International Journal of Plant & Soil Science

Volume 36, Issue 12, Page 292-304, 2024; Article no.IJPSS.128022
ISSN: 2320-7035

Residual Effect of Organics and Humic Acid on Physical, Chemical and Biological Property of Soil after Harvest of Succeeding Chickpea

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Authors' contributions

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

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i125203

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/128022

Original Research Article

Received: 11/10/2024
Accepted: 14/12/2024
Published: 18/12/2024

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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Cite as: *Chauhan, Ankitkumar, N. I. Patel, J. R. Jat, and Janki A. Patel. 2024. "Residual Effect of Organics and Humic Acid on Physical, Chemical and Biological Property of Soil After Harvest of Succeeding Chickpea". International Journal of Plant & Soil Science 36 (12):292-304. https://doi.org/10.9734/ijpss/2024/v36i125203.*

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 OC (0.298, 0.302 and 0.300 per cent), available N (177.28, 180.10 and 178.69 kg ha^{-1}), P_2O_5 (41.20, 42.04 and41.62 kg ha^{-1}) was observed during both the year and pooled result and total bacterial count (156.26 cfu g $soil^{-1}$) in pooled result soil with the application of FYM @ 10 t ha^{-1}. While application of humic acid did not get significant result and but numerically increased above mention parameter under the soil application of humic acid 30 kg ha^{-1}.

Keywords: Organic manures; humic acid; chemical property; macro and micro nutrient; biological property and chickpea crop.

1. INTRODUCTION

Organic matter in tropical soils undergoes constant transformation, necessitating its regular replenishment to sustain soil health. Maintaining soil organic matter at an optimal level is critical for achieving sustainable and high productivity over extended periods (Govindaswamy, 2002). Proper management of organic matter is often referred to as the cornerstone of sustainable agriculture (Stevenson, 1994). However, the availability of organic matter for soil incorporation is becoming increasingly scarce.

Farmyard manure (FYM) serves as a valuable source of primary, secondary, and micronutrients for plants. It also acts as a continuous energy source for heterotrophic microorganisms, enhancing nutrient availability and improving both the quality and quantity of crop yields (Deiana et al., 1990). Fertilizing with FYM is one of the most effective measures for improving soil properties, including nutrient accumulation, increased humus content, and intensified biological activity. Historically, FYM has been a widely used organic manure in field crops, while vermicompost has gained popularity as an alternative (Tan, 2003). However, limited availability and the slow release of nutrients from these organic sources pose significant challenges to their use.

To address these constraints, fertilization strategies incorporating soil and foliar applications of organic molecules like humic acids have been introduced. These substances are environmentally friendly and synergistically enhance nutrient and compost efficiency (Lee and Bartlett, 1976).

Among humic substances, humic acid has garnered the most attention. Often referred to as the "dark gold of agriculture," humic acid 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 soluble in alkali, humic acid is insoluble in acid and typically has a molecular weight ranging from 10,000 to 100,000 Daltons. It contains 51-57% carbon, 4-6% nitrogen, 0.2-1% phosphorus, and trace amounts of other micronutrients (Haworth, 1971). The effectiveness of humic acid is attributed to its diverse functional groups—carboxylic, phenolic, alcoholic, and hydroxyl—that form electrovalent and covalent bonds as well as intracomplex compounds (Solaiappan et al., 1995). Humic acids are abundant in nature, occurring in soils, natural waters, compost heaps, peat bogs, lignites, and brown coals (Sathiyabhama et al., 2003).

In cereal-pulse cropping systems, chickpea is a highly suitable pulse crop following pearl millet. As a cool-season crop, chickpea ranks second in area and third in production among pulses globally. Its seeds are nutritionally rich, containing 20–30% protein, approximately 40% carbohydrates, 3–6% oil, 6% crude fiber, and 3% ash (Gil et al., 1996). Additionally, chickpea is a good source of essential minerals like phosphorus, calcium, magnesium, iron, and zinc, as well as β-carotene. Its protein quality surpasses that of most other legumes. Also, 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. The study presents the importance of diversity in sources of organic fertilization and methods of addition to the soil properties. 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.

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 AND DISCUSSION

3.1 Soil Physical Properties

3.1.1 Bulk density

The data on bulk density of soil after harvest of chickpea as influenced by residual effect of organic manures and humic acid are given in Table 1 The data revealed that neither individual treatments of organic manures and humic acid nor its interaction with each other were found significant on soil bulk density after harvest of chickpea, but in pooled basis,

Table 1. Bulk density in soil after harvest of chickpea as influenced by residual effect of organics and humic acid

Treatments	Bulk density (g cm^{-3})		
	2022-23	**2023-24**	**Pooled**
Levels of organics (M)			
M_1: FYM @ 10 t/ha	1.402	1.390	1.396
M_2: Vermicompost @ 5 t/ha	1.435	1.418	1.426
M_3: Castor shell compost @ 5 t/ha	1.420	1.404	1.412
S.Em. ±	0.0157	0.0131	0.0102
C.D. (P= 0.05)	NS	NS	NS
Levels of soil application of humic acid (HS)			
HS_1:00 kg/ha	1.439	1.412	1.425
HS_2:10 kg/ha	1.415	1.407	1.411
HS_3:20 kg/ha	1.412	1.404	1.408
HS_4:30 kg/ha	1.409	1.392	1.401
S.Em. ±	0.0181	0.0151	0.0118
C.D. (P= 0.05)	NS	NS	NS
Levels of foliar application of humic acid (HF)			
HF_1:00 PPM	1.427	1.411	1.419
HF_2:10 PPM	1.425	1.406	1.415
HF_3:20 PPM	1.420	1.401	1.410
HF_4:30 PPM	1.404	1.398	1.401
Mean	1.419	1.404	1.411
S.Em. ±	0.0181	0.0151	0.0118
C.D. (P= 0.05)	NS	NS	NS
Sig. interactions(S)	-	-	-
CV%	7.65	6.45	7.08
Initial	1.497		

numerically the lowest bulk density was noted under the application of FYM @ 10 t ha^{-1} compared to rest of the organic manures.

3.2 Chemical Properties

3.2.1 Electric conductivity

The data presented in Table 2 explicit that residual effect of different organic manures and humic acid did not exert any significant influences on EC and pH of soil after harvest of chickpea during both the individual years and in pooled results.

3.3 Residual Effect of Organic Manures

3.3.1 Organic carbon

The data given in Table 2 indicated that residual effect of organic manures showed significant effect on organic carbon content in soil after harvest of chickpea during both the years of study and in pooled data the application of FYM @ 10 t ha^{-1} to preceding pearlmillet crop significantly improved the organic carbon content in soil *i.e.,* 0.298, 0.302 and 0.300 during both the individual year and in pooled study after harvest of succeeding chickpea crop and it remained at par with treatments vermicompost @ 5 t ha^{-1} during both the year of result only.

On pooled basis, the magnitude of increase in soil organic carbon due to the residual effect of FYM @ 10 t ha^{-1} was to the tune of 2.05 and 3.093 per cent over vermicompost @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively. This might be due to higher organic matter added under FYM treatment compared to rest of the treatments. Similar findings were obtained by Kalyani et al. (2019).

3.3.2 Available nitrogen

A perusal of data given in Table 3 revealed that the available N after harvest of chickpea was significantly influenced due to residual effect of different organic manures during individual years of study and in pooled basis, residual effect of FYM @ 10 t ha^{-1} produced significantly higher available N (180.10 and 178.69 kg ha^{-1}) over rest of treatments during second year and in pooled basis. On pooled basis, the magnitude of increase in available nitrogen after harvest of chickpea due to the residual effect of FYM @ 10 t ha^{-1} was to the tune of 2.71 and 3.72 per cent over vermicompost @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively.

The residual effect of FYM @ 10 t ha^{-1} significantly increased the available N content in soil after harvest of pearlmillet could be due to release of sufficient amount of N in soil by mineralization and reduce a leaching loss which resulted in higher amount of residual content of available N in soil. Similar results were obtained by Lakum et al. (2020).

3.3.3 Available phosphorus

The data given in Table 3 indicated that residual effect of organic manures had significant effect on available P_2O_5 content in soil after harvest of chickpea during both the year and in pooled data. Application of FYM @ 10 t ha^{-1} to preceding pearlmillet crop significantly highest available P_2O_5 content in soil (41.62 kg ha^{-1}) after harvest of succeeding chickpea crop during in pooled study only.

On pooled basis, the magnitude of increase in available P_2O_5 after harvest of chickpea due to the residual effect of FYM @ 10 t ha^{-1} was to the tune of 3.73 and 2.00 per cent over vermicompost @ 5 t ha^{-1} and castor shell compost @ 5 t ha^{-1}, respectively. The reason for significantly higher P_2O_5 might be due to the lower losses of nutrients because FYM will slowly release nutrients will make nutrients more available to plants but with a steady pace. Another reason for this might be due to release of organic acid during microbial decomposition of organic manure might help in increasing solubility of native phosphates, thus increased available phosphorus pool in the soil. Similar results were obtained by Lakum et al. (2020).

3.3.4 Available potassium

The data indicated that residual effect of organic manures did not have any significant effect on available K_2O content in soil after harvest of chickpea during both the years of study and in pooled analysis. However, numerically maximum available P_2O_5 (242, 246 and 244 kg ha^{-1}, respectively) was found in treatment application of FYM @ 10 t ha^{-1} than other treatments.

3.3.5 DTPA-extractable mirconutrient

The application of various organic manures in preceding pearlmillet crop did not affect the DTPA-extractable Fe, Mn, Zn and Cu status of soil during 2022-23, 2023-24 and in pooled analysis after harvest of chickpea.

Table 2. Electircal conductivity, pH and OC in soil after harvest of chickpea as influenced by residual effect of organics and humic acid

Treatments	$EC_{(1:2.5)}$ (ds/m)			$pH_{(1:2.5)}$			Organic carbon (%)		
	2022-23	2023-24	2022-23	2022-23	2022-23	Pooled	2022-23	2022-23	Pooled
Levels of organics (M)									
M_1: FYM @ 10 t/ha	0.134	0.131	0.133	7.20	7.28	7.24	0.298	0.302	0.300
M_2: Vermicompost @ 5 t/ha	0.132	0.130	0.131	7.18	7.26	7.22	0.292	0.296	0.294
M_3: Castor shell compost @ 5 t/ha	0.129	0.128	0.129	7.17	7.21	7.19	0.289	0.293	0.291
S.Em. ±	0.0018	0.0014	0.0011	0.04	0.04	0.03	0.002	0.002	0.002
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	0.007	0.007	0.005
Levels of soil application of humic acid (HS)									
HS_1:00 kg/ha	0.133	0.131	0.132	7.23	7.28	7.25	0.290	0.292	0.291
HS_2:10 kg/ha	0.134	0.130	0.132	7.19	7.26	7.22	0.291	0.294	0.292
HS_3:20 kg/ha	0.131	0.129	0.130	7.17	7.24	7.20	0.293	0.298	0.296
HS_4:30 kg/ha	0.129	0.129	0.129	7.13	7.22	7.18	0.299	0.303	0.301
S.Em. ±	0.0020	0.0016	0.0013	0.05	0.05	0.04	0.0027	0.0029	0.0020
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Levels of foliar application of humic acid (HF)									
HF_1:00 PPM	0.132	0.130	0.131	7.22	7.29	7.25	0.290	0.292	0.291
HF_2:10 PPM	0.133	0.129	0.131	7.18	7.25	7.22	0.291	0.297	0.294
HF_3:20 PPM	0.132	0.132	0.132	7.17	7.23	7.20	0.293	0.299	0.296
HF_4:30 PPM	0.130	0.129	0.129	7.16	7.22	7.19	0.297	0.302	0.299
Mean	0.132	0.130	0.131	7.18	7.25	7.21	0.293	0.297	0.295
S.Em. ±	0.0020	0.0016	0.0013	0.05	0.05	0.04	0.0027	0.0029	0.0020
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sig. interactions(S)	-	-	-	-	-	-	-	-	-
CV%	9.31	7.60	8.51	4.33	3.94	4.14	5.58	5.78	5.68
Initial	0.162			7.42			0.258		

Table 3. Available N, P_2O_5 and K_2O in soil after harvest of chickpea as influenced by residual effect of organics and humic acid

Treatments	N (kg ha^{-1})			P_2O_5 (kg ha^{-1})			K_2O (kg ha^{-1})		
	2022-23	2022-23	Pooled	2022-23	2022-23	Pooled	2022-23	2022-23	Pooled
Levels of organics (M)									
M_1: FYM @ 10 t/ha	177.28	180.10	178.69	41.20	42.04	41.62	242	246	244
M_2: Vermicompost @ 5 t/ha	172.65	175.28	173.96	39.48	40.76	40.12	239	241	240
M_3: Castor shell compost @ 5 t/ha	170.55	173.99	172.27	40.79	40.81	40.80	240	243	241
S.Em. ±	2.06	1.76	1.35	0.526	0.436	0.342	1.69	1.79	1.23
C.D. (P= 0.05)	NS	4.94	3.78	NS	NS	0.954	NS	NS	NS
Levels of soil application of humic acid (HS)									
HS_1:00 kg/ha	171.80	174.40	173.10	39.29	40.68	39.99	238	241	240
HS_2:10 kg/ha	173.50	175.82	174.66	40.62	41.29	40.95	240	243	241
HS_3:20 kg/ha	173.60	176.09	174.84	41.04	41.38	41.21	241	244	242
HS_4:30 kg/ha	175.06	179.52	177.29	41.01	41.46	41.23	243	246	244
S.Em. ±	2.38	2.03	1.56	0.608	0.504	0.395	1.95	2.07	1.42
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Levels of foliar application of humic acid (HF)									
HF_1:00 PPM	171.59	174.49	173.04	39.64	40.42	40.03	237	241	239
HF_2:10 PPM	172.41	175.56	173.98	40.58	40.95	40.76	240	243	241
HF_3:20 PPM	173.99	177.36	175.67	40.60	41.44	41.02	242	243	243
HF_4:30 PPM	175.99	178.42	177.21	41.14	42.01	41.58	243	246	244
Mean	173.49	176.46	174.97	40.49	41.21	40.85	240	243	242
S.Em. ±	2.38	2.03	1.56	0.61	0.50	0.39	1.95	2.07	1.42
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sig. interactions(S)	-			-	-	-	-	-	-
CV%	8.21	6.91	7.58	9.01	7.34	8.20	4.87	5.10	4.99
Initial	167.28			44.61			228		

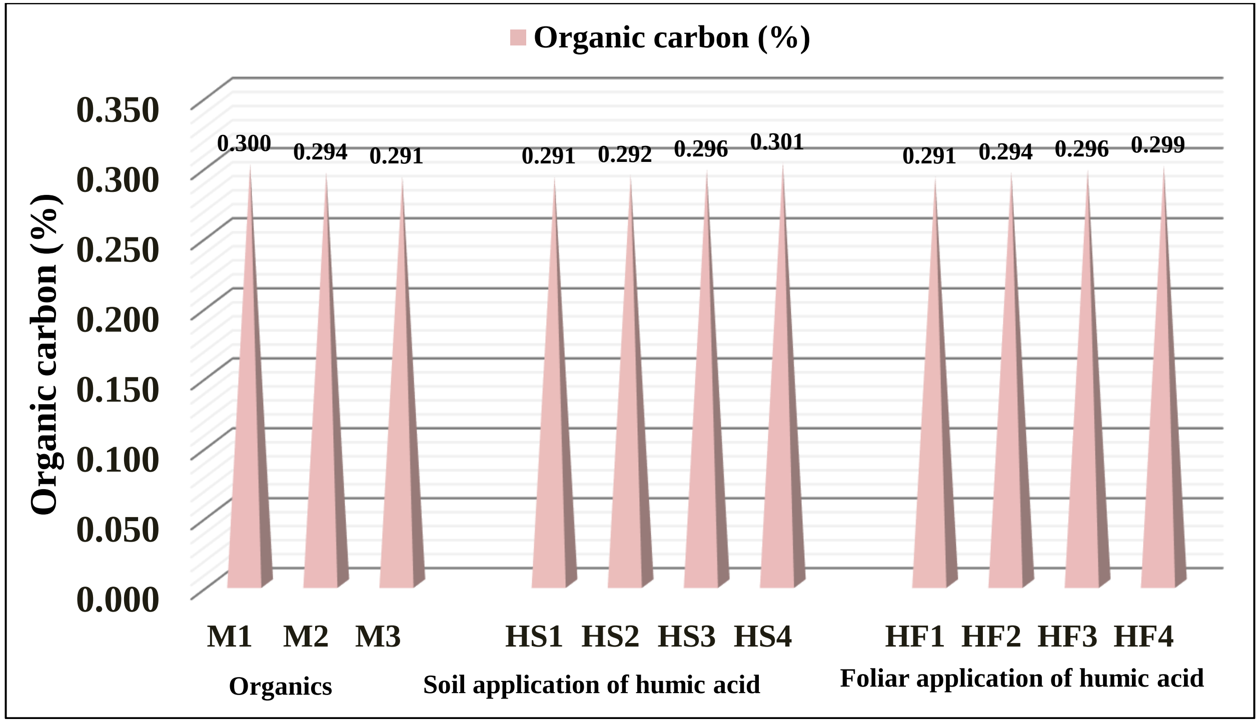

Fig. 1. Organic carbon in soil after harvest of chickpea as influenced by residual effect of organics and humic acid

