield and biomass production were not significantly reduced by splitting the N rate. The negative effect of splitting the N rate in two applications on Antero yield and biomass could be due to a combination of at least 3 factors: low soil N levels (6.5 lb NO_3-N /ac to 24 in depth) at planting; the second application done too late (Feekes 10/boot stage); and lack of adequate soil moisture for N uptake and utilization by Antero.

Also, there was a significant N rate x variety interaction for grain protein content. Byrd had significant higher grain protein content than Antero regardless of the N rate (Table 3e). On average, Byrd's grain protein content was 0.8 % higher than that of Antero. A 10% increase in Antero's grain protein content was observed as N rate increased from 0 lb/ac to 120 lb/ac. In contrast, an increase in N rate from 0 lb/ac to 120 lb/ac only represented a 3% increase in Byrd's grain protein content.

Based on the data from 2013-2014, soil residual NO_3-N played an important role on the response of wheat to increasing N rates. Soil test is an excellent tool to help farmers to decide the need of N fertilization.

Fall and Current Activities

In late September 2014, three sites were planted (Akron, Brandon and Bristol) to Antero and Byrd following the same N rates and timing of applications treatments as on 2013. The N fertilizer treatments were applied in late October. 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).

At present, we are processing tissue samples (whole plant and flag leaves) for total N to be able to calculate total N uptake and N use efficiency. Grain samples are also undergoing further analyses to determine single kernel attributes such hardness, kernel weight and diameter.

