FINAL REPORT

Effect of Nitrogen Fertilization Practices on Spring Wheat Protein Content

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Abstract/Summary of Results and Conclusions (about ½ page summarizing key findings and conclusions/recommendations of the research that was conducted):

Three nitrogen studies were conducted in Siskiyou County at the Intermountain Research and Extension Center (IREC). The studies were designed to compare the yield and protein content of four prominent spring wheats in the intermountain area (Yecora Rojo, Hank, Fusion and Malbec). Seven different nitrogen fertilizer regimes (different timings and total amount of N) were evaluated. Fertilized plots yielded approximately 0.8 tons higher than the non-fertilized control plots. Split applications tended to yield higher than a preplant application alone but the yield differences were not as great as those observed in the 2011 study. An additional study was conducted 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 preliminary results suggested that yield was maximized when the majority of the N was applied at tillering (nearly all the N at tillering with a small amount at flowering). 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. The same trend was evident for both the 150 and 250 lb. N/acre rates. Shifting away from preplant applications and applying more of the N at tillering and later also improved protein content—grain yields over 4 tons with greater than 14 percent protein were achieved. Additional research is clearly needed, but these data suggest that at least for this year an application at tillering was important and had a greater effect on yield than preplant applications.

Introduction and Objectives

Protein content is a significant issue for wheat producers throughout California. It is nearly as important as yield because the price a grower receives is determined by the grain protein content with a discount for wheat with less 14% for northern California grain marketed in the Pacific Northwest. This has obvious economic consequences for wheat producers. The primary factors that influence protein content are cultivar selection, yield level and nitrogen fertility management. Unfortunately, yield and protein content are often inversely related, and is difficult to achieve both, especially without optimum nitrogen fertility management.

Some producers may over-apply N to achieve both yield and protein goals in fewer applications but this can lead to inefficient fertilizer use, reduced profitability and can have unwanted environmental consequences such as excessive nitrate leaching. It is common for intermountain growers to apply all the nitrogen preplant. The research we conducted in 2011 showed that a preplant application alone at the rates tested was insufficient, and a split application of N was needed to achieve acceptable yield and especially to meet protein goals. Late-season N applications, between boot and flowering, were important to increase grain protein but had little effect on yield. Late-season nitrogen applications to spring wheat have not been common in the Intermountain Region but as a result of our initial research are becoming more popular.

Many growers plant Yecora Rojo (often a lower yielding variety) because it usually has higher protein content than many of the newer varieties. Research is needed to determine the optimum fertilization rate and timing to maximize yield and protein for newer wheat varieties compared with the older standard Yecora Rojo.

Research is also needed to determine when the most efficient time to apply nitrogen to wheat is. 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?

The objectives of this research were to:

1. Compare the protein content of popular hard red spring wheats
2. Assess the effectiveness of different N application timings and rates to increase protein in different spring wheat varieties
3. Compare different nitrogen sources and timings to maximize protein content
4. Determine the relative proportion of nitrogen that should be applied at different wheat growth stages to maximize yield and protein content.

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

There were three components to this research. The first was to evaluate the effect of different cultivars and N regime on yield, protein and bushel weight. The second study was to evaluate late-season N application timing and fertilizer source on yield, protein content and bushel weight. And the third component was to determine the relative proportion of N that should be applied at each growth stage to maximize yield and protein. All three trials were conducted in the Klamath Basin at the Intermountain Research and Extension Center (IREC) in Tulelake.

Cultivar and Nitrogen Regime Studies. A factorial experimental design was used to evaluate the effect of wheat cultivar and N treatment. Four cultivars were evaluated—Yecora Rojo, Hank, Fusion and Malbec. Seven N treatments/strategies were evaluated as shown in Table 1. Urea was the N fertilizer source used for all applications. The fertilizer was broadcast using a hand spreader and irrigated within a day after application.

Table 1. Nitrogen treatments evaluated in Cultivar and Nitrogen Regime Study, IREC 2012.

