**Direct and residual effect of nutrient management in maize (Zea mays) – wheat (Triticum aestivum) cropping system**

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**ABSTRACT**

A field experiment was conducted at New Delhi to investigate the response of maize (Zea mays L.) – wheat [Triticum aestivum (L.)] cropping system to different nutrient-management practices during 2003-04 and 2004-05. The highest leaf-area index (LAI), yield attributes and yield of maize were recorded with the application of 120 kg N + 26.2 kg P + 41.5 kg K/ha, closely followed by 120 kg N + 5 kg Zn + 10 t FYM/ha. The LAI, yield attributes and yield of wheat were found maximum at the residual fertility of 5 kg Zn + 20 t FYM/ha. Wheat gave 22.7% more yield at residual fertility of 5 kg Zn + 20 t FYM/ha. The data on maize-wheat system indicated that when 120 kg N + 5 kg Zn/ha was applied with 10 t FYM/ha, production efficiency (46.0 kg/ha-day), total productivity (10.8 t/ha), net returns (Rs 46,784/ha) and benefit : cost ratio (2.17) were the maximum. The Zn uptake by maize and wheat was the highest at 120 kg N + 5 kg Zn + 10 t FYM/ha and 5 kg Zn + 20 t FYM/ha, respectively. Except available P at 60 kg N + 10 t FYM/ha, 5 kg Zn + 10 t FYM/ha and 5 kg Zn + 20 t of FYM/ha, all the nutrients increased in the soil at different fertility levels. Higher residual organic C and available N, P, K and Zn in the soil were obtained with 5 kg Zn + 20 t FYM/ha. It was concluded that combined application of 120 kg N + 5 kg Zn +10 t FYM/ha was essential for higher productivity and profitability of maize – wheat cropping system.

**Key words:** Economics, Nutrient management, Nutrient uptake, Residual nutrients, Triticum aestivum, Yield, Zea mays

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Maize (Zea mays L.) - wheat [Triticum aestivum (L.)] emend. Fiori & Paol.] is the most prominent and popular double cropping system under irrigated conditions in north-western parts of India. The contribution of this cropping system to total cereal production is considerably large, being 31% of wheat (72.06 million t) and 6% of maize (14.1 million t) (FAI, 2006). Moreover, 60% area of rainy-season (kharif) maize is followed by wheat in winter season (Yadav et al., 2000). Among the factors responsible for poor productivity, inadequate fertilizer use and emergence of multiple-nutrient deficiency due to poor recycling of organic sources and unbalanced use of fertilizers are important. Besides N, P and K, Zn is the important micronutrient for cereals as it plays major role in synthesis of tryptophan, which is precursor of indole acetic acid (Tsui, 1988). The long-term trials indicated that application of nutrients through chemical fertilizers have a deleterious effect on soil health, leading to unsustainable productivity (Swarup, 2002). Therefore, there is need to improve the nutrient-supply system in terms of integrated nutrient management, involving the use of chemical fertilizers in conjunction with organic manures. Application of different organic-inorganic sources was found very effective in realizing high yields, better economics (Kumar et al., 2005) and improved residual fertility of the soil (Pathak et al., 2005). Adequate information is available on the response of maize and wheat to either inorganic or organic fertilizers on single crop. However, meager information is available on the effect of different combinations of nutrient sources on maize and wheat grown in a system. The present experiment comprising different levels of inorganic and organic fertilizers was undertaken to study their direct and residual effects in maize - wheat cropping system.

**MATERIALS AND METHODS**

A field experiment was carried out on sandy loam soil of Indian Agricultural Research Institute New Delhi during the crop years 2003-04 and 2004-05. The soil was low in organic C (0.38%), available N (149.3 kg/ha) and K (153.1 kg/ha), and medium in available P (11.6 kg/ha) C with Zn content 1.09 ppm and pH 7.6. Nine fertilizer treatments to maize, viz. control: 120 kg N + 26.2 kg P + 41.5 kg K/ha (recommended dose of NPK, RDF) (N120 P26.2 K41), 60 kg N + 13.1 kg P + 20.8 kg K/ha...
without 5 kg N, with Pathak (2005) also observed similar findings.