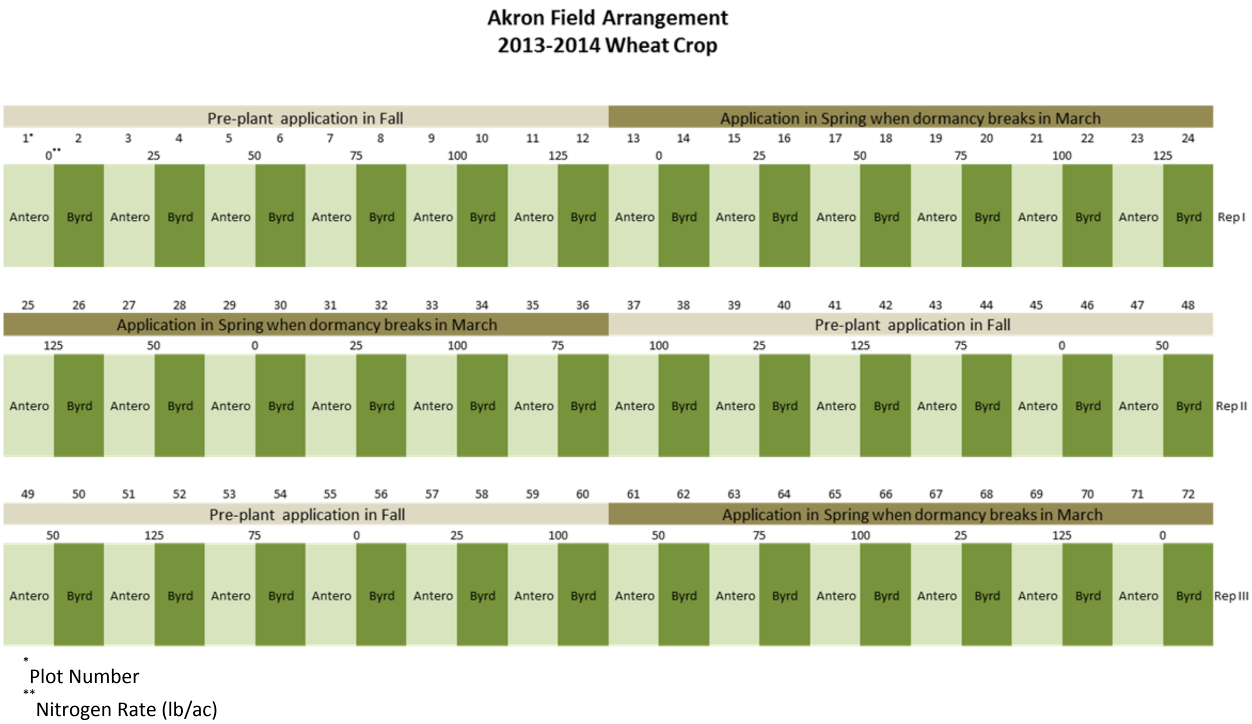

Figure 1. Field arrangement of treatments at Akron, CO

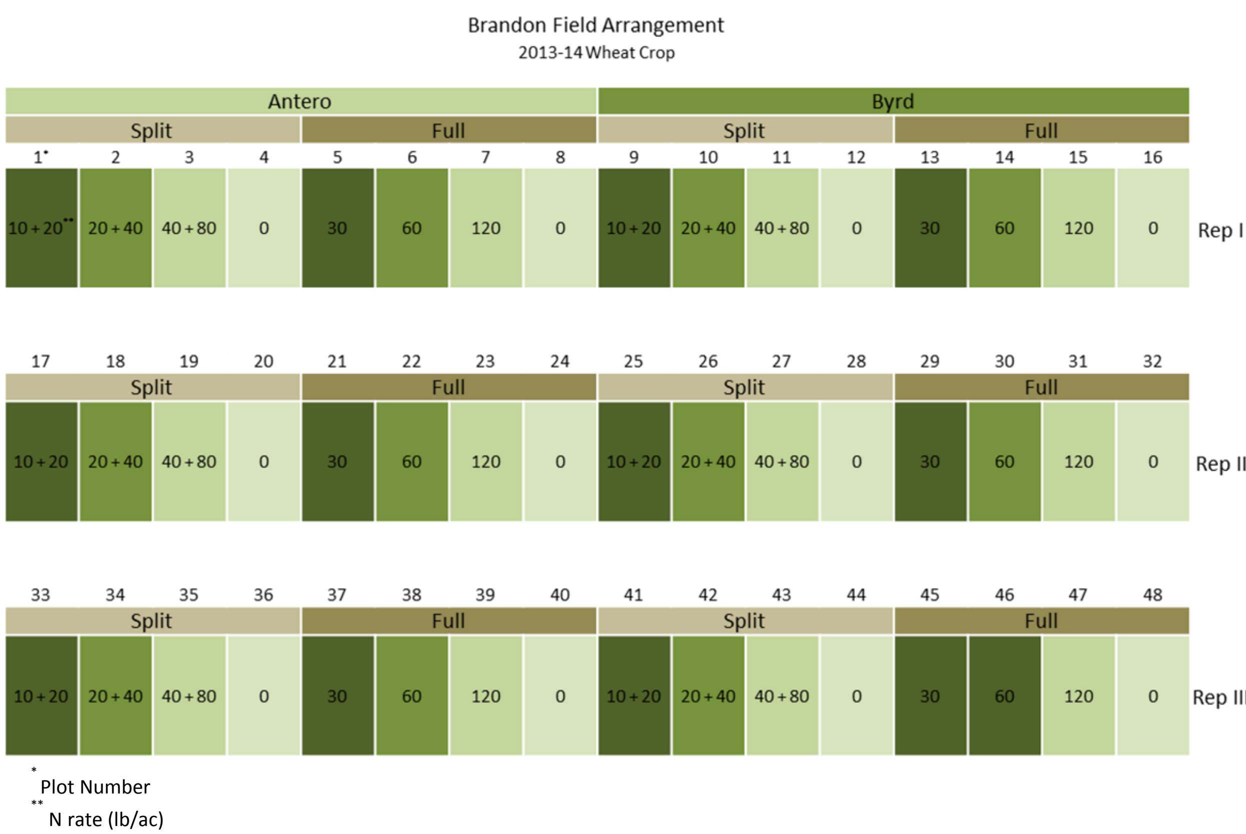

