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# Evaluation of organic and inorganic sources of nutrients in maize (*Zea mays*) and their residual effect on wheat (*Triticum aestivum*) under different fertility levels

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ABSTRACT

A field experiment was conducted during 2004–06 at New Delhi to evaluate the response of maize (*Zea mays* L.) – wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system to different nutrients management practices. Application of recommended dose of fertilizers (120 N+ 26 P + 32 K kg/ha) to maize resulted in maximum growth and yield of maize during both the years. During second year 60 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter* treatment proved as effective as 120 N+ 26 P + 32 K kg/ha in terms of growth, yield attributes and yields of maize. However, wheat showed the highest response on residual fertility of 60 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter*. Application of 120 N + 26 P + 50 K kg/ha showed the superiority over 60 N + 13P + 25 K in both maize and wheat. The uptake of N, P and K also exhibited similar trend to both direct and residual fertility to different nutrient management practices applied to either crop. The value of soil organic carbon increased from the initial status of 0.39% to the maximum status of 0.52% with the application of 60 kg N/ha (farmyard manure) +cowpea green manuring + *Azotobacter*. Similar trend was also found in respect of available soil N, P and K. The mean productivity (10.77 and 11.72 tonnes/ha maize equivalents), production efficiency (44.3 and 47.1 kg/ha/day), net returns (Rs 50 123 and Rs 55 655/ha) and net returns/rupee (Rs 1.97 and Rs 2.17) of maize–wheat cropping system were maximum with the application of 60 kg N/ha (farmyard manure) + cowpea + *Azotobacter* to maize. Interaction data on system productivity indicated the 50% saving of NPK in wheat by application of 60 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter* in maize.

**Key words**: Cropping system, Economics, Maize, Nutrient uptake, Organic nutrient management, Residual fertility, *Triticum aestivum,* Wheat, *Zea mays,*

Maize (*Zea mays* L.) – wheat (*Triticum aestivum* L. emend. Fiori & Paol.) is an important cropping system of northern and central India and occupies 1.8 million ha. Nutrient management plays key role in sustaining the productivity of this system, as both the crops are high nutrient-requiring ones and respond well to higher levels of chemical fertilizers. But deterioration in soil health associated with global crises of energy, escalation in the prices of chemical fertilizers and environmental hazards due to excessive use of fertilizers, lead to emphasize on supplementation or substitution of chemical fertilizers with low priced nutrient sources such as organic and biosources. Application of these nutrient sources alone or in combination with inorganic sources had been found beneficial not only in enhancing the productivity of maize and wheat (Jamwal 2005) but also had the beneficial impact on soil properties (Pathak *et al.* 2005). The beneficial effect of organic sources applied in preceding crops was recorded in succeeding wheat crop (Yadav *et al.* 2005, Yadav *et al*. 2008). The carry over effect of fertilizers and manures applied to maize had also been reported in wheat (Jamwal 2005, Kumar and Ahlawat 2004, Tiwari *et al.* 2004). However, on the residual fertility after maize, the full yield potential of improved wheat varieties cannot be achieved because of their high nutrient need. Thus there is need to supply certain amount of nutrients to wheat crop. The existing nutrient management practices are based on individual crop and in fact, there is meager information on cropping system-based nutrient management, particularly in maize–wheat cropping system. Therefore, an attempt was made to study the effects of direct and residual effect of inorganic and organic fertilizers on the productivity and soil properties in maize–wheat cropping system.

## MATERIALS AND METHODS

A field experiment was carried at Indian Agricultural Research Institute, New Delhi during 2004–06. The sandy loam soil had 0.39% organic C with the available N, P and K

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contents of 153.8, 12.2 and 165.6 kg/ha, respectively. The zinc content in the soil was 1.09 ppm with *p*H 7.6. The experiment was laid out in factorial randomized block design with 3 replications. Treatments comprised 6 nutrient management practices to maize [Control, 120N+26P+32 K kg/ha (recommended dose), 60 kgN/ha (urea)+ 60 kgN/ha (farmyard manure), 90 kgN/ha (farmyard manure) + *Azotobacter*, 90 kgN/ha (farmyard manure) + cowpea green manuring, 60 kgN/ha (farmyard manure) + cowpea green manuring+ *Azotobacter*] and 2 levels of inorganic fertilizers to wheat (120N+26P+50 K kg/ha and 60N+13P+25 K kg/ha).

