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Micronutrients and bioinoculants management in chickpea (*Cicer arietinum* L.) under rainfed conditions

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Abstract
A field experiment was conducted at College of Agriculture (RVSKVV), Indore during *rabi* 2020-21 to study the effect of micronutrients and bionoculants in relation to eight nutrient management treatments (T_1: Control, T_2: Zn @ 5 kg/ha, T_3: Zn @ 7.5 kg/ha, T_4: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ at 30 DAS, T_5: Zn @ 7.5 kg/ha + seed treatment with molybdenum @ 2 g/kg seed, T_6: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ at 30 DAS + seed treatment with molybdenum @ 2 g/kg seed, T_7: Zn @ 7.5 kg/ha + seed treatment with NPK consortia @10 ml/kg, T_8: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ at 30 DAS + seed treatment with molybdenum @ 2 g/kg seed + NPK consortia @10 ml/kg seed). Results shows that the higher growth parameters (plant height, branches/plant, dry matter accumulation/plant) and physiological parameters (leaf area, leaf area index, CGR, RGR, Chlorophyll content) were observed with the application of Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ at 30 DAS + seed treatment with molybdenum @ 2 g/kg seed + NPK consortia @10 ml/kg seed in comparison to rest of the treatments. Significantly maximum seed yield (1899 kg/ha) was obtained with Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ at 30 DAS + seed treatment with molybdenum @ 2 g/kg seed + NPK consortia @10 ml/kg seed which was at par with T_5, T_6 and T_7. In terms of percentage seed yield increased by due to T_8 treatment by 24.68 over control. The straw yield and harvest index of chickpea did not influenced by various treatments. Thus, application of 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ at 30 DAS along with seed treatment with molybdenum @ 2 g/kg seed and NPK consortia @10 ml/kg may be best practices for improving the growth and productivity of chickpea under rainfed conditions of Malwa Plateau region of Madhya Pradesh.

Keywords: Bioinoculants, chickpea, micronutrients, physiological parameters, yields

Introduction
Pulses are played an important role in sustaining soil productivity by improving its physico-chemical and biological properties; it further enhances soil nitrogen content by increased trapping of atmospheric nitrogen in their root nodules. It seeds contain essential amino acids like isoleucine, leucine, lysine, valine, and aniline and protein is highly digestible (70- 90%). It seed contains about 18-22% protein, 61-62% carbohydrate, 4.5% fat 280 mg/100 g calcium, 12.3 mg/100 g iron and phosphorus 301 mg/100 g (Chandra *et al*., 2020) [4]. The major gram growing states in India are Madhya Pradesh, Maharashtra and Rajasthan. In India, it is cultivated in 9.44 Mha area, production 10.13 Mt with an average productivity 1073 kg/ha. Madhya Pradesh is the leading state in India having 3.43 Mha area and production of 4.61 Mt with an average productivity 1344 kg/ha and contributed 36.73% of the total area and 45.54% of total production in the country (Anonymous, 2019) [1].

Micronutrients are required in relatively smaller quantities for plant growth and often act as co-factors in enzyme activity and participate in redox reactions, in addition to having several other vital functions in plants (Kumar *et al*., 2018a,b) [10, 11]. Micronutrients play an important role in increasing the yield of pulses, oilseeds and legumes through their direct effects on the plant and through symbiotic nitrogen fixation process. The continuous use of micronutrients free high nitrogen and phosphorous fertilizers in the intensive cropping system with diminishing use of organic manures has resulted in the depletion of micronutrients cations from the soil reserves. Owing to this, the productivity of many crops has reduced substantially over the years (Kumar *et al*., 2010, Khandkar *et al*., 2019 and Kumawat *et al*., 2017) [8, 7, 13]. In legumes, during symbiotic

N fixation, molybdenum (Mo) acts as a co-factor for nitrogenase enzymes to catalyze the redox potential to convert elemental N into ammonium (NH_4^+) ions and nitrate reductase enzymes required for the assimilation of soil nitrates. Therefore, plant N metabolism is closely related to the Mo concentration in soil, especially for leguminous plants (Kumar *et al*., 2010 and Kumar *et al*., 2018a) [8, 10]. Zn plays an important role in plant reproductive development for initiation of flowering, floral development, male and female gametogenesis, fertilization and seed development. Zn deficiency induced a change in exine morphology and reduced pollen viability. It deficiency has also been shown to change stigmatic size, morphology and exudations, inhibiting pollen-stigma interaction (Kumar *et al*., 2014 and Kumawat *et al*., 2019). [9, 12] The prices of chemical fertilizers are increasing day-by-day and ultimately availability of fertilizers and therefore, it is necessary to minimize the cost of fertilizers by using bioinoculants for enhances the productivity of crops. As know that bio-fertilizers cannot replace synthetic fertilizers, but a little amount is capable of reducing their input (Raja and Takankhar, 2018) [20]. Therefore, the present investigation was undertaken to study the effect of micronutrients and bioinoculants on chickpea under rainfed conditions in vertisols.

