Original Research Article

Effect of Different Micronutrients on Turmeric Variety Suranjana in Terai Region of West Bengal, India

S. Datta*, S. Chakraborty, J.C. Jana, A. Debnath, M.K. Roy and S. Haque

Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, 736165, India

*Corresponding author

ABSTRACT

An experiment was undertaken at Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal to study the effect of boron, iron, manganese and zinc on the growth and yield of turmeric during the year of 2010-11, 2011-12, 2012-13 and 2015-16. The experiment was laid out in randomized block design with three replications. Different treatments of the experiment were T1 - control (no micronutrients), T2 - soil application of boron (as borax) @ 25Kg ha⁻¹, T3 - soil application of manganese (as MnSO₄) @ 25Kg ha⁻¹, T4 - soil application of iron (as Fe₂SO₄) @ 25Kg ha⁻¹, T5 - soil application of zinc (as ZnSO₄) @ 25Kg ha⁻¹, T6 - foliar spray of manganese (as MnSO₄) @ 0.5% after 60 and 90 days of planting, T7 - foliar spray of iron (as Fe₂SO₄) @ 0.5% after 60 and 90 days of planting, T8 - foliar spray of boron (as borax) @ 0.5% after 60 and 90 days of planting and T9 - foliar spray of zinc (as ZnSO₄) @ 0.5% after 60 and 90 days of planting. The results revealed that soil application of boron (as borax) @ 25Kg ha⁻¹ gave the highest yield (11.13 kg/3 m² and 22.45 t/ha) which was also statistically at par with foliar spray of boron as borax @ 0.5% @ 60 and 90 days after planting (10.59 kg/3 m² and 21.36 t/ha). The lowest yield (7.17 kg/3m² and 14.45 t/ha) was recorded in the control treatment (i.e. without micronutrient application). The highest cost benefit ratio (1: 2.04) was recorded with soil application of boron (as borax) @ 25Kg ha⁻¹ followed by foliar spray of boron (1: 1.95) (as borax) @ 0.5% at 60 and 90 days after planting.

Keywords
Micronutrients, Boron, Iron, Manganese, Zinc, Turmeric, Yield

Introduction

Turmeric (*Curcuma longa* L.) is an important rhizomatous spice crop of India and World too. India is a leading producer, consumer and exporter of turmeric in the world. India is the major producer and exporter of turmeric and earned a foreign exchange of 2000 million $ (Anonymous, 2012). Apart from its spice and medicinal value it is also used in the dye, food and cosmetic industries. It is also used in the auspicious religious occasions. Turmeric inhibits the development of cataracts, breast cancer, colon cancer, and lymphoma (Devi et al., 2011). In India it is cultivated with an area of 1.95 lakh hectare (ha) with a production of 9.99 lakh tonnes. In West Bengal, it is cultivated with an area of 15.8 thousand ha and production of 42 thousand tonnes. Productivity of turmeric in West Bengal is quite low (2.66 tones/ha) compared to national average (5.11 tones/ha). It is a soil exhausting crop and application of N, P and K are recommended for its cultivation. Normally micronutrients do not find a place in the nutrient recommendations. However, high rhizome yields in turmeric with increasing concentrations of foliar sprays of...
magnesium sulphate in the acidic soils of Meghalaya have been reported (Chandra et al., 1997). Turmeric is highly responsive to chemical fertilizers. In addition, micronutrients fertilizers are mostly liable to reduce disease incidence and enhance durability of the post harvest life of ginger and turmeric (Halder et al., 2007). (Banafer et al., 1995), (Gupta and Singer, 1998), (Roy et al., 1992) stated in their reports that ginger and turmeric are highly responsive to chemical fertilizers and increased the growth and rhizome yield with increments of fertilizer rates. Bose et al., (2008) reported that inclusion of S and Mg in the fertilization schedule greatly improved the fresh yields of turmeric in the depleted red lateritic soils of West Bengal. Similarly, Kavitha (2012) revealed that in the rhizomatous crop kacholam (Kaempferia galanga L.), top dressing of sulphur and magnesium resulted in higher rhizome yields. Recent research has shown that application of Fe significantly increased in yield of crops. Chhibba et al., (2007) reported that the foliar application of Fe increased yield and Fe concentration in fenugreek. Beneficial effect of Effect of Zn, Fe and B on growth and yield of ginger was reported by Roy et al., (1992). Halder et al (2007) reported the beneficial effect of zinc and boron on turmeric yield and quality. Very information is available with respect to the effect of boron, iron, manganese and zinc on the growth and yield of turmeric, with keeping this views, the present experiment was undertaken with the effect of boron, iron, manganese and zinc on the growth and yield of turmeric.

