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Grain Yield and Protein Response to Late-Season Nitrogen in Irrigated Spring Wheat

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Grain protein in wheat has significant impact on the marketability and price that growers receive, thereby affecting the profitability of wheat production. Montana wheat producers are increasingly utilizing late-season applications of nitrogen (N) fertilizer as a means of boosting the protein level in harvested grain. This is particularly the case in years when growing conditions indicate average or better-than-average yields and growers become concerned that early-season N may not be sufficient to maintain protein accumulation throughout the grain-filling period.

Research has shown that applications of liquid or dry N fertilizer materials at heading can be effective in maintaining crop N status and increasing grain protein, but results vary with early-season fertilization practices, yield potential, pest problems, and other growing conditions. Most often, producers are not able to document the effectiveness of late-season N and take it on faith that the extra effort represents "dollars well spent". Our objective was to better define for Montana irrigated wheat producers the effects of late-season N application on grain yields and protein levels in wheat and to provide some general guidelines for the practice.

We chose to conduct the study under irrigated conditions to ensure the best consistency of results, using three varieties of hard red spring wheat: Len, Newana, and Hi-Line. These varieties were planted as replicated blocks at up to six sites across the state: the Eastern (Sidney), Northwestern (Kalispell), Southern (Huntley), Western (Corvallis), and Western Triangle (Conrad) Agricultural Research Centers and at the Post Farm in Bozeman. They were fertilized initially before planting or shortly after seedling emergence with granular urea at four rates ranging from 0 up to 150 to 300 lbs N/a depending on residual soil N analysis and yield potential for the site.

At heading, half of each N rate plot received an additional 40 lbs N/a as granular urea and the other half remained without further N application. Comparisons were made among all treatments for grain yield and protein level. Responses are reported as averages of the three varieties, since results were consistent across varieties.

Grain Yield Responses

Grain yields responded to initial N application rates at four locations in 1994 **(Table 1)**, with optimum rates of 50 to 60 lbs N/a at Bozeman and Kalispell and 100 lbs N/a or greater at Conrad and Huntley. These latter two sites were the only ones that elicited a yield response to late-season N application, on the order of 3 to 9 bu/a where initial N rates were in the responsive range. These results from Conrad and Huntley indicate that yield responses to late-season N may be expressed at N-deficient sites where strong responses to early-season N are also found. At sites with moderate yield responses to N, late-season N did not affect yield.

Table 1. Nitrogen rate and late-season application effects on irrigated spring wheat yield and protein in 1994, averaged across three varieties.

Location	Initial N rate	Grain Yield		Grain Protein		
		N applied at heading (lbs/a)				Diff.
		0	40	0	40	
	lbs N/a	--- *bu/a* ---		------------- % -------------		
Bozeman	0	83	84	13.1	14.5	1.4
	60	91	88	14.1	14.8	0.6
	120	89	91	14.4	14.7	0.3
	180	91	89	14.6	14.7	0.2
Conrad	0	54	58	10.1	13.9	3.9
	20	60	67	10.3	13.4	3.0
	95	74	77	12.3	14.3	2.0
	170	79	83	13.9	14.7	0.8
Huntley	0	22	25	8.7	15.8	7.1
	60	59	68	8.0	13.3	5.3
	120	86	93	10.5	13.2	2.7
	180	95	94	12.3	14.3	2.0
Kalispell	0	66	64	13.4	15.6	2.2
	50	67	71	14.1	15.5	1.3
	100	70	71	14.8	15.6	0.8
	150	72	70	15.3	16.0	0.7

In 1995 **(Table 2)**, grain yields responded to moderate initial N rates of at least 60 lbs N/a at Bozeman and Corvallis, 100 lbs N/a at Kalispell, and once again to higher rates of 140 to 150 lbs N/a at Conrad and Huntley. Yields were unresponsive to applied N at Sidney, perhaps due to N made available from breakdown of residues from the previous year's sugar beet crop. At most of the N responsive sites, late-season N increased grain yields only when initial N was below optimum (60 to 150 lbs N/a). Similar to 1994, these responses were on the order of 3 to 7 bu/a and did not compensate for yield deficits due to under-fertilization. Kalispell was the exception, with yield increases of 6 bu/a due to late-season N regardless of the initial N rate. This site was higher yielding than the previous year, likely due to favorable growing conditions during grain-fill which were also conducive to utilization of late-season N.

