

# Effect of soil test based nutrient management on soil fertility, cane yield and quality of sugarcane (*Saccharum species complex hybrid*) in calcareous soil of Bihar

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## ABSTRACT

A field experiment was conducted at the Sugarcane Research Institute, Rajendra Agricultural University, Pusa, Bihar, during 2012–13 to 2014–15 with an aim to assess the influence of different plant nutrients on yield and quality of the sugarcane in calcareous soils of Bihar. The treatments comprised different plant nutrients, viz. N, P, K, S, Zn, Fe, Mn and their combinations. The FYM @ 20 t/ha was also in one of the treatments. Number of tillers, single cane weight, number of millable cane (NMC) and cane yield were significantly influenced due to different treatments. A significant increase in cane yield was recorded with application of NPK (RDF) alone or in combination with secondary nutrient like S and micronutrients (Zn, Fe and Mn) over the control. Application of fertilizers on soil-test basis (STB: 200 kg N, 44.0 kg P, 83.0 kg K, 40.0 kg S and 5.0 kg Zn) recorded significantly higher NMC (97,310/ha), cane yield (96.8 t/ha) and benefit: cost ratio (2.42) over rest of the treatments. The juice quality, viz. brix, sucrose and purity content, in cane juice was not affected significantly due to different treatments. The nutrient uptake and sugar yield were also higher in treatment receiving fertilizers on the basis of soil test. The maximum gain of N, P and K (62.3-7.7 and 24.3 kg/ha) was noticed in plot receiving fertilizer on STB. Thus, Soil test based fertilizer application proved the best for maintaining soil fertility and exploring higher productivity and profitability in calcareous soil of Bihar.

**Key words:** Cane yield, Plant nutrients, Quality, Soil fertility, Sugarcane,

Sugarcane is a long-duration nutrient-exhaustive crop which removes considerable amount of nutrients from the soil. Sustainable sugarcane production coupled with improved quality traits needs sufficient and balanced amount of plant nutrients in soil. Chemical fertilizers play key role in development of cane and sugar yields, but imbalanced use of fertilizers seems to be one of the factors responsible for the constantly low cane yield. The frequent and excessive use of NPK fertilizers has created various problems like widespread deficiency of secondary and micronutrients, decline in crop productivity and increasing environmental pollution (Pathak and Ghosh, 1996). Secondary nutrients like sulphur is indispensable element for carbohydrate metabolism and crop production. Improvements in the yield and quality of sugarcane owing to the application of sulphur have been reported by Singh *et al.* (1995). Micronutrients are required in smaller amounts by the crops but they are equally important for proper growth and de-

velopment of crop. These nutrients play an important role in enzyme systems that regulate various metabolic activities and control several oxidation–reduction systems. Indo-gangetic alluvial plains are generally deficient in micronutrients such as Zn, Fe, Mn and Cu due to imbalanced and improper inorganic fertilizer application. Thus, the application of these micronutrients is essential for normal growth and development of crop (Gupta and Rao, 1980). In Bihar, lower average productivity of sugarcane is mainly due to erratic and imbalanced use of chemical fertilizers. The N, P and K fertilizers are generally applied to sugarcane. The soil fertility is declining due to non-addition of organic matter. Farmers are experiencing declining responses to N and P due to omission of other essential nutrients in their fertilizer schedules. Sugarcane being a heavy feeder crop, depletes essential nutrients from soil and therefore, an addition of adequate nutrient is important for proper growth and cane development. Adoption of balanced and judicious use of all needed nutrients can help improve cane productivity and enhance sugar recovery by rendering resistance against biotic and abiotic

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stresses, and better synthesis and storage of sugar. The aim of present experiments was to study the effect of different plant nutrients on soil fertility and performance of sugarcane in calcareous soils of Bihar.