Treat #	120 lbs N Preplant	50 lbs N Tillering	30 lbs N Boot	30 lbs N Flowering	Total lbs N/acre
1					0
2	✶				120
3	✶			✶	150
4	✶	✶			170
5	✶	✶	✶		200
6	✶	✶		✶	200
7	✶	✶	✶	✶	230

Late-Season Nitrogen Application Timing and Fertilizer Source. All plots received a uniform application of N preplant as urea. Then the fertilizers listed in Table 2 were applied. They were applied at the flag leaf stage and then to another set of plots at anthesis. Plots were harvested on September 19, 2012. The yield data has not been compiled yet and protein and bushel weight has not been determined.

Table 2. Nitrogen source treatments applied at flag leaf and anthesis at IREC (Siskiyou County), 2012.

Fertilizer Source	Lbs N/acre
Urea	30
Urea + Agrotain	30
N-Demand	3
N-Demand	9
CoRoN	3
CoRoN	9
UN-32	3
UN-32	9
UN-32	30

Nitrogen Fertilizer Proportion Study. 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. The

350 pound per acre rate was evaluated 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 3. The fertilizer treatments were applied to a single variety, Yecora Rojo, which is the most popular variety in the area. The N was applied as urea at all treatment timings.

Table 3. Differential nitrogen treatment timings evaluated for 150 and 250 pound per acre rates of nitrogen applied to Yecora Rojo spring wheat at IREC, 2012.

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

Budget (describe how the Commission funding was spent)

The funds were spent on the IREC recharge rate for hourly labor and for materials (primarily urea). Funds were also spent for a Student Assistant who helped with field labor. Laboratory analyses were paid with this grant to analyze selected treatments for flag leaf total N, total N content of the leaf below the flag leaf and nitrate-N concentration of the bottom of the stem. These data are being used in cooperation with Michael Tarter of UC Berkeley to perform a statistical procedure to assess the ability of different plant parts to predict grain protein concentration to assess the need for a late-season N application. 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):

Cultivar and Nitrogen Regime Studies. Nitrogen fertilization increased grain yield over the untreated control by about 0.8 tons per acre (Table 4.). Additional applications after the preplant application also tended to increased yield but there was a much smaller increase than was observed last year. The 230 pounds N per acre application did not increase yield over the other fertilization strategies that included a topdress application. In the 2011 trial, Hank was the highest yielding variety but this year there was very little difference between cultivars and Yecora Rojo yielded as well or better than the other varieties in many cases. Nitrogen had a significant effect on bushel weight, as was observed in 2011. The variety Hank tended to have lower bushel weight than the other three varieties. There was also a trend for the unfertilized plots to have higher bushel weight than the fertilized plots. This trend was observed last year as well. It is believed that the unfertilized plots likely had fewer tillers per plant (the plots appeared thinner) and the fewer tillers that were present produced fuller heads. Protein content varied greatly with wheat cultivar and N fertilization rate. In agreement with 2011 results, the variety Hank tended to have the lowest protein content, while Yecora Rojo tended to have the highest. Protein content increased 3 to 4 percentage points from the untreated control plots to the highest N rate. The 14 percent protein marketing threshold was only achieved with the variety Yecora Rojo at the highest rate. A preplant N application followed by 30 pounds of N per acre at flowering was insufficient to achieve the protein goal of 14 percent, in fact, that treatment only resulted in a protein content of around 12.6 percent.

Table 4. Effect of nitrogen strategy on yield, protein and bushel weight of four hard red spring wheat varieties grown at the Intermountain Research and Extension Center (Siskiyou County).

