FINAL REPORT

Nitrogen Fertilization Practices to Maximize Yield and Protein of Intermountain Hard Red Spring Wheat

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Abstract/Summary of Results and Conclusions

Nitrogen (N) management is key to achieve maximum yield at an acceptable protein level. Research was needed to evaluate the effectiveness of different N management strategies for a range of varieties and to determine the most economical N fertility management strategy to maximize N use efficiency. Two trials were conducted in the intermountain area of Northern California and these were duplicated in the Central Valley. In one trial, four prominent hard red spring wheat varieties (Yecora Rojo, Hank, WB 9668 and WB 9518) were evaluated at four different levels of N fertilization (0, 150, 225 and 300 lbs. N/acre). Both WB varieties out yielded the standard Yecora Rojo—WB 9518 by approximately 0.5 tons and WB 9668 by approximately 1 ton. WB 9518 had protein similar to Yecora Rojo. WB 9668 did not meet the 14 percent standard but had higher protein than Hank. These varieties have potential to replace Yecora Rojo. In the second trial we investigated different N application timings at given rates of total N to determine the optimum proportion of N to apply at different grain growth stages. In the N timing study it was found that preplant N was not critical and that yield was higher when zero N was applied preplant and a significant amount of the N was applied at tillering. In addition, it was found that all treatments that received N at flowering met industry protein standards.

Introduction and Objectives

Achieving acceptable protein content is a continual challenge for wheat producers throughout California. It is especially difficult in the intermountain area because many growers market their grain in the Pacific Northwest where there is a discount for wheat with less than 14%, compared with 13% for California markets. These protein levels are difficult to achieve, especially in high yielding irrigated fields.

The primary production factors that affect protein content are cultivar selection and N fertility management. Yield and protein content are somewhat inversely related and it is difficult to achieve both but optimum N fertilization practices can help.

With the cost of fertilizers and their application, growers need to maximize N use efficiency while at the same time minimize the number of fertilizer applications. Growers need to get the most from each unit of applied N. Specifically, what proportion of the total nitrogen should be applied at different growth stages to get the most benefit? Currently, most intermountain growers apply all or nearly all of the nitrogen as a preplant application. However, our results indicate that split application are beneficial. Furthermore, it appears that high rates of N are not needed preplant, but that tillering may be the key time to apply nitrogen for maximum yield benefit because this is the beginning of the period of peak N uptake by wheat plants. Further research is needed to confirm this finding.

The objectives of this research were to:

1. Compare the yield, protein content and bushel weight of four hard red spring wheat cultivars
2. Determine the effect of different N fertilization regimes on yield, protein and test weight of four hard red spring wheat varieties
3. Evaluate the effect of different N management strategies (including different application timings and total amount of N applied) on yield and quality of Yecora Rojo wheat

Materials and Methods

Trials were conducted at the Intermountain Research and Extension Center in Tulelake (the major wheat production area in the Intermountain Region). The design of the trials was different from the previous research we have conducted on N management in wheat. There were two trial designs. One trial focused on the interaction between wheat cultivar and N fertilization regime. This trial was essentially duplicated at the West Side Research and Extension Center (WSREC) with Steve Wright but using different cultivars which are adapted to that area. The second trial focused on N rate and timing (different proportions of the total N applied at different growth stages similar to previous work at IREC) with a single wheat cultivar. This trial was also conducted with different cultivars at the WSREC with Steve Wright and on the Davis campus with Mark Lundy.

A. Variety and Nitrogen Fertilization Regime

Four hard red spring cultivars were evaluated, Yecoro Rojo (standard cultivar used in Tulelake for years due to its high protein content), Hank (a high yielding cultivar but typically low protein), WB 9668 and WB 9518 (newer cultivars that have performed well in trials). A split-plot experimental design was used with the four varieties as the main plot and nitrogen regime as the subplot (Table 1). The four nitrogen regimes are presented in Table 1. The total amount of N was 0, 150, 225, and 300 pounds per acre. Yield, bushel weight and protein content were determined. Post-harvest soil samples will be collected to determine nitrate-N levels associated with the different treatments.

B. Application Rate and Timing Study

A single variety (Yecora Rojo) received the N treatments in Table 2. The total amount of N received was 0, 150, 225 or 300 pounds of N per acre. The proportion of the total N applied at the different growth stages varied. Trial design was a 3 x 6 factorial (3 different total N rates x 6 different timings). Yield, protein content and test weight were determined. Post-harvest soil samples were also taken from each plot for evaluation to determine N uptake and leaching risk.

Budget
The funds spent on the IREC recharge rate were for labor used for field preparation, irrigation, harvest, general plot maintenance, and data collection. Funds were also spent on a Field Assistant housed at my office in Yreka who helped with field labor, data entry and protein analysis. $1684 was spent on IREC charges, $625 on transportation to IREC and $7311 for field assistance.

