OPTIMIZING NITROGEN USE AND EVALUATING ETHEPHON USE IN WAXY BARLEY

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Introduction

The Food and Drug Administration has ruled that barley could have the same health food claim as oats, in that, if enough beta-glucan soluble fiber was consumed, it would reduce the risk of coronary heart disease (Federal Register 2005). A high beta-glucan variety, 'Salute', is available from Western Plant Breeders. Western Plant Breeders applied for plant variety protection on February 26, 2007, which is currently pending (U.S. Plant Variety Protection Office). Waxy starch (lower amylase, more amylopectin) is another favorable trait that may increase demand for food barley and is currently available in released varieties. It has properties that may benefit the snack food industry, such as longer shelf life and crispier texture. Higher protein barley may also be beneficial as it would increase the nutritional value of the grain.

'Merlin' and Salute, spring genotypes developed by WestBred (Bozeman, MT), are among the best adapted waxy cultivars available for the Treasure Valley (Brown 2006). Whereas spring genotypes are currently available, a fall barley genotype would be considerably more productive in the Treasure Valley system. Unfortunately, there are currently no fall waxy barley cultivars available. The fall planting of spring genotypes has been evaluated, but fall planting involves considerable risk of winter kill.

Little research has evaluated nitrogen (N) management for growing waxy barley varieties to optimize both higher protein and beta-glucan soluble fiber content. Research is needed to help producers know how to apply N for optimum yield, protein and soluble fiber, yet prevent groundwater contamination from excessive nitrate. This report summarizes trials over 2 years to determine winter survival of 2 fall-planted spring waxy barley varieties, compare yield and quality under different N treatments applied in late winter and at heading, and to evaluate Ethephon growth regulator to reduce lodging.

Methods

Experimental methods for the first year of the experiment have been published (Norberg et al. 2007). The experiment in 2007 was planted on an Owyhee silt loam at the Malheur Experiment Station following potatoes in 2006. A similar experiment was planted at the University of Idaho, Parma Research and Extension Center, but is not reported here. Soil samples were collected prior to fall tillage and showed 55 ppm phosphorus (P) (Olson method), 310 ppm potassium (K), 14 ppm sulfate (SO_4), 2,765 ppm calcium (Ca), 337 ppm magnesium (Mg), 2 ppm zinc (Zn), 3 ppm iron (Fe), 2 ppm manganese (Mn), 0.5 ppm copper (Cu), 0.6 ppm boron (B), 1.72 percent organic matter, and 44, 20, and 24 lb/acre available N in the first, second, and third foot of soil, respectively. In the fall prior to tillage, 2 lb/acre B and 200 lb/acre elemental sulfur fertilizer were applied to the field. Soil mineralization bags were placed in the control plots at the 0- to 1- and 1- to 2-ft depths on April 11, 2007 as described by Westermann and Crothers (1980). One set of mineralization bags was pulled at the same time that the flag leaves were sampled. The second set was pulled at harvest time.

Seedbed preparation included disking, cultivating, and furrowing. The field was planted on October 20, 2006 with a plot drill on 30-inch beds with 3 drill rows per bed. The plant stand was estimated visually on March 12, 2007. We determined at that time that replanting was required and that occurred on March 14 and 15. To eliminate the old stand, Roundup® was sprayed at 1.5 qt/acre in conjunction with Buctril® herbicide at 1 qt/acre for weeds on March 15, 2007.

The experimental design was a randomized complete block design with three replications. The treatment design was a split, split, factorial plot design. Year was considered as the whole plot, with variety being the subplot. Within variety, there was an incomplete factorial design consisting of combinations of late winter N rate and heading stage N treatments. To overcome the confounding effects of late winter N applications on the experiment, only the control heading treatment were included in the analysis. A complete analysis of all factors was also done to determine heading treatment effects and interactions with heading treatments. Late winter applications consisted of 0, 60, 120, or 180 lb N/acre applied by hand on February 20 and 23. Where Merlin and Salute received late winter application of 180 lb N/acre, the grain did not receive any further treatments.

Spring applications at 50 percent heading were made on May 30 at 0, 40 lb N/acre as topdressed dry urea, 40 lb N/acre as foliar liquid urea, or 40 lb N/acre as foliar liquid urea plus ethephon. Ethephon 2 (ethephon) Micro Flo Co. LLC) was applied at the boot stage at a rate of 2.0 pt/acre on May 12 prior to head emergence.

