Original Research Article

Residual effect of the organic fertilizer and ~~inorganic fertilizers~~micronutrient management on the growth indices of chickpea under soybean-chickpea system in ~~vertisol~~Vertisol of central India

ABSTRACT

A field experiment was conducted at ICAR-Indian Institute of Pulses Research, Regional Station, Bhopalto evaluate the residual effect of the fertilizer with organic manure on the growth indices of chickpea in soybean-chickpea system in ~~vertisol~~ Vertisolof central India. The experiment was laid out in a split-plot design comprising two levels of farm yard manure (5 t FYM ha^{-1} or No FYM) in the main plots and six micronutrient management levels (control, 25 kg $ZnSO_4$ ha^{-1}, 12.5 kg $ZnSO_4$ ha^{-1} + zinc solubilizer~~solubilolizer~~, ammonium molybdate (AM) 1 g kg^{-1} seed treatment + 25 kg $ZnSO_4$ ha^{-1}, ammonium molybdate (AM) 1 kg ha^{-1} soil application + 25 kg $ZnSO_4$ ha^{-1}, and ammonium molybdate (AM) 1 g kg^{-1} seed treatment + 0.5% foliar spray of $ZnSO_4$ at 30 and 60 days after sowing) in sub-plots with three replications.The results revealed that the application of 5 t FYM ha^{-1} resulted in significantly higher values of plant height, dry matter accumulation, branches plant^{-1}, leaf area index, leaf area duration, absolute growth rate, crop growth rate, and relative growth rate than no application of FYM.Furthermore, ammonium molybdate (AM) at 1 kg ha^{-1} as a basal application with 25 kg ha^{-1} ZnSO4 significantly improved all the growth parameters, viz. plant height, dry matter accumulation (DMA), branches plant^{-1}, leaf area index, leaf area duration, absolute growth rate, crop growth rate, and relative growth rate over the control, 25 kg ZnSO4 ha^{-1} and 12.5 kg ZnSO4 ha^{-1} + zinc solubilizer.However, it was statistically on par with the AM 1 g kg^{-1} seed treatment + 25 kg ZnSO4 ha^{-1} + 25 kg ZnSO4 ha^{-1} and AM 1 g kg^{-1} seed treatment + 0.5% foliar spray of ZnSO4 with respect to all growth parameters.Thus, the application of farmyard manure 5 t ha^{-1} with AM at 1 kg ha^{-1} as a basal application with 25 kg ha^{-1} ZnSO4 could be used to sustain chickpea production and maintain soil fertility.The results highlight the importance of using plant nutrients from various sources and methods of application for realizing high chickpea productivity.

Kew words: FYM, Chickpea, ~~micronutrient~~Micronutrient, ~~vertisol~~Vertisol, Molybdenum and Zinc

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the second most important pulse crop globally, after the common bean (*Phaseolus vulgaris*), with a global production of about 17.2 Mt from 17.8 Mha (FAOSTAT, 2018).India is the largest chickpea-producing country in the world (followed by Australia and Turkey), accounting for approximately 66.19%, and contributes 86.03% of the total chickpea production in Asia.Other chickpea-producing countries are the United States, Canada, Mexico, Iran, Ethiopia, Pakistan, Turkey, Australia, and Myanmar (Jukanti*et al.*, 2012).Chickpea is a quality food rich in proteins, minerals, vitamins, and fibers that benefits the health of the domestic stock and humans (Graham and Vance, 2003; Jukanti*et al.*, 2012; Bohra *et al.*, 2014). They can be an affordable source of staple grain for

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Comment [AB1]: Very old reference. Please use latest reference.

millions of the world's poorest and are a nutritious stock feed (Bampidis and Christodoulou, 2011). At present, it is mainly used as a popular staple food in the Indian subcontinent. The dry seeds are ground into flour, eventually after roasting to make it more flavourful. There are a few names used in parallel: Chickpea flour, besan flour, gram flour, and garbanzo (bean) flour. The flour is high in protein and gluten-free (Reff????). Additionally, it provides benefits to farming systems that range from a smaller carbon footprint owing to biological nitrogen fixation to improved soil health.Chickpea is predominantly grown under rainfed conditions on stored soil water in arid and semiarid regions and is an integral component of cereal-legume cropping systems in many countries (Reff?????).

