Wheat Yield and Protein Content as Predictors For Nitrogen Fertilization in Northeast Oregon

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Summary

Yields and protein content of winter wheat grown without or with nitrogen fertilization in northeast Oregon varied considerably between fields. Yield of a particular field was only weakly correlated with percent protein in the grain or the yield increase resulting from nitrogen fertilization. Yield of a field is of little value as a guide in establishing reliable nitrogen fertilizer recommendations.

Larger yield increases from fertilizing with nitrogen were obtained in the higher yielding fields than in the lower yielding fields. The major cause of low yields in the low-producing fields is not a shortage of nitrogen.

The protein content of the grain not fertilized with nitrogen was negatively correlated with yield increase resulting from fertilizing with nitrogen. This negative correlation may prove useful as a tool in predicting the need for nitrogen fertilization. Data indicate that the rate of nitrogen applied should be adjusted to produce grain with a protein content of 8.7 to 8.9%. Allowance would need to be made for the variety grown and the yearly effects of the fertilizer.

Introduction

Producer practices and experimental results have shown that wheat yields can be increased in the Pacific Northwest by the application of nitrogen (N) fertilizers (*1, 3, 5, 7, 8, 9, 11, 13, 14*). An examination of published data reveals that yield increases from fertilizing vary from no increase to increases giving economical returns. This immediately suggests a need for a method which will determine which soils will respond and how much fertilizer to apply.

Ideally, a method which will predict the need for fertilization should be reliable over a wide range of conditions and should be simple and inexpensive. Numerous attempts have been made to develop methods which are useable. Leggett (*10*) proposed a method which predicts the need for nitrogen fertilization for the current crop from available soil moisture, expected precipitation, and nitrate in the soil.

Work by Hunter and others (*4*) in the Columbia Basin of Oregon suggests that protein content of wheat grain might be useful as a guide to the need for nitrogen fertilization of the subsequent wheat crop. Significant yield increases from nitrogen fertilization were usually produced on sites which produced wheat with comparatively low protein content (slightly above an average of 7%). Nitrogen fertilization was of little or no benefit in increasing grain yields on sites producing wheat with higher protein content (above an average of 9%).

Considerable information has been published relating to the effect of nitrogen fertilization on the protein of soft white wheat (*3, 4, 6, 7, 8, 11, 13, 14*). Usually the protein content of the grain increased rapidly if more nitrogen was applied than the plant used in producing more grain. A protein content of less than 10% is preferred in soft white wheat for pastries (*12, 15*). Raising the protein content above this level by unnecessary or indiscriminate nitrogen fertilization is not desirable.

Wheat yield and protein data obtained in fertilizer experiments conducted in northeast Oregon have been subjected to multiple-regression analysis. The objective was to determine if one or more strong relationships existed among the available variables which might be useful in making nitrogen fertilizer recommendations.

Numbers in parentheses refer to the Literature Cited section on page 5.

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Procedure

Nitrogen-fertilizer experiments on winter wheat were conducted in Baker, Union, and Wallowa counties. These experiments were established to study various nitrogen fertilization practices, such as rate of application, time of application, and source of nitrogen. Data from rates of nitrogen applied in early spring were used in the regression analyses reported here.

Varieties of wheat grown in these experiments were Elgin, Omar, and Gaines. Each experiment contained four or five replications with the treatments applied in a randomized block design. Nitrogen was applied at rates of 30, 60, 90, and 120 pounds per acre in the experiments conducted in 1959 and 1960. Ammonium sulfate was used as the source of nitrogen. In experiments conducted in 1963, 1964, and 1965, ammonium nitrate was applied at rates of 40, 80, and 120 pounds of N per acre. Unpublished data of experiments conducted by T. L. Jackson and F. V. Pumphrey indicated no difference between these two sources of nitrogen when properly applied.

