Effect of Source and Rate of Nitrogen on N Uptake and Fertilizer Efficiency by Spring Wheat and Barley

J. Alessi and J. F. Power

ABSTRACT

Field experiment was conducted to determine the effect of fertilizer N source and rate on N uptake and recovery by small grains. Five N sources — NH₄NO₃, (NH₄)₂SO₄, Ca(NO₃)₂, Uramite, and Nitroform (urea-formaldehyde) — were applied to Temvik silt loam for 4 years at rates of 0, 34, and 68 kg N/ha to spring wheat (Triticum aestivum L.) and barley (Hordeum vulgare L.) under an annual dryland cropping system. Residual responses were measured until effects were no longer significant. N content of plants was usually increased at all stages of growth by all N sources; N uptake was greatest for the ammonium and nitrate sources at the 68-kg rate. At the end of the residual period, recoveries averaged 78% for the ammonium and nitrate sources, and 44% for the urea-formaldehyde materials. Recoveries increased by 12 to 29% during the residual period, with the greatest increase occurring for the calcium nitrate treatment. Highest average N recovery for the 8-year period was 87% for Ca(NO₃)₂. No accumulation of NO₃-N remained in the upper 180 cm of soil at the end of the experiment.

Results from this long-term study indicate that ammonium and nitrate sources of fertilizer N are superior to urea-formaldehyde for small grain production in semiarid regions.

Additional index words: Slow-release N-fertilizers, N absorption by small grains, N recovery.

Information is desirable on the fate of fertilizer N added to soils in order to assess the relative pollution hazard to surface and ground waters. When fertilizer N is applied to a soil, only part is used by the crop. Some becomes unavailable by combination into resistant soil organic matter or fixed ammonium, or lost from the system by surface runoff, leaching, denitrification, or ammonia volatilization. With the use of various N fertilizers crop utilization of available N may vary.

The fertility status of a soil influences the recovery of N by crop plants. Carpenter et al. (7) found that N recovery by spring wheat (Triticum aestivum L.) on low-N soils declined rapidly following the heading stage, while N uptake continued on the high-N soils. Boawn et al. (4) reported high recovery of fertilizer N from NH₄NO₃, (NH₄)₂SO₄, and Ca(NO₃)₂ when applied to several irrigated crops over a 6-year period. Likewise, Cairns (6) found little difference in recovery among various N sources applied to bromegrass (Bromus sp.) on a solonetzic soil, except in dry years when urea was least effective. Power et al. also found urea less effective than ammonium or nitrate sources of N when broadcast on bromegrass (11). Devine and Holmes (9) observed delayed emergence of spring barley (Hordeum vulgare L.) from Ca(NO₃)₂ drilled in close proximity to the seed at rates in excess of 50 kg N/ha.

Since denitrification and leaching losses of fertilizer N involve mainly the nitrate (NO₃—) form, various fertilizer materials are available in which the rate of formation or solubilization of NO₃-N is restricted. One of the most common of these “slow-release” materials is urea-formaldehyde. Hays and Haden (10) found these materials decreased nitrification rates and leaching. In laboratory experiments Corke and Robinson (8) found that rate of nitrification was decidedly lower for urea-formaldehyde than for (NH₄)₂SO₄. At temperatures below 15 C Basaraba (3) found that less
than 30% of the N in urea-formaldehyde was nitrified after 14 weeks of incubation. In field experiments with Italian ryegrass (Lolium multiflorum), Widdowson et al. (13) obtained much better yields from "Nitro-chalk" than from urea-forms, with final recovery values of 90 and 54%, respectively. This paper provides data on N uptake and recovery from five N fertilizers by a dryland spring grain cropping system.

**MATERIALS AND METHODS**

An experiment was initiated at Mandan, N.D. in 1960 to measure the effects of N carrier and rate on an annual spring grain cropping system. The nitrogen treatments were applied to a depth of 5 cm with a double-disk drill furrow opener prior to seeding in 1960 through 1963. Shallow ditches were maintained between replications to control the flow of surface water. All plots received 44 kg P/ha in 1960 and again in 1963. Nitrogen fertilizers were applied to a depth of 5 cm with a double-disk drill furrow opener prior to seeding in 1960 through 1963. Residual studies began in 1964. The experiment was continued until N uptake or growth from N-fertilized and 0-N (check) plots did not differ significantly at the 5% probability level.

Spring barley (var. 'Traill') was seeded in 15-cm rows at 78 kg/ha in 1960 and again in 1963. Nitrogen fertilizers were applied to a depth of 5 cm with a double-disk drill furrow opener prior to seeding in 1960 through 1963. Residual studies began in 1964. The experiment was continued until N uptake or growth from N-fertilized and 0-N (check) plots did not differ significantly at the 5% probability level.

