



## Effect of integrated nutrient management on productivity, profitability, nutrient uptake and soil fertility in rainfed maize (*Zea mays*)

J.P. TETARWAL, BALDEV RAM AND D.S. MEENA

Agricultural Research Sub Station, Maharana Pratap University of Agriculture & Technology, Aklera, Jhalawar, Rajasthan 326 033

Received: September 2010; Revised accepted : August 2011

### ABSTRACT

A field experiment was conducted at Agricultural Research Sub Station, Aklera, Jhalawar (Rajasthan) in two consecutive rainy (*kharif*) seasons of 2008 and 2009 to evaluate the effect of integrated nutrient management on productivity, profitability, nutrient uptake and soil fertility in maize (*Zea mays* L.). Application of 150 % RDF (N<sub>60</sub> P<sub>22.5</sub>) produced significantly higher plant height (207.3 cm), dry matter (149.1 g/plant), number of cobs/plant (1.4), number of grains/cob (209), grain (3.22 t/ha) and biological (8.23 t/ha) yield, net return (₹19,251/ha) and B: C ratio (1.90), N, P and Zn uptake compared to control. However, RDF + FYM 10 t/ha produced higher plant height, dry matter, number of cobs/plant, number of grains/cob, grain, biological yield and Zn uptake and RDF + Zn in net return, B: C ratio and Zn uptake. Significant built up of organic carbon (0.74%), available N (316.0 kg/ha) and available P (10.8 kg/ha) was registered with RDF + FYM 10 t/ha. Maximum P balance (3.3 kg/ha) was recorded under application of FYM 10 t/ha alone and Zn content (0.45 mg/kg) was recorded under RDF + Zn.

**Key words:** *Azotobacter*, Farmyard manures, Integrated nutrient management, Phosphate solubilizing bacteria, Zinc

Rainfed agriculture has a prime place in Indian agriculture contributing 67 % in area and 42 % in national food grain production. Maize is predominantly cultivated under rainfed condition in *kharif* season at Mewar, Bangar and Hadoti region of Rajasthan. In recent years, cultivation of hybrid maize has been found to be more remunerative than soybean in south eastern parts of Rajasthan. Rajasthan has the highest area of maize i.e. 1.0 Mha in the country with a production of 1.1 Mt. However, the average productivity is 1,100 kg/ha, which is very low as compared to national average productivity of 2334 kg/ha (FAI, 2008-09). Under rainfed production system, low productivity of crops is linked to the water stress, virtually no use of organic manures, poor recycling of crop residues and low use of nitrogen and phosphorus that leads to negative balances of nitrogen and phosphorus (Rego *et al.* 2003). Wide spread deficiency of sulphur, zinc and boron (Sahrawat *et al.* 2007) also leads to low productivity of dry land crops.

Hybrid maize is a heavy feeder and more responsive to nutrients and the required amount of nutrients may be supplied through organic manures and inorganic fertilizers to grow it and to maintain soil fertility on a sustained manner

(Sarkar *et al.*, 2000). Farmyard manure contains high amount of organic matter which increases the moisture retention of the soil and helps in dissolution of nutrients. FYM although not useful as a sole source of nutrients, is a good complementary and supplementary source to mineral fertilizers (Chaudhary *et al.*, 2004). Integrated plant nutrient system (IPNS) therefore appears to be choice for the rainfed maize production. A study was therefore conducted for two consecutive seasons to evolve a viable nutrient management option for higher productivity and profitability of rainfed maize.