Sites were selected to cover the wide range of conditions under which wheat is grown in these counties. Management practices were those used by the farmer-cooperator, except that the cooperator did not apply any fertilizer to the experimental site. Phosphorus fertilizer containing sulfur was uniformly applied to sites which had low available phosphorus as indicated by a soil test.

Protein content in 1959 and 1960 was determined by the Soils Department of Oregon State University. Protein content was determined in 1963, 1964, and 1965 by the Udy dye binding method under the supervision of R. E. Ramig of the Pendleton Experiment Station.

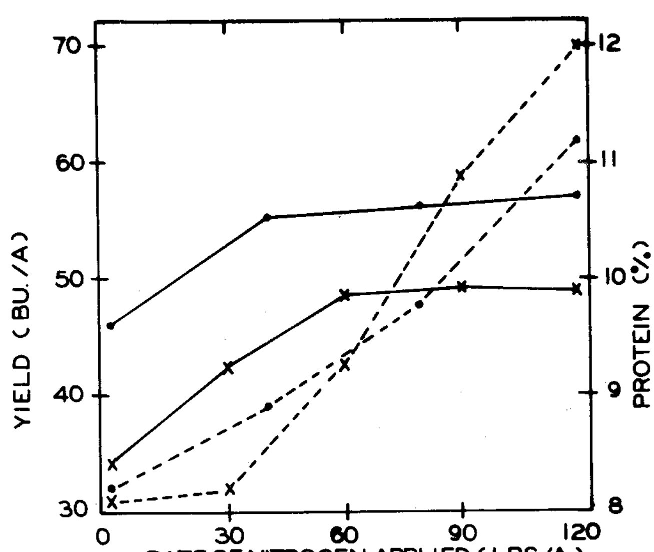
Regression equations and correlation coefficients among the several variables were calculated for each rate of nitrogen applied in order to avoid extrapolating data from one rate to another rate.

Results

Yield and protein content of the wheat not fertilized with nitrogen (checks) varied considerably (Appendix Table 1). Check yields ranged from 20 to 95 bushels per acre. The extreme range in the protein content of the checks was 6.3 to 10.5%.

Grain yields increased as the rate of nitrogen applied increased, until 90 or more pounds of nitrogen was applied per acre (Figure 1). The first increment of nitrogen applied produced the largest increase in yield, and the last increments of nitrogen had no practical effect on yield. Near-maximum average yield was obtained where nitrogen at the rate of 40 to 60 pounds per acre was applied. An examination of data from individual experiments (Appendix Table 1) reveals a wide range between fields in yield response to nitrogen fertilization. This wide range in yield response between fields is consistent with other data reported in Oregon and Washington (*1, 3, 5, 7, 9, 11, 13, 14*).

Nitrogen fertilization increased the protein content of the grain (Figure 1). The first increment of nitrogen applied produced less average increase in protein than did additional increments of nitrogen. The average protein was raised to an objectionably high level where 80 or more pounds of nitrogen were applied. This effect of the nitrogen fertilizer on protein is consistent with published data on white wheat (*3, 4, 7, 11, 13, 14*).



x——x Average yield of 30, 60, 90, and 120 N rate experiments.
x- - - -x Average protein content of grain in 30, 60, 90, and 120 N rate experiments.
•——• Average yield of 40, 80, and 120 N rate experiments.
•- - - -• Average protein content of grain in 40, 80, and 120 N rate experiments.

Figure 1. Average yield and protein content of wheat as affected by rates of nitrogen.

Prediction equations for yield increase and protein increase resulting from nitrogen fertilizer application were calculated. The calculated prediction equations were:

Yield increase $= -17{,}8687 + .1431$ (rate of N) $+ .8158$ (yield) $+ .0022$ (rate) (yield) $- .0014$ (rate)^2 $- .0076$ (yield)^2

$r = .647$

Protein increase $= -.0710 + .0214$ (rate of N) $- .0002$ (rate) (yield) $+ .0002$ (rate)^2

$r = .718$

The curves reported in Figures 2 and 3 were calculated from the above prediction equations. Grain yields of 20, 40, 60, and 80 bushels per acre and nitrogen fertilizer rates of 0, 25, 50, 75, and 100 pounds per acre were assumed.

