International Journal of Plant & Soil Science

Volume 37, Issue 8, Page 552-561, 2025; Article no.IJPSS.140973
ISSN: 2320-7035

Combined Application of Micronutrients and Biofertilizers on the Yield and Quality of Chickpea (*Cicer arietinum* L.) in Vertisols

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2025/v37i85655

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/140973

Original Research Article

Received: 20/05/2025
Accepted: 30/07/2025
Published: 06/08/2025

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***Cite as:** Ajjannavar, Deepa Basappa, Vidyavathi G Yadahalli, Shivakumar Menasinakai, Muttavva Awaradi, and Vidyashree Dundappa Malakai. 2025. "Combined Application of Micronutrients and Biofertilizers on the Yield and Quality of Chickpea (Cicer Arietinum L.) in Vertisols". International Journal of Plant & Soil Science 37 (8):552-61. https://doi.org/10.9734/ijpss/2025/v37i85655.*

ABSTRACT

Chickpea (*Cicer arietinum* L.) is the third most vital food legume, belongs to the family Fabaceae. It is most frequently grown in the world's semi-arid regions and has a well-branched tap root that grows deep in the soil profile with moisture retained to support growth. A study was carried out to know the effect of different combinations of micronutrients and biofertilizers on dry matter accumulation, protein content, nutrient content and yield in Chickpea in Vertisol at College of Agriculture, Vijayapura, Karnataka, India, during *Rabi* 2020-21. The experiment was laid out in a randomised complete block design (RCBD) with nine treatments, each replicated thrice. Treatments included application of ferrous sulphate @10 kg ha^{-1}, zinc sulphate @10 kg ha^{-1}, borax @ 10 kg ha^{-1} and sodium molybdate @ 1.0 g kg^{-1} seeds in various combinations along with the recommended dose (10:25:00 N: P_2O_5 :K_2O kg ha^{-1}). Results of the experiment showed that, the treatment which received RDF + *Rhizobium* + PSB (@ 1250 g ha^{-1}) + $FeSO_4$ @ 10 kg ha^{-1} + $ZnSO_4$@ 10 kg ha^{-1} +Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds (T_8) resulted in significantly higher dry matter accumulation, protein content, nutrient content, grain yield (1591.40), straw yield (1350 kg ha^{-1}) and harvest index (0.54) in chickpea at harvest of the crop whereas significant lower values for these were observed in treatment where fertilizers were applied as per recommended dose. Thus, the combined application of RDF (10:25:00 N: P_2O_5 :K_2O kg ha^{-1}) + *Rhizobium* + PSB (@ 1250 g ha^{-1}) + $FeSO_4$ @ 10 kg ha^{-1} + $ZnSO_4$@ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds, found optimum for higher productivity of chickpea in Vertisols.

Keywords: Borax; chickpea; ferrous sulphate; phosphorus Solubilising bacteria; sodium molybdate and zinc.

1. INTRODUCTION

Pulses are known for their biological nitrogen fixation, and 80 per cent of their area is under a rainfed situation. Due to their profuse and ramified deep root system, pulses are resistant to drought and very well adapted to climatic vagaries. They have greater nitrogen-fixing capacity with *Rhizobium* bacteria, which is a unique feature contributing to higher agricultural production and maintaining soil health.

Chickpea (*Cicer arietinum* L.) is the third most vital food legume, belongs to the family Fabaceae. It is most frequently grown in the world's semi-arid regions and has a well-branched tap root that grows deep in the soil profile with moisture retained to support growth. Proteins obtained from chickpea are a good and balanced source of essential amino acids, with high bioavailability. Chickpea protein hydrolysate exhibits various biological activities such as reduction of antigenic activity and angiotensin I-converting enzyme (ACE) inhibition (Begum et al., 2023).

Among the micronutrients, boron (B) and molybdenum (Mo) play the most important role in legume growth. Application of micronutrients through soil, foliage or seed treatment enhances the biochemical activities of plants, thereby enhancing the physiological process of plants, resulting in higher crop yields (Movalia et al., 2020).

Iron (Fe) plays a crucial role in the redox system in cells and various enzymes. Dicotyledonous and gramineaceous plants have different strategies to acquire iron Fe (Marschner, 2012). Chickpea genotypes vary in their sensitivity to iron Fe deficiency. B is a trace element that can be applied in soil as well as foliar. When B was applied as H_3BO_3 increased the plant height, relative growth rate, net assimilation rate and leaf area index.