### MATERIALS AND METHODS

A field experiment was conducted at Agricultural Research Sub Station, Aklera, Jhalawar in two consecutive *kharif* seasons of 2008 and 2009 on a fixed site. The soil of the experimental field was clay loam in texture, slightly alkaline in reaction (pH 7.5), medium in organic carbon (0.66 %) and available N (312 kg/ha), low in available phosphorus (9.4 kg P/ha) and high in available potassium (253 kg K/ha). The DTPA extractable Zn content of the soil was low (0.41 mg/kg). The experiment comprising eight treatments [control, RDF (Recommended dose of fertilizer i.e. 40-15 kg N-P/ha), RDF + Zn (40-15-5 N-P-

Zn kg/ha), RDF + *Azotobacter* + PSB, RDF + FYM 10 t/ha, FYM 10 t/ha, 150 % RDF and farmers practice (30-15 kg N-P/ha)] was carried out in a randomized block design with four replications. The hybrid maize 'PEHM-2' was sown at 60 cm x 25 cm on 5 July in 2008 and 20 July in 2009. Total rainfall received during crop growth period was 459 mm in 2008 and 380 mm in 2009. Minimum temperature ranged from 14.5 to 32.0 and maximum temperature from 28.4 to 44.6 °C during the two years of study. Environmental conditions of temperature and rainfall during 2008 were more conducive to maize growth and therefore, gave higher grain yield as compared to second year.

Farm yardmanure (FYM) was incorporated in ear marked plots as per treatments and its composition on oven dry basis was 0.51 % N, 0.22 % P and 0.54 % K. The recommended dose of fertilizers (RDF) for rainfed maize in south eastern parts of Rajasthan is 40 kg N and 15 kg P<sub>2</sub>O<sub>5</sub>/ha, while the general farmers practice of the region is an application of 30 kg N + 15 kg P<sub>2</sub>O<sub>5</sub>/ha. Zinc @ 5 kg Zn/ha was applied in the plots as per treatment. Entire dose of P, Zn and 50 % N were applied before sowing. The remaining half dose of N was top dressed prior to tassaling stage on a rainy day. The crop was harvested on 13 October in 2008 and 20 October, in 2009.

## RESULTS AND DISCUSSION

### Growth and yield attributes

The increased doses of RDF enhanced plant height, number of cobs/plant and grains/cob in maize due to increased availability of nutrients. However, RDF + FYM 10 t/ha was statistically on par with 150 % RDF for most of the characters studied (Table 1). The per cent increase was registered to the tune of 42.0, 100.0 and 56.0 over control, respectively. Combined use of farmyard manure along with nitrogen and phosphorus fertilizers had better

effect in increasing cob yield of maize over FYM alone. These results confirm the findings of Totawat *et al.* (2001).

Application of Zn along with RDF significantly increased plant height, dry matter production, cobs/plant and number of grains/cob. Zinc therefore is main yield limiting plant nutrient in Rajasthan. Zn is reported to enhance the absorption of native as well as added major nutrients such as N and P, there by increased yield attributes and production of maize (Bhattacharya *et al.* 2008). All the nutrient management practices in maize significantly increased test weight (1,000 grain weight) over control and maximum test weight (233.3 g) was recorded in 150 % RDF treatment followed by RDF + FYM 10 t/ha, whereas lowest test weight was recorded in 10 t FYM/ha alone.

### Yield

Adequate nutrient management in maize either with inorganic sources and organic sources or their combined use significantly enhanced grain and biological yield of maize compared to no nutrition (Table 1). Application of 150 % RDF produced the maximum and significantly higher grain and biological yields to the tune of 170.6 and 143.5 % over control but was statistically on par with RDF + FYM 10 t/ha. The second best treatment was RDF + Zn, which also recorded higher grain and biological yields over rest of the treatments. Seed inoculation with *Azotobacter* + PSB along with RDF produced remarkable grain and biological yields of maize compared to application of RDF alone. The increase in grain and biological yields might be due to increased growth and yield attributes. These results corroborate the findings of Kumar and Thakur (2004), who reported a significant increase in grain yield of maize with the application of RDF + 10 t FYM/ha in the rainfed mid hill region of Himachal Pradesh. Application of Zn along with RDF increased pro-

