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Impact of Organic Manures and Humic Acid on Nutrient Dynamics and Crop Performance in Pearl Millet–Chickpea Cropping System

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Authors' contributions

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

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ABSTRACT

A field experiment was conducted at Agronomy Instructional Farm, Department of Agronomy, C. P. College of Agriculture, SDAU, Sardarkrushinagar to study the effect of organics and humic acid on *kharif* pearlmillet and their residual effect on succeeding chickpea during *kharif*- 2022 to 2023 and

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rabi 2022-23 to 2023-24. The soil of the experimental plot was loamy sand in texture, alkaline in reaction, normal in salinity, low in organic carbon, available N, medium in available P_2O_5 and K_2O and low DTPA- extractable Fe, Mn, Zn and Cu. The treatments were applied in *kharif* pearlmillet crop and their residual effect was studied in succeeding chickpea crop.
Residual effect of FYM @ 10 t ha^{-1} recorded significantly increased nutrients content *viz.,* N (), P, K, Fe in seed and stover and nutrients uptake *viz.,* N, P, K, Fe, Mn, Zn, Cu by seed and stover were significantly increased due to the residual effect of FYM @ 10 t ha^{-1}. Pooled results also revealed that residual effect of soil application of humic acid @ 30 kg ha^{-1} significantly increased nutrient uptake *viz*., N, P, K, Fe, Mn, Zn and Cu by seed and stover.

Keywords: Chickpea; FYM; humic acid; nutrient.

1. INTRODUCTION

As organic substances constantly undergo changes in the tropical soils, it must be replenished. For sustainable and high productivity of soil over prolonged period, maintenance of soil organic matter at a satisfactory level is necessary (Govindaswamy, 2002). Also it has been said that proper management of organic matter is the heart of sustainable agriculture (Stevenson, 1994). The sources of organic matter for incorporation into the soil are becoming scarce. The FYM is the source of primary, secondary and micro nutrients for plant and is a constant source of energy for heterotrophic microorganisms, which helps in increasing the availability of nutrients, quality and quantity of the crop produce (Deiana et al., 1990). Thus, fertilizing with FYM is one of the important measures favouring soil improvement, *i.e.* the special accumulation of nutrients, the increase in the amount of humus and the intensification of biological activity. The FYM is being used as a major source of organic manure in field crops since ancient times, while vermicompost is also becoming popular among the farmers as organic manure (Tan, 2003). However, limited availability of these manures and slow release of plant nutrients from the manures are an important constraints in their use as source of nutrients.

Recently, among the fertilization strategies, the soil and foliar spray with different molecules as humic acids had been introduced. These organic substances have no harmful threat to the quality of the environment and have excellent beneficial synergy with nutrients and compost (Lee and Bartlett, 1976).

Of the three humic substances, humic acid have received by far the most attention. Humic acid, often dubbed as the "dark gold of agriculture", is a naturally occurring polymeric organic compound derived from the decomposition of organic matter, found in humus, peat, and lignite (Sharif et al*.,* 2002). While alkali soluble, humic acid is insoluble in acid, with a molecular weight typically ranging from 10,000 to 100,000 Daltons (Da). Humic acid has a carbon content of 51-57%, nitrogen content of 4-6%, phosphorus content of 0.2-1% and other micronutrients are found in minute quantities (Haworth, 1971).The considerable and wide ranging action of humic acid primarily due to the presence of many functional groups (carboxylic, phenolic, alcoholic, hydroxyls *etc.*), which are capable of forming electrovalent and covalent bonds and intra complex compounds (Solaiappan et al*.,* 1995). Humic acids are most widely distributed organic materials in the earth and are found not only in the soils, but in natural waters, sewage, compost heaps, marine and lake sediments, peat bogs, carbonaceous shales, lignites, brown coals *etc* (Sathiyabhama et al. 2003). The study is concerned with using natural organic sources to reduce the use of mineral fertilization, Organic fertilization is environmentally friendly, improves soil properties, reduces carbon emissions, and mitigates the effects resulting from excessive mineral fertilization.

In cereal-pulses cropping system after pearl millet, chickpea is most fitted pulse crop in the system. Chickpea is a cool season crop that ranks second in area and third in production among the pulses worldwide. A chickpea seed contains 20–30% protein, about 40% carbohydrates, 3 – 6% oil, 6% crude fiber and 3% ash (Gil et al*.,* 1996). Chickpea is a good source of minerals (phosphorus, calcium, magnesium, iron and zinc) and β-carotene. Its protein quality is better than that of most other legume crops. As with other legumes, chickpea have ability to fix 80 to 120 kg of nitrogen per hectare through symbiotic nitrogen fixation and can be rotated with nitrogen-intensive crops such as cereals to improve soil conditions. interest in the chickpea crop is a leguminous crop; Chickpea is a good source of minerals (phosphorus, calcium, magnesium, iron and zinc) and β-carotene. Its protein quality is better than that of most other legume crops. As with other legumes, chickpea have ability to fix 80 to 120 kg of nitrogen per hectare through symbiotic nitrogen fixation and can be rotated with nitrogen-intensive crops such as cereals to improve soil conditions.

2. MATERIALS AND METHODS

The field experiment was laid out on a fixed site of plot number C-2 during *kharif*- 2022 and 2023 and *rabi* season of 2022-23 and 2023-24 at Agronomy Instructional Farm, C. P. College of Agriculture, SDAU, Sardarkrushinagar, Banaskantha (Gujarat). The topography of the experimental site was fairly uniform and levelled. The experiment was consisted of 48 treatment combinations *viz*. three sources *viz*., M_1:FYM @ 10 t ha^{-1}, M_2:Vermicompost @ 5 t ha^{-1} and M_3: Castor shell compost @ 5 t ha^{-1} and four levels of soil application of humic acid *viz*., HS_1: 00 kg ha^{-1}, HS_2:10 kg ha^{-1}, HS_3: 20 kg ha^{-1} and HS_4 : 30 kg ha^{-1} and four levels of foliar application of humic acid *viz*., HF_1 : 00 ppm, HF_2 :10 ppm, HF_3: 20 ppm and HF_4: 30 ppm were embedded in Randomized Block Design (factorial) with three replication. GG 5 chickpea variety used as test crop. The soil of the experimental plot was loamy sand in texture, alkaline in reaction, normal in salinity, low in organic carbon, available N, medium in available P_2O_5 and K_2O and low DTPA- extractable Fe, Mn, Zn and Cu. The treatments were applied in *kharif* pearlmillet crop and their residual effect was studied in succeeding chickpea crop.

