

**INFLUENCE OF ZINC, COPPER, MANGANESE AND BORON ON MORPHO-PHYSIOLOGICAL PARAMETERS AND YIELD IN WHEAT (*Triticum aestivum* L.)**Vaibhavi P. Madavi<sup>1</sup>, Prashant V. Shende<sup>2</sup>, Akshay R. Uike<sup>3</sup> and Nikita R. Landge<sup>4</sup>**ABSTRACT**

Field trial was conducted at College of Agriculture, Nagpur during *rabi* season of 2020-2021 to study the probable response of zinc, copper, manganese and boron for improving morpho-physiological and yield parameters in wheat (*Triticum aestivum* L.). The experiment was laid out in randomized block design with three replications. Research design comprised of ten treatments of zinc, copper, manganese and boron *i.e.*, T<sub>1</sub> (control), T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>), T<sub>5</sub> (1% Boron), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron) and T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). Spraying of zinc, copper, manganese and boron was done two times *i.e.*, on 25 and 40 DAS. Observations about morpho- physiological parameters like plant height, no. of tillers, sq. m<sup>-1</sup> 50% flowering, days to maturity, total dry weight plant<sup>-1</sup>, leaf area, leaf area index, seed yield ha<sup>-1</sup> and harvest index were recorded and calculated. Application of 1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron followed by 1% ZnSO<sub>4</sub> + 1% Boron gave significantly higher results in all parameters studied.

(Key words : ZnSO<sub>4</sub>, MnSO<sub>4</sub>, CuSO<sub>4</sub>, Boron, foliar spray, morpho-physiological parameters)

**INTRODUCTION**

Wheat is a self-pollinated crop originated from south-western Asia, is considered as the second most important cereal crop in the world after rice. It has been described as the 'King of cereals' because of the acreage it occupies, high productivity and the prominent position it holds in the international food grain trade. It belongs to genus '*Triticum*' of poaceae (gramineae) family and there are 17 different species. Most of the cultivated wheat varieties belongs to three main species of the genus *Triticum*. These are the hexaploid, *T. aestivum* (L.) (bread wheat), the tetraploid, *T. durum* and the diploid, *T. dicocum*. Globally, *T. aestivum* wheat is the most important species which covers 95 per cent of the area. Second popular wheat is durum wheat which covers about 4 per cent while, *T. dicocum* wheat cover less than one per cent of the total area. Wheat is one of the most essential foods in the world. To increase its productivity, nutrient management is one of the most important factors. In wheat production, micronutrients play a vital role in the yield improvement. Zn, Mn, B, Fe, Cu and Mo are known to be the most important micronutrients for higher plants. Micronutrients occupy a major portion as they are essential for increasing the growth of plant. Their importance increases due to their role in plant nutrition and increasing the soil productivity (Zain *et al.*, 2015). Yashona *et al.* (2018) reported that zinc is involved in growth, enzyme activation metabolism of carbohydrates,

lipids, nucleic acid, gene expression regulation, protein synthesis and reproductive development plant. Its availability to plants limits due to inherently infertile soils, micronutrient depletion by intensification of cultivation and poor mobility of zinc in two and within the plants. Panwar *et al.* (2019) stated that micronutrients namely zinc, iron, copper, manganese and boron are essential nutrients required in very small quantities for normal plant growth which are involved in various enzymes and other physiological activity. Metwally and Hefny (2018) also stated that in Egypt, wheat (*Triticum aestivum* L.) is the most important cereal crop as it is the staple food of the Egyptian people, but the gap between wheat consumption and production is continuously increasing due to steady increase in the human population with limited cultivated area.