Materials and Methods

An investigation was undertaken to study the effect of boron, iron, manganese and zinc on the growth and yield of turmeric in Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal during the year of 2010-11, 2011-12, 2012-13 and 2015-16. The experimental soil was sandy clay loam having pH 5.6, 0.90% organic carbon, 131.45 kg/ha available nitrogen, 47.38 kg/ha available phosphorus and 65.82 kg/ha potash. The climatic condition of this region is subtropical humid in nature. The experiment was laid out in Randomized Block Design with five replications. Raised beds of 3 m X 1 m size and 15 cm height were prepared. Turmeric rhizome of the variety Suranjana was planted with a spacing of 30 cm x 20 cm during the first week of May 2010, 2011, 2012 and 2015, respectively. The experiment was laid out in randomized block design with 9 treatments and three replications. The treatment details were T1 - control (no micronutrients), T2 - soil application of boron (as borax) @ 25Kg ha\(^{-1}\), T3 - soil application of manganese (as MnSO\(_4\)) @ 25Kg ha\(^{-1}\), T4 - soil application of iron (as Fe\(_2\)SO\(_4\)) @ 25Kg ha\(^{-1}\), T5 - soil application of zinc (as ZnSO\(_4\)) @ 25Kg ha\(^{-1}\), T6 - foliar spray of manganese (as MnSO\(_4\)) @ 0.5% after 60 and 90 days of planting, T7 - foliar spray of iron (as Fe\(_2\)SO\(_4\)) @ 0.5% after 60 and 90 days of planting, T8 - foliar spray of boron (as borax) @ 0.5% after 60 and 90 days of planting and T9 - foliar spray of zinc (as ZnSO\(_4\)) @ 0.5% after 60 and 90 days of planting. Full dose of Farm yard manure @ 15 t/ha was applied as basal. Inorganic fertilizers were applied at the rate of 80: 80: 120 kg/ha of N: P\(_2\)O\(_5\): K\(_2\)O.

Among the inorganic fertilizers, full dose of P\(_2\)O\(_5\) and 1/3 dose of N was applied as basal, rest 2/3rd N and K\(_2\)O were applied in two equal splits at 45 and 90 days after planting. Observations on different morphological and yield attributing characters were recorded from five randomly selected plants from each plots. Rhizome yield per hectare was calculated on the plot weight basis. Statistical analysis of the data was done as per method suggested by Gomez and Gomez (1984).
**Results and Discussion**

Perusal of the data presented in tables 1–6 revealed that there was a significant variation in the different, growth, rhizome weight and rhizome yield. Maximum plant height was recorded in the soil application of boron (as borax) @ 25Kg ha\(^{-1}\) (97.82 cm) which was statistically at par with soil application of zinc (as ZnSO\(_4\)) @ 25Kg ha\(^{-1}\) (94.75 cm) (Table 1).

Higher plant height was also recorded in treatment of foliar spray of zinc (as ZnSO\(_4\)) @ 0.5% after 60 and 90 days of planting (91.37 cm) and soil application of manganese (as MnSO\(_4\)) @ 25Kg ha\(^{-1}\) (90.25 cm). Whereas the lowest plant height (84.31 cm) was recorded in control plots. With respect to tillers per plant, more number of tillers per plant was recorded with soil application of iron (as Fe\(_2\)SO\(_4\)) @ 25Kg ha\(^{-1}\) (3.38) followed by soil application of iron (as Fe\(_2\)SO\(_4\)) @ 25Kg ha\(^{-1}\) (3.26), foliar spray of boron (as borax) @ 0.5% after 60 and 90 days of planting (3.19), soil application of zinc (as ZnSO\(_4\)) @ 25Kg ha\(^{-1}\) (2.95) and soil application of boron (as borax) @ 25Kg ha\(^{-1}\) (2.88) and minimum number recorded in control treatment (no micronutrients) (2.16).

Soil application of manganese (as MnSO\(_4\)) @ 25Kg ha\(^{-1}\) showed the highest number of leaves (8.66) which was also statistically at par with soil application of zinc (as ZnSO\(_4\)) @ 25Kg ha\(^{-1}\) (8.41), soil application of boron (as borax) @ 25Kg ha\(^{-1}\) (8.22) and soil application of zinc (as ZnSO\(_4\)) @ 25Kg ha\(^{-1}\) (8.22) and it was lowest with control (no micronutrients) treatment (7.83) (Table 2).

Maximum leaf length was recorded with soil application of boron (as borax) @ 25Kg ha\(^{-1}\) (41.38) followed by soil application of iron (as Fe\(_2\)SO\(_4\)) @ 25Kg ha\(^{-1}\) (41.34 cm), soil application of manganese (as MnSO\(_4\)) @ 25Kg ha\(^{-1}\) (40.49 cm), soil application of zinc (as ZnSO\(_4\)) @ 25Kg ha\(^{-1}\) (39.96) T6 (39.95) and foliar spray of iron (as Fe\(_2\)SO\(_4\)) @ 0.5% after 60 and 90 days of planting (39.74 cm) (Table 2).