3. RESULTS

3.1 Nutrient Content

3.1.1 Residual effect of organic manures

3.1.1.1 Nitrogen content

An examination of data presented in Table 1 explicit that the significantly the higher nitrogen content in seed *i.e.,* 3.312, 3.352 and 3.332 per cent during 2022-23, 2023-24 and in pooled results, respectively were recorded under the influence of FYM @ 10 t ha^{-1} over rest of the organic manures but it was remained at par with treatment vermicompost @ 5 t ha^{-1} during both the individual years and in pooled results. In case of stover significantly higher nitrogen content was recorded with FYM @ 10 t ha^{-1} during 2022-23, 2023-24 and in pooled results *i.e.,* 1.405. 1.413 and 1.409 per cent, respectively over rest of the treatment during both the years and in pooled results but it was remained at par with vrmicompost @ 5 t ha^{-1} during second year of experiment.

On pooled basis, the magnitude of increase in nitrogen content in succeeding chickpea seed and stover were 1.28 and 2.50 per cent and 1.73 and 3.99 per cent due to FYM @ 10 t ha^{-1} over vermicompot @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively.

3.1.2 Phosphorus content

It is explicit from the data presented in Table 2 indicate that significantly higher phosphorus content in chickpea seed *i.e.,* 0.507, 0.520 and 0.514 per cent and in stover *i.e.,* 0.188, 0.190 and 0.189 per cent were observed with the application FYM @ 10 t ha^{-1} during 2022-23, 2023-24 and in pooled basis, respectively as compared to rest of the treatments during both the individual year and in pooled results but it was remained at par with treatment vermicompost @ 5 t ha^{-1} in stover during both the years of experiments only.

On pooled basis, the magnitude of increase in phosphorus content in chikpea seed and stover were 6.42 and 10.77 per cent and 10.75 and 3.27 per cent, due to the application of FYM @ 10 t ha^{-1} compared to vermicompost @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively.

3.1.3 Potassium content

A perusal of data given in Table 3 revealed that the potassium content by seed and stover of chickpea was influenced significantly due to residual effect of different organic manures during both the individual years and in pooled study. Application of FYM @ 10 t ha^{-1} gave significantly higher potassium content in seed (0.693, 0.704 and 0.698 percent) and in stover (1.279, 1.283 and 1.281 percent) during both the individual year and in pooled basis, were is at par with application of vermicopost @ 5 t ha^{-1} in stover during second year only.

The magnitude of increase in potassium content in chickpea seed and stover were 2.95 and 3.86 per cent and 2.65 and 4.66 per cent, due to the application of FYM @ 10 t ha^{-1} compared to vermicompost @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively.

Application of huge quantity of farm yard manure to pearlmillet crop which firstly mineralized the nutrients and slowly releasing them up on the action of micro-organisms with lapse of time and also improved and sustained soil health. Secondly, due to mineralization process, the losses of nutrients either through leaching or volatilization might have been restricted. Which has increased the availability of plant nutrients throughout the crop period might be resulted in higher nutrients (N, P and K) content in seed and stover. These results are in close confirmity with the findings of Maitra et al. (2014).

3.1.4 Iron content

Significantly the higher content of iron by seed *i.e.,* 58.35, 59.21 and 58.78 mg and stover of chickpea were recorded under residual effect of FYM @ 10 t ha^{-1} as compared to castor shell compost and vermicpost @ 5 t ha^{-1} during both the year and in pooled results. This might be due to an application of large quantity of farm yard manure to pearlmillet crop led to more availability of iron by residual fertility status which resulted into higher concentration of iron in grain and stover. These results are in close confirmity with Dhaliwal et al. (2023).

3.1.5 Manganese, Zinc and copper content

The data pertaining to the Mn, Zn and Cu content in chickpea seed and stover did not differ significantly by treatment contenting residual effect of application of organics during both individual year and in pooled basis (Table 4.).

3.2 Residual Effect of Soil and Foliar Application of Humic Acid

The data pertaining to the residual effect of different levels of soil application of humic acid and foliar application of humic acid had no significant effect on N, P, K, Fe, Mn, Zn and Cu content in chickpea seed and stover during both the years of study and in pooled results

3.3 Interaction Effect

An evaluation of mean data presented in revealed that there is no any significant interaction effect was obtained due to the residual effect of organic manures and humic acid on N, P, K, Fe, Mn, Zn and Cu content in chickpea seed and stover.

3.4 Nutrient Uptake

3.4.1 Residual effect of organic manures

3.4.1.1 Nitrogen uptake

A critical scrutiny of data presented in Table 4. indicated that among all the organic manures significantly the higher residual effect was registered under the influence of FYM @ 10 t ha^{-1} over rest of the organic manures during both the individual years as well as in pooled results but it remined at par with treatment vermicompost @ 5 t ha^{-1} in seed of chickpea during the first year only. Residual effect of FYM @ 10 t ha^{-1} significantly improved the nitrogen uptake by seed were 5.17 and 13.9 per cent and in stover were 6.28 and 16.23 per cent over vermicompost @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively, on pooled basis.

This might be due to FYM provide more favourable condition for N fixation by chickpea and higher seed and stover yields are also found under FYM. The results of this study also corroborated the findings of Senthilvalavan and Ravichandran (2016).

3.4.2 Phosphorus uptake

A critical examination of data presented in Table 4. revealed that the application of FYM @ 10 t ha^{-1} to preceding pearlmillet recorded significantly higher phosphorus uptake by succeeding chickpea seed (11.12, 12.07 and 11.64 kg ha^{-1}) and stover (6.58, 6.91 and 6.75 kg ha^{-1}) during 2022-23, 2023-24 and on pooled basis, respectively over rest of the treatments both in seed and stover during both the individual year and in pooled results.