Materials and Methods

The experiment was carried out at College of Agriculture, Indore during *rabi*, 2020-21. It is situated at 75° 48' East longitude and 22° 43' North latitude with an altitude of 567 meters above mean sea level. In Madhya Pradesh, this region falls under agroclimatic Zone IX (Malwa plateau). The experiment was laid out in randomized block design with eight treatments in three replications. Treatments comprised of T_1: Control, T_2: Zn @ 5 kg/ha, T_3: Zn @ 7.5 kg/ha, T_4: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ at 30 DAS, T_5: Zn @ 7.5 kg/ha + seed treatment with molybdenum @ 2 g/kg seed, T_6: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ at 30 DAS + seed treatment with molybdenum @ 2 g/kg seed, T_7: Zn @ 7.5 kg/ha + seed treatment with NPK consortia @10 ml/kg, T_8: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ at 30 DAS + seed treatment with molybdenum @ 2 g/kg seed + seed treatment with NPK consortia @10 ml/kg seed. Chickpea variety RVG- 202 was selected in the experiment. Seed treatment with NPK consortia @ 10 kg/ha was done at the time of sowing. Chickpea was sown in a planting geometry of 40 ×10 cm. All other cultural practices and plant protection measures were followed as per recommendation for this region. A full dose of N, P_2O_5 and K_2O were applied at the time of sowing. Recommended local crop management practices, weed control measures and plant protection measures were done in the crops. Data on growth attributes i.e. plant height, horizontal plant spread, number of branches/plant and dry weight/plant were recorded at different crop growth stages. Chlorophyll content in leaves was measured periodically at 30 60 DAS and at harvest with the help of SPAD 502 chlorophyll meter. Three leaves (from lower, middle and upper) from each plant were selected. Each leaf was clamped in the chlorophyll meter for a fraction of second than chlorophyll meter gave the value in SPAD on digital display of screen. The value of chlorophyll content (SPAD) shows relative distribution of chlorophyll in leaves. Leaf area was measured by leaf area meter at 30 and 60 DAS. It was obtained by leaf area by dividing it to ground area at 30 and 60 DAS. LAI = leaf area/ground area.

The CGR explains the dry matter accumulated per unit land area per unit time. It was calculated at 30, 60 DAS and at harvest stage. Its unit is g/m^2/day. It was calculated by the following formula (Watson, 1956) [22]:

$$CGR = \frac{(W_2 - W_1)}{(T_2 - T_1) \times SA}$$

Where, W_1 and W_2 are whole plant dry weight at time $T_1 - T_2$, respectively
SA is the ground area on which W_1 and W_2 are recorded

Relative Growth Rate (RGR) expresses the total plant dry weight increase in a time interval in relation to the initial weight or dry matter increment per unit biomass per unit time or grams of dry weight increase per gram of dry weight. It was also calculated at 30, 60 DAS and at harvest stage. It is expressed as g/g/day and given by the following formula (Blackman, 1919) [3]: -

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

W_1 = Initial dry weight
W_2 = Final dry weight
t_2-t_1 = time interval between two observations

Leaf area was measured by leaf area meter at 30 and 60 DAS. It was obtained by leaf area by dividing it to ground area at 30 and 60 DAS.

LAI = leaf area/ground area.

After harvesting of crop, threshing and winnowing done and weight of seeds for each net plot area was recorded in kg/plot and then converted to q/ha. The net plot seed yield was converted to seed yield in terms of kg ha^{-1}. All the data obtained from trial was statistically analyzed using the F-test (Gomez and Gomez, 1984) [6]. Critical difference (CD) values at 5% probability were used for determine the significance of differences between mean values of treatments.

Results and Discussion

Growth parameters

The growth characters *viz*., plant height, branches/plant, dry matter accumulation/plant were significantly affected by micronutrients and bionoculants at different growth stages of chickpea during the course of study except 30 DAS (Table 1). The higher plant height (40.82 and 47.00 cm), branches/plant (11.14 and 10.46) and dry matter accumulation/plant (8.50 and 67.04 g) were found with the application of Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ (at 30 DAS) + molybdenum @ 2 g/kg seed + NPK consortia @ 10 ml/kg seed (T_8) at 30 and 60 DAS, respectively. This might be due to combined application of Zn, Mo, NPK consortia as well as foliar spray of Zn improve the growth parameters of gram, might be due to enhanced level of nutrient available in the rhizoecosystem of the foliar applied nutrients resulting in better plant growth and development. Application of nutrients would have resulted in better vegetative growth as observed by taller plants, more branches and efficient nodulation. This favourable influence of foliar application of Zn

