Nitrogen Availability from Potato-Processing Wastewater for Growing Corn

J. H. SMITH AND C. W. HAYDEN
Nitrogen Availability from Potato-Processing Wastewater for Growing Corn

J. H. SMITH AND C. W. HAYDEN

ABSTRACT

A line source sprinkler was used to irrigate corn (Zea mays L.) plots with potato (Solanum tuberosum L.)-processing wastewater in 1979, 1980, and 1981. Nitrogen applications ranged from about 4 to 600 kg/ha. Corn yields were measured for each row, the grain and stalks were analyzed for total N, and N uptake was calculated. The plots were split by years, one-third of the area was fertilized with wastewater 3 y, one-third 2 y, and one-third 1 y. This allowed evaluation of current and residual value of wastewater fertilization. Corn responded well to wastewater fertilization, with N applications in the wastewater increasing corn yields with increasing increments of N up to about 200 to 250 kg/ha annually, and corn grain yields ranged up to about 12 Mg/ha. Yield comparisons were made with plots fertilized with ammonium nitrate fertilizer. We determined that potato-processing wastewater N was almost equal to ammonium nitrate N for growing corn. Wastewater applications that will apply approximately 200 to 250 kg N/ha annually should be optimum for growing corn on this soil. Wastewater N from potato processing has good residual and carry-over for 1 y but under conditions of this experiment did not carry over for more than 1 y. Whether the excess N was lost from denitrification or leaching was not determined.

Additional Index Words: line source sprinkler, residual nitrogen, corn grain.


Irrigating with food-processing wastewater for growing crops is an established practice used by a large segment of the food processing industry (2, 4, 5, 6, 7, 8, and 11). In many existing systems, emphasis has been placed on disposing of wastewater with maximum applications of both the wastewater and included plant nutrients. Large amounts of wastewater and nutrients from potato (Solanum tuberosum L.)-processing operations have been applied to land with up to 550 cm of water and 2550 kg N/ha in 1 y (10). These seemingly excessive applications have not always created groundwater pollution problems, but in some cases have promoted almost total denitrification because of the anaerobic conditions in the soil related to the high water applications and the high energy content of the organic constituents of the wastewater (9). Well-managed wastewater irrigation fields growing grass for hay or forage look good and yield well because of the heavy fertilization with wastewater nutrients. Consequently, there has been interest from farmers in obtaining wastewater for crop irrigation and fertilizer in areas adjacent to fields already irrigated with wastewater. With this developing interest in utilizing wastewater for its nutrient value, a need was seen for evaluating potato-processing wastewater and determining its potential nutrient value for growing crops.

The objectives of this research were to compare potato-processing wastewater and NH₄NO₃-N sources for corn (Zea mays L.) production and thereby evaluate the wastewater as a N source.

MATERIALS AND METHODS

A field plot area was selected where both potato-processing wastewater and irrigation water were available. The wastewater was pumped to the plot area through a pipeline from a potato-processing plant nearby. An area 30.5 m wide by 183 m long containing 40 rows of corn of Moulton fine sandy loam soil (mixed mesic Typic Hapludalfs) near Caldwell, Idaho was irrigated with wastewater using a line source sprinkler in the center of the plot running the length of the plot. Sprinkler nozzles were spaced at 6-m intervals. Sixty rain gauges were installed in three rows of 20 across the plot in alternate corn rows to measure wastewater applications and the water was sampled during each irrigation to determine the N and chemical oxygen demand (COD) contents of the wastewaters. The total N content of the wastewater averaged 76 mg/L with < 2 mg/L NO₃-N. Nitrogen in the wastewater applied to the plots ranged from 4 to 600 kg/ha (Table 1). Wastewater was applied five times in 1979 during the growing season and twice each year before planting corn in 1980 and 1981. During the first year the entire plot area was irrigated with wastewater; in the second year 122 m of length was irrigated and the 61 m remaining was left without wastewater irrigation for residual fertilization evaluation; in the third year 61 m of the plot was irrigated with wastewater, 61 m was evaluated for residual following 2 y of wastewater irrigation, and 61 m was evaluated for residual fertility value following 1 y of irrigation with wastewater. Each 61 m plot area was divided into three areas of 20 m each for sampling. These served as replications for statistical analyses. An adjoining set of plots with the same soil and cropping history, 10 by 23 m each, was fertilized with NH₄NO₃ to provide 100, 200, or 300 kg N/ha annually. Each plot was split to fertilizer one-third of the area with one, one-third with two, and one-third with three annual applications of fertilizer during the experiment for residual N evaluation. These plots were arranged in a randomized block design replicated three times.