Figure 2. Field arrangement of treatments at Brandon, CO

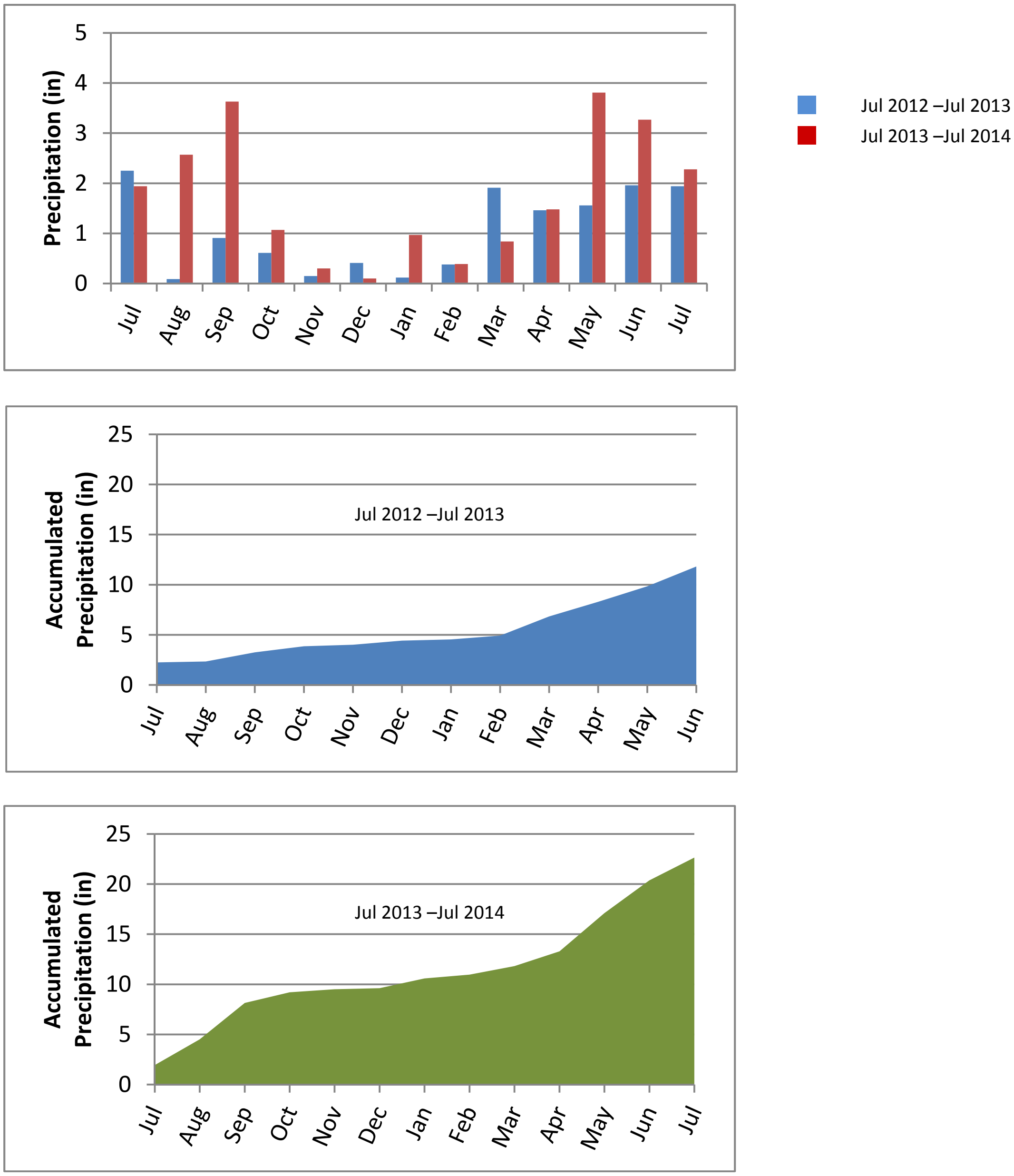

Figure 3. Monthly and total precipitation from July 2012 to July 2014 at Akron, CO

