NITROGEN RATE AND TIMING EFFECT ON IRRIGATED HARD RED SPRING WHEAT: 1999 ON-FARM TRIALS IN CENTRAL OREGON

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Introduction

Wheat is a valuable crop in central Oregon for breaking disease and weed cycles, if not for profit. Given current market prices for soft wheats, there is increased interest in cultivating hard red spring wheat. The limiting factor in utilizing higher value hard wheats is lack of knowledge on how to manage the crop to assure high protein levels needed to guarantee marketability. Grain protein concentration in wheat is strongly influenced by amount and timing of nitrogen application' (e.g. Christensen and Killorn, 1981; Fischer et al., 1993; Knowles et al., 1994). Farmers need to know how much, and when, to apply N to attain high yields and high protein in an efficient manner. A diagnostic tool for in-season application of N would be a useful asset for farmers in guiding N fertilizer use. Work in Idaho has indicated that flag leaf nitrogen concentration may be used to predict whether topdressing N in-season is called for or not (Tindall et al., 1995). The objective of this work was: 1) determine the protein and yield response of hard red spring wheat to N in on-farm environments in central Oregon; 2) determine the utility of using flag leaf N as a guide for in-season N application; 3) determine whether topdressing some N versus all basal application is beneficial for increasing grain protein concentration, or for avoiding N loss to the environment.

Methods and Materials

Plant culture and experimental design. The trials were conducted at on-farm sites in Madras; Culver, and Prineville; the cooperating farmers were Mr. Rich Lewis, Macy Ranches, and Mr. Brian Barney, respectively. The hard red spring wheat varieties planted at Madras, Culver, and Prineville were `Yecora Rojo', 'Hank', and 'Express'. The plots were managed along with the rest of the field at the farmers' discretion, except for nitrogen management. The fields were irrigated by hand line sprinlder at Culver and Prineville, while a rolling wheel line sprinlder system was used at the Madras location. Plot size was 10-feet by 30-feet and the trial was laid out in a randomized complete block design with three replications at each site.

In all cases, basal nitrogen applications were made at or before the three leaf stage. The basal application dates occurred on April 22, April 22, and April 23 at Madras, Culver, and Prineville. Topdress treatments were made within a few days of anthesis. The topdress applications were made on calendar dates June 22, July 2, and July 1 at Madras, Culver, and Prineville. The nitrogen source was ammonium nitrate. Nitrogen treatments are listed in Table 1.

The trial sites were sampled in early April. Soil test information is presented in Table 2, Table 3, and Table 4 for Culver, Madras, and Prineville. The soil tests (0-24"depth) indicated initial soil nitrate levels were 61 lb/ac nitrate-N per acre at Culver, 166 lb/ac nitrate-N per acre at Madras, 210 lb/ac nitrate-N per acre at Prineville. Only nitrate-N is used in the nitrogen budget.

Table 1. Nitrogen rate treatments for the nitrogen rate and timing effect on hard red spring wheat trials located at Culver, Madras, and Prineville.

Trt.#	Basal Fertilizer N (lb/ac)	Topdress N (lb/ac)	Total Fertilizer N (lb/ac)
1)	0	0	0
2)	0	40	40
3)	70	0	70
4)	30	40	70
5)	140	0	140
6)	100	40	140
7)	210	0	210
8)	170	40	210
9)	280	0	280
10)	240	40	280

Table 2. Soil test results from the samples taken in early April, 1999 at Macy Farms, Culver, Oregon.

Depth	pH	NO3 (lb/ac)	NH4 (lb/ac)	P (ppm)	K (ppm)
0-12"	6.5	30	15	66	215
12-24"	6.9	31	13	27	162
Total		61	28		

Table 3. Soil test results from the samples taken in early April, 1999 at the Rich Lewis Farm, Madras, Oregon.

Depth	pH	NO3 (lb/ac)	NH4 (lb/ac)	P (ppm)	K (ppm)
0-12"	6.1	60	20	72	419
12-24"	6.8	106	20	33	284
Total		166	40		

Table 4. Soil test results from the samples taken in early April, 1999 at the Brian Barney Farm, Prineville, Oregon.

Depth	pH	NO 3	NH4 (lb/ac)	P (ppm)	K (ppm)
0-12"	7.6	74	14	29	649
12-24"	7.6	136	8	10	666
Total		210	22		

Sampling and statistics. Flag leaf nitrogen and SPAD chlorophyll meter (Minolta Camera Co., Osaka, Japan) readings were determined by sampling 30 leaves per plot at heading. After obtaining a SPAD measurement from each leaf, leaves were dried at 150 F, ground, and analyzed for N by combustion analysis (Horneck and Miller, 1998). Basal stem segments (20 cm in length) were also collected at the time the flag leaves were sampled. The stem segments were initially frozen, then dried at 150 degrees F, ground and analyzed for stem nitrate using an ion-specific electrode. Canopy nitrogen was determined by sampling six feet of row at the soft dough stage. These whole samples were weighed fresh and a 3-plant subsample taken and weighed immediately. The subsample was then dried, ground and analyzed for N (Horneck and Miller, 1998). The subsample data was converted back to a land-area basis using the whole plot fresh weight and percent dry matter from the subsample. A bordered area of about five-feet by 20-feet area (each harvested plot length was measured) was harvested from each plot using a small plot combine to determine grain yield. The trials were harvested on August 19, September 9, and September 15 at Madras, Culver, and Prineville. Plant height and lodging scores were recorded at harvest. Grain protein was determined using NIR analysis. Grain nitrogen per acre was estimated by multiplying seed yield by NIR protein values and dividing by the protein:N ratio of 5.7. Final soil nitrate was determined by sampling (5 cores per plot) from each plot after harvest to a depth of 2' (0-1' and 1-2') with a Kaufman hydraulic soil auger. The samples were taken on

2-3, September 10, and September 22 at Madras, Culver, and Prineville. All data were analyzed as a randomized complete design using the PROC GLM routine in SAS statistical software (SAS Institute, Cary, NC).