Biofertilizers are cost-effective, eco-friendly, and renewable sources of plant nutrition (Khan et al., 2007). These are also known as microbial inoculants. Biofertilizers are live or dormant cells that are applied to soil, seeds, or seedlings in order to increase the availability and absorption of nutrients from the soil. As an alternative to chemical-based fertilisers, using biofertilizers has become recognised as being more cost-effective and ecologically friendly (Pandit, 2024; Keerthanan et al., 2025). There are different types of microbial inoculants. Some important inoculants are *Rhizobium* inoculants, *Azotobacter* inoculants, Arbuscular Mycorrhiza (AM), blue-green algae inoculants, azolla, phosphate-solubilising bacterial (PSB) inoculants, etc. *Rhizobium* inoculants are widely used as biofertilizers to enhance chickpea growth and yield as they fix atmospheric nitrogen symbiotically. They improve soil fertility level by fixing atmospheric nitrogen, solubilising insoluble soil phosphates and releasing plant growth substances in the soil (Venkatashwarlu, 2008). The present study was carried out to know the effect of different combinations of micronutrients and biofertilizers on dry matter accumulation, protein content, nutrient content and yield in Chickpea in Vertisol at College of Agriculture, Vijayapura, Karnataka, India.

2. MATERIALS AND METHODS

A field experiment was conducted to assess the effect of different combinations of micronutrients and biofertilizers on dry matter accumulation, protein content, nutrient content and yield in Chickpea in Vertisol under dry land conditions at College of Agriculture, Vijayapura, Karnataka, India, during *Rabi* 2020-21. Vijayapura is situated in the Northern Dry Zone (Zone-3) of Karnataka. Geographically, it is located in the northern part of the state at 16°46'58" N latitude and 75°48'46" E longitude and at an altitude of 593.80 m above the mean sea level. The soil is black and clayey in texture with 7.20, 18.30, 15.30 and 59.20 per cent of coarse sand, fine sand, silt and clay, respectively. The soil pH is estimated by the Potentiometric method (Sparks, 1996), and it is alkaline in reaction (pH 8.33) and electrical conductivity of soil is estimated by the Conductometric method (Sparks, 1996) and is low in soluble salts (0.38 dS m^{-1}). The soil was low in organic carbon (3.90 g kg^{-1}) and available N (209 kg ha^{-1}) and medium in available P (14 kg ha^{-1}), while it was high in available K (340 kg ha^{-1}) and sulphur (14 kg ha^{-1}). The free calcium carbonate content was 13.40 meq 100 g^{-1}. The DTPA extractable micronutrient content, viz., zinc, iron, copper and manganese, was 0.2, 1.6, 0.6 and 6.1 mg kg^{-1}, respectively. The content of Zn and Fe in soil was below the critical limits. The experiment was laid out in a randomised complete block design (RCBD) design with nine treatments and three replications. The RDF @10: 25: 0 kg N: P_2O_5: K_2O ha^{-1} was applied to all the treatments. Iron, zinc and Borax were applied to soil as per treatments through ferrous sulphate ($FeSO_4 .7H_2O$) containing 19 per cent Fe and 10.50 per cent S, zinc sulphate ($ZnSO_4 .7 H_2O$) containing 21 per cent Zn and 10 per cent S and, B applied through borax ($Na_2[B_4O_5 (OH)_4].8H_2O$). Iron sulphate ($FeSO_4$) and zinc sulphate ($ZnSO_4$) were chelated with vermicompost at a 1:1 ratio for 15 days before sowing. Rhizobium, phosphate-solubilising bacteria (PSB) and sodium molybdate were seed-treated. Treatments included were, T1 : RDF (10: 25: 0 kg N:P_2O_5: K_2O ha^{-1}), T2 :T1+Rhizobium + PSB (@ 1250 g ha^{-1} each), T3 : T2 + FeSO4 @ 10 kg ha^{-1} ,T4 : T2 + $ZnSO_4$ @ 10 kg ha^{-1},T5 : T2 + Borax @10 kg ha^{-1} , T6 : T2 + Sodium Molybdate @ 1.0 g kg^{-1} seeds,T7 : T2 + $FeSO_4$ @ 10 kg ha^{-1} + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} ,T8 : T2 + $FeSO_4$ @ 10 kg ha^{-1} + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds and T9 : $FeSO_4$ @ 10 kg ha^{-1} + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds. Recommended dose of nitrogen (10 kg N ha^{-1}) and phosphorus (25 kg P_2O_5 ha^{-1}) was applied through urea and DAP. The entire quantity of fertiliser was applied as a basal dose. The soil samples after the harvest of the crop were analysed for various chemical properties as mentioned by Page et al. (1982). The data collected from the experiment during the crop growth period were subjected to statistical analysis.