'PEMH 1' maize was sown in the last week of June and harvested during second week of October during both the years. After harvesting of maize, 'HD 2824' wheat variety was sown in third week of November and harvested during second week of April in both the years. The required amount of farmyard manure (containing 0.49% N, 0.20% P and 0.46% K) as per treatments was incorporated into the soil 10 days prior to maize planting. One row of 'Pusa Komal' cowpea was sown between 2 rows of maize and the crop residue of cowpea was incorporated into the soil at 45 and 50 days after sowing during 2004 and 2005, respectively. The maize seed was inoculated with *Azotobacter* before sowing for treated plots. One-fourth of N and whole amount of P and K as per treatment were applied as basal in maize and remaining amount of N was divided into 2 equal splits and top-dressed at knee-high and silking stage. In wheat, full amount of P and K as per treatments was applied as basal and nitrogen was applied into 3 equal splits 1/3 each at sowing, jointing and pre flowering stage. Four and five irrigations were applied in maize and wheat, respectively during both the years. Various growth and yield parameters were observed at harvest following the standard procedure. Prevailing market prices of inputs as per treatments of both the crops were considered for working out the cost of cultivation. For working out the maize grain equivalent yield and economics the market prices of grain of maize (Rs 5 250/ tonne) and wheat (Rs 7 000/tonne) and maize stover (Rs 500/ tonne) and wheat straw (Rs 2 500/tonne) were considered. Grains and stover/straw of maize and wheat were analyzed for N, P and K concentration following standard procedures and the total uptake was calculated based on grain and stover/ straw yields of these crops. Soil samples up to the depth of 30 cm were collected after completion of one year crop cycle and analyzed for the organic carbon and available nitrogen, phosphorus and potassium contents as per the standard methods. The bulk density of 30 cm soil was determined after completion of one year cropping cycle by using Core sampler method.

## RESULTS AND DISCUSSION

*Effect of nutrient management practices on maize and wheat*

Nutrient management practices to maize significantly affected the leaf area index and dry weight/plant of maize during both the years (Table 1). The maximum leaf area index and dry weight/plant of maize was found with the application of recommended dose of fertilizers (120 N+ 26 P + 32 K kg/ ha) during both the years. The nutrients management treatments, viz 60 kg N/ha (urea) + 60 kg N/ha (farmyard manure), 90 kg N (farmyard manure) + cowpea green manuring and 60 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter*, being at par recorded higher leaf area index with more dry weight/plant over control and 90 kg N/ha (farmyard manure) + *Azotobacter* treatments during both the years. However, it is important to note that during second year, the integrated application of different organic sources, viz 60 kg N/ha (urea) + 60 kg N/ha (farmyard manure), 90 kg N/ha (farmyard manure) + cowpea green manuring and 60 kg N/ha (farmyard manure) + cowpea green manuring +*Azotobacter* gave the dry weight/plant equal to recommended dose of NPK (120:26:32). Application of organic sources in maize might have increased the activities of beneficial micro organisms due to increased organic pool in soil, which resulted in production of growth-promoting substances and improved nutrient availability for longer period throughout the crop growth and thus the use of organic sources had the beneficial effect on the growth of maize (Yadav *et al*. 2008). The findings are in close conformity of Jamwal (2005).

The leaf area index and dry weight/$m^2$ of wheat also differed significantly due to different nutrient management practices to maize (Table 2). Significantly highest leaf area index and dry weight/$m^2$ of wheat plants were recorded on the residual fertility of 60 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter* treatment during both the years. However, application of 90 kg N/ha (farmyard manure) + *Azotobacter* was at par with that of 60 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter*. This was because of higher residual availability of nutrients under the treatments having organic sources, viz farmyard manure, green manure and *Azotobacter.* Similar positive residual effect of organic sources on wheat was reported in by Jamwal (2005) and Kumar (2008).

*Yield attributes*

Cobs/plant, number of grains/cob and test weight of maize differed significantly due to nutrient management practices (Table 1). Highest number of cobs/plant and grains/cob were recorded at the fertility level of 120 N + 26 P + 32 K kg/ha than all other treatments during first year. While during second year, the application of 60 kg N/ha (urea) + 60 kg N/ ha (farmyard manure) or 90 kg N/ha (farmyard manure) + cowpea green manuring or 60 kg N/ha (urea) + cowpea green manuring + *Azotobacter* resulted in cobs/plant, grains/cob and test weight, which were at with that of 120 N + 26 P + 32 K kg/ha treatment. The control recorded the lowest values of all the yield attributes.