**Table 1.** Effect of integrated nutrient management practices on growth, yield attributes, yield and economics of maize (pooled data of 2 year)

| Treatment              | Plant height at harvest (cm) | Dry matter at harvest (g/plant) | Cobs/plant | Grains/cob | 1,000-grain weight (g) | Grain yield (t/ha) | Biological yield (t/ha) | Cost of cultivation (×10 <sup>3</sup> ₹/ha) | Net returns (×10 <sup>3</sup> ₹/ha) | B : C ratio |
|------------------------|------------------------------|---------------------------------|------------|------------|------------------------|--------------------|-------------------------|---|-------------------------------------|-------------|
| Control                | 145.9                        | 70.9                            | 0.7        | 134        | 214.5                  | 1.19               | 3.38                    | 9.0   | 2.0                                 | 0.23        |
| RDF                    | 171.3                        | 122.3                           | 1.0        | 185        | 227.5                  | 2.28               | 6.08                    | 9.8   | 11.2                                | 1.15        |
| RDF + Zn               | 186.3                        | 134.5                           | 1.2        | 193        | 230.3                  | 2.80               | 7.14                    | 10.8  | 14.8                                | 1.38        |
| RDF + <i>Azo</i> + PSB | 166.3                        | 124.9                           | 1.2        | 183        | 229.0                  | 2.48               | 6.63                    | 9.8   | 13.0                                | 1.32        |
| RDF + 10 t FYM/ha      | 198.5                        | 150.9                           | 1.4        | 207        | 231.3                  | 3.12               | 7.97                    | 14.8  | 13.7                                | 0.93        |
| 10 t FYM/ha            | 163.0                        | 89.0                            | 0.9        | 174        | 226.3                  | 1.94               | 5.30                    | 14.0  | 3.9                                 | 0.28        |
| 150 % RDF              | 207.3                        | 149.1                           | 1.4        | 209        | 233.3                  | 3.22               | 8.23                    | 10.1  | 19.3                                | 1.90        |
| Farmers practice       | 166.3                        | 91.7                            | 0.9        | 173        | 226.8                  | 2.11               | 5.62                    | 11.6  | 7.7                                 | 0.66        |
| SEm±                   | 4.65                         | 4.18                            | 0.036      | 4.0        | 3.33                   | 0.07               | 0.12                    | -   | 0.61                                | 0.05        |
| C D (P=0.05)           | 12.9                         | 11.6                            | 0.1        | 11.1       | 9.22                   | 0.21               | 0.35                    | -   | 1.7                                 | 0.15        |

RDF: Recommended dose of fertilizers for rainfed maize (40-15-0 kg N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O/ha); Zn: 25 kg ZnSO<sub>4</sub>/ha; Farmers practice: (30-15-0 kg N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O/ha); *Azo*: *Azotobacter chroococcum*, PSB: Phosphorus solubilizing bacteria (*Bacillus subtilis*), Sale price of maize: Grain ₹8,000/t (2008), ₹9,000/t (2009), Straw ₹500/t (both year), Price of zinc: ₹200/kg Zn

ductivity of maize over RDF alone and farmers practice to the tune of 22.8 and 32.7 %, respectively due to their favorable effects on yield attributes. Application of 150 % RDF, RDF + FYM 10 t/ha, RDF + Zn and RDF + *Azotobacter* + *PSB* produced higher grain as well as biological yield over farmer's practice of the region.

### Economics

Application of 150 % RDF fetched significantly higher net returns (₹19,251/ha) and benefit: cost ratio (1.90) over the rest of the nutrient management practices and control (Table 1). The additional net return was to the tune of ₹17,221/ha due to application of 150% RDF over control. The second best treatment was RDF + Zn, which fetched a net return of ₹14,815/ha and benefit: cost ratio of 1.38 and was followed by RDF + FYM 10 t/ha in terms of net return (₹13,741) and RDF + *Azotobacter* + *PSB* in terms of benefit: cost ratio (1.32). Nutrient management practice of RDF + Zn, RDF + *Azotobacter* + *PSB* and RDF + FYM 10 t/ha were also recorded significantly higher economic

returns over farmers practice but these remained statistically on par with each other. This might be due to achieved higher productivity as well as lower cost of cultivation owing to increased economic returns in maize under rainfed situations of Rajasthan. These results are in close conformity with the findings of Chadrashkar *et al.*, (2000).

