INTERIM REPORT

Effect of Nitrogen Fertilization Practices on Spring Wheat Yield and Protein Content

Project Leader
Steve Orloff
Farm Advisor/ County Director
UCCE Siskiyou County
1655 S. Main St. Yreka, CA
(530) 842-2711
sborloff@ucdavis.edu

Cooperators:
Steve Wright
Farm Advisor –Tulare/Kings Counties
UCCE Tulare County
4437 S. Laspina, Ste. B. Tulare, CA 93274-9539
559-684-3315
sdwright@ucdavis.edu

Rob Wilson
IREC Director and Farm Advisor
Tulelake, CA
(530) 667-5117
rgwilson@ucdavis.edu

Abstract/Summary of Results and Conclusions

Three nitrogen studies were conducted in Siskiyou County at the Intermountain Research and Extension Center (IREC). One study was conducted along with Michael Tarter from UC Berkeley to determine the relationship between plant tissue levels from different plant parts and grain yield and protein. The intent is to develop a method to evaluate the late-season N needs of the crop to ascertain if additional fertilizer is needed to achieve protein goals. An additional study was conducted (identical to the 2012 study) where nitrogen was applied at 150 or 250 pounds of N per acre at eight different application timings for each rate. Treatments varied in the proportion of the total N that was applied preplant, at tillering, at boot or at the flowering growth stage. The yield in 2013 was lower than 2012 likely due to a very hard spring frost. Despite the lower yield levels, the results were similar to 2012. A key finding is that yield was maximized when the majority of the N was applied at tillering (the beginning of the phase of maximum N uptake for wheat). This treatment yielded higher than when most of the nitrogen was applied preplant or when the nitrogen was evenly split between preplant and boot stage. Unlike the results in 2012, a preplant application alone yielded well for the 250 pound rate. This was likely due to the lower yield potential in 2013. With 250 pounds of N applied preplant, enough N remained in the soil for the critical tillering time with the lower yield potential in 2013. Shifting away from high preplant applications and applying more of the N at tillering and later improved protein content in 2012. However, grain protein content has not yet been determined for the 2013 samples due to the grain harvest date in the Intermountain region. If the protein results are similar to 2013 this will further demonstrate the importance of N and tillering and the need for later N applications to achieve protein goals. The fertilizer source study showed an increase in yield with each increase in total N application. However, when applied at the same rate the different nitrogen sources all performed similarly, suggesting that it may not be possible to lower N rates with different fertilizer sources. However, as noted above, we do not have grain protein results yet so it may be that while slow release N sources do not improve yield, they could make more N available later in the season to improve protein levels.

Introduction and Objectives

Yield and protein content are the key issues affecting profitability for wheat producers. With a discount in Pacific Northwest markets for wheat with less than 14% protein, there is significant incentive for producers in the northern California to obtain high protein. This is not easy to achieve. The primary factors that influence protein content are cultivar selection, yield level and nitrogen fertility management. Yield and protein content are often inversely related, making it very difficult to achieve both high yield and high protein. This can only be accomplished with optimum nitrogen fertility management.

It is common for intermountain growers to apply all the nitrogen preplant. However, research we conducted in 2011 and 2012 showed that a preplant N application alone at the rates tested was insufficient, and a split application of N was needed to achieve acceptable yield and meet protein goals. In fact, acceptable protein levels were never achieved without applying a split application of nitrogen. Late-season N applications, between boot and flowering, were important to increase grain protein but had little effect on yield. While late-season N applications to spring wheat have not been common in the Intermountain Region, they are becoming more common as a result of our initial research.

Nitrogen fertilizer is an expensive input, particularly at the rates required to produce hard red wheat. Research was needed to determine the most efficient times to apply nitrogen to achieve the greatest benefit. Specifically, what proportion of the total nitrogen should be applied at each growth stage? Can nitrogen-use-efficiency be improved by applying N at timings that more closely match periods of peak crop uptake? In addition, a technique is needed to accurately assess the nitrogen status of the plant at heading to determine whether a late-season application of nitrogen is needed to make protein goals. Lastly, there has been considerable interest in slow release forms of nitrogen to minimize losses and improve nitrogen use efficiency.

