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# Effect of Chelated Zink, Iron and Boron on Growth and Yield of Chickpea (*Cicer arietinum* L.)

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**Abstract**

The present investigation entitled "**Effect of Chelated Zink, Iron and Boron on Growth and Yield of Chickpea (*Cicer arietinum*)**" was carried out Agronomy Research Farm, Department of Agronomy, Faculty of Agriculture, Bhagwant University, Ajmer, during rabi season, 2021-22 and 2022-23. The topography of the experimental field was uniform levelled and uniform in depth up to 60 cm. The type of soil is black soil developed from Volcanic rocks and lava- flow. the soil comes under the vertisole order. The soil of the experimental field was slightly saline in nature, pH was 7.01 and 6.67, moderately alkyl in EC 0.484 and 0.433 ($dSm^{-1}$) and low organic carbon 0.30 and 0.31 (%) as well as the initial soil fertility of the experimental field was low in available nitrogen 210.2 and 208.1 kg $ha^{-1}$, Low in available phosphorus 20.5 and 19 kg $ha^{-1}$ and low in available potassium 142.2 and 139 kg $ha^{-1}$.

Among the different nutrient management treatments application of GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 exhibited significantly higher Number of branches (22.26 and 22.81), spared $plant^{-1}$ (45.98 cm) and 50 % Flowering (57.80 and 58.85 days) at harvest as compared to rest of nutrient management treatments during rabi 2021-2022. The chickpea crop fertilized with GRDF + soil application of multi micronutrient Grade-II @ 10 kg $ha^{-1}$ produced significantly higher grain yield (28.48 q $ha^{-1}$), straw yield (31.68 q $ha^{-1}$), biological (60.05 q $ha^{-1}$) and harvest index (47.33%) as compared to other nutrient management treatments under study. While significantly minimum days for flower initiation (48.00 days), days to 50% flowering (54.68 days) and early maturity (101.00 days) were observed when chickpea crop was not fertilized with any nutrient.

**INTRODUCTION-**

Chickpea (*Cicer Arietinum* L.) is an annual legume crop of the family Fabaceae and subfamily Faboideae. Chickpea (*Cicer arietinum* L.) is a winter season legume crop cultivated in several countries worldwide as a food source. Seed is the main edible part of the plant and value in terms of higher protein content, carbohydrates, and minerals, especially for the vegetarian population and the plant has the nitrogen-fixing ability and alternative crop for crop diversification.

There are two types of chickpeas recognized, the white-seeded "Kabuli" and the brown-seeded "Desi" (Knights and Hobson, 2016). Kabuli chickpea is relatively bigger, having a thinner seed coat while the Desi type seeds are relatively smaller in size having a thicker seed coat. The Desi type chickpea contributes around 80% and the Kabuli type around 20% of the total production of chickpea.

There has been an impressive growth in chickpea area, production, and productivity in India during the past decade. It is interesting to note that the growth rate of chickpea production was 5.89 % during the last decade which is much higher than other crops.

Iron plays an essential role in the metabolism of chlorophyll, respiratory mechanism, and a component of several electron carriers. In neutral or alkaline soil iron is the insoluble form (Verma, 2010) Iron deficiency occurs in a variety of soil, affected soil usually has pH > 6. Iron deficiency is a potential problem in most calcareous soil (Chen and Bark, 1982). Zinc plays a key role in plants with enzymes and proteins involved in carbohydrate

metabolism, protein synthesis, gene expression, auxin (growth regulator) metabolism, pollen formation, maintenance of biological membranes, protection against photo-oxidative damage and heat stress, and resistance to infection by certain pathogens (Alloway, 2008). The critical Zn concentrations in soils vary from 0.48 mg kg–1 to 2.5 mg kg–1 depending on soil type (Ahlawat *et al.*, 2007).

Zinc solubility decrease with an increase in pH, reduction in solution $Zn^{2+}$ typically has been observed for every unit pH increase between 5 and 7. (Havlin *et al.*, 1999).

Boron regulates the transport of sugars through membranes, cell division, cell development, and auxin metabolism. Without adequate levels of boron, plants may continue to grow and add new leaves but fail to produce fruits or seeds. The application of B is important when the concentration of B in the soil is less than 0.3 mg kg–1 (Ahlawat *et al.*, 2007). A continuous supply of boron is important for adequate plant growth and optimum yields. Boron (B) is one of the most common deficiencies in the soils of India. Its deficiency is found in nearly 30% of the soils of the country, which are highly calcareous, leached, or sandy (Sakal *et al.*, 1998). Boron is a trace element that can be applied in the soil as well as foliar. B applied as boric acid increased the plant height, relative growth rate, net assimilation rate, and leaf area index. Boron (B) may cause yield losses of up to 100% (Ahlawat *et al.*, 2007).