Residual effect of FYM @ 10 t ha^{-1} significantly improved the phosphorus uptake by seed were 10.76 and 22.40 per cent and in stover were 6.81 and 15.19 per cent over vermicompost @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively, on pooled basis. This might be due to higher residual available phosphorus was obtained under the treatment of FYM. These results are in close conforming to the finding of Senthilvalavan and Ravichandran (2016) in blackgram.

3.4.3 Potassium uptake

A perusal of data given in Table 4. revealed that the potassium uptake by seed and stover of chickpea influenced significantly due to the residual effect of different organic manures during both the years of study and in pooled data. An application of FYM @ 10 t ha^{-1} to preceding pearlmillet significantly improved the potassium uptake by succeeding chickpea seed and stover during both the individual years and in pooled results.

Residual effect of FYM @ 10 t ha^{-1} significantly improved the potassium uptake by seed were 7.25 and 17.80 per cent and in stover were 7.14 and 16.95 per cent over vermicompost @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively, on pooled basis. This might be due to higher residual available potassium and grain and stover yield of chikcpea was obtained under the treatment of FYM. The results of this study also corroborated the findings of Senthilvalavan and Ravichandran (2016).

3.4.4 Iron uptake

The data presented in Table 4. indicated that significantly higher uptake of iron by seed (129.12, 137.09 and 133.10 g ha^{-1}) and stover (586.45, 620.87 and 603.66 g ha^{-1}) of succeeding chickpea were recorded due to the residual effect of FYM @ 10 t ha^{-1} during both the individual years of field experiment and in pooled results as compared to rest of the treatments. Residual effect of FYM @ 10 t ha^{-1} significantly improved iron uptake by seed were 11.72 and 12.84 per cent and in stover were 8.014 and 13.46 per cent over vermicompost @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively, on pooled basis.

The increased uptake of micronutrients in seed and stover due FYM @ 10 t ha^{-1} application is ascribed to the role of organic matter in supplying different micronutrients, also it improved physical properties of the soil. These improvements, in turn, bring the native Fe into soluble from which ultimately improve iron uptake by chickpeas seed and stover. These results are in close conformity with Dhaliwal et al. (2023).

3.4.5 Manganese uptake

A perusal of data presented in Table 4. revealed that the Mn uptake by chickpea seed influence significantly due to residual effect of different organic manures during both the individual years of study and in pooled basis, significantly higher Mn uptake by seed (37.83, 40.05 and 38.94 g ha^{-1}) and stover (162.73, 170.63 and 166.68 g ha^{-1}) was obtained under the residual effect of FYM @ 10 t ha^{-1} produced and remained at par with vermicompost @ 5 t ha^{-1} in seed during first year only.

On pooled basis, the magnitude of increased in Mn uptake through residual effect of FYM @ 10 t ha^{-1} by chickpea seed were 4.48 and 11.70 per cent and by stover were 5.73 and 13.50 per cent over vermicompost 5 t ha^{-1} and castor shell compost 5 t ha^{-1}, respectively.

This might be due to FYM provide more favourable condition for N fixation by chickpea and higher seed and stover yields are also found under FYM. The results of this study also corroborated the findings of Senthilvalavan and Ravichandran (2016).

3.4.6 Zinc uptake

A perusal of data presented in Table 4. revealed that the zinc uptake by chickpea seed and stover influence significantly due to residual effect of different organic manures during both the individual years in pooled basis, significantly higher zinc uptake by seed (96.90, 102.05 and 99.47 g ha^{-1}) and by stover (125.05, 130.42 and 127.74 g ha^{-1}) was obtained under the residual effect of FYM @ 10 t ha^{-1} during 2022-23, 2023-24 and in pooled results, respectively under the residual influenced of FYM @ 10 t ha^{-1} over rest of treatments. Residual effect of FYM @ 10 t ha^{-1} significantly improved the zinc uptake by seed were 5.55 and 11.23 per cent and in stover were 6.22 and 13.22 per cent over vermicompost @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively, on pooled basis.

It might be due to the fact that at higher dose of organic manures especially FYM content higher zinc content and microbial count, easily decompose the organic matters and produce some acids which increase the availability of zinc. Thus, the favourable effect of organic manures near rhizosphere creates a better environment for absorption of nutrients by chickpea and their translocation to different plant parts including seed and stover. These results are in close conforming to the finding of Dhaliwal et al. (2023).

3.4.7 Copper uptake

The data presented in Table 4. indicated that significantly higher uptake of Cu by seed (10.12, 10.69 and 10.41 g ha^{-1}) and stover (23.61, 24.87 and 24.24 g ha^{-1}) of succeeding chickpea were recorded due to the residual effect of FYM @ 10 t ha^{-1} during both the individual years of field experiment and in pooled results as compared to rest of the treatments but it was remained at par with treatments vermicompost @ 5 t ha^{-1} by seed during first year and stover both the year and in pooled.

Residual effect of FYM @ 10 t ha^{-1} significantly improved iron uptake by seed were 4.73 and 12.30 per cent and in stover were 6.04 and 12.85 per cent over vermicompost @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively, on pooled basis.

The increased uptake of micronutrients in seed and stover due FYM @ 10 t ha^{-1} application is ascribed to the role of organic matter in supplying different micronutrients, also it improved physical properties of the soil. These improvements, in turn, bring the native Cu into soluble from which ultimately improve iron uptake by chickpea seed and stover. These results are in close conformity with Dhaliwal et al. (2023).

3.5 Residual Effect of Soil Application of Humic Acid

3.5.1 Nitrogen uptake

It is evident from the result furnished in Table 4. explicit that N uptake by chickpea seed and stover influenced significantly due to residual effect of soil application of humic acid during both the individual years and in pooled data. The highest N uptake by seed (71.96, 75.45 and 73.71 kg ha^{-1}) and (47.15, 50.73 and 48.94 kg ha^{-1}) by stover of chickpea was observed with the soil application of humic acid @ 30 kg ha^{-1} it was remained at par with treatment soil application of humic acid @ 20 kg ha^{-1} during both the individual years of study and in second year and in pooled results in stover.