Thirty flag leaves were sampled from each plot on May 24 and sent to Brookside Laboratory, New Knoxville, Ohio, for analysis. Twenty of those flag leaves were measured individually with a SPAD meter (chlorophyll meter) for greenness on the same day.

The trial was furrow irrigated for 24 hours on April 26, May 15, May 30, and June 14. Plant height was measured on June 13, 2007. Plots were cut to size and harvested with a Hege combine on July 18 and 19. Yield and protein were corrected to a 12 percent moisture basis, using 48 lb = bushel.

Response variables were compared using GLM ANOVA and least significant differences at the 5 percent probability, LSD (0.05). Differences between response variables should be equal to or greater than the corresponding LSD (0.05) value before means are considered different from others.

Results

Planting spring genotypes in fall of 2006 resulted in failed plant stands coming out of the winter. Merlin had a 12 percent stand, whereas Salute had only 3 percent stand. Spring replanting after eliminating the fall planted barley resulted in excellent stands. Results for 2007 are based on this spring planting.

Yield of barley varieties was affected differently by interactions of years and late winter N rates (Fig. 1), combinations of years and varieties (Table 1), and by combinations of years, varieties, and N rate (Fig. 2). In 2007, the average yield of Merlin was 39.6 bu/acre more than Salute. Averaged over years, Salute's yield peaked at 60 lb N/acre, whereas Merlin peaked at 120 lb N/acre. In 2007, the application of Ethephon increased Salute yield by 24.9 bu/acre. This increase in Salute yield occurred as lodging was near 100 percent in many of the higher N-rate plots (Table 2). The lodging decreased test weight and increased the number of seeds per pound. Lodging was not eliminated by Ethephon treatments but it was reduced from 37 to 22 percent (Table 4).

Seeds per area responded to increasing N rate very similarly to yield (Fig. 1). Seeds per area followed trends in yield for different combinations of years and varieties (Table 1). Applying 40 lb N/acre at heading increased the number of seeds per area by 7 percent compared to the control (Table 3). Applying Ethephon increased the seed number per area 8 percent over foliar N alone. Merlin responded to Ethephon by a decreasing seed weight (increased number of seeds per pound) whereas Salute did not (Fig. 3). Test weight was also decreased by the fluid urea plus ethephon application treatment and the dry N treatments when N rate is increased (Fig. 4).

Merlin plant height increased 8.2 inches by increasing N rate from 0 to 180 lb/acre, compared to only 3 inches of increased growth for Salute over the same range of supplemental N. Averaged over years and N rates, Merlin was 26.3 inches tall compared to Salute at 40.4 inches tall. Applying N at heading actually slightly reduced plant height for Salute, but not for Merlin (Table 6). Applying Ethephon to Salute reduced plant height on average 3.2 inches compared to 2 inches for Merlin (Table 5).

Grain protein was influenced by year, variety, N rate and N at heading, and Ethephon application (Table 3). Grain protein was 2.2 percent higher in 2006 than 2007. Merlin was 0.8 percent higher in protein content than Salute. Increasing the N rate from 0 to 180 lb/acre increased grain protein from 10.0 to 12.9 percent. Applying 40 lb/acre N dry or fluid at heading increased protein consistently about 1 percent. Applying Ethephon decreased grain protein content by 0.4 percent.

Beta-glucan content was increased by dry N at heading in 2006 compared to the control, but not significantly in 2007 (Table 4). The combination of fluid N plus Ethephon decreased beta-glucan compared to the control (Fig. 5). In 2007, fluid N plus Ethephon increased beta-glucan content compared to the control.

Total leaf N and SPAD (chlorophyll) were impacted by the interaction of variety by year and N rate (Fig. 6). Both total leaf N and SPAD had a more linear response in 2007. The response may have been more linear since leaf concentrations were lower in 2007. Soil samples show less N was available in 2007 (Table 7). In 2007, grain proteins were lower than in 2006. Total leaf N had a strong significant relationship with grain protein ($R^2 = 0.79$) (Fig. 7).

Conclusion

As shown in 2006-2007, neither Merlin nor Salute had enough winter hardiness to be planted in the fall in the Treasure Valley without risking significant winter kill. Merlin has more desirable agronomic characteristics than Salute. Merlin is shorter than Salute and exhibits less lodging in higher fertility conditions. Grain protein content and test weight of Merlin was consistently higher than Salute. In this experiment Merlin out-yielded Salute at higher fertility levels. Total N fertilizer required to maximize yield for Merlin in the 2 years of this study was 120 lb N/acre while only 0 to 60 lb N/acre were needed for Salute. Ethephon reduced lodging and can potentially increase yields when lodging is present. More research should be done before recommendations can be made for producing high protein barley based on total leaf N and flag leaf. Our data show that the total leaf N content was a good indicator of grain protein at harvest.

