MT-S
1986

TITLE: Maximum barley production under varying soil moisture regimes

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PROJECT DURATION: March 1985 - January 1988

EXPERIMENTAL LOCATION: 3 sites in south central Montana

OBJECTIVES:

1. To determine the effect of soil moisture on barley response to N and P fertilization applied in different rate combinations and using different fertilizer placements.

2. To develop fertilizer N - water production functions for barley.

3. To determine if growth regulators, and other intensive crop mangement practices are needed for maximum production under adequate soil moisture and high N fertility conditions.

4. To initiate a yield goal of 130 bu/a under adequate soil moisture conditions.

5. To develop efficient fertilizer management practices for barley which can be applied to a wide range of climatic conditions.

RESULTS, DISCUSSION, AND CONCLUSIONS:

Objective 1:

Fertilizer P studies

A fertilizer P placement-water regime study was established in 1986 on property of the Southern Agricultural Research Center. Early season moisture conditions, crop emergence and stand establishment were excellent at this site. The moisture regimes were created with a line-source sprinkler system. Irrigation water was applied on five dates during the growing season. The study incorporated two P rates, and three placements (broadcast + incorporation, deep-banding, seed-placed or seed banding). The sodium bicarbonate extractable P level at this site tested 8 ppm. At this soil test level and using extractable P - yield potential curves for a wheat-fallow system the yield potential is estimated to be at 75% of the maximum. (Halvorson, A. Soil test and P rate relationships to maximum yield. Maximum wheat yield research systems workshop. Denver, March, 1986). This would appear to indicate a potentially large P responsive site. However, grain yield results across the four soil moisture regimes showed no improvement with application of fertilizer P (Table 1). Test weight results were also not affected by P fertilization (data not shown). Because there was no significant yield increase from P fertilizer we cannot draw any conclusions about the relative efficiency of the different fertilizer P application methods (objective 5).

While the lack of response to P fertilizer at this site was disappointing the results are consistent with fertilizer studies we have conducted in the previous two years. Previous experience with P fertilization studies has shown it difficult to predict, based on the $NaHCO_3$ test, the likelihood of observing a response to P fertilization. There would appear to be a need for improvement in P testing procedures in our region.

Fertilizer N studies

A fertilizer N rate - water regime study was conducted on a farm cooperator's field near Ballantine, Montana. The site tested low in N. Nitrate-N levels in the upper 24" were equivalent to 35 lbs N/a (6.7 ppm N, 0-12"; 2.2 ppm 12-24"). All treatments, except the control, received 15 and 34 lbs/a of seed-placed N and P (as 18-46-0). The control treatment received 34 lbs/a of seed-placed P (as 0-45-0). Nitrogen rates above 15 lbs/a were established by applying appropriate level of urea in a deep-band (4" depth) at planting. Moisture regimes were created with a line-source sprinkler system. Irrigation water was applied on five dates during the growing season.

Grain yield results indicated a very large and significant response to the applied water and N fertilizer levels (Table 2). The response from fertilizer N was over 80 bu/a within the wettest soil moisture regime (13.5"). Within individual N levels yield differences across the four water regimes increase as N fertilizer level increased. For example at the 225 lbs/a N level yield differences between the 13.5" and 5.1" moisture regimes were equivalent to 73.1 bu/a. At the 0 N level the yield

difference was only 13.2 bu/a. This effect can be attributed to increased consumptive water use rates by the N fertilized plants.

Grain protein levels were also effected by N and water at this site (Table 3). Within the two driest regimes, N fertilization increased grain protein until a plateau was achieved. Within the two wettest regimes initial fertilizer N applications, upto 50 lbs/a, decreased or had no effect on grain protein. Above 50 lbs/a fertilizer N increased grain protein until a platea was achieved. The plateau level for the four moisture regimes increased as moisture decreased. Highest grain protein levels were achieved under high N fertility within the 5.1" moisture regime.

Grain test weight was affected by N fertilization in only the two driest regimes (Table 4). In the two driest regimes N fertilization tended to decreased test weight. This effect may in part be explained by differences in water use amoung the N fertilizer treatments. Nitrogen fertilization on N deficient sites will increase water consumption. This may lead to greater drought stress during the ripening period where moisture is limiting, and inturn kernels which are lighter and less plump.