The residual effect of humic acid on a succeeding chickpea crop enhances nutrient uptake by improving nutrient availability through chelation, boosting soil structure, increasing cation exchange capacity (CEC) and stimulating root growth. It also promotes microbial activity, aiding in nutrient mineralization and organic matter breakdown, which ensures essential nutrients remain accessible to the crop. These favorable conditions may improve nitrogen fixation in chickpeas, contributing to higher seed and stover yields under humic acid application, ultimately leading to better plant health and productivity were with closely confirm with Nardi et al. (2002), Canellas et al. (2015) and Nardi et al. (2021).

3.5.2 Phosphorus uptake

The data presented in Table 4. indicated that phosphorus uptake by chickpea seed and stover influenced significantly due to residual effect of soil application of humic acid during second year and in pooled data. The phosphorus uptake by seed (11.38 and 11.01 kg ha^{-1}) and (6.76 and 6.59 kg ha^{-1}) in stover of chickpea was observed with the soil application of humic acid 30 kg ha^{-1} it was remained at par with treatment soil application of humic acid 20 kg ha^{-1} in stover during second years of study and in pooled results.

The residual effect of humic acid on a succeeding chickpea crop enhances nutrient uptake by improving nutrient availability through chelation, boosting soil structure, increasing cation exchange capacity (CEC) and stimulating root growth. It also promotes microbial activity, aiding in nutrient mineralization and organic matter breakdown, which ensures essential nutrients remain accessible to the crop. These favorable conditions may improve nitrogen fixation in chickpeas, contributing to higher seed and stover yields under humic acid application, ultimately leading to better plant health and productivity were with closely confirm with Canellas et al. (2015), Nardi et al. (2002) and Nardi et al. (2021).

3.5.3 Potassium uptake

The data presented in Table 4. ndicated that potassium uptake by chikcpea seed and stover influenced significantly due to residual effect of soil application of humic acid during both the individual years and in pooled data. The highest potassium uptake by seed (15.79 and 15.31 kg ha^{-1}) and (45.48 and 44.05 kg ha^{-1}) Stover of chickpea was observed with the soil application of humic acid 30 kg ha^{-1} it was remained at par with treatment soil application of humic acid 20 kg ha^{-1} during second year and in pooled results by seed and stover. The residual effect of humic acid on a succeeding chickpea crop enhances nutrient uptake by improving nutrient availability through chelation, boosting soil structure, increasing cation exchange capacity (CEC) and stimulating root growth. It also promotes microbial activity, aiding in nutrient mineralization and organic matter breakdown, which ensures essential nutrients remain accessible to the crop. These favorable conditions may improve nitrogen fixation in chickpeas, contributing to higher seed and stover yields under humic acid application, ultimately leading to better plant health and productivity were with closely confirm with Canellas et al. (2015) and Nardi et al. (2002).

3.5.4 Iron uptake

The data presented in Table 4. indicated that iron uptake by chickpea seed and stover had significant influence due to the residual effect of soil application of humic acid during both the individual year and in pooled basis. The soil application of humic acid 30 kg ha^{-1} observed highest iron content by seed (124.75, 131.90 and 129.33 g ha^{-1}) and (572.87, 610.86 and 591.86 g ha^{-1}) stover of chickpea and it was remained at par with soil application of humic acid 10 and 20 kg ha^{-1} in seed during first year. Soil application of humic acid 20 kg ha^{-1} in stover during both the year and in pooled result.

The residual effect of humic acid on a succeeding chickpea crop enhances nutrient uptake by improving nutrient availability through chelation, boosting soil structure, increasing cation exchange capacity (CEC) and stimulating root growth. It also promotes microbial activity, aiding in nutrient mineralization and organic matter breakdown, which ensures essential nutrients remain accessible to the crop. These favorable conditions may improve nitrogen fixation in chickpeas, contributing to higher seed and stover yields under humic acid application, ultimately leading to better plant health and productivity were with closely confirm with Canellas et al. (2015) and Nardi et al. (2002).

3.5.5 Manganese uptake

The data presented in Table 2 indicated that Mn uptake by chickpea seed and stover had significant influence due to the residual effect of soil application of humic acid during second year and in pooled basis. The soil application of humic acid 30kg ha^{-1} observed highest iron uptake by seed (39.77 and 38.49 g ha^{-1}) and (168.21 and 163.21 g ha^{-1}) stover of chickpea and it was remained at par with treatment soil application of humic acid 20 kg ha^{-1} in seed during second year and in stover during second year and in pooled result.

The residual effect of humic acid on a succeeding chickpea crop enhances nutrient uptake by improving nutrient availability through chelation, boosting soil structure, increasing cation exchange capacity and stimulating root growth. It also promotes microbial activity, aiding in nutrient mineralization and organic matter breakdown, which ensures essential nutrients remain accessible to the crop. These favorable conditions may improve nitrogen fixation in chickpeas, contributing to higher seed and stover yields under humic acid application, ultimately leading to better plant health and productivity were with closely confirm with Canellas et al. (2015) and Nardi et al. (2002).

3.5.6 Zinc uptake

Significant differences were observed (Table 4) on zinc uptake by seed and stover of chickpea due to residual effect of soil application of humic acid during each individual years and also in pooled analysis. The highest zinc uptake by seed *i.e,* 100.88 and 97.66 g ha^{-1} was observed with the soil application of humic acid 30 kg ha^{-1} rest of treatment but in case of stover Zn uptake by stover (125.36 g ha^{-1}) in pooled result only under the Soil application of humic acid 30 kg ha^{-1} and it was at with soil application of humic acid 20 kg ha^{-1}, respectively.

3.5.7 Copper uptake

The data presented in Table 4. indicated that Cu uptake by chickpea seed and stover had significant influence due to the residual effect of soil application of humic acid during second year and in pooled basis. The soil application of humic acid 30 kg ha^{-1} observed highest cu uptake by seed i.e., 10.46 and 10.16 g ha and by stover *i.e.,* 24.39 and 23.65 g ha^{-1} during second year and in pooled result and it was remained at par with treatment of soil application of humic acid 20 kg ha^{-1} second year and in pooled basis.