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Results and Discussion

Yield and protein response to N. There was a significant yield response to N at Culver and Prineville, and a trend for increased yield with greater N at Madras (Table 5 and Fig. 1). Reserving a portion of N for topdressing appeared to exacerbate N deficiency effects on yield in plots where N was yield limiting (Tables 5 and 6). Protein was responsive to N at Madras and Culver, but not at Prineville where all the plots showed high grain protein (Table 5 and Fig. 2). At first glance, the Prineville data appears incongruous. There is a yield response but not a protein response to N. Indeed, the plots low in N were visibly N deficient during vegetative growth and yet all plots had high protein. One explanation for this is that the field was very high in N initially, and perhaps this N was leached out of the root zone during vegetative growth but became available later in growth as roots grew deeper. Thus N may have been limiting during vegetative growth when yield was determined, but was not limiting later on when protein was determined. The field was irrigated with 24 hour sets twice, while the rest of the irrigations were 12 hour sets. At Madras, all of the plots had sufficient initial N to acheive high yields, but not enough N to ensure high protein. Culver was the only site that showed a typical yield and protein response (Fig. 1 and 2).

Plotting protein versus yield at Culver, initially protein declined due to a dilution effect as yield increased from 40 to about 70 bushels per acre in response to N (Fig. 3). Yield, and to a lesser extent protein, both increased over the next increment of N. Above this nitrogen level, only protein responded to applied N while yield remained the same - the curve going effectively straight up. The protein percentage where the yield response is saturated was below 12 % - much lower than the desired level of 14 %. One obvious but important implication of this is that fertilizing for yield, and fertilizing for 14 % protein, are two different goals. Also note that while there was an effect of topdressing on protein percent when basal N was insufficient for yield, once sufficient basal N was present for yield (greater than 140 lbs N per acre in this case), there was no effect of topdressing N versus full basal application on grain protein. This was also true at the other sites (Fig. 2). It appears from this data that at low levels of N, holding a portion of N back for topdressing only increases protein by decreasing yield. At levels of N sufficient for both yield and protein, it appears that timing of application does not significantly effect protein concentration (provided enough N is applied basally to ensure yield). Considerations such as delaying N application to avoid lodging, cost of application later in the season, and the importance of avoiding a low-protein crop (i.e. topdressing as an insurance against very low protein) needs to be taken into account when deciding whether to split apply N or not.

Flag leaves were sampled near heading to evaluate whether or not flag leaf N concentration could be used as a predictor of grain protein concentration, and thus as an in-season diagnostic tool to guide N application. Grain protein concentration was correlated with flag leaf N (Fig. 4); however, the relation may not be strong enough to be of use on a practical level. For instance, at the Madras site, there were some points with high flag leaf N concentration which finished the season with low grain protein. Chlorophyll meter readings (SPAD Meter, Minolta Camera Co., Osaka, Japan) were taken from the flag leaves to see if this could be used as a predictor of grain protein; however, the correlation was weaker than that of flag leaf N concentration (Fig. 5). Stem nitrate samples taken at the same time as the flag leaf samples also failed to show a consistent relationship with grain protein (Fig. 6). The data from these trials suggests that neither flag leaf N concentration, nor the SPAD readings have much promise as tools for guiding in-season N applications. Stem nitrate samples taken near anthesis also failed to consistently predict grain protein concentration. Perhaps with some further refinement these tools could be useful, but as tried here they were not very promising.
Two different methods to estimate the total amount of N needed to maximize yield and attain 14 % protein were evaluated. One method was to plot grain N per acre versus total available N (Fig. 7). This seemed to agree well across sites and with data from earlier studies in central Oregon (Crowe et al., 1986 and 1987). Averaging the regression equations for each set of points in Figure 5 gives the following relation:

N requirement = ([(desired yield*60)*(desired protein percent/5.7)/100)]-59.6) / 0.329

The term of "yield*60" converts the yield value from bushels to pounds of grain. The value of 5.7 is the ratio of protein to N in wheat. Dividing protein by 5.7 converts the value to percent N, so when it is multiplied times total grain dry matter it yields pounds of grain N per acre.

The other method was to plot grain protein versus applied N per bushel of yield, using only the plots receiving all their N basally (Fig. 8). The reason for this is including topdress treatments where N was insufficient for yield would skew the analysis, showing artificially high protein concentration that came at the expense of lower yield. This analysis estimates that 2.8 lbs N per bushel of yield is needed to attain 14 % protein. Comparing the two methods (Table 7), one sees that the grain N method predicts efficiency of N use will decline as yield increases, while the N per bushel method estimates a constant efficiency of N use. Data from other studies (Cassman et al., 1992) suggest that N efficiency does in fact decline as rates of N application are increased.
While these data are consistent with that from earlier studies (Crowe et al., 1986 and 1987) and with work from Montana (Westcott, 1998), it should be emphasized that the analysis is based on

one season's data. The trial needs to be repeated before firm conclusions are drawn as to reccomended amounts of N to be applied to hard red spring wheat in central Oregon.

Efficiency of N use. The amount of N in the crop (canopy N) increased with applied N at all three sites (Fig. 9). The total amount of N in the canopy tended to be lower for the topdress treatments than for the full-basal treatments (Fig. 9 and Table 8). Nitrogen harvest index (NBI), on the other hand tended to be greater with topdressing than with full-basal application of N (Fig. 10). Thus it appears that N top-dressed at heading was not taken up as efficiently as N applied basally; however, the partitioning of N to grain (NBI) tended to be greater with topdressing at all levels of N. In this trial the two effects appeared to cancel each other out so that at high levels of N, grain protein concentration was similar whether all N was applied basally or not (Fig. 2). The N topdress in these trials was timed to occur within 3 days of anthesis. It may be that a N topdress applied earlier (e.g. early boot stage) might be more efficiently absorbed by the plant. This is a point that needs further research.

The amount of N unaccounted for at the end of the trial tended to be greater with topdressing than with full-basal application (Fig. 11). Negative values presumably are due to N mineralization, where apparently the Madras site had greater rates of N mineralization, or less leaching of N out of the profile. Nitrate-N in the soil at the end of the season increased with the amount of applied N (Fig. 12). The end-of-season nitrate-nitrogen results are presented in Table 9, Table 10 and Table 11 for Culver, Madras, and Prineville.