Treatments	Total N lbs/A	Yield tons/A	Protein (%)	Test Wt. (lbs/bu)
Yecora Rojo				
Untreated	0	3.43	10.1	62.8
Pre-plant	120	4.18	12.5	62.6
Pre-plant + Flowering	150	4.22	12.6	61.9
Pre-plant + Tillering	170	4.25	13.5	62.2
Pre-plant + Tillering + Boot	200	4.31	13.3	62.3
Pre-plant + Tillering + Flowering	200	4.30	13.6	62.5
Pre-plant + Tillering + Boot + Flowering	230	4.26	14.0	62.2
Hank				
Untreated	0	3.38	9.9	60.6
Pre-plant	120	3.98	11.9	59.9
Pre-plant + Flowering	150	4.10	12.2	60.4
Pre-plant + Tillering	170	4.22	12.5	59.9
Pre-plant + Tillering + Boot	200	4.11	12.4	58.2
Pre-plant + Tillering + Flowering	200	4.09	12.4	59.5
Pre-plant + Tillering + Boot + Flowering	230	4.01	12.7	59.5
Fuzion				
Untreated	0	3.32	9.9	62.2
Pre-plant	120	4.13	11.8	60.9
Pre-plant + Flowering	150	4.12	12.9	60.3
Pre-plant + Tillering	170	4.14	12.9	61.3
Pre-plant + Tillering + Boot	200	4.23	13.1	61.5
Pre-plant + Tillering + Flowering	200	4.25	13.0	60.7
Pre-plant + Tillering + Boot + Flowering	230	4.26	13.3	60.7
Malbek				
Untreated	0	3.44	10.1	62.6
Pre-plant	120	4.12	11.8	61.6
Pre-plant + Flowering	150	4.10	12.6	61.7
Pre-plant + Tillering	170	4.29	12.7	62.1
Pre-plant + Tillering + Boot	200	4.17	12.5	62.3
Pre-plant + Tillering + Flowering	200	4.21	13.1	61.3
Pre-plant + Tillering + Boot + Flowering	230	4.29	13.1	62.0
LSD 0.05		0.26	0.7	1.0

Late-Season Nitrogen Application Timing and Fertilizer Source. The results of this study were inconclusive. There was a minimal yield response and protein results were variable (statistically significant at the 0.1 but not the 0.05 level). The yield level was lower this year than it was for the same experiment in 2011, and the protein levels where higher. Perhaps this was the reason for less of an impact from these late-season N applications.

Fertilizer Source	N (lbs/A)	Yield (tons/A)		Protein (%)	
		Flag	Anthesis	Flag	Anthesis
Urea	30	3.88	3.85	14.3	14.1
Urea + Agrotain	30	4.01	3.90	14.1	14.3
Ndemand	3	3.92	3.90	14.1	14.3
Ndemand	9	3.93	3.83	14.1	14.2
CoRoN	3	3.99	3.77	14.3	13.6
CoRoN	9	3.83	3.73	14.4	14.1
UN-32	3	3.83	3.83	14.1	14.1
UN-32	9	3.80	3.83	14.0	14.1
UN-32	30	3.86	3.64	14.3	13.8
Check	--	3.77		13.5	
LSD 0.05		0.18		NS	

Nitrogen Fertilizer Proportion Study. The untreated control plots yielded significantly less than the fertilized treatments in the nitrogen timing study (Table 5). The difference was greater than in the cultivar and nitrogen regime study. The untreated control plots yielded over 1.5 tons/acre less per acre than the most effective treatments. Plots that received 250 pounds of N per acre yielded higher than the 150 pound rate but the difference was only a little over 0.1 tons when compared at the same treatment timing. The single treatment that received 350 pounds of nitrogen per acre did not yield higher than most of the 250 pound treatments and, in fact, was numerically slightly less than the most effective 250 rate timing. This was likely because the majority of the N applied with this treatment was applied preplant.