The residual effect of humic acid on a succeeding chickpea crop enhances nutrient uptake by improving nutrient availability through chelation, boosting soil structure, increasing cation exchange capacity and stimulating root growth. It also promotes microbial activity, aiding in nutrient mineralization and organic matter breakdown, which ensures essential nutrients remain accessible to the crop. These favorable conditions may improve nitrogen fixation in chickpeas, contributing to higher seed and stover yields under humic acid application, ultimately leading to better plant health and productivity were with closely confirm with Canellas et al. (2015) and Nardi et al. (2002).

Table 1. Nitrogen and phosphorus content of chickpea as influenced by residual effect organics and humic acid

Treatments	**N content (%)**						**P content (%)**					
	Seed			**Stover**			**Seed**			**Stover**		
	2022-23	**2023-23**	**Pooled**	**2022-23**	**2023-24**	**Pooled**	**2022-23**	**2023-23**	**Pooled**	**2022-23**	**2023-23**	**Pooled**
Levels of organics (M)												
M_1: FYM @ 10t/ha	3.312	3.352	3.332	1.405	1.413	1.409	0.507	0.520	0.514	0.188	0.190	0.189
M_2: VC @ 5 t/ha	3.278	3.303	3.290	1.371	1.398	1.385	0.480	0.486	0.483	0.183	0.186	0.185
M_3: CSC @ 5 t/ha	3.235	3.268	3.251	1.350	1.360	1.355	0.463	0.466	0.464	0.182	0.184	0.183
S.Em. ±	0.022	0.024	0.016	0.011	0.009	0.007	0.0040	0.0053	0.00	0.002	0.002	0.001
C.D. (P= 0.05)	0.061	0.067	0.045	0.030	0.026	0.019	0.0112	0.0148	0.009	0.004	0.005	0.003
Levels of soil application of humic acid (HS)												
HS_1: 00 kg/ha	3.232	3.292	3.262	1.372	1.375	1.374	0.479	0.481	0.480	0.181	0.184	0.183
HS_2:10 kg/ha	3.258	3.300	3.279	1.372	1.382	1.377	0.481	0.487	0.484	0.184	0.186	0.185
HS_3:20 kg/ha	3.294	3.314	3.304	1.377	1.392	1.385	0.483	0.494	0.489	0.185	0.188	0.187
HS_4:30 kg/ha	3.315	3.325	3.320	1.381	1.412	1.396	0.490	0.500	0.495	0.187	0.189	0.188
S.Em. ±	0.025	0.028	0.019	0.012	0.011	0.008	0.0046	0.0061	0.0038	0.002	0.002	0.001
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Levels of foliar application of humic acid (HF)												
HF_1: 00 PPM	3.264	3.273	3.269	1.369	1.380	1.374	0.477	0.485	0.481	0.183	0.185	0.184
HF_2:10 PPM	3.268	3.304	3.286	1.373	1.385	1.379	0.483	0.486	0.485	0.184	0.186	0.185
HF_3:20 PPM	3.282	3.308	3.295	1.378	1.393	1.386	0.483	0.494	0.489	0.185	0.187	0.186
HF_4:30 PPM	3.284	3.345	3.315	1.382	1.403	1.393	0.489	0.497	0.493	0.186	0.189	0.187
S.Em. ±	0.025	0.028	0.019	0.01	0.01	0.01	0.005	0.006	0.004	0.0018	0.0022	0.0014
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sig. interactions	-	-	0.0915	-	-	-	-	-	-	-	-	-
CV%	4.61	5.01	4.82	5.30	4.59	4.95	5.72	7.46	6.66	5.78	7.04	6.45

Table 2. Potassium content of chickpea as influenced by residual effect organics and humic acid

Treatments	**K content (%)**					
	Seed			**Stover**		
	2022-23	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**
Levels of organics (M)						
M_1: FYM @ 10 t/ha	0.693	0.704	0.698	1.279	1.283	1.281
M_2: Vermicompost @ 5 t/ha	0.675	0.680	0.678	1.237	1.259	1.248
M_3: Castor shell compost @ 5 t/ha	0.669	0.675	0.672	1.214	1.235	1.224
S.Em. ±	0.004	0.005	0.003	0.012	0.009	0.007
C.D. (P= 0.05)	0.012	0.015	0.009	0.032	0.025	0.020
Levels of soil application of humic acid (HS)						
HS_1:00 kg/ha	0.675	0.679	0.677	1.238	1.253	1.245
HS_2:10 kg/ha	0.677	0.686	0.682	1.240	1.254	1.247
HS_3:20 kg/ha	0.680	0.686	0.683	1.247	1.263	1.255
HS_4:30 kg/ha	0.683	0.695	0.689	1.248	1.266	1.257
S.Em. ±	0.005	0.006	0.004	0.013	0.010	0.008
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS
Levels of foliar application of humic acid (HF)						
HF_1:00 PPM	0.674	0.682	0.678	1.228	1.250	1.239
HF_2:10 PPM	0.679	0.687	0.683	1.236	1.257	1.246
HF_3:20 PPM	0.681	0.688	0.684	1.254	1.263	1.259
HF_4:30 PPM	0.682	0.690	0.686	1.255	1.265	1.260
S.Em. ±	0.005	0.006	0.004	0.013	0.010	0.008
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS
Sig. interactions(S)	-	-	-	-	-	
CV%	4.45	5.27	4.88	6.43	4.86	5.69

Table 3. Iron and manganese content of chickpea as influenced by residual effect organics and humic acid