Table 1 Growth, yield attributes, yield and nutrient uptake by maize as influenced by different nutrient management practice

| Treatment | Leaf area index | | Dry weight (g/plant) | | Cobs/plant | | Grains/cob | | Test weight (g) | | Grain yield (tonnes/ha) | | Stover yield (tonnes/ha) | | Nutrient uptake by maize | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | N (kg/ha) | | P(kg/ha) | | K(kg/ha) | |
| | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 |
| *Nutrient management to maize* | | | | | | | | | | | | | | | | | | | | |
| Control | 2.60 | 2.52 | 60.5 | 55.2 | 0.9 | 0.8 | 235 | 238 | 236.0 | 230.2 | 2.44 | 1.87 | 3.40 | 2.92 | 45.8 | 36.8 | 10.4 | 8.2 | 43.0 | 36.2 |
| 120N+26P+ 32 K kg/ha | 4.19 | 4.05 | 128.4 | 119.3 | 1.5 | 1.4 | 284 | 278 | 241.2 | 238.9 | 4.40 | 4.23 | 6.87 | 6.20 | 122.3 | 113.9 | 29.7 | 27.4 | 111.9 | 101.8 |
| 60 kgN/ha (urea) +60 kgN/ha (FYM) | 3.48 | 3.62 | 102.1 | 112.2 | 1.0 | 1.3 | 251 | 271 | 232.1 | 239.0 | 3.73 | 3.80 | 5.55 | 6.01 | 100.7 | 100.8 | 22.7 | 23.6 | 95.2 | 93.0 |
| 90 kgN/ha (FYM) + *Azotobacter* | 3.10 | 3.40 | 97.8 | 100.8 | 0.9 | 1.0 | 246 | 259 | 228.0 | 235.0 | 3.60 | 3.67 | 5.41 | 5.81 | 88.5 | 85.6 | 19.4 | 19.3 | 85.5 | 80.4 |
| 90 kgN/ha(FYM)+ Cowpea green manuring | 3.55 | 3.63 | 105.6 | 112.4 | 1.1 | 1.3 | 259 | 261 | 237.4 | 236.1 | 3.67 | 3.82 | 5.73 | 5.93 | 93.6 | 93.5 | 20.7 | 21.3 | 89.8 | 85.1 |
| 60 kgN/ha(FYM)+ Cowpea green manuring+ *Azotobacter* | 3.60 | 3.67 | 108.0 | 118.6 | 1.2 | 1.3 | 266 | 277 | 238.6 | 237.0 | 3.72 | 4.05 | 5.87 | 6.08 | 95.7 | 100.3 | 21.3 | 22.9 | 92.8 | 89.9 |
| CD ($P$=0.05) | 0.18 | 0.21 | 7.2 | 8.1 | 0.2 | 0.2 | 10 | 11 | 4.5 | 4.8 | 0.23 | 0.23 | 0.33 | 0.28 | 15.2 | 14.0 | 5.4 | 4.1 | 10.5 | 9.0 |
| *Nutrient management to wheat* | | | | | | | | | | | | | | | | | | | | |
| 120N+26P+ 50 K kg/ha | | 3.58 | | 104.4 | | 1.2 | | 268 | | 237.6 | | 3.70 | | 5.63 | | 91.5 | | 22.3 | | 85.7 |
| 60N+13P+ 25 K kg/ha | | 3.48 | | 101.7 | | 1.0 | | 260 | | 234.5 | | 3.44 | | 5.35 | | 83.8 | | 18.5 | | 78.1 |
| CD ($P$=0.05) | | 0.10 | | 2.8 | | 0.2 | | 7.0 | | 2.9 | | 0.18 | | 0.22 | | 7.4 | | 3.7 | | 6.2 |

Different nutrient management practices of maize significantly affected effective tillers/$m^2$, number of grains/ear and test weight of succeeding wheat crop (Table 2). The treatments 60 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter* and 90 kg N/ha (farmyard manure) + cowpea green manuring were at par but significantly higher than the remaining treatments during both the years. The application of 90 kg N/ha (farmyard manure) + *Azotobacter* also showed the superiority over 120 N + 26P + 32 K kg/ha in terms of number of effective tillers/$m^2$ and grains/ear and test weight. The results indicated that integrated organic sources of nutrients comprising of farmyard manure, green manure and biofertilizer were better than inorganic nutrient source in maize –wheat cropping system. The results confirm the findings of Jamwal (2005) and Kumar and Ahlawat (2004).

