IMPROVED NITROGEN AND IRRIGATION EFFICIENCY FOR WHEAT PRODUCTION

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Summary

Management alternatives to reduce N fertilizer and to lessen irrigation amounts were tested for furrow irrigated wheat in replicated half acre plots. The recommended N fertilizer rate and 40 percent of the recommended N fertilizer rate were tested under conventional furrow irrigation (continuous) and surge irrigation. With the recommended N rate, wheat yielded 113.4 bu/acre averaged over both irrigation methods, significantly more yield than the 99.8 bu/acre obtained at the 40 percent N rate. Surge irrigation required only 13.4 acre-inch/acre of water compared to 25.4 acre-inch/acre for conventional furrow irrigation, while yields were not significantly less: 104.3 bu/acre compared to 108.9 bu/acre averaged over both N rates.

Introduction

Previous small plot research at the Malheur Experiment Station has demonstrated the effectiveness of using greatly reduced application of nitrogen fertilizer for optimum wheat production.

Surge irrigation is a tool that can be used to improve the efficiency of water applied by furrow irrigation. In surge irrigation, water is applied to an irrigation furrow intermittently during an irrigation set, whereas in continuous-flow (or conventional) irrigation, water is applied to the furrow during the entire irrigation set. With surge irrigation, an automated switching valve, commonly referred to as a surge valve, is used to repeatedly cycle water from one half of the field to the other half. Total water application can be reduced substantially with the use of surge irrigation. Previous research at the Malheur Experiment Station with wheat, onions, potatoes, and sugar beets has demonstrated the effectiveness of surge irrigation in reducing water applications while maintaining crop yield and quality equivalent to conventional furrow irrigation.

The reduced water applications with surge irrigation could result in a reduction of nitrate leaching and adjustment in N fertilizer practices. This trial compared wheat production with moderate and reduced N inputs under either conventional furrow irrigation or surge irrigation in field scale strip plots. Strip plots were 0.5 acres each with 620-foot long irrigation runs. The objective was to investigate the interaction between reduced nitrogen fertilizer and reduced water inputs on crop yield and quality with a field length relevant to furrow irrigated agriculture.

Methods

The 1997 trial was conducted on a Greenleaf silt loam previously planted to sugar beets at the Malheur Experiment Station. The field was disked, ripped, plowed and groundhogged in the fall of 1996 following sugar beets. Each plot was sampled in 1-foot increments to six-foot depth in three locations corresponding to the top, middle, and bottom of the plot. At each location the soil samples for the top two feet of soil consisted of 20 subsamples and below the second foot the sample consisted of four Giddings probe holes at 1-foot increments. The field was groundhogged, 120 lb/acre Penewawa spring wheat was drilled and bedded into 30-inch centers on March 24, 1997. A soil sample showed a pH of 7.7, 1.1 percent organic matter, 18 meq/100 g of soil cation exchange capacity.

The experimental design had the irrigation and nitrogen fertilizer rates arranged in a randomized complete block factorial design replicated three times. The plots were 36 feet wide and 620 feet long. Treatments consisted of two fertility levels and two irrigation methods (Table 1). The amount of fertilizer to be applied to each fertilized plot was based on late March soil samples at 0 to 2 foot depth at 100 percent of the recommended N rate and 40 percent of the recommended rate (Gardner et al. 1985). The 100 percent recommended rate consisted of applying approximately 115 lb N/acre for a total N supply (soil NO_3-N + NH_4-N in the 0 to 2 foot depth plus fertilizer N) of 200 lb N/acre. The N was applied as broadcast urea.

Gated pipe was arranged to permit all 12 plots to be irrigated simultaneously. A surge valve (Waterman, Model LVC-5) automatically oscillated water from three of the surge irrigation plots to the other three surge irrigation plots. The valves on the gated pipe were adjusted to deliver the same flow rate to all furrows in the surge and in the conventional irrigation systems. The field was irrigated on May 8, May 22, June 2, and June 25.

To estimate sediment losses, water inflow, water outflow, and net infiltration, an objective measurement and calculation method was used (Shock and Shock, 1997). Onset times of water inflow and outflow, and interval measurements of water inflow rate, water outflow rate, and sediment yield were recorded during each irrigation.

For each water outflow reading, a 1-liter sample was placed in an Imhoff cone and allowed to settle for 15 minutes. Sediment content in the water, in g/l, was found to be related to the Imhoff cone reading (x) after 15 minutes by the equation

$y = 1.015x$ with $r^2 = 0.98$ and $p < 0.0001$.

Total inflow, outflow, infiltration, and sediment loss were integrated from field measurements using a Lotus Improv program, "InfilCal" (Shock and Shock, 1995). The InfilCal program utilizes simple approximations of the integrals of inflow rates, outflow rates, and sediment content over time to estimate the inflow, outflow, and sediment loss. Each flow rate reading and Imhoff cone sediment sample is taken to be representative of the interval of time closest to the reading. In other words, if readings and sediment samples are taken at times t_{n-1}, t_n, and t_{n+1}, the flow rate reading and sediment sample at time t_n are taken to be representative of the interval of time from

$$\frac{t_{n-1}+t_{n+1}}{2}$$

to

$$\frac{t_n+t_{n+1}}{2}$$

The estimated inflow volume for the interval about t_n is therefore given by

$$InflowVolume(t_n) = \left(\frac{t_{n+1}+t_{n-1}}{2}\right) InflowRate(t_n)$$

where InflowRate(t_n) is the measured inflow rate at time t_n. The outflow volume is given by the same equation, replacing the inflow rate with the outflow rate. The estimated sediment loss for the interval about t_n is given by

$$SedLoss(t_n) = OutflowVolume(t_n)Content(t_n)$$

where Content(t_n) is the sediment content given by the above Imhoff cone method. Although measurements should be taken on an established schedule, the time intervals between measurements need not be constant.