## MATERIALS AND METHODS

The experiment was lied in Experimental field of Bhagwant University, Ajmer, Rajasthan. during *rabi* season 2021-22 and 2022-23 and Climatic condition during experiment was cold in November with minimum average temperature was (4.9 $^0$C) and highest Temperature recorded in March with average of (39.0 $^0$C).

The experiment was laid out in randomized block design with three replications. Eight treatment combinations were formed considering eight micronutrients treatment through different sources.

The topography of the experimental field was uniform levelled and uniform in depth up to 60 cm. The type of soil is black soil developed from Volcanic rocks and lava- flow. the soil comes under the vertisole order. The soil of the experimental field was slightly saline in nature, pH was 6.67 moderately alkyl in EC 0.484 and 0.433 (dSm$^{-1}$) and low organic carbon 0.30 and 0.31 (%). The experiment was laid out in randomized block design with three replications. Eight treatment combinations were formed considering eight micronutrients treatment through different sources.

Plant spread shows the vigor of the plant. The greatest horizontal area filled by the plant between the tips of two extreme leaves on either side of the plant was measured on five observation-tagged plants at 30, 60, 90, and the time of harvest. Five observation plants were averaged to get the mean plant spread. After harvest, all of the pods from the five sampled plants were counted separately, and the average number of pods per plant-1 was carefully calculated. The total grains obtained from every observation plant were weighed separately on analytical weighing balance and mean value was calculated for obtaining weight of grains plant$^{-1}$. After removing the grain from pods, the stalks along with empty pods were dried in the sun. Upon drying, the weight of the bundle of stalk plot$^{-1}$ was recorded. The weight plot$^{-1}$ was transferred into hectare basis by utilizing hectare factor.

Available zinc, copper, iron and magnesium were extracted by using Atomic Absorption Spectrophotometer as explained by Lindsay and Norvell (1978). The concentration of zinc, copper, iron and manganese in the extract was estimated using Atomic Absorption Spectrophotometer (AAS, Shimadzu model), expressed as ppm soil and interpreted as deficient and sufficient using critical values.

The net monetary returns (₹ ha$^{-1}$) for each treatment was worked out by deducting the cost of cultivation of each treatment from gross monetary returns of respective treatments.

Net monetary returns (₹ ha$^{-1}$) = Gross monetary returns (₹ ha$^{-1}$) - Cost of cultivation (₹ ha$^{-1}$)

## RESULT AND DISCUSSION

### Number of branches

Data regarding number of branches plant-1 of chickpea as influenced by different treatments during rabi season, 2021-22 and 2022-23 are presented in table 9 and graphically depicted in fig. 4. The mean number of branches plant-1 were 3.02-3.53, 13.09-13.84, 17.54-18.95, and 22.26-22.81 at 30, 60, 90, DAS and at harvest during both the years, respectively. The data in respect number of branches plant-1 in chickpea were influenced significantly due to different nutrient management treatments at all growth stages.

The application of GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha- 1 to chickpea produced significantly higher number branches plant-1 at all growth stages but it was at par with GRDF + multi-micronutrient Grade-II 0.5 % (foliar spray) at 30 and 90 DAS. While, GRDF + chelated Fe EDTA 0.2 % (foliar spray) was at par at 30 DAS only. No application of fertilizer to chickpea produced significantly minimum number of branches at all

growth stages during the experimentation. The chickpea crop experienced luxurious availability of macro as well as micro nutrients with GRDF + soil application of multi- micronutrient Grade-II @ 10 kg ha-1 as iron is essential for chlorophyll metabolism while zinc offered its role in carbohydrate and protein synthesis and also boron is essential for transport of photosynthates and cell development. Copper and manganese are essential for energy transfer and photosynthesis. Copper increases nodulation and nitrogen fixation while manganese is vital for protoplast metabolism which was reflected in luxurious growth habit of chickpea