**RESULTS AND DISCUSSION**

**Direct effect on maize**

Significantly higher leaf-area index (LAI) was recorded with the application of 120 kg N + 26.2 kg P + 41.5 kg K/ha (RDF) compared with that of the remaining fertility levels except 120 kg N + 5 kg Zn + 10 t FYM/ha (Table 1). The fertility levels of 120 kg N + 10 t FYM/ha with and without 5 kg Zn/ha, being at par, also recorded higher LAI than other treatments. Adequate and continuous availability of nutrients with recommended dose of NPK or combined application of FYM with N might have improved the LAI of maize. These results are in close conformity with Pathak et al. (2005). The grain yield of maize was also significantly influenced by different fertility levels. Application of 120 kg N + 26.2 kg P + 41.5 kg K/ha recorded the highest grain yield which was 134.6, 35.1, 29.7, 7.1, 23.7, 4.4, 53.0 and 42.6% more than the control, 60 kg N + 13.1 kg P + 20.8 kg K/ha, 60 kg N + 10 t FYM/ha, 120 kg N + 10 t FYM/ha, 60 kg N + 5 kg Zn + 10 t FYM/ha, 120 kg N + 5 kg Zn + 10 t FYM/ha, 5 kg Zn + 10 t FYM/ha and 5 kg Zn + 20 t FYM/ha, respectively. When 120 kg N/ha and 10 t FYM/ha were applied with or without 5 kg Zn/ha, the yield was on par with that of RDF, and these treatments proved superior to the remaining fertility levels. Higher values of cobs/plant and test weight were also noticed with the application of RDF or 120 kg N + 5 kg Zn + 10 t FYM/ha over other treatments due to improved growth in terms of LAI with these treatments, which consequently improved the yield. Kumar et al. (2005) also observed similar findings.

**Residual effect on wheat**

The highest value LAI of wheat was recorded at the residual fertility of 5 kg Zn + 20 t FYM/ha, which was significantly more than that of all other fertility levels (Table 1). Similarly, fertility levels of 5 kg Zn + 10 t FYM/ha and 120 kg N + 5 kg Zn + 10 t FYM/ha, being at par, proved superior to the remaining treatments. The findings of Kumar et al. (2005) confirm these results. In comparison with the control, 93.2, 40.4, 61.4, 27.3, 13.9, 22.8, 10.0 and 6.4% higher grain yield of wheat was recorded at the residual fertility of 5 kg Zn + 20 t FYM/ha, RDF, 50% RDF, 60 kg N + 10 t FYM/ha, 120 kg N + 10 t FYM/ha, 60 kg N + 5 kg Zn + 10 t FYM/ha, 120 kg N + 5 kg Zn + 10 t FYM/ha, respectively. Similarly, the application of 5 kg Zn + 10 t FYM/ha with or without 120 kg N/ha resulted in marked improvement in grain yield of wheat than of 120 kg N + 26.2 kg P + 41.5 kg K/ha. The higher number of effective tillers, grains/spike and test weight were noticed with the fertilizers incorporating FYM, which improved the yield of wheat. After maize, the treatments having FYM might have left more nutrients in the soil than inorganic fertilizers, which was available for wheat crop. Jamwal (2005) also obtained similar positive residual effect of FYM on wheat in maize - wheat cropping system.

**Production efficiency and system productivity**

The highest production efficiency (46.0 kg/h/day) and total productivity (10.8 t/ha) in terms of maize-grain equivalents (MGE) was obtained with the application of 120 kg N + 5 kg Zn + 10 t FYM/ha, followed by 120 kg N + 10 t FYM/ha, indicating yield stability with the use of FYM along with inorganic fertilizers (Table 2). It is also important to note that application of 5 kg Zn + 20 t FYM/ha and 60 kg N + 5 kg Zn + 10 t FYM/ha gave the production efficiency and total productivity equal to that of RDF fertilizers. The findings are in close conformity with those of Jamwal (2005).