Data from the individual experiments were used to calculate relationships existing between the several variables studied in these experiments. Only weak correlations existed between many of the variables (Appendix Tables 2 and 3). Low yields were only slightly associated with low protein and high yields were only slightly associated with high protein in the grain. The correlation between the yield of the nonfertilized field (check) and yield increase from fertilization was not significant at any rate of nitrogen application. Protein in the check and yield increase were negatively correlated at each rate of nitrogen applied. This means that an increase in grain yield was obtained from nitrogen fertilization where the protein content of the nonfertilized grain was low; and, in contrast, little increase in grain yield was obtained from nitrogen fertilization where the protein content was high.

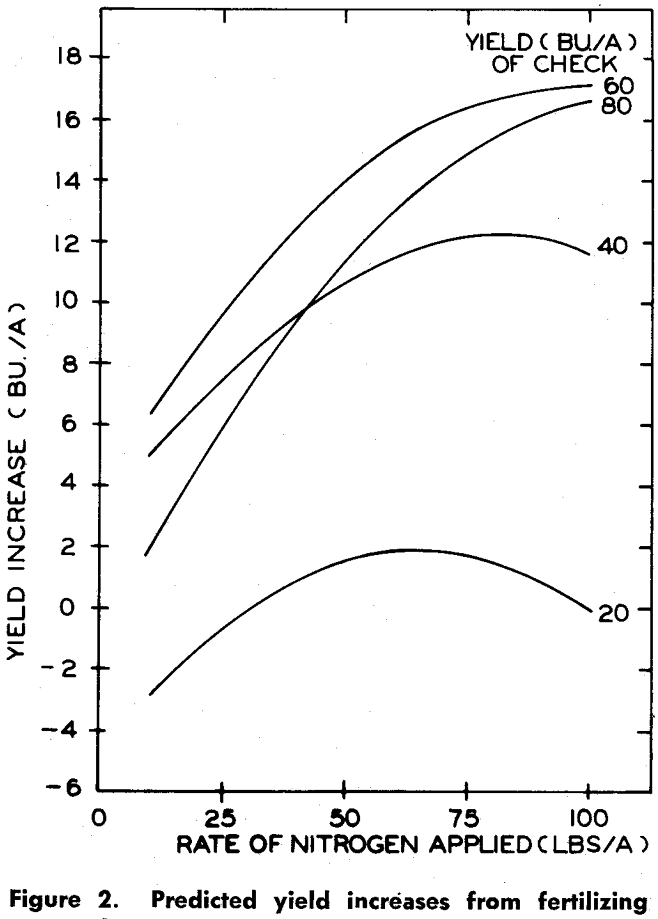


Figure 2. Predicted yield increases from fertilizing with nitrogen in fields of different yield levels.