**Table 1. Number of branches plant-1 of chickpea as influenced by different treatments.**

| Treatment | Number of branches | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | 60 DAS | | 90 DAS | | At Harvest | |
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 |
| T1 : Control | 1.46 | 1.54 | 2.40 | 2.51 | 6.46 | 6.69 | 8.89 | 9.21 |
| T2 : RDF (25:50:30 N :$P_2O_5$ :$K_2O$ kg $ha^{-1}$) | 2.06 | 2.22 | 6.63 | 6.68 | 9.39 | 10.21 | 12.66 | 13.21 |
| T3 : GRDF (25:50:30 N :$P_2O_5$ :$K_2O$ kg $ha^{-1}$ + FYM 5 $tha^{-1}$) | 2.18 | 2.45 | 9.0 | 9.47 | 12.83 | 13.54 | 16.19 | 16.87 |
| T4 : GRDF + Chelated Fe EDTA 0.2 % (foliar spray) | 2.70 | 2.94 | 11.16 | 11.84 | 15.71 | 16.59 | 19.30 | 19.85 |
| T5 : GRDF + Chelated Zn EDTA 0.2 % (foliar spray) | 2.5 | 2.61 | 10.2 | 10.68 | 15.00 | 15.84 | 17.61 | 18.25 |
| T6 : GRDF + Boric acid 0.1 % (foliar spray) | 2.28 | 2.52 | 10.13 | 10.98 | 13.86 | 14.26 | 17.19 | 17.92 |
| GRDF + Multi micronutrient Grade-II 0.5 % (foliar spray) | 2.95 | 3.12 | 11.79 | 12.21 | 17.48 | 18.24 | 20.12 | 20.85 |
| GRDF + Multi micronutrient Grade-II @ 10 kg $ha^{-1}$ (soil application) | 3.02 | 3.53 | 13.09 | 13.84 | 17.54 | 18.95 | 22.26 | 22.81 |
| S. Em ± | 0.04 | 0.6 | 0.14 | 0.16 | 0.22 | 0.25 | 0.39 | 0.42 |
| C.D. at 5 % | 0.14 | 0.19 | 0.43 | 0.47 | 0.68 | 0.71 | 1.21 | 1.31 |

**Spread $plant^{-1}$**

The plant spread is the function of healthy crop growth. Chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 exerted maximum plant spread due benefit of required availability of macro and micro nutrients. Iron, zinc and boron were essential part of chlorophyll synthesis, carbohydrate synthesis and also cell division and cell development. Copper and manganese are essential for energy transfer and photosynthesis. Copper increases nodulation and nitrogen fixation while manganese is vital for protoplast metabolism. The results are in close association with Balachandar *et al.* (2003) and Abraham and Abraham (2011).

**Days to 50 % flowering**

Data regarding days to 50 % flowering of chickpea as influenced by different treatments during rabi season, 2021-22 and 2022-23 are presented in table 12. The mean days to 50 % flowering of chickpea were 57.80 and 58.85 days during both the years of investigation. The data in respect of days to 50 % flowering in chickpea were influenced significantly due to different nutrient management treatments.

The chickpea with no fertilizer required significantly minimum number of days (54.68 and 55.13 days) for 50 % flowering. Significantly maximum number of days (57.80 and 58.85 days) required for chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1. The chickpea with no fertilizers faced macro and micro nutrient stress and which was reflected in early 50 % flowering.

**Table 2. Spread plant-1 of chickpea as influenced by different treatments.**

| Treatment | Plant spread (cm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | 60 DAS | | 90 DAS | | At Harvest | |
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 |
| $T_1$ : Control | 8.93 | 9.12 | 14.35 | 14.46 | 22.16 | 22.54 | 25.02 | 25.32 |
| $T_2$ : RDF (25:50:30 N :$P_2O_5$ :$K_2O$ kg $ha^{-1}$) | 13.06 | 13.45 | 26.62 | 27.12 | 35.06 | 35.65 | 37.87 | 38.12 |
| $T_3$ : GRDF (25:50:30 N :$P_2O_5$ :$K_2O$ kg $ha^{-1}$ + FYM 5 $tha^{-1}$) | 13.18 | 13.82 | 32.49 | 33.51 | 37.15 | 37.84 | 39.34 | 40.28 |
| $T_4$ : GRDF + Chelated Fe EDTA 0.2 % (foliar spray) | 17.10 | 17.54 | 37.79 | 38.54 | 42.09 | 42.57 | 43.61 | 44.65 |
| $T_5$ : GRDF + Chelated Zn EDTA 0.2 % (foliar spray) | 16.40 | 16.83 | 36.39 | 37.34 | 39.50. | 39.89 | 41.46 | 42.58 |
| $T_6$ : GRDF + Boric acid 0.1 % (foliar spray) | 14.18 | 14.74 | 36.19 | 37.10 | 38.49 | 39.21 | 40.82 | 41.35 |
| $T_7$ : GRDF + Multi micronutrient Grade-II 0.5 % (foliar spray) | 17.23 | 17.46 | 39.71 | 40.46 | 43.30 | 44.51 | 44.95 | 45.89 |
| $T_8$ : GRDF + Multi micronutrient Grade-II @ 10 kg $ha^{-1}$(soil application) | 17.95 | 18.24 | 41.73 | 42.15 | 45.32 | 46.35 | 45.98 | 47.52 |
| S. Em ± | 0.21 | 0.22 | 0.83 | 1.24 | 0.66 | 0.74 | 0.89 | 1.12 |
| C.D. at 5 % | 0.66 | 0.64 | 2.52 | 3.51 | 2.03 | 2.14 | 2.72 | 3.34 |