Organic manure helps maintain soil fertility by providing important plant nutrients, particularly micronutrients, which increase crop growth [(Sharma *et al*., 2014].). The use of manure also improves the physical, chemical, and biological quality of soil (Damse*et al*., 2014), thus having a long-term impact on subsequent crops (Dhaliwal *et al*.,2019; Kemal and Abera, 2015). Farmyard manure improves soil structure, water and nutrient retention capacity, root penetration, microbial activity, and nutrient exchange capacity, which in turn enhances soil fertility (Yazdanpanah *et al*., 2016; Zhao *et al*.,2016).Numerous research efforts have realized the balanced supply of micronutrients to be extremely important for maximizing overall development of pulse crops.Zinc deficiency is a major nutritional problem worldwide.Approximately 49% of Indian soils are deficient in zinc, and a response to zinc application has been reported for a number of crops, including chickpea (Katyal *et al*., 2004).Chickpea is mostly grown in rainfed areas and marginal soils with low available zinc (Zn); however, its productivity isaffected by micronutrient deficiencies in soil, particularly Zn deficiency. Zn is an essential micronutrient that plays an active role in plant metabolic activities and is directly or indirectly required by several enzymatic systems, including auxin, protein synthesis, seed production, and rate of maturity.In addition, it reduces water use, water use efficiency, nodulation, and N fixation (Ahlawat *et al*., 2007).Molybdenum is required for the growth of most biological organisms, including plants (Graham and Stangoulis 2005).Generally, Mo is an essential micronutrient for plants and bacteria (Williams and Fraustoda Silva 2002).The role of molybdenum in the normal assimilation of nitrogen by plants is well known because molybdenum is an essential component of nitrate reductase and nitogenase, which controls the reduction of inorganic nitrate and helps to fix N_2 to NH_3 (Meagher *et al.* (1991). Thus, molybdenum is key to nitrogen fixation by legumes.Molybdenum stimulates nodulation and biological nitrogen fixation (Brkics *et al*. 2004; Jongruaysup*et al*. 1993), and ascorbic acid synthesis is implicated in the physiological availability of iron (Katyal and Randhawa 1983).It also facilitates diverse physiological and biochemical processes, including photosynthesis as well as carbohydrate and sulfur metabolism.Optimization of Mo nutrition is invariably linked to the accelerated phyto-availability of other essential nutrients to crops.To the best of our knowledge, information on the effects of different combinations of organic and chemical fertilizers on chickpea growth and yield is lacking.Therefore, the present study aimed to examine the effects of FYM and different micronutrient management options on chickpea growth parameters.

Comment [AB2]: Please put reference

Comment [AB3]: Please put reference

Formatted: Subscript

Formatted: Subscript

Comment [AB4]: Please write something about Vertisol as you mentioned it in the title and link it with your literature review.