**MATERIALS AND METHODS**

The project entitled "Influence of zinc, copper, manganese and boron on morpho-physiological parameters and yield in wheat (*Triticum aestivum* L.)" was carried out during *rabi* 2022-23 in the field area of section of Agricultural Botany, College of Agriculture, Nagpur in a Randomized Block Design with twelve treatments and three replications. Twelve Treatments *viz.*, T<sub>1</sub> (control), T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>), T<sub>5</sub> (1% Boron), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>9</sub>

1 & 4. P.G. Students, Botany Section, College of Agriculture, Nagpur, Maharashtra, India

2. Assoc. Professor, Botany Section, College of Agriculture, Nagpur, Maharashtra, India

3. Ph.D. Scholar, Dept. of Plant Breeding and Genetics, Assam Agriculture University, Jorhat, Assam, India

(1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron) and T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron) were tested. The gross plot size was 2 m x 2.5 m and net plot size was 1.8 m x 2.3 m with spacing line sowing at 20 cm. Five plants from each plot were selected randomly and data were collected at 30, 50 and 70 DAS on plant height, number of tillers sq<sup>-1</sup> m, 50% flowering, days to maturity, total dry weight plant<sup>-1</sup> and leaf area were recorded at 30, 50 and 70 DAS and LAI was calculated at the same stages.

## RESULTS AND DISCUSSION

Height is an important measure of growth. It is one of the visible measurements and is a function of internodes and leaf emergence. Since, leaves are born on stem leaf area development and biomass production shows a close relationship with plant height. Plant height under various treatments was recorded at three observational stages *viz.*, 30, 50 and 70 DAS. Significant variation with gradual increase (50-70 DAS) was observed in plant height at all the stages of observations.

The data regarding the plant height at 30 DAS was found statistically significant. At 30 DAS the range of plant height was recorded 31.81 – 45.21 cm. Significantly maximum plant height was registered in treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron) and the treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>) and T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron) were found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Similarly the treatments T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron), T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) were found significantly higher in plant height as compared to control (T<sub>1</sub>).

At 50 DAS the range of plant height was recorded 41.54 – 62.52 cm and at 70 DAS the range of plant height was observed 57.54 – 68.52 cm. At these stages significantly highest plant height was noticed in plant expose to the treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron) and treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>) and T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron) were found at par with T<sub>12</sub> when compared to control and rest of the treatments. Treatments T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) also showed their significance in plant height over control (T<sub>1</sub>).

These results are also in conformity with the findings of Tahir *et al.* (2021), where they found significant effect of foliar application of micronutrient mixture (Zn, B, Fe, Mn and Cu) on plant height. Tiwari *et al.* (2023) found significant increase in plant height by the foliar application of 100% RDF + soil application of Zn @ 25 kg ZnSO<sub>4</sub> ha<sup>-1</sup> + two foliar application of Fe (0.5%). Kaur *et al.* (2023) found significant increase in plant height by the foliar application

of micronutrients (0.25% and 0.5% of B and Zn) in cauliflower.

### Number of tillers sq. m<sup>-1</sup>

Number of tillers under various treatments was recorded at three observational stages *viz.*, 30, 50 and 70 DAS. At 30 DAS data recorded about number of tillers was statistically significant. At 30 DAS range of number of tillers recorded were 245.00– 314.00. Significantly highest number of tillers was recorded in treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). Treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>) and T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron), T<sub>3</sub> (1% ZnSO<sub>4</sub>) and T<sub>2</sub> (1% CuSO<sub>4</sub>) were found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Whereas, the treatments T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) also significantly increased number of tillers as compared to control (T<sub>1</sub>).

At 50 DAS range of number of tillers recorded was 255.00 – 317.33. At 70 DAS range of number of tillers recorded was 257.00 – 319.33. At 50 and 70 DAS significantly highest number of tillers were observed in treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). This treatment was found at par with treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron) and T<sub>3</sub> (1% ZnSO<sub>4</sub>) when compared with control and rest of the treatments. Application of 1% CuSO<sub>4</sub>, 1% MnSO<sub>4</sub> and 1% Boron also showed their significance in number of tillers as compared to control (T<sub>1</sub>).

These results are also in conformity with the findings of Misu (2021), where they found significant effect of foliar application of boron on number of tillers in wheat. Jondhale *et al.* (2021) found that application of 100% RDF + Soil application of ZnSO<sub>4</sub> 7 H<sub>2</sub>O @ 15 kg ha<sup>-1</sup> at the time of transplanting significantly increase plant height, number of tillers, length of panicals, kernel panical<sup>-1</sup>, 100 kernal weight, grain yield and dry matter of rice.

