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# Effect of foliar application of micronutrient grade II on yield and micronutrient uptake of mustard (*Brassica juncea* L.) in vertisol

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**Abstract**
A field experiment was conducted during the *rabi* season of 2025-26 at the Research Farm, AICRP, Mustard, College of Agriculture, Nagpur, to assess the response of mustard (*Brassica juncea L.*) to foliar application of micronutrient Grade II with respect to nutrient uptake and yield under Vertisol conditions. The experiment comprised seven treatments, *viz*., absolute control ($T_1$) RDF + $ZnSO_4$ + $FeSO_4$ + borax @ 2 g $L^{-1}$ (farmers' practice) ($T_2$) RDF + two foliar sprays of micronutrient grade II @ 5 ml $L^{-1}$ ($T_3$) RDF + two foliar sprays @ 7.5 ml $L^{-1}$ ($T_4$) RDF + two foliar sprays @ 10 ml $L^{-1}$ ($T_5$) RDF + one foliar spray @ 12.5 ml $L^{-1}$ ($T_6$) and RDF + one foliar spray @ 15 ml $L^{-1}$ ($T_7$), arranged in a randomized block design with four replications. Treatments included the recommended fertilizer dose was 50:40:0 N:$P_2O_5$: $K_2O$ kg $ha^{-1}$. Micronutrient Grade II contained Fe 2.5%, Zn 3.0%, B 0.5%, Mn 1.0%, Cu 1.0% and Mo 0.1%. The two sprays of Grade II at 10 ml $L^{-1}$ with RDF ($T_5$) produced the highest seed yield (14.43 q $ha^{-1}$) and stover yield (40.39 q $ha^{-1}$). It also resulted in the highest Fe, Mn, Zn and Cu concentrations in seed and stover and maximum total uptake of Fe (5141.75 g $ha^{-1}$), Mn (2803.70 g $ha^{-1}$), Zn (1778.33 g $ha^{-1}$) and Cu (601.41 g $ha^{-1}$). Relative to the absolute control, total uptake increased by 25.9, 32.4, 32.8 and 26.8% for Fe, Mn, Zn and Cu, respectively. The findings indicate that, foliar application of Grade II, particularly two sprays at 10 ml $L^{-1}$, improved micronutrient accumulation and productivity of mustard under Vertisol conditions.

**Keywords:** *Brassica juncea*, foliar application, micronutrient uptake, iron, manganese, zinc, copper, Vertisol, yield

## Introduction
Indian mustard (*Brassica juncea* L.) is an important *rabi* oilseed crop and a major contributor to edible oil production in India. Sustained crop production under intensive cultivation depends not only on adequate macronutrient supply but also on maintaining an appropriate balance of micronutrients. Iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) participate in enzyme activity, photosynthesis, chlorophyll formation, redox reactions and other metabolic processes that influence plant growth and reproductive development. Deficiency of these elements can therefore restrict biomass production, nutrient accumulation and yield.
Vertisols occupy a large area of central India and are characterized by high clay content and substantial moisture-holding capacity. At the same time, relatively high soil reaction and carbonate-associated fixation can reduce the availability of several micronutrients. The experimental soil in the present study was slightly alkaline, with an initial pH of 7.48. Under such conditions, foliar nutrition provides a direct route for supplying nutrients to the crop during periods of high demand. The Grade II formulation evaluated in the experiment supplied Fe, Zn, B, Mn, Cu and Mo simultaneously. Previous studies have reported that, micronutrient management can improve nutrient accumulation and productivity of mustard. Bhadauria *et al.* (2012) [1] reported increased micronutrient uptake with micronutrient application, while Jat *et al.* (2013) [5] observed improved Fe and Zn uptake under combined application of FYM and mineral nutrients. Dhaliwal *et al.* (2021) further showed that, foliar application of Fe, Zn and N enhanced Fe and Zn uptake in Indian mustard. Sharma *et al.* (2023) [7].

also reported greater seed concentrations of Fe, Mn, Zn and Cu with foliar nano-nutrient application. Although individual micronutrient applications have been studied extensively, information on a combined Grade II foliar formulation under Vertisol conditions is comparatively limited. Therefore, the present investigation was undertaken to determine the response of mustard to different concentrations and spray frequencies of Grade II, with emphasis on seed and stover yield and the concentration and uptake of Fe, Mn, Zn and Cu.