With respect to leaf breadth (Table 3), the widest leaf was recorded in the treatment of application of boron (as borax) @ 25Kg ha\(^{-1}\) (10.36 cm) followed by soil application of iron (as Fe\(_2\)SO\(_4\)) @ 25Kg ha\(^{-1}\) (10.14 cm), foliar spray of manganese (as MnSO\(_4\)) @ 0.5% after 60 and 90 days of planting (10.12 cm), foliar spray of iron (as Fe\(_2\)SO\(_4\)) @ 0.5% after 60 and 90 days of planting (9.98 cm) and soil application of manganese (as MnSO\(_4\)) @ 25Kg ha\(^{-1}\) (9.89 cm). The lowest leaf breadth was recorded in the treatment of soil application of zinc (as ZnSO\(_4\)) @ 25Kg ha\(^{-1}\) (8.74 cm).

In this experiment weight of mother rhizome varied from 44.36 g to 66.31 g. Maximum mother rhizome weight was recorded with soil application of iron (as Fe\(_2\)SO\(_4\)) @ 25Kg ha\(^{-1}\) (66.31 g) which was also statically at par with soil application of manganese (as MnSO\(_4\)) @ 25Kg ha\(^{-1}\) (64.31 g) treatment (Table 3). The lowest mother rhizome weight (44.36) was recorded in control treatment (i.e. without micronutrient). The results revealed that application micronutrient significantly increased the weight of primary and secondary rhizome per plant (Table 4).

Maximum weight of mother rhizome was record with the treatment of foliar spray of iron (as Fe\(_2\)SO\(_4\)) @ 0.5% after 60 and 90 days of planting (115.37 g) followed by soil application of zinc (as ZnSO\(_4\)) @ 25Kg ha\(^{-1}\) (114.25 g), soil application of manganese (as MnSO\(_4\)) @ 25Kg ha\(^{-1}\) (113.17 g) and foliar spray of boron (as borax) @ 0.5% after 60 and 90 days of planting (110.63 g) (Table 4).
### Table 1: Effect of boron, manganese, zinc and iron on plant height and tiller number of turmeric

| Treatment | Plant height (cm) | Tiller Number |
|-----------|------------------|---------------|
|           | 2010-11  | 2011-12  | 2012-13  | 2015-16 | Pooled | 2010-11  | 2011-12  | 2012-13  | 2015-16 | Pooled |
| T1        | 82.00     | 80.47     | 78.83     | 95.93   | 84.31  | 2.00     | 1.88     | 1.89     | 2.87    | 2.16   |
| T2        | 96.33     | 96.07     | 90.40     | 108.47  | 97.82  | 2.56     | 2.29     | 1.93     | 4.73    | 2.88   |
| T3        | 94.03     | 85.23     | 78.73     | 103.00  | 90.25  | 2.56     | 1.72     | 2.11     | 3.53    | 2.48   |
| T4        | 81.99     | 79.32     | 73.82     | 92.33   | 81.87  | 3.56     | 3.17     | 3.13     | 3.67    | 3.38   |
| T5        | 94.40     | 91.64     | 83.81     | 109.13  | 94.75  | 3.11     | 2.50     | 2.13     | 4.07    | 2.95   |
| T6        | 88.41     | 86.51     | 81.60     | 101.67  | 89.55  | 2.44     | 1.83     | 2.33     | 3.53    | 2.53   |
| T7        | 86.34     | 78.35     | 73.54     | 118.00  | 89.06  | 2.56     | 1.96     | 1.97     | 3.87    | 2.59   |
| T8        | 84.12     | 74.11     | 87.28     | 110.40  | 88.98  | 3.44     | 2.27     | 2.32     | 4.73    | 3.19   |
| T9        | 92.57     | 84.97     | 80.13     | 107.80  | 91.37  | 3.33     | 2.69     | 2.33     | 4.67    | 3.26   |
| SEm±      | 3.03      | 3.66      | 3.65      | 1.74    | 1.65   | 0.21     | 0.30     | 0.31     | 0.23    | 0.13   |
| CD (P = 0.05) | 9.10 | 10.97     | 10.95     | 5.20    | 4.64   | 0.64     | 0.90     | 0.92     | 0.68    | 0.37   |
| CV        | 5.99      | 7.54      | 7.82      | 2.86    | 6.35   | 12.93    | 23.04    | 23.86    | 9.93    | 15.87  |