could be ascribed to more and quick access to nutrients by plants at seedling and early development stages. This may be helps in increasing availability of nutrients to plants leading to maximum plant growth in terms of plant height and leaf area which in turn contributed higher dry matter production. Foliar feeding can provide the nutrients needed for normal developments of crops in cases where absorption of nutrients from the soil is disturbed. As uptake of nutrients through the foliage is considerably faster than through roots, foliar sprays is also the method of choice when prompt correction of nutrient deficiencies is required (Maheswari and Karthik, 2017 and Kumawat *et al*., 2020) [16, 15].

Physiological parameters

The physiological parameters (leaf area, leaf area index, CGR, RGR and chlorophyll content) were influenced by micronutrients and bionoculants at different growth stages of chickpea during the experimentation (Table 2 & 3). The maximum leaf area (84.77 and 460.86 cm^2), leaf area index (0.212 and 1.152) and chlorophyll content (63.41 and 65.64 SPAD value) at 30 and 60 DAS; while CGR (0.040, 0.243 and 1.951 $g/m^2/day$) and RGR (0.006, 0.066 and 0.136 $g\ g^{-1}plant^{-1}$) at 30, 60 and harvest stage were observed with Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ (at 30 DAS) + molybdenum @ 2 g/kg seed + NPK consortia @ 10 ml/kg seed (T_8) followed by Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ (at 30 DAS) + molybdenum @ 2 g/kg seed (T_6). This might be due to the ability of Zn to synthesize the plant growth regulator such as auxins, which takes active role in enlargement and elongation of plant cell (Ehsanullah *et al*., 2015 and Kumawat *et al*., 2021) [5, 14]. Zn and Mo are responsible for many metabolic and enzymatic activities and growth hormones essential for chlorophyll formation. The significant increase in physiological parameters might be due to combination of nutrients (Zn and Mo) and NPK consortia play a major role in growth development and metabolism in plants. This might have also favoured better translocation of assimilates to sink resulted in enhancement in growth characters. Foliar application of Zn might also have enhanced the CO_2 fixation, induced activity of carbohydrate synthesizing enzymes coupled with effective partitioning of dry matter into reproductive sink as earlier reported by Marimuthu and Surendran (2015) [17].

Yields

Seed yield of chickpea significantly influenced by micronutrients and bioinoculants (NPK consortia) (Table 3). The highest seed yield (1899 kg/ha) was recorded under Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ + seed treatment with molybdenum @ 2 g/kg seed + seed treatment with NPK consortia @ 10 ml/kg seed (T_8) which was at par with Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ + seed treatment with molybdenum @ 2 gm/kg seed (T_6), Zn @ 7.5 kg/ha + seed treatment with molybdenum @ 2 g/kg seed (T_5) and Zn @ 7.5 kg/ha + NPK consortia @10 ml/kg (T_7). The quantum difference in seed yield was 376 kg/ha which in terms of percentage was 24.68 over control. The straw yield and harvest index were remained unaffected by different treatments (Table 3). This might be due to more number of new loading sinks and role of Zn in metabolic activity. The higher photosynthetic rate, translocation and assimilation of metabolites in the sink which ultimately increased the yield attributes. The Zn application also improves protein and carbohydrates synthesis and their transportation to the site of seed formation. Similarly, Mo plays an important role in synthesis of chlorophyll and plant growth regulator and also improves photosynthesis and assimilates transportation to sink and finally increases seed yields (Banjara and Mujgahe, 2019 and Rahangdale *et al*., 2021) [2, 19]. The application of Mo allowed synthesis of more nodule tissue due to better supply of Mo from soil to plants and also by maintaining supply of essential metabolites to the nodules might be due to more availability of nitrogen throughout crop season due to basal N application, N-fixation and urea spray. The NPK consortia might have helps in better availability of N, P and K nutrients caused well developed root system having higher nitrogen fixing capacity resulting better growth and development of plants and better diversion of photosynthates towards sink (Singh *et al*., 2018 and Rahangdale *et al*., 2022) [21, 18].