All of the experimental area was irrigated in the furrows between rows with Boise River water to meet the water requirements of the corn crop and to remove the water variable imposed by the wastewater irrigation. In 1979 the wastewater was applied in the early spring before planting and during the growing season to apply the desired amount of N. The following 2 y one irrigation was applied in the fall following harvest and another in the spring before planting. The excess water applied by wastewater irrigation in the center of the plots caused some extra leaching. Previous research (10) showed that the organic constituents of wastewater were removed from the water almost quantitatively in 60 cm of soil and would not leach. Therefore, the relatively uniform irrigations with river water were considered to eliminate the water variable for this experiment.

The plots were treated with Atrex and Dual postemergence at recommended rates for weed control. Corn was grown on the plot areas for 3 y, harvested at maturity, and yields of corn grain and stalks were determined separately. At harvest, three 3-m row sections were cut by hand from each of 40 rows for each wastewater irrigation treatment, weighed, the ears removed, bagged, and weighed. The stalks were run through a forage chopper and sampled for moisture and chemical analysis. The stalk samples and ears were dried in an oven at 60°C, the corn shelled, and both corn and stalks were ground and analyzed for total N by a Kjeldahl procedure (I). The cobs were discarded. The corn rows were numbered from 1 to 20, starting at the center of the plot and going to the outside row, which was number 20, on one side of the plot. Corn varieties grown on the plots and adjacent area were 'Greenway 55' in 1979 and 'Pioneer 3901' in 1980 and 1981. Plot preparation, planting, cultivation, irrigation, and harvest after plot samples were removed were performed by the cooperator.
Table 1—Wastewater and N applied to plot area through a line source sprinkler.

<table>
<thead>
<tr>
<th>Corn row</th>
<th>Wastewater N</th>
<th>1979</th>
<th>1980</th>
<th>1981</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cm</td>
<td>kg/ha</td>
<td>cm</td>
<td>kg/ha</td>
</tr>
<tr>
<td>1</td>
<td>71.8</td>
<td>600</td>
<td>45.7</td>
<td>434</td>
</tr>
<tr>
<td>2</td>
<td>56.0</td>
<td>468</td>
<td>49.4</td>
<td>439</td>
</tr>
<tr>
<td>3</td>
<td>55.2</td>
<td>447</td>
<td>47.6</td>
<td>425</td>
</tr>
<tr>
<td>4</td>
<td>47.7</td>
<td>404</td>
<td>38.8</td>
<td>346</td>
</tr>
<tr>
<td>5</td>
<td>45.0</td>
<td>378</td>
<td>33.2</td>
<td>298</td>
</tr>
<tr>
<td>6</td>
<td>35.8</td>
<td>303</td>
<td>28.1</td>
<td>251</td>
</tr>
<tr>
<td>7</td>
<td>26.6</td>
<td>229</td>
<td>19.5</td>
<td>174</td>
</tr>
<tr>
<td>8</td>
<td>18.9</td>
<td>120</td>
<td>12.1</td>
<td>106</td>
</tr>
<tr>
<td>9</td>
<td>5.2</td>
<td>46</td>
<td>4.5</td>
<td>39</td>
</tr>
<tr>
<td>10</td>
<td>0.4</td>
<td>4</td>
<td>0.7</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td>600 45.7 434 50.4 407</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2—Corn grain yield from potato-processing wastewater irrigation field in 1979, 1980, and 1981 at Caldwell, Idaho.