## Materials and Methods

### Experimental site and design

The experiment was conducted during the *rabi* season of 2025-26 at the Research Farm, AICRP Mustard, College of Agriculture, Nagpur, Maharashtra. Mustard variety PDKV-Kartik was used. The experiment was laid out in a randomized block design with seven treatments and four replications. The crop was sown on 13 November 2025 at 45 cm × 10 cm spacing with a seed rate of 5 kg ha$^{-1}$. The gross plot size was 7.2 × 6.0 m$^2$ and the net plot size was 6.3 × 5.4 m$^2$.

### Treatments and foliar application

The recommended fertilizer dose was 50:40:0 N:$P_2O_5$: $K_2O$ kg ha$^{-1}$. Grade II contained Fe 2.5%, Zn 3.0%, B 0.5%, Mn 1.0%, Cu 1.0% and Mo 0.1%. One foliar spray was applied at 45 days after sowing (DAS), whereas two sprays were applied at 45 and 65 DAS. The treatment details are presented in table 1.

**Table 1:** Treatments details

| Treatments | Treatment details |
|---|---|
| $T_1$ | Absolute control |
| $T_2$ | RDF + $ZnSO_4$ + $FeSO_4$ + borax each @ 2 gm L$^{-1}$ (Farmers practice) |
| $T_3$ | RDF + Two foliar spray of micronutrient grade II @ 5 ml L$^{-1}$ |
| $T_4$ | RDF + Two foliar spray of micronutrient grade II @7.5 ml L$^{-1}$ |
| $T_5$ | RDF + Two foliar spray of micronutrient grade II @ 10 ml L$^{-1}$ |
| $T_6$ | RDF + One foliar spray of micronutrient grade II @ 12.5 ml L$^{-1}$ |
| $T_7$ | RDF + One foliar spray of micronutrient grade II @ 15 ml L$^{-1}$ |

Note: RDF- 50:40:0 NPK kg ha$^{-1}$

### Plant sampling and micronutrient analysis

Plant samples representing seed and stover were collected treatment-wise. Samples were washed with tap water followed by deionized water to remove adhering soil, oven-dried at 50-60°C, ground and stored in clean polyethylene pouches. A di-acid digest was prepared using nitric acid and perchloric acid in a 9:4 ratio. Concentrations of Fe, Mn, Zn and Cu were determined from the digest using an atomic absorption spectrophotometer following Isaac and Kerber (1971) [4]. Micronutrient uptake was calculated from the respective nutrient concentration and dry matter yield, and the total uptake was obtained by adding seed and stover uptake.

### Yield measurement and statistical analysis

Seed yield was determined after drying and weighing the harvested produce and expressed in q ha$^{-1}$. Stover yield was determined after drying the harvested stalks and converting plot yield to kg ha$^{-1}$ or q ha$^{-1}$. The experimental data were statistically analysed according to the procedures described by Gomez and Gomez (1984) [3]. Treatment means were compared using the critical difference at the 5% probability level.

## Results and Discussion

### Seed and stover yield

Foliar application of Grade II affected mustard productivity, with the response varying according to concentration and spray frequency. The data presented is table 2 indicated seed yield ranged from 11.25 to 14.43 q ha$^{-1}$, whereas stover yield ranged from 34.26 to 40.39 q ha$^{-1}$. Treatment $T_5$, consisting of RDF with two sprays of Grade II at 10 ml L$^{-1}$, produced the maximum seed yield (14.43 q ha$^{-1}$) and stover yield (40.39 q ha$^{-1}$). The absolute control ($T_1$) recorded the minimum seed yield (11.25 q ha$^{-1}$) and stover yield (34.26 q ha$^{-1}$). Thus, $T_5$ improved seed yield by 28.3% over the absolute control. The response suggests that supplying a balanced mixture of micronutrients through foliage at flowering and siliqua formation supported crop growth and reproductive development. The superior performance of $T_5$ is consistent with the nutrient-uptake response presented below. Laishram and jaswal. (2023) [6] obtained the highest mustard yield of 2867.83 kg ha$^{-1}$ with RDF + 1% urea foliar spray + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 45 DAS.

