Bulletin No. 389 - Irrigation and Nitrogen Fertilization of Field Corn in Northwest Wyoming

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J. R. Partridge

University of Wyoming
Agricultural Experiment Station
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Irrigation and Nitrogen Fertilization of Field Corn in Northwest Wyoming

By R. D. Burman, L. I. Painter, and J. R. Partridge

Field studies began during the spring of 1958 and continued through 1960 to determine the common effects of nitrogen fertilization and irrigation frequency upon the yield of field corn grown at the University of Wyoming Agricultural Substation at Powell. These studies were prompted by the increasing interest in corn grown for ensilage as well as grain. The wise and conservative use of irrigation water is becoming more and more important. Emphasis on this fact has resulted in this study.

Description of Studies

The major aim was to determine the effect upon corn yields of both irrigation frequency (or pre-irrigation soil-moisture level) and nitrogen fertilization. Field plots, 6 rows wide and 50 ft. long with 36-in.-row spacing, were planted with Kingscrosst KC-3 hybrid seed to provide an average of 22,000 plants per acre. The middle two rows of each 50-ft. plot were harvested for ensilage yield, and at a later date, when the corn was mature, the next two outer rows of the six rows were harvested to determine the grain yield. In the three study years, the plots were arranged so that three to four irrigation variations and three to four nitrogen variations could be studied in all possible combinations. These combinations are reported in the discussion of each year's results (pages 4 to 8). The irrigation and nitrogen variations were changed from year to year as knowledge and experience were gained.

During the three seasons, nitrogen-fertilizer applications of 0, 80, 160, and 240 lbs. of actual nitrogen per acre were studied. The fertilizer was applied by side dressing in a single application during the second week of June.

Soil-moisture tension, or as it is often called "soil-moisture suction", is a measure of the force the plants must overcome to obtain moisture. One or two days after ir-

1Assistant Professor of Agricultural Engineering and Professor of Soils, University of Wyoming at Laramie, Wyoming; Soils Technician at Powell, Wyoming.
Irrigation, when the condition known as field capacity had been reached, the soil-moisture tension was very low. Plants at that time have to exert force of only about 1/10 of an atmosphere, which is approximately 1.5 lbs. per square inch, to obtain the water from the soil.

When the soil is very dry and near the permanent wilting point, the moisture is held tightly. Then a force of 15 atmospheres or about 220 lbs. per square inch must be overcome for plants to imbibe moisture.

Soil-moisture tension is a common denominator which describes moisture conditions regardless of texture. It must be recognized at the same time that the amount of moisture held at any tension may vary from soil to soil. A clay loam soil will hold much more moisture between field capacity and wilting point than will a sandy loam soil.

The soil-moisture variations were achieved by withholding irrigation until the tension was reasonably near to 1, 2, 4, and 8 atmospheres at a depth of 6 in. below the ground surface. Tension at this depth was determined by measuring the electrical resistance of gypsum blocks placed in the soil. Moisture within the porous blocks comes into equilibrium with moisture within the soil. As the blocks become dry their electrical resistance tends to become higher. The resistance readings in ohms were converted to atmospheres of soil-moisture tension by use of a slide rule developed by Miller.¹

**Discussion of Results**

**1958 Field Studies**

Three soil-moisture levels, with irrigation at 1, 2, and 4 atmospheres, and three nitrogen levels, with applications of 0, 80, and 160 pounds of actual nitrogen per acre, were imposed upon the corn so that each treatment was repeated three times. Tables 1 and 2 show the influence of different irrigation frequencies and nitrogen fertility on yield, with results as shown in Figure 1. Table 2 shows no statistical difference in yield of corn, for use either as ensilage or grain, caused by the variations in irrigation frequency, even though the wettest plots were irrigated eight times and the driest plots only three or four times. Highly significant differences were caused by different applications of nitrogen for both grain and ensilage.

The soil conditions at the Powell substation are described by Bindschadler* as follow:

¹Miller, W. McNab. Unpublished data, University of Wyoming, Agricultural Experiment Station. 1955.

*Unpublished, personal communication April 9, 1962.
The soils upon which this study were made are identified as Garland clay loam. These Sierozem soils are characterized by their light color, non calcareous sola, clay-loam textures, horizons of lime-carbonate enrichment and moderate depths. The very porous coarse sands, gravel, and cobble, which occur at about 36 inches, provide excellent sub-drainage. The reaction is moderately alkaline. Their moderately fine-textured, calcareous parent materials weather from a highly mineralized alluvium of local origin. They occupy nearly level remnant benches and terraces in arid climates.

FIG. 1—Grain and silage yields of corn as influenced by soil moisture and by nitrogen fertility, Powell, Wyoming, 1958.

