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INFLUENCE OF ZINC, COPPER, MANGANESE AND BORON ON MORPHO-PHYSIOLOGICAL PARAMETERS AND YIELD IN WHEAT (*Triticum aestivim* L.)

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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_1 (control), T_2 (1% $CuSO_4$), T_3 (1% $ZnSO_4$), T_4 (1% $MnSO_4$), T_5 (1% Boron), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$), T_8 (1% $CuSO_4$ +1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_{10} (1% $ZnSO_4$ + 1% Boron, T_{11} (1% $MnSO_4$ + 1% Boron) and T_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ +1% $MnSO_4$ + 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^{-1} 50% flowering, days to maturity, total dry weight $plant^{-1}$, leaf area, leaf area index, seed yield ha^{-1} and harvest index were recorded and calculated. Application of 1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron followed by 1% $ZnSO_4$ + 1% Boron gave significantly higher results in all parameters studied.

(Key words : $ZnSO_4$, $MnSO_4$, $CuSO_4$, 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. dicoccum* 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_1 (control), T_2 (1% $CuSO_4$), T_3 (1% $ZnSO_4$), T_4 (1% $MnSO_4$), T_5 (1% Boron), T_6 (1% $CuSO_4$+1% $ZnSO_4$), T_7 (1% $CuSO_4$+1% $MnSO_4$), T_8 (1% $CuSO_4$+1% Boron), T_9

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(1% $ZnSO_4$ + 1% $MnSO_4$), T_{10} (1% $ZnSO_4$ + 1% Boron, T_{11} (1% $MnSO_4$ +1% Boron) and T_{12} (1% $CuSO_4$ +1% $ZnSO_4$ +1% $MnSO_4$ +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^{-1} m, 50% flowering, days to maturity, total dry weight $plant^{-1}$ 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_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron) and the treatments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$) and T_8 (1% $CuSO_4$ + 1% Boron) were found at par with treatment T_{12} when compared with control and rest of the treatments. Similarly the treatments T_{11} (1% $MnSO_4$ + 1% Boron), T_3 (1% $ZnSO_4$), T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$) and T_5 (1% Boron) were found significantly higher in plant height as compared to control (T_1).

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_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron) and treatments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$) and T_8 (1% $CuSO_4$ + 1% Boron), T_{11} (1% $MnSO_4$ + 1% Boron) were found at par with T_{12} when compared to control and rest of the treatments. Treatments T_3 (1% $ZnSO_4$), T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$) and T_5 (1% Boron) also showed their significance in plant height over control (T_1).

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 $ZnSO_4$ ha^{-1} + 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^{-1}

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_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron). Treatments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$) and T_8 (1% $CuSO_4$ + 1% Boron), T_{11} (1% $MnSO_4$ + 1% Boron), T_3 (1% $ZnSO_4$) and T_2 (1% $CuSO_4$) were found at par with treatment T_{12} when compared with control and rest of the treatments. Whereas, the treatments T_4 (1% $MnSO_4$) and T_5 (1% Boron) also significantly increased number of tillers as compared to control (T_1).

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_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron). This treatment was found at par with treaments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$), T_8 (1% $CuSO_4$ + 1% Boron), T_{11} (1% $MnSO_4$ + 1% Boron) and T_3 (1% $ZnSO_4$) when compared with control and rest of the treatments. Application of 1% $CuSO_4$, 1% $MnSO_4$ and 1% Boron also showed their significance in number of tillers as compared to control (T_1).

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 $ZnSO_4$ 7 H_2O @ 15 kg ha^{-1} at the time of transplanting significantly increase plant height, number of tillers, length of panicals, kernel $panical^{-1}$, 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_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron). Treatments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$) and T_8 (1% $CuSO_4$ + 1% Boron) and T_{11} (1% $MnSO_4$ + 1% Boron) were found at par with this treatment when compared with control and rest of the treatments. Whereas, the treatments T_3 (1% $ZnSO_4$), T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$), T_5 (1% Boron) also showed their significance in days to 50% flowering as compared to control (T_1).