The objectives of this research were to:

1. Determine the relative proportion of nitrogen that should be applied at different wheat growth stages to maximize yield and protein content and improve nitrogen use efficiency.
2. Through a complex statistical procedure determine the relationship between plant tissue N levels (stem nitrate level, total N in the flag leaf and total N in the penultimate leaf) and wheat yield and protein content to develop an improved technique to evaluate the need for a late-season application of N fertilizer.
3. Compare different nitrogen sources and timings to improve nitrogen use efficiency and to determine whether N rates or the number of applications could be reduced when the N is supplied in a slow-release form.

Materials and Methods (describe the experimental design, data collected, and methods used for data analysis):

There were three components to this research. The first study is in cooperation with UC Berkeley Statistics Professor Michael Tarter to determine the relationship between plant tissue test levels and grain yield and protein to develop a diagnostic method to assess N fertilizer needs at the time of heading to achieve protein goals. The second study was to determine the relative proportion of N that should be applied at each growth stage to maximize yield and protein. The third study was to evaluate different fertilizer sources and rates to see if the N fertilizer rate could be reduced when a slow release fertilizer or bio-organic microbial enhancing product was applied. All three trials were conducted in the Klamath Basin at the Intermountain Research and Extension Center (IREC) in Tulelake.

<u>Statistical Analysis of Plant Tissue Values and Grain Yield and Protein.</u> A study was conducted in cooperation with UC Berkeley Statistics professor Michael Tarter where we evaluated the effect of 80 different fertilizer rates ranging from 0 to 400 pounds per acre with the actual interval between rates being less around the 225 to 275 lbs/acre rate range (the rate range considered to be optimal for maximum yield and protein. We collected tissue samples to assess the levels of stem nitrate, total flag leaf N and total N in the penultimate leaf at 50 percent heading. The intent is to develop a diagnostic tool to enable growers to assess the nitrogen status of the crop late season to know whether or not a late-season application of N is needed and how much is needed to achieve protein goals. This part of the project is still in progress pending laboratory results and the complex statistical procedure to be performed by Dr. Tarter.

<u>Nitrogen Fertilizer Proportion Study</u>. This trial is a repeat of the trial that was conducted in 2012 with encouraging results. Treatments in this study included an untreated control with no fertilizer, a series of treatments with a total of 150 pounds of N per acre, a series of treatments with a total of 250 pounds of N per acre, and a single treatment with 350 pounds of N per acre. The 150 pound per acre rate represents a typical application rate for the Intermountain region and the 250 pound per acre rate represents a rate that is more likely needed to achieve maximum yield and protein based on our previous research in 2011 and 2012. The 350 pound per acre rate was included to be certain that we bracketed the rates needed for maximum yield at the desired protein content. Different proportions of the total amount of nitrogen fertilizer were applied at each of four application timings (preplant, tillering, boot and flowering) as shown in Table 1. The fertilizer treatments were applied to a single variety, Yecora Rojo, which is still the most popular variety in the area. The N was applied as urea at all treatment timings.

Table 1. Differential nitrogen treatment timings evaluated for 150 and 250 pound per acre rates of nitrogen applied to Yecora Rojo spring wheat at IREC, 2013.

Treat	PrePlant	Tillering	Boot	Flowering	Total
#			lbs. N/acre		
1	0	0	0	0	0
2	150	0	0	0	150
3	120	0	0	30	150
4	90	60	0	0	150
5	90	0	60	0	150
6	60	60	0	30	150
7	60	0	60	30	150
8	0	60	60	30	150
9	0	120	0	30	150
10	250	0	0	0	250
11	200	0	0	50	250
12	150	100	0	0	250
13	150	0	100	0	250
14	100	100	0	50	250
15	100	0	100	50	250
16	0	100	100	50	250
17	0	200	0	50	250
18	150	150	0	50	350

Nitrogen Fertilizer Source Study

Four different N fertilizer sources were evaluated including urea (the standard), ESN (a polymer coated urea), Agrotain (nitrogen stabilizer with a urease inhibitor) and NutriSmart (bio-organic microbial enhancing product). Each fertilizer was applied at three rates. All of the Nutrismart was applied preplant at 45, 60 or 90 lbs. per acre, as suggested by the manufacturer. Urea was applied 50 pounds per acre at the tillering, boot and flowering stages. Urea, ESN and Agrotain coated urea were all applied preplant at 50, 100 or 170 pounds of N per acre with an additional 50 pounds of urea applied at the boot stage. The plot were harvested for grain yield in September and subsamples collected for bushel weight and protein content (protein content has not yet been determined.