3. RESULTS AND DISCUSSION

3.1 Influence of Micronutrients and Biofertilizers on Total Dry Matter Accumulation (g plant $^{-1}$) in Chickpea

The data on total dry matter accumulation in chickpea at different stages as influenced by the different micronutrients and biofertilizers are presented in the Table 1.

The total dry matter accumulation in the chickpea crop at different stages was significantly influenced by the soil application of micronutrients and biofertilizers in combination along with RDF. The treatment received RDF + *Rhizobium* + PSB (@ 1250g ha^{-1}) + Fe SO_4 @ 10 kg ha^{-1} + Zn SO_4@ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds (T_8) resulted in maximum total dry matter accumulation at flowering (12.60 g plant $^{-1}$), at pod filling (22.57 g $plant^{-1}$) and at harvest (25.56 g $plant^{-1}$) and was superior over all the treatments except treatment receiving RDF + *Rhizobium* + PSB @ 1250g ha^{-1} + Fe SO_4 @ 10 kg ha^{-1} + Zn SO_4@ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} (T_7). The lower total dry matter accumulation at flowering (9.5 g $plant^{-1}$), at pod filling (16.50 g $plant^{-1)}$, and at harvesting (21.26 g $plant^{-1}$) was recorded in the treatment which received RDF alone (T_1). The application of individual micronutrients, biofertilizers and their combinations (T_2 to T_6) was on par with each other. However, the said treatments were significantly lower than T_8. It might be due to the continuous supply of chelated micronutrients along with biofertilizers ensures balanced nutrition for crops throughout their growth. Rhizobium enhances nitrogen fixation, boosting protein, carbohydrate, and starch production, leading to higher dry matter accumulation and more branches per plant. Inoculating with *Rhizobium* and PSB increases growth regulators, releases ammonia, and solubilises phosphates, which could result in higher yields. Molybdenum (Mo) supports nodule-forming bacteria, increasing nodulation, branches, nodules, and dry nodule weight, particularly at 45 DAS (Movalia et al*.,* 2020). Chelated micronutrients and biofertilizers ensure balanced crop nutrition. Rhizobium enhances nitrogen fixation, increasing dry matter, branches, and yield. PSB boosts growth regulators and phosphate availability. Molybdenum supports nodulation, while boron aids photosynthate translocation. Sodium molybdate treatment improves nitrogen fixation, plant growth, and ultimately, crop yield (Movalia et al*.,* 2020; Valenciano et al., 2010).

Table 1. Influence of different micronutrients and biofertilizers on dry matter accumulation at different growth stages of chickpea

Treatments	Total dry matter accumulation (g plant^{-1})		
	At flowering stage	At pod filling stage	At harvesting stage
T_1 -RDF (10: 25: 00 kg N: P_2O_5: K_2O ha^{-1})	9.50	16.50	21.26
T_2 -*Rhizobium* + PSB (@ 1250 g ha^{-1})	10.23	17.93	21.80
T_3 -T_2 + Fe SO_4 @ 10 kg ha^{-1}	10.63	19.13	22.00
T_4 -T_2 + Zn SO_4 @ 10 kg ha^{-1}	10.33	18.86	21.90
T_5 -T_2 + Borax @ 10 kg ha^{-1}	9.93	17.30	21.36
T_6 -T_2 + Sodium molybdate @ 1.0 g kg^{-1} seeds	10.68	19.23	22.06
T_7 -T_2 + Fe SO_4 @ 10 kg ha^{-1} + Zn SO_4 @ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1}	12.10	21.16	24.23
T_8-T_2 + Fe SO_4 @ 10 kg ha^{-1} + Zn SO_4@ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds	12.60	22.57	25.56
T_9- Fe SO_4 @ 10 kg ha^{-1} + Zn SO_4 @ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds	11.73	20.63	23.93
S.Em.±	0.55	0.98	0.94
C. D. (P = 0.05)	1.65	2.94	2.84