T1 - Control (No micronutrients), T2 - Soil application of Boron (Borax) @ 25Kg ha\(^{-1}\), T3 - Soil application of Manganese (MnSO\(_4\)) @ 25Kg ha\(^{-1}\), T4 - Soil application of Iron (Fe\(_2\)SO\(_4\)) @ 25Kg ha\(^{-1}\), T5 - Soil application of Zinc (ZnSO\(_4\)) @ 25Kg ha\(^{-1}\), T6 - Foliar spray of Manganese (MnSO\(_4\)) @ 0.5% after 60 and 90 days of planting, T7 - Foliar spray of Iron (Fe\(_2\)SO\(_4\)) @ 0.5% after 60 and 90 days of planting, T8 - Foliar spray of Boron (Borax) @ 0.5% after 60 and 90 days of planting and T9 - Foliar spray of Zinc (ZnSO\(_4\)) @ 0.5% after 60 and 90 days of planting.
Table 2 Effect of boron, manganese, zinc and iron on number of leaves and leaf length of turmeric

| Treatment | Number of leaves | Leaf length (cm) |
|-----------|-----------------|-----------------|
|           | 2010-11 | 2011-12 | 2012-13 | 2015-16 | Pooled | 2010-11 | 2011-12 | 2012-13 | 2015-16 | Pooled |
| T₁        | 7.00     | 8.50     | 8.50     | 7.07     | 7.77   | 35.10     | 40.17     | 39.60     | 35.90     | 37.69     |
| T₂        | 8.44     | 7.61     | 7.89     | 9.07     | 8.25   | 44.78     | 42.28     | 37.38     | 41.08     | 41.38     |
| T₃        | 8.33     | 9.44     | 9.00     | 7.87     | 8.66   | 43.11     | 39.78     | 39.16     | 39.92     | 40.49     |
| T₄        | 8.11     | 7.94     | 7.61     | 8.20     | 7.97   | 36.87     | 33.40     | 34.07     | 36.86     | 35.30     |
| T₅        | 8.22     | 8.50     | 8.44     | 8.47     | 8.41   | 43.89     | 40.26     | 35.59     | 40.08     | 39.96     |
| T₆        | 8.00     | 6.16     | 6.10     | 7.73     | 7.00   | 40.46     | 40.90     | 37.23     | 41.20     | 39.95     |
| T₇        | 7.89     | 7.17     | 7.33     | 9.13     | 7.88   | 40.30     | 39.70     | 36.83     | 42.12     | 39.74     |
| T₈        | 7.89     | 6.45     | 8.33     | 10.20    | 8.22   | 37.23     | 37.90     | 36.00     | 43.57     | 38.68     |
| T₉        | 8.11     | 7.11     | 6.67     | 9.33     | 7.81   | 41.72     | 40.72     | 40.23     | 42.67     | 41.34     |
| SEM±      | 0.36     | 0.48     | 0.49     | 0.24     | 0.21   | 1.52      | 1.36      | 1.78      | 1.07      | 0.78      |
| CD (P = 0.05) | 1.09 | 1.44 | 1.46 | 0.71 | 0.60 | 4.56 | 4.09 | 5.33 | 3.21 | 2.21 |
| CV        | 7.86     | 10.87    | 10.87    | 4.76     | 9.21   | 6.52      | 5.99      | 8.24      | 4.59      | 6.88      |

T₁ - Control (No micronutrients), T₂ - Soil application of Boron (Borax) @ 25Kg ha⁻¹, T₃ - Soil application of Manganese (MnSO₄) @ 25Kg ha⁻¹, T₄ - Soil application of Iron (Fe₂SO₄) @ 25Kg ha⁻¹, T₅ - Soil application of Zinc (ZnSO₄) @ 25Kg ha⁻¹, T₆ - Foliar spray of Manganese (MnSO₄) @ 0.5% after 60 and 90 days of planting, T₇ - Foliar spray of Iron (Fe₂SO₄) @ 0.5% after 60 and 90 days of planting, T₈ - Foliar spray of Boron (Borax) @ 0.5% after 60 and 90 days of planting and T₉ - Foliar spray of Zinc (ZnSO₄) @ 0.5% after 60 and 90 days of planting.
Table 3: Effect of boron, manganese, zinc and iron on breadth and weight of mother rhizome of turmeric

