

Water Use Efficiency as Influenced by Topsoil Thickness and Fertility on Reclaimed Land

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The efficiency of corn silage production on a reclaimed site per unit of water used by the crop increased significantly as topsoil or first lift material was increased in thickness in 2 of 5 years in an experiment near Beulah, North Dakota. Water use efficiency (WUE) of wheat was increased significantly in 3 of 5 years. Nitrogen fertilization caused a statistically significant increase in corn silage WUE values for 1978 and 1979 in an experiment utilizing a uniform first lift thickness. Comparable effects were not produced for wheat grains, caused in part by insects that reduced yields.

INTRODUCTION

Vegetative growth and grain production are governed by many factors which include available water and adequate fertility levels. The weight of vegetative matter (i.e., corn silage) or grain yield divided by the total amount of water used in the evapotranspiration process during crop growth is defined as the water use efficiency (WUE). The higher the WUE value, the more efficient the water present in the soil at planting and precipitation are utilized for crop growth. In a crop production climatic area of marginal annual precipitation such as exists in the study areas, the largest production of crop per unit of water available to that crop is extremely important.

Several researchers (4, 5) have reported positive responses by corn and wheat to phosphorus (P) and nitrogen (N) fertilizers and various topsoil depths on reclaimed spoilbanks. In this article the effects of fertility treatments and topsoil thickness on WUE will be discussed for corn and wheat for 5 years of data collected at two reclaimed mining sites.

MATERIALS AND METHODS

Research plots were established in the fall of 1974 at the Knife River Coal Mining Company site near Beulah, and in the spring of 1975 at the Consolidation Coal Corporation Glenharold mine near Stanton (1). Phosphorus fertilizer (0-46-0) was broadcast on the spoil at a rate of 90 lbs P/acre before topsoil was respread at Knife River in the spring of 1975. Four topsoil thicknesses of 2, 6, 12 and 24 inches were placed over the levelled spoil material. Additional fertilizer was applied for the corn at planting at rates of 16 lbs P/acre banded and 100 lbs N/acre broadcast. For wheat the rates were 11 lbs P/acre banded and 80 lbs N/acre broadcast. Nitrogen fertilizer used was 34-0-0.

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Two feet of topsoil was placed over the levelled spoil materials at Consolidation. A rate of 40 lbs P/acre was broadcast and incorporated after topsoil placement. Additional fertilizer was added at planting at rates of 16 lbs P/acre banded and either 0 or 60 lbs N/acre broadcast for corn and 11 lbs P/acre banded and either 0 or 40 lbs N/acre broadcast for wheat.

The experimental area at both sites was split so that half was planted to wheat and half to corn in an alternating small grain-row crop rotation over the years with four replications per topsoil thickness or fertility level and crop. Waldron or Olaf (1979 only) wheat was planted at a rate of 1.25 bu/acre in 6-inch spacing. Agsco "Hi-N-Dry" corn (except in 1977 and 1978 when a 75-day variety was used) was planted in 36-inch spacing and thinned to 16,000 plants per acre.

RESULTS AND DISCUSSION

WUE values for corn silage and wheat yields as affected by topsoil thickness at the Knife River site are shown in Table 1. Corn silage WUE values as affected by topsoil thickness were statistically significant only in 1975 and 1976. Only in 1976 was there a statistically significant difference between the two thickest topsoil treatments. However, in 4 of 5 years the two thickest treatments did result in higher WUE values than the thinner treatments. Values also generally increased from one year to the next for each topsoil thickness. Although differences among the 5-year averages were not statistically significant, WUE values increased with increases in topsoil thickness.

No statistically significant differences in available water at planting due to topsoil thickness were found within any of the years or the 5-year average (Table 1). Only in 1975 did the thickest topsoil treatment have more available water at planting than the other three thicknesses.

WUE values for wheat yield at Knife River showed similar trends as did corn silage (Table 1). Statistically significant differences between topsoil thicknesses were obtained in 3 of 5 years. As with corn silage, the values generally increased over time and thicker topsoil had higher WUE values. The low values obtained in 1977 (especially for the 2-inch topsoil thickness) were due to very poor stands. The 5-year averages were not statistically different among topsoil thicknesses.

Available water for wheat at planting (Table 1) showed no statistically significant differences within the years or the 5-year average. At no time during the experimental period did the thickest topsoil treatment have more available water at planting than the thinner.

The different magnitude of WUE averages for either corn silage or wheat yield may be due to climatic differences among years (precipitation frequency and storm damage), differences in the amount of available water in the soil at planting, and/or nonuniformity of the topsoil material causing variability within treatments. These data show thicker topsoil treatments generally have the best WUE values.

WUE values for corn silage and wheat yield as affected by nitrogen fertilizer application at the Consolidation site are shown in Table 2. During the last two years of 1978 and 1979 the addition of nitrogen produced a statistically

significant effect on WUE values for corn silage. Prior years' results probably lacked response because nitrogen was present in sufficient quantities in the topsoil and spoil when the experiment was initiated (3). This nitrogen supply was reduced over time to the point where it was inadequate for maximum crop production, thus affecting the WUE values.

No statistically significant differences in available water at planting were found within any of the years or the 5-year average (Table 2). The inherent variability of a site often associated with mineland reclamation research contributed to the presence or absence of statistically significant differences for both available water and the WUE values shown.