**RDF (Recommended dose of fertilisers) is common to all treatments*

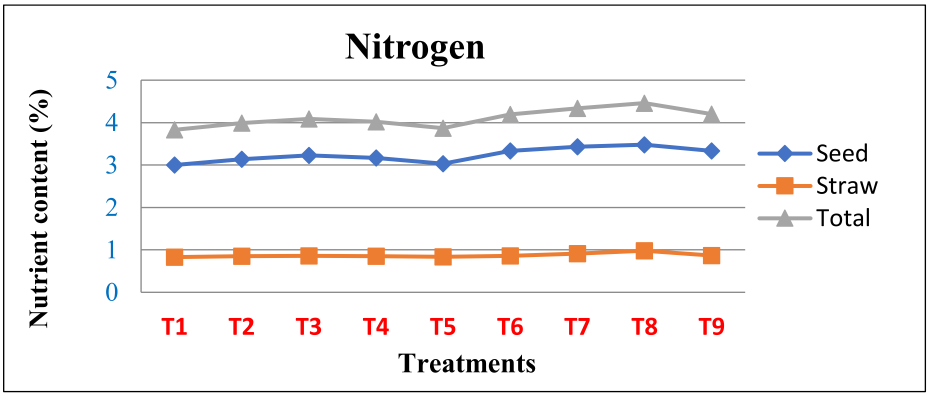

Fig. 1. Nitrogen content

Table 2. Influence of different micronutrients and biofertilizers on protein content in chickpea seed

Treatments	Protein content in seeds (%)
T_1 -RDF (10: 25: 0 kg N: P_2O_5: K_2O ha^{-1})	18.75
T_2 -*Rhizobium* + PSB (@ 1250 g ha^{-1})	19.62
T_3 -T_2 + Fe SO_4 @ 10 kg ha^{-1}	20.31
T_4 -T_2 + Zn SO_4 @ 10 kg ha^{-1}	19.81
T_5 -T_2 + Borax @ 10 kg ha^{-1}	18.93
T_6 -T_2 + Sodium molybdate @ 1.0 g kg^{-1} seeds	20.81
T_7 -T_2 + Fe SO_4 @ 10 kg ha^{-1} + Zn SO_4 @ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1}	21.43
T_8-T_2 + Fe SO_4 @ 10 kg ha^{-1} + Zn SO_4@ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds	21.75
T_9- Fe SO_4 @ 10 kg ha^{-1} + Zn SO_4 @ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds	20.81
S.Em.±	0.29
C. D. (P = 0.05)	0.86

**RDF (Recommended dose of fertilisers) is common to all treatments*

Table 3. Influence of different micronutrients and biofertilizers on grain yield, haulm yield and harvest index of chickpea

Treatments	Grain yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index
T_1 -RDF (10: 25: 0 kg N: P_2O_5: K_2O ha^{-1})	1088	1058	0.50
T_2 -*Rhizobium* + PSB (@ 1250 g ha^{-1})	1216	1137	0.51
T_3 -T_2 + Fe SO_4 @ 10 kg ha^{-1}	1291	1162	0.52
T_4 -T_2 + Zn SO_4 @ 10 kg ha^{-1}	1280	1152	0.52
T_5 -T_2 + Borax @ 10 kg ha^{-1}	1200	1112	0.50
T_6 -T_2 + Sodium molybdate @ 1.0 g kg^{-1} seeds	1347	1176	0.53
T_7 -T_2 + Fe SO_4 @ 10 kg ha^{-1} + Zn SO_4 @ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1}	1450	1212	0.54
T_8 -T_2 + Fe SO_4 @ 10 kg ha^{-1} + Zn SO_4@ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds	1591	1350	0.54
T_9 - Fe SO_4 @ 10 kg ha^{-1} + Zn SO_4 @ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds	1361	1188	0.53
S.Em.±	48.45	45.86	0.03
C. D. (P = 0.05)	145.27	137.50	NS