**Table 3. Days to flower initiation, 50 % flowering and physiological maturity of chickpea as influenced by different treatments.**

| Treatment | Days to 50 % flowering | |
|---|---|---|
| | 2021 | 2022 |
| T1: Control | 54.68 | 55.13 |
| T2: RDF (25:50:30 N :$P_2O_5$ :$K_2O$ kg $ha^{-1}$) | 55.00 | 55.54 |
| T3: GRDF (25:50:30 N :$P_2O_5$ :$K_2O$ kg $ha^{-1}$ + FYM 5 t $ha^{-1}$) | 55.38 | 56.28 |
| T4: GRDF + Chelated Fe EDTA 0.2 % (foliar spray) | 56.67 | 57.26 |
| T5: GRDF + Chelated Zn EDTA 0.2 % (foliar spray) | 56.67 | 57.45 |
| T6: GRDF + Boric acid 0.1 % (foliar spray) | 56.36 | 57.11 |
| T7: GRDF + Multi micronutrient Grade-II 0.5 % (foliar spray) | 57.33 | 58.26 |
| T8: GRDF + Multi micronutrient Grade-II @10 kg $ha^{-1}$ (soil application) | 57.80 | 58.85 |
| S. Em ± | 1.10 | 1.23 |
| C.D. at 5 % | 3.15 | 3.61 |

**Number of pods plant$^{-1}$**

Data regarding number of pods plant$^{-1}$ of chickpea as influenced by different treatments during *rabi* season, 2021-22 and 2022-23 are presented in table 13 and graphically depicted in fig. 8. The data in respect number of pods plant$^{-1}$ in chickpea were influenced significantly due to different nutrient management treatments.

The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 produced significantly highest number of pods plant$^{-1}$ (41.92 and 44.23) as compared to rest of the nutrient management treatments during both the years, respectively. No application of fertilizer to chickpea produced significantly minimum number of pods plant$^{-1}$ during the experimentation.

The yield attributes are the symbol of healthy plant growth. The precise application of nutrients to chickpea in treatment GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 offered easy availability for the absorption of macro and essential micro nutrients. The efficient utilization of iron helped for chlorophyll metabolism, respiratory mechanism, which favoured more photosynthesis. Zinc also involved in carbohydrate and protein synthesis and also protein formation. Boron regulated transport of photosynthates from source to sink. Copper and manganese are essential for energy transfer and photosynthesis. Copper increases nodulation and nitrogen fixation while manganese was essential for protoplast metabolism. This was reflected in production of higher number of pods plant -1 of chickpea.

The results are in close association with Valenciano *et al.* (2010), Gupta and Sahu (2012) and Balai *et al.* (2017).

**Grain yield**

Data regarding grain yield of chickpea as influenced by different treatments during rabi season, 2021-22 and 2022-23 are presented in table 14 and graphically depicted in fig. 9. The data in respect grain yield of chickpea were influenced significantly due to different nutrient management treatments.

The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade- II @ 10 kg ha-1 recorded significantly maximum grain yield (28.48 and 29.84 q ha-1) as compared to rest of the nutrient management treatments during both the years, respectively. No application of fertilizer to chickpea produced significantly minimum grain yield.

The grain yield of chickpea is function luxurious growth, dry matter accumulation, yield attributes and physiological characters. The nutrient management to chickpea in terms of GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 exhibited healthy crop growth, the sufficient availability of macro as well as micro nutrients and its efficient utilization by chickpea crop reflected in higher magnitude of growth and yield attributes as chlorophyll metabolism and more photosynthesis is facilitated due to iron. Carbohydrate and protein synthesis is a function of zinc. while boron regulated transport of sugar and cell division and cell development. Copper and manganese are essential for energy transfer and photosynthesis. Copper is helpful to increase nodulation and nitrogen fixation, while manganese is vital for protoplast metabolism. Thus there was cumulative effect in the production of higher grain yield of chickpea than other nutrient management treatments. The chickpea crop fertilized with GRDF + soil application of multi- micronutrient Grade-I @ 10 kg $ha^{-1}$ recorded 55.49 and 56.84 % more grain yield as compared to recommended dose of fertilizer.

The results are in close association with Patel and Singh (2010), Valenciano *et al.* (2010) and Gupta and Sahu (2012).

**Straw yield**

Data regarding straw yield of chickpea as influenced by different treatments during *rabi* season, 2021-2022 and 2022-23 are presented in table 14 and graphically depicted in fig. 9. The data in respect straw yield of chickpea were influenced significantly due to different nutrient management treatments.