### Nutrient uptake and balance

The highest and significantly higher amount of N and P uptake by maize crop was recorded with an application of 150% RDF and on par with RDF + FYM 10 t/ha. Application of 150 % RDF also recorded maximum and significantly higher Zn uptake but, being on par with RDF + FYM 10 t/ha and RDF + Zn application and superior over the rest of the treatments (Table 2). The per cent increase in N, P and Zn uptake under 150 % RDF to the tune of 175.8, 252.1 and 175.7, respectively over control. However, application of RDF + FYM 10 t/ha also recorded significantly higher uptake of N, P and Zn to the magnitude

**Table 2.** Effect of integrated nutrient management practices on nutrient uptake by maize and soil fertility (pooled data of 2 year)

| Treatment         | Total nutrient uptake |           |           | Available nutrient status in soil |                     |                     |                 |
|-------------------|-----------------------|-----------|-----------|-----------------------------------|---------------------|---------------------|-----------------|
|                   | N (kg/ha)             | P (kg/ha) | Zn (g/ha) | Organic carbon (%)                | Available N (kg/ha) | Available P (kg/ha) | DTPA Zn (mg/kg) |
| Control           | 17.8                  | 4.8       | 63.1      | 0.53                              | 277.6               | 7.1                 | 0.35            |
| RDF               | 33.8                  | 10.2      | 125.4     | 0.62                              | 298.1               | 8.7                 | 0.36            |
| RDF + Zn          | 40.8                  | 13.3      | 167.4     | 0.63                              | 301.4               | 10.1                | 0.45            |
| RDF + Azo + PSB   | 38.4                  | 12.7      | 139.2     | 0.69                              | 310.5               | 10.3                | 0.39            |
| RDF + 10 t FYM/ha | 47.8                  | 16.9      | 172.8     | 0.74                              | 316.0               | 10.8                | 0.43            |
| 10 t FYM/ha       | 29.8                  | 9.3       | 110.9     | 0.72                              | 309.1               | 8.9                 | 0.40            |
| 150 % RDF         | 49.1                  | 16.9      | 174.0     | 0.70                              | 314.6               | 10.1                | 0.41            |
| Farmers practice  | 30.7                  | 9.1       | 113.6     | 0.61                              | 297.2               | 8.6                 | 0.37            |
| SEm±              | 0.92                  | 0.29      | 4.08      | 0.012                             | 1.83                | 0.14                | 0.006           |
| CD (P=0.05)       | 2.54                  | 0.79      | 11.31     | 0.034                             | 5.07                | 0.39                | 0.017           |