MATERIALS AND METHODS

The field experiment was conducted at the research farm of the ICAR-Indian Institute of Pulses Research, Regional Station, Bhopal, India during 2016-17.The site is located at 23°22'N latitude and 77°19'E longitude, 519 m above Mean Sea Level.The location falls under the agroclimatic zone “central plateau and hills region.”The total rainfall during the crop season from October to April was 41.6 mm during 2016–17. The average monthly maximum temperature of the study area varied from 24.2 ◦C to 33.9 ◦C however, the minimum temperature varied from 7.4 ◦C to 17.2 ◦C during the growing season of chickpea.The experimental soil was categorized as clay-loamin texture, slightly alkaline in reaction with pH 8.21, low in soil organic carbon (0.26%) &available nitrogen (243.05 kg ha-1) and medium phosphorus (14.26 kg ha-1) and high potassium (248.61 kg ha-1). The experiment was laid out in a split-plot design with three replications.The main plot consisted of two levels of FYM management (5 t FYM $ha^{-1}$and without FYM) and a sub-plot consisting of six treatments with different levels of micronutrient management (control, 25 kg $ZnSO_4$ ha-1, 12.5 kg $ZnSO_4$ ha-1 + zinc solubilizer, AM 1 g kg-1 seed treatment + 25 kg $ZnSO_4$ ha-1, AM 1 kg ha-1 soil application + 25 kg $ZnSO_4$ ha-1, and AM 1 g kg-1 seed treatment + 0.5% foliar spray of $ZnSO_4$ at 30 and 60 days after sowing).All of these treatments were imposed only on soybean crops during the kharif season and the residual effect of the treatments on chickpea grown during the rabi season.The recommended fertilizer doses of N, P_2O_5, and K_2O were, 30, 60 and 40 kg ha^{-1} for soybean, and 20, 60, and 40 kg ha^{-1} for chickpea.Zinc was added to the soil through $ZnSO_4$ and as a foliar spray of 0.5% $ZnSO_4$ on the aerial crop canopy.Molybdenum was applied through Ammonium Molybdate (1 kg ha^{-1} as soil application and 1 g kg^{-1} as seed treatment) per treatment.Before sowing, soybean seeds were treated with AM at 1 g kg^{-1} seed and Zn solubilizer at 3 ml kg^{-1} seed as per treatments, followed by Rhizobium inoculum (at 3–5 g kg^{-1} seed was mixed with jaggery solution and sprinkled over the healthy seeds). The seeds were thoroughly mixed to spread the inoculums over the entire surface of the seeds. Seeds were sown at 75 kg per ha with a spacing of 30 cm × 10 cm.All recommended practices were followed during the crop growth period, and the crops were harvested at maturity.Periodic data on plant height, dry matter accumulation, branches $plant^{-1}$ and leaf area were recorded at different growth stages to evaluate different growth indices. The following formula were used to determine various growth indices:

Absolute Growth Rate (AGR):

$$AGR\ (cm\ day^{-1}) = \frac{h_2 - h_1}{t_2 - t_1}$$

Absolute growth rate was determined by using the formula given by Radford (1967)

where, h_1 and h_2 are the plant height at t_1 and t_2 times, respectively

The crop growth rate (CGR) was determined using Watson’s (1956) formula:

$$\mathrm{CGR\ (g\ \ m^{-2}\ day^{-1})} = \frac{1}{\mathrm{p}} \cdot \frac{\mathrm{w_2 - w_1}}{\mathrm{t_2 - t_1}}$$

where w_1 and w_2 are whole-plant dry weights at t_1 and t_2 time, respectively. p is the ground area on which w_1 and w_2 were recorded.

Relative growth rate (RGR) was determined using the formula given by Fisher (1921).

$$\mathrm{RGR\ (g\ \ g^{-1}\ day^{-1})} = \frac{\log_e \mathrm{w_2} - \log_e \mathrm{w_1}}{\mathrm{t_2 - t_1}}$$

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Comment [AB5]: What about important chemical fertilizers like Nitrogen (N), Phosphorus (P) and Potassium (K). Did you apply these chemical fertilizers in the experimental fields. If yes, then please mention the dose of the chemical fertilizers which are the sources of N, P and K.

where w_1 and w_2 are the dry weights of the entire plant at times t_1 and t_2, respectively.

Leaf area index (LAI) was determined using the formula given by Williams (1946).

$$\mathrm{LAI} = \frac{\text{Total leaf area of the plant}}{\text{Ground area occupied by the plant}}$$

Leaf area ratio (LAR) was determined by using the formula given by Radford (1967).

Leaf Area Duration (LAD) was determined using the formula described by Power *et al*. (1967). LAD is expressed in days.

$$\mathrm{LAD} = \frac{L_1 + L_2}{2} \times (t_2 - t_1)$$

L_1 = LAI at the first stage, L_2 = LAI at the second stage, (t_2 - t_1) = Time interval in day

$$\mathrm{LAD}\ (\mathrm{g}\ cm^{-2}) = \frac{Leaf\ area\ per\ plant}{Plant\ dry\ weight}$$

All data were subjected to statistical analysis of variance (ANOVA) using OPSTAT software.Treatment means were compared using the least significant difference (LSD) test at 5%.