| Treatment | Leaf breadth (cm) | Weight of mother rhizome (g) |
|-----------|------------------|-------------------------------|
|           | 2010-11 | 2011-12 | 2012-13 | 2015-16 | Pooled | 2010-11 | 2011-12 | 2012-13 | 2015-16 | Pooled |
| T1        | 9.00     | 9.39    | 8.39    | 8.98    | 8.94   | 40.89   | 43.22   | 42.56    | 50.77    | 44.36 |
| T2        | 11.09    | 10.28   | 9.53    | 10.53   | 10.36  | 52.22   | 47.78   | 43.78    | 59.81    | 50.90 |
| T3        | 10.03    | 9.83    | 9.67    | 10.02   | 9.89   | 63.00   | 62.11   | 65.11    | 67.03    | 64.31 |
| T4        | 9.74     | 8.58    | 8.44    | 8.87    | 8.91   | 45.78   | 44.45   | 48.78    | 56.67    | 48.92 |
| T5        | 9.52     | 8.28    | 8.11    | 9.05    | 8.74   | 48.44   | 40.44   | 43.67    | 52.56    | 46.28 |
| T6        | 10.67    | 10.21   | 9.50    | 10.12   | 10.12  | 47.44   | 43.72   | 40.22    | 51.33    | 45.68 |
| T7        | 10.41    | 10.08   | 8.96    | 10.47   | 9.98   | 57.56   | 53.78   | 52.17    | 60.43    | 55.98 |
| T8        | 9.27     | 9.60    | 9.35    | 10.56   | 9.70   | 64.22   | 55.83   | 56.17    | 65.14    | 60.34 |
| T9        | 9.61     | 10.28   | 10.22   | 10.46   | 10.14  | 64.00   | 65.94   | 66.94    | 68.37    | 66.31 |
| SEM±      | 0.51     | 0.74    | 0.81    | 0.18    | 0.32   | 3.29    | 2.46    | 5.0       | 1.65     | 1.64 |
| CD (P = 0.05) | 1.52 | 2.22    | 2.42    | 0.55    | 0.90   | 9.87    | 7.39    | 11.98    | 4.97     | 4.63 |
| CV        | 8.82     | 13.32   | 15.32   | 3.24    | 11.50  | 10.76   | 8.41    | 16.95    | 4.06     | 1.64 |

T1 - Control (No micronutrients), T2 - Soil application of Boron (Borax) @ 25Kg ha⁻¹, T3 - Soil application of Manganese (MnSO₄) @ 25Kg ha⁻¹, T4 - Soil application of Iron (Fe₂SO₄) @ 25Kg ha⁻¹, T5 - Soil application of Zinc (ZnSO₄) @ 25Kg ha⁻¹, T6 - Foliar spray of Manganese (MnSO₄) @ 0.5% after 60 and 90 days of planting, T7 - Foliar spray of Iron (Fe₂SO₄) @ 0.5% after 60 and 90 days of planting, T8 - Foliar spray of Boron (Borax) @ 0.5% after 60 and 90 days of planting and T9 - Foliar spray of Zinc (ZnSO₄) @ 0.5% after 60 and 90 days of planting.
Table 4 Effect of boron, manganese, zinc and iron on weight of primary and secondary rhizome of turmeric

| Treatment   | Weight of primary rhizome | Weight of secondary rhizome |
|-------------|---------------------------|-----------------------------|
|             | 2010-11 | 2011-12 | 2012-13 | 2015-16 | Pooled | 2010-11 | 2011-12 | 2012-13 | 2015-16 | Pooled |
| T₁          | 87.00   | 71.67   | 69.00   | 90.71   | 79.59   | 80.67   | 36.22   | 35.06   | 45.95   | 49.48   |
| T₂          | 102.67  | 93.68   | 78.67   | 130.26  | 101.32  | 120.44  | 58.76   | 56.92   | 86.93   | 80.76   |
| T₃          | 112.89  | 118.50  | 107.00  | 114.29  | 113.17  | 137.56  | 56.39   | 54.39   | 79.47   | 81.95   |
| T₄          | 98.89   | 102.50  | 102.06  | 115.03  | 104.62  | 127.11  | 62.98   | 60.21   | 77.08   | 81.85   |
| T₅          | 111.78  | 114.11  | 111.94  | 119.15  | 114.25  | 110.78  | 60.67   | 58.89   | 75.45   | 76.45   |
| T₆          | 111.00  | 84.78   | 72.78   | 113.45  | 95.50   | 144.00  | 48.17   | 48.83   | 78.03   | 79.76   |
| T₇          | 153.56  | 109.61  | 103.10  | 95.21   | 115.37  | 139.00  | 58.67   | 58.61   | 55.16   | 77.86   |
| T₈          | 123.22  | 95.61   | 99.22   | 124.47  | 110.63  | 130.00  | 43.83   | 44.39   | 82.10   | 75.08   |
| T₉          | 126.33  | 81.39   | 81.94   | 119.60  | 102.32  | 144.33  | 40.94   | 42.57   | 83.04   | 77.72   |
| SEM±        | 4.47    | 3.55    | 5.41    | 1.97    | 1.97    | 3.74    | 2.28    | 2.86    | 1.66    | 1.39    |
| CD (P = 0.05) | 13.42  | 10.65   | 16.22   | 5.91    | 5.55    | 11.21   | 6.82    | 8.58    | 5.06    | 3.91    |
| CV          | 6.82    | 6.36    | 10.21   | 3.00    | 6.56    | 5.14    | 7.60    | 9.70    | 3.96    | 6.35    |