Lodging and plant height. There was no lodging at any of the sites. Plant height was increased by increasing rates of nitrogen at Culver, but basal N rates or N timing had no significant effect at the Madras or Prineville locations.

Summary

In 1999 three on-farm trials (Madras, Culver, and Prineville) were conducted to determine the yield and protein response of hard red spring wheat to amount and timing of N application. Topdressing N at heading enhanced grain protein over full basal application when the total amount of N applied was insufficient to maximize yield. At levels of N where yield was not limited, timing of application did not effect protein concentration (i.e. there was no benefit to topdressing versus full basal application of N). It appears that N applied at heading was not as efficiently taken up by the plant as was N applied basally. However, once in the plant, top-dressed N was more efficiently partitioned to grain, so that in terms of grain protein concentration there was no loss or benefit from topdressing at higher levels of N application. Flag leaf N concentration, and stem nitrate concentration at heading were both inadequate tools for predicting grain protein or for guiding N application at heading, in our opinion.

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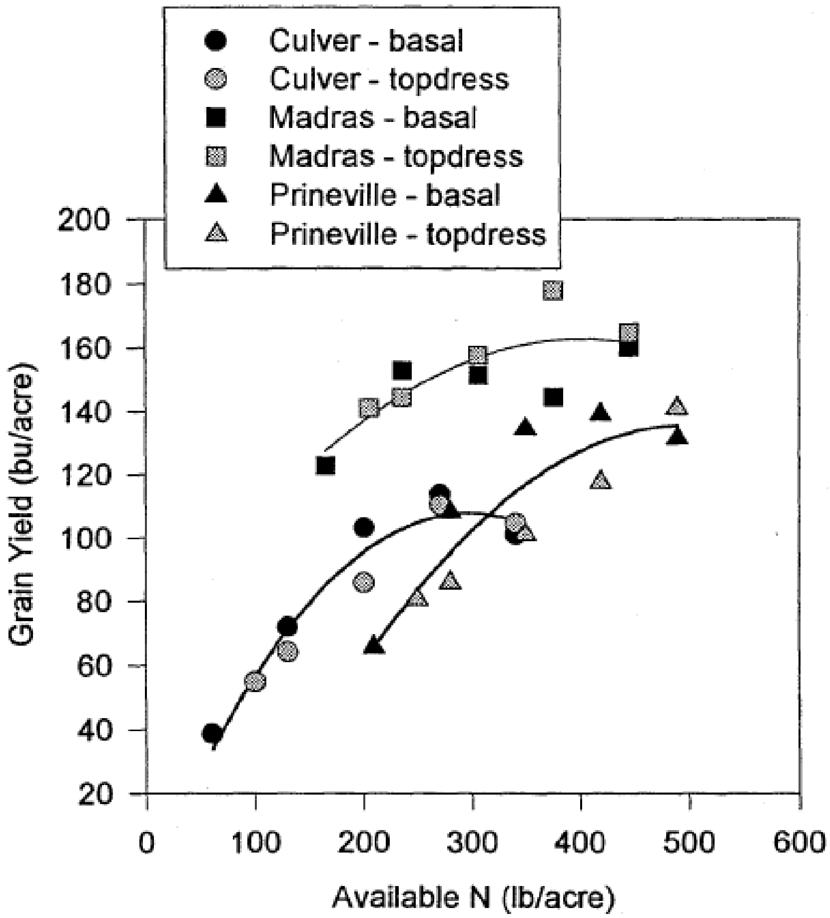

Figure 1. Response of grain yield to available N (initial soil nitrate to a depth of 2' plus applied N) at three sites in central Oregon. Nitrogen was either all applied basally, or 40 lbs N per acre were reserved from the basal application for topdressing at heading.