## MATERIALS AND METHODS

The field experiment was conducted during 2012–13 to 2015–16 under All India Coordinated Research Project on Sugarcane at the Sugarcane Research Institute, Pusa (25°57' N, 85°40' E, 52.0 m above mean sea-level) Bihar, to assess the effect of different plant nutrients on soil fertility, cane yield and juice quality in calcareous soils of Bihar. The climate of Bihar is subtropical and mean annual rainfall of the area is about 1,200 mm. The soil was sandy loam, calcareous ( $\text{CaCO}_3$  31.2%) having pH 8.28 and electrical conductivity 0.23 dS/m. The soil was low in organic C (0.48%), and available N, P and K (226, 16.5 and 93.8 kg/ha). The available S, Zn, Fe and Mn were 10.6, 0.72, 11.2 and 3.89 mg/kg respectively. The experiment was laid out in a randomized block design with 13 treatments and 3 replications. The treatments comprised: T<sub>1</sub>, control (no fertilizer); T<sub>2</sub>, N; T<sub>3</sub>, NP; T<sub>4</sub>, NPK [recommended dose of fertilizer (RDF)]; T<sub>5</sub>, NPK + S, T<sub>6</sub>, NPK + Zn; T<sub>7</sub>, NPK + Fe; T<sub>8</sub>, NPK + Mn; T<sub>9</sub>, NPK + S + Zn; T<sub>10</sub>, NPK + S + Zn + Fe; T<sub>11</sub>, NPK + S + Zn + Fe + Mn; T<sub>12</sub>, Soil-test-based fertilizer application (STB); and T<sub>13</sub>, FYM @ 20 t/ha. The N-P-K fertilizers were applied @ 150–37.4–49.8 kg/ha respectively. The S, Zn and Mn were applied @ 40.0, 5.0 and 1.5 kg/ha, while 3 spraying of Fe @ 1% was given at weekly interval. The soil-test-based fertilizers application included 200 kg N, 44.0 kg P, 83.0 kg K, 40.0 kg S and 5.0 kg Zn/ha. The NPK fertilizers were applied through urea (46% N), diammonium phosphate (18% N and 46% P<sub>2</sub>O<sub>5</sub>) and muriate of potash (60% K<sub>2</sub>O) respectively. Nitrogen was applied in split doses, half at the time of planting, one-fourth at the time of first irrigation and rest at the time of earthing up, i.e. on onset of monsoon. The mid-late sugarcane variety 'BO 154' was planted at a row distance of 90 cm in the last week of February and harvested after 1 year. Four irrigations were given before monsoon. Recommended practices were adopted for sugarcane crop. Soil samples, collected initially and after harvesting of crop were analyzed for organic carbon, available N, P, K and S contents by method described by Jackson (1973). The DTPA-extractable Zn, Fe and Mn were analysed by the method of Lindsay and Norvell (1978). Cane juice was extracted with power crusher and juice quality was estimated as per method given by Spencer and Meade (1955). Sugar yield was calculated as; Sugar yield (t/ha) =  $[S - 0.4(B - S) \times 0.73] \times \text{cane yield (t/ha)} / 100$ ; where S and B are the sucrose and brix per cent in cane juice. Whole cane samples were analyzed for N, P and K contents. The up-

take of N, P and K were calculated by multiplying their concentration with dry-matter yield. The economics was worked out on prevailing market prices.

## RESULTS AND DISCUSSION

### Cane yield

Sugarcane production was influenced by different plant nutrients (Table 1). The application of NPK alone or in combination with secondary and micronutrients significantly increased tillers, single cane weight, number of millable canes (NMC) and cane yield over the control, while effect on germination, plant height and girth was not significant. The maximum number of tillers ( $135.2 \times 10^3/\text{ha}$ ) and NMC ( $97.3 \times 10^3/\text{ha}$ ) were recorded under treatment T<sub>12</sub> receiving fertilizers on soil-test-basis. The significantly higher cane yield (96.8 t/ha) was also achieved under T<sub>12</sub>, indicating significance of replenishment of nutrients on soil-test-basis. This could be ascribed to higher yield-attributing characters like NMC and single cane weight owing to balanced fertilization. Fertilizers application based on soil-test recommendations have increasing effects on crop yields. However, inadequate and excessive applications of NPK fertilizers not only limit crop yield but may increase soil and environment problems (Soomro *et al.*, 2014). These results are in agreement with the findings of Kumar *et al.* (2012) and Thakur *et al.* (2013). The application of RDF along with secondary plant nutrients (S) and micronutrients (Zn, Fe and Mn) alone did not show significant increase in cane yield (T<sub>5</sub>–T<sub>8</sub>) over NPK (T<sub>4</sub>). However, combined application of S and Zn along with RDF resulted in significantly higher cane yield over RDF. This might be owing to the beneficial effect of S and Zn on cane yield, as the experimental soil was low in N, K and Zn. These results corroborate the findings of Singh *et al.* (2003), who opined that application of NPK and S along with Zn significantly improved the cane yield. The cane yield obtained under T<sub>13</sub> was at par with that under T<sub>2</sub> indicating that only organics could not meet the requirement of the plant nutrients. Singh and Biswas (2000) also proved that neither chemical fertilizer alone nor organic sources exclusively can achieve the production sustainability of soil and crop. Economics is one of the important parameters for fertilizer recommendation. The net returns (₹ 145,015) and benefit: cost ratio were significantly higher (2.42) under T<sub>12</sub> over rest of the treatments, indicating importance of fertilizers addition on soil-test-basis for getting higher yield and profitability.