*Yield*

Significant variation in grain and stover yields of maize was recorded due to nutrient management practices in both the years (Table 1). Higher grain and stover yields of maize were recorded with the application of 120N+26P+32 K kg/ha as compared to other treatments. However, different integrated nutrient management treatments did not differ with each other during the first year. During second year application of 60 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter* was at par with recommended dose of NPK (120:26:32). This was attributed to the better growth with higher values of yield attributes on the same nutrient management treatments. Mazzonccini *et al.* (2008) also reported the similar results.

The grain and straw yield of succeeding wheat differed significantly due to varying fertility management in preceding maize (Table 2). When 60 kg N (farmyard manure) + cowpea green manuring + *Azotobacter* were applied to maize, the grain and straw yield of wheat recorded the highest value in both the years. The treatment of 90 kg N/ha (farmyard manure) + cowpea green manuring was at par with 60 kg N (farmyard manure)+ cowpea green manuring + *Azotobacter* in respect of grain yield during second year and straw yield during both the years. However, grain and straw yields of recommended dose of NPK (120 N + 26 P + 32 K kg/ha) and control were statistically lower than all the treatments consisting of integrated sources of nutrients. In general, grain and straw yields of wheat were higher during second year in comparison to first year and the increase in yields was higher in the treatments of combined use of different nutrients sources. Cowpea green manuring and addition of farmyard manure and *Azotobacter* might have resulted in higher residual fertility which consequently improved the growth, yield and yield attributes of maize and wheat. The results are in agreement with that of Kumar and Ahlawat (2004) and Kumar (2008).

*Nutrient uptake*

Significant variation in N, P and K uptake by maize was noticed due to varying nutrient management practices in maize during both the years (Table 1). Highest N, P and K uptake by maize was found with the application of 120 N + 26 P + 32 K kg/ha in both the years. However, N, P and K uptake at 120 N + 26 P + 32 K kg/ha were statistically at par with that of 60 kg N (urea) + 60 kg N (farmyard manure). Integrated nutrient management practices did not differ in respect of nutrients uptake during both the years except 90 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter* which recorded higher N and K uptake as compared to other treatments during second year only.

Application of 60 kg N (farmyard manure) + cowpea green manuring + *Azotobacter* recorded the significantly highest N, P and K uptake by wheat, which was however at par with that of 90 kg N/ha (FYM)+ cowpea green manuring.

*Effect of NPK levels*

*Growth:* The leaf area index and dry weight of maize and wheat varied under different fertility treatments applied to wheat and growth parameters were higher at 120 N + 26 P + 50 K kg/ha than 60 N + 13P + 25 K kg/ha (Table 1) during both the years. More availability of nutrients with recommended dose of NPK might have improved growth of maize and wheat. Kumar (2008) also reported the similar trend.

*Yield attributes:* The fertility levels of wheat significantly influenced the yield attributes of both wheat and maize. Markedly more number of cobs/plant and grains/cob and test weight of maize (Table 1) and effective tillers/$m^2$ and grains/ear and test weight of wheat (Table 2) were noticed with the application of 120 N + 26 P + 50 K kg/ha as compared to 60 N + 13P + 25 K kg/ha. Higher leaf area index and dry weight of maize and wheat with 120 N + 26 P + 50 K kg/ha resulted in higher values of yield attributes. Kumar (2008) confirmed these findings.

*Yield:* The application of 120 N + 26 P + 50 K kg/ha significantly increased both grain and straw yields of wheat by 12.6 and 16.6%; and by 13.9 and 12.7% as compared to that of 60 N + 13 P + 25 K kg/ha treatment during both the years, respectively (Table 2). With regard to response of maize to residual fertility of treatments applied to wheat, 7.6 and 5.2% higher grain and stover yield of maize were found with the application of 120 N + 26 P + 50 K kg/ha over 60 N + 13 P + 25 K kg/ha (Table 1). The findings are in close conformity of Kumar (2008).