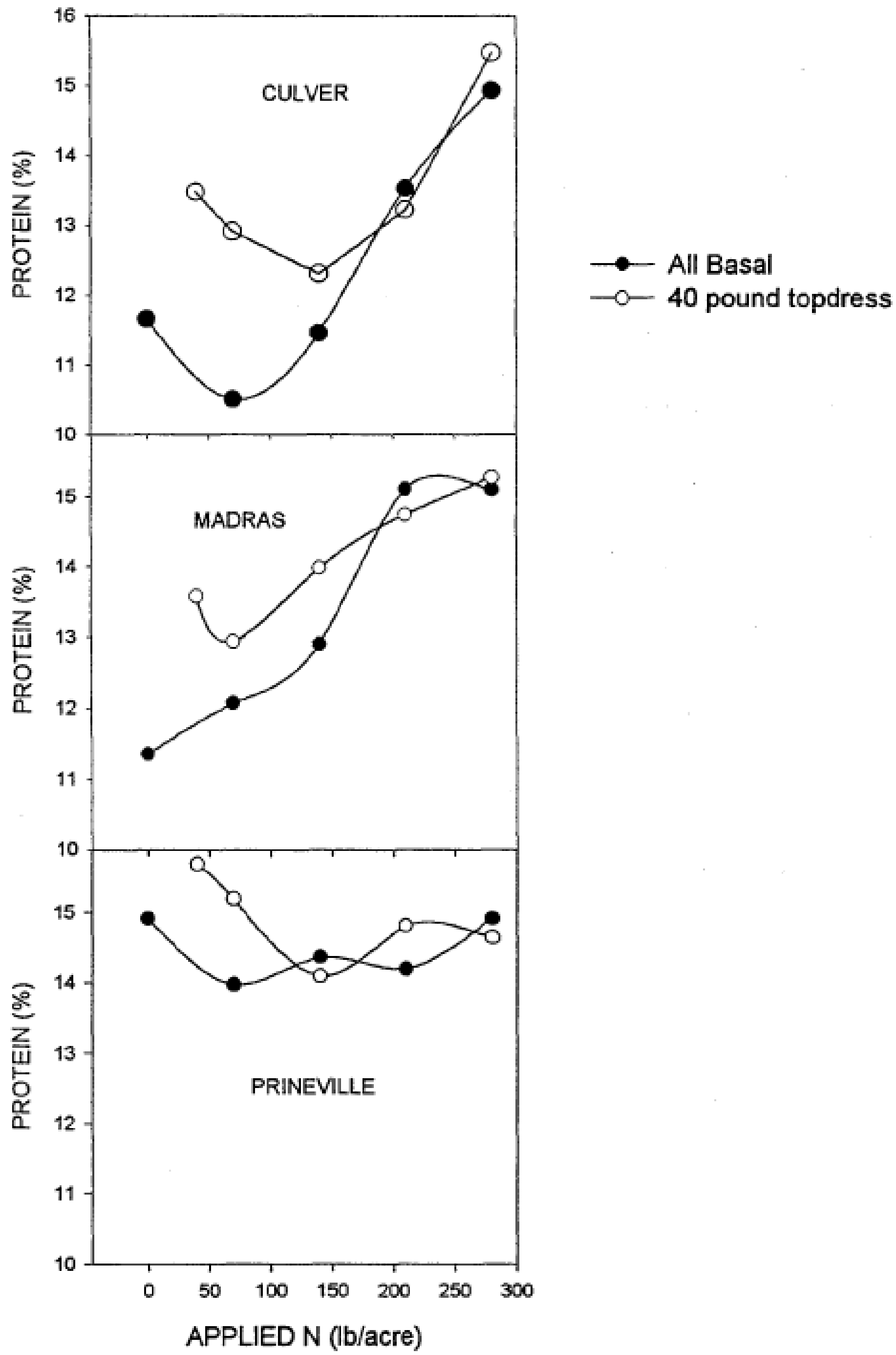

Figure 2. Grain protein versus applied N at three on-farm sites in central Oregon. Nitrogen was either all applied basally, or 40 lbs N per acre were reserved from the basal application for topdressing at heading. Initial soil nitrate (0-2' depth) values were 61, 166, and 210 lb per acre at the Culver, Madras, and Prineville sites, respectively.

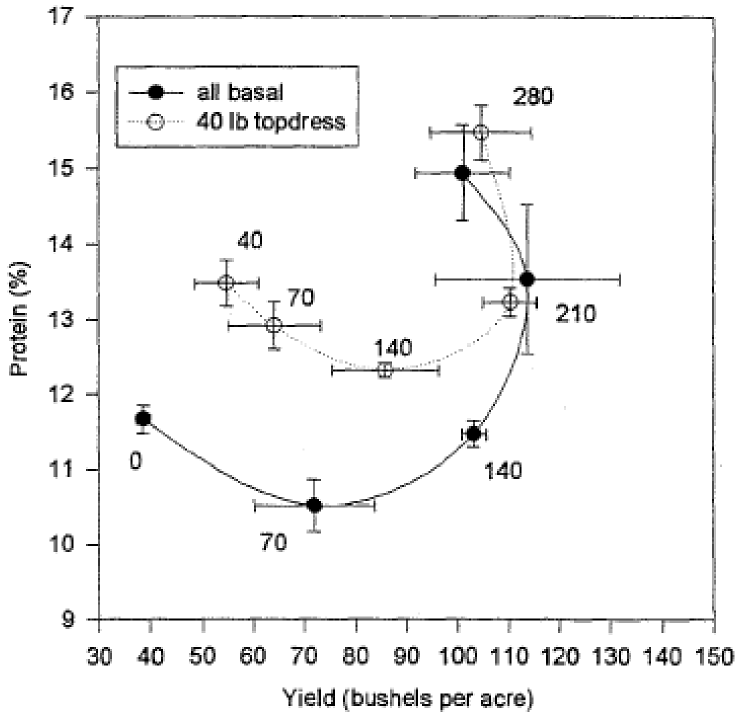

Figure 3. Grain protein versus grain yield at the Culver site. Nitrogen was varied from zero to 280 lb per acre applied N. Nitrogen rates are shown near their respective points. Bars show plus/minus one standard error of the mean. Initial soil nitrate content was 61 lbs per acre.

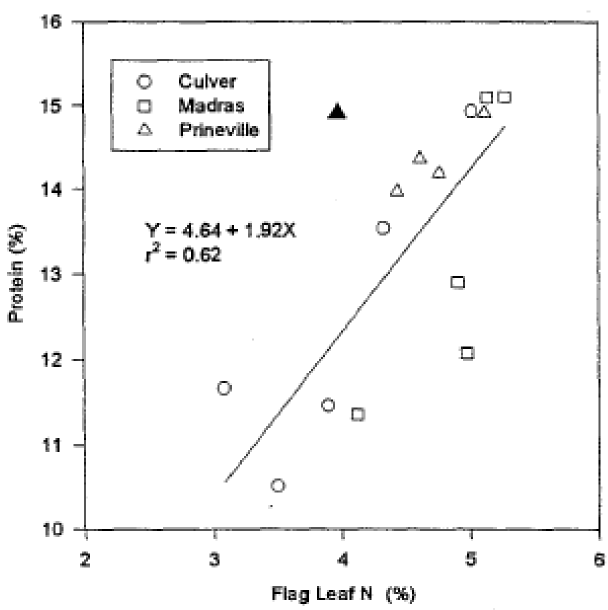

Figure 4. Grain protein versus flag leaf N concentration at heading. Data are from three on-farm trials conducted in central Oregon in 1999 where basal nitrogen application was varied from zero to 280 lbs N per acre. Data from the zero treatment at Prineville (marked with a filled triangle) was not included in the regression analysis.