### Nutrient uptake

On an average, the uptake of N, P and K by plant were respectively 3.18, 0.31 and 2.86 kg/tonnes of cane produced. The uptake of N, P and K by plant crop varied

from 109.1 to 346.2, 10.7 to 32.5 and 100.3 to 299.8 kg/ha respectively (Table 2). The highest uptake was recorded under T<sub>12</sub> and lowest in the control. This could be attributed to soil-test-based fertilizer application supplied balanced available nutrients to the plants needed for their growth, resulting higher uptake and cane yield. The results further indicated that uptake of N and K was higher than compared to P. These results are in agreement with the findings of Sankar Babu *et al.* (2007), Thakur *et al.* (2012) and Kumar *et al.* (2015). The cane juice quality did not

exhibit significant variation in respect of brix, sucrose and purity percent (Table 2). However, sugar yield followed similar trend of cane yield and maximum sugar yield (11.00 t/ha) was recorded under treatment T<sub>12</sub> and the minimum in the control (4.30 t/ha). Thakur *et al.* (2010) also reported similar findings.

#### Soil properties

The pH and electrical conductivity (EC) of soil did not differ under different treatments after harvesting of the

**Table 1.** Effect of different plant nutrients on growth, yield attributing parameters, cane yield and economics of sugarcane (pooled data of 3 years)