**RDF (Reommended dose of fertilizers) is common to all treatments*

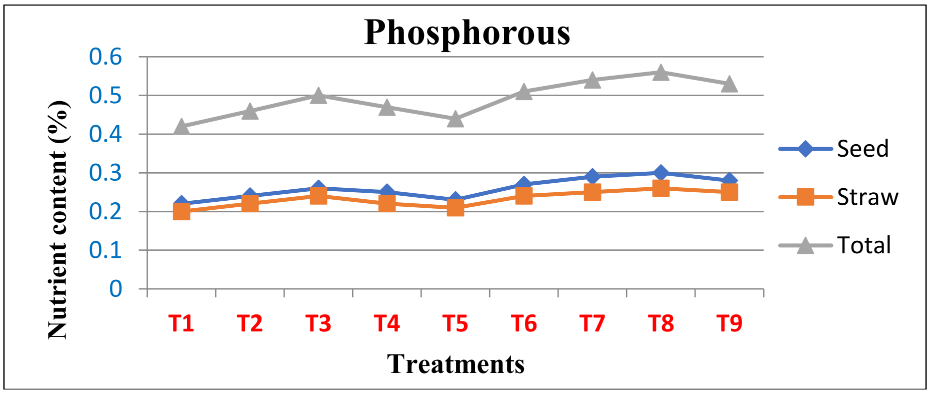

Fig. 2. Phosphorous content

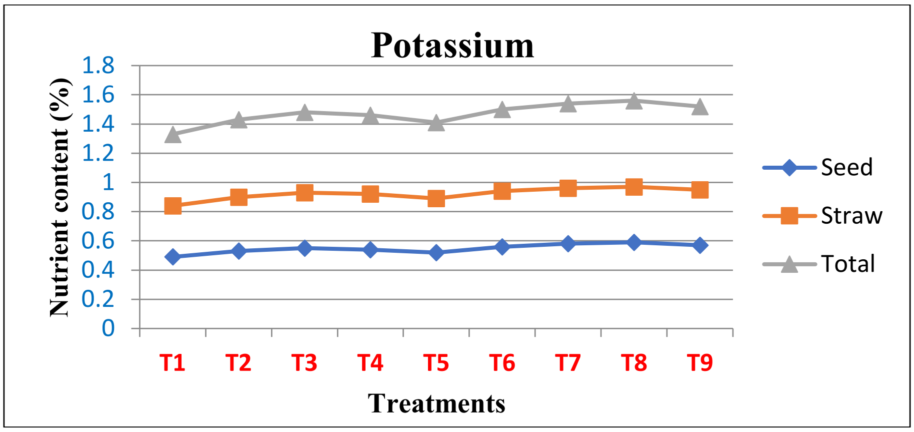

Fig. 3. Potassium content

3.2 Influence of Micronutrients and Biofertilizers on Protein Content (%) in Chickpea Seeds

The data on protein content of chickpea ranged from 21.75 to 18.75 per cent and was significantly influenced by the different micronutrients and biofertilizers in combination when compared with RDF, and it is represented in Table 2.

Significantly maximum protein content in chickpea was recorded in the treatment which received RDF + *Rhizobium* + PSB (@ 1250 g ha^{-1}) + $FeSO_4$ @ 10 kg ha^{-1} + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium Molybdate @ 1.0 g kg^{-1} seed (T_8). An increase in protein content by 16 per cent was observed over the control (T_1). The increase in crude protein content may be due to iron and sulphur in the enzyme activities and amino acid synthesis. It helps in the conversion of amino acids to high-quality protein. As Fe and Zn help in the translocation of N to grain, this might have resulted in increased protein content in grain. Besides, the increase may be related to the role of Fe in chlorophyll formation, respiration, photosynthesis and symbiotic N fixation in plants (Hemn, 2013), while Zn is required as structural and catalytic components of proteins and enzymes for normal growth and development (Broadley et al., 2007). As B is important for sugar translocation, nitrogen utilisation and protein synthesis. B plays an important role in the synthesis of essential amino acids like cystine, methonine & certain vitamins like biotine, thymine, vitamin B_1 as well as the formation of ferodoxin & iron-containing plants, thus B play a role in increasing protein content (Movalia et al*.,* 2020).