<table>
<thead>
<tr>
<th>Corn row</th>
<th>1979 Corn yield</th>
<th>1980 Corn yield</th>
<th>1981 Corn yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.73 cd 11.36 fgh 11.36 def 7.41† 4.90† 4.46†</td>
<td>10.29 cd 14.00 i 12.57 f 5.90 5.06 3.83</td>
<td>9.35 cd 12.24 gdh 11.61 ef 6.09 4.90 4.46</td>
</tr>
<tr>
<td>2</td>
<td>10.73 cd 12.87 hi 10.36 def 6.15 4.88 4.58</td>
<td>8.79 bcd 12.93 hi 11.74 ef 6.15 5.52 5.62</td>
<td>11.61 d 11.58 fgh 10.48 ede 6.97 5.27 5.68</td>
</tr>
<tr>
<td>3</td>
<td>8.79 bcd 12.62 hi 11.06 def 7.85 5.21 5.02</td>
<td>8.35 bcd 11.55 fte 10.73 de 7.28 4.96 5.08</td>
<td>10.48 cd 13.06 hi 10.17 ede 7.34 5.52 5.08</td>
</tr>
<tr>
<td>5</td>
<td>10.36 cd 10.42 def 10.72 dde 5.59 3.61 4.64</td>
<td>9.79 cd 9.60 ede 10.48 ede 4.52 3.14 4.21</td>
<td>7.91 bc 9.16 bcd 9.67 cd 5.52 3.83 4.64</td>
</tr>
<tr>
<td>6</td>
<td>7.66 bc 7.97 abc 8.98 bc 3.20 2.20 2.64</td>
<td>5.62 ab 9.10 bcd 7.97 ab 5.21 3.89 4.52</td>
<td>5.66 ab 7.76 ab 8.10 ab 4.77 3.69 4.64</td>
</tr>
<tr>
<td>7</td>
<td>4.02 ab 7.16 a 6.90 a 4.27 3.64 4.27</td>
<td>3.89 a 8.66 abc 7.53 ab 4.02 3.77 4.27</td>
<td>Mean 8.10 10.86 b 10.17 a 5.90 b 4.46 a 4.52 a</td>
</tr>
</tbody>
</table>

* Numbers in columns followed by different letters are different at the 95% probability level. Means were compared by harvest years.
† No statistical differences were observed in these columns.

The wastewater N applications shown in Table 1 were calculated from the N concentration and amount of wastewater collected in the rain gauges. The gauges were placed in alternate rows; therefore, the application rates for N were calculated for every other row. The applications to both sides of the sprinkler line were averaged for inclusion in the tables. The data were analyzed by analyses of variance and compared by Duncan Multiple Range Tests (3). Phosphorus and potassium analyses of potato-processing wastewater as reported by Smith et al. (10) averaged 13 and 135 mg/L.

Table 3—Nitrogen recovered in corn grain grown on a field irrigated with potato-processing wastewater in 1979, 1980, and 1981 at Caldwell, Idaho.