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% $FeSO_4$ + 0.5% $ZnSO_4$) on days to maturity of chickpea. Kesarkar *et al.* (2022) also found significant effect of foliar application of micronutrient mixture (0.5% $FeSO_4$ + 1% $ZnSO_4$) on 50% flowering and days to maturity of safflower.

Total dry weight plant^{-1} (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^{-1} was observed in treatment T_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron). Treatments T_{10} (1% $ZnSO_4$ + 1% Boron) and T_9 (1% $ZnSO_4$ + 1% $MnSO_4$) were found at par with treatment T_{12} when compared with control and rest of the treatments. Similarly, the treatments T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$), T_8 (1% $CuSO_4$ + 1% Boron), T_{11} (1% $MnSO_4$ + 1% Boron), T_3 (1% $ZnSO_4$), T_2 (1% $CuSO_4$) and T_4 (1% $MnSO_4$) and T_5 (1% Boron) also significantly increased total dry weight plant^{-1} as compared to control (T_1).

At 50 DAS the range of total dry weight plant^{-1} was observed 1.65 – 2.50 g. The mean values of total dry weight showed that treatment T_{12} (1% $CuSO_4$ +% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron) was found significantly highest in total dry weight plant^{-1}. Treatments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$), T_8 (1% $CuSO_4$ + 1% Boron) and T_{11} (1% $MnSO_4$ + 1% Boron) were found at par with treatment T_{12} when compared with control and rest of the treatments. Similarly, the treatments T_3 (1% $ZnSO_4$) and T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$) and T_5 (1% Boron) also enhanced total dry weight plant^{-1} significantly as compared to control (T_1).

At 70 DAS the range of total dry weight plant^{-1} was observed 3.72 – 5.21 g. The mean values of total dry weight showed that treatment T_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron) had significantly highest in total dry weight plant^{-1}. Treatments T_{10} (1% $ZnSO_4$ + 1% Boron) and T_9 (1% $ZnSO_4$ + 1% $MnSO_4$) were found at par with treatment T_{12} when compared with control and rest of the treatments. Whereas the treatments T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$) and T_8 (1% $CuSO_4$ + 1% Boron), T_{11} (1% $MnSO_4$ + 1% Boron) and T_3 (1% $ZnSO_4$), T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$) and T_5 (1% Boron) also significantly higher in total dry weight plant^{-1} as compared to control (T_1).

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% $FeSO_4$ + 0.5% $ZnSO_4$) on total dry weight of chickpea. Purushottam *et al*. (2018) revealed that treatment I_4 (*i.e.* irrigation at branching + pre flowering + pod development) and Zn_2 (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% $FeSO_4$ + 1% $ZnSO_4$) on total dry weight of safflower.

Leaf area plant^{-1}

Leaf area plant^{-1} 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^{-1} 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^{-1} recorded was 23.07 – 31.50 cm^2. The most pronounced effect observed in plant exposed to the treatment T_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron). Treatments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$), T_8 (1% $CuSO_4$ + 1% Boron), T_{11} (1% $MnSO_4$ + 1% Boron), T_3 (1% $ZnSO_4$) were also found at par with treatment T_{12} when compared with control and rest of the treatments. Whereas the treatments T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$) and T_5 (1% Boron) also recorded significantly higher leaf area plant^{-1} as compared to control (T_1).

At 50 DAS the range leaf area plant^{-1} recorded was 43.25 – 53.99 cm^2. The significantly highest leaf area over control was observed at 50 DAS in treatment T_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron). Treatments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$), T_8 (1% $CuSO_4$ + 1% Boron), T_{11} (1% $MnSO_4$ + 1% Boron), T_3 (1% $ZnSO_4$) were found at par with treatment T_{12} when compared with control and rest of the treatments. Whereas the treatments T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$) and T_5 (1% Boron) also found significantly higher in leaf area plant^{-1} as compared to control (T_1).

At 70 DAS the range of leaf area plant^{-1} recorded was 95.37 – 109.97 cm^2. At 70 DAS significantly highest leaf area was registered in treatment T_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron). Treatments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$) were found at par with treatment T_{12} when compared with control and rest of the treatments. Whereas the treatments T_8 (1% $CuSO_4$ + 1% Boron), T_{11} (1% $MnSO_4$ + 1% Boron), T_3 (1% $ZnSO_4$), T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$), T_5 (1% Boron) also significantly increased leaf area plant^{-1} as compared to control (T_1).