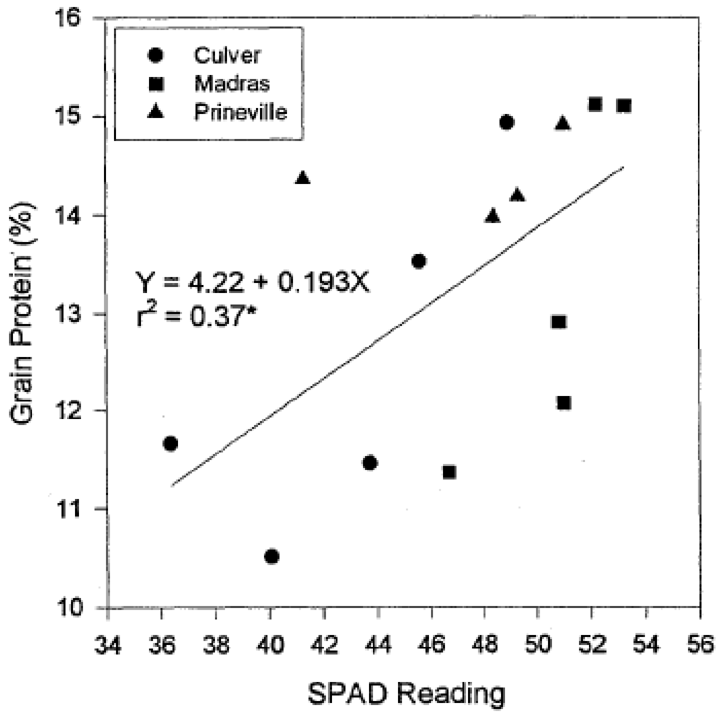

Fig. 5. Grain protein versus SPAD meter readings of wheat flag leaves taken at anthesis. Thirty flag leaves were sampled per plot at anthesis.

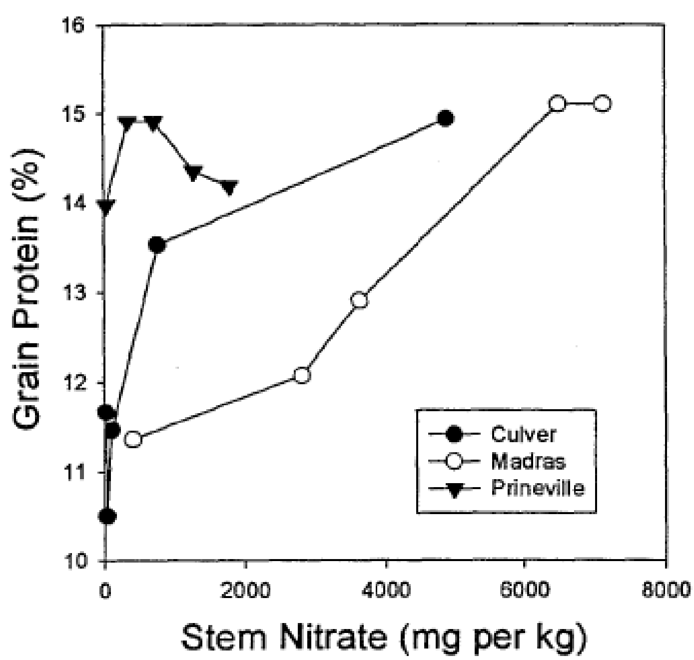

Fig. 6. Grain protein versus stem nitrate sampled within 3 days of anthesis. Stem samples were dried, ground, and stem nitrate determined using an ion specific electrode.

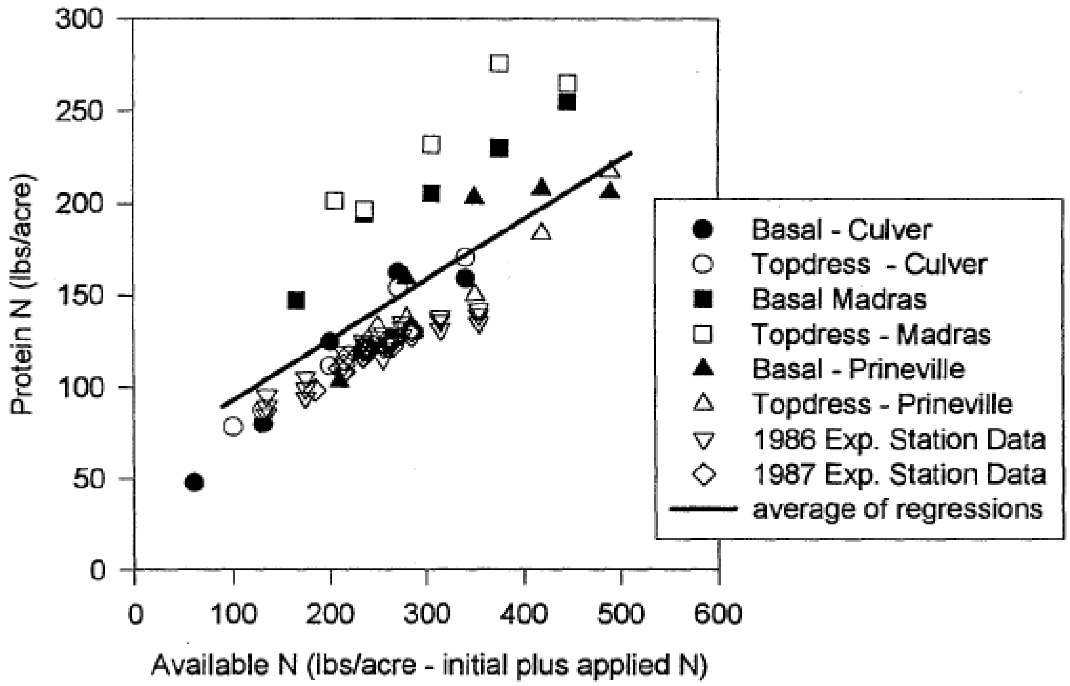

Fig. 7. Protein nitrogen versusavailable N using data from three on-farm trials conducted in central Oregon in 1999 with experiment station results from N rate trials conducted in previous years (Crowe et al., 1986 and 1987). The regression line shown (59.6 + 0.329X) is the average (slope and intercept) for all individual regression equations.