### Days to 50% flowering and days to maturity

The data recorded about days to 50% flowering and days to maturity were found statistically significant. The number of days to 50% flowering and days to maturity were recorded earliest in treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). Treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>) and T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron) and T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron) were found at par with this treatment when compared with control and rest of the treatments. Whereas, the treatments T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>), T<sub>5</sub> (1% Boron) also showed their significance in days to 50% flowering as compared to control (T<sub>1</sub>).

These results are also in conformity with the findings of Karad *et al.* (2021), where they found significant

effect of foliar application of micronutrient mixture (0.5% FeSO<sub>4</sub> + 0.5% ZnSO<sub>4</sub>) on days to maturity of chickpea. Kesarkar *et al.* (2022) also found significant effect of foliar application of micronutrient mixture (0.5% FeSO<sub>4</sub> + 1% ZnSO<sub>4</sub>) on 50% flowering and days to maturity of safflower.

#### Total dry weight plant<sup>-1</sup> (g)

Total dry weight is an important criterion. It determines source-sink relationship and depends upon the net gain in processes on anabolism and catabolism of plant. Total dry matter production, its distribution and partitioning is integral part of growth and development over the entire growth period and is directly related to seed yield. Total dry weight is an important criterion. It determines source sink relationship and depends upon the net gain in processes on anabolism and catabolism of plant. Total dry matter production, its distribution and partitioning is integral part of growth and development over the entire growth period and is directly related to seed yield. At 30 DAS the range of total dry weight was observed 0.42-0.81 g. Significantly maximum total dry weight plant<sup>-1</sup> was observed in treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). Treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron) and T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>) were found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Similarly, the treatments T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron), T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>2</sub> (1% CuSO<sub>4</sub>) and T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) also significantly increased total dry weight plant<sup>-1</sup> as compared to control (T<sub>1</sub>).

At 50 DAS the range of total dry weight plant<sup>-1</sup> was observed 1.65 – 2.50 g. The mean values of total dry weight showed that treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron) was found significantly highest in total dry weight plant<sup>-1</sup>. Treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron) and T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron) were found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Similarly, the treatments T<sub>3</sub> (1% ZnSO<sub>4</sub>) and T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) also enhanced total dry weight plant<sup>-1</sup> significantly as compared to control (T<sub>1</sub>).

At 70 DAS the range of total dry weight plant<sup>-1</sup> was observed 3.72 – 5.21 g. The mean values of total dry weight showed that treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron) had significantly highest in total dry weight plant<sup>-1</sup>. Treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron) and T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>) were found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Whereas the treatments T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>) and T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron) and T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) also significantly higher in total dry weight plant<sup>-1</sup> as compared to control (T<sub>1</sub>).

These results are also in conformity with the

findings of Karad *et al.* (2021), where they found significant effect of foliar application of micronutrient mixture (0.5% FeSO<sub>4</sub> + 0.5% ZnSO<sub>4</sub>) on total dry weight of chickpea. Purushottam *et al.* (2018) revealed that treatment I<sub>4</sub> (*i.e.* irrigation at branching + pre flowering + pod development) and Zn<sub>2</sub> (0.5% zinc sulphate) recorded highest dry weight among all the treatments in chickpea. Kesarkar *et al.* (2022) also noted significant effect of foliar application of micronutrient mixture (0.5% FeSO<sub>4</sub> + 1% ZnSO<sub>4</sub>) on total dry weight of safflower.

#### Leaf area plant<sup>-1</sup>

Leaf area plant<sup>-1</sup> depends upon the number and size of leaves. Leaf size is influenced by light, moisture and nutrients. Photosynthetic capacity of the plant is a function of leaf area development. Leaf area ultimately is a decisive factor of yield of crop. The data on leaf area plant<sup>-1</sup> were recorded at three growth stages *i.e.*, 30, 50, 70 DAS. Significant variation was recorded at these stages of observations.