Treatments	Fe content (mg kg^{-1})						Mn content (mg kg^{-1})					
	Seed			Stover			Seed			Stover		
	2022-23	2023-23	Pooled	2022-23	2023-24	Pooled	2022-23	2023-23	Pooled	2022-23	2023-23	Pooled
Levels of organics (M)												
M$_1$: FYM @ 10t/ha	58.35	59.21	58.78	167.06	170.57	168.82	17.11	17.35	17.23	46.30	46.83	46.57
M$_2$: VC @ 5 t/ha	54.50	54.97	54.74	162.07	164.23	163.15	16.97	17.23	17.10	45.85	46.23	46.04
M$_3$: CSC @ 5 t/ha	57.14	58.16	57.65	165.14	167.08	166.11	16.90	17.12	17.01	45.53	46.16	45.85
S.Em. ±	0.55	0.47	0.36	1.34	1.79	1.12	0.15	0.15	0.11	0.31	0.35	0.23
C.D. (P= 0.05)	1.54	1.31	1.00	3.77	5.03	3.12	NS	NS	NS	NS	NS	NS
Levels of soil application of humic acid (HS)												
HS$_1$: 00 kg/ha	55.19	57.07	56.13	161.71	166.16	163.93	16.76	16.94	16.85	45.64	46.09	45.87
HS$_2$:10 kg/ha	56.98	57.18	57.08	163.78	166.34	165.06	17.02	17.21	17.12	45.72	46.29	46.01
HS$_3$:20 kg/ha	57.10	57.48	57.29	166.04	166.51	166.28	17.06	17.26	17.16	45.93	46.44	46.18
HS$_4$:30 kg/ha	57.39	58.06	57.73	167.49	170.16	168.82	17.13	17.53	17.33	46.29	46.81	46.55
S.Em. ±	0.63	0.54	0.42	1.55	2.07	1.29	0.17	0.18	0.12	0.35	0.40	0.27
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Levels of foliar application of humic acid (HF)												
HF$_1$: 00 PPM	55.98	56.85	56.41	162.73	164.50	163.62	16.91	16.81	16.86	45.31	46.13	45.72
HF$_2$:10 PPM	56.33	57.15	56.74	164.36	167.43	165.90	16.94	17.30	17.12	45.88	46.33	46.10
HF$_3$:20 PPM	56.78	57.79	57.28	164.49	168.22	166.36	17.01	17.41	17.21	46.05	46.52	46.29
HF$_4$:30 PPM	57.58	58.00	57.79	167.44	169.01	168.23	17.12	17.42	17.27	46.34	46.65	46.50
S.Em. ±	0.63	0.54	0.42	1.55	2.07	1.29	0.17	0.18	0.12	0.35	0.40	0.27
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sig. interactions	-		-	-	-	-	-	-	-	-	-	-
CV%	6.69	5.64	6.18	5.64	7.41	6.60	5.92	6.11	6.02	4.63	5.16	4.90

Table 4. Zinc and copper content of chickpea as influenced by residual effect organics and humic acid

Treatments	Zn content (mg kg^{-1})						Cu content (mg kg^{-1})					
	Seed			Stover			Seed			Stover		
	2022-23	2023-23	Pooled	2022-23	2023-24	Pooled	2022-23	2023-23	Pooled	2022-23	2023-23	Pooled
Levels of organics (M)												
M_1: FYM @ 10t/ha	43.84	44.16	44.00	35.60	35.81	35.70	4.580	4.616	4.598	6.721	6.821	6.771
M_2: VC @ 5 t/ha	42.94	43.53	43.24	34.71	35.49	35.10	4.550	4.583	4.566	6.696	6.655	6.676
M_3: CSC @ 5 t/ha	43.23	43.91	43.57	35.13	35.37	35.25	4.492	4.564	4.528	6.649	6.764	6.706
S.Em. ±	0.30	0.35	0.23	0.26	0.25	0.18	0.03	0.03	0.02	0.050	0.048	0.035
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Levels of soil application of humic acid (HS)												
HS_1: 00 kg/ha	42.71	43.34	43.02	34.68	35.64	35.16	4.500	4.506	4.50	6.675	6.662	6.668
HS_2:10 kg/ha	43.51	43.54	43.52	34.87	35.68	35.28	4.546	4.600	4.57	6.678	6.757	6.718
HS_3:20 kg/ha	43.56	44.20	43.88	35.23	35.14	35.19	4.575	4.636	4.61	6.686	6.781	6.734
HS_4:30 kg/ha	43.57	44.39	43.98	35.79	35.76	35.78	4.541	4.608	4.57	6.715	6.787	6.751
S.Em. ±	0.35	0.41	0.27	0.30	0.29	0.21	0.04	0.04	0.03	0.058	0.056	0.040
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Levels of foliar application of humic acid (HF)												
HF_1: 00 PPM	43.14	43.12	43.13	34.48	35.51	34.99	4.528	4.554	4.54	6.656	6.687	6.672
HF_2:10 PPM	43.22	43.80	43.51	35.22	35.39	35.30	4.533	4.560	4.55	6.678	6.756	6.717
HF_3:20 PPM	43.46	43.83	43.65	35.28	35.48	35.38	4.536	4.578	4.56	6.687	6.767	6.727
HF_4:30 PPM	43.54	44.72	44.13	35.60	35.85	35.72	4.565	4.659	4.61	6.733	6.776	6.754
S.Em. ±	0.35	0.41	0.27	0.30	0.29	0.21	0.04	0.04	0.03	0.058	0.056	0.040
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sig. interactions	-	-	-	-	-	-	-	-	-	-	-	-
CV%	4.86	5.56	5.22	5.10	4.96	5.03	4.95	5.09	5.02	5.22	4.96	5.09

Table 5. Nitrogen and phosphorus uptake by chickpea as influenced by residual effect of organics and humic acid