| Treatment  | Germination (%) | Tillers ( $\times 10^3$ /ha) | Plant height (cm) | Girth (cm) | Single cane weight (g) | NMC ( $\times 10^3$ /ha) | Cane yield (t/ha) | Net returns ( $\times 10^3$ /ha) | Benefit: cost ratio |
|--|-----------------|------------------------------|-------------------|------------|------------------------|--------------------------|-------------------|----------------------------------|---------------------|
| T <sub>1</sub> , N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> (Control)  | 34.4            | 85.5                         | 258.0             | 2.46       | 707                    | 54.4                     | 39.3              | 26.6                             | 1.36                |
| T <sub>2</sub> , N <sub>150</sub>  | 33.6            | 95.7                         | 260.0             | 2.57       | 735                    | 59.8                     | 44.6              | 37.0                             | 1.48                |
| T <sub>3</sub> , N <sub>150</sub> P <sub>37.4</sub>  | 32.7            | 95.8                         | 258.0             | 2.64       | 783                    | 62.9                     | 49.9              | 45.3                             | 1.55                |
| T <sub>4</sub> , N <sub>150</sub> P <sub>37.4</sub> K <sub>49.8</sub> (RDF)  | 33.4            | 114.7                        | 267.3             | 2.67       | 877                    | 81.9                     | 71.6              | 95.3                             | 2.09                |
| T <sub>5</sub> , RDF + S <sub>40.0</sub>   | 33.3            | 117.2                        | 267.3             | 2.67       | 880                    | 83.7                     | 74.2              | 94.9                             | 2.01                |
| T <sub>6</sub> , RDF + Zn <sub>5.0</sub>   | 34.0            | 120.6                        | 266.0             | 2.71       | 902                    | 82.9                     | 76.2              | 104.9                            | 2.17                |
| T <sub>7</sub> , RDF + Fe (1% spray)   | 33.8            | 119.7                        | 266.3             | 2.68       | 877                    | 83.7                     | 73.5              | 96.2                             | 2.06                |
| T <sub>8</sub> , RDF + Mn <sub>1.5</sub>   | 34.6            | 116.1                        | 267.7             | 2.67       | 873                    | 81.2                     | 71.9              | 94.4                             | 2.06                |
| T <sub>9</sub> , RDF + S <sub>40.0</sub> + Zn <sub>5.0</sub>   | 32.9            | 124.9                        | 268.0             | 2.63       | 932                    | 86.5                     | 80.8              | 109.3                            | 2.13                |
| T <sub>10</sub> , RDF + S <sub>40.0</sub> + Zn <sub>5.0</sub> + Fe (1% spray)  | 35.0            | 127.7                        | 270.3             | 2.72       | 944                    | 88.4                     | 83.7              | 111.1                            | 2.09                |
| T <sub>11</sub> , RDF + S <sub>40.0</sub> + Zn <sub>5.0</sub> + Fe (1% spray) + Mn <sub>1.5</sub>                    | 33.2            | 128.6                        | 272.0             | 2.68       | 974                    | 89.3                     | 88.0              | 121.4                            | 2.18                |
| T <sub>12</sub> , N <sub>200</sub> P <sub>44.0</sub> K <sub>83.0</sub> + S <sub>40.0</sub> + Zn <sub>5.0</sub> (STB) | 35.2            | 135.2                        | 274.7             | 2.62       | 999                    | 97.3                     | 96.8              | 145.0                            | 2.42                |
| T <sub>13</sub> , FYM @ 20 t/ha  | 33.7            | 111.6                        | 266.3             | 2.62       | 773                    | 69.9                     | 53.4              | 49.1                             | 1.56                |
| SEm $\pm$  | 1.5             | 3.6                          | 7.8               | 0.09       | 33.8                   | 2.8                      | 3.5               | 4.9                              | 0.05                |
| CD (P=0.05)  | NS              | 10.2                         | NS                | NS         | 95.6                   | 7.8                      | 9.8               | 14.3                             | 0.14                |

NMC, Number of millable canes; RDF, recommended dose of fertilizer

**Table 2.** Effect of plant nutrients on cane juice quality and uptake of nutrients by plant crop of sugarcane (pooled data of 3 years)

| Treatment  | Juice quality |             |            | Sugar yield (t/ha) | Uptake of nutrients |           |           |
|--|---------------|-------------|------------|--------------------|---------------------|-----------|-----------|
|  | Brix (%)      | Sucrose (%) | Purity (%) |                    | N (kg/ha)           | P (kg/ha) | K (kg/ha) |
| T <sub>1</sub> , N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> (Control)  | 18.3          | 15.8        | 86.3       | 4.30               | 109.1               | 10.7      | 100.3     |
| T <sub>2</sub> , N <sub>150</sub>  | 18.1          | 15.7        | 87.4       | 4.94               | 130.2               | 12.9      | 116.7     |
| T <sub>3</sub> , N <sub>150</sub> P <sub>37.4</sub>  | 18.4          | 16.1        | 87.5       | 5.60               | 150.8               | 15.2      | 137.5     |
| T <sub>4</sub> , N <sub>150</sub> P <sub>37.4</sub> K <sub>49.8</sub> (RDF)  | 18.7          | 16.3        | 87.3       | 7.86               | 232.5               | 22.5      | 212.7     |
| T <sub>5</sub> , RDF + S <sub>40.0</sub>   | 18.5          | 16.0        | 86.9       | 8.13               | 234.4               | 23.2      | 217.4     |
| T <sub>6</sub> , RDF + Zn <sub>5.0</sub>   | 18.4          | 15.9        | 86.9       | 8.48               | 253.4               | 24.2      | 228.8     |
| T <sub>7</sub> , RDF + Fe (1% spray)   | 18.5          | 15.9        | 86.7       | 7.95               | 235.9               | 23.4      | 216.9     |
| T <sub>8</sub> , RDF + Mn <sub>1.5</sub>   | 18.6          | 16.3        | 87.4       | 8.08               | 231.3               | 22.6      | 208.3     |
| T <sub>9</sub> , RDF + S <sub>40.0</sub> + Zn <sub>5.0</sub>   | 18.7          | 16.4        | 87.4       | 8.97               | 268.6               | 25.8      | 239.1     |
| T <sub>10</sub> , RDF + S <sub>40.0</sub> + Zn <sub>5.0</sub> + Fe (1% spray)  | 18.7          | 16.4        | 87.6       | 9.40               | 277.8               | 27.5      | 250.3     |
| T <sub>11</sub> , RDF + S <sub>40.0</sub> + Zn <sub>5.0</sub> + Fe (1% spray) + Mn <sub>1.5</sub>                    | 18.7          | 16.4        | 88.1       | 9.88               | 301.4               | 29.4      | 262.7     |
| T <sub>12</sub> , N <sub>200</sub> P <sub>44.0</sub> K <sub>83.0</sub> + S <sub>40.0</sub> + Zn <sub>5.0</sub> (STB) | 18.8          | 16.5        | 87.5       | 11.00              | 346.2               | 32.5      | 299.8     |
| T <sub>13</sub> , FYM @ 20 t/ha  | 18.5          | 16.3        | 87.9       | 5.97               | 151.3               | 14.8      | 134.8     |
| SEm $\pm$  | 0.3           | 1.2         | 0.9        | 0.66               | 11.0                | 1.2       | 11.5      |
| CD (P=0.05)  | NS            | NS          | NS         | 1.83               | 30.5                | 3.3       | 31.8      |