Grain yield in bushels per acre at 15% moisture  
Silage yield in tons per acre

5
TABLE 1—Summary of Treatment Yields in the Corn, Nitrogen, Irrigation Experiment.

<table>
<thead>
<tr>
<th>Year</th>
<th>Available nitrogen application lbs./acre</th>
<th>Pre-irrigation soil-moisture tension atmospheres</th>
<th>Ensilage Tons per acre treatments</th>
<th>Grain yield Corrected to 15% moisture Bushels per acre treatments</th>
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<td>18.0</td>
<td>78.2</td>
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<td>80</td>
<td>4</td>
<td>17.0*</td>
<td>94.8*</td>
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<td>80</td>
<td>8</td>
<td>13.8*</td>
<td>85.4*</td>
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<td>19.9*</td>
<td>115.5*</td>
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<td>118.6</td>
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<td>240</td>
<td>4</td>
<td>23.6</td>
<td>116.8</td>
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<tr>
<td></td>
<td>240</td>
<td>8</td>
<td>23.5</td>
<td>114.7</td>
</tr>
</tbody>
</table>

1In 1959 means having the same letter or letters in the superscript are not statistically different at the 5% level of significance.
TABLE 2—Nitrogen and Irrigation-Effect Summaries on Field Corn, Powell, Wyoming

<table>
<thead>
<tr>
<th>Available nitrogen application (Lbs./A.)</th>
<th>1958</th>
<th>1959</th>
<th>1960</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Silage</td>
<td>Grain</td>
<td>Silage</td>
</tr>
<tr>
<td></td>
<td>Tons/A. Bu./A.</td>
<td>Tons/A. Bu./A.</td>
<td>Tons/A. Bu./A.</td>
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<tr>
<td>0</td>
<td>15.0&lt;sup&gt;a&lt;/sup&gt; 66.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.6&lt;sup&gt;a&lt;/sup&gt; 43.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.7&lt;sup&gt;a&lt;/sup&gt; 63.2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>80</td>
<td>18.4&lt;sup&gt;b&lt;/sup&gt; 78.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>16.0&lt;sup&gt;b&lt;/sup&gt; 85.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>20.8&lt;sup&gt;b&lt;/sup&gt; 93.8&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>160</td>
<td>19.7&lt;sup&gt;c&lt;/sup&gt; 90.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>19.0&lt;sup&gt;c&lt;/sup&gt; 112.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>24.1&lt;sup&gt;c&lt;/sup&gt; 112.1&lt;sup&gt;c&lt;/sup&gt;</td>
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</table>

<table>
<thead>
<tr>
<th>Pre-irrigation soil-moisture tension (atmospheres)</th>
<th>1958</th>
<th>1959</th>
<th>1960</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Silage</td>
<td>Grain</td>
<td>Silage</td>
</tr>
<tr>
<td></td>
<td>Tons/A. Bu./A.</td>
<td>Tons/A. Bu./A.</td>
<td>Tons/A. Bu./A.</td>
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<td>18.5&lt;sup&gt;a&lt;/sup&gt; 82.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.1&lt;sup&gt;a&lt;/sup&gt; 79.9&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>2</td>
<td>17.6&lt;sup&gt;a&lt;/sup&gt; 76.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.2&lt;sup&gt;a&lt;/sup&gt; 78.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.2&lt;sup&gt;a&lt;/sup&gt; 100.5&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>4</td>
<td>17.0&lt;sup&gt;a&lt;/sup&gt; 75.2&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>8</td>
<td>12.4&lt;sup&gt;a&lt;/sup&gt; 77.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.3&lt;sup&gt;a&lt;/sup&gt; 93.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letter or letters in the superscript are not significantly different at the 5% level.
1959 Field Studies

The results of the 1958 study indicated that an additional dry soil moisture of long-frequency irrigation was needed to define a lower limit of soil-moisture conditions. As a result, irrigation at 8 atmospheres was added to the three regimes at 1, 2, and 4 atmospheres. The nitrogen-fertility treatments were maintained as before with applications of 0, 80, and 160 lbs. of actual nitrogen per acre. Table 1 shows that the yield of both ensilage and grain was significantly reduced under high soil-moisture stress (irrigation at 8 atmospheres) when 160 lbs. of nitrogen was applied. The multiple-range analysis of the data shows that the yields of both grain and ensilage for 80 lbs. of actual nitrogen for all irrigations and for 160 lbs. of nitrogen under dry conditions were essentially the same. Throughout the remainder of the possible comparisons only nitrogen fertilizer had any significant effect on the yields of both ensilage and grain.

Figure 2 shows the combined effect of pre-irrigation soil-moisture level and of nitrogen fertility level on the yield of corn.