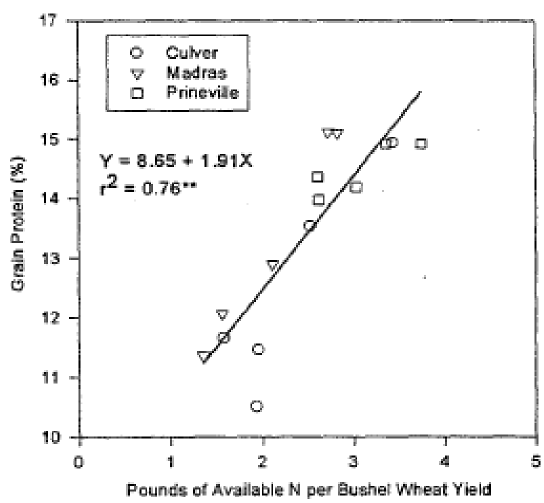

Figure 8. Grain protein versus total available N per bushel of yield for hard red spring wheat from three on-farm trials conducted in central Oregon. Top-dressed treatments were not included in this graph. The regression equation predicts a ratio of 2.8 lbs of N per bushel yield to attain 14 % protein.

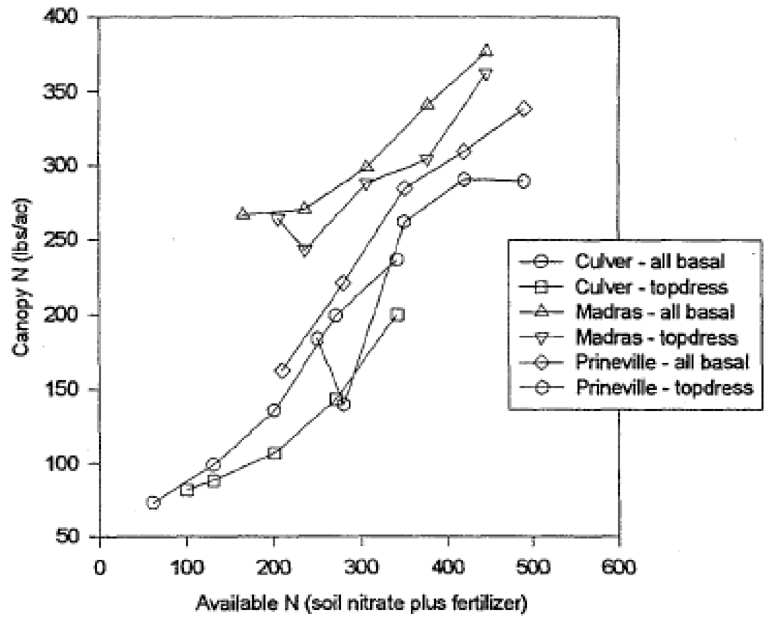

Figure 9. Total canopy N at soft dough versus available soil N in on-farm trials where applied N was varied from 0 to 280 lbs per acre.

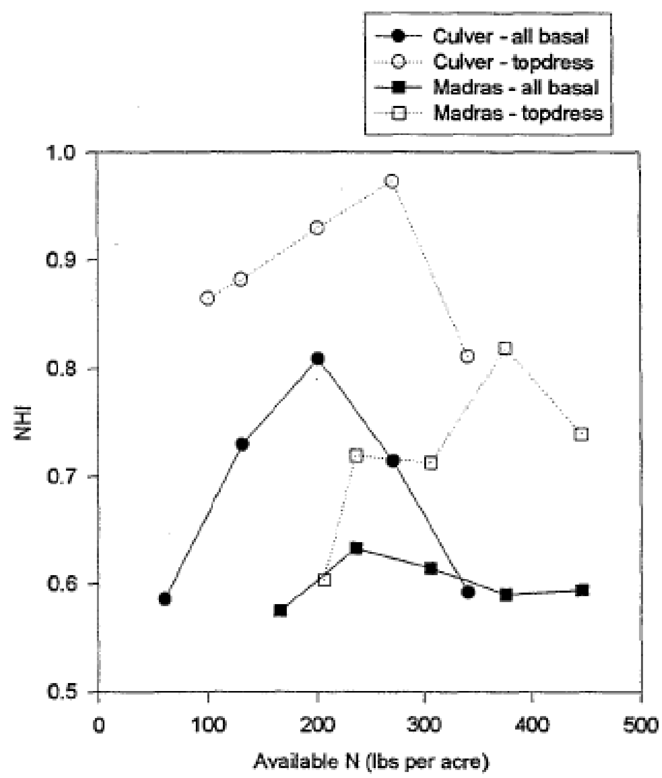

Figure 10. Nitrogen harvest index versus available N from two on-farm trials in central Oregon. A third site (Prineville) was not included in the graph because it appeared to access N late in the season which made the results anomalous.

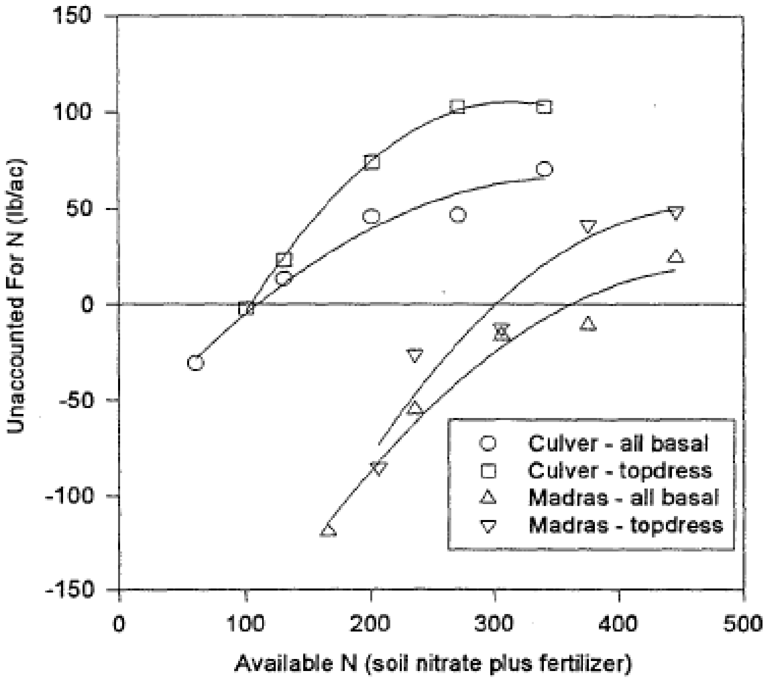

Figure 11. Nitrogen unaccounted for versus available N at Culver and Madras. Data from Prineville is not shown because of anomalies. Negative values imply N mineralization. Unaccounted for nitrogen is the difference between available N minus the sum of canopy N and end-of-season soil nitrate.