Results
Overall, wheat yield was lower this year, as yields were down in the Klamath Basin as a whole. Yecora Rojo was the lowest yielding variety at every N rate. At the higher N rates it was 0.5 to 1 ton lower than the higher yielding cultivars. The cultivars Hank and WB 9518 had similar yield. WB 9668 tended to be the highest yielding cultivar especially at the highest N rate.

Nitrogen had a dramatic effect on wheat yield for all four cultivars. Yield more than tripled comparing the higher N rates to the unfertilized controls. The fertilizer response over the control was even greater than previously observed. These studies were in the same field as the spring wheat seeding rate/seeding date study. As mentioned in the report for that study, the field was somewhat moisture stressed after tillering as a result of the drought and the irrigation needs of the crop were underestimated by IREC staff. It appears that moisture stress may have an even greater effect on severely nitrogen deficient plants than plants with adequate N. Perhaps root growth is diminished in nitrogen deficient plants exacerbating the effect of inadequate soil moisture. There was no yield increase beyond the 225 pounds per acre rate for Yecora Rojo or Hank but yield increased slightly for the WB varieties as N rate increased to 300 pounds per acre.

Nitrogen rate had a dramatic effect on protein content. For the variety Yecora Rojo, protein content increased two full percentage points for the 300 pound rate compared to the unfertilized. Surprisingly, protein content was significantly higher for the unfertilized plots for some cultivars compared with the 150 pound per acre N rate. This was likely because the yield in these plots was so low that more of the N was allocated to the grain. The variety Hank tended to have the lowest protein content at each N rate. Both WB cultivars had higher protein content and the protein content of WB 9518 was comparable to Yecora Rojo at many of the N rates.

In general, yield tended to increase with increasing N rate, but this was not always the case (Table 6). It depended on the nitrogen timing. Yield did not increase when the N rate went from 225 to 300 lbs/A for any of the treatments that received an application at the tillering stage, but did for both of the nitrogen fertilization regimes where most of the N was applied preplant. It appears, in agreement with previous studies at IREC, that a tillering stage application is especially important. Averaged over all N rates, the highest yield occurred when the N was split between tillering and preplant and the overall highest yielding treatment was when no preplant N was applied and nearly all the N was applied at tillering. This agrees with previous research at IREC indicating the importance of a tillering application over preplant N applications.

A preplant application of N alone was not sufficient to meet the 14% protein standard, but came close at the 300 pound per acre N rate. Significantly higher protein concentrations occurred when less N was

applied preplant and more was delayed until the flowering stage. Protein goals were met by all treatments where total applied N was 225 pounds or greater and an application was made at flowering.

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?)

Yecoro Rojo has been the standard hard red spring wheat variety in the Klamath Basin for decades. It is not grown in other parts of the state even though it has the reputation as being a high protein variety because of its lower yield potential. However, historically its yield has not been that much below many other varieties in the Tulelake area, and higher yielding varieties such as Hank have had much lower protein concentration. Therefore, it has been difficult to find a replacement. However, both of the WB varieties evaluated in this study may have potential. They were significantly higher yielding than Yecora Rojo. The variety WB 9518 yielded over half a ton higher than Yecora Rojo at the 225 lbs/acre N rate and nearly three quarters of a ton higher yield at the 300 lbs/acre N rate with acceptable quality at both rates. WB 9668 yielded nearly one ton higher than Yecora Rojo at the higher N rates (significantly higher than Hank) but did not make quality goals. A different N regime that enables WB 9668 to meet protein goals may enable this to be a commercial variety in the Klamath Basin.

The N timing study produced very interesting results, showing again that preplant N is not critical and that there are benefits to putting on a significant amount of the seasonal N at tillering. The treatment where no N was applied preplant and nearly all of the N was applied at tillering with a follow-up smaller application at flowering had the highest yield—approximately half a ton higher than when all of the N was applied preplant or preplant and flowering. This is an interesting finding. While it is not as easy or convenient for growers to apply N at tillering compared to preplant, there appear to be significant advantages. The plots that had no N preplant were noticeably N deficient at tillering but the high N application at tillering stimulated the plants in some way and these plots ended up producing more. Further research is needed to confirm this finding and to help explain how the physiology of the grain plant is affected by an early-season N deficiency followed by a significant application of N at tillering. *Does a heavy dose of N preplant encourage excessive tiller production, many of which abort and do not become productive tillers? Or, does an application of N at tillering encourage tiller production and more become reproductive tillers?* Research is needed to explain why the tillering application appears to be so effective.

These results also show how important a late-season N application is for enhancing protein content. At both the 225 and 300 pound application rate, all treatments that received an N application at the flowering stage exceeded the 14 percent protein goal.