The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade- II @ 10 kg ha-1 recorded significantly maximum straw yield (49.80 and 50.14 q $ha^{-1}$) as compared to rest of the nutrient management treatments during both the years, respectively. No application of fertilizer to chickpea produced significantly minimum straw yield.

The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade- II @ 10 kg ha-1 achieved luxurious crop growth due to efficient utilization of essential macro and micro nutrients which was reflected in production of higher straw yield.

The results are in close association with Patel and Singh (2010) and Gupta and Sahu (2012) and Elayaraja (2014)

**Harvest index**

Data regarding harvest index of chickpea as influenced by different treatments during rabi season, 2021-2022 and 2022-23are presented in table 14. The data in respect of harvest index of chickpea were influenced significantly due to different nutrient management treatments.

The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade- II @ 10 kg ha-1 noticed significantly higher value of harvest index (47.33 and 47.82 %) and this treatment was at par with GRDF + Cheated Fe EDTA 0.2 % (foliar spray), GRDF + Cheated Zn EDTA 0.2 % (foliar spray), GRDF + Boric acid 0.1 % (foliar spray) and GRDF + multi-micronutrient Grade-II 0.5 % (foliar spray). No application of fertilizer to chickpea recorded significantly minimum harvest index during both the years, respectively.

The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade- II @ 10 kg ha-1 showed its efficiency in chlorophyll metabolism, more accumulation of photosynthates and its transport form source to sink due to better availability of macro as well as micro nutrients. This was reflected in more grain yield of chickpea and achieved higher harvest index.

The results are in close association with Valenciano *et al.* (2010).

**Table 4. Yield and harvest index of chickpea as influenced by different treatment**

| Treatment | Yield (q ha$^{-1}$) | | | | | | Harvest index (%) | |
|---|---|---|---|---|---|---|---|---|
| | Grain | | Straw | | Biologicalyield | | | |
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 |
| T1: Control | 12.68 | 12.71 | 20.11 | 20.25 | 32.06 | 32.24 | 38.66 | 39.21 |
| T2: RDF (25:50:30 N :$P_2O_5$ :$K_2O$ Kg ha$^{-1}$) | 18.31 | 18.37 | 26.68 | 27.11 | 44.94 | 45.21 | 40.50 | 41.21 |
| T3: GRDF (25:50:30 N :$P_2O_5$ :$K_2O$ kg ha$^{-1}$ + FYM 5 t ha$^{-1}$) | 21.93 | 22.10 | 37.68 | 39.41 | 49.57 | 50.35 | 44.25 | 45.28 |
| T4: GRDF + Chelated Fe EDTA 0.2 %(foliar spray) | 24.85 | 25.10 | 42.18 | 43.51 | 52.99 | 53.65 | 46.89 | 47.75 |
| T5: GRDF + Chelated Zn EDTA 0.2 %(foliar spray) | 24.67 | 24.87 | 43.30 | 44.81 | 52.79 | 53.61 | 46.64 | 47.27 |
| T6: GRDF + Boric acid 0.1% (foliar spray) | 24.12 | 24.45 | 42.70 | 43.27 | 51.81 | 52.71 | 46.51 | 46.94 |
| T7: GRDF + Multi micronutrient Grade-II 0.5 % (foliar spray) | 25.46 | 26.23 | 44.55 | 46.21 | 54.12 | 55.76 | 47.12 | 47.21 |
| T8: GRDF + Multi micronutrient Grade II @ 10 kg ha$^{-1}$ (soil application) | 28.48 | 29.84 | 49.80 | 50.14 | 60.05 | 61.21 | 47.33 | 47.82 |
| S. Em ± | 0.48 | 0.51 | 0.55 | 0.67 | 0.79 | 0.91 | 1.05 | 1.24 |
| C.D. at 5 % | 1.46 | 1.52 | 1.67 | 1.82 | 2.39 | 2.75 | 3.20 | 3.67 |

**Iron content in grain and straw**

Data regarding iron content in grain and straw of chickpea as influenced by different treatments during rabi season, 2021-2022 and 2022-23 are presented in table 18 and graphically depicted in fig. 15. The data in respect iron content in grain and straw of chickpea were influenced significantly due to different nutrient management treatments.

The chickpea fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 observed significantly higher iron content in grain (58.91 and 59.62 ppm) and straw (18.84 and 18.84 ppm) as compared to other nutrient management treatments during both the years of investigation, respectively. While it was at par with GRDF + multi- micronutrient Grade-II 0.5 % (foliar spray) for iron content in grain only. No application of fertilizer to chickpea produced significantly minimum iron content in grain and straw of chickpea. The initial value of iron content in grain of chickpea was 50.90 and 51.12 ppm which was at lower magnitude during both the years of investigation, respectively.