RESULTS AND DISCUSSION

Growth:

Plant height^{-1}:

The use of farmyard manure exhibited significant effects on various growth parameters, as shown in Table 1.The maximum plant height at all growth stages wasobtained with the application of 5 t FYM ha^{-1},which was significantly superior to no application of FYM.The percent increases in height at 30 DAS, 60 DAS, 90 DAS, and at harvest were 7.61, 10.71, 9.18 & 11.10 per cent, respectively over control.Significantly, lower plant height, DMA, and branch plant^{-1}in treatment F0 as compared to F1 clearly indicated the role of farmyard manure in enhancing growth parameters.The application of farmyard manure raises soil organic matter, which simultaneously improves soil structure and increases nutrient availability at the same time [(Apriyani, *et al*., 2021].).

Furthermore, among the micronutrient management options, the plant heght^{-1} at all growth stages (30, 60, 90 DAS, and at harvest) was significantly superior to the supply of AM at 1 kg ha^{-1} as basal application with 25 kg ha^{-1} $ZnSO_4$ over the rest of the treatment.However, it was statistically on par with the AM 1 g kg^{-1} seed treatment + 25 kg $ZnSO_4$ ha^{-1} and AM 1 g kg^{-1} seed treatment + 0.5% foliar spray of $ZnSO_4$.The above results might be due to the application of $ZnSO_4$, which influences plant vigor through the absorption of nutrients at critical stages that enhance the physiological activity of crops and increase the assimilation of photosynthates, ultimately increasing dry matter accumulation.Similar results have been reported by Amanullah *et al*. (2010).

Dry Matter Accumulation (DMA):

Comment [AB6]: Please write the elaboration of DAS

Comment [AB7]: Please follow same style for writing references in the text.

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Dry matter accumulation in chickpeas was significantly affected by the supply of farmyard manure to the crops.The application of 5 t FYM ha^{-1} significantly improved dry matter accumulation at 30, 60, and 90 DAS and at harvest by 21.13, 25.51, 19.08%, and 17.28 %, respectively, compared to the no use of FYM.The addition of FYM to soil enhances crop growth and indirectly affects the soil physical qualities, that is, aggregate stability and porosity, which can boost root growth and stimulate plant growth(Latare*et al.*, 2014).

Furthermore, a significant improvement in dry matter accumulation was also observed under different micronutrient management options.Application of AM at 1 kg ha^{-1} as a basal application with 25 kg ha^{-1} $ZnSO_4$ resulted in significantly higher dry matter accumulation at 30, 60, 90, and at harvest by 38.80, 40.59, 71.85%, and 48.28 %, respectively, compared to the control.However, it was statistically equivalent to the AM 1 g kg^{-1} seed treatment + 25 kg $ZnSO_4$ ha^{-1} and AM 1 g kg^{-1} seed treatment + 0.5% foliar spray of $ZnSO_4$.The results obtained were in tune with the findings of Mahilane and Singh (2018) and Wasaya *et al*. (2017) in their findings.

Table 1. Effect of farm yard manure and micronutrient levels on plant height, dry matter accumulation and branches $plant^{-1}$

Treatments	**Plant height** (cm)				**Dry matter accumulation** (g/m2)				**Branches plant^{-1}**
	30DAS	**60DAS**	**90DAS**	**At harvest**	**30DAS**	**60DAS**	**90DAS**	**At harvest**	
Farm Yard Manure (FYM)									
F0	20.75	35.65	51.94	52.61	0.71	2.43	8.28	26.97	2.98
F1	22.33	39.47	56.71	58.45	0.86	3.05	9.86	31.63	3.49
CD at 5%	1.97	3.41	4.18	4.72	0.13	0.42	0.95	2.59	0.37
Micronutrient management									
M0	19.28	33.97	49.22	50.85	0.67	1.99	7.34	23.26	2.67
M1	21.58	37.35	53.55	54.45	0.75	2.58	9.42	25.61	3.05
M2	21.15	36.42	53.48	54.48	0.72	2.21	8.07	28.39	3.10
M3	22.23	39.08	56.17	57.53	0.85	3.17	9.97	30.98	3.52
M4	23.23	40.48	58.43	59.15	0.93	3.42	10.32	34.49	3.58
M5	21.78	38.08	55.05	56.73	0.81	3.04	9.32	33.08	3.49
CD at 5%	1.69	2.81	4.42	4.23	0.14	0.46	0.99	2.84	0.34