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% $FeSO_4$ + 0.5% $ZnSO_4$) on leaf area of chickpea. Kesarkar *et al.* (2022) noticed significant effect of foliar application of micronutrient mixture (0.5% $FeSO_4$ + 1% $ZnSO_4$) 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_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron). Treatments T_{10} (1% $ZnSO_4$ + 1% Boron) and T_9 (1% $ZnSO_4$ + 1% $MnSO_4$) were found at par with treatment T_{12} when compared with control and rest of the treatments. Whereas, the treatments T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$), T_8 (1% $CuSO_4$ + 1% Boron), T_{11} (1% $MnSO_4$ + 1% Boron), T_3 (1% $ZnSO_4$), T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$) and T_5 (1% Boron) also recorded significantly higher leaf area index as compared to control (T_1).

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_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron). Treatments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$) and T_8 (1% $CuSO_4$ + 1% Boron) were found at par with treatment T_{12} when compared with control and rest of the treatments. Whereas, the treatments T_{11} (1% $MnSO_4$ + 1% Boron), T_3 (1% $ZnSO_4$), T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$) and T_5 (1% Boron) also significantly increase leaf area index as compared to control (T_1).

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_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron). Treatments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$) and T_8 (1% $CuSO_4$ + 1% Boron) were found at par with treatment T_{12} when compared with control and rest of the treatments. Whereas, the treatments T_{11} (1% $MnSO_4$ + 1% Boron), T_3 (1% $ZnSO_4$), T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$) and T_5 (1% Boron) also significantly higher in leaf area index as compared to control (T_1).

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% $FeSO_4$ + 0.5% $ZnSO_4$) 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^{-1}

Significantly maximum seed yield ha^{1} was recorded in treatment T_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron). Treatment T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$) and T_8 (1% $CuSO_4$ + 1% Boron) were found at par with treatment T_{12} when compared with control and rest of the treatments. Whereas, the treatments T_{11} (1% $MnSO_4$ + 1% Boron), T_3 (1% $ZnSO_4$), T_2 (1% $CuSO_4$), T_4 (1% $MnSO_4$) and T_5 (1% Boron) also significantly higher in seed yield ha^{-1} as compared to control (T_1).

Pise *et al*. (2020) found that two foliar sprays of RDF + $ZnSO_4$ 0.5% + $FeSO_4$ 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^{-1} + two sprayed of zinc sulphate @ 0.5% at 30 and 45 DAS improved seed yield of pigeopea. Karad *et al*. (2021) found significant effect of foliar application of micronutrient mixture (0.5% $FeSO_4$ + 0.5% $ZnSO_4$) on seed yield of wheat. Kurrey *et al*. (2022) reported that combined application of NAA 400 ppm + $ZnSO_4$ 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% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 1% Boron (T_{12}). But treatments T_{10} (1% $ZnSO_4$ + 1% Boron), T_9 (1% $ZnSO_4$ + 1% $MnSO_4$), T_6 (1% $CuSO_4$ + 1% $ZnSO_4$), T_7 (1% $CuSO_4$ + 1% $MnSO_4$), T_8 (1% $CuSO_4$ + 1% Boron), T_{11} (1% $MnSO_4$ + 1% Boron), T_3 (1% $ZnSO_4$) and T_2 (1% $CuSO_4$) were found at par with each other when compared with control and rest of the treatments. Whereas, the treatments T_4 (1% $MnSO_4$) and T_5 (1% Boron) were also found significantly higher in harvest index as compared to control (T_1).