Observations recorded at 30 DAS indicated significant variation at 30 DAS. The range of leaf area plant<sup>-1</sup> recorded was 23.07 – 31.50 cm<sup>2</sup>. The most pronounced effect observed in plant exposed to the treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). Treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron), T<sub>3</sub> (1% ZnSO<sub>4</sub>) were also found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Whereas the treatments T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) also recorded significantly higher leaf area plant<sup>-1</sup> as compared to control (T<sub>1</sub>).

At 50 DAS the range leaf area plant<sup>-1</sup> recorded was 43.25 – 53.99 cm<sup>2</sup>. The significantly highest leaf area over control was observed at 50 DAS in treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). Treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron), T<sub>3</sub> (1% ZnSO<sub>4</sub>) were found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Whereas the treatments T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) also found significantly higher in leaf area plant<sup>-1</sup> as compared to control (T<sub>1</sub>).

At 70 DAS the range of leaf area plant<sup>-1</sup> recorded was 95.37 – 109.97 cm<sup>2</sup>. At 70 DAS significantly highest leaf area was registered in treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). Treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>) were found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Whereas the treatments T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron), T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>), T<sub>5</sub> (1% Boron) also significantly increased leaf area plant<sup>-1</sup> as compared to control (T<sub>1</sub>).

Leaf area was significantly increased by the application of zinc, copper, manganese and boron possibly because it helps in greater assimilation of food material by the plant which resulted in greater meristematic activities of cells and consequently the number of leaves, length and width of leaf of plant.

These results are also in conformity with the findings of Farhan *et al.* (2021), where they found significant effect of foliar application of different times of boron application on leaf area of wheat. Karad *et al.* (2021) also recorded significant effect of foliar application of micronutrient mixture (0.5% FeSO<sub>4</sub> + 0.5% ZnSO<sub>4</sub>) on leaf area of chickpea. Kesarkar *et al.* (2022) noticed significant effect of foliar application of micronutrient mixture (0.5% FeSO<sub>4</sub> + 1% ZnSO<sub>4</sub>) on leaf area of safflower.

#### Leaf Area Index (LAI)

At 30 DAS the range of leaf area index was observed 11.57–20.32. At this stage significantly maximum LAI was noted in treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). Treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron) and T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>) were found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Whereas, the treatments T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron), T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) also recorded significantly higher leaf area index as compared to control (T<sub>1</sub>).

At 50 DAS the range of leaf area index was observed 21.36–29.37. At this stages significantly maximum LAI was noted in treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). Treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>) and T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron) were found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Whereas, the treatments T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron), T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) also significantly increase leaf area index as compared to control (T<sub>1</sub>).

At 70 DAS the range of leaf area index was observed 43.36–51.37. At this stage significantly maximum LAI was noted in treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). Treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>) and T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron) were found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Whereas, the treatments T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron), T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) also significantly higher in leaf area index as compared to control (T<sub>1</sub>).

These results are also in conformity with the findings of Karad *et al.* (2021), where they found significant effect of foliar application of micronutrient mixture (0.5% FeSO<sub>4</sub> + 0.5% ZnSO<sub>4</sub>) on leaf area of chickpea. Purushottam *et al.* (2018) also found that the leaf area index of chickpea was significantly influenced by spraying of zinc @ 0.5 %.

#### Seed yield ha<sup>-1</sup>

Significantly maximum seed yield ha<sup>-1</sup> was recorded in treatment T<sub>12</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron). Treatment T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>) and T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron) were found at par with treatment T<sub>12</sub> when compared with control and rest of the treatments. Whereas, the treatments T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron), T<sub>3</sub> (1% ZnSO<sub>4</sub>), T<sub>2</sub> (1% CuSO<sub>4</sub>), T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) also significantly higher in seed yield ha<sup>-1</sup> as compared to control (T<sub>1</sub>).