3.3 Influence of Micronutrients and Biofertilizers on Macronutrient Content in Chickpea (N, P, K and S)

The data pertaining to the macro nutrient (N, P, K and S) content in chickpea as influenced by the different micronutrients and biofertilizers is presented in the Fig. 1 to 4. Application of micronutrients and biofertilizers did not differ significantly for macronutrient content in chickpea straw and seeds. However, the treatment which received RDF + *Rhizobium* + PSB (@ 1250g ha^{-1}) + $FeSO_4$ @ 10 kg ha^{-1} + $ZnSO_4$@ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds (T_8) resulted in numerically higher N, P, K and S content in chickpea seed (3.48, 0.30, 0.59 and 0.44 %, respectively) and straw (0.98, 0.26, 0.97 and 0.30 %, respectively). The lower N, P, K and S content in chickpea seed (3.00, 0.22, 0.49 and 0.35 %, respectively) and straw (0.83, 0.20, 0.84 and 0.20 %, respectively) was recorded in the treatment which received RDF alone (T_1). The nitrogen uptake increased with the application of fertilisers with or without biofertilizers. It might be due to favourable soil conditions, which enhanced nutrient availability and nutrient uptake as well as a better growth and activity of roots (Idries & Sandhu, 1979, Jagdale et al*.,* 1980 and Bera et al*.,* 2013). Greater availability and uptake of phosphorus due to the additive effect of these PSB biofertilizers in improving the nutritional environment enhanced the growth in terms of branches and dry matter, photosynthetic area, production of assimilates and their translocation to reproductive structures, thereby increasing the yield attributes and ultimately, yield of the crop. Significant increase in straw yield due to bio-fertiliser inoculation could be attributed to the increased vegetative growth, possibly as a result of effective utilisation of nutrients absorbed through an extensive root system and prolific shoot development on account of improved nourishment (Gangwar and Dubey, 2012). An increase in potassium uptake is also due to the increase in dry matter production due to the balanced nutrition with micronutrients and biofertilizers.

3.4 Influence of Micronutrients and Biofertilizers on Micronutrient Content in Chickpea (Fe, Zn, Mn and Cu)

The data pertaining to the micronutrient (Fe, Zn, Mn and Cu) content in chickpea as influenced by the different micronutrients and biofertilizers is presented in Figs. 5 to 8.

Application of micronutrients and biofertilizers did not differ significantly for micronutrient content in chickpea straw and seeds. However, the treatment which received RDF + *Rhizobium* + PSB (@ 1250g ha^{-1}) + $FeSO_4$ @ 10 kg ha^{-1} + $ZnSO_4$ @ 10kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium molybdate @ 1.0 g kg^{-1} seeds (T_8) resulted in numerically higher iron, zinc, manganese and copper content in chickpea seed (69.94, 28.46, 28.80 and 27.42 ppm, respectively) and straw (45.09, 18.57, 47.93 and 38.80 ppm, respectively). The lower iron, zinc, manganese and copper content in chickpea straw (63.01, 22.21, 22.40 and 25.65 ppm, respectively) and straw (18.48, 16.64, 45.34 and 35.63 ppm, respectively) were recorded in the treatment which received RDF alone (T_1). Uptake of any nutrient is the function of its content and the dry matter production of the crop. Higher nutrient content in the produce and higher biomass production of chickpea might be the pertinent reason for higher uptake of nutrients (Singh et al*.,* 2004). It might also be due to the synergetic effect between iron and zinc in plants and higher dry matter production (Mousavi et al*.,* 2012).