T₁ - Control (No micronutrients), T₂ - Soil application of Boron (Borax) @ 25Kg ha⁻¹, T₃ - Soil application of Manganese (MnSO₄) @ 25Kg ha⁻¹, T₄ - Soil application of Iron (Fe₂SO₄) @ 25Kg ha⁻¹, T₅ - Soil application of Zinc (ZnSO₄) @ 25Kg ha⁻¹, T₆ - Foliar spray of Manganese (MnSO₄) @ 0.5% after 60 and 90 days of planting, T₇ - Foliar spray of Iron (Fe₂SO₄) @ 0.5% after 60 and 90 days of planting, T₈ - Foliar spray of Boron (Borax) @ 0.5% after 60 and 90 days of planting and T₉ - Foliar spray of Zinc (ZnSO₄) @ 0.5% after 60 and 90 days of planting.
Table 5 Effect of boron, manganese, zinc and iron on plant population of turmeric

| Treatment | Plant population at (30DAP) | Plant population at (60DAP) |
|-----------|-----------------------------|-----------------------------|
|           | 2010-11  | 2011-12  | 2012-13  | 2015-16  | Pooled | 2010-11  | 2011-12  | 2012-13  | 2015-16  | Pooled |
| T₁        | 36.00    | 37.67    | 37.67    | 39.33    | 37.67    | 35.00    | 35.67    | 35.67    | 38.67    | 36.25    |
| T₂        | 38.67    | 34.67    | 35.00    | 38.67    | 36.75    | 38.67    | 34.00    | 34.00    | 36.67    | 35.83    |
| T₃        | 39.33    | 34.67    | 36.67    | 37.67    | 37.08    | 38.33    | 34.33    | 36.33    | 36.67    | 36.25    |
| T₄        | 38.33    | 36.33    | 36.67    | 38.00    | 37.33    | 36.67    | 35.33    | 37.00    | 38.00    | 36.75    |
| T₅        | 37.33    | 36.67    | 37.00    | 38.33    | 37.33    | 36.67    | 35.33    | 37.00    | 38.00    | 36.75    |
| T₆        | 38.67    | 38.00    | 38.33    | 37.67    | 38.17    | 36.67    | 37.33    | 38.00    | 37.00    | 37.25    |
| T₇        | 39.67    | 35.67    | 36.00    | 37.67    | 37.25    | 36.67    | 35.33    | 35.33    | 37.67    | 36.25    |
| T₈        | 40.00    | 39.67    | 39.00    | 38.00    | 39.17    | 37.33    | 38.00    | 38.33    | 38.00    | 37.92    |
| T₉        | 37.33    | 38.67    | 38.33    | 39.67    | 38.50    | 37.33    | 37.33    | 38.00    | 39.67    | 38.08    |
| SEM±      | 0.81     | 1.13     | 1.00     | 0.86     | 0.51     | 1.09     | 1.14     | 0.93     | .71      | 0.51     |
| CD (P = 0.05) | 2.45  | 3.38     | 3.01     | 2.59     | 1.44     | 3.28     | 3.43     | 2.80     | 2.14     | 1.43     |
| CV        | 3.69     | 5.30     | 4.68     | 3.91     | 4.68     | 5.12     | 5.51     | 4.42     | 3.28     | 4.77     |

T₁ - Control (No micronutrients), T₂ - Soil application of Boron (Borax) @ 25Kg ha⁻¹, T₃ - Soil application of Manganese (MnSO₄) @ 25Kg ha⁻¹, T₄ - Soil application of Iron (Fe₂SO₄) @ 25Kg ha⁻¹, T₅ - Soil application of Zinc (ZnSO₄) @ 25Kg ha⁻¹, T₆ - Foliar spray of Manganese (MnSO₄) @ 0.5% after 60 and 90 days of planting, T₇ - Foliar spray of Iron (Fe₂SO₄) @ 0.5% after 60 and 90 days of planting, T₈ - Foliar spray of Boron (Borax) @ 0.5% after 60 and 90 days of planting and T₉ - Foliar spray of Zinc (ZnSO₄) @ 0.5% after 60 and 90 days of planting.
Table. 6 Effect of boron, manganese, zinc and iron on rhizome yield of turmeric