Pise *et al.* (2020) found that two foliar sprays of RDF + ZnSO<sub>4</sub> 0.5% + FeSO<sub>4</sub> 0.5% at 25 and 40 DAS significantly increased yield and yield attribute of lathyrus. Mane *et al.* (2021) reported that application of RDF + Zinc sulphate @ 25 kg ha<sup>-1</sup> + two sprayed of zinc sulphate @ 0.5% at 30 and 45 DAS improved seed yield of pigeonpea. Karad *et al.* (2021) found significant effect of foliar application of micronutrient mixture (0.5% FeSO<sub>4</sub> + 0.5% ZnSO<sub>4</sub>) on seed yield of wheat. Kurrey *et al.* (2022) reported that combined application of NAA 400 ppm + ZnSO<sub>4</sub> 0.5% was found most effective treatment in yield and yield attributing characters of mango.

#### Harvest index

The range of harvest index obtained was 26.25 in control to 36.99% in treatment receiving 1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub> + 1% Boron (T<sub>12</sub>). But treatments T<sub>10</sub> (1% ZnSO<sub>4</sub> + 1% Boron), T<sub>9</sub> (1% ZnSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>6</sub> (1% CuSO<sub>4</sub> + 1% ZnSO<sub>4</sub>), T<sub>7</sub> (1% CuSO<sub>4</sub> + 1% MnSO<sub>4</sub>), T<sub>8</sub> (1% CuSO<sub>4</sub> + 1% Boron), T<sub>11</sub> (1% MnSO<sub>4</sub> + 1% Boron), T<sub>3</sub> (1% ZnSO<sub>4</sub>) and T<sub>2</sub> (1% CuSO<sub>4</sub>) were found at par with each other when compared with control and rest of the treatments. Whereas, the treatments T<sub>4</sub> (1% MnSO<sub>4</sub>) and T<sub>5</sub> (1% Boron) were also found significantly higher in harvest index as compared to control (T<sub>1</sub>).

These results are also in conformity with the findings of Karad *et al.* (2021), where they found significant effect of foliar application of micronutrient mixture (0.5% FeSO<sub>4</sub> + 0.5% ZnSO<sub>4</sub>) on harvest index of wheat. Ijaz *et al.* (2023) also observed significant effect of foliar application of micronutrient mixture (Zn + Fe + Cu + B) on harvest index of wheat. Javed *et al.* (2023) found significant effect of foliar application of boron (B<sub>0</sub>: 0 g ha<sup>-1</sup>, B<sub>1</sub>: 50 g ha<sup>-1</sup>, B<sub>2</sub>: 60 g ha<sup>-1</sup> and B<sub>3</sub>: 70 g ha<sup>-1</sup>) on harvest index of wheat.

**Table 1. Effect of zinc, copper, manganese and boron on plant height, number of tillers, days to 50% flowering and days to maturity on wheat**

Treatments	Plant height (cm)			No. of tillers (sq. m <sup>-1</sup> )			Days to 50% flowering	Days to maturity
	30 DAS	50DAS	70DAS	30DAS	50DAS	70 DAS		
T <sub>1</sub> (Control)	31.81	41.54	57.54	245.00	255.00	257.00	61.98	95.00
T <sub>2</sub> (1% CuSO <sub>4</sub> )	34.92	47.80	53.46	259.33	269.33	271.33	60.95	92.67
T <sub>3</sub> (1% ZnSO <sub>4</sub> )	36.60	48.82	54.82	263.33	273.33	275.33	60.23	92.00
T <sub>4</sub> (1% MnSO <sub>4</sub> )	34.23	46.76	52.76	255.00	265.00	267.00	61.50	93.00
T <sub>5</sub> (1% Boron)	33.59	46.55	52.55	251.67	261.00	263.00	61.74	94.00
T <sub>6</sub> (1% CuSO <sub>4</sub> + 1% ZnSO <sub>4</sub> )	40.50	57.86	63.86	298.33	309.33	311.33	58.65	89.67
T <sub>7</sub> (1% CuSO <sub>4</sub> + 1% MnSO <sub>4</sub> )	39.93	57.15	63.15	297.00	308.33	310.33	58.73	90.33
T <sub>8</sub> (1% CuSO <sub>4</sub> + 1% Boron)	38.88	56.90	62.90	294.33	304.33	306.33	59.04	91.00
T <sub>9</sub> (1% ZnSO <sub>4</sub> + 1% MnSO <sub>4</sub> )	41.81	60.17	66.50	299.33	312.00	314.00	58.11	89.00
T <sub>10</sub> (1% ZnSO <sub>4</sub> + 1% Boron)	43.20	61.49	67.83	302.33	312.33	314.33	57.91	88.33
T <sub>11</sub> (1% MnSO <sub>4</sub> + 1% Boron)	37.66	56.83	63.16	267.67	279.67	281.67	59.23	91.33
T <sub>12</sub> (1% CuSO <sub>4</sub> + 1% ZnSO <sub>4</sub> + 1% MnSO <sub>4</sub> + 1% Boron)	45.21	62.52	68.52	314.00	317.33	319.33	57.55	87.00
SE(m) ±	2.34	3.48	3.52	15.25	15.46	15.46	1.04	1.57
CD at 5 %	6.87	10.21	10.33	44.72	45.34	45.34	3.05	4.61