The chickpea fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 and GRDF + multi-micronutrient Grade-II 0.5 % (foliar spray) experienced easy iron availability and efficient use of iron associated with other macro and micro nutrients upgraded iron content in chickpea grain and straw.

The results are in close association with Gupta *et al.* (2012), Henda *et al.* (2004) and Khan *et al.* (2014).

**Zinc content in grain and straw**

Data regarding zinc content in grain and straw of chickpea as influenced by different treatments during rabi season, 2021-2022 and 2022-23 are presented in table 18 and graphically depicted in fig. 16. The data in respect zinc content in grain and straw of chickpea were influenced significantly due to different nutrient management treatments.

The chickpea fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 exhibited significantly higher zinc content in grain (33.01 and 33.51 ppm) and straw (18.75 and 19.86 ppm) as compared to other nutrient management treatments during both the years of investigation, respectively. No application of fertilizer to chickpea produced significantly minimum zinc content in grain and straw of chickpea. The initial value

of zinc content in chickpea grain was (15.81 and 16.29 ppm) which was at lower magnitude during both the years of investigation, respectively.

The chickpea fertilized with GRDF + soil application of multi-micronutrient Grade-I @ 10 kg ha- 1 found superior which supplied essential quantity of zinc to chickpea crop and its efficient use reflected in enrichment of zinc content grain and straw of chickpea.

The results are in close association with Singh and Gupta (1986), Khan *et al.* (2000) and Sahu and Singh (2009) and Gupta *et al.* (2012).

**Table 5 Micro nutrient content in grain and straw of chickpea as influenced by different treatments.**

| Treatment | Fe (ppm) | | | | Zn (ppm) | | | | B (ppm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain | | Straw | | Grain | | Straw | | Grain | | Straw | |
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 |
| $T_1$: Control | 50.90 | 51.12 | 15.86 | 16.22 | 15.81 | 16.29 | 16.12 | 16.28 | 13.17 | 14.28 | 56.46 | 57.81 |
| $T_2$ : RDF (25:50:30 N :$P_2O_5$ :$K_2O$ kg $ha^{-1}$) | 54.96 | 55.32 | 16.02 | 16.54 | 18.10 | 18.29 | 16.07 | 16.18 | 14.75 | 15.26 | 58.42 | 59.31 |
| $T_3$ : GRDF (25:50:30 N :$P_2O_5$ :$K_2O$ kg $ha^{-1}$ + FYM 5 t $ha^{-1}$) | 55.52 | 55.68 | 16.32 | 16.82 | 20.04 | 20.51 | 16.40 | 16.59 | 15.02 | 16.38 | 60.17 | 61.35 |
| $T_4$ : GRDF + Chelated Fe EDTA 0.2 % (foliar spray) | 57.10 | 57.54 | 17.69 | 18.31 | 23.70 | 24.57 | 17.14 | 17.82 | 16.32 | 17.39 | 65.13 | 66.34 |
| $T_5$ : GRDF +Chelated Zn EDTA 0.2 % (foliar spray) | 56.23 | 56.89 | 17.22 | 17.65 | 27.10 | 27.83 | 17.52 | 18.24 | 15.55 | 16.27 | 62.57 | 63.49 |
| $T_6$ : GRDF +Boric acid 0.1 % (foliar spray) | 55.94 | 56.21 | 16.93 | 17.18 | 21.01 | 22.51 | 16.75 | 17.21 | 16.51 | 17.21 | 66.18 | 67.28 |
| $T_7$ : GRDF + Multi micronutrient Grade-II 0.5 % (foliar spray) | 57.96 | 58.32 | 18.26 | 18.67 | 29.10 | 29.91 | 18.33 | 19.61 | 18.04 | 19.32 | 72.36 | 73.26 |
| $T_8$ : GRDF + Multi micronutrient Grade-II. @ 10 kg $ha^{-1}$ (soil application) | 58.91 | 59.62 | 18.84 | 19.38 | 33.01 | 33.51 | 18.75 | 19.86 | 18.56 | 19.94 | 74.35 | 75.21 |
| S. Em ± | 0.48 | 0.56 | 0.09 | 0.11 | 0.85 | 0.92 | 0.07 | 0.09 | 0.36 | 0.54 | 0.54 | 0.68 |
| C.D. at 5 % | 3.79 | 1.62 | 0.29 | 0.28 | 2.48 | 2.69 | 0.23 | 0.27 | 0.97 | 1.56 | 1.65 | 1.89 |

**Boron content in grain and straw (ppm)**

Data regarding boron content in grain and straw of chickpea as influenced by different treatments during rabi season, 2021-2022 and 2022-23 are presented in table 18 and graphically depicted in fig.19. The data in respect boron content in grain and straw of chickpea were influenced significantly due to different nutrient management treatments.