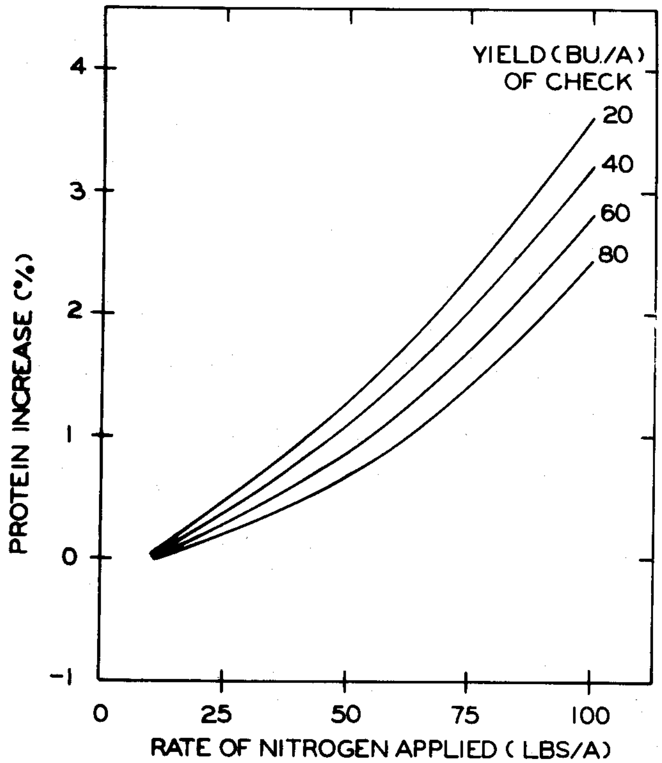


Figure 3. Predicted protein increase in wheat from fertilizing with nitrogen in fields of different yield levels.

The standard deviations for yield increase and for protein increase are larger than their respective increases from the applied nitrogen fertilizer (Appendix Table 3). The size of these standard deviations compared to their means emphasizes the extent of the variable effect the nitrogen fertilizer had on yield and protein content of the wheat.

Discussion and Conclusions

The information presented in Figure 1 shows that on the average nitrogen fertilization can be expected to increase the yield of wheat and increase the protein content of the grain. The standard deviations reported in Appendix Table 2 show that the averages consist of data which have great variability in yield, in protein content, and in the effects of the applied nitrogen. This great variability in yield and in response to nitrogen fertilization between fields greatly reduced the possibility of accurately predicting what effect nitrogen fertilization would have on an individual field.

Grain yield of the unfertilized field and yield increase from an application of nitrogen fertilizer were only slightly related—*r* value = .283 (Appendix Table 1). The need for additional nitrogen was not sufficient to indicate that yields were dominated by this single factor for plant growth and production. The yield of a field is not a satisfactory guide for establishing reliable nitrogen fertilizer recommendations.

Expected yield increases vary

The curves in Figure 2 were drawn from the yield increase prediction equation using assumed yields and rates of nitrogen application. They show that the yield increases which can be expected are not the same for all yield levels. Yield increases from fertilizing with nitrogen are approximately the same in the higher yielding fields (60 and 80 bushels per acre). These increases are in contrast to yield increases which can be expected in low-producing fields (20 bushels per acre). This 20-bushel per acre prediction curve emphasizes that nitrogen fertilizer applied to the lower yielding fields produces yield changes which vary from small decreases to small increases. The major cause of low yields in the low-yielding fields usually is not a shortage of nitrogen. Inadequate moisture for optimum growth of wheat is a major factor in limiting yields in nonirrigated, low-yielding fields in low rainfall areas. Some low-producing fields have a weed problem; they may be extremely wet during the late winter and early spring because of inadequate drainage; they may contain excess soluble salts (alkali problem); and they may have been planted unusually late or have a serious disease problem (often foot rot). The addition of nitrogen is not a cure for these problems.

Other workers in Oregon report results which show that yield response to fertilizing is influenced by many factors. Buetler and Foote (*1*) show interactions between varieties, seeding dates, and response to nitrogen. Goetze (*2*) reported that the protein content of wheat varies considerably between years, geographical areas, and varieties. Differences in protein content between varieties are also shown by Ramig (*14*). He reported that the variety Brevor had a higher protein content than Omar or Gaines.

More yield response can be expected from higher rates of nitrogen application in the higher yielding fields than in the lower yielding fields (Figure 2). At the higher levels of 60 and 80 bushels per acre, yields continue to increase as the rate of nitrogen applied increases to 100 pounds per acre. Yields in the lower levels reached a maximum from an application of 75 or less pounds of nitrogen per acre.