Acknowledgements

This research was supported by grants from the Oregon Grains Commission and USDA, Barley for Rural Development.

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Table 1. Barley yield and seeds per area as influenced by years and varieties and averaged over late winter nitrogen rate, Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

Year	Variety	Yield	Seeds per area
		bu/acre	Seeds ft^2
2006	Merlin	97.3	1,336
	Salute	103.4	1,324
2007	Merlin	123.2	1,336
	Salute	83.6	947
LSD (0.05)		11.3	147

Table 2. Barley lodging, test weight, and seed weight as influenced by years, varieties, and late winter nitrogen rate, Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

Year	Variety	N rate	Lodging	Test weight	Seed weight
		lb N/acre	%	lb/bu	no. seeds/lb
2006	Merlin	0	0	61.9	9,476
		60	0	61.4	9,790
		120	0	61.8	10,081
		180	0	61.4	10,436
2006	Salute	0	0	53.3	9,187
		60	0	53.5	9,216
		120	0	53.5	9,447
		180	0	53.0	9,288
2007	Merlin	0	0	59.4	10,049
		60	0	60.7	9,592
		120	3	61.2	9,825
		180	35	61.1	9,972
2007	Salute	0	30	50.8	10,174
		60	98	50.4	9,749
		120	100.0	49.3	10,692
		180	100.0	48.7	10,677
LSD $_{Y \times Var \times N}$ (0.05)			16	1.2	546

Table 3. Barley yield, grain moisture, SPAD meter reading, plant height, lodging, test weight and seed weight as influenced by years, varieties, and late winter nitrogen rate, Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

Main effect		Yield	Seeds per area	Seed weight	Test weight	Protein	Moist-ure	Spad	Plant height	Lodging	Total leaf N	Beta-glucan
		bu/acre	no./ft^2	no. seeds/lb	lb/bu	%	%		inches	%	%	%
Year:	2006	100.3	1,330	9,915	57.5	12.5	7.6	47.6	33.9	0.0	3.9	5.6
	2007	103.4	1,142	10,091	55.2	10.3	8.7	43.4	32.8	45.8	3.3	5.3
	LSD (0.05)	NS	NS	NS	0.4	0.7	0.3	1.1	NS	5.6	0.1	NS
Variety:	Merlin	110.2	1,336	9,903	61.1	11.8	9.1	48.4	26.3	4.8	3.7	5.4
	Salute	93.5	1,135	9,804	51.6	11.0	7.2	42.7	40.4	41.0	3.5	5.4
	LSD (0.05)	7.7	91.4	NS	0.4	0.7	0.3	1.1	0.8	5.6	0.1	NS
Late winter N rate:	0 lb/acre	89.5	1,062	9,722	56.3	10.0	8.2	40.0	29.8	7.5	2.8	5.3
	60 lb N/acre	107.8	1,278	9,587	56.5	10.7	8.1	44.3	33.2	24.6	3.5	5.3
	120 lb N/acre	108.2	1,337	10,011	56.4	11.9	8.3	47.1	35.0	25.8	3.9	5.9
	180 lb N/acre	101.9	1,266	10,093	56.1	12.9	8.0	50.7	35.5	33.8	4.2	5.5
	LSD (0.05)	10.9	129.2	273.1	NS	1.0	NS	1.6	1.2	7.9	0.2	NS
Heading trt:	Control	101.8	1,226	9,773	56.4	10.9	8.2	N/A[a]	32.7	19.3	N/A	5.4
	40 lb N/acre dry urea	109.4	1,307	9,683	56.6	11.9	8.1	N/A	32.0	14.4	N/A	5.7
	40 lb N/acre liquid urea	108.9	1,311	9,722	56.4	12.0	8.0	N/A	32.0	18.3	N/A	5.7
	40 lb N/acre liquid urea plus Ethephon	115.0	1,411	9,952	56.5	11.6	8.2	N/A	29.4	11.2	N/A	5.4
	LSD (0.05)	5.6	74	131	NS	0.4	NS	N/A	0.8	6.5	N/A	0.3

[a] N/A = Not appropriate since treatment came after measurement.