**Zn uptake**

Zinc uptake by both maize and wheat significantly varied due to different fertility levels (Table 4). The highest...
Zn uptake by maize was noted with the application of 120 kg N + 5 kg Zn + 10 t FYM/ha compared with the remaining fertility levels. It was followed by RDF, which also remained superior to the rest of the treatments. However, in wheat the fertility level of 5 kg Zn + 20 t FYM/ha, being on par with that of 5 kg Zn + 10 t FYM/ha, recorded higher Zn uptake than the remaining fertility levels (Table 4). The nutrient uptake by the crop is determined by its nutrient content and yield. It was evident that yield was a greater deciding factor for the uptake of nutrients by the crop. These results confirm the findings of Latha et al. (2001).

**Nutrient balance sheet**

Nitrogen addition to the soil through fertilizers and FYM was the highest with 120 kg N and 10 t FYM/ha, whereas P and K addition was the maximum with 5 kg Zn + 20 t FYM/ha (Table 3). The N and K harvest was the highest when 120 kg N was applied with 5 kg Zn + 10 t FYM/ha, whereas P harvest remained maximum with RDF. Based on the initial N, P and K of the soil and addition and depletion of these nutrients, the expected N, P and K balance was positive in all the treatments except K with the application of 120 kg N + 5 kg Zn + 10 t FYM/ha. In general, the expected balance of N was more favourable with the application of 120 kg N + 10 t FYM/ha and of P and K with that of 5 kg Zn + 20 t FYM/ha. The data on gain or loss of nutrients in soil indicated that N, P and K contents showed the positive trend in all the treatments except 60 kg N + 10 t FYM/ha, 5 kg Zn + 10 t FYM/ha and 5 kg Zn + 20 t FYM/ha for P content, which ranged from -0.3 to -21.7 kg/ha. The maximum gain in N and K was noticed with 5 kg Zn + 10 t FYM/ha and 120 kg N + 5 kg Zn + 10 t FYM/ha, respectively. This could be ascribed to the application of FYM and N and variations in the addition and uptake of nutrients by the crops. These