It is interesting to note that the highest yielding treatment timing was the same for both the 150 and 250 pound rates. These high-yielding treatments (9 and 17) received no preplant N but had a high rate at tillering. 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 may be 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, which is the beginning of the maximum uptake period. Treatments where all, or the majority, of the N was applied preplant (2, 3, 10 and 11) tended to be the lowest yielding treatments. A treatment that received a moderate rate of N preplant and then an equal amount at boot (7 and 15) did not yield nearly as well as when the same amount of N was all applied at tillering. This suggests that tillering may be a critical time to apply N, at least under the environmental conditions experienced this year. A significant amount of the total annual precipitation this year occurred in spring. Perhaps some of the N with a preplant application leached below the root zone and was subsequently unavailable for uptake, but this is not very likely in Tulelake soils (heavy clay loam with high OM) and with the careful irrigation management employed.

Nitrogen fertilization did not affect bushel weight (data not shown) but had a profound effect on protein content. There was nearly a 6 percentage point difference in protein between the control and the most effective treatment. The 250 or 350 pound per acre applications of N had significantly higher protein content than the 150 pound per acre rate. In fact, with only one of the 150 pound application rates was the protein goal of 14 percent achieved. Not only is the total amount of N applied important, timing is critical. Appling the same quantity of N had a broad range of effect on protein content depending on the timing of the application. This trial illustrated the importance of late-season N to meet protein requirements. As was observed with yield, it was better to apply less of the N preplant (or none at all) and apply more of the N at tillering, boot and flowering. For example, applying all 250 pounds of N preplant resulted in a protein content of 13.4 percent, while applying more of the N at boot or flowering raised the protein content over 14 percent. However, when the 250 was just split between a 200 pound preplant application and 50 pounds at flowering, the protein content was only 13.8 percent. It is difficult to identify the single most effective treatment, but the treatment with zero preplant N, 200 pounds at tillering, and 50 at flowering resulted in the yield of 4.53 tons and a protein content of 14.1 percent.

Table 5. Effect of nitrogen rate and the proportion applied at different growth stages on the yield and protein content of Yecora Rojo wheat grown at the Intermountain Research and Extension Center (Siskiyou County).

Treat	Preplant	Tillering	Boot	Flowering	Total	Yield	Protein
#	lbs. N/acre					Tons/A	%
1	0	0	0	0	0	2.87	9.6
2	150	0	0	0	150	4.05	12.0
3	120	0	0	30	150	4.01	12.4
4	90	60	0	0	150	4.14	12.1
5	90	0	60	0	150	4.00	12.7
6	60	60	0	30	150	4.07	12.7
7	60	0	60	30	150	3.88	14.3
8	0	60	60	30	150	4.16	13.7
9	0	120	0	30	150	4.43	13.2
10	250	0	0	0	250	4.17	13.4
11	200	0	0	50	250	4.22	13.8
12	150	100	0	0	250	4.27	13.2
13	150	0	100	0	250	4.27	14.2
14	100	100	0	50	250	4.32	14.2
15	100	0	100	50	250	4.17	14.5
16	0	100	100	50	250	4.30	15.3
17	0	200	0	50	250	4.53	14.1
18	150	150	0	50	350	4.35	14.3
LSD 0.05						0.18	0.8

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 and protein content. The wheat cultivar had a significant impact on protein level. These results confirmed prior field experience regarding these cultivars and their protein levels. Nitrogen fertilization also had a significant effect on protein. In agreement with the results from 2011, a preplant N application alone at the rate tested (120 pounds of N per acre) was insufficient to attain acceptable protein levels. In the cultivar and N regime study, only with the highest protein variety and the highest N rate was the protein goal of 14 percent achieved. The 2011 research showed very similar results. This was the impetus for the N fertilizer proportion study to focus on application timing in more detail. 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? A preplant N application alone has been a common fertilizer program for many growers in the intermountain area. However, these data clearly demonstrate that a preplant application alone is insufficient. Although these data just represent a single year, they clearly suggest that shifting away from high preplant applications and applying more of the N later in the season has merit for both yield and protein improvement. 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. Both of these areas will be addressed in CWC Mini-Grant research projects funded for the coming year.