Table 4. Barley lodging, seed weight, and beta-glucan as influenced by years and heading applications, and averaged over varieties and late winter nitrogen rate, Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

Year	Heading applications	Lodging	Seed weight	Beta-glucan
		%	no. seeds/lb	%
2006	Heading trt: Control	0.0	9,533	5.6
	40 lb N/acre dry urea	0.0	9,568	6.1
	40 lb N/a liquid urea	0.0	9,644	5.8
	40 lb N/a liquid urea plus ethephon	0.0	9,922	5.2
2007	Heading trt: Control	38.6	10,014	5.2
	40 lb N/acre dry urea	28.8	9,798	5.4
	40 lb N/a liquid urea	36.6	9,801	5.5
	40 lb N/a liquid urea plus ethephon	22.3	9,981	5.6
	LSD $_{\mathrm{Y\,x\,Trt}}$ (0.05)	9	186	0.4

Table 5. Barley grain moisture and plant height as influenced by varieties and late winter nitrogen rate, and averaged over years, Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

Variety	Late winter N rate	Grain moisture	Plant height
	lb/acre	%	inches
Merlin	0	9.4	21.5
	60	8.7	25.7
	120	9.3	28.6
	180	9.2	29.7
Salute	0	7.1	38.2
	60	7.5	40.7
	120	7.3	41.5
	180	6.9	41.2
	LSD (0.05) $_{\mathrm{V\,x\,N}}$	0.5	1.7

Table 6. Barley plant height as influenced by varieties and heading applications and averaged over years and late winter nitrogen rate, Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

Variety	Heading application	Plant height
		inches
Merlin	Control	25.2
	40 lb N/acre dry urea	25.1
	40 lb N/acre liquid urea	25.3
	40 lb N/acre liquid urea plus Ethephon	23.3
Salute	Control	40.1
	40 lb N/acre dry urea	38.9
	40 lb N/acre liquid urea	38.7
	40 lb N/acre liquid urea plus Ethephon	35.5
	LSD (0.05) $_{V \times Trt}$	1.2

Table 7. Nitrogen available to the experiment from soil tests and mineralization bags. Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

Available N in the top 2 ft	2006		2007	
	lb/acre	date	lb/acre	date
A. At fall planting to 2 ft	72	1/10/05	64	10/04/06
B. Amount mineralized early mid-April to 50% heading (flag-leaf sampling)	60	4/17/06 to 5/31/06	8	4/11/07 to 5/30/07
C. Amount mineralized from 50% heading to harvest	56	5/31/06 to 7/10/06	24	5/30/07 to 7/18/07
Total mineralized (B+C)	116		32	
Total available (A + total mineralized)	188		96	