*Interaction effect of integrated nutrient management and NPK* levels on wheat yield

The data of interaction effect on wheat grain yield showed that the highest grain yield was recorded with the application of 60 kg N/ha (farmyard manure) + cowpea green manuring

Table 2 Growth, yield attributes, yield and nutrient uptake by wheat as influenced by different nutrient management practices

| Treatments | Leaf area index | | Dry weight g/m$^2$ | | Effective tillers/m$^2$ | | Grains/ear | | Test weight (g) | | Grain yield (tonnes/ha) | | Straw yield (tonnes/ha) | | Nutrient uptake by wheat | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | N (kg/ha) | | P(kg/ha) | | K(kg/ha) | |
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| *Nutrient management to maize* | | | | | | | | | | | | | | | | | | | | |
| Control | 2.64 | 2.87 | 315.8 | 328.2 | 298 | 308 | 30.6 | 31.3 | 40.4 | 40.7 | 3.56 | 3.87 | 4.92 | 5.10 | 82.4 | 87.5 | 14.4 | 15.0 | 116.8 | 119.2 |
| 120N+26P+ 32 K kg/ha | 3.61 | 3.68 | 570.2 | 581.8 | 305 | 313 | 34.6 | 34.4 | 40.9 | 41.3 | 4.22 | 4.30 | 5.40 | 5.52 | 102.2 | 103.0 | 17.7 | 18.0 | 131.2 | 133.4 |
| 60 kgN/ha (urea)+ 60 kgN/ha (FYM) | 3.77 | 3.88 | 591.8 | 605.0 | 312 | 320 | 37.5 | 40.0 | 41.0 | 41.9 | 4.64 | 4.97 | 5.80 | 6.18 | 115.7 | 123.0 | 19.8 | 21.2 | 143.8 | 152.2 |
| 90 kgN/ha (FYM)+ *Azotobacter* | 3.84 | 3.97 | 603.2 | 635.0 | 335 | 341 | 39.2 | 43.9 | 42.2 | 43.4 | 4.82 | 5.23 | 6.13 | 6.25 | 123.9 | 133.3 | 21.2 | 22.1 | 154.8 | 157.7 |
| 90 kgN/ha (FYM) + Cowpea green manuring | 3.92 | 4.05 | 615.8 | 640.3 | 342 | 350 | 41.0 | 46.4 | 43.6 | 44.0 | 5.00 | 5.55 | 6.27 | 6.41 | 129.8 | 143.0 | 22.0 | 23.2 | 162.2 | 166.1 |
| 60 kgN/ha(FYM) + Cowpea green manuring+ *Azotobacter* | 4.04 | 4.13 | 630.6 | 656.0 | 357 | 371 | 45.8 | 48.1 | 44.8 | 45.2 | 5.30 | 5.78 | 6.38 | 6.72 | 140.0 | 151.5 | 23.6 | 24.9 | 170.8 | 179.9 |
| CD ($P$=0.05) | 0.18 | 0.20 | 18.4 | 22.3 | 21.2 | 24.0 | 3.2 | 3.9 | 1.3 | 1.5 | 0.22 | 0.25 | 0.29 | 0.32 | 10.6 | 10.9 | 1.7 | 1.8 | 12.6 | 14.0 |
| *Nutrient management to wheat* | | | | | | | | | | | | | | | | | | | | |
| 120N+26P+ 50 K kg/ha | 3.72 | 3.88 | 561.8 | 582.8 | 335 | 342 | 39.6 | 42.5 | 43.7 | 43.9 | 4.85 | 5.33 | 6.20 | 6.39 | 125.2 | 134.7 | 21.3 | 22.5 | 157.6 | 161.8 |
| 60N+13P+ 25 K kg/ha | 3.55 | 3.64 | 547.3 | 565.9 | 314 | 325 | 36.6 | 38.9 | 40.6 | 41.6 | 4.33 | 4.57 | 5.44 | 5.67 | 105.8 | 111.2 | 17.6 | 18.5 | 134.6 | 139.8 |
| CD ($P$=0.05) | 0.15 | 0.21 | 13.8 | 15.4 | 16.4 | 17.1 | 2.8 | 3.0 | 1.8 | 1.9 | 0.27 | 0.31 | 0.25 | 0.29 | 9.9 | 10.2 | 1.1 | 1.7 | 11.0 | 13.1 |