RDF, recommended dose of fertilizer; STB, soil-test-based

**Table 3.** Effect of plant nutrients on nutrients status after harvesting of sugarcane (pooled data of 3 years)

| Treatment  | pH   | EC<br>(dS/m) | Org. C<br>(%) | N<br>(kg/ha) | P<br>(kg/ha) | K<br>(kg/ha) | S<br>(mg/kg) | Zn<br>(mg/kg) | Fe<br>(mg/kg) | Mn<br>(mg/kg) |
|--|------|--------------|---------------|--------------|--------------|--------------|--------------|---------------|---------------|---------------|
| T <sub>1</sub> , N <sub>0</sub> P <sub>0</sub> K <sub>0</sub> (Control)  | 8.26 | 0.23         | 0.47          | 216.2        | 14.5         | 86.9         | 9.46         | 0.68          | 9.63          | 3.68          |
| T <sub>2</sub> , N <sub>150</sub>  | 8.22 | 0.21         | 0.48          | 230.8        | 16.0         | 92.1         | 9.50         | 0.69          | 9.48          | 3.69          |
| T <sub>3</sub> , N <sub>150</sub> P <sub>37.4</sub>  | 8.23 | 0.19         | 0.49          | 230.0        | 19.1         | 93.3         | 9.38         | 0.68          | 9.28          | 3.84          |
| T <sub>4</sub> , N <sub>150</sub> P <sub>37.4</sub> K <sub>49.8</sub> (RDF)  | 8.26 | 0.20         | 0.54          | 263.3        | 20.8         | 102.9        | 9.10         | 0.65          | 9.34          | 3.54          |
| T <sub>5</sub> , RDF + S <sub>40.0</sub>   | 8.26 | 0.21         | 0.52          | 262.9        | 20.8         | 103.3        | 13.78        | 0.65          | 9.44          | 3.66          |
| T <sub>6</sub> , RDF + Zn <sub>5.0</sub>   | 8.25 | 0.21         | 0.52          | 267.0        | 19.9         | 105.8        | 9.54         | 0.83          | 9.36          | 3.61          |
| T <sub>7</sub> , RDF + Fe (1% spray)   | 8.24 | 0.20         | 0.52          | 263.8        | 20.0         | 105.1        | 9.17         | 0.66          | 12.22         | 3.78          |
| T <sub>8</sub> , RDF + Mn <sub>1.5</sub>   | 8.29 | 0.22         | 0.52          | 266.8        | 20.3         | 107.6        | 8.98         | 0.63          | 9.05          | 4.75          |
| T <sub>9</sub> , RDF + S <sub>40.0</sub> + Zn <sub>5.0</sub>   | 8.26 | 0.20         | 0.54          | 271.9        | 21.2         | 104.9        | 14.33        | 0.86          | 9.17          | 3.91          |
| T <sub>10</sub> , RDF + S <sub>40.0</sub> + Zn <sub>5.0</sub> + Fe (1% spray)  | 8.25 | 0.20         | 0.54          | 273.8        | 20.9         | 109.9        | 13.76        | 0.87          | 12.69         | 3.69          |
| T <sub>11</sub> , RDF + S <sub>40.0</sub> + Zn <sub>5.0</sub> + Fe (1% spray) + Mn <sub>1.5</sub>                    | 8.24 | 0.22         | 0.53          | 269.2        | 22.1         | 110.6        | 14.77        | 0.86          | 12.81         | 5.16          |
| T <sub>12</sub> , N <sub>200</sub> P <sub>44.0</sub> K <sub>83.0</sub> + S <sub>40.0</sub> + Zn <sub>5.0</sub> (STB) | 8.23 | 0.23         | 0.56          | 289.2        | 24.2         | 118.1        | 14.24        | 0.89          | 11.22         | 3.93          |
| T <sub>13</sub> , FYM @ 20 t/ha  | 8.25 | 0.21         | 0.57          | 249.7        | 19.3         | 92.1         | 9.92         | 0.69          | 10.09         | 3.82          |
| SEm±   | 0.05 | 0.01         | 0.02          | 8.5          | 1.5          | 3.5          | 0.12         | 0.02          | 0.38          | 0.13          |
| CD (P=0.05)  | NS   | NS           | NS            | 24.2         | 4.2          | 10.0         | 0.33         | 0.06          | 1.02          | 0.37          |