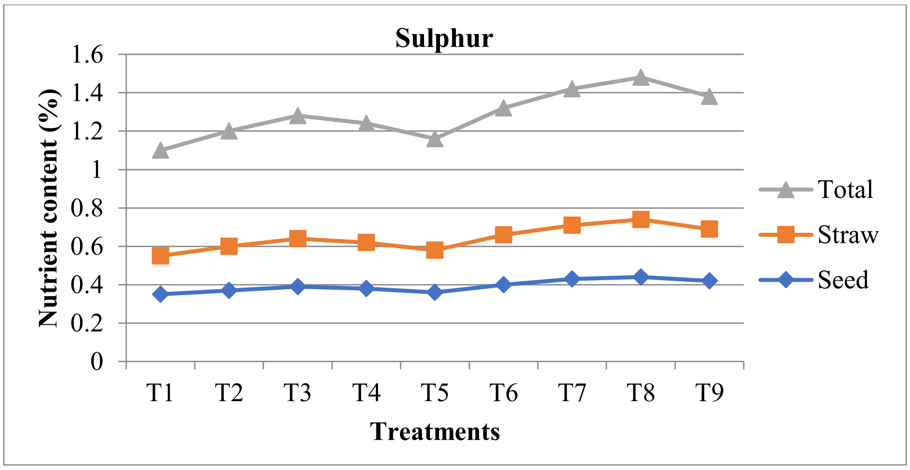

Fig. 4. Sulphur content

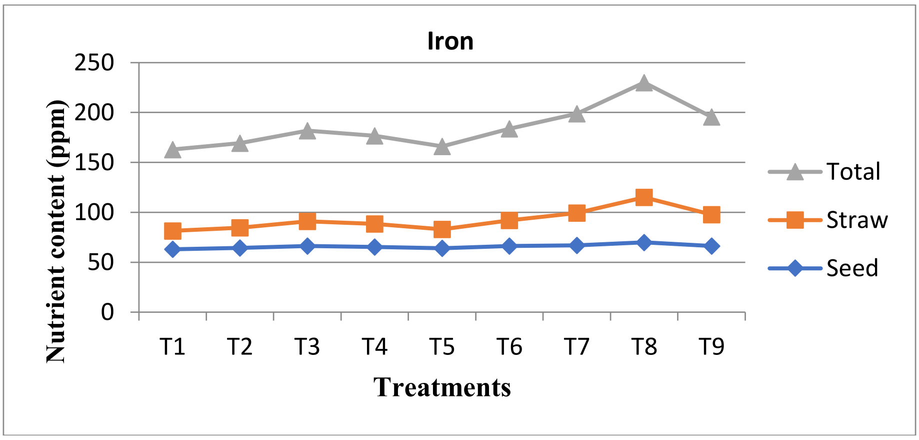

Fig. 5. Iron content

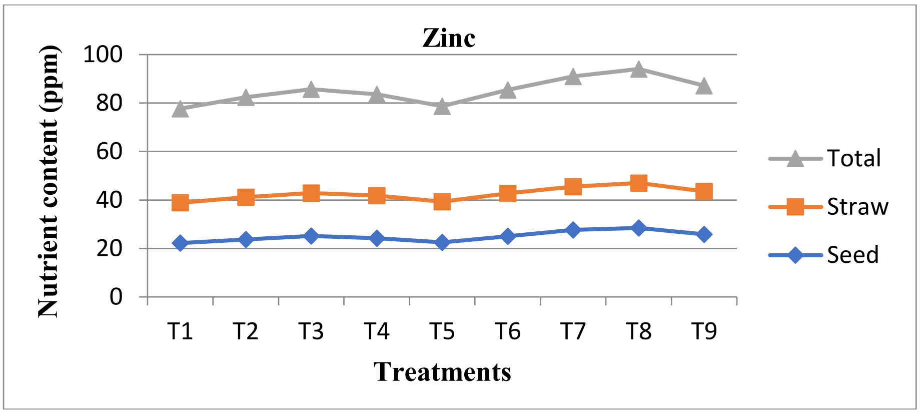

Fig. 6. Zinc content

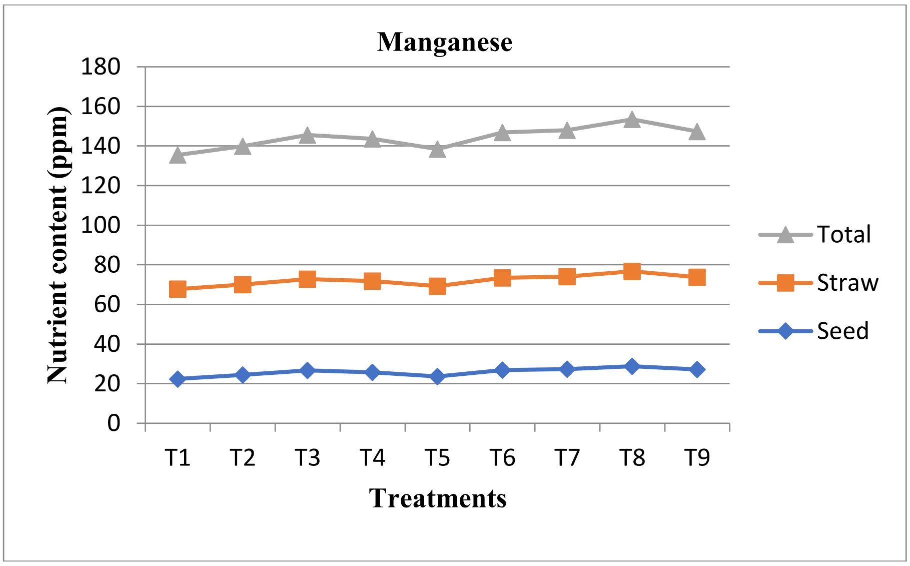

Fig. 7. Manganese content

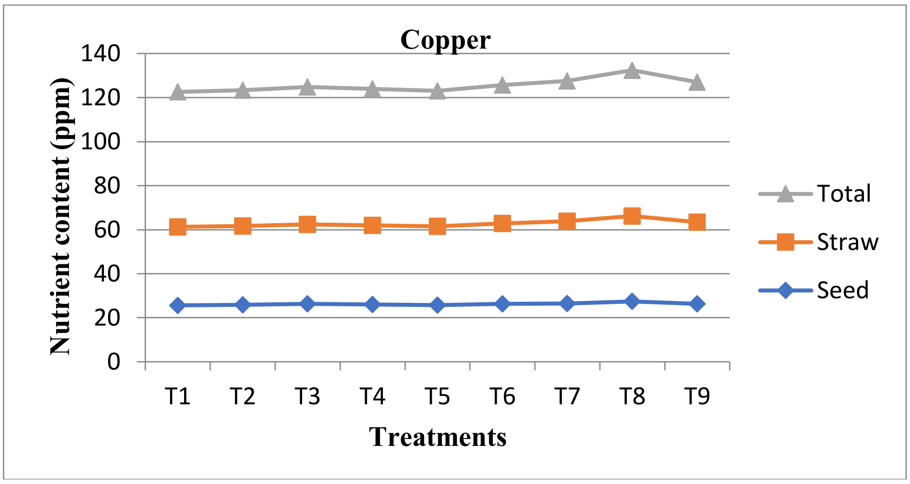

Fig. 8. Copper content

3.5 Influence of Different Micronutrients and Biofertilizers on Grain Yield, Haulm Yield and Harvest Index of Chickpea

The grain yield increased by 46.17 per cent, haulm yield increased by 27.59 per cent and harvest index increased by 8 per cent with the application of RDF + *Rhizobium* + PSB (@ 1250g ha^{-1}) + $FeSO_4$ @ 10 kg ha^{-1} + $ZnSO_4$@ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} + Sodium Molybdate @ 1.0 g kg^{-1} seeds (T_8) followed by RDF + *Rhizobium* + PSB (@ 1250g ha^{-1}) + $FeSO_4$ @ 10 kg ha^{-1} + $ZnSO_4$@ 10 kg ha^{-1} + Borax @ 10 kg ha^{-1} (T_7). The lowest grain and haulm yield was found in the control treatment (T_1) (Table 3). These results might be due to an improvement in the efficiency and utilisation of native as well as applied nutrients. The increase in yield attributes is mainly due to an increase in photosynthesis activity of leaves, translocation of photosynthates from source to sink and nutrient uptake (Mishra and Tiwari, 2001 and Hossain et al., 2018). The increased yield of chickpea is due to an increase in growth and yield parameters like plant height, number of branches per plant, total dry matter accumulation, number of pods, pod weight and test weight. A combination of all micronutrients, *viz*., Fe + B + Zn + Mo, might have increased the growth and yield significantly over RDF alone.