Branches plant^{-1}:

Application of farm yard manuresignificantly influenced branch $plant^{-1}$ at chickpea harvest.Maximum branches $plant^{-1}$was recorded with the addition of 5 t FYM ha^{-1}, which was significantly higher by17.11 percent as compared that without the use of FYM.The FYM added macro- and micro-nutrients to the soil, which are readily available in soil solution and quickly absorbed by plants and their increasing amount of nutrients required for cell development, cell division, and elongation of the cell in the meristematic region of the plant, assisting in stem elongation ~~[~~(Verma*et al*., 2018~~]~~~~.~~).This may be because the use of FYM helps in maintaining nutritional status and availability of nutrients by supplying macro-and micronutrients, improving soil chemical and physical properties, increasing SOM content, and promoting overall plant growth ~~[~~(Singh and Sukul,2019;Agegnehu, *et al*.,2016~~]~~~~.~~).

Furthermore, micronutrient management options resulted in significant variations in branches plant^{-1}at harvest.Significantly higher branches plant^{-1}were observed under the treatment of AM at 1 kg ha^{-1} with 25 kg ha^{-1} $ZnSO_4$.However, it was at par withthe AM 1 g kg^{-1} seed treatment + 25 kg $ZnSO_4$ ha^{-1} and AM 1 g kg^{-1} seed treatment + 0.5% foliar spray of $ZnSO_4$.The result confirms the findings of Mahilane and Singh (2018).

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Growth indices:

The effects of farm yard manure and micronutrient levels on different growth indices, such as the absolute growth rate, crop growth rate, relative growth rate, leaf area index, and leaf area ratio, are presented in ~~Table~~ table 2.

Absolute growth rate:

Application of FYM significantly improved theabsolute growth rate at different growth stages up to 90 d after sowing.The 5 t FYM ha^{-1}treatment resulted in a significant enhancement in the absolute growth rate compared to that without FYM application.The maximum absolute growth rate was observed at 90 DAS and the lowest at 30 DAS.Because the absolute growth rate is directly related to plant height, a higher plant height under 5 t FYM ha^{-1}resulted in a higher absolute growth rate over not used.This result confirmed the findings of Malek *et al.* (2012). Micronutrient levels also influenced the absolute growth rate at all growth stages.The highest absolute growth rate was observed under AM at 1 kg ha^{-1} with 25 kg ha^{-1} ZnSO4, while the lowest was observed in the control.This might be due to the greater availability of nutrients, which affects the height of crop plants and leads to an increase in the absolute growth rate. Sharma *et al*. (2014) also reported similar results.

Crop growth rate (CGR):

The crop growth rate significantly influenced all growth stages with the supply of FYM.A significantly higher crop growth rate was registered under 5 t FYM ha^{-1}compared to that of the control.This may be due to the improvement in dry matter accumulation with the use of farmyard manure. Similar results were also reported by Thakur (2005). Micronutrient options significantly influenced the CGR at all crop growth stages.Application of AM at 1 kg ha^{-1} with 25 kg ha^{-1} $ZnSO_4$resulted in the highest crop growth rate at all growth stages.This was statistically at par with AM 1 g kg^{-1} seed treatment + 25 kg $ZnSO_4$ ha^{-1} and AM 1 g kg^{-1} seed treatment + 0.5% foliar spray of $ZnSO_4$.This might be due to the better nutritional environment for plant growth at the active vegetative stage as a result of improved root growth, which ultimately increases the dry matter and CGR.Similar results have been reported by Vyas and Kushwah (2015). Significantly higher CGR was recorded with 75 kg seed/ha at 30 days after sowing.The increase in CGR in chickpeas with Zn and Mo application might be due to the involvement of these nutrients in plant metabolism as

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

structural and functional constituents of enzymes, which further promotes plant water status, chlorophyll synthesis increases the translocation of photosynthetic assimilates and utilization of major and minor nutrients, increase in size and growth rate of organs, accumulation of dry matter, and CO_2 assimilation.The similar results were also reported by Mahilane and Singh (2018) Sritharan *et al.* (2015) and Wasaya *et al*. (2017).