Budget (describe how the Commission funding was spent)

The funds were spent on the IREC recharge rate for hourly labor ($12.64 per hour) and for materials (primarily urea). This includes labor used for field preparation, irrigation, harvest and general plot maintenance as well as data collection. This project was labor intensive due to the number or fertilizer rates and timings, all of which were hand applied. Funds were also spent for two Student Assistants who helped with field labor. A more detailed accounting of how funds were spent can be prepared if desired.

Results (present the results of the experiments conducted for each project objective; include figures and tables if needed for illustration purposes and clarity):

Nitrogen Fertilizer Proportion Study. The untreated control plots yielded significantly less than the fertilized treatments in the nitrogen timing study (Table 2). The control plots averaged 1.98 tons per acre, while the highest yielding fertilizer treatments yielded nearly twice as much at over 3.8 tons per acre. Plots that received 250 pounds of N per acre yielded higher than the 150 pound rate, but the difference averaged less than 0.3 tons per acres. This is consistent with last year where the difference with the extra 100 lbs. per acre of N only increased yield an average of slightly over 0.1 tons per acre (Table 2). The single treatment that received 350 pounds of nitrogen per acre did not yield higher than the more effective of the 250 pound treatments. This is consistent with the 2012 results, indicating that 350 pounds of N is more than necessary to achieve maximum yield.

In agreement with last year's results, the highest yielding treatment timing for the 150 lb. total N applications was when there was no N applied preplant and 80 percent of the N (120 lbs.) was applied at tillering with the other 20 percent (30 lbs.) applied at flowering. This treatment timing was also one of the highest yielding treatments for the 250 lb. total N treatments. This underscores the importance of having a high level of N available at tillering, which coincides with the beginning of the phase of maximum N uptake for wheat. Unlike 2012, a preplant application alone yielded very well for the 250 pound rate. This was likely due to the lower yield potential in 2013 compared with 2012, which is most likely due to the hard spring frost after planting. It is likely that when 250 pounds of N was applied preplant enough N still remained in the soil for the critical tillering time with the lower yield potential in 2013.

The treatments (8 and 16) where no N was applied preplant and the bulk of the N was split between tillering and boot did not yield as well as when the majority was applied at tillering. This was evident in 2012 as well. Again, this is most likely due to the fact that the period of peak N uptake is from tillering to boot, so the majority of the N is needed at tillering. Just as in 2012, the lowest yielding treatments for their application grouping (either 150 or 250 lbs. total N per acre) were treatments 7 and 15. These treatments received a moderate rate of N preplant and then an equal amount at boot. These treatments did not yield nearly as well as when the same amount of N was all applied at tillering. This provides further evidence that tillering may be the most critical time to apply N.

Nitrogen fertilization did not affect bushel weight (data not shown). The 2012 data showed that nitrogen fertilizer timing and rate had a highly significant effect on protein content. Applications where a higher percentage of the N was applied later in the season improved protein content considerably (see the 2012 Final Report for this project). However, as noted above, due to the production season in the Intermountain Region there is not sufficient time after harvest until this report is due to analyze for protein content. This will be completed in time for the December meeting.

Table 2. Effect of nitrogen rate and the proportion applied at different growth stages on the yield of Yecora Rojo wheat grown at the Intermountain Research and Extension Center (Siskiyou County) in 2012 and 2013.