Wheat yield WUE values due to nitrogen application (Table 2) showed no statistically significant differences for any of the experimental years. In 3 of 5 years, WUE values

Table 1. Average WUE and available water values at the Knife River Coal Company, Beulah, North Dakota as affected by topsoil depth.^{1/}

Topsoil Thickness (inches)	Year					5-Year Average
	1975	1976	1977	1978	1979	
Corn Silage (tons/acre/inch)						
2	0.16 a	0.14 a	0.21 a	0.58 a	0.60 a	0.34 a
6	0.14 a	0.27 a	0.14 a	0.52 a	0.80 a	0.38 a
12	0.27 ab	0.31 b	0.20 a	0.60 a	0.94 a	0.46 a
24	0.30 b	0.63 c	0.18 a	0.59 a	0.84 a	0.53 a
Available Water (inches)^{2/}						
2	-0.35 a	2.55 a	-1.37 a	1.65 a	1.88 a	0.00 a
6	0.98 a	2.60 a	0.37 a	2.37 a	2.63 a	1.79 a
12	0.83 a	1.39 a	0.63 a	0.36 a	0.64 a	0.79 a
24	1.60 a	2.28 a	0.08 a	2.27 a	-1.01 a	1.09 a
GSP ^{3/}	7.77	6.27	7.56	6.09	8.97	
Wheat Yields (bushels/acre/inch)						
2	0.23 a	1.07 a	0.13 a	1.45 a	1.70 a	0.91 a
6	0.36 ab	1.52 a	0.76 b	1.85 ab	2.18 a	1.32 a
12	0.58 b	1.35 a	0.64 b	2.24 b	2.34 a	1.42 a
24	0.51 ab	1.24 a	0.61 b	2.24 b	2.41 a	1.40 a
Available Water (inches)^{2/}						
2	2.20 a	0.58 a	1.68 a	0.14 a	1.89 a	1.36 a
6	2.18 a	2.24 a	1.58 a	2.84 a	1.40 a	2.00 a
12	0.90 a	2.02 a	0.81 a	1.38 a	0.90 a	1.20 a
24	1.84 a	1.82 a	1.00 a	1.54 a	1.48 a	1.54 a
GSP ^{3/}	5.82	6.42	8.04	7.85	7.45	

^{1/} Based upon four replications per topsoil depth. Values followed by the same letter within columns are not significantly different at the 10% level (Newman-Kuels' range test).

^{2/} Available at planting date to a depth of four feet. Negative values indicate a deficit.

^{3/} Growing season precipitation in inches (between planting and harvesting dates).

Table 2. Average WUE and available water values at the Consolidation Coal Corporation, Stanton, North Dakota as affected by fertilizer application.^{1/}

N Fertilizer Rate (lbs/acre) ^{2/}	Year					5-Year Average
	1975	1976	1977	1978	1979	
Corn Silage (tons/acre/inch)						
0	0.58 a	0.60 a	0.21 a	0.71 a	0.66 a	0.55 a
60	0.55 a	0.49 a	0.22 a	1.01 b	0.83 b	0.62 a
Available Water (inches)^{3/}						
0	3.88 a	1.86 a	1.93 a	2.40 a	2.97 a	2.61 a
60	3.44 a	2.86 a	1.25 a	2.66 a	2.38 a	2.52 a
GSP ^{4/}	6.85	4.64	8.63	6.68	11.81	
Wheat Yields (bushels/acre/inch)						
0	2.21 a	2.25 a	0.16 a	1.54 a	2.49 a	1.73 a
40	2.18 a	2.54 a	0.18 a	1.34 a	2.44 a	1.74 a
Available Water (inches)^{3/}						
0	2.06 a	3.41 a	0.05 a	3.38 a	1.50 a	2.08 a
40	3.33 a	2.91 a	1.42 b	2.69 a	2.14 a	2.50 a
GSP ^{4/}	5.79	4.94	8.50	8.06	6.16	

^{1/} Based upon four replications per N fertilizer rate. Values followed by the same letter within columns are not significantly different at the 10% level (Newman-Kuels' range tests).

^{2/} Corn received 16 lbs P/acre banded and wheat 11 lbs P/acre banded.

^{3/} Available at planting date to a depth of four feet.

^{4/} Growing season precipitation (between planting and harvesting dates).

trended lower where nitrogen was added when compared to plots where none was added. This was probably the direct result of variability within plots. The low values for 1977 were caused by insect and hail damage resulting in lower yields. The 5-year WUE averages for wheat yields were essentially equal for the 0- and 40-pound rates of N per acre.

In 1977 a statistically significant difference was observed for available water at planting, but this effect was not apparent in the WUE values for that year because of the previously mentioned insect and hail damage. No other statistically significant differences were found for the other years or the 5-year average.

CONCLUSIONS

Thicker topsoil treatments for corn silage near Beulah produced significantly greater WUE values for 1975 and 1976, with the last three years producing similar but non-significant trends. Data indicate that corn used water more efficiently when topsoil thickness was 12 inches or greater. Differences in WUE of wheat among topsoil thicknesses are more apparent though generally there was no difference between the 12- and 24-inch thick treatments.

The addition of nitrogen fertilizer in an experiment near Stanton had minimal effect on WUE for wheat. However,

differences in WUE are now beginning to appear for corn silage, and since corn requires more nitrogen than wheat, residual nitrogen in the topsoil and spoil has become more of a limiting factor in crop production than it was when the experiment was initiated.

Inherent variability in the experimental plots caused by reclamation may have overshadowed statistically significant differences. Differential damage by insects within plots for the various years has also probably contributed to the presence or absence of statistically significant differences.

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