<table>
<thead>
<tr>
<th>Corn row</th>
<th>1979</th>
<th>1980</th>
<th>1981</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>146 cd 171 hi 160 k 87 ab 50 ab 48 a</td>
<td>187 cd 196 j 161 k 66 cd e 54 a 46 ab</td>
<td>183 cd 180 ij 152 ik 63 cd e 46 ab 43 ab</td>
</tr>
<tr>
<td>2</td>
<td>156 cd 176 hij 138 hi 64 cd e 54 ab 44 a</td>
<td>128 bed 173 hi 146 ij 67 cde 52 ab 45 a</td>
<td>124 bed 154 fgh 136 efg 77 abcd 47 ab 52 a</td>
</tr>
<tr>
<td>3</td>
<td>149 cd 167 ghi 118 e 78 abcd 52 ab 50 a</td>
<td>120 bcd 171 hi 129 fgh 91 a 50 ab 49 a</td>
<td>114 cd 152 fgh 135 gh 74 bcd 52 ab 38 ab</td>
</tr>
<tr>
<td>4</td>
<td>164 cd 152 fgh 135 gh 74 bcd 52 ab 38 ab</td>
<td>166 cd 140 ef 133 gh 77 abcd 47 ab 55 a</td>
<td>167 cd 129 de 132 gh 72 def 36 abc 52 a</td>
</tr>
<tr>
<td>5</td>
<td>143 cd 114 cd 123 ef 48 fe 33 bc 48 a</td>
<td>143 cd 114 cd 123 ef 48 fe 33 bc 48 a</td>
<td>117 bc 106 bc 105 d 56 ef 36 abc 48 a</td>
</tr>
<tr>
<td>6</td>
<td>115 bc 91 ab 96 c 33 g 21 e 28 b</td>
<td>115 bc 91 ab 96 c 33 g 21 e 28 b</td>
<td>172 a 100 abc 86 b 50 fg 38 abc 46 ab</td>
</tr>
<tr>
<td>7</td>
<td>124 bed 154 fgh 136 efg 77 abcd 47 ab 52 a</td>
<td>124 bed 154 fgh 136 efg 77 abcd 47 ab 52 a</td>
<td>84 ab 84 a 86 b 48 fg 41 ab 49 a</td>
</tr>
<tr>
<td>8</td>
<td>156 cd 140 ef 133 gh 77 abcd 47 ab 55 a</td>
<td>156 cd 140 ef 133 gh 77 abcd 47 ab 55 a</td>
<td>54 a 76 a 69 a 40 g 36 abc 45 ab</td>
</tr>
<tr>
<td>9</td>
<td>143 cd 114 cd 123 ef 48 fe 33 bc 48 a</td>
<td>143 cd 114 cd 123 ef 48 fe 33 bc 48 a</td>
<td>60 a 95 abc 81 b 36 g 36 abc 49 a</td>
</tr>
<tr>
<td>Mean 127</td>
<td>139 b 121 a 65 b 44 a 47 a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Numbers in columns followed by different letters are different at the 95% probability level. Means were compared by harvest years.

RESULTS

Corn grain yields in both 1979 and 1980 were increased with increasing wastewater N fertilization up to about 200 to 250 kg N/ha with optimum wastewater fertilization yielding approximately 10 Mg of corn grain per ha (Table 2). The extra N added to rows 1 to about 13 gave no further yield increase. Yields were somewhat higher in 1980 than in 1979 but decreased greatly in 1981. Corn grain yields in 1981 were probably depressed by an early season weed infestation that was cleaned out of the plots by hand weeding. Also, the general corn yields for the area were somewhat lower in 1981 than in 1980 because of seasonal differences. In 1981 the only significance in the statistical analyses was the difference between current years and residual fertilization. The 1981 fertilization produced higher yields, even when very high amounts of N had been applied in previous years in the wastewater irrigations. At the high wastewater N applications, the corn received much more N than it could assimilate, and N applications above the 200 to 250 kg/ha rate, even up to 600 kg N, were probably not responsible for variations in yield.

Nitrogen uptake in the corn followed similar trends to total corn yields in all 3 years (Table 3). The N uptake increased up to about the 200 kg/ha wastewater N fertilization level. Nitrogen uptake in the residual evaluation areas in 1981 were lower than the 1981 fertilized plot areas. In the two residual areas, significance from wastewater fertilization had disappeared.