Inoculation of *Rhizobium* and PSB is known to produce the endogenous growth regulators and release ammonia from *Rhizobium* and supply phosphorus nutrients by solubilising insoluble phosphate by PSB, resulting in higher yield. Seed treatment with the combined application of *Rhizobium*, PSB and molybdenum enhanced the crop yield. Mo is essential for N_2-fixation, which might have ensured better N supply to the crop and activation of the enzyme *Nitrate reductase,* and it is also responsible for better yield and yield attributes of the crop (Movalia et al., 2020).

The absorption of Zn and Fe might have increased the rate of nitrogen metabolism, biosynthesis of hormones and rate of photosynthesis, which ultimately increases the yield of the crop (Athokpam et al*.,* 2009).

Influence of different micronutrients and biofertilizers on nitrogen content (Fig. 1), phosphorus content (Fig. 2) and potassium content (Fig. 3).

Influence of different micronutrients and biofertilizers on sulphur content (Fig.4), iron content (Fig. 5) and zinc content (Fig. 6).

Influence of different micronutrients and biofertilizers on Manganese content (Fig.7), and Copper content (Fig. 8).

4. CONCLUSION

The study revealed that application of RDF (10:25:00: N: P2 O5: K2 O kg ha^{-1}) + Rhizobium + PSB (@ 1250 g ha^{-1}) + $FeSO_4$ @ 10 kg ha^{-1} +ZnSO4 @ 10 kg ha^{-1} +Borax @ 10 kg ha^{-1} + Sodium Molybdate @ 1.0 g kg^{-1} seed, recorded significantly higher dry matter accumulation, protein content, nutrient content and yield in chickpea crop in Vertisols.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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