Treatments	N uptake (kg ha^{-1})						P uptake (kg ha^{-1})					
	Seed			Stover			Seed			Stover		
	2022-23	2023-23	Pooled	2022-23	2023-24	Pooled	2022-23	2023-23	Pooled	2022-23	2023-23	Pooled
Levels of organics (M)												
M_1: FYM @ 10t/ha	73.23	77.50	75.36	49.37	51.50	50.44	11.22	12.07	11.64	6.58	6.91	6.75
M_2: VC @ 5 t/ha	70.78	72.53	71.66	46.32	48.61	47.46	10.35	10.67	10.51	6.18	6.46	6.32
M_3: CSC @ 5 t/ha	65.58	67.70	66.64	42.97	43.83	43.40	9.36	9.65	9.51	5.79	5.93	5.86
S.Em. ±	1.120	1.436	0.911	0.848	0.951	0.637	0.158	0.244	0.146	0.108	0.126	0.083
C.D. (P= 0.05)	3.14	4.03	2.54	2.38	2.67	1.78	0.44	0.69	0.41	0.30	0.35	0.23
Levels of soil application of humic acid (HS)												
HS_1: 00 kg/ha	67.11	69.92	68.52	45.05	45.79	45.42	9.94	10.24	10.09	5.95	6.13	6.04
HS_2:10 kg/ha	69.30	70.56	69.93	45.93	46.97	46.45	10.25	10.41	10.33	6.12	6.31	6.22
HS_3:20 kg/ha	71.08	74.36	72.72	46.73	48.44	47.59	10.41	11.15	10.78	6.28	6.52	6.40
HS_4:30 kg/ha	71.96	75.45	73.71	47.15	50.73	48.94	10.63	11.38	11.01	6.40	6.79	6.59
S.Em. ±	1.293	1.658	1.051	0.979	1.098	0.735	0.182	0.282	0.168	0.125	0.146	0.096
C.D. (P= 0.05)	3.63	4.66	2.93	NS	3.08	2.05	NS	0.793	0.469	NS	0.41	0.27
Levels of foliar application of humic acid (HF)												
HF_1: 00 PPM	69.45	69.98	69.72	45.63	46.43	46.03	10.14	10.40	10.27	6.10	6.22	6.16
HF_2:10 PPM	69.65	72.25	70.95	46.19	47.51	46.85	10.31	10.66	10.48	6.17	6.38	6.28
HF_3:20 PPM	70.06	72.91	71.48	46.40	48.67	47.53	10.31	10.92	10.62	6.21	6.51	6.36
HF_4:30 PPM	70.29	75.16	72.73	46.65	49.31	47.98	10.47	11.20	10.84	6.26	6.63	6.44
S.Em. ±	1.29	1.66	1.05	0.98	1.10	0.74	0.182	0.282	0.168	0.12	0.15	0.10
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sig. interactions	-	-	-	-	-	-	-	-	-	-	-	-
CV%	11.10	13.71	12.53	12.71	13.73	13.25	10.62	15.69	13.51	12.11	13.59	12.91

Table 6. Potassium uptake by chickpea as influenced by residual effect of organics and humic acid

Treatments	K uptake (kg ha^{-1})					
	Seed			Stover		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Levels of organics (M)						
M_1: FYM @ 10 t/ha	15.33	16.33	15.83	44.89	46.76	45.82
M_2: Vermicompost @ 5 t/ha	14.59	14.94	14.76	41.78	43.76	42.77
M_3: Castor shell compost @ 5 t/ha	13.59	13.99	13.79	38.61	39.75	39.18
S.Em. ±	0.256	0.318	0.204	0.779	0.828	0.568
C.D. (P= 0.05)	0.72	0.89	0.57	2.19	2.33	1.59
Levels of soil application of humic acid (HS)						
HS_1: 00 kg/ha	14.03	14.45	14.24	40.71	41.70	41.20
HS_2:10 kg/ha	14.42	14.68	14.55	41.53	42.60	42.07
HS_3:20 kg/ha	14.72	15.44	15.08	42.18	43.91	43.05
HS_4:30 kg/ha	14.83	15.79	15.31	42.61	45.48	44.05
S.Em. ±	0.296	0.367	0.236	0.899	0.957	0.656
C.D. (P= 0.05)	NS	1.032	0.658	NS	2.69	1.83
Levels of foliar application of humic acid (HF)						
HF_1: 00 PPM	14.36	14.62	14.49	41.09	42.03	41.56
HF_2:10 PPM	14.50	15.05	14.77	41.47	43.10	42.29
HF_3:20 PPM	14.54	15.19	14.87	42.12	44.11	43.12
HF_4:30 PPM	14.59	15.51	15.05	42.35	44.46	43.41
Mean	14.50	15.09	14.79	41.76	43.43	42.59
S.Em. ±	0.296	0.367	0.236	0.90	0.96	0.66
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS
Year						
S.Em. ±	-	-	0.167	-	-	0.464
C.D. (P= 0.05)	-	-	NS	-	-	NS
Y × M × HS × HF						
S.Em. ±	-	-	1.156		-	3.216
C.D. (P= 0.05)	-	-	NS	-	-	NS
Sig. interactions(S)	-	-	-	-	-	-
CV%	12.25	14.61	13.54	12.92	13.22	13.08

Table 7. Iron uptake by chickpea as influenced by residual effect of organics and humic acid

Treatments	Fe uptake (g ha^{-1})						Mn uptake (g ha^{-1})					
	Seed			Stover			Seed			Stover		
	2022-23	2023-23	Pooled	2022-23	2023-24	Pooled	2022-23	2023-23	Pooled	2022-23	2023-23	Pooled
Levels of organics (M)												
M_1: FYM @ 10t/ha	129.12	137.09	133.10	586.45	620.87	603.66	37.83	40.05	38.94	162.73	170.63	166.68
M_2: VC @ 5 t/ha	117.76	120.50	119.13	546.75	570.98	558.87	36.72	37.82	37.27	154.66	160.61	157.64
M_3: CSC @ 5 t/ha	115.55	120.37	117.96	525.39	538.68	532.04	34.25	35.47	34.86	144.91	148.81	146.86
S.Em. ±	2.013	2.489	1.601	8.720	11.907	7.379	0.628	0.759	0.493	2.675	3.053	2.030
C.D. (P= 0.05)	5.65	6.99	4.47	24.48	33.43	20.59	1.76	2.13	1.37	7.51	8.57	5.66
Levels of soil application of humic acid (HS)												
HS_1: 00 kg/ha	114.10	120.86	117.48	530.50	552.40	541.45	34.78	35.74	35.26	149.63	153.07	151.35
HS_2:10 kg/ha	121.30	122.09	121.69	547.21	565.33	556.27	36.22	36.78	36.50	153.04	157.41	155.22
HS_3:20 kg/ha	123.07	129.10	126.08	560.88	578.79	569.83	36.84	38.84	37.84	155.63	161.38	158.50
HS_4:30 kg/ha	124.75	131.90	128.33	572.87	610.86	591.87	37.21	39.77	38.49	158.12	168.21	163.17
S.Em. ±	2.325	2.874	1.848	10.069	13.749	8.521	0.726	0.876	0.569	3.089	3.526	2.344
C.D. (P= 0.05)	6.53	8.07	5.16	28.27	38.61	23.77	NS	2.46	1.59	NS	9.90	6.54
Levels of foliar application of humic acid (HF)												
HF_1: 00 PPM	118.98	121.22	120.10	541.84	553.42	547.63	36.01	35.74	35.87	150.98	155.06	153.02
HF_2:10 PPM	119.95	125.05	122.50	551.91	574.02	562.96	36.17	37.88	37.03	154.08	158.80	156.44
HF_3:20 PPM	121.36	127.30	124.33	553.87	584.77	569.32	36.27	38.38	37.33	154.95	162.26	158.60
HF_4:30 PPM	122.94	130.37	126.66	563.84	595.16	579.50	36.61	39.13	37.87	156.40	163.96	160.18
S.Em. ±	118.98	2.87	1.85	10.07	13.75	8.52	0.73	0.88	0.57	3.09	3.53	2.34
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	2.46	NS	NS	NS	NS
Sig. interactions	-	-	-	-	-	-	-	-	-	-	-	-
CV%	11.55	13.69	12.71	10.93	14.30	12.80	12.01	13.91	13.04	12.03	13.22	12.66