On the average, N uptake in the corn and stalks decreased from 1979 to 1980 to 1981.
residual plots was less than in the wastewater-fertilized areas (Table 4). Generally, N uptake increased from row 20 to row 13 with increasing wastewater N applications for the 3 y. Differences in N uptake at higher N applications is apparently random error. The statistical trends for these data are about the same as those for the data from the corn and corn stalk N shown separately.

While 1980 corn yields were much higher than the other years, the stalk yields for that year were lower than the other 2 y, indicating that there is little if any correlation between stalk and corn grain yields (Table 5). There were no statistically significant differences between stalk yields from rows representing differences in wastewater N applications. The corn grain yields responded to the wastewater fertilization but the stalks did not. This lack of yield response in the corn stalks probably resulted from low fertility that produced good stalk growth, but was not sufficient to produce maximum ear growth or corn grain yield in the outer rows. While stalk yield was not significantly influenced by N in the wastewater applications, there was a difference in N uptake in the stalks (Table 6). Nitrogen uptake increased from the lowest wastewater fertilization to about row 13 with 229 kg wastewater N application in 1979. In the following years and in the residual N evaluation areas, N uptake in the stalks was not significantly influenced by wastewater N applications. The N in the stalks in 1979 averaged about 95 kg/ha and in following years was reduced to half that value or less. It should be noted that from time to time differences in observations for individual rows appear to be statistically
Table 7—Corn grain yield and N recovery from ammonium nitrate-fertilized plots at Caldwell, Idaho.

<table>
<thead>
<tr>
<th>N Fertilizer</th>
<th>Corn grain yield</th>
<th>N Recovery in corn and stalks</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg/ha</td>
<td>Mg/ha</td>
<td>kg/ha</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>200</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>300</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100 100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>200 200</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>300 300 300</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* Numbers in columns followed by different letters are different at the 95% probability level.

In 1979, applications of NH₄NO₃-N up to 200 kg/ha increased corn yields (Table 7). In 1980 the plots that were fertilized only in 1979 showed a trend upward in yields from the check treatments to the 300-kg N treatments, but no significant differences were observed. The plots that received 300 kg N/ha for both 1979 and 1980 had higher corn yields than the plots receiving lower rates that were not different from each other, with yields up to about 10 or 11 Mg/ha. The maximum corn yields on the ammonium nitrate-fertilized plots in 1981 were about 3 Mg lower than the maximum yields in 1980. The corn fertilized in 1979 and 1980 had fertility carryover in 1981 that increased slightly with increasing rates, causing a trend toward better yields at the higher N rates. The corn fertilized the 3 y had sufficient N for excellent yields but some other factor limited yields. The amount of N in the corn grain showed similar trends to yields with N uptake increasing to the intermediate rate of N application in 1979 and no differences in N uptake for the plots that were cropped a second year without additional N. Nitrogen uptake in the corn grain in 1980 was greater for the 200 and 300 kg/ha application rates than the check, the residual plots, or the 100-kg N/ha rates.

Table 8 shows the relative N recovery rates from the various wastewater N applications by calculating N recovery by rows of corn representing four fertilization rates. The rows selected for evaluation were row 3, representing the highest fertilization rates; row 11, representing intermediate high rates; row 13, representing the average maximum application at which N response was observed; and row 15, representing relatively low N applications. The first line of data for each set shows N uptake in the crop (both stalks and corn grain). The next line of data shows a check plot N uptake that represents the N recovered without fertilization. These figures were taken from check plot N uptake from the NH₄NO₃-fertilized plot areas. The third line is...
Table 9—An analysis of N uptake in corn and stalks from plots treated with NH$_4$NO$_3$.