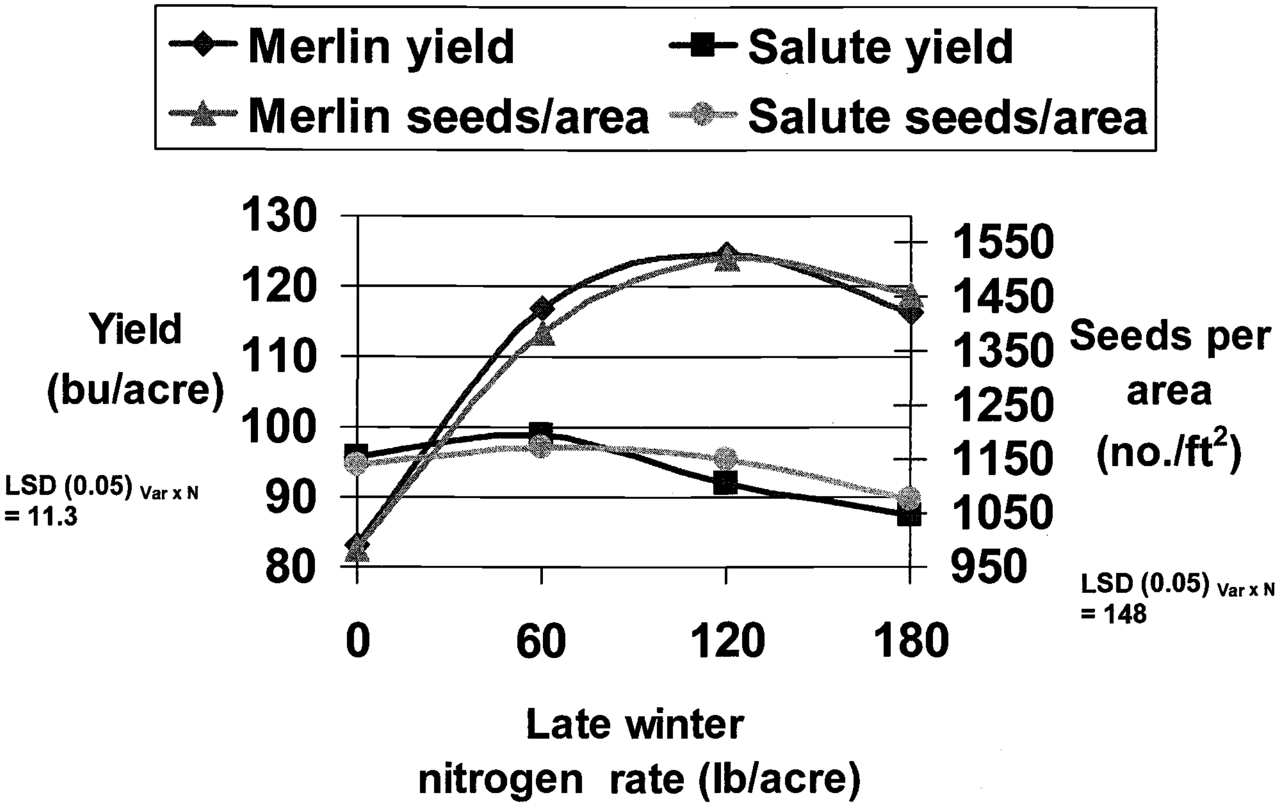

Figure 1. Yield and seeds per area of barley as influenced by variety and late winter N application rate (lb N/acre urea), and averaged over years, Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

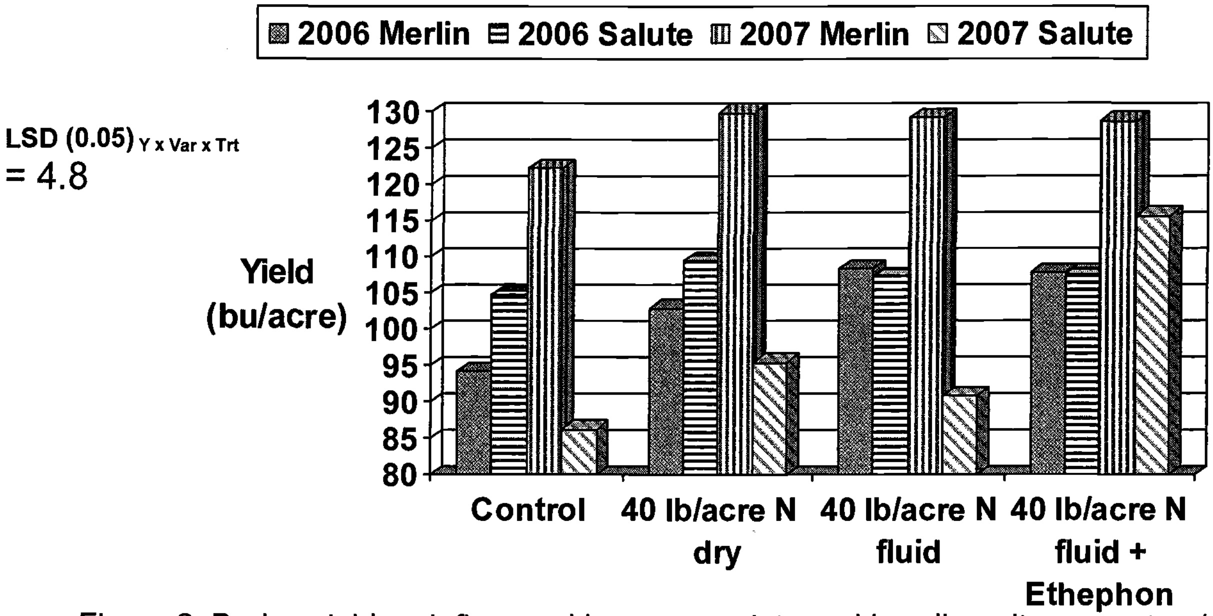

Figure 2. Barley yield as influenced by year, variety and heading nitrogen rates (dry and fluid urea, and Ethephon) averaged over late winter N rate at Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