**Table 2:** Effect of foliar application of micronutrient grade II on seed and stover yield (q ha$^{-1}$) of mustard

| Treatments | Treatment details | seed yield | stover yield |
|---|---|---|---|
| $T_1$ | Absolute control | 11.25 | 34.26 |
| $T_2$ | RDF + $ZnSO_4$ + $FeSO_4$ + borax each @ 2 gm L$^{-1}$ (Farmers practice) | 13.25 | 39.39 |
| $T_3$ | RDF + Two foliar spray of micronutrient grade II @ 5 ml L$^{-1}$ | 13.75 | 37.10 |
| $T_4$ | RDF + Two foliar spray of micronutrient grade II @7.5 ml L$^{-1}$ | 14.07 | 39.93 |
| $T_5$ | RDF + Two foliar spray of micronutrient grade II @ 10 ml L$^{-1}$ | 14.43 | 40.39 |
| $T_6$ | RDF + One foliar spray of micronutrient grade II @ 12.5 ml L$^{-1}$ | 14.26 | 38.50 |
| $T_7$ | RDF + One foliar spray of micronutrient grade II @ 15 ml L$^{-1}$ | 13.72 | 38.42 |
| | SE (m)± | 0.18 | 0.45 |
| | CD at 5% | 0.54 | 1.36 |

### Iron concentration and uptake

The result presented in table 3 show that, seed Fe concentration varied from 87.88 to 92.98 mg kg$^{-1}$ and stover Fe concentration from 90.38 to 94.10 mg kg$^{-1}$. The maximum concentration in both seed and stover was recorded with $T_5$. Seed and stover Fe uptake under $T_5$ were 1340.68 and 3801.06 g ha$^{-1}$, respectively, giving a total uptake of 5141.75 g ha$^{-1}$. In comparison, $T_1$ recorded 4083.53 g ha$^{-1}$ total Fe uptake. The 25.9% increase over the control indicates that improved Fe concentration was accompanied by greater crop biomass and hence greater nutrient removal. Dhaliwal *et al.* (2021) similarly reported enhanced Fe uptake in Indian mustard by foliar application of Fe and Zn with nitrogen. Zn and Fe uptake in grain of 54.7% and 34.3%, respectively, while their uptake in stover increased by 110.5% and 46.1%. Jat *et al.* (2013) [5] also reported that, the highest Fe uptake in stover (868.5 g ha$^{-1}$) under 10 t FYM + 40 kg S + 25 kg $ZnSO_4$ + 50 kg $FeSO_4$ ha$^{-1}$

**Table 3:** Effect of foliar application of micronutrient grade II on content (mg $kg^{-1}$), uptake (g $ha^{-1}$) and total uptake (g $ha^{-1}$) of Fe by mustard

| Treatments | | Fe content (mg $kg^{-1}$) | | Fe uptake (g $ha^{-1}$) | | Total Fe uptake (g $ha^{-1}$) |
|---|---|---|---|---|---|---|
| | | Seed | Stover | Seed | Stover | |
| $T_1$ | Absolute control | 87.88 | 90.38 | 988.23 | 3095.30 | 4083.53 |
| $T_2$ | RDF+ $ZnSO_4$ +$FeSO_4$ + borax @ 2 g $L^{-1}$ (Farmers practice) | 90.93 | 93.05 | 1204.37 | 3664.75 | 4869.12 |
| $T_3$ | RDF + Two foliar spray of micronutrient grade II @ 5 ml $L^{-1}$ | 91.08 | 92.88 | 1251.78 | 3443.84 | 4696.99 |
| $T_4$ | RDF + Two foliar spray of micronutrient grade II @ 7.5 ml $L^{-1}$ | 91.70 | 93.08 | 1289.76 | 3715.81 | 5005.57 |
| $T_5$ | RDF + Two foliar spray of micronutrient grade II @ 10 ml $L^{-1}$ | 92.98 | 94.10 | 1340.68 | 3801.06 | 5141.75 |
| $T_6$ | RDF + One foliar spray of micronutrient grade II @ 12.5 ml $L^{-1}$ | 92.93 | 92.80 | 1324.66 | 3571.94 | 4896.60 |
| $T_7$ | RDF + One foliar spray of micronutrient grade II @ 15 ml $L^{-1}$ | 91.35 | 92.75 | 1253.25 | 3562.12 | 4816.36 |
| | SE (m) ± | 0.56 | 0.19 | 18.99 | 47.59 | 56.20 |
| | CD at 5% | 1.69 | 0.57 | 56.94 | 142.68 | 168.49 |