The chickpea fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 noticed significantly higher boron content in grain (18.56 and 19.94 ppm) and straw (74.35 and 75.21 ppm) as compared to other nutrient management treatments while it was at par with GRDF + multi-micronutrient Grade-II 0.5 % (foliar spray) for boron content in grain only during both the years of investigation, respectively. No application of fertilizer to chickpea produced significantly minimum boron content in grain and straw of chickpea. The initial value of boron content in grain of chickpea was 13.17 and 14.28 ppm which was at lower magnitude during both the years of investigation, respectively.

The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade- I @ 10 kg ha- 1 and GRDF + multi-micronutrient Grade-II 0.5 % (foliar spray) experienced precise availability of trace element boron and efficient utilization by chickpea crop showed fortification of boron in grain and straw of chickpea.

The results are in close association with Sahu and Singh (2009), Gupta *et al.* (2012) and Alam *et al.* (2017)

**Iron uptake in grain and straw**

Iron uptake in grain and straw of chickpea as influenced by different treatments during rabi season, 2021-2022 and 2022-23 are presented in table 20 and graphically depicted in fig. 23. The mean iron uptake in grain and straw of chickpea were (152.4 and 153.4 g $ha^{-1}$) and (53.11 and 53.7 g ha-1), during both the years of investigation, respectively. The data in respect iron uptake in grain and straw of chickpea were influenced significantly due to different nutrient management treatments.

The chickpea fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 observed significantly higher iron uptake in grain (173.6 and 174.3 g ha-1) and straw (62.1 and 62.1 g ha-1) as compared to other nutrient management treatments during both the years of investigation, respectively.

**Table 6 Micro nutrient uptake in grain and straw of chickpea as influenced by different treatments.**

| Treatment | Fe (g $ha^{-1}$) | | | | Zn (g $ha^{-1}$) | | | | Cu (kg $ha^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain | | Straw | | Grain | | Straw | | Grain | | Straw | |
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 |
| T1: Control | 126.2 | 127.2 | 44.3 | 45.2 | 32.3 | 33.1 | 18.7 | 19.4 | 72.52 | 73.25 | 60.76 | 61.08 |
| T2 : RDF (25:50:30 N :$P_2O_5$ :$K_2O$ kg $ha^{-1}$) | 142.7 | 143.5 | 48.7 | 49.5 | 40.1 | 41.2 | 20.7 | 21.3 | 80.61 | 81.26 | 67.51 | 68.54 |
| T3 : GRDF (25:50:30 N :$P_2O_5$ :$K_2O$ kg $ha^{-1}$ + FYM 5 t $ha^{-1}$) | 138.2 | 139.8 | 46.3 | 47.3 | 37.6 | 38.5 | 21.4 | 22.6 | 87.33 | 88.56 | 73.31 | 75.24 |
| T4 : GRDF + Chelated Fe EDTA 0.2 %(foliar spray) | 153.3 | 154.2 | 50.9 | 51.3 | 44.2 | 45.2 | 23.7 | 24.8 | 87.90 | 88.91 | 73.93 | 76.25 |
| T5 : GRDF +Chelated Zn EDTA 0.2 % (foliar spray) | 164.6 | 165.3 | 57.8 | 58.9 | 49.6 | 52.0 | 24.3 | 25.3 | 93.32 | 94.28 | 79.93 | 83.25 |
| T6 : GRDF +Boric acid 0.1 % (foliar spray) | 156.4 | 157.8 | 55.8 | 56.2 | 44.5 | 45.2 | 24.3 | 25.8 | 101.89 | 103.2 | 86.82 | 91.25 |
| T7 : GRDF + Multi micronutrient Grade-II 0.5 % (foliar spray) | 164.2 | 165.4 | 59.0 | 60.2 | 49.1 | 51.2 | 25.3 | 26.1 | 104.04 | 106.58 | 88.36 | 96.25 |
| T8 : GRDF + Multi micronutrient Grade-II. @ 10 kg $ha^{-1}$ (soil application) | 173.6 | 174.3 | 62.1 | 61.1 | 54.5 | 56.2 | 28.2 | 29.3 | 107.56 | 109.26 | 94.35 | 99.21 |
| General mean | 152.4 | 153.4 | 53.1 | 53.7 | 43.9 | 45.3 | 23.3 | 24.3 | 91.90 | 93.16 | 78.12 | 81.38 |

**Zinc uptake in grain and straw**

Zinc uptake in grain and straw of chickpea as influenced by different treatments during rabi season, 2021-2022 and 2022-23 are presented in table 20 and graphically depicted in fig. 24. The mean zinc uptake in grain and straw of chickpea were (43.98 and 45.3 g $ha^{-1}$) and (23.32 and 24.3 g ha-1), during both the years of investigation, respectively. The data in respect zinc uptake in grain and straw of chickpea were influenced significantly due to different nutrient management treatments.