EC, Electrical conductivity; Org. C, Organic carbon; RDF, recommended dose of fertilizer; STB, soil-test based

crop (Table 3). The pH ranged from 8.22 to 8.29 and EC from 0.19 to 0.23 dS/m. The organic carbon also showed non-significant variation with the maximum (0.57%) in the plot receiving FYM @ 20 t/ha and the minimum (0.47%) in the control. The post-harvest soil revealed the highest (18.7%) improvement in soil organic carbon over the initial owing to application of FYM @ 20 t/ha and corresponding increase (16.6%) because of application of nutrients on soil-test-basis. High content of cellulosic compounds as well as crop residues may be responsible for increase in the organic carbon content of the soil (Srivastava, *et al.*, 2008). The available major soil nutrients (N, P and K) after harvesting of the crop were significantly higher in NPK treated plots over the control. The maximum available N, P and K was recorded under treatment T<sub>12</sub> (289.2, 24.2 and 118.1 kg/ha), while the lowest in the control. Treatment T<sub>12</sub> also revealed significantly higher available N, P and K than the treatment T<sub>4</sub> (RDF). This could be attributed to the higher biomass accumulation in the soil owing to balanced fertilization which leads to the stimulated growth and activity of microorganisms on account of improved rhizospheric environment, resulting higher mineralization leading to higher available N while, improved P might be owing to reduced P sorption and K might be because of addition of K in available pool due to mineralization. The net positive gain of the N, P and K nutrients over initial was noticed under treatment T<sub>4</sub>–T<sub>13</sub>, indicating positive impact of balanced use of plant nutrients for maintaining of soil fertility. The gain of N, P and K were 3.12–62.3, 2.6–7.7 and 9.1–24.3 kg/ha after harvesting of sugarcane over the initial and the highest

was with T<sub>12</sub> Treatment, indicating balanced application of nutrients is the key factor for improvement of soil fertility and enhancing sugarcane productivity. Our results confirm the findings of Patel *et al.* (2010) Kumar (2012) and Thakur *et al.* (2013). Significant improvement in micronutrients (S, Zn, Fe and Mn) was noticed in treated plots over non-treated ones. The available S, Zn, Fe and Mn varied from 8.98 to 14.77, 0.63 to 0.89, 9.05 to 12.81 and 3.54 to 5.16 mg/kg, respectively, indicating build up of these nutrients in the soil.

Based on these investigations, it may be concluded that flat recommendation was not effective in improving yield and quality of sugarcane. Soil-test-based fertilizer application proved the best for maintaining soil fertility and exploring higher productivity and profitability in calcareous soil of Bihar.

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