Table 1. Variety and Nitrogen Fertilization Regime Study

TREATMENT	**Preplant Application (lbs N/acre) ***	**Tillering Application (lbs N/acre)**	**Boot Stage Application (lbs N/acre)**	**Total N Applied (lbs/acre)**
1	0	0	0	0
2	70	40	40	150
3	110	60	55	225
4	150	75	75	300

Table 2. Application Rate and Timing Study

Treatment	Preplant Application (lbs N/acre)	Tillering Application (lbs N/acre)	Boot Stage Application (lbs N/acre)	Flowering Stage Application (lbs N/acre)	Total N Applied (lbs/acre)
	----------N/acre----------				
1	0	0	0	0	0
2	150	0	0	0	150
3	120	0	0	30	150
4	100	50	0	0	150
5	70	40	40	0	150
6	70	50	0	30	150
7	0	120	0	30	150
8	225	0	0	0	225
9	185	0	0	40	225
10	150	75	0	0	225
11	110	60	55	0	225
12	110	75	0	40	225
13	0	185	0	40	225
14	300	0	0	0	300
15	250	0	0	50	300
16	200	100	0	0	300
17	150	75	75	0	300
18	150	100	0	50	300
19	0	250	0	50	300

Table 3. Effect of Spring Wheat Cultivar and Nitrogen Application Timing on Yield, Tulelake, CA.

	Yield			
	Nitrogen Rate			
	0	150	225	300
Variety	----------tons/A----------			
Yecora Rojo	0.86	2.82	2.94	2.95
Hank	1.11	3.27	3.70	3.60
WB 9668	1.15	3.32	3.80	4.07
WB 9518	0.94	3.12	3.48	3.67

95 percent confidence interval for the interaction of N rate and variety is 0.21.

Table 4. Effect of Spring Wheat Cultivar and Nitrogen Application Timing on Percent Protein, Tulelake, CA.

	Protein Content			
	Nitrogen Rate			
	0	150	225	300
Variety	----------%----------			
Yecora Rojo	12.6	12.4	14.1	14.6
Hank	12.4	11.9	12.7	13.3
WB 9668	13.5	12.0	13.1	13.5
WB 9518	14.6	13.1	14.0	14.1

95 percent confidence interval for the interaction of N rate and variety is 0.3.

Table 5. Effect of Spring Wheat Cultivar and Nitrogen Application Timing on Test Weight, Tulelake, CA.

	Bushel Weight			
	Nitrogen Rate			
	0	150	225	300
Variety	----------lbs.----------			
Yecora Rojo	59.4	59.8	59.4	59.4
Hank	61.8	60.4	60.3	59.4
WB 9668	61.3	61.8	61.4	61.1
WB 9518	61.4	61.5	60.8	61.0

95 percent confidence interval for the interaction of N rate and variety is 0.6.

Table 6. Effect on Nitrogen Fertilizer Rate and Timing on Yield of Yecora Rojo wheat in Tulelake, CA.

	Yield		
	Nitrogen Rate		
	150	225	300
N Timing	----------tons/A----------		
Pre Only	2.82	2.74	3.16
Pre/Flower	2.63	2.96	3.12
Pre/Tiller	3.00	2.97	2.99
Pre/Tiller/Boot	2.82	3.13	3.12
Pre/Tiller/Flower	3.03	3.35	3.24
Tiller/Flower	3.27	3.53	3.48

95 percent confidence interval for the interaction of N rate and application timing is 0.25.

Table 7. Effect on Nitrogen Fertilizer Rate and Timing on Protein Content of Yecora Rojo wheat in Tulelake, CA.

	Protein Content		
	Nitrogen Rate		
	150	225	300
N Timing	----------%----------		
Pre Only	12.0	13.7	13.9
Pre/Flower	14.0	14.7	15.0
Pre/Tiller	11.3	12.9	14.3
Pre/Tiller/Boot	12.9	13.7	14.1
Pre/Tiller/Flower	13.7	14.4	15.1
Tiller/Flower	13.2	14.3	14.6

95 percent confidence interval for the interaction of N rate and application timing is 0.4.

Table 8. Effect of Nitrogen Fertilizer Rate and Timing on Test Weight of Yecora Rojo Wheat in Tulelake, CA.

	Bushel Weight		
	Nitrogen Rate		
	150	225	300
N Timing	----------lbs.----------		
Pre Only	59.0	58.8	58.8
Pre/Flower	59.5	59.5	59.0
Pre/Tiller	59.3	58.5	59.3
Pre/Tiller/Boot	59.8	59.3	58.3
Pre/Tiller/Flower	60.0	59.8	59.3
Tiller/Flower	60.0	60.0	59.5

95 percent confidence interval for the interaction of N rate and application timing is 0.7.

Figure 1. Effect of Nitrogen Fertilizer Rate and Timing on the Yield and Protein Content of Yecora Rojo Wheat in Tulelake, CA (averaged over the 150, 225 and 300 pound/acre rates).