**RESULTS AND DISCUSSION**

Information on spring wheat and barley yields and soil pH was presented in an earlier publication (1). In general, plant growth and grain yields were similar for 34% nitrate-ammonium sources [NH₄NO₃, (NH₄)₂SO₄, and Ca(NO₃)₂], although they were somewhat lower for the urea-formaldehyde materials. The effects of N source and rate on the average N content in barley (1960 + 1962) and in wheat (1961 + 1963) are presented in Table I. Application of N usually increased N content at each stage of growth. The nitrate-ammonium sources (treatments A, B, and C in Table I) increased plant N content more than the urea-formaldehyde sources, particularly at the 68-kg N/ha rate. Percent total N was similar among N sources within each fertilizer group (nitrate-ammonium vs urea-forms). Average N contents in barley and wheat grains were 2.08 and 3.44%, respectively, for nitrate-ammonium sources and 1.90 and 3.25% for urea-formaldehyde sources. Wheat was lower in percent total N at tillering, but higher at other stages than barley.

Yearly N uptake data are shown in Table 2. Data for 1967 show no significant differences (P = 0.05) in total N uptake among treatments, indicating that residual responses were complete when the experiment was terminated. Similar results were obtained in 1966, but the experiment was continued in 1967, since residual N influenced 1966 dry weight. Data in Table 2 indicate higher N uptake for the nitrate-ammonium sources than for urea-form sources. The effects of urea-formaldehyde materials on total N uptake were intermediate between those of nitrate-ammonium sources and the O-N treatment. Each year, N sources and rates.

**Table 1. Average N concentration in grain crop at various stages of growth.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N rate</th>
<th>Tilling</th>
<th>Header</th>
<th>Whole plant</th>
<th>Grain</th>
<th>Straw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/ha</td>
<td>% N</td>
<td>% N</td>
<td>% N</td>
<td>% N</td>
<td>% N</td>
</tr>
<tr>
<td>Check</td>
<td>0</td>
<td>0.46</td>
<td>0.47</td>
<td>0.47</td>
<td>0.57</td>
<td>0.63</td>
</tr>
<tr>
<td>NH₄NO₃</td>
<td>34</td>
<td>0.57</td>
<td>0.59</td>
<td>0.61</td>
<td>0.70</td>
<td>0.72</td>
</tr>
<tr>
<td>(NH₄)₂SO₄</td>
<td>34</td>
<td>0.70</td>
<td>0.72</td>
<td>0.72</td>
<td>0.80</td>
<td>0.82</td>
</tr>
<tr>
<td>Ca(NO₃)₂</td>
<td>34</td>
<td>0.73</td>
<td>0.75</td>
<td>0.75</td>
<td>0.83</td>
<td>0.85</td>
</tr>
</tbody>
</table>

*Fertilizer application discontinued in the years following 1963. *Mean within a column followed by the same letter are not significantly different at the 0.05 level.

Table 2. Total N uptake by grain plus straw of small grains as influenced by fertilizer N sources and rates.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/ha</td>
<td>28</td>
<td>34</td>
<td>40</td>
<td>46</td>
<td>52</td>
<td>58</td>
<td>64</td>
<td>70</td>
<td>79</td>
</tr>
<tr>
<td>NH₄NO₃</td>
<td>34</td>
<td>5.04</td>
<td>5.35</td>
<td>5.64</td>
<td>5.91</td>
<td>6.27</td>
<td>6.53</td>
<td>6.79</td>
<td>7.14</td>
<td>7.88</td>
</tr>
<tr>
<td>(NH₄)₂SO₄</td>
<td>34</td>
<td>5.04</td>
<td>5.35</td>
<td>5.64</td>
<td>5.91</td>
<td>6.27</td>
<td>6.53</td>
<td>6.79</td>
<td>7.14</td>
<td>7.88</td>
</tr>
<tr>
<td>Ca(NO₃)₂</td>
<td>34</td>
<td>5.04</td>
<td>5.35</td>
<td>5.64</td>
<td>5.91</td>
<td>6.27</td>
<td>6.53</td>
<td>6.79</td>
<td>7.14</td>
<td>7.88</td>
</tr>
</tbody>
</table>

*Fertilizer application discontinued in the years following 1963. *Mean within a column followed by the same letter are not significantly different at the 0.05 level.

Further evidence that residual N effects were complete after the 1967 harvest is demonstrated by lack of accumulation of residual NO₃-N in the soil profile for
any treatment (Table 3). Soil sampled in the spring of 1960 before initial N fertilization contained 5.0 ppm or 17 kg N/ha in the surface 30-cm depth. In the spring of 1964, urea-formaldehyde treatments exhibited no movement of nitrate-N below the 30-cm depth under dryland conditions. These data agree with those of other workers (10), showing leaching from these materials to be nil. Slightly more nitrate-N was found at depths below 30 cm for the ammonium nitrate sources during the fertilization period, but ammonium and nitrate sources were generally minor during the fertilization period. Approximately 50% of the N in such materials was utilized by the fertilized crop and more than 75% was eventually recovered by plant growth after residual effects were exhausted.

The 8-year yields indicate that ammonium and nitrate sources of fertilizer N are superior to urea-formaldehyde for small grain production in semiarid regions. Differences in effectiveness of the various ammonium and nitrate sources were generally minor during the fertilization period. Approximately 50% of the N in such materials was utilized by the fertilized crop and more than 75% was eventually recovered by plant growth after residual effects were exhausted.

**LITERATURE CITED**