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% $FeSO_4$ + 0.5% $ZnSO_4$) 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_0 : 0 g ha^{-1}, B_1 : 50 g ha^{-1}, B_2 : 60 g ha^{-1} and B_3 : 70 g ha^{-1}) 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^{-1})			Days to 50% flowering	Days to maturity
	30 DAS	50DAS	70DAS	30DAS	50DAS	70 DAS		
T_1 (Control)	31.81	41.54	57.54	245.00	255.00	257.00	61.98	95.00
T_2 (1% $CuSO_4$)	34.92	47.80	53.46	259.33	269.33	271.33	60.95	92.67
T_3 (1% $ZnSO_4$)	36.60	48.82	54.82	263.33	273.33	275.33	60.23	92.00
T_4 (1% $MnSO_4$)	34.23	46.76	52.76	255.00	265.00	267.00	61.50	93.00
T_5 (1% Boron)	33.59	46.55	52.55	251.67	261.00	263.00	61.74	94.00
T_6 (1% $CuSO_4$ + 1% $ZnSO_4$)	40.50	57.86	63.86	298.33	309.33	311.33	58.65	89.67
T_7 (1% $CuSO_4$ + 1% $MnSO_4$)	39.93	57.15	63.15	297.00	308.33	310.33	58.73	90.33
T_8 (1% $CuSO_4$ + 1% Boron)	38.88	56.90	62.90	294.33	304.33	306.33	59.04	91.00
T_9 (1% $ZnSO_4$ + 1% $MnSO_4$)	41.81	60.17	66.50	299.33	312.00	314.00	58.11	89.00
T_{10} (1% $ZnSO_4$ + 1% Boron)	43.20	61.49	67.83	302.33	312.33	314.33	57.91	88.33
T_{11} (1% $MnSO_4$ + 1% Boron)	37.66	56.83	63.16	267.67	279.67	281.67	59.23	91.33
T_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 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 $plant^{-1}$, leaf area $plant^{-1}$, leaf area index, seed yield ha^{-1}, harvest index of wheat

Treatments	Total dry weight $plant^{-1}$(g)			Leaf area $plant^{-1}$(cm^2)			Leaf area index			Seed yield ha^{-1}	Harvest index
	30DAS	50DAS	70DAS	30DAS	50DAS	70DAS	30DAS	50DAS	70DAS		
T_1 (Control)	0.42	1.65	3.72	23.07	43.25	95.37	11.57	21.36	43.36	29.43	26.25
T_2 (1% $CuSO_4$)	0.53	1.74	4.14	24.98	46.98	97.90	13.47	23.22	45.22	30.69	29.98
T_3 (1% $ZnSO_4$)	0.56	1.90	4.30	25.29	47.29	98.00	14.49	23.80	45.80	31.23	30.29
T_4 (1% $MnSO_4$)	0.49	1.71	4.03	23.22	45.14	97.70	13.01	22.80	44.80	30.49	28.14
T_5 (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_6 (1% $CuSO_4$ + 1% $ZnSO_4$)	0.69	2.27	4.69	30.52	52.52	104.97	17.50	28.59	50.59	33.53	35.52
T_7 (1% $CuSO_4$ + 1% $MnSO_4$)	0.65	2.13	4.59	30.33	52.33	102.63	16.17	28.48	50.48	32.81	35.33
T_8 (1% $CuSO_4$ + 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_9 (1% $ZnSO_4$ + 1% $MnSO_4$)	0.72	2.34	4.83	31.18	53.22	106.63	17.68	28.83	50.83	34.07	36.22
T_{10} (1% $ZnSO_4$ + 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_{11} (1% $MnSO_4$ + 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_{12} (1% $CuSO_4$ + 1% $ZnSO_4$ + 1% $MnSO_4$ + 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

REFERENCES

Farhan, H. N., S. A.Salim, A. A. M. Alalwany, B. H. Abdullah and H. M. Aobad, 2021.Effect of boron on the yield of wheat (*Triticum aestivum* L.) under center pivot sprinkler irrigation system in the West Desert of Iraq.

Ijaz, B., M. S. Shahid Nazeer, M. Nadeem, H. Anwar, M. Idrees, M. Nawaz and R. H. U. Khan, 2023. Effect of various foliar applied micronutrients (Zn + Fe + Cu + B) on growth and yield of wheat under Faisalabad condition. J. Glob. Innov. Agric. Sci. **11**(2): 184-189.

Javed, M. S. 2023. Impact of foliar application of boron on productivity of different varieties of *Triticum aestivum* (L.).Haya Saudi J. Life Sci. **8**(6): 84-88.