Relative growth rate:

The use of FYM significantly did not affect relative growth rate at all the growth stages of chickpea. Further, micronutrient levels also significantly affected the relative growth rate at 30,60 and 90 days after sowing. The highest value of relative growth rate was recorded with AM at 1 kg ha^{-1} with 25 kg ha^{-1} $ZnSO_4$ followed by AM 1 g kg-1 seed treatment + 25 kg $ZnSO_4$ ha^{-1} and AM 1 g kg^{-1} seed treatment + 0.5% foliar spray of $ZnSO_4$. The lowest value of RGR was recorded in control. This increase is due to increase in leaf area, chlorophyll content and photosynthesis all these factors reflected the increase in RGR and total biomass. The similar findings reported by (Valenciano*et at* 2010).

Table 2. Effect of farm yard manure and micronutrient levels on absolute growth rate, crop growth rate, relative growth rate, leaf area index and leaf area duration

Treatments	**AGR** (cm/day)			**CGR** (g/m2 /day)			**RGR** (mg/g/day)			**LAI**			**LAD**		
	30DAS	**60DAS**	**90DAS**	**30DAS**	**60DAS**	**90DAS**	**30DAS**	**60DAS**	**90DAS**	**30DAS**	**60DAS**	**90DAS**	**30DAS**	**60DAS**	**90DAS**
Farm Yard Manure (FYM)															
F0	0.69	0.50	0.54	0.79	1.91	9.20	45.80	41.38	141.33	0.51	0.89	1.63	7.65	5.36	6.75
F1	0.74	0.57	0.57	0.96	2.43	10.96	41.98	39.50	141.74	0.53	0.97	2.09	7.95	5.96	9.12
CD at 5%	0.04	0.06	0.02	0.13	0.26	1.50	3.28	NS	NS	NS	0.07	0.30	NS	0.50	2.10
Micronutrient management															
M0	0.64	0.49	0.51	0.74	1.47	8.16	36.29	43.51	151.06	0.50	0.82	1.59	7.50	4.95	5.96
M1	0.72	0.53	0.54	0.83	2.03	10.47	41.18	43.17	150.88	0.53	0.92	1.94	7.95	5.76	8.24
M2	0.71	0.51	0.57	0.80	1.66	8.97	37.38	43.17	153.63	0.52	0.90	1.88	7.80	5.54	7.70
M3	0.74	0.56	0.57	0.94	2.58	11.08	43.88	38.19	136.52	0.58	0.97	2.06	8.70	6.74	10.21
M4	0.77	0.58	0.60	1.03	2.77	11.47	43.41	36.81	142.89	0.61	0.99	2.19	9.15	7.32	11.64
M5	0.73	0.54	0.57	0.90	2.48	10.36	44.09	37.34	151.91	0.57	0.96	1.99	8.55	6.54	9.65
CD at 5%	0.05	0.04	0.07	0.11	0.24	1.05	3.95	4.41	16.14	0.06	0.08	0.12	0.89	0.62	1.35

Formatted: Font: 12 pt

Formatted: Justified

Leaf area index:

Significant improvement in the leaf area index was noted under the application of farm yard manure except 30DAS. The 5 t FYM ha^{-1}significantly enhanced the value of leaf area index over without FYM. These results corroborated with the findings of Singh *et al*. (2010). Among the micronutrient options, the leaf area index significantly influenced all growth stages with the use of AM at 1 kg ha^{-1} with 25 kg ha^{-1} $ZnSO_4$ over the remaining treatments.However, it was statistically similar to the AM 1 g kg-1 seed treatment + 25 kg $ZnSO_4$ ha^{-1} and AM 1 g kg^{-1} seed treatment + 0.5% foliar spray of $ZnSO_4$ Similar results were also found by Das (2015).The higher leaf area might be due to the role of these nutrients in increasing the growth of the plant by supplementing the soil with available nutrients and influencing various physiological processes. The results obtained were in tune with the findings of Malik *et al*. (2015), Sritharan *et al.* (2015), and Sujeet (2016), respectively.