Table 1. Effect of water and P fertilization on barley production levels. Southern Agricultural Rearch Center, 1986.

Phosphorus treatment		Growing season precipitation (irrigation + rainfall, inches)			
Placement	Rate	12.1"	9.4"	6.9"	4.5"
		bu/a			
-	0	98.6	88.6	49.6	28.9
bci @	10	94.8	89.8	54.6	27.9
	20	98.1	90.5	50.3	29.2
db #	10	92.7	90.3	50.1	26.3
	20	100.7	87.7	53.7	32.0
sp &	10	104.1	85.7	56.5	36.6
	20	99.8	86.1	48.0	33.1
sp+db	10+10	96.0	90.8	50.0	32.3
Mean		98.1	88.7	51.6	30.8
LSD (0.05)		6.8	ns	ns	ns

@ bci=broadcast and incorporated with surface (0-4") 0-45-0
# db=deep-banded (6") phosphoric acid
& sp=seed-placed 0-45-0

Table 2. Effect of water and N fertilization on barley grain yield. Oblander farm. Balantine, Montana. 1986.

Nitrogen fertilizer level	Growing season precipitation (irrigation + rainfall, inches)			
	13.5"	11.3"	6.9"	5.1"
	bu/a			
0	33.6	33.7	26.2	20.4
15	44.2	44.2	39.8	26.5
50	77.8	76.5	56.4	37.7
85	97.8	87.2	59.6	37.0
120	103.7	94.1	62.3	40.1
155	106.8	95.4	63.3	42.7
190	109.2	98.5	60.3	37.7
225	115.3	102.0	65.1	42.2
LSD (0.05)	7.5	6.9	4.0	4.3

Table 3. Effect of water and N fertilization on barley grain protein. Oblander farm. Balantine, Montana. 1986.

Nitrogen fertilizer level	Growing season precipitation (irrigation + rainfall, inches)			
	13.5"	11.3"	6.9"	5.1"
	% protein			
0	8.7	8.8	9.1	10.3
15	8.6	8.7	9.9	10.5
50	7.8	8.9	10.9	12.9
85	8.9	10.0	12.2	14.9
120	10.4	11.2	13.5	15.7
155	11.1	12.2	14.3	16.2
190	11.4	12.8	14.4	16.7
225	11.9	12.8	14.8	16.5
LSD (0.05)	0.7	0.7	0.8	0.9

Table 4. Effect of water and N fertilization on barley grain test weight. Oblander farm. Balantine, Montana. 1986.

Nitrogen fertilizer level	Growing season precipitation (irrigation + rainfall, inches)			
	13.5"	11.3"	6.9"	5.1"
	lbs/bu			
0	52.0	51.7	52.1	48.3
15	52.2	52.4	51.9	45.6
50	52.1	52.0	49.8	44.0
85	52.6	52.1	49.2	43.5
120	52.5	52.2	49.2	42.9
155	52.6	51.7	49.0	43.9
190	51.8	51.6	48.6	43.1
225	51.7	51.6	48.6	43.2
LSD (0.05)	ns	ns	0.9	1.9

Objective 2

Using the grain yield data from the N fertilizer-water study (Table 2) regression equations or crop production functions were developed relating yield to irrigation applied and fertilizer N. A quadratic type equation of the type indicated below was used:

$$\text{Yield} = \text{Intercept} + a\,N + b\,W + c\,N^2 + d\,W^2 + e\,N^2$$

were yield is expressed in bu/a, N is the fertilizer N (lbs/a) applied; W is the irrigation applied (inches); and a, b, c, d, and e are regression coefficients.

Using the regression equation above (Table 5) maximum economic yields (MEY) can be computed across a wide range of moisture regimes. At the MEY level return from fertilizer N is maximized and additional N does not increase yield sufficient to recover the cost of the applied fertilizer N. The MEY level will be influenced by the ratio of N cost to barley price. In the example below (Table 6) a ratio of 0.11 was used, i.e. N was priced at $ .22/lb and barley at $2.00/bu. As anticipated MEY level and its N fertilizer requirement increased with growing season moisture. However, the rate of increase in MEY decreased with each inch of additional water. For example, grain yield increased 11.2 bu/a from 5" to 6" of water, but only 5.5 bu/a from 12" to 13" of moisture. Fertilizer N requirement increased at a constant rate. With every inch of additional growing season

Table 5. Regression coefficients relating yield (bu/a) to fertilizer N applied (lbs/a), and irrigation water applied (inches).