Jondhale, D. G., T. J. Bedse, M.R. Wahane and N.H. Khobragade, 2021. Influence of zinc nutrition on yield, yield attributing characters and economics of rice cultivation. J. Soils and Crops, **31**(1): 83-88.

Karad, V. S., P. V. Shende, A. P. Kesarkar, V. S. Madke and S. D. Tupkar, 2021. Influence of ferrous sulphate and zinc sulphate on morpho-physiological parameters and yield in chickpea. J. Soils and Crops, **32**(1):184-192.

Kaur, B., S. Singh, M. Devi, A. Kaur and N. Kaur, 2023.Effect of foliar application of boron and zinc on the growth and yield of cauliflower (*Brassica oleracea*). J. Soils and Crops, **33**(2):277-280.

Kesarkar, A., P. V. Shende, V. Karad, P. R. Manapure, R. D. Deotale and S. D. Tupkar, 2022. Effect of foliar application of iron and zinc on morpho- physiological parameters and yield in safflower (*Carthamust inctorius* L.). J. Soils and Crops, **32**(1):127-132.

Kurrey, Priyanka, ReshmaTahelyani, Gangaram Rana, G. L. Sharma and Ishwarram Banjara, 2022. Comparative effect of plant growth regulators with a zinc and boron on yield and yield attributes of mango fruits cv. Chhattisgarh nandiraj. J. Soils and Crops, **32**(2): 342-344.

Mane, S. S., K. T Jadhav and V. V Sonwane, 2021.Interactive effect of zinc and pigeopea cultivars on yield, nutrient uptake and quality of produce in inceptisol. J. Soils and Crops, **31**(2): 328-331.

Metwally, A. A. and Y.A.A. Hefny, 2018. Influence of some cropping systems and mineral nitrogen fertilizer levels on wheat productivity and its attributes under sandy soil condition. J. Soils and Crops, **28** (2):259-264.

Misu, U. M. 2021. Influence of Boron Application Methods on Morpho-physiological Attributes and Yield of Wheat (*Triticum aestivum* L.) Doctoral dissertation, Department of Agricultural Botany, Sher-E- Bangla Agriculture University, Dhaka, Bangladesh.

Panwar, Sunil, A.K. Dwivedi, Anshita Gupta and D.S. Dwivedi, 2019.Correlation coefficient of zinc fraction with various soil fertility parameters by long term application of inorganic fertilizers and farmyard manure in vertisol. J. Soils and Crops, **29**(1): 86- 91.

Pise, S. E., P. V. Shende, R. D. Deotale, Prema R. Manapure, Vandana S. Madke, D.A. Raut and A. Blessena, 2020. Response of zinc and iron on chemical, biochemical, yield contributing parametrs and yiled of lathyrus (*Lathyrus sativus* L.). J. Soils and Crops, **30**(1):165-171.

Purushottam, S. K. Gupta, B. K. Saren, B. Sodi and O.P. Rajwade, 2018. Growth and yield of chickpea (*Cicer arietinum* L.) as influenced by irrigation scheduling and zinc application. IJCS.**6**(1): 1130-1133.

Tahir,M., M.T . Naveed, A.A.Sheikh, and R. Maqbool, 2021. Growth, Yield and Quality Response of Three Wheat Varieties to Foliar Spray of Micro Nutrients. Biological Sciences - PJSIR, **64**(1):49-54.

Tiwari, T., U. S. Tiwari, S. Sharma, H. P. Pandey, R. Sachan, D. Kumar and K. K. Singh, 2023. Effect of biofortification with zinc and iron on growth parameters, yield attributes and yield of barley (*Hordeum vulgare* L.). Plant and Soil Sci. **35**(18): 1148-1157.

Yoshona, D. S., U.S. Mishra, S. B. Aher, 2018. Response of pour crops to sole and combine more of zinc application : a review. J. Soils and Crops, **28**(2): 249-258.

Zain, M., I. Khan, R. W. K. Qadri, U. Ashraf, S. Hussain, S. Minhas and M. Bashir, 2015. Foliar application of micronutrients enhances wheat growth, yield and related attributes. Plant Sci.**6**(7):86.

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