The chickpea fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 exhibited significantly higher zinc uptake in grain (54.5 g ha-1) and straw (28.2 g ha-1) as compared to other nutrient management treatments during both the years of investigation, respectively.

**Boron uptake in grain and straw (ppm)**

Boron uptake in grain and straw of chickpea as influenced by different treatments during rabi season, 2021-2022 and 2022-23 are presented in table 20 and graphically depicted in fig.27. The mean boron uptake in grain of chickpea were (91.90 and 93.16 kg $ha^{-1}$) and straw (78.12 and 81.38 Kg ha-1), during both the years of investigation, respectively. The data in respect boron content in grain and straw of chickpea were influenced significantly due to different nutrient management treatments.

The chickpea fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 noticed significantly higher boron content in grain (107.56 and 109.26 Kg ha-1) and straw (94.35 and 99.21Kg ha-1) as compared to other nutrient management treatments during both the years of investigation, respectively.

**Gross monetary returns**

Mean gross monetary returns of chickpea obtained during rabi 2021-22 and 2022-23 were Rs 92902.75 ha-1. The gross monetary returns of chickpea crop were influenced significantly due to different nutrient management treatments. The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 found superior and obtained significantly maximum gross monetary returns of (Rs 116932 and 119620 $ha^{-1}$) during rabi 2021 and 2022 than other nutrient management treatments during both the years of investigation, respectively. No application of fertilizer to chickpea produced significantly lower values of gross monetary return (Rs 52520 and 54862 $ha^{-1}$).

The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade- II @ 10 kg ha-1 has been produced higher grain and straw yield due to boosting of luxurious crop growth and yield attributes. This was reflected in obtaining highest gross monetary returns.

The results are in close association with Patel and Singh (2010) and Balai *et al.* (2017).

**Cost of cultivation**

The chickpea crop fertilized with GRDF + chelated Zn EDTA 0.2 % (foliar spray) required more cost of cultivation (Rs 49870 and 51984 $ha^{-1}$) than other nutrient management treatments. The chickpea crop with no fertilizer required less cost of cultivation (Rs 34170 and 35640 $ha^{-1}$) than rest of nutrient management treatments during both the years, respectively**.**

**Net monetary returns**

The net monetary return was influenced significantly due to different nutrient management treatments. The chickpea crop fertilized with GRDF + soil application of multi- micronutrient Grade-I @ 10 kg ha-1 produced significantly higher net monetary returns of (Rs 68748 and 69938 $ha^{-1}$) during rabi 2021-22 and 2022-23 as compared to other nutrient management treatments. The chickpea crop with no fertilizers obtained significantly lowest net monetary returns (Rs 18350 and 19222 $ha^{-1}$) than rest of nutrient management treatments. The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 produced higher grain and straw yield which was reflected in obtaining higher net monetary return.

The results are in close association with Patel and Singh (2010) and Balai *et al.* (2017)

**Benefit cost ratio**

The benefit cost ratio of chickpea fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 was found significantly superior (2.43 and 2.64) as compared to other nutrient management treatments. Significantly minimum benefit cost ratio (1.54 and 1.59) was obtained in chickpea with no fertilizer during both the years of investigation, respectively.

The benefit cost ratio is the function of gross monetary returns and cost of cultivation. The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade-I @ 10 kg ha-1 obtained higher gross monetary returns which was reflected in achieving maximum benefit cost ratio. The chickpea crop fertilized with GRDF + soil application of multi-micronutrient Grade-II @ 10 kg ha-1 recorded highest incremental benefit cost ratio (2.43 and 2.64) as compared to recommended dose of fertilizer.

The results are in close association with Patel and Singh (2010) and Balai *et al.* (2017).

**CONCLUSION-**

It could be concluded that, the chickpea crop fertilized with GRDF (25:50:30 N: $P_2O_5$: $K_2O$ kg ha-1 + FYM 5 t ha-1) + soil application of multi micronutrient Grade-II @ 10 kg ha- 1 (Zn 5 %, Fe 2 %, Mn 1 %, B 1 % and Cu 0.5 %) registered maximum growth, yield attributes, grain yield and economic returns as well as found better for fortification of micronutrients in chickpea.

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