## Manganese concentration and uptake

As presented in table 4 manganese concentration in seed ranged from 53.88 to 56.75 mg $kg^{-1}$, while stover concentration ranged from 44.13 to 49.15 mg $kg^{-1}$. $T_5$ recorded the highest Mn concentration in both plant components. Seed Mn uptake reached 818.35 g $ha^{-1}$ and stover uptake 1985.35 g $ha^{-1}$ under $T_5$, resulting in the maximum total uptake of 2803.70 g $ha^{-1}$. The absolute control recorded 2117.11 g $ha^{-1}$, giving a 32.4% increase under $T_5$. The greater Mn uptake appears to reflect the combined effect of improved Mn concentration and higher seed and stover production. These results support earlier observations that micronutrient supplementation can increase nutrient accumulation in mustard. Sharma *et al.* (2023) [7] reported the highest seed concentrations of Fe (124.12 mg $kg^{-1}$), Mn (91.96 mg $kg^{-1}$), Zn (59.22 mg $kg^{-1}$) and Cu (12.86 mg $kg^{-1}$) under 100% NPK + Zn with two foliar sprays of nano-N and nano-Zn at 30 and 45 DAS.

**Table 4:** Effect of foliar application of micronutrient grade II on content (mg $kg^{-1}$), uptake (g $ha^{-1}$) and total uptake (g $ha^{-1}$) of micronutrient Mn by mustard

| Treatments | | Mn content (mg $kg^{-1}$) | | Mn uptake (g $ha^{-1}$) | | Total Mn uptake (g $ha^{-1}$) |
|---|---|---|---|---|---|---|
| | | Seed | Stover | Seed | Stover | |
| $T_1$ | Absolute control | 53.88 | 44.13 | 605.83 | 1511.27 | 2117.11 |
| $T_2$ | RDF+ $ZnSO_4$ +$FeSO_4$ + borax @ 2 g $L^{-1}$ (Farmers practice) | 56.25 | 47.93 | 744.86 | 1887.54 | 2632.40 |
| $T_3$ | RDF + Two foliar spray of micronutrient grade II @ 5 ml $L^{-1}$ | 55.25 | 47.98 | 759.33 | 1779.63 | 2538.96 |
| $T_4$ | RDF + Two foliar spray of micronutrient grade II @ 7.5 ml $L^{-1}$ | 56.28 | 47.95 | 791.54 | 1914.31 | 2705.85 |
| $T_5$ | RDF + Two foliar spray of micronutrient grade II @ 10 ml $L^{-1}$ | 56.75 | 49.15 | 818.35 | 1985.35 | 2803.70 |
| $T_6$ | RDF + One foliar spray of micronutrient grade II @ 12.5 ml $L^{1}$ | 55.63 | 48.10 | 792.95 | 1851.38 | 2644.33 |
| $T_7$ | RDF + One foliar spray of micronutrient grade II @ 15 ml $L^{-1}$ | 56.20 | 47.90 | 770.58 | 1840.14 | 2610.72 |
| | SE (m) ± | 0.24 | 0.12 | 9.75 | 22.42 | 27.40 |
| | CD at 5% | 0.72 | 0.36 | 29.23 | 67.22 | 82.16 |

## Zinc concentration and uptake

The data presented in table 5 indicate that, Seed Zn concentration increased from 44.13 mg $kg^{-1}$ in $T_1$ to 47.15 mg $kg^{-1}$ in $T_5$, while stover Zn increased from 24.62 to 27.19 mg $kg^{-1}$. The corresponding Zn uptake under $T_5$ was 679.99 g $ha^{-1}$ in seed and 1098.34 g $ha^{-1}$ in stover. Consequently, total Zn uptake reached 1778.33 g $ha^{-1}$ compared with 1339.50 g $ha^{-1}$ under the absolute control, representing a 32.8% increase. The higher Zn removal under $T_5$ can be related to improved Zn concentration together with increased seed and stover production. Dhaliwal *et al.* (2021) reported that, foliar 0.5% $FeSO_4$ +0.5% $ZnSO_4$ + 1% urea at 45 and 60 DAS increased Zn uptake in seed and stover by 54.7 and 102.6%, respectively, over the control.