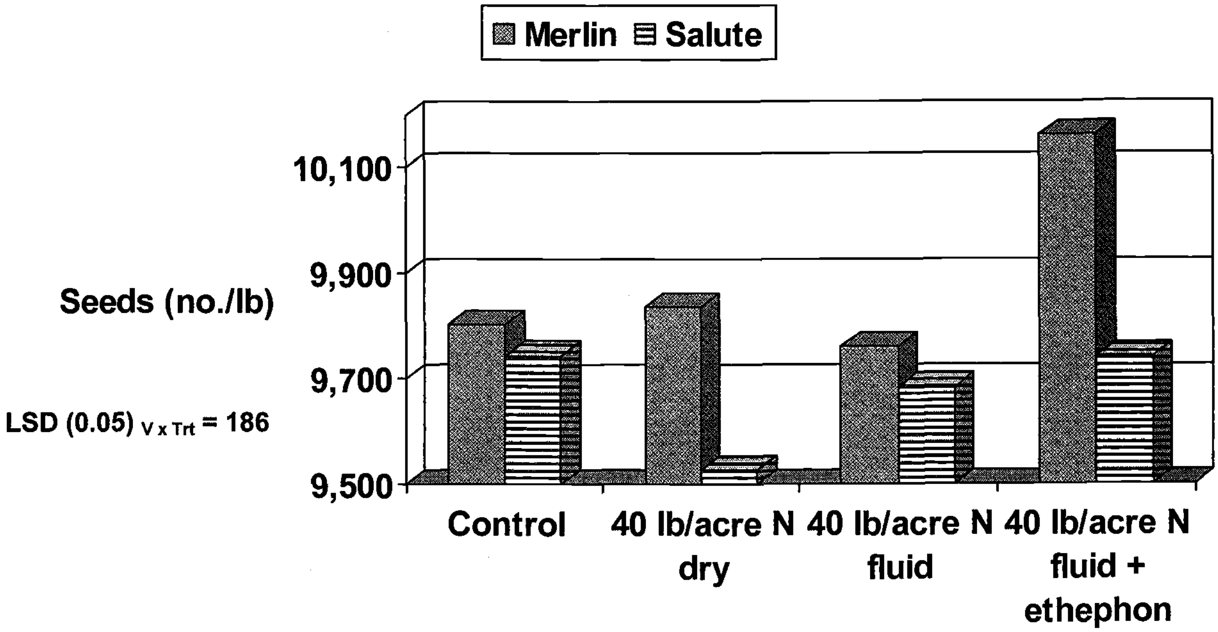

Figure 3. Seed weight (seed no./lb) of barley as influenced by heading applications of nitrogen and ethephon and averaged over years, varieties, and late winter N application rate (lb N/acre urea), Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