Clearly, this method must account for the time between onset and the first measurement and, likewise, between the last measurement and shutoff. The inflow rate value at the time of onset is taken to be the same as the first inflow rate measurement after onset, and the value at the time of shutoff is taken to be the same as the last inflow rate measurement before shutoff. The outflow rate value at the time of onset is taken to be zero, as is the outflow rate at the end of the irrigation. Each of these values applies to the first half of the time interval between onset and the first measurement, or to the last half of the time interval between the last measurement and shutoff.

Strips were harvested July 28 with a Hege plot combine at the top, middle, and bottom of each strip. A 9 ft^2 area was harvested in the top, middle, and bottom tiers of each strip to determine stubble yield and grain-to-stubble ratio. Stubble and grain were ground and analyzed for total N.

After harvest, between August 26 and 28,1997, the soil from each plot was sampled to six-foot depth in one-foot increments in the top, middle, and bottom of each 620 foot strip as it had been before planting.

The available N balances were calculated by subtracting the N supply (available soil N in spring plus fertilizer N) from the postharvest accounted N (crop N uptake plus available soil N after harvest).

Treatment differences in irrigation, infiltration, runoff, sediment loss, crop yield and quality, and nitrogen recovery were compared using analysis of variance and the protected least significant difference test at the five percent level, LSD (0.05).

Results and Discussion

Conventional furrow irrigated plots required 4 irrigations totaling 132 hours, and surge irrigated plots required 4 irrigations totaling 132 hours in order to maintain the soil adequately wet for wheat growth and development. The actual duration of water applications with surge irrigation were half of that for conventional irrigation. Actual water applications were 132 hours for conventional irrigation and 66 hours for surge irrigation resulting in a 45 percent reduction in applied water (Table 1). Infiltration was very high in this field, which resulted in low levels of run off and low levels of sediment loss.

The wheat fertilized at the full recommended rate (115 lb N/acre) was 13 percent more productive than wheat that received only 40 percent of the recommended N rate (Table 2). Conventional furrow irrigation was 4.6 bu/acre more productive than surge irrigation (difference not statistically significant) with almost twice the applied water.

The soil N balance was not influenced by the treatments (Table 3). The N balances were all positive, suggesting a substantial N contribution from organic matter mineralization.

Literature Cited

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Table 1. Effect of furrow irrigation method on the water applied, runoff, infiltration, and sediment loss in a field of Penewawa spring wheat during four irrigations, Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1997.

Furrow irrigation method	Net water movements by irrigation					Total sediment loss
	----------- acre-inch/acre -----------					lb/acre
	May 8	May 22	June 2	June 25	Total	
Conventional						49.5
Applied	8.8	4.2	6.8	4.7	24.5	
Runoff	0	0	0.8	0.8	1.6	
Infiltration	8.8	4.2	6.0	3.9	22.9	
Surge						19.6
Applied	4.3	2.8	3.9	2.5	13.4	
Runoff	0.3	0	0.2	0.2	0.7	
Infiltration	4.0	2.8	3.7	2.3	12.7	
LSD (0.05)						27.4
Applied	0.33	1.22	2.09	0.47	3.1	
Runoff	NS	NA	NS	0.40	NS	
Infiltration	0.43	1.22	1.82	0.44	2.9	

Table 2. Influence of N rate and surge irrigation on the yield and quality of Penewawa spring wheat, Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1997.

Treatment		Wheat response				
Furrow irrigation method	N fertilizer rate	Yield (60 lb/bu)	Harvest index	Grain protein	Straw yield	Straw NS content
	lb/acre	bu/acre	%	%	lb/ac	%
Continuous	115	117.9	58	13.1	5603	0.781
Continuous	44	100.0	57	12.2	4832	0.530
Surge	115	108.8	59	14.5	4581	0.701
Surge	44	99.6	58	12.4	4217	0.546
LSD (0.05) Irrigation		NS	NS	NS	815	NS
LSD (0.05) N rate		8.7	NS	1.1	NS	0.044
LSD (0.05) Irrig. x N		NS	NS	NS	NS	0.062

Table 3. Influence of N rate and furrow irrigation method on wheat N uptake and the available nitrogen accounting, Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1997.

Treatment		N Supply			Fall nitrogen accounting					
						Plant N at harvest				
Furrow irrigation method	N fertilizer rate	Pre-plant soil available N 0-2'	Fertilizer N	Total	Fall soil avail. N (0-2')	Straw N recovery	Grain N recovery	Total N recovery	Total accounted N	Balance based on 0-2' depth
	-----lb n/acre-----									
Cont.	115	91	115	206	62	42	165	207	269	63
Cont.	44	86	44	130	55	26	133	159	214	84
Surge	115	79	115	196	65	33	163	196	261	67
Surge	44	95	44	139	62	23	119	142	204	65
LSD (0.05) Irrig.		NS	--	NS	NS	NS	NS	NS	NS	NS
LSD (0.05) N rate		NS	--	6	NS	7	29	33	32	NS
LSD (0.05) I x N		NS	--	9	NS	NS	NS	NS	NS	NS