Variable	Estimate	F value (significance)
Intercept	18.0	**
N	0.436	**
N^2	-0.00163	**
W	7.23	**
W	-0.572	**
N * W	0.0327	**
R squared	0.97	

** Significant at or below 0.01 level

Table 6. Effect of growing season precipitation on maximum economic yield and associated fertilizer N requirement, and ratio of fertilizer and total N (soil N + fertilizer N) to bushel of grain produced.

Growing season precipitation	Maximum economic yield (MEY)	Nitrogen relations at MEY point		
		Fertilizer N needed	Fert N: bushel	Total N: bushel
inches	bus/acre			
13	112.0	181	1.6	1.8
12	106.5	171	1.6	1.8
11	100.2	161	1.6	1.8
10	93.1	151	1.6	1.8
9	85.2	141	1.7	1.9
8	76.4	131	1.7	2.0
7	66.9	121	1.8	2.1
6	56.5	111	2.0	2.3
5	45.3	101	2.2	2.7

precipitation the fertilizer N requirement was raised by 10 lbs/a. This value was lower than was observed in N fertilizer-water studies of the previous two years. In 1984 and 1985 the fertilizer N requirement was observed to increase 13 and 18 lbs/a, respectively, with each inch of additional growing season moisture. The lower rate of change in fertilizer N requirement in 1986 was indicative of the good growing conditions and higher yield potentials observed this past year relative to the previous two. The ratio of fertilizer N and total N (soil N + fertilizer N) to bushel of grain produced at the MEY point was higher under condition of drought compared to the wet moisture conditions. This indicates that as growing season precipitation increased N became more efficient.

Objective 3 and 4

An intensive crop management study was estabished in 1986 on a farmer-cooperator's field near Huntley, Montana. This study was intiated to to address specifically objectives 3 and 4. The study incorporated three row spacings (4", 6" and 12"), three seeding rates (20, 25, and 30 seeds/ft^2), and four barley varieties (Menuet, Movarian III, Klages, and Clark) in complete factorial arrangement. In addition, two of the varieties, Menuet and Klages, were treated with and without the growth regulator cerone. Fertilizer N, P, and K was broadcast applied and incorporated at a rate of 130, 45, and 40 lbs/a in the fall of 1985. An additional, 100 lbs/a of N (34-0-0) was applied when the barley was tillering (Feekes growth stage 3-4). The study was conducted on a flood irrigated site. Irrigation was applied at jointing and shortly after the heads had completely emerged. A total of 7.3" of precipitation was received during the growing season.

Barley crop production levels (Table 7) were well below the yield goal level of 130 bu/a. Plant emergence, tillering, and stand establishment were excellent at this location. Production levels were affected by lodging, grasshoppers, and deer. Under the conditions of this study yield levels were not affected by row spacing, and no consistent relationship exists between seeding rate and yield amoung the four varieties.

Grasshoppers were a severe problem in south central Montana and affected barley production at this site in 1986. Lodging occurred amoung all varieties after the second irrigation event. Lodging was most severe for Clark, Klages, and Moravian III. Menuet exhibited the least amount of lodging. This result was not surprising as our experience at the Southern Agricultural Research Center has shown Menuet to exhibit good straw strength relative to most other varieties. Though Menuet lodged less than the other varieties, it yielded well below the other three. This result can be explained by the foraging activity of deer. During the three weeks prior to harvest numerous deer invaded our plots during the evening and night. The preference by the deer was for the barley that remained most upright, i.e. Menuet. In many of the plots over 70% of the heads had been lost by the time the

grain was ready to harvest. Application of cerone to Klages and Menuet reduced the lodging index (Table 8), and in the case of Menuet reduced the foraging losses (increased barley yield 27.4 bus/a) from deer. This latter phenomena was a result of the angle of the barley heads. Heads and awns on Menuet which received cerone remained more upright, thus leading to less foraging activity by deer.