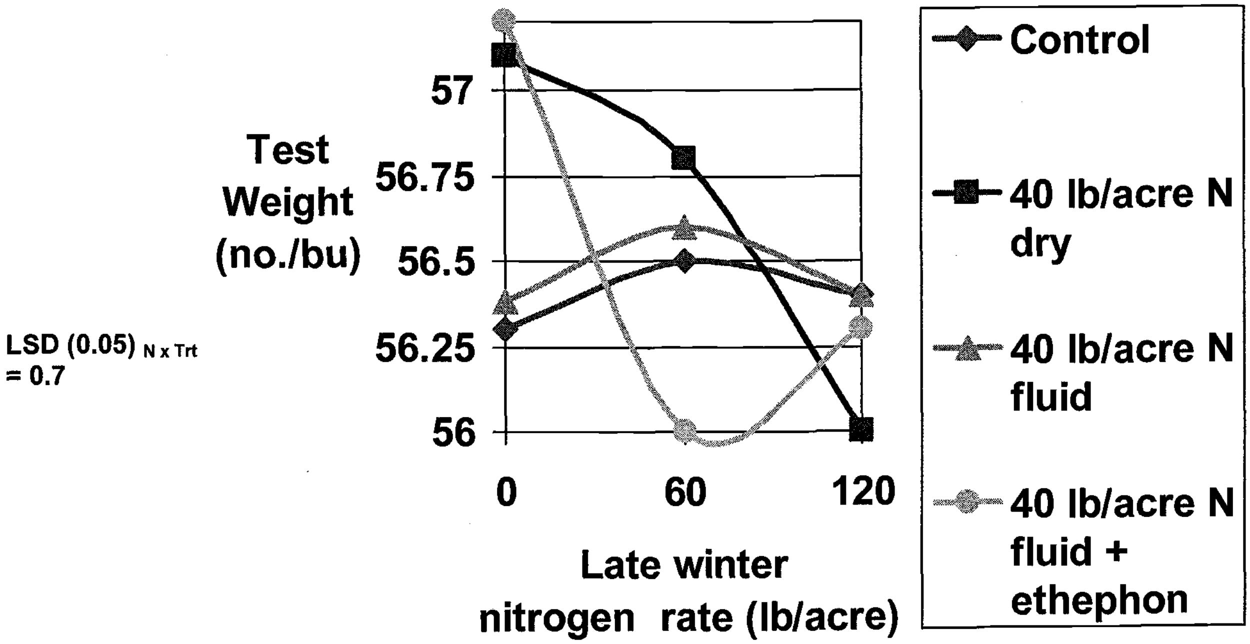

Figure 4. Test weight (seed no./lb) of barley as influenced by late winter N application rate (lb N/acre urea), heading applications of nitrogen, ethephon and averaged over years and varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

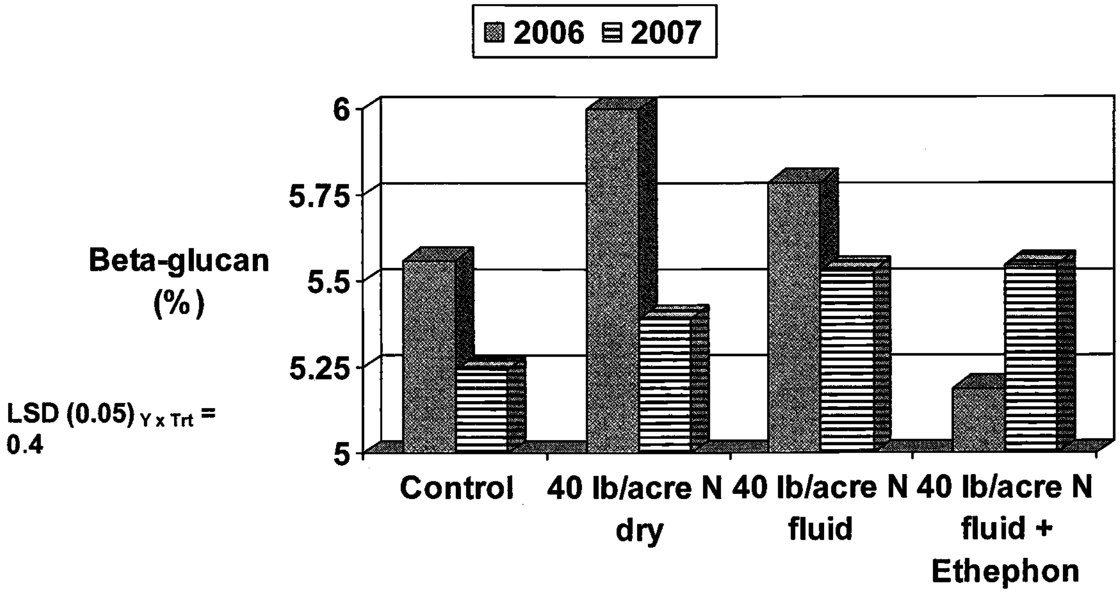

Figure 5. Beta-glucan content of barley as influenced by heading applications of nitrogen and ethephon and averaged over years and varieties, and late winter N application rate (lb N/acre urea), Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