+ *Azotobacter* in maize and 120 N + 26 P + 50 K kg/ha in wheat, followed by 90 kg N/ha (farmyard manure) + cowpea green manuring in maize and 120 N + 26 P + 50 K kg/ha in wheat treatments. It is important to note that when 60 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter* was applied in maize and subsequently 60 N + 13 P + 25 K kg/ha in wheat, grain yield of wheat remained statistically at par with that of 90 kg N/ha (farmyard manure) + cowpea green manuring to maize and 120 N + 26 P + 50 K kg/ha to wheat during both the years (Table 4). This indicated that there can be 50% saving of NPK in wheat by application of 60 kg N/ha (farmyard manure) + cowpea green manuring + *Azotobacter* in maize. The findings confirmed the observation of Kumar and Ahlawat (2004).

*Effect on maize–wheat cropping system*

*System productivity:* Highest average productivity of maize–wheat cropping system (10.77 and 11.72 tonnes/ha maize equivalents) and production efficiency (44.3 and 47.1 kg/ha/day) were recorded with the application of 60 kg N/ha (FYM) + cowpea + *Azotobacter* to maize crop; which were closely followed by 90 kg N/ha (FYM) + cowpea green manuring treatment (Table 5). Application of 120 N + 26 P + 50 K kg/ha resulted in 11.22 and 12.51% more system productivity and 11.11 and 12.43% more production efficiency than 60 N + 13P + 25 K kg/ha during first and second year, respectively. Higher system productivity and production efficiency with increased nutrient levels was also reported by Kumar (2008).

The interaction data on system productivity (Table 5) indicated that the application of 60 kg N/ha (FYM) + cowpea green manuring + *Azotobacter* in maize and 120 N + 26 P + 50 K kg/ha in wheat gave the highest productivity. But when 60 kg N/ha (FYM) + cowpea green manuring + *Azotobacter* were applied in maize along with the application of 60 N + 13 P + 25 K kg/ha in wheat, the productivity were at par with that of 60 kg N/ha (FYM) + cowpea green manuring + *Azotobacter* or 90 kg N/ha (FYM) + cowpea green manuring in maize, followed by application of 120 N + 26 P + 50 K kg/ha in wheat. This shows that with the application of 60 kg N/ha (FYM) + cowpea green manuring + *Azotobacter* in maize one can save 50% NPK in subsequent wheat.

Table 3 Productivity and economics of maize–wheat cropping system as influenced by different nutrient management practices

| Treatment | Production efficiency (kg/ha/day) | | Total cost of cultivation (Rs/ha) | | Net returns (Rs/ha) | | Net returns/rupee invested (Rs) | |
|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| *Nutrient management to maize* | | | | | | | | |
| Control | 29.5 | 28.2 | 20 788 | 21 038 | 30 943 | 30 080 | 1.49 | 1.43 |
| 120N + 26P + 32 K kg/ha | 41.2 | 39.9 | 23 357 | 23 607 | 46 219 | 45 651 | 1.98 | 1.93 |
| 60 kgN/ha (urea) + 60 kgN/ha (FYM) | 40.7 | 41.8 | 24 388 | 24 638 | 45 180 | 48 328 | 1.85 | 1.96 |
| 90 kgN/ha(FYM) + *Azotobacter* | 41.2 | 42.7 | 26 198 | 26 448 | 44 673 | 47 760 | 1.71 | 1.81 |
| 90 kgN/ha(FYM) + Cowpea green manuring | 42.5 | 45.0 | 27 238 | 27 488 | 45 670 | 50 308 | 1.68 | 1.83 |
| 60 kgN/ha(FYM)+ Cowpea green manuring+ *Azotobacter* | 44.3 | 47.1 | 25 448 | 25 698 | 50 123 | 55 655 | 1.97 | 2.17 |
| *Nutrient management to wheat* | | | | | | | | |
| 120N+26P+50 K kg/ha | 42.8 | 43.4 | 25 249 | 25 436 | 45 900 | 50 027 | 1.82 | 1.97 |
| 60N+13P+25 K kg/ha | 38.5 | 38.6 | 23 890 | 24 140 | 41 719 | 42 761 | 1.74 | 1.77 |