Objective 5

Results from the ferlizer N - study indicate that MEY increased at a curvilinear, second order, rate with growing season water. The fertilizer N requirement needed to obtain the MEY level increased at 10 lbs N/inch increase in moisture. The ratio of fertilizer N required to bushel of grain produced at the MEY level was fairly constant (1.6-1.7) over 8-13" of growing season moisture. Under more droughty conditions, the ratio increased as moisture decreased. This indicates that fertilizer N efficiency at the MEY level decreased as moisture dropped below 8".

YIELD LIMITING FACTORS OBSERVED THIS YEAR:

Phosphorus placement-water regime study. Barley was seeded at this site on May 5. This is somewhat later than normal and yields may have been improved had we been able to seed earlier. Fertility levels for nutrients other than P were all considered adequate. Moisture was maintained at an adequate level in the wettest moisture regime as determined by neutron probe. Grasshoppers were a factor at this site, however spraying seemed to control this problem. Maximum yields were over 100 bus/a at this site.

Nitrogen rate-water regime study. Some lodging occurred at the 190 and 225 lbs N/a treatments. Yield losses from lodging were probably small however, i.e. less than 10 bus/a. Grasshoppers were severe problem at this site, however twice-weekly spraying seemed to control this problem. The highest yielding plot in an individual replication was 130 bu/a for the 225 lbs N/a treatment. The 116 bu/a mean treatment yield (225 lbs N/a) observed at this was the highest yield we observed this year. In general, this trial was the most successful one we have established in the past three years. There were no specific factors we could pinpoint as limiting yield. We feel we achieved for the variety Clark its yield potential (or very close to it) when grown under the south central Montana environment.

Intensive crop management study. As noted above lodging, grasshoppers and deer were a problem at this study. The yield losses from deer were tremendous and caught us totally by surprise.

Table 7. Effect of row spacing, seeding rates, and variety on barley grain yield. Gabel farm. Huntley, Montana. 1986.

Row spacing	Seeding rate	Variety			
		Moravian	Menuet	Clark	Klages
inches	seed/ft^2				
4	20	89.9	68.6	109.6	74.1
4	25	90.7	72.8	105.8	83.4
4	30	93.3	75.3	108.1	78.7
6	20	87.3	57.5	102.7	82.3
6	25	83.8	64.4	99.0	91.4
6	30	86.5	67.0	103.2	80.4
12	20	85.0	47.5	108.3	81.3
12	25	87.9	70.5	108.5	88.9
12	30	87.3	66.8	109.1	86.5
Means		88.0	65.6	106.0	83.0

L.S.D (0.05): Variety means = 12.7
Variety*seeding rate = 6.9

Table 8. Effect of cerone on grain yield, test weight, and lodging index of Klages and Menuet.

Variety	Cerone	Grain yield bus/a	Test weight lbs/bus	Lodging Index@
Klages	-	82.8	49.1	5.18
	+	88.6	49.6	0.50
Menuet	-	65.3	51.6	2.08
	+	92.7	51.8	0.00
		LSD (0.05) Cerone (within each variety)		
		11.6	ns	1.49

@ Lodging index = S * I * 0.2
S is surface area lodged, 0-9 scale
(0=no lodging, 9=100% lodged)
I is intensity of lodging, 0-5 scale
(0=completely upright, 5=completely flat)

PLANNED CHANGES FOR NEXT YEAR:

No big changes are planned next year for the P-water and ICM studies as related to treatment variables. Site selection will be changed next year. We need to find a site were we can be reasonable be sure of having a P response. The ICM study will be conducted at the experiment station and away from our native white-tail deer population. The N-water study was seeded to winter wheat this past fall. The reason for this was to spread the work load and to see if we could minimize the number of hours spent spraying insecticide for grasshopper control. It has been our experience the past two years that grasshopper activity and resulting damage is particularly severe in barley relative to winter wheat.

CAN PPI/FAR CITE DATA?

Yes.

DO THE DATA SHOW AND ECONOMIC ADVANTAGES FROM THE DIFFERENT TREATMENTS?

Yes. Yield vs. nitrogen-water response curves show fertilizer N requirements for maximum economic yield increase 10 lbs N/a for every inch increase in growing season precipitation.