**Table 5:** Effect of foliar application of micronutrient grade II on content (mg $kg^{-1}$), uptake (g $ha^{-1}$) and total uptake (g $ha^{-1}$) of micronutrient Zn by mustard

| Treatments | | Zn content (mg $kg^{-1}$) | | Zn uptake (g $ha^{-1}$) | | Total Zn uptake (g $ha^{-1}$) |
|---|---|---|---|---|---|---|
| | | Seed | Stover | Seed | stover | |
| $T_1$ | Absolute control | 44.13 | 24.62 | 496.17 | 843.32 | 1339.50 |
| $T_2$ | RDF+ $ZnSO_4$ +$FeSO_4$ + borax @ 2 g $L^{-1}$ (Farmers practice) | 46.25 | 26.75 | 612.56 | 1053.44 | 1666.00 |
| $T_3$ | RDF + Two foliar spray of micronutrient grade II @ 5 ml $L^{-1}$ | 46.30 | 26.68 | 636.43 | 989.69 | 1626.12 |
| $T_4$ | RDF + Two foliar spray of micronutrient grade II @ 7.5 ml $L^{-1}$ | 46.80 | 27.15 | 658.24 | 1083.87 | 1742.11 |
| $T_5$ | RDF + Two foliar spray of micronutrient grade II @ 10 ml $L^{-1}$ | 47.15 | 27.19 | 679.99 | 1098.34 | 1778.33 |
| $T_6$ | RDF + One foliar spray of micronutrient grade II @ 12.5 ml $L^{-1}$ | 45.88 | 26.80 | 653.97 | 1031.38 | 1685.34 |
| $T_7$ | RDF + One foliar spray of micronutrient grade II @ 15 ml $L^{-1}$ | 46.55 | 26.73 | 638.43 | 1026.81 | 1665.24 |
| | SE (m)± | 0.21 | 0.05 | 9.53 | 12.13 | 18.58 |
| | CD at 5% | 0.62 | 0.15 | 28.58 | 36.38 | 55.70 |

**Copper concentration and uptake**

The data presented in table 6 show that, copper concentration in seed ranged from 12.65 to 13.68 mg $kg^{-1}$ and in stover from 9.70 to 10.01 mg $kg^{-1}$. $T_5$ produced the highest concentration in both components. Seed Cu uptake under $T_5$ was 197.23 g $ha^{-1}$ and stover uptake was 404.18 g $ha^{-1}$, resulting in a total Cu uptake of 601.41 g $ha^{-1}$. The corresponding value under $T_1$ was 474.28 g $ha^{-1}$, representing a 26.8% increase with $T_5$. The increase in total Cu uptake was associated with higher Cu concentration and greater crop yield. Bhadauria *et al.* (2012) [1] also reported enhanced micronutrient uptake in mustard following micronutrient application.

**Table 6:** Effect of foliar application of micronutrient grade II on content (mg kg-1), uptake (g ha-1) and total uptake (g ha-1) of micronutrient Cu by mustard