A high negative correlation between protein content and yield increase would lead to the conclusion that low protein indicates that yield was limited by a shortage of nitrogen. The next conclusion would be that the protein content of the grain could be used as a guide for recommending nitrogen fertilization. In this work the consistent negative correlation between protein in the check and yield increase from the applied nitrogen suggests that this correlation is the only one which might have promise as a guide for recommending the application of nitrogen. This consistent negative correlation agrees with work in the Columbia Basin in Oregon (*4*).

To properly evaluate the relationship between protein content of the grain and yield increase from nitrogen fertilizations as a predictive tool, additional data should be obtained using the protein content of one crop and the nitrogen fertilizer effect on the next crop. Such a method combines the climatic and biological variabilities encountered in two cropping years into one set of data and correlations. This addition of more variability would have the effect of lowering the predictive value compared to the data reported here.

Nitrogen increases protein

Nitrogen fertilization can be expected to increase the protein content of the grain more in the lower producing fields than in the higher producing fields (Figure 3). This should be expected from the curves in Figure 2 and consistent results which show that the protein is increased rapidly if the nitrogen applied is not used in producing increased yield. However, in both low- and high-producing fields more protein increase can be expected from the last increment nitrogen applied than from the first increment applied.

A nonstatistical appraisal of the data in Appendix Table 1 shows that grain yields continued to be substantially increased by the addition of nitrogen until the protein in the grain exceeded 8.7 to 8.9%. A producer, using this information as a guide to fertilizing, would decide to increase, to decrease, or to continue the same nitrogen program according to where the protein content of his grain varied from 8.7 to 8.9%. Additional nitrogen would be applied if the protein content of the grain was 8.7% or less; less nitrogen would be applied if the protein content was above 8.9%. Some allowance would need to be made for the variety grown and yearly effects of the nitrogen applications.

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Appendix

Appendix Table 1. Yield and protein content of soft white wheat as influenced by nitrogen fertilization

Experiment		Lbs./A. nitrogen applied				L.S.D. 5%
		0	40	80	120	
106–65	Bu/A	56	56	53	53	N.S.[2]
	Percent protein[1]	9.2	10.1	10.9	12.2	
107–65	Bu/A	36	51	53	51	7.9
	Percent protein	6.7	7.4	9.4	12.3	
109–65	Bu/A	43	70	67	67	12.3
	Percent protein	6.7	7.0	9.0	11.9	
110–65	Bu/A	24	28	20	21	N.S.
	Percent protein	10.5	10.3	9.9	10.0	
111–65	Bu/A	95	96	103	103	N.S.
	Percent protein	9.3	10.5	10.3	10.5	
112–65	Bu/A	60	72	65	65	N.S.
	Percent protein	9.0	9.5	11.2	11.9	
116–64	Bu/A	29	46	49	53	6.1
	Percent protein	8.4	9.2	10.4	11.9	
117–64	Bu/A	34	40	39	32	4.6
	Percent protein	8.5	11.7	12.7	15.7	
118–64	Bu/A	69	73	71	66	N.S.
	Percent protein	10.2	10.9	11.2	11.5	
126–63	Bu/A	39	43	52	58	7.1
	Percent protein	6.4	6.1	6.3	8.1	
127–63	Bu/A	41	50	54	60	5.7
	Percent protein	6.9	7.6	9.1	10.0	
128–63	Bu/A	29	42	52	63	4.3
	Percent protein	6.3	6.3	6.9	8.4	