Leaf area Duration:

Leaf area duration was significantly influenced by the different FYM application options at all growth stages except 30DAS.The maximum value of leaf area duration was recorded with the use of 5 t FYM ha^{-1}, which was significantly higher than that when no FYM was used.Furthermore, micronutrient levels significantly influenced the LAR at all growth stages.The highest value of leaf area ratio was observed with AM at 1 kg ha^{-1} with 25 kg ha^{-1} $ZnSO_4$, whereas the lowest value was observed in the control.These results support the findings of Mahilane and Singh (2018).

CONCLUSON

The combined application of farm yard manure with ~~chemical fertilizers~~micronutrient provides essential nutrients to the crop, which could be considered as an alternate way of enhancing crop growth and sustaining crop productivity. Based on the data, it was concluded that 5 t FYM ha-1 with AM at 1 kg ha^{-1} with 25 kg ha^{-1} $ZnSO_4$ could be more beneficial for improving chickpea growth and sustainable crop production of chickpea under the soybean-chickpea system in vertisol in central India.

References:

Agegnehu, G.~~; ~~.,Nelson, P.N.~~; ~~.,Bird, M.I. 2016. Crop yield, plant nutrient uptake and soil physicochemical properties under organic soil amendments and nitrogen fertilization on nitisols. *Soil Tillage Res.* ***160*** 1–13.

AHLAWAT I.P.S., GANGAIAH B., ASHRAF ZADID M., 2007. Nutrient management in chickpea. In: Chickpea breeding and management (Yadav S.S., Redden R., Chen W., Sharma, B., eds.). CAB Int, Wallingford, Oxon, UK. pp. 213-232.

Apriyani, S.; Wahyuni, S.; Harsanti, E.S.; Zu'amah, H.; Kartikawati, R.; Sutriadi, M.T. 2021.Effect of inorganic fertilizer and farmyard manure to available P, growth and rice yield in rainfed lowland central java. *IOP Earth Environ. Sci. 648*, 012190.

Bampidis V.A. et Christodoulou V. 2011. Chickpeas (Cicer arietinum L.) in animal

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Formatted: Subscript

Comment [AB8]: Please follow same style for writing full references.

Damse, D.N.; Bhaleka, M.N.; Pawar, P.K. 2014. Effect of integrated nutrient management on growth and yield of garlic. *Bioscan*, **9**, 1557–1560.

Dhaliwal, S.S.; Ram, H.; Walia, S.S.; Walia, M.K.; Kumar, B.; Dhaliwal, M.K. 2019. Long-term influence of nutrient management on carbon and nutrients in Typic-Ustochrept soils. *Commun. Soil Sci. Plant Anal***50** 2420–2428.

Fisher, R.A. 1921. Statistical method for research works. Oliver and Boyd and Co. Inc. Endinburgh, UNITED KINGDOM

Graham RD, Stangoulis JRS 2005. Molybdenum and disease. In:Mineral nutrition and plant diseases (Dantoff L, Elmer W, Huber D.Eds) St. Paul, MN: APS Press

Graham, P.H. and Vance, C.P. (2003) Legume Importance and Constraints to Greater Use. *Plant Physiology***131**872-877. http://dx.doi.org/10.1104/pp.017004

Jongruaysup S., Ohara G.W., Dell B. and Bell R.W. 1993. Effects of low molybdenum seed on nodule initiation, development and N2 fixation in black gram (Vigna mungo L). *Plant-Soil*,**156:** 345 – 348.

Jukanti, A.K.; Gaur, P.M.; Gowda, C.L.L.; Chibbar, R.N. 2012. Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): A review. *Br. J. Nutr. 108*, S12–S26.

Katyal, J. and N. S. Randhawa. 1983. Micronutrients. FAO. Fertilizer and Plant Nutrition, Bulletin No. 7. United Nation.

Katyal, J.C., Rattan, R.K and Dutta, S.P. 2004. Management of Zn and B for sustainable crop production. *Fertiliser News*,**49**(12): 83-89

Kemal, Y.O.; Abera, M. 2015. Contribution of integrated nutrient management practices for sustainable crop productivity, nutrient uptake and soil nutrient status in maize-based cropping systems. *J. Nutr.***2** 1–26

Latare, A.M.; Kumar, O.; Singh, S.K.; Gupta, A. 2014. Direct and residual effect of sewage sludge on yield, heavy metals content and soil fertility under rice-wheat system. *Ecol. Eng. **69*** 17–24

Mahilane C, Singh V. 2018. Effect of Zinc and Molybdenum on Growth, Yield Attributes,Yield and Protein in Grain on Summer Blackgram (Vignamungo L.).*International Journal of Current Microbiology and Applied Sciences***7**(1):1156-1162.