| Treatments | | Cu content (mg $kg^{-1}$) | | Cu uptake (g $ha^{-1}$) | | Total Cu uptake (g $ha^{-1}$) |
|---|---|---|---|---|---|---|
| | | Seed | Stover | Seed | Stover | |
| $T_1$ | Absolute control | 12.65 | 9.70 | 142.23 | 332.05 | 474.28 |
| $T_2$ | RDF+ $ZnSO_4$ +$FeSO_4$ + borax @ 2 g $L^{-1}$ (Farmers practice) | 13.55 | 9.77 | 179.35 | 384.69 | 564.05 |
| $T_3$ | RDF + Two foliar spray of micronutrient grade II @ 5 ml $L^{-1}$ | 13.08 | 9.75 | 179.82 | 361.65 | 541.50 |
| $T_4$ | RDF + Two foliar spray of micronutrient grade II @ 7.5 ml $L^{-1}$ | 12.88 | 9.81 | 181.07 | 391.44 | 572.51 |
| $T_5$ | RDF + Two foliar spray of micronutrient grade II @ 10 ml $L^{-1}$ | 13.68 | 10.01 | 197.23 | 404.18 | 601.41 |
| $T_6$ | RDF + One foliar spray of micronutrient grade II @ 12.5 ml $L^{-1}$ | 13.03 | 9.73 | 185.68 | 374.62 | 560.30 |
| $T_7$ | RDF + One foliar spray of micronutrient grade II @ 15 ml $L^{-1}$ | 13.13 | 9.72 | 180.06 | 373.41 | 553.47 |
| | SE (m)± | 0.19 | 0.04 | 3.29 | 5.50 | 6.67 |
| | CD at 5% | 0.56 | 0.12 | 9.87 | 16.49 | 20.01 |

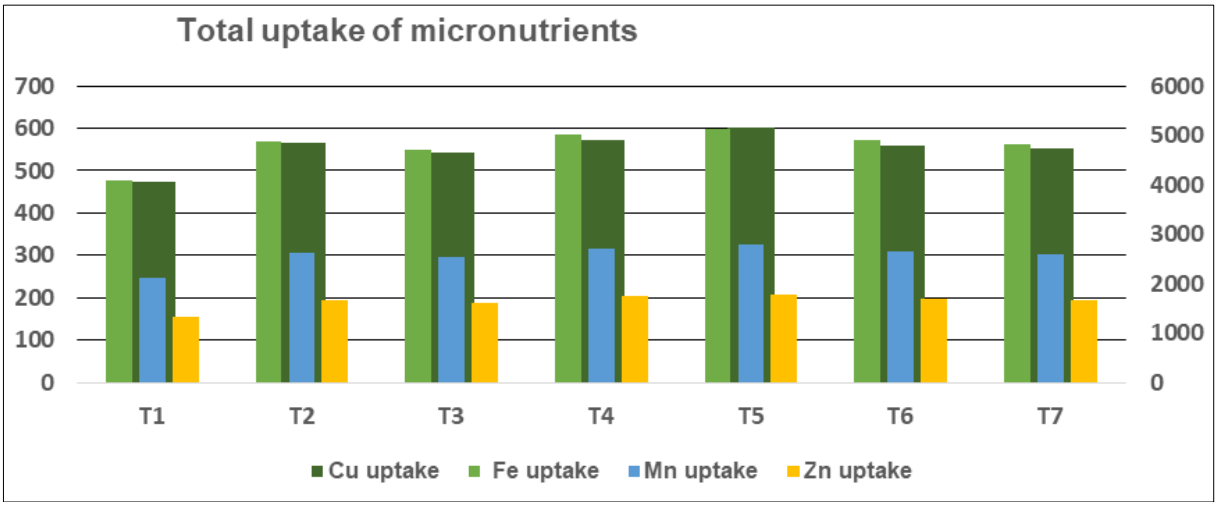


**Fig 1**: Effect of foliar application of micronutrient grade II on total uptake of Fe, Mn, Zn, Cu

## Conclusion

Foliar application of micronutrient Grade II improved mustard yield and micronutrient accumulation under the experimental conditions. Among the treatments, RDF (50:40:0 NPK) + two foliar sprays of Grade II at 10 ml $L^{-1}$ ($T_5$) recorded the highest seed yield (14.43 q $ha^{-1}$), stover yield (40.39 q $ha^{-1}$) and maximum total uptake of Fe (5141.75 g $ha^{-1}$), Mn (2803.70 g $ha^{-1}$), Zn (1778.33 g $ha^{-1}$) and Cu (601.41 g $ha^{-1}$). The results indicated that appropriately timed foliar application of micronutrients improved micronutrient acquisition and productivity of mustard.

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