Table 8. Zinc and copper uptake by chickpea as influenced by residual effect of organics and humic aci

Treatments	Zn uptake (g ha^{-1})						Cu uptake (g ha^{-1})					
	Seed			Stover			Seed			Stover		
	2022-23	2023-23	Pooled	2022-23	2023-24	Pooled	2022-23	2023-23	Pooled	2022-23	2023-23	Pooled
Levels of organics (M)												
M_1: FYM @ 10t/ha	96.90	102.05	99.47	125.05	130.42	127.74	10.12	10.69	10.41	23.61	24.87	24.24
M_2: VC @ 5 t/ha	92.87	95.61	94.24	117.13	123.39	120.26	9.82	10.06	9.94	22.58	23.13	22.86
M_3: CSC @ 5 t/ha	87.74	91.12	89.43	111.76	113.91	112.83	9.09	9.44	9.27	21.16	21.79	21.48
S.Em. ±	1.619	1.838	1.225	2.041	2.378	1.567	0.146	0.198	0.123	0.384	0.456	0.298
C.D. (P= 0.05)	4.55	5.16	3.42	5.73	6.68	4.37	0.41	0.56	0.34	1.08	1.28	0.83
Levels of soil application of humic acid (HS)												
HS_1: 00 kg/ha	88.81	91.93	90.37	113.86	118.37	116.12	9.33	9.57	9.45	21.90	22.11	22.00
HS_2:10 kg/ha	92.60	93.14	92.87	116.68	121.32	119.00	9.66	9.81	9.73	22.34	22.97	22.65
HS_3:20 kg/ha	94.16	99.08	96.62	119.17	122.10	120.63	9.86	10.42	10.14	22.65	23.59	23.12
HS_4:30 kg/ha	94.44	100.88	97.66	122.22	128.50	125.36	9.85	10.46	10.16	22.91	24.39	23.65
S.Em. ±	1.870	2.123	1.414	2.357	2.746	1.809	0.168	0.228	0.142	0.444	0.526	0.344
C.D. (P= 0.05)	NS	5.96	3.95	NS	NS	5.05	NS	0.64	0.40	NS	1.48	0.96
Levels of foliar application of humic acid (HF)												
HF_1: 00 PPM	91.91	91.95	91.93	114.98	119.52	117.25	9.64	9.73	9.69	22.18	22.50	22.34
HF_2:10 PPM	92.23	95.73	93.98	118.15	121.30	119.72	9.65	9.99	9.82	22.45	23.17	22.81
HF_3:20 PPM	92.82	96.75	94.79	118.81	123.53	121.17	9.66	10.09	9.88	22.50	23.61	23.06
HF_4:30 PPM	93.05	100.60	96.83	119.99	125.94	122.96	9.75	10.44	10.10	22.67	23.79	23.23
S.Em. ±	1.87	2.12	1.41	2.36	2.75	1.81	0.17	0.23	0.14	0.44	0.53	0.34
C.D. (P= 0.05)	NS	5.96	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sig. interactions	-	M×HS	-	-	-	-	-	-	-	-	-	-
CV%	12.13	13.23	12.72	11.99	13.44	12.77	10.44	13.62	12.20	11.86	13.58	12.78

Table 9. Interaction effect on Zn uptake by chickpea as influenced by residual effect of organics and humic acid

M × HS	**2023-24**			
	HS_1	**HS_2**	**HS_3**	**HS_4**
M_1	101.62	92.84	100.20	113.52
M_2	90.30	100.16	96.00	95.97
M_3	83.85	86.44	101.03	93.16
S.Em. ±	3.68			
C.D. (P= 0.05)	10.32			

3.5.8 Residual effect of foliar application of humic acid on zinc uptake

The data indicated that the N, P, K, Fe, Mn and Cu uptake by chickpea seed and stover was did not differ significanlty by the foliar application of humic acid during both the individual year and in pooled result.

But in case of Zn uptake by chickpea seed differ significantly due to residual effect of foliar application of humic acid during second year only. Residual effect of foliar application of humic aicid 30 ppm gave significantly highest Zn uptake by seed (100.60 g ha^{-1}) during second year only. In case of stover did not influence significantly due to residual effect of foliar application of humic acid.

3.5.9 Interaction effect

An evaluation of mean data on N, P, K, Fe, Mn and Cu uptake by seed and stover of chickpea did not show any significant interaction due to the residual effect of organic manures and humic acid during both the individual years and in pooled result

Whereas, Zn uptake by chickpea seed found significant interaction due to residual effect of organic manures and humic acid. Treatment combination M_1HS_4 (application of FYM 10 t ha^{-1} + soil application of humic acid 30 kg ha^{-1}) gave significantly highest Zn uptake by seed (113.52 g ha^{-1}) during second year only.

4. CONCLUSION

residual effect of application of FYM 10 t ha^{-1} and soil application of humic acid 30 kg ha^{-1} gave significant result on nutrient content and uptake by succeeding chickpea crop. This treatment reduced the cost of production as a result of reducing the addition of mineral fertilizers.

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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