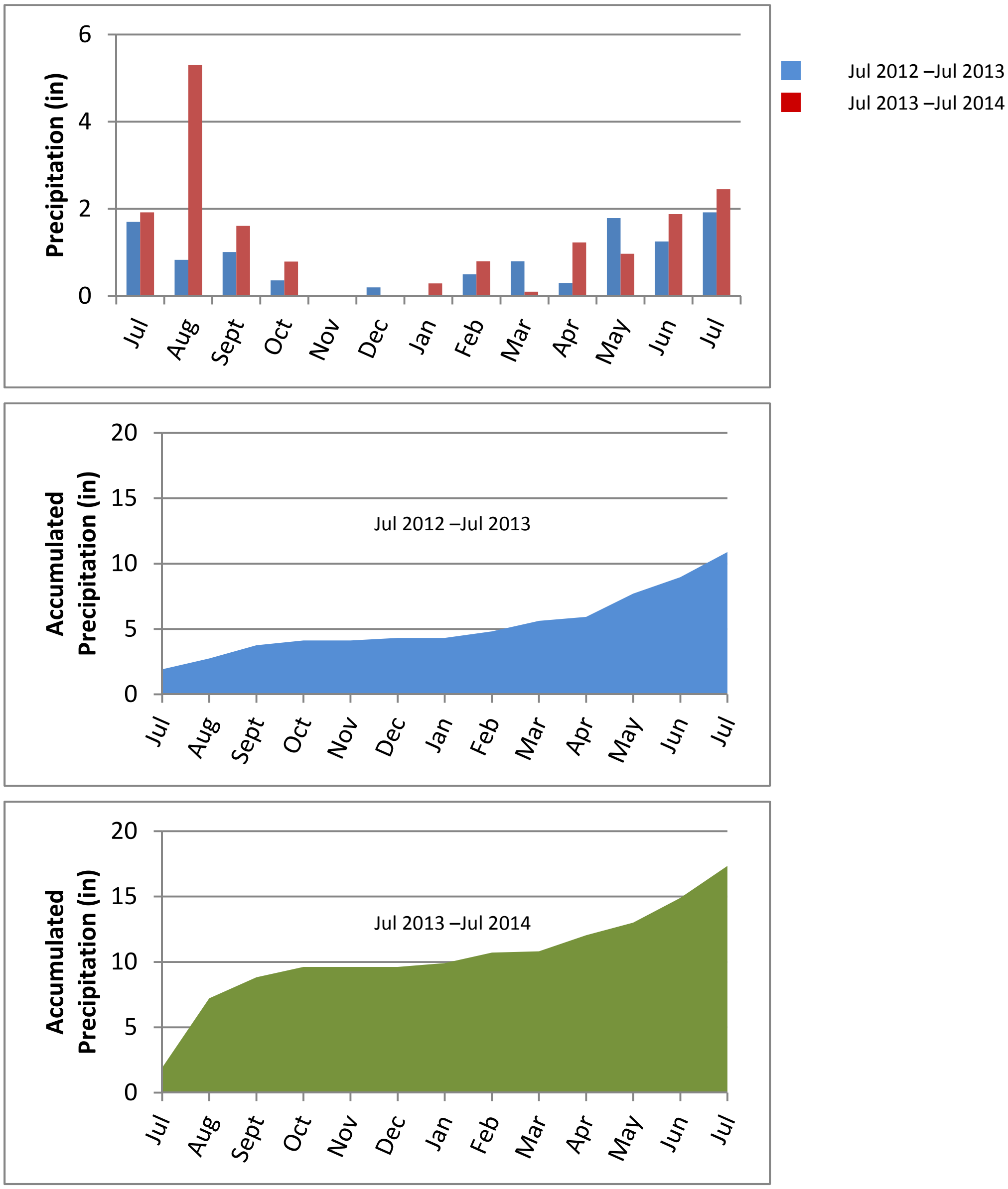

Figure 4. Monthly and total precipitation from July 2012 to July 2014 at Brandon, CO