Table 4 Wheat grain yield as influenced by interaction effects of nutrient management practices to maize and wheat

| Treatment | Control | 120N+26P+ 32 K kg/ha | 60 kgN/ha (urea) +60 kgN/ha (FYM) | 90 kgN/ha (FYM) + *Azotobacter* | 90 kgN/ha (FYM)+ cowpea green manuring | 60 kgN/ha (FYM) + cowpea green manuring + *Azotobacter* |
|---|---|---|---|---|---|---|
| | | | *2004–05* | | | |
| 120N+26P+50 K kg/ha | 3.90 | 4.57 | 4.85 | 5.12 | 5.21 | 5.45 |
| 60N+13P+25 K kg/ha | 3.22 | 3.87 | 4.43 | 4.52 | 4.79 | 5.15 |
| CD (*P*=0.05) 0.15 | | | | | | |
| | | | *2005–06* | | | |
| 120N+26P+50 K kg/ha | 4.51 | 4.70 | 5.45 | 5.70 | 5.73 | 5.90 |
| 60N+13P+25 K kg/ha | 3.23 | 3.90 | 4.49 | 4.76 | 5.37 | 5.66 |
| CD (*P*=0.05) 0.17 | | | | | | |

*Economics*

The cost of cultivation/ha of maize–wheat system varied from Rs 20 788 to Rs 27 238 and Rs 21 038 to Rs 27 488 with control and 90 kg N/ha (FYM) + cowpea green manuring treatment during first and second year, respectively (Table 3). The treatments comprising organic sources of nutrients had higher cost than the fertilizer based treatment (120 N+26P+32 K kg/ha) due to higher cost of farmyard manure than inorganic fertilizer. However, net returns (Rs 50 123 and Rs 55 655/ha) and net returns/rupee (Rs 1.97 and Rs 2.17) were highest with the application of 60 kg N/ha (farmyard manure)+ cowpea green manuring + *Azotobacter*, while the control treatment recorded lowest values of net returns and net returns/rupee invested.

The higher cost of cultivation (Rs 25 249, Rs 25 436/ha) was incurred when 120 N + 26 P + 50 K kg/ha was applied to wheat in comparison to 60 N + 13 P + 25 kg K/ha (Rs 23 890, Rs 24 140/ha). Similarly, the values of net returns (Rs 45 900, Rs 50 027/ha) and net returns/rupee (Rs 1.82, Rs 1.97) were also maximum with the application of 120 N + 26 P + 50 K kg/ha to wheat, which is attributed to higher system productivity with 120 N + 26 P + 50 K kg/ha, thus enhancing the net returns.

*Soil properties*

The value of soil organic carbon increased from the initial status of 0.39% to the maximum status of 0.52% with the application of 60 kg N/ha (farmyard manure) +cowpea green

Table 5 System productivity (maize equivalents tonnes/ha) as influenced by interaction effects of nutrient management practices to maize and wheat

| Treatment | Control | 120N+26P+ 32 K kg/ha | 60 kgN/ha (urea) + 60 kgN/ha (FYM) | 90 kgN/ha (FYM) + *Azotobacter* | 90 kgN/ha (FYM) + cowpea green manuring | 60 kgN/ha (FYM) + cowpea green manuring + *Azotobacter* | Mean |
|---|---|---|---|---|---|---|---|
| | | | *2004–05* | | | | |
| 120N+26P+50 K kg/ha | 7.44 | 10.90 | 10.47 | 10.17 | 10.42 | 10.80 | 10.03 |
| 60N+13P+25 K kg/ha | 6.90 | 9.22 | 9.90 | 10.01 | 10.32 | 10.77 | 9.52 |
| Mean | 7.17 | 10.01 | 10.18 | 10.09 | 10.37 | 10.78 | |
| CD (*P*=0.05) 0.38 | | | | | | | |
| | | | *2005–06* | | | | |
| 120N+26P+50 K kg/ha | 7.95 | 10.90 | 11.17 | 11.17 | 11.63 | 11.95 | 10.80 |
| 60N+13P+25 K kg/ha | 6.09 | 9.00 | 9.65 | 10.09 | 10.77 | 11.49 | 9.6 |
| Mean | 7.02 | 9.95 | 10.41 | 10.63 | 11.20 | 11.72 | |
| CD (*P*=0.05) 0.49 | | | | | | | |