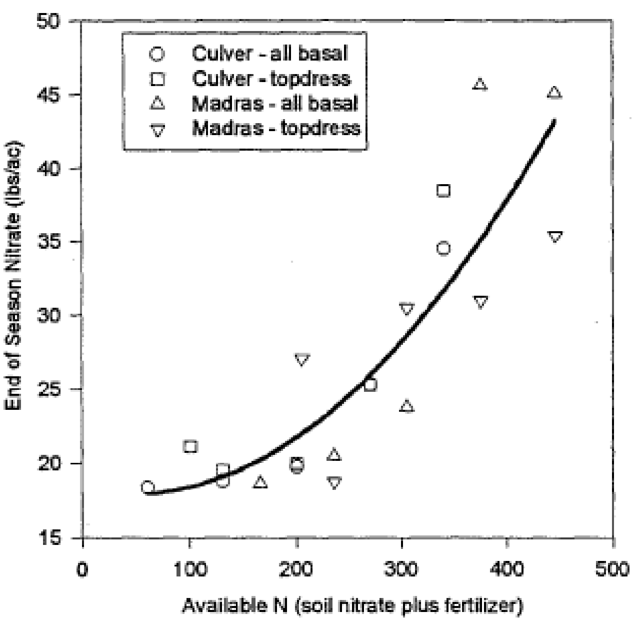

Figure 12. Soil nitrate (0-2' depth) at the end of the season versus available N. Data are from two on-farm trials with hard red spring wheat grown in central Oregon. Data from Prineville is not shown because of anomalies.

Table 5. Nitrogen rate and timing effect on yield, protein, protein nitrogen, flag leaf nitrogen, and plant height results at Culver, Madras, and Prineville.

	Applied Nitrogen	Topdress	Yield	Protein	Protein Nitrogen	Flag Leaf Nitrogen	Height	N use efficiency of total N avail.
		(40 lbs)	(bu/a)	(%)	(lb/a)	(%)	(in)	(%)
Culver	0	N	39	11.7	41.9	3.1	25	69
Variety: Hank	40	Y	55	13.5	68.3	3.0	27	68
611bs initial NO_3	70	N	72	10.5	69.8	3.5	31	53
	70	Y	64	12.9	77.1	3.3	28	59
	140	N	103	11.5	109.5	3.9	33	54
	140	Y	86	12.3	97.8	3.7	31	49
	210	N	114	13.5	139.3	4.3	34	51
	210	Y	110	13.2	134.9	4.3	34	67
	280	N	101	14.9	138.9	5.0	36	41
	280	Y	105	15.5	149.2	5.0	35	44
MEAN			88	12.9	106.5	4.0	31	
LSD (0.05)			26	1.3	23.9	0.6	3.0	
CV (%)			18	6	13	8	5	
Madras	0	N	123	11.4	127.6	4.1	34	77
Variety: Yecora Rojo	40	Y	141	13.6	169.6	4.3	34	82
166 lbs initial NO_3	70	N	153	12.1	169.0	5.0	34	72
	70	Y	144	12.9	172.6	4.8	35	73
	140	N	151	12.9	180.5	4.9	37	59
	140	Y	158	14.0	203.3	5.0	38	66
	210	N	145	15.1	202.2	5.3	35	54
	210	Y	178	14.7	242.8	4.9	36	65
	280	N	160	15.1	224.4	5.1	40	50
	280	Y	165	15.3	228.2	5.2	36	51
MEAN			153	13.7	193.2	4.9	36	
LSD (0.05)			NS	2.2	38.3	0.7	NS	
CV (%)			15	10	12	8	6	
Prineville	0	N	66	14.9	91.4	4.0	32	44
Variety: Express	40	Y	81	15.7	116.3	3.9	29	48
210 lbs initial NO_3	70	N	108	14.0	139.9	4.4	33	50
	70	Y	86	15.2	121.3	3.7	31	43
	140	N	134	14.4	178.8	4.6	32	51
	140	Y	101	14.1	135.0	4.5	34	39
	210	N	139	14.2	182.8	4.8	28	44
	210	Y	118	14.8	162.0	4.6	32	39
	280	N	132	14.9	181.4	5.1	33	37
	280	Y	141	14.6	191.2	4.9	31	39
MEAN			115	14.6	155.0	4.5	32	
LSD (0.05)			32	NS	49	0.4	NS	
CV (%)			17	5.1	19	5	13	

The statistical analysis treated each level of applied N by split application as a discrete treatment without analysis for main effects. This was done because the control and the 40 lb/ac topdress treatment would otherwise unbalance the statistical analysis.

Table 6. Basal rate and topdress N effect on crude protein, protein N, canopy nitrogen, nitrogen harvest index, unaccounted for nitrogen, end-of-season nitrate-nitrogen, and harvest index at Culver, Madras, and Prineville.

Site	Split Application	Yield	Crude Protein'	Protein N	Canopy Nitrogen
		(bu/a)	(%)	(lb/a)	(Ib/a)
Culver	N	97.5	12.6	114.4	188.0
Culver	Y	91.3	13.5	114.8	151.1
Madras	N	152.3	13.8	194.0	361.1
Madras	Y	160.9	14.2	210.2	335.9
Prineville	N	128.3	14.4	170.7	323.8
Prineville	Y	113.7	14.7	155.2	275.5
P-values for split application effect:					
Culver		0.368	0.016	0.948	0.001
Madras		0.269	0.265	0.040	0.219
Prineville		0.065	0.298	0.172	0.072

Site	Split Application	Nitrogen Harvest Index	Unaccounted Nitrogen	End-of-season NO,	Harvest Index
			(lb/ac)	(lb/ac)	
Culver	N	0.71	23.4	24.6	0.52
Culver	Y	0.90	59.1	25.8	0.57
Madras	N	0.61	-53.9	33.8	0.55
Madras	Y	0.75	-23.9	28.9	0.65
Prineville	N	0.61	30.3	30.9	0.54
Prineville	Y	0.76	73.0	36.5	0.57
P-values for split application effect:					
Culver		0.001	0.522	0.522	0.048
Madras		0.004	0.293	0.293	0.015
Prineville		0.357	0.433	0.433	0.469

The comparison of topdressing versus basal application of nitrogen Means are of plots that received 70, 140, 210, and 280 lbs N per acre. Other treatments are excluded after taking out main effects of N, so that the means are balanced.