Malek MA, Mondal MMA, Ismail MR, Rafii MY and Berahim Z. 2012. Physiology of seed yield in soybean: Growth and dry matter production. *African Journal of Biotechnology***11**(30): 7643-7649.

Meagher,W. R., M. Johnson and P. R. Stout. 1991. Molybdenum requirement of leguminous plants supplied with fixed nitrogen. *Plant Physiol.***27**(2): 623-629.

nutrition: A review. *Animal Feed Science and Technology* Vol. **168**(1-2). p. 1-20.

Radford, D.J. (1967) Growth analysis formulae - their use and abuse. *Crop Science* **7**, 171–175.

Sharma, M.; Sharma, Y.K.; Dotaniya, M.L. 2014, Effect of press mud and FYM application with zinc sulphate on yield of hybrid rice. *J. Environ. Agric. Sci.***1**, 21–34.

Singh, G., Sekhon, H.S., Ram, H. and Sharma, P. (2010). Effect of farmyard manure, phosphorus and phosphate solubilizing bacteria on nodulation, growth and yield of kabuli chickpea. *Journal of Food Legumes***23** (3&4): 226-229.

Singh, L.; Sukul, P. **2019.** Impact of vermicompost, farmyard manure, fly ash and inorganic fertilizers on growth and yield attributing characters of maize (*Zea mays* L.). *Plant Arch. **19***2193–2200.

Sritharan N, Rajavel M, Senthilkumar R. 2015. Physiological approaches Yield improvement in blackgram. *Legume Research***38**(1):91-95

Sujeet SJ. 2016. Relation between leaf area and leaf relative water content under the effect of different boron concentrations. *International Journal of Advanced Research***4**(1):1578-1580

Thakur BS. 2005. Relative performance of soybean varieties under varying plant population and row spacing. M.Sc. Thesis, Department of Agronomy, JNKVV, Jabalpur, India.

Valenciano, J. A. Boto and V. Marcelo 2010. Response of chickpea (Cicer arietinum L.) yield to zinc, boron and molybdenum application under pot conditions.*Spanish J. Agric. Res.***8**(3), 797-807.

Verma, K.; Bindra, A.D.; Singh, J.; Negi, S.C.; Datt, N.; Rana, U.; Manuja, S. 2018. Effect of integrated nutrient management on growth, yield attributes and yield of maize and wheat in maize-wheat cropping system in mid hills of Himachal Pradesh. *Int. J. Pure Appl. Biosci.* **6** 282–301

Vyas MD and Kushwah SS. 2015. Response of soybean [Glycine max (L.) Merril] varieties to fertility levels in Vertisols of Vindhyan Plateau of Madhya Pradesh. *Soybean Research***13**(2): 09-18.

Watson, D.J. (1956) Leaf growth in relation to crop yield. In: *The Growth of Leaves* (Ed. F.L. Milthorpe) pp. 178–191. Butterworth, U.K.

Williams RJP, Frausto da Silva JJR. 2002**.** The involvement of molybdenum in life. *Biochemical and Biophysical Research Communications* 292: 293–299.

Williams, R. F. 1946. The physiology of plant growth with special references to the concept of net assimilation rate. *Annals of Botany*, **10** 41-72.https://doi.org/10.1093/oxfordjournals.aob.a083119

Yazdanpanah, N.; Mahmoodabadi, M.; Cerda, A. 2016. The impact of organic amendments on soil hydrology, structure and microbial respiration in semiarid lands. *Geoderma***266** 58–65

Zhao, J.; Ni, T.; Li, J.; Lu, Q.; Fang, Z.; Huang, Q.; Zhang, R.; Li, R.; Shen, B.; Shen, Q. 2016. Effects of organic–inorganic compound fertilizer with reduced chemical fertilizer application on crop yields, soil biological activity and bacterial community structure in a rice-wheat cropping system. *Appl. Soil Ecol.***99** 1–12.