a. Yield

N Rate (lb/ac)	Antero		Byrd	
	Fall	Spring	Fall	Spring
	Yield (bu/ac			
0	63.1	60.7	69.4	65.1
25	63.9	66.1	70.2	69.0
50	61.6	55.1	74.5	72.4
75	61.5	65.2	67.0	69.3
100	53.6	61.4	65.2	71.6
125	59.0	65.5	68.2	71.6

b. Biomass

N Rate (lb/ac)	Antero		Byrd	
	Fall	Spring	Fall	Spring
	Biomass (lb/ac)			
0	1714	1689	1842	2149
25	1663	1893	2482	1637
50	1535	2072	2252	2328
75	1689	1765	1791	1663
100	1919	1842	2021	1382
125	1740	1893	2200	1868

c. Chlorophyll

N Rate (lb/ac)	Antero		Byrd	
	Fall	Spring	Fall	Spring
	Chlorophyll Reading			
0	0.56	0.59	0.60	0.61
25	0.58	0.63	0.60	0.60
50	0.60	0.59	0.61	0.60
75	0.60	0.64	0.59	0.62
100	0.57	0.61	0.62	0.64
125	0.60	0.61	0.61	0.64

d. NDVI

N Rate (lb/ac)	Antero		Byrd	
	Fall	Spring	Fall	Spring
	NDVI Reading			
0	49.4	48.9	51.8	49.5
25	47.4	49.8	51.0	52.8
50	48.4	49.7	47.8	51.6
75	48.3	50.1	52.8	52.5
100	47.5	49.3	50.4	50.5
125	50.5	50.7	49.8	50.9

Table 1. Antero and Byrd responses to N rate and timing of application in Akron, CO

N Rate	Fall		Spring	
	Grain Protein (%)			
0	13.7	bc	13.2	c
25	13.9	ab	13.7	bc
50	13.7	bc	14.3	ab
75	14.2	ab	14.6	a
100	14.4	ab	14.6	a
125	14.1	ab	14.6	a

Table 2. Wheat grain protein content response to N rate and timing of application in Akron, CO.

a. Yield

N Rate (lb/ac)	Antero		Byrd	
	Full	Split	Full	Split
	(bu/ac)			
0	32.1 b	30.9 b	34.7 b	33.3 b
30	46.0 ab	36.2 b	35.0 b	33.5 b
60	48.8 a	38.1 ab	35.5 b	35.0 b
120	52.3 a	43.7 ab	37.9 ab	35.9 b

b. Biomass

N Rate (lb/ac)	Antero		Byrd	
	Full	Split	Full	Split
	(lb/ac)			
0	972.3 bc	690.8 c	997.9 bc	818.7 bc
30	1407.2 ab	909.3 bc	1100.2 b	997.9 bc
60	1816.6 a	1113.0 bc	1240.9 b	1330.5 ab
120	1803.8 a	1330.5 ab	1279.3 b	1381.6 a

c. Chlorophyll

N Rate (lb/ac)	Antero		Byrd	
	Full	Split	Full	Split
	Chlorophyll			
0	48.2	47.7	49.9	48.3
30	47.7	48.8	48.9	48.7
60	46.7	48.1	47.6	49.2
120	45.5	49.9	46.6	49.7

c. NDVI

N Rate (lb/ac)	Antero		Byrd	
	Full	Split	Full	Split
	NDVI			
0	0.32	0.30	0.31	0.29
30	0.44	0.32	0.29	0.29
60	0.45	0.29	0.31	0.28
120	0.41	0.31	0.32	0.32

e. Grain Protein

N Rate (lb/ac)	Antero	Byrd
	(%)	
0	11.8 d	12.9 b
30	12.4 c	13.1 ab
60	12.8 b	13.4 a
120	13.0 b	13.6 a

Table 3. Antero and Byrd responses to N rates and timing of application in Brandon, CO.