<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>N applied</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>N uptake in crop</td>
<td>156</td>
<td>161</td>
<td>105</td>
<td>210</td>
<td>161</td>
<td>69</td>
<td>31.0</td>
<td>16.6</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>N in check crop</td>
<td>68</td>
<td>71</td>
<td>75</td>
<td>68</td>
<td>71</td>
<td>75</td>
<td>68</td>
<td>71</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>N from NH$_4$NO$_3$</td>
<td>300</td>
<td>507</td>
<td>207</td>
<td>723</td>
<td>423</td>
<td>179</td>
<td>31.0</td>
<td>16.6</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>N applied and residual</td>
<td>300</td>
<td>507</td>
<td>207</td>
<td>723</td>
<td>423</td>
<td>179</td>
<td>31.0</td>
<td>16.6</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>N from NH$_4$NO$_3$, %</td>
<td>31.0</td>
<td>16.6</td>
<td>13.5</td>
<td>21.3</td>
<td>22.3</td>
<td>17.9</td>
<td>31.0</td>
<td>16.6</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>N applied</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>N uptake in crop</td>
<td>149</td>
<td>128</td>
<td>92</td>
<td>166</td>
<td>168</td>
<td>98</td>
<td>43</td>
<td>16.2</td>
<td>13.2</td>
<td>39.9</td>
</tr>
<tr>
<td>N in check crop</td>
<td>68</td>
<td>77</td>
<td>77</td>
<td>68</td>
<td>77</td>
<td>77</td>
<td>68</td>
<td>77</td>
<td>77</td>
<td>63</td>
</tr>
<tr>
<td>N from NH$_4$NO$_3$</td>
<td>300</td>
<td>314</td>
<td>114</td>
<td>463</td>
<td>263</td>
<td>99</td>
<td>43.0</td>
<td>16.2</td>
<td>13.2</td>
<td>39.9</td>
</tr>
<tr>
<td>N applied and residual</td>
<td>300</td>
<td>314</td>
<td>114</td>
<td>463</td>
<td>263</td>
<td>99</td>
<td>43.0</td>
<td>16.2</td>
<td>13.2</td>
<td>39.9</td>
</tr>
<tr>
<td>N from NH$_4$NO$_3$, %</td>
<td>43.0</td>
<td>16.2</td>
<td>13.2</td>
<td>22.2</td>
<td>39.9</td>
<td>99</td>
<td>43.0</td>
<td>16.2</td>
<td>13.2</td>
<td>39.9</td>
</tr>
<tr>
<td>N applied</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>N uptake in crop</td>
<td>131</td>
<td>90</td>
<td>76</td>
<td>92</td>
<td>132</td>
<td>58</td>
<td>131</td>
<td>90</td>
<td>76</td>
<td>92</td>
</tr>
<tr>
<td>N in check crop</td>
<td>68</td>
<td>77</td>
<td>77</td>
<td>68</td>
<td>77</td>
<td>77</td>
<td>68</td>
<td>77</td>
<td>77</td>
<td>68</td>
</tr>
<tr>
<td>N from NH$_4$NO$_3$</td>
<td>100</td>
<td>132</td>
<td>32</td>
<td>219</td>
<td>119</td>
<td>32</td>
<td>68.0</td>
<td>4.6</td>
<td>0</td>
<td>13.7</td>
</tr>
<tr>
<td>N applied and residual</td>
<td>100</td>
<td>132</td>
<td>32</td>
<td>219</td>
<td>119</td>
<td>32</td>
<td>68.0</td>
<td>4.6</td>
<td>0</td>
<td>13.7</td>
</tr>
<tr>
<td>N from NH$_4$NO$_3$, %</td>
<td>68.0</td>
<td>4.6</td>
<td>0</td>
<td>13.7</td>
<td>58.0</td>
<td>0</td>
<td>68.0</td>
<td>4.6</td>
<td>0</td>
<td>13.7</td>
</tr>
</tbody>
</table>

The N uptake in the corn and stalks from the applied wastewater. The fourth line represents the amount of fertilizer applied in the wastewater in 1979 and in each successive year the N applied in the wastewater minus the N utilized by the crop for either additional wastewater N applications or residual N evaluations from previously applied wastewater N. The fifth line is an efficiency factor.