**Table 1.** Growth, yield attributes and yield of maize and wheat as influenced by different nutrient-management practices (mean data of 2 years)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Maize</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Leaf-area index</td>
<td>Grain yield (t/ha)</td>
</tr>
<tr>
<td>Control</td>
<td>2.30</td>
<td>0.7</td>
</tr>
<tr>
<td>N₁₂₀P₆₀K₅₀</td>
<td>3.01</td>
<td>1.4</td>
</tr>
<tr>
<td>N₀₆₀P₁₃₁ₕK₂₀₅</td>
<td>2.68</td>
<td>0.9</td>
</tr>
<tr>
<td>N₀₆₀FYM₁₀</td>
<td>2.70</td>
<td>1.0</td>
</tr>
<tr>
<td>N₁₂₀FYM₅₀</td>
<td>2.88</td>
<td>1.2</td>
</tr>
<tr>
<td>N₀₆₀ZnFYM₅₀</td>
<td>2.72</td>
<td>1.1</td>
</tr>
<tr>
<td>N₁₂₀ZnFYM₁₀</td>
<td>2.95</td>
<td>1.3</td>
</tr>
<tr>
<td>Zn₅₀FYM₅₀</td>
<td>2.62</td>
<td>0.8</td>
</tr>
<tr>
<td>Zn₅₀FYM₁₀</td>
<td>2.66</td>
<td>1.0</td>
</tr>
<tr>
<td>SEm⁺</td>
<td>0.03</td>
<td>0.1</td>
</tr>
<tr>
<td>CD(P=0.05)</td>
<td>0.11</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Table 2.** Production efficiency, total productivity and economic return of maize - wheat cropping sequence as influenced by different nutrient-management practices (mean data of 2 years)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Production efficiency (MGEY* kg/ha/day)</th>
<th>Total productivity (MGEY* t/ha)</th>
<th>Net returns (x10² Rs/ha)</th>
<th>Benefit : cost ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>maize</td>
<td>wheat</td>
<td>maize - wheat</td>
<td>maize</td>
</tr>
<tr>
<td>Control</td>
<td>23.2</td>
<td>5.44</td>
<td>9.2</td>
<td>10.2</td>
</tr>
<tr>
<td>N₁₂₀P₆₀K₅₀</td>
<td>42.2</td>
<td>9.92</td>
<td>25.4</td>
<td>16.9</td>
</tr>
<tr>
<td>N₀₆₀P₁₃₁ₕK₂₀₅</td>
<td>33.5</td>
<td>7.66</td>
<td>18.3</td>
<td>14.4</td>
</tr>
<tr>
<td>N₀₆₀FYM₁₀</td>
<td>38.2</td>
<td>8.98</td>
<td>17.5</td>
<td>19.3</td>
</tr>
<tr>
<td>N₁₂₀FYM₅₀</td>
<td>44.5</td>
<td>10.46</td>
<td>22.4</td>
<td>22.8</td>
</tr>
<tr>
<td>N₀₆₀ZnFYM₅₀</td>
<td>39.8</td>
<td>9.36</td>
<td>18.2</td>
<td>20.4</td>
</tr>
<tr>
<td>N₁₂₀ZnFYM₁₀</td>
<td>46.0</td>
<td>10.82</td>
<td>22.5</td>
<td>24.3</td>
</tr>
<tr>
<td>Zn₅₀FYM₅₀</td>
<td>38.9</td>
<td>9.16</td>
<td>13.8</td>
<td>25.3</td>
</tr>
<tr>
<td>Zn₅₀FYM₁₀</td>
<td>41.6</td>
<td>9.78</td>
<td>13.3</td>
<td>27.3</td>
</tr>
<tr>
<td>SEm⁺</td>
<td>1.0</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>3.0</td>
<td>0.71</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
findings support those of Mundra et al. (2002).

**Economics**

Application of RDF resulted in the highest net returns and benefit: cost ratio from maize. But in wheat, the maximum net returns and B : C ratio were obtained when it was grown on residual fertility of 5 kg Zn + 20 t FYM/ha (Table 2). The data on overall economics of maize-wheat cropping system indicated that 120 kg N + 5 kg Zn + 10 t FYM/ha was the most profitable by recording net return of Rs 46,784/ha and B : C ratio of 2.17, closely followed by 120 kg N + 10 t FYM/ha (net returns Rs 45,196/ha and B : C ratio, 2.16). In general, the maize treatments having FYM had lower values of net return and benefit: cost ratio than those having inorganic fertilizers due to higher cost of application of FYM. On the contrary, wheat showed the reverse trend due to better response on residual fertility after FYM-containing treatments. These findings confirm those of Jamwal (2005) and Kumar et al. (2005).

**Residual soil fertility**

When FYM was applied with inorganic fertilizers to maize, there was improvement in soil-organic C and available N, P, K and Zn status (Table 4). The highest residual contents of organic and available N, P, K and Zn were analysed in the soil at the fertility level of 5 kg Zn + 20 t FYM/ha. The residual available N of 120 kg N + 5 kg Zn + 10 t FYM/ha remained similar to that of 5 kg Zn + 20 t FYM/ha. The improvement in organic C could be attributed to addition of organic matter through FYM, and higher amounts of residual available N, P and K analysed might be attributed to the increased activity of microorganisms, leading to greater mineralization of applied and inherent nutrients. The reason for higher Zn content in the soil with FYM was that FYM improved the availability of both native and added Zn through transformation of solid phase to soluble metal complex (Latha et al., 2001). Jamwal (2005) and Pathak et al. (2005) also reported similar effect of FYM and N in maize-wheat.