Treat	Preplant	Tillering	Boot	Flowering	Total	Yield	Yield
#	lbs. N/acre					Tons/A	Tons/A
1	0	0	0	0	0	2.87	1.98
2	150	0	0	0	150	4.05	3.40
3	120	0	0	30	150	4.01	3.20
4	90	60	0	0	150	4.14	3.55
5	90	0	60	0	150	4.00	3.26
6	60	60	0	30	150	4.07	3.58
7	60	0	60	30	150	3.88	3.16
8	0	60	60	30	150	4.16	3.51
9	0	120	0	30	150	4.43	3.72
10	250	0	0	0	250	4.17	3.86
11	200	0	0	50	250	4.22	3.66
12	150	100	0	0	250	4.27	3.82
13	150	0	100	0	250	4.27	3.65
14	100	100	0	50	250	4.32	3.82
15	100	0	100	50	250	4.17	3.47
16	0	100	100	50	250	4.30	3.55
17	0	200	0	50	250	4.53	3.82
18	150	150	0	50	350	4.35	3.81
LSD 0.05						0.18	0.29

Nitrogen Fertilizer Source Study The unfertilized control plots in this study only yielded 1.27 tons per acre, while the plots that received a total of 220 lbs. of N per acre averaged more than twice as much at over 3.3 tons per acre (Table 3). Yield increased with increasing rate of N fertilizer for all nitrogen fertilizer treatments. However, for the NutiSmart treatments yield did not increase with increasing rate of NutriSmart. Because of the protocol proposed by the NutriSmart Company it is difficult to directly compare the NutriSmart treatment with the other fertilizer treatments. The theory was that Nutrismart treated plots would need less nitrogen fertilizer than plots receiving more conventional nitrogen containing fertilizers. However, this did not appear to be the case. Plots receiving the same rate of total fertilizer whether the preplant application was urea, ESN or Agrotain all yielded nearly the same (Table 3). This suggests that it may not be possible to lower N rates with alternative slow-release fertilizer sources. However, as noted above, we do not have grain protein results yet so it may be that while slow release N sources do not improve yield, they could make more N available later in the season to improve protein content.

Table 3. Effect of nitrogen rate and fertilizer source on the yield of Yecora Rojo wheat grown at the Intermountain Research and Extension Center (Siskiyou County) 2013.

Fertilizer	Pre-Plant	Tillering	Boot	Flowering	Total Fertilizer N	Yield tons/A	Bushel Wt.
Nutrismart	45*	50	50	50		2.25	61.3
Urea	50		50		100	2.23	62.1
ESN	50		50		100	2.17	61.9
Agrotain	50		50		100	2.19	62.9
Nutrismart	60*	50	50	50		2.09	61.4
Urea	100		50		150	2.98	63.5
ESN	100		50		150	2.99	63.5
Agrotain	100		50		150	2.81	63.0
Nutrismart	90*	50	50	50		2.35	61.8
Urea	170		50		220	3.28	63.2
ESN	170		50		220	3.30	63.2
Agrotain	170		50		220	3.43	62.2
Untreated					0	1.27	60.8
LSD 0.05						0.51	1.6

*Amount of NutriSmart product applied.

Discussion, Conclusions and Recommendations (Discuss the implications of the results of the research on project objectives. What conclusions can be made based on current findings and what future research is needed?)

These results confirm that N fertilizer is essential to achieve acceptable yield. Yield was approximately double for the best fertilization treatments compared with the untreated control in both trials. When considering only yield, we found no advantage for the slow release nitrogen treatments or for the product NutirSmart. However, these products could potentially delay nitrogen availability until later in the season so it is conceivable that we may see an increase in protein content. Protein data will be available at a later date. The fertilizer proportion study was conducted for two years and was designed to answer the question: *For a given rate of N (either 150 or 250 pounds per acre) when should the grower apply the N to get the maximum benefit*? These results clearly show the importance of proper fertilizer timing. An application of a total of 150 or 250 pounds of N results in fairly dramatic differences in yield depending on the exact timing of the application. While a preplant N application alone has been a common fertilizer program for many growers in the intermountain area, these data clearly suggest that a preplant application itself is not critical. What does appear to be critical is to have an adequate supply of N in the soil at tillering which is the initiation of the period of maximum uptake. Any treatment where there was an adequate amount of N available at tillering resulted in the highest yield. These results clearly suggest that shifting away from high preplant applications and applying more of the N later in the season has merit for improving yield and, based on last year's results, a significant protein improvement as well. Applying most of the N at tillering followed by an application at boot or flowering resulted in higher yield and much improved protein content—high enough to avoid dockage.

Additional research is needed to confirm the results found this year in regards to fertilizer timing to optimize benefit. Research is also needed to develop diagnostic tools for use during the production season to ascertain if more mid-season N is needed to maximize yield and achieve protein goals.