**Table 2. Effect of zinc, copper, manganese and boron on total dry weight plant<sup>-1</sup>, leaf area plant<sup>-1</sup>, leaf area index, seed yield ha<sup>-1</sup>, harvest index of wheat**

Treatments	Total dry weight plant <sup>-1</sup> (g)			Leaf area plant <sup>-1</sup> (cm <sup>2</sup> )			Leaf area index			Seed yield ha <sup>-1</sup>	Harvest index
	30DAS	50DAS	70DAS	30DAS	50DAS	70DAS	30DAS	50DAS	70DAS		
T <sub>1</sub> (Control)	0.42	1.65	3.72	23.07	43.25	95.37	11.57	21.36	43.36	29.43	26.25
T <sub>2</sub> (1% CuSO <sub>4</sub> )	0.53	1.74	4.14	24.98	46.98	97.90	13.47	23.22	45.22	30.69	29.98
T <sub>3</sub> (1% ZnSO <sub>4</sub> )	0.56	1.90	4.30	25.29	47.29	98.00	14.49	23.80	45.80	31.23	30.29
T <sub>4</sub> (1% MnSO <sub>4</sub> )	0.49	1.71	4.03	23.22	45.14	97.70	13.01	22.80	44.80	30.49	28.14
T <sub>5</sub> (1% Boron)	0.44	1.66	3.77	23.14	44.88	96.60	12.46	21.94	43.94	30.08	27.88
T <sub>6</sub> (1% CuSO <sub>4</sub> + 1% ZnSO <sub>4</sub> )	0.69	2.27	4.69	30.52	52.52	104.97	17.50	28.59	50.59	33.53	35.52
T <sub>7</sub> (1% CuSO <sub>4</sub> + 1% MnSO <sub>4</sub> )	0.65	2.13	4.59	30.33	52.33	102.63	16.17	28.48	50.48	32.81	35.33
T <sub>8</sub> (1% CuSO <sub>4</sub> + 1% Boron)	0.63	2.03	4.49	29.06	51.06	100.60	15.90	28.06	50.06	32.48	34.06
T <sub>9</sub> (1% ZnSO <sub>4</sub> + 1% MnSO <sub>4</sub> )	0.72	2.34	4.83	31.18	53.22	106.63	17.68	28.83	50.83	34.07	36.22
T <sub>10</sub> (1% ZnSO <sub>4</sub> + 1% Boron)	0.76	2.43	4.90	31.24	53.24	107.17	18.79	28.92	50.92	34.32	36.24
T <sub>11</sub> (1% MnSO <sub>4</sub> + 1% Boron)	0.60	1.97	4.46	28.02	50.02	98.23	15.50	24.16	46.16	32.08	33.02
T <sub>12</sub> (1% CuSO <sub>4</sub> + 1% ZnSO <sub>4</sub> + 1% MnSO <sub>4</sub> + 1% Boron)	0.81	2.50	5.21	31.50	53.99	109.97	20.32	29.37	51.37	34.69	36.99
SE(m) ±	0.04	0.20	0.20	2.19	2.31	5.14	0.93	1.54	1.54	1.16	2.31
CD at 5 %	0.12	0.60	0.60	6.43	6.78	9.21	2.72	4.53	4.53	3.41	6.78

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