'Crude protein predicted by NIRS.

Table 7. Predicted nitrogen requirement using two different methods. The protein N method predicts N use efficiency will decline at higher yield levels while the N per bushel method predicts nitrogen use efficiency is static across yield levels.

Yield Goal	Protein Goal	Nitrogen per bushel method'	Protein nitrogen per acre method'
(bu/ac)	(%)	(lb/ac)	(lb/ac)
70	14	196	132
80	14	224	177
90	14	252	222
100	14	280	267
110	14	308	312
120	14	336	356
130	14	364	401
140	14	392	446

'Figuring 2.8 lbs/bu.

'See Figure 3 for explanation.

Table 8. Nitrogen basal rate and topdress nitrogen rate effect on canopy nitrogen, nitrogen harvest index, end-of-season NO_3, and harvest index results for Culver, Madras, and Prineville, OR.

	Applied Nitrogen	Topdress	Canopy Nitrogen	Nitrogen Harvest Index	End-of-Season NO	Harvest Index
		(40 lbs)	(lb/ac)		(lb/ac)	
Culver	0	N	82.1	0.59	18.4	0.42
Variety: Hank	40	Y	91.8	0.86	21.1	0.58
611bs initial NO_3	70	N	111.0	0.73	18.8	0.55
	70	Y	99.2	0.88	19.6	0.59
	140	N	152.2	0.81	19.8	0.55
	140	Y	120.1	0.93	20.0	0.55
	210	N	223.4	0.71	25.3	0.49
	210	Y	160.8	0.97	25.3	0.59
	280	N	265.4	0.59	34.5	0.47
	280	Y	224.3	0.81	38.5	0.55
MEAN			159.8	0.78	24.4	0.53
LSD (0.05)			41.5	0.22	7.2	NS
CV (%)			16	14	17	16
Madras	0	N	299.5	0.57	18.6	0.54
Variety: Yecora Rojo	40	Y	296.8	0.60	27.1	0.54
166 lbs initial NO_3	70	N	303.7	0.63	20.5	0.56
	70	Y	272.8	0.72	18.7	0.60
	140	N	335.1	0.61	23.8	0.59
	140	Y	323.1	0.71	30.5	0.64
	210	N	383.0	0.59	45.6	0.52
	210	Y	341.1	0.82	31.0	0.72
	280	N	422.8	0.59	45.1	0.56
	280	Y	406.8	0.74	35.4	0.63
MEAN			343.0	0.67	29.9	0.60
LSD (0.05)			NS	NS	17.7	NS
CV (%)			20	18	35	16
Prineville	0	N	182.7	0.57	22.8	0.52
Variety: Express	40	N	206.2	0.53	34.6	0.46
210 lbs initial NO_3	70	N	248.3	0.65	21.1	0.50
	70	Y	157.0	0.88	44.4	0.72
	140	N	319.3	0.63	29.3	0.58
	140	Y	294.2	0.52	28.2	0.46
	210	N	347.4	0.62	44.5	0.57
	210	Y	326.2	0.66	43.7	0.56
	280	N	380.1	0.55	28.7	0.51
	280	Y	324.8	0.67	29.8	0.61
MEAN			286.7	.63	32.5	0.55
LSD (0.05)			104	NS	NS	NS
CV (%)			22	26	53	0.25

Initial soil nitrates were sampled from the top two feet of the soil profile. The statistical analysis treated each level of applied N by split application as a discrete treatment without analysis for main effects. This was done because the control and the 40 lb topdress treatment would otherwise unbalance the statistical analysis.

Table 9. Season-ending nitrate-N results for the 0-12 inch, 12-24 inch, and 0-24 inch soil depth for all of the nitrogen treatments at the Culver, Oregon site.

N Treatment	1	2	3	4	5	6	7	8	9	10
Soil Depth	----------	----------	----------	----------	(lb NO_3 per acre)	------	--------	--------	-------	
0-12" 0-12"	10.1	12.9	10.6	11.7	11.3	12.3	14.6	14.5	20.5	24.6
12-24"	8.3	8.3	8.2	7.9	8.4	7.6	10.7	10.8	14.0	13.9
Total (0-24")	18.4	21.2	18.8	19.6	19.7	19.9	25.3	25.3	34.5	38.5

Table 10. Season-ending nitrate-N results for the 0-12 inch, 12-24 inch, and 0-24 inch soil depth for all of the nitrogen treatments at the Madras, Oregon site.

N Treatment										
Soil Depth					-(lb NO_3 per acre)-		------------			
0-12"	12.1	16.4	12.3	12.3	15.5	22.0	27.9	17.0	30.9	25.1
12-24"	6.5	10.7	8.2	6.4	8.3	8.5	17.7	14.0	14.2	10.3
Total (0-24")	18.6	27.1	20.5	18.7	23.8	30.5	45.6	31.0	45.1	35.4

Table 11. Season-ending nitrate-N results for the 0-12 inch, 12-24 inch, and 0-24 inch soil depth for all of the nitrogen treatments at the Prineville, Oregon site.

N Treatment	1	2	3	4	5	6	7	8	9	10
Soil Depth	----------	----------	----------	----------	(lb NO_3 per acre)-					
0-12"	12.7	19.8	13.9	23.8	16.0	15.5	25.7	22.6	16.2	16.9
12-24"	10.1	14.8	7.3	20.6	13.3	12.7	18.8	21.0	12.5	12.9
Total (0-24")	22.8	34.6	21.2	44.4	29.3	28.2	44.5	43.6	28.7	29.8