Table 6 Physical and chemical properties of soil after maize–wheat cropping system as influenced by different nutrient management practices

| Treatment | Soil properties | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Bulk density ($g/cm^3$) | | Organic Carbon (%) | | Available N (kg/ha) | | Available P (kg/ha) | | Available K (kg/ha) | |
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| *Nutrient management to maize* | | | | | | | | | | |
| Control | 1.48 | 1.47 | 0.35 | 0.30 | 135.6 | 128.6 | 10.4 | 9.8 | 150.8 | 138.9 |
| 120N+26P+32 K kg/ha | 1.45 | 1.45 | 0.38 | 0.41 | 150.6 | 141.9 | 13.7 | 14.1 | 158.6 | 161.9 |
| 60 kgN/ha (urea)+60 kgN/ha(FYM) | 1.41 | 1.40 | 0.40 | 0.44 | 153.6 | 164.2 | 12.4 | 13.7 | 168.6 | 178.3 |
| 90 kgN/ha(FYM)+ *Azotobacter* | 1.39 | 1.38 | 0.43 | 0.46 | 165.4 | 178.6 | 12.0 | 13.5 | 170.4 | 184.3 |
| 90 kgN/ha(FYM)+ Cowpea green manuring | 1.39 | 1.36 | 0.47 | 0.49 | 180.3 | 188.4 | 13.9 | 14.2 | 181.9 | 195.8 |
| 60 kgN/ha(FYM)+ Cowpea green manuring+ *Azotobacter* | 1.37 | 1.34 | 0.49 | 0.52 | 185.8 | 195.2 | 14.8 | 15.6 | 198.4 | 201.4 |
| CD (*P*=0.05) | 0.06 | 0.07 | 0.05 | 0.06 | 4.8 | 6.1 | 0.9 | 1.2 | 5.1 | 6.2 |
| *Nutrient management to wheat* | | | | | | | | | | |
| 120N+26P+50 K kg/ha | 1.41 | 1.39 | 0.44 | 0.45 | 170.6 | 175.8 | 14.1 | 15.0 | 181.0 | 187.3 |
| 60N+13P+25 K kg/ha | 1.42 | 1.41 | 0.40 | 0.43 | 153.2 | 156.5 | 11.6 | 12.0 | 163.9 | 166.3 |
| CD (*P*=0.05) | NS | NS | NS | NS | 4.2 | 5.0 | 0.6 | 0.9 | 4.8 | 6.0 |

Initial OC-0.39%, avail. N-140.3,P-12.2,K150.6 Kg/ha, B.D-1.49 g/cc

manuring + *Azotobacter* (Table 6). The other integrated nutrient management practices, i e 90 kg N/ha (farmyard manure) + *Azotobacter*, 90 kg N/ha (farmyard manure) + cowpea green manuring, 60 kg N/ha (farmyard manure) +60 kg N/ha (urea) also improved the soil organic carbon status. Pathak *et al.* (2005) reported similar improvements in organic carbon content in soil with combined use of different sources of nutrients.

The application of nitrogen through farmyard manure along with organic sources improved the status of available soil N, P and K as compared to initial values. Maximum values were recorded with application of 60 kg N/ha (farmyard manure) + cowpea green manuring +*Azotobacter*. The build-up of available N, P and K nutrients was higher during second year than first year (Table 6). The addition of organic sources continuously for 2 years built-up organic matter status of soil and might have enhanced the physical and microbiological activities in the soil which consequently enhanced the contents of available N P K in soil with these treatments. Significantly more available N, P and K contents in soil were recorded with the application of 120 N + 26 P + 50 K kg/ha as compared to 60 N + 13 P + 25 kg K/ha application in wheat.

The values of bulk density were significantly lower (1.34 to 1.41 g/cm$^3$) with the treatments consisting organic sources of nutrients than the treatments having inorganic sources of nutrient (1.45 g/cm$^3$)and control (1.47–1.48 g/cm$^3$). This could be attributed to higher organic carbon content in these treatments which had better soil aggregate and higher macro pore space (Bellaki *et al.* 1998). However, no change in bulk density and organic carbon in soil were recorded due to fertility levels applied to wheat.

For getting the better productivity and returns from maize wheat cropping system, 60 kg N/ha through farmyard manure along with cowpea green manuring and *Azotobacter* should be applied to maize, followed by application of 60 N, 13P, and 25 K kg/ha in wheat, which resulted in 50% NPK saving in wheat.

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