Table 2. Nitrogen rate and late-season application effects on irrigated spring wheat, grain yields and protein levels in 1995, averaged across three varieties.

Location	Initial N rate	Grain Yield		Grain Protein		
		N applied at heading (lbs/a)				Diff.
		0	40	0	40	
	lbs N/a	---- *bu/a* ----		------------ *%* ------------		
Bozeman	0	29	32	11.3	14.8	3.5
	60	49	53	11.7	14.1	2.4
	120	59	57	13.3	14.1	0.8
	180	59	61	13.8	14.1	0.3
Conrad	0	68	73	11.1	14.0	2.9
	150	99	101	13.3	13.8	0.5
	225	102	98	13.6	13.9	0.3
	300	101	102	13.7	14.0	0.3
Corvallis	0	54	61	10.9	14.0	3.1
	60	75	74	11.7	13.2	1.5
	120	75	76	13.9	14.1	0.2
	180	81	78	14.5	14.6	0.1
Huntley	20	40	46	10.3	13.2	2.9
	80	65	70	9.9	12.5	2.6
	140	72	72	11.2	13.1	1.9
	200	56	56	12.8	13.7	0.9
Kalispell	0	51	60	13.1	14.2	1.1
	50	69	75	12.1	13.7	1.6
	100	79	81	12.8	14.1	1.2
	150	75	82	13.5	14.2	0.7
Sidney	0	60	61	13.5	14.9	1.4
	60	59	63	14.1	14.6	0.5
	120	61	54	14.2	14.8	0.6
	180	55	56	14.1	14.5	0.4

Grain Protein Responses

Grain protein levels responded consistently to increasing initial N rates in 1994 (Table 1), in excess of yield responses. The low grain protein levels with low N application rates at Conrad and Huntley further indicate N deficiencies at these sites. At Bozeman and Kalispell, protein levels of 14% were attained with optimum initial N rates, but these levels were not attainable with even the very high initial N application at Conrad and Huntley.

Nitrogen application at heading increased grain protein regardless of initial N rate at all sites, though the degree of increase depended on conditions of N fertilization and initial soil N. Where initial N rates were in excess of the optimum at Bozeman, grain protein levels were increased by only 0.2 to 0.3% with late-season N application, whereas under the severely N deficient conditions at Huntley, increases as high as 7% were realized. Within these extremes, grain protein increases ranged from 0.6 to 2% due to N topdressing where initial N was near optimum for yield. Though a grower would normally expect grain protein of 11 to 12% with optimum yields, we were able to attain protein levels of 14% at all sites with a combination of initial N application optimum for yield and the addition of 40 lbs N/a at heading.

Results were similar in 1995 (Table 2). All sites except Kalispell showed some grain protein response to initial N rate, though levels of 14% were generally very difficult to attain without the addition of late-season N. Once again, late-season N increased protein levels, to some degree, in all cases, with a range of increase of 0.5 to 1.9% where initial N was optimum for yield. Protein levels of 14% were realized with late-season N application at all sites except Huntley, though N at heading was very effective in increasing protein levels at this site. The combination of an optimum rate of initial N and topdressing of 40 lbs N/a at heading consistently resulted in grain protein levels of over 13%.

Fertilizer Facts

- Grain yields do not generally respond to late-season N applications. Where early-season N applications are less than optimum, yield increases on the order of 3 to 6 bu/a may be realized with the addition of 40 lbs N/a at heading, but these responses are not sufficient to compensate for early-season deficiencies.

- Where the initial N is adequate for yield potential, grain protein is increased 0.5 to 2% by N application at heading. This response is consistent where irrigation following application ensures effective crop utilization of the late-season N.

- Across all years and sites, 40 lbs N/a applied at heading increased grain protein 1.65%.

- It is not always possible to attain high protein levels using only early-season N application, and even when it is possible, it is often inefficient compared to a program that includes late-season N. The most effective and efficient approach to N fertilization for yield and protein in irrigated spring wheat is to make an early-season (preplant or postemergence) application of N targeted for a yield potential in consideration of soil analysis, followed with an application of N at heading to increase grain protein.

- The decision to make the late-season N application should be supported with a diagnostic assessment of likelihood for protein response based on flag leaf analysis, covered in Fertilizer Facts #12.

- Dryland wheat producers have more risk associated with late season N applications due to the high variability in the likelihood of adequate precipitation shortly after application.

Edited by Jeff Jacobsen, Extension Soil Scientist