Table 1: Effect of micronutrients and bioinoculants on growth parameters of chickpea

Treatments	Plant height (cm)			Number of branches/plant			Dry matter accumulation/plant (g)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1: Control	17.55	35.26	38.85	3.41	8.67	8.02	0.74	6.17	56.31
T_2: Zn @ 5 kg/ha	17.86	37.90	41.93	3.44	9.93	9.10	0.74	7.40	60.93
T_3: Zn @ 7.5 kg/ha	18.00	38.37	42.45	3.50	10.11	9.15	0.75	7.34	62.84
T_4: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$	17.96	38.91	43.14	3.66	10.11	9.56	0.76	7.40	62.96
T_5: Zn @ 7.5 kg/ha + seed treatment with molybdenum @ 2 g/kg seed	18.12	39.73	44.84	3.70	10.84	10.06	0.78	8.32	64.37
T_6: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ + molybdenum @ 2 g/kg seed	18.44	40.07	45.59	3.72	10.89	10.29	0.81	8.29	65.43
T_7: Zn @ 7.5 kg/ha + seed treatment with NPK consortia @10 ml/kg	18.07	39.30	44.38	3.65	10.65	9.80	0.76	7.80	63.42
T_8: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ + molybdenum @ 2 g/kg seed + NPK consortia @10 ml/kg seed	18.49	40.82	47.00	3.80	11.14	10.46	0.81	8.50	67.04
S.Em ±	0.51	0.77	1.02	0.18	0.39	0.33	0.04	0.38	1.53
CD (P=0.05)	NS	2.26	3.00	NS	1.13	0.97	NS	1.12	4.49

Table 2: Effect of micronutrients and bioinoculants on physiological parameters of chickpea

Treatments	Leaf area (cm^2)		Leaf area index		CGR (g/plant/day)			RGR (g/g/day)		
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1: Control	66.17	288.25	0.165	0.721	0.038	0.168	1.671	0.004	0.054	0.130
T_2: Zn @ 5 kg/ha	68.57	272.57	0.171	0.681	0.038	0.208	1.785	0.004	0.061	0.133
T_3: Zn @ 7.5 kg/ha	70.67	413.33	0.177	1.033	0.038	0.206	1.850	0.005	0.060	0.134
T_4: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$	73.64	439.38	0.184	1.098	0.039	0.208	1.852	0.005	0.061	0.134
T_5: Zn @ 7.5 kg/ha + seed treatment with molybdenum @ 2 g/kg seed	76.43	453.33	0.191	1.133	0.039	0.238	1.868	0.006	0.065	0.134
T_6: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ + molybdenum @ 2 g/kg seed	80.33	458.25	0.201	1.146	0.040	0.236	1.905	0.006	0.065	0.135
T_7: Zn @ 7.5 kg/ha + seed treatment with NPK consortia @10 ml/kg	75.97	442.60	0.190	1.106	0.039	0.221	1.854	0.005	0.063	0.134
T_8: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ + molybdenum @ 2 g/kg seed + NPK consortia @10 ml/kg seed	84.77	460.86	0.212	1.152	0.040	0.243	1.951	0.006	0.066	0.136
S.Em ±	2.46	48.30	0.006	0.121	0.001	0.013	0.056	0.001	0.002	0.00
CD (P=0.05)	7.19	141.32	0.018	0.353	NS	0.038	0.165	NS	0.006	NS

Table 3: Effect of micronutrients and bioinoculants on chlorophyll content and yields of chickpea

Treatments	Chlorophyll content (SPAD value)		Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
	30 DAS	60 DAS			
T_1: Control	60.67	60.99	1523	1566	49.29
T_2: Zn @ 5 kg/ha	61.94	62.86	1597	1642	49.32
T_3: Zn @ 7.5 kg/ha	62.03	63.42	1625	1629	50.05
T_4: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$	62.67	63.52	1638	1709	49.00
T_5: Zn @ 7.5 kg/ha + seed treatment with molybdenum @ 2 g/kg seed	62.70	64.70	1834	1821	50.18
T_6: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ + molybdenum @ 2 g/kg seed	62.63	65.11	1876	1775	51.40
T_7: Zn @ 7.5 kg/ha + seed treatment with NPK consortia @10 ml/kg	61.60	64.64	1774	1863	49.32
T_8: Zn @ 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ + molybdenum @ 2 g/kg seed + NPK consortia @10 ml/kg seed	63.71	65.64	1899	1 808	51.48
S.Em ±	1.51	1.23	65.18	135.50	1.75
CD (P=0.05)	NS	3.60	190.73	NS	NS

Conclusion

From the above research findings, it could be concluded that growth characters (plant height, branches/plant, dry matter accumulation/plant), physiological parameters (leaf area, leaf area index, CGR, RGR and chlorophyll content) and seed yield of chickpea significantly enhanced by the application of 7.5 kg/ha + 0.5% foliar spray of $ZnSO_4$ at 30 DAS along with seed treatment with molybdenum @ 2 g/kg seed and NPK consortia @10 ml/kg under rainfed conditions of Malwa Plateau region of Madhya Pradesh.

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