In row 3, N recovery values were relatively low because of the high fertilizer applications in 1979 and 1980 and the relatively low corn yields in 1981. The 1979 crop utilized 36% of the applied N and the residual carryover was 50% utilized in 1980, representing 68% of the originally applied wastewater N. No additional N was absorbed by the 1981 crop. With each additional wastewater N application at the high rates, the recovery decreased.

In row 11, the 1979 crop utilized 72% of the wastewater-applied N and in 1980 the residual was utilized 100%, leaving none to carry over for the second year residual evaluation. Again, the additional wastewater N applications in 1980 and 1981 decreased the N recovery percentages as shown in Table 8. In row 13, where wastewater N fertilization seemed to be optimum, 93% of the 1979-applied wastewater N was used by the corn in that year with 100% of the residual being used the following year. The second wastewater N application on row 13 that occurred in 1980 had a lower utilization efficiency, with 53%. Fertilization in 1981 and other residual evaluations showed low efficiencies in 1981 because of relatively low yields and low N utilization.

In row 15, where wastewater N fertilization was below optimum, N utilization in 1979 appeared to be 100%. With wastewater N application for 2 y, 70% N utilization was observed and for wastewater N applications for 3 y, the utilization dropped to 10%.

An analysis of N uptake by corn fertilized with NH$_4$NO$_3$ is presented in Table 9. At the 300 kg/ha N rate, recovery in 1979 was 31% followed by lower recovery values for the following 2 y fertilization. These applications were higher than the corn crop could utilize efficiently. At the 200 kg/ha N rate, recovery in 1979 was 43% followed by values about one-half that the following 2 y. At the 100 kg/ha N rate, recovery in 1979 was 68%. The next highest recovery was 58% obtained in 1980 from 2 y fertilization with NH$_4$NO$_3$. Residual N recovery values are also reported in Table 9.

Overall N recovery in corn and stalks fertilized with NH$_4$NO$_3$ ranged from 36 to 40% for plots fertilized 3 y at the three N rates, and deviated from those figures by only a few points for plots fertilized 2 y and cropped 3 y. N recovery overall increased greatly and ranged from 42 to 81% for corn fertilized 1 y and cropped 3 y (Table 10). The low fertilization rate, while it produced high N recovery, produced low corn yields.

Comparing wastewater N and NH$_4$NO$_3$-N recovery percentages in Tables 8 and 9 shows the wastewater N recovery to be higher in most cases during the first 2 y of the experiment than the fertilizer N recovery. In 1981, the wastewater-N–treated corn plots had fairly satisfactory corn yields but the N uptake was severely depressed. There is no satisfactory explanation of this difference, and comparison between the two N sources for 1981 is fruitless.
CONCLUSION

Nitrogen from potato-processing wastewater appears to produce a maximum corn yield with about 200 kg N/ha annually. The wastewater N produces corn growth response equivalent to that of commercial fertilizer N from ammonium nitrate. In good cropping years, wastewater fertilization may have a potential for yields somewhat better than the commercial fertilizer N source. There is some carry-over of applied wastewater N from year to year when excessive amounts are applied, but the carry-over does not appear to last > 1 y. Residual fertility value of the wastewater N, even when applied at very high rates, appears to be utilized in the second year. Whether the wastewater N that was not used by the crop was leached or denitrified was not determined.

Wastewater irrigation with potato-processing wastewater is an effective method of disposing of the wastewater and nutrients. Using the wastewater for growing crops instead of disposal in waterways reduces pollution and utilizes some of the wastewater nutrients that would otherwise be wasted. Spreading the wastewater over a large enough area to efficiently utilize the included plant nutrients is a desirable advancement in wastewater irrigation. This research will provide guidelines for more nearly optimum wastewater application and utilization of the included N for crop growth and maintenance, rather than applying maximum wastewater in the disposal mode.

LITERATURE CITED