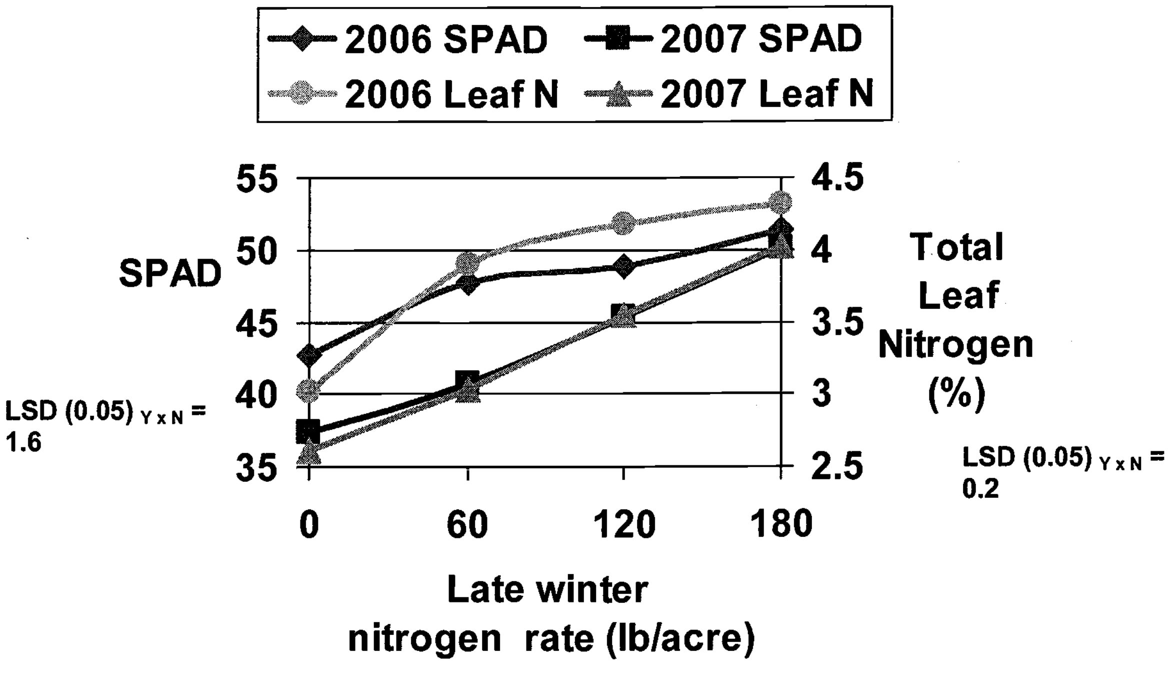

Figure 6. Total leaf nitrogen content and SPAD meter readings of barley as influenced by late winter N application rate (lb N/acre urea) and averaged over years and varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.

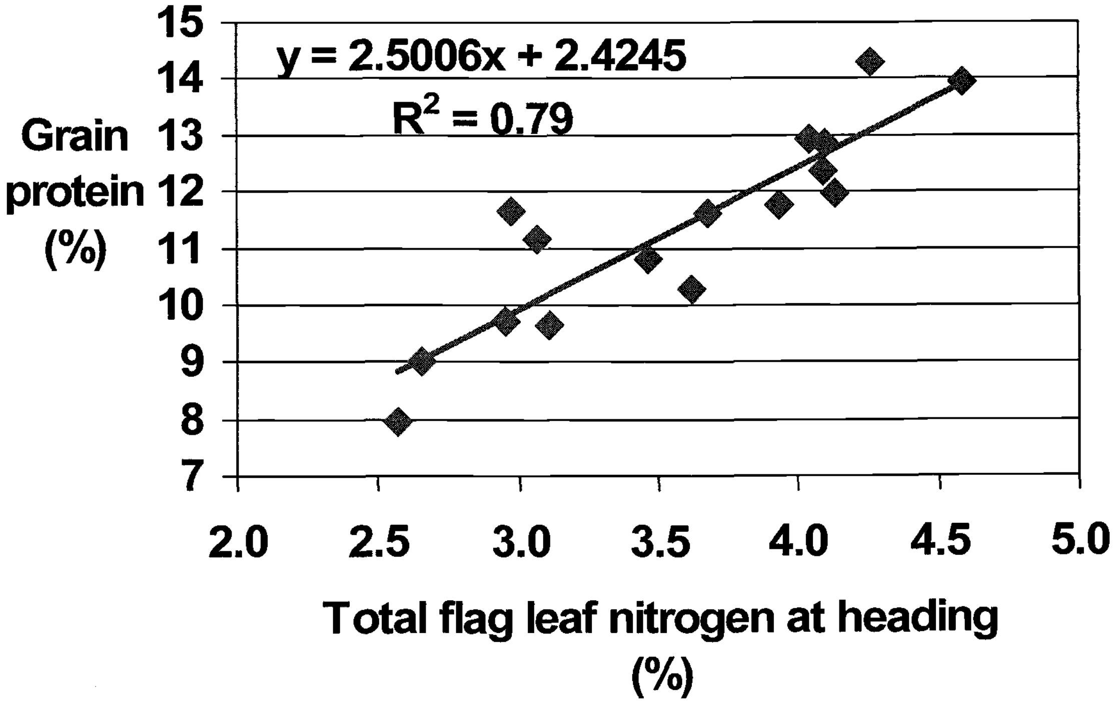

Figure 7. Relationship of total leaf nitrogen content with grain protein in barley. The means from the year and N rate means averaged over varieties was used, Malheur Experiment Station, Oregon State University, Ontario, OR, 2006 and 2007.