**Table 3.** Nutrient balance sheet as influenced by integrated nutrient management in maize (pooled data of 2 year)

| Treatment         | Nitrogen (kg/ha)          |             |                      |                                 |  |                     | Phosphorus (kg/ha)        |             |                      |                                 |  |                     |
|-------------------|---------------------------|-------------|----------------------|---------------------------------|--|---------------------|---------------------------|-------------|----------------------|---------------------------------|--|---------------------|
|                   | Initial soil N status (a) | N added (b) | N uptake by crop (c) | Soil N status after harvest (d) | Actual gain/loss over initial status (a-d) | Balance (a+b)-(c+d) | Initial soil P status (a) | P added (b) | P uptake by crop (c) | Soil P status after harvest (d) | Actual gain/loss over initial status (a-d) | Balance (a+b)-(c+d) |
| Control           | 312.0                     | 0.0         | 17.8                 | 277.6                           | 34.4                                       | 16.6                | 9.4                       | 0.0         | 4.8                  | 7.1                             | 2.3  | -2.5                |
| RDF               | 312.0                     | 40.0        | 33.8                 | 298.1                           | 13.9                                       | 20.1                | 9.4                       | 6.6         | 10.2                 | 8.7                             | 0.6  | -3.0                |
| RDF + Zn          | 312.0                     | 40.0        | 40.8                 | 301.4                           | 10.6                                       | 9.8                 | 9.4                       | 6.6         | 13.3                 | 10.1                            | -0.7                                       | -7.4                |
| RDF + Azo + PSB   | 312.0                     | 40.0        | 38.4                 | 310.5                           | 1.5  | 3.1                 | 9.4                       | 6.6         | 12.7                 | 10.3                            | -0.9                                       | -7.0                |
| RDF + 10 t FYM/ha | 312.0                     | 68.1        | 47.8                 | 316.0                           | -4.0                                       | 16.3                | 9.4                       | 18.7        | 16.9                 | 10.8                            | -1.5                                       | 0.3                 |
| 10 t FYM/ha       | 312.0                     | 28.1        | 29.8                 | 309.1                           | 2.9  | 1.2                 | 9.4                       | 12.1        | 9.3                  | 8.9                             | 0.5  | 3.3                 |
| 150 % RDF         | 312.0                     | 60.0        | 49.1                 | 314.6                           | -2.6                                       | 8.3                 | 9.4                       | 9.8         | 16.9                 | 10.1                            | -0.7                                       | -7.8                |
| Farmers practice  | 312.0                     | 30.0        | 30.7                 | 297.2                           | 14.8                                       | 14.1                | 9.4                       | 6.6         | 9.1                  | 8.6                             | 0.8  | -1.7                |
| SEm±              |                           |             | 0.92                 | 1.83                            |  |                     |                           |             | 0.28                 | 0.14                            |  |                     |
| CD (P=0.05)       |                           |             | 2.54                 | 5.07                            |  |                     |                           |             | 0.79                 | 0.39                            |  |                     |

of 30.0, 12.1 kg/ha and 109.7 g/ha, respectively compared to control. This increase was mainly due to increased maize grain and stover yield and higher concentration of respective applied nutrients i.e. N, P and Zn. A similar result was also reported by Singh *et al.*, 2010 in baby corn. Application of Zn along with recommended dose of nutrients enhanced the total uptake of N, P and Zn by maize crop compared to rest of the other treatments.

A positive N balance was observed under all the nutrient management treatments and maximum positive balance of nitrogen (20.1 kg/ha) was recorded under recommended dose of fertilizers (RDF) (Table 2). A negative P balance was computed under all the treatments which indicated P mining except in treatments where FYM was applied i.e. RDF + FYM 10 t/ha and FYM 10 t/ha that showed a positive P balance.

### Soil fertility

Integrated use of inorganic and organic sources of nutrient to maize crop influenced physico-chemical properties of the soil under rainfed situation (Table 2). The organic carbon was significantly higher in treatment RDF + FYM 10 t/ha over rest of the INM practices and was statistically on par with FYM 10 t/ha; the increase was to the tune of 39.6 and 21.3 % over control and farmers practice, respectively. The net gain in organic carbon over initial soil status was to the tune of 12.1 % under RDF + FYM 10 t/ha and 9.1 % under FYM 10 t/ha. Application of RDF + FYM 10 t/ha recorded maximum values of available N and P, per cent increase was 1.28 for N and 14.89 for P over initial soil fertility. These results corroborate the findings of Panwar (2008). Application of RDF + Zn registered significantly higher Zn content in soil and remained statistically at par with RDF + FYM 10 t/ha over rest of the treatments. Soil application of Zn enhanced the nutrient availability in deficient soil and showed more response to the soil applied Zn. Similarly, application of FYM also increased the Zn content in the soil compared to control. This might be due to addition of FYM, improved availability of both native as well as added Zn through transformation of solid phase to soluble metal complex and increased the Zn content in the soil (Pathak *et al.* 2005).

It is concluded that application of 10 t/ha FYM along with RDF is the right choice for increasing the grain yield of rainfed hybrid maize in Rajasthan. Zinc is also a limit-

ing nutrient in Rajasthan and needs to be applied.

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