		Lbs./A nitrogen applied					L.S.D. 5%
		0	30	60	90	120	
101–60	Bu/A	30	31	38	38	39	5.9
	Percent protein	7.6	7.4	9.1	9.9	13.0	
109–60	Bu/A	30	47	47	52	51	8.2
	Percent protein	8.0	8.0	9.1	9.9	10.4	
114–60	Bu/A	23	26	34	36	36	4.6
	Percent protein	8.7	8.7	9.0	10.2	10.6	
115–60	Bu/A	30	48	52	57	51	6.7
	Percent protein	8.6	8.0	9.8	10.2	13.2	
120–60	Bu/A	26	31	32	26	25	3.0
	Percent protein	8.7	9.4	10.7	14.8	17.3	
105–59	Bu/A	44	56	60	59	62	7.8
	Percent protein	7.3	8.0	9.2	10.3	11.5	
112–59	Bu/A	50	51	54	57	50	7.5
	Percent protein	9.2	10.0	11.8	13.5	12.6	
114–59	Bu/A	62	70	73	65	67	N.S.
	Percent protein	7.3	8.0	8.7	12.9	12.2	
115–59	Bu/A	28	45	51	50	57	6.9
	Percent protein	7.4	7.1	7.9	8.3	10.0	
121–59	Bu/A	20	24	47	55	55	5.9
	Percent protein	8.2	7.4	7.7	9.1	9.6	

[1] Fourteen percent moisture basis.
[2] Not significant at the 5% level of probability.

Appendix Table 2. Correlation coefficients (r), means, and standard deviations for several variables using the data in Table 1

Variable	r value			Means and standard deviations		
					Mean	St. dev.
Check treatment				Check yield	40.80	18.21
Yield x percent protein	0.272			Percent protein	8.14	1.19
Thirty pounds per acre nitrogen						
	Check yield	Protein in check	Yield increase			
Protein increase	.703*	.030	-.291	Check yield	34.32	13.33
Check yield		-.259	-.059	Protein in check	8.10	0.68
Protein in check			-.340	Yield increase	8.48	6.94
				Protein increase	0.10	0.59
Forty pounds per acre nitrogen						
	Check yield	Protein in check	Yield increase			
Protein increase	.156	.200	-.162	Check yield	46.21	20.43
Check yield		.397	-.391	Protein in check	8.18	1.52
Protein in check			-.536*	Yield increase	9.41	7.79
				Protein increase	0.71	0.91
Sixty pounds per acre nitrogen						
	Check yield	Protein in check	Yield increase			
Protein increase	.612	.168	-.734*	Check yield	34.32	13.33
Check yield		-.259	-.406	Protein in check	8.10	0.68
Protein in check			-.300	Yield increase	14.53	7.83
				Protein increase	1.20	0.91
Eighty pounds per acre nitrogen						
	Check yield	Protein in check	Yield increase			
Protein increase	-.362	-.183	.168	Check yield	46.21	20.43
Check yield		.397	-.310	Protein in check	8.18	1.52
Protein in check			-.833**	Yield increase	10.34	9.55
				Protein increase	1.60	1.31
Ninety pounds per acre nitrogen						
	Check yield	Protein in check	Yield increase			
Protein increase	.619*	.114	-.828**	Check yield	34.32	13.33
Check yield		-.259	-.520	Protein in check	8.10	0.68
Protein in check			-.035	Yield increase	15.16	11.31
				Protein increase	2.81	1.90
One hundred and twenty pounds per acre nitrogen						
	Check yield	Protein in check	Yield increase			
Protein increase	-.161	-.288	-.183	Check yield	40.80	18.21
Check yield		.262	-.409	Protein in check	8.14	1.19
Protein in check			-.667**	Yield increase	12.97	12.33
				Protein increase	3.44	2.13

* Indicates significant at the 5% level of probability.
** Indicates significant at the 1% level of probability.

Appendix Table 3. Correlation coefficients (r), means, and standard deviations for combined analysis of all data in Table 1

	Correlation coefficients			
	Yield	Percent protein	Yield increase	Protein increase
Yield	1.000	.103	.283	.111
Rate of nitrogen	.261	.617*	.452*	.696*

	Means and standard deviations	
	Mean	St. dev.
Yield	49.37	17.48
Percent protein	9.61	2.12
Yield increase	9.22	10.07
Protein increase	1.47	1.88

* Indicates significant at the 5% level of probability.