| Treatment | Yield per Plot (kg/3 m²) | Projected Yield (t/ha) |
|-----------|-------------------------|------------------------|
|           | 2010-11  | 2011-12  | 2012-13  | 2015-16  | Pooled  | 2010-11  | 2011-12  | 2012-13  | 2015-16  | Pooled  |
| T₁        | 6.89     | 6.70     | 6.50     | 8.57     | 7.17    | 13.89    | 13.51    | 13.10    | 17.28    | 14.45   |
| T₂        | 10.17    | 10.33    | 10.17    | 13.87    | 11.13   | 20.50    | 20.83    | 20.50    | 27.96    | 22.45   |
| T₃        | 9.33     | 7.60     | 7.93     | 11.78    | 9.16    | 18.82    | 15.32    | 15.99    | 23.74    | 18.47   |
| T₄        | 8.67     | 7.83     | 7.90     | 11.61    | 9.00    | 17.47    | 15.79    | 15.93    | 23.41    | 18.15   |
| T₅        | 9.33     | 7.73     | 8.00     | 11.40    | 9.11    | 18.82    | 15.59    | 16.13    | 22.98    | 18.38   |
| T₆        | 8.83     | 8.37     | 7.57     | 11.15    | 8.98    | 17.81    | 16.87    | 15.25    | 22.47    | 18.10   |
| T₇        | 7.50     | 6.37     | 5.83     | 9.80     | 7.38    | 15.12    | 12.84    | 11.76    | 19.75    | 14.87   |
| T₈        | 8.83     | 10.03    | 10.17    | 13.35    | 10.59   | 17.81    | 20.23    | 20.50    | 26.91    | 21.36   |
| T₉        | 9.83     | 7.97     | 8.47     | 13.21    | 9.87    | 19.82    | 16.06    | 17.07    | 26.64    | 19.90   |
| SEm±      | 0.71     | 0.73     | 0.79     | 0.25     | 0.43    | 1.42     | 1.48     | 1.60     | 0.50     | 0.86    |
| CD (P = 0.05) | 2.11   | 2.20     | 2.38     | 0.76     | 1.20    | 4.26     | 4.43     | 4.80     | 1.52     | 2.42    |
| CV%       | 13.84    | 15.68    | 17.07    | 3.75     | 16.10   | 13.84    | 15.68    | 17.64    | 3.75     | 16.09   |

T₁ - Control (No micronutrients), T₂ - Soil application of Boron (Borax) @ 25Kg ha⁻¹, T₃ - Soil application of Manganese (MnSO₄) @ 25Kg ha⁻¹, T₄ - Soil application of Iron (Fe₂SO₄) @ 25Kg ha⁻¹, T₅ - Soil application of Zinc (ZnSO₄) @ 25Kg ha⁻¹, T₆ - Foliar spray of Manganese (MnSO₄) @ 0.5% after 60 and 90 days of planting, T₇ - Foliar spray of Iron (Fe₂SO₄) @ 0.5% after 60 and 90 days of planting, T₈ - Foliar spray of Boron (Borax) @ 0.5% after 60 and 90 days of planting and T₉ - Foliar spray of Zinc (ZnSO₄) @ 0.5% after 60 and 90 days of planting.
Table 7 Cost Benefit ratio of different treatments

| Treatments | Expense (Rs./ha) | Income (Rs./ha) | Net income (Rs./ha) | C:B |
|------------|-----------------|-----------------|--------------------|-----|
|            | Land Preparation | Seed rhizome cost | Micronutrient and application cost | Labour (Bed preparation, sowing, weeding, harvesting, spraying etc) | Fertilizer | Total | Producti on (ton/ha) | Rate (Rs./t) | Sell amount (Rs.) |      |
| T1         | 10000           | 50,000          | 0                  | 1,25,572                | 1,056 | 3,075 | 3,206 | 22,500                 | 2,15,409 | 14.45 | 20,000 | 289000 | 73,591 | 1:1.34 |
| T2         | 10000           | 50,000          | 5,512              | 1,25,572                | 1,056 | 3,075 | 3,206 | 22,500                 | 2,20,921 | 22.45 | 20,000 | 449000 | 2,28,079 | 1:2.03 |
| T3         | 10000           | 50,000          | 2,512              | 1,25,572                | 1,056 | 3,075 | 3,206 | 22,500                 | 2,17,921 | 18.47 | 20,000 | 369400 | 1,51,479 | 1:1.70 |
| T4         | 10000           | 50,000          | 1,137              | 1,25,572                | 1,056 | 3,075 | 3,206 | 22,500                 | 2,16,546 | 18.15 | 20,000 | 363000 | 1,46,454 | 1:1.68 |
| T5         | 10000           | 50,000          | 1.962              | 1,25,572                | 1,056 | 3,075 | 3,206 | 22,500                 | 2,17,371 | 18.38 | 20,000 | 367600 | 1,50,229 | 1:1.69 |
| T6         | 10000           | 50,000          | 2,528              | 1,25,572                | 1,056 | 3,075 | 3,206 | 22,500                 | 2,17,937 | 18.1 | 20,000 | 362000 | 1,44,063 | 1:1.66 |
| T7         | 10000           | 50,000          | 2,198              | 1,25,572                | 1,056 | 3,075 | 3,206 | 22,500                 | 2,17,607 | 14.87 | 20,000 | 297400 | 79,793 | 1:1.37 |
| T8         | 10000           | 50,000          | 3,284              | 1,25,572                | 1,056 | 3,075 | 3,206 | 22,500                 | 2,18,693 | 21.36 | 20,000 | 427200 | 2,08,507 | 1:1.95 |
| T9         | 10000           | 50,000          | 2,384              | 1,25,572                | 1,056 | 3,075 | 3,206 | 22,500                 | 2,17,793 | 19.9 | 20,000 | 398000 | 1,80,207 | 1:1.83 |