1960 Field Studies

The 1959 studies tend to show that small differences in yield were noted between irrigation at one atmosphere and irrigation at two atmospheres, even though this changed the number of irrigations required from six or seven to eight or nine. Examination of the 1959 results also disclosed that it might be desirable to increase the application of nitrogen from 160 to as high as 240 lbs. of available nitrogen per acre. The treatments were changed in 1960 to eliminate the wettest soil-moisture regime, irrigation at 1 atmosphere, and to include nitrogen fertilization at the rate of 240 lbs. of actual nitrogen per acre. Applying nitrogen fertilizer caused significant increases in the yields of both grain and ensilage while changing the numbers of irrigations from three to six or seven significantly changed the yield of only the ensilage. The results show that the soil-moisture treatments did not cause changes in grain yields that were of statistical significance.

Figure 3 shows the combined effect of pre-irrigation soil-moisture level and of nitrogen fertility level on the yield of corn for 1960.
FIG. 2—Grain and silage yields of corn as influenced by soil moisture and by nitrogen fertility, Powell, Wyoming, 1959.

Grain yield in bushels per acre at 15% moisture

Silage yield in tons per acre
FIG. 3—Grain and silage yields of corn as influenced by soil moisture and by nitrogen fertility, Powell, Wyoming, 1960.

Grain yield in bushels per acre at 15% moisture

Silage yield in tons per acre
Effect of Nitrogen Fertility on Irrigation Frequency

Throughout the study, all treatments were replicated three times per season. Each individual plot combination of fertility and soil-moisture regime was irrigated when the mean tension of the three replicates was reasonably close to the design level. By this means it was possible to determine if more frequent irrigation would be needed to maintain certain minimum soil-moisture levels under high fertility as compared with low fertility.

Out of ten possible comparisons, high-nitrogen-fertility conditions caused more rapid depletion of soil moisture on four occasions. For one regime, high-nitrogen-fertility conditions required one fewer irrigation than did the application of no nitrogen fertilizer. Since there was no difference in the number of irrigations required to maintain desired soil-moisture conditions in the remaining five comparisons, it must be concluded that there was no consistent trend which indicated that changing the fertility conditions caused a change in the rate of moisture removal from the soil. Figures 4 through 6 show a log of tension at the depth of six inches throughout the growing season. These figures show the times of irrigation for the various fertility levels within each soil-moisture regime.

TABLE 3—Number of Irrigations Required to Maintain Desired Soil-Moisture Conditions for Various Nitrogen Applications.

<table>
<thead>
<tr>
<th>Year</th>
<th>1 Atmos. N treatments</th>
<th>2 Atmos. N treatments</th>
<th>4 Atmos. N treatments</th>
<th>8 Atmos. N treatments</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>0 80 160 240</td>
<td>0 80 160 240</td>
<td>0 80 160 240</td>
<td>0 80 160 240</td>
</tr>
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<td>8 8 9</td>
<td>7 6 6</td>
<td>4 4 4</td>
<td>3 3 3</td>
</tr>
</tbody>
</table>

1 Includes one irrigation by mistake.

Conclusions

1. Throughout the three years of study, nitrogen-fertilizer applications (80, 160, and 240 lbs. of actual nitrogen per acre) always caused significant increases in the yield of field corn over the check plots, harvested for use as either grain or ensilage. This was true for a wide range of soil-moisture regimes.

2. In two years out of the three-
FIG. 4—Soil-moisture tension log, Powell Substation, 1959 corn-nitrogen irrigation experiment showing times of irrigation and soil-moisture tension for various fertility levels. Soil-moisture tension at the depth of 6 inches. 1 and 2 atmosphere treatments.
FIG. 5—Soil-moisture tension log, Powell Substation, 1959 corn/nitrogen irrigation experiment showing times of irrigation and soil-moisture tension for various fertility levels. Soil-moisture tension at the depth of 6 inches. 4 atmosphere treatment.
Fig. 6—Soil-moisture tension log, Powell Substation, 1959 corn/nitrogen irrigation experiment showing times of irrigation and soil-moisture tension for various fertility levels. Soil-moisture tension at the depth of 6 inches. 8 atmosphere treatment.
year study, frequent irrigations, or irrigation at low tension, caused a significant increase in the yield of ensilage.

3. Irrigation frequency or pre-irrigation tension limits did not cause a significant change in one year in the yield of corn harvested for grain. Severe conditions of drought were not studied. While this was true, the range in annual irrigations was from two to nine per season.

4. In 1959 there was a significant interaction between pre-irrigation soil-moisture level and nitrogen - fertilization level. This indicates that the yield response due to fertilization was different under different conditions. The response to high nitrogen (160 lbs. per acre) was much higher under irrigation at 1, 2, and 4 atmospheres of soil-moisture tension than under the high stress condition of irrigation at 8 atmospheres. In 1959 an application of 80 lbs. of actual nitrogen per acre, irrigated from four to nine times, produced nearly the same amount of ensilage and grain as 160 lbs. of nitrogen per acre when irrigated only two times during the season.

5. There was no consistent change in the number of irrigations required to maintain desired soil-moisture conditions because of nitrogen-fertilization levels.