### Table 3. Balance sheet of N, P and K as influenced by different nutrient-management practices (based on data of 2 years)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total available nutrients (initial + added through fertilizers) (kg/ha)</th>
<th>Nutrient harvest (kg/ha)</th>
<th>Expected nutrient balance after last harvest (kg/ha)</th>
<th>Net loss or gain in nutrient content in soil (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
<td>K</td>
<td>N</td>
</tr>
<tr>
<td>Control</td>
<td>149.3</td>
<td>11.6</td>
<td>153.1</td>
<td>109.0</td>
</tr>
<tr>
<td>N120P36K4.5</td>
<td>269.3</td>
<td>37.8</td>
<td>194.6</td>
<td>231.8</td>
</tr>
<tr>
<td>N50P13.1K20.8</td>
<td>209.3</td>
<td>24.7</td>
<td>173.9</td>
<td>173.6</td>
</tr>
<tr>
<td>N60FYM10</td>
<td>255.3</td>
<td>34.6</td>
<td>201.1</td>
<td>195.5</td>
</tr>
<tr>
<td>N120ZnFYM0</td>
<td>315.3</td>
<td>34.6</td>
<td>201.1</td>
<td>237.5</td>
</tr>
<tr>
<td>N60ZnFYM6</td>
<td>255.3</td>
<td>34.6</td>
<td>201.1</td>
<td>206.9</td>
</tr>
<tr>
<td>N120ZnFYM10</td>
<td>315.3</td>
<td>34.6</td>
<td>201.1</td>
<td>249.4</td>
</tr>
<tr>
<td>ZnFYM10</td>
<td>195.3</td>
<td>34.6</td>
<td>201.1</td>
<td>194.3</td>
</tr>
<tr>
<td>ZnFYM10</td>
<td>241.3</td>
<td>57.6</td>
<td>249.1</td>
<td>211.6</td>
</tr>
</tbody>
</table>

### Table 4. Zinc uptake and residual contents of organic C and available nutrients in soil after maize-wheat cropping sequence as influenced by different nutrient-management practices (after completion of 2 years)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Zn uptake (g/ha)</th>
<th>Organic C (%)</th>
<th>Available nutrients (kg/ha)</th>
<th>Available Zn (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Wheat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>131.0</td>
<td>121.0</td>
<td>0.34</td>
<td>120.3</td>
</tr>
<tr>
<td>N120P36K4.5</td>
<td>486.7</td>
<td>249.6</td>
<td>0.36</td>
<td>140.4</td>
</tr>
<tr>
<td>N50P13.1K20.8</td>
<td>358.6</td>
<td>172.0</td>
<td>0.35</td>
<td>137.0</td>
</tr>
<tr>
<td>N60FYM10</td>
<td>355.9</td>
<td>231.6</td>
<td>0.41</td>
<td>145.6</td>
</tr>
<tr>
<td>N120FYM0</td>
<td>430.6</td>
<td>306.1</td>
<td>0.40</td>
<td>161.4</td>
</tr>
<tr>
<td>N60ZnFYM10</td>
<td>438.4</td>
<td>285.2</td>
<td>0.39</td>
<td>144.2</td>
</tr>
<tr>
<td>N120ZnFYM0</td>
<td>565.6</td>
<td>370.0</td>
<td>0.41</td>
<td>162.7</td>
</tr>
<tr>
<td>ZnFYM10</td>
<td>367.6</td>
<td>380.0</td>
<td>0.43</td>
<td>144.4</td>
</tr>
<tr>
<td>ZnFYM10</td>
<td>393.6</td>
<td>390.1</td>
<td>0.45</td>
<td>165.0</td>
</tr>
<tr>
<td>SEm</td>
<td>5.0</td>
<td>3.6</td>
<td>0.003</td>
<td>1.6</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>15.2</td>
<td>10.8</td>
<td>0.01</td>
<td>4.8</td>
</tr>
</tbody>
</table>
It was concluded that the combined application of 120 kg N + 5 kg Zn + 10 t FYM/ha was essential for higher productivity and profitability of maize – wheat cropping system.

REFERENCES