T1 - Control (No micronutrients), T2 - Soil application of Boron (Borax) @ 25Kg ha⁻¹, T3 - Soil application of Manganese (MnSO₄) @ 25Kg ha⁻¹, T4 - Soil application of Iron (FeSO₄) @ 25Kg ha⁻¹, T5 - Soil application of Zinc (ZnSO₄) @ 25Kg ha⁻¹, T6 - Foliar spray of Manganese (MnSO₄) @ 0.5% after 60 and 90 days of planting, T7 - Foliar spray of Iron (FeSO₄) @ 0.5% after 60 and 90 days of planting, T8 - Foliar spray of Boron (Borax) @ 0.5% after 60 and 90 days of planting, T9 - Foliar spray of Zinc (ZnSO₄) @ 0.5% after 60 and 90 days of planting.
With respect to the weight of secondary rhizome, the higher weight of secondary rhizome was recorded with the treatment of soil application of manganese (as MnSO₄) @ 25Kg ha⁻¹ (81.95 g), soil application of iron (as Fe₂SO₄) @ 25Kg ha⁻¹ (81.85 g) and soil application of boron (as borax) @ 25Kg ha⁻¹ (80.76 g). Lowest primary and secondary rhizome weight was recorded in the control treatment (79.59 g and 49.48 g, respectively) (Table 4). Effect of micronutrient on the turmeric plant population survival from 30 days after transplanting to the maturity (i.e. at the time harvest) was almost nothing (Table 5).

Among the different treatment, soil application of boron (as borax) @ 25Kg ha⁻¹ gave the highest yield (11.13 kg/3m² and 22.45 t/ha) which was also statistically at par with foliar spray of boron (as borax) @ 0.5% after 60 and 90 days of planting treatment (10.59 kg/3m² and 21.36 t/ha) (Table 4). Higher yield of turmeric rhizome was also recorded in the treatment of soil application of iron (as Fe₂SO₄) @ 25Kg ha⁻¹ (9.87 kg/3m² and 19.90 t/ha). The lowest yield was recorded in the control plot (7.17 kg/3m² and 14.45 t/ha). In this experiment higher yield recorded in micronutrient treated plot as compared to the control plots. This might be due the beneficial effect of the micronutrient on turmeric yield. Among the different micronutrient, soil application of boron gave highest yield as compared to the other treatment. Sugto and Mafutuchah (1995), Pawar and Gavande (1992) and Singh et al., (1992) also observed similar findings in their report as found in boron application.

Considering cost benefit ratio, the highest C : B ratio (1 : 2.04) was recorded with the soil application of boron (as borax) @ 25Kg ha⁻¹ followed by foliar spray of boron (1 : 1.95) (as borax) @ 0.5% at 60 and 90 days after planting and lowest C : B ratio (1 : 1.34) was recorded in the control treatment (i.e. application of no micronutrient) (Table 7).

In conclusion, from the above discussion it may be concluded that soil application of boron (as borax) @ 25Kg ha⁻¹ and foliar spray of boron (as borax) @ 0.5% at 60 and 90 days after planting (1 : 1.95) were beneficial for getting higher yield in turmeric.

Acknowledgement

The authors are highly indebted to Indian Institute of Spices Research–Indian Council of Agricultural Research, for their financial help by providing research grant, guidance and support in every step of experiment.

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How to cite this article:

Datta, S., S. Chakraborty, J.C. Jana, A. Debnath, M.K. Roy and Haque, S. 2017. Effect of Different Micronutrients on Turmeric Variety Suranjana in Terai Region of West Bengal, India. Int.J.Curr.Microbiol.App.Sci. 6(5): 1471-1482. doi: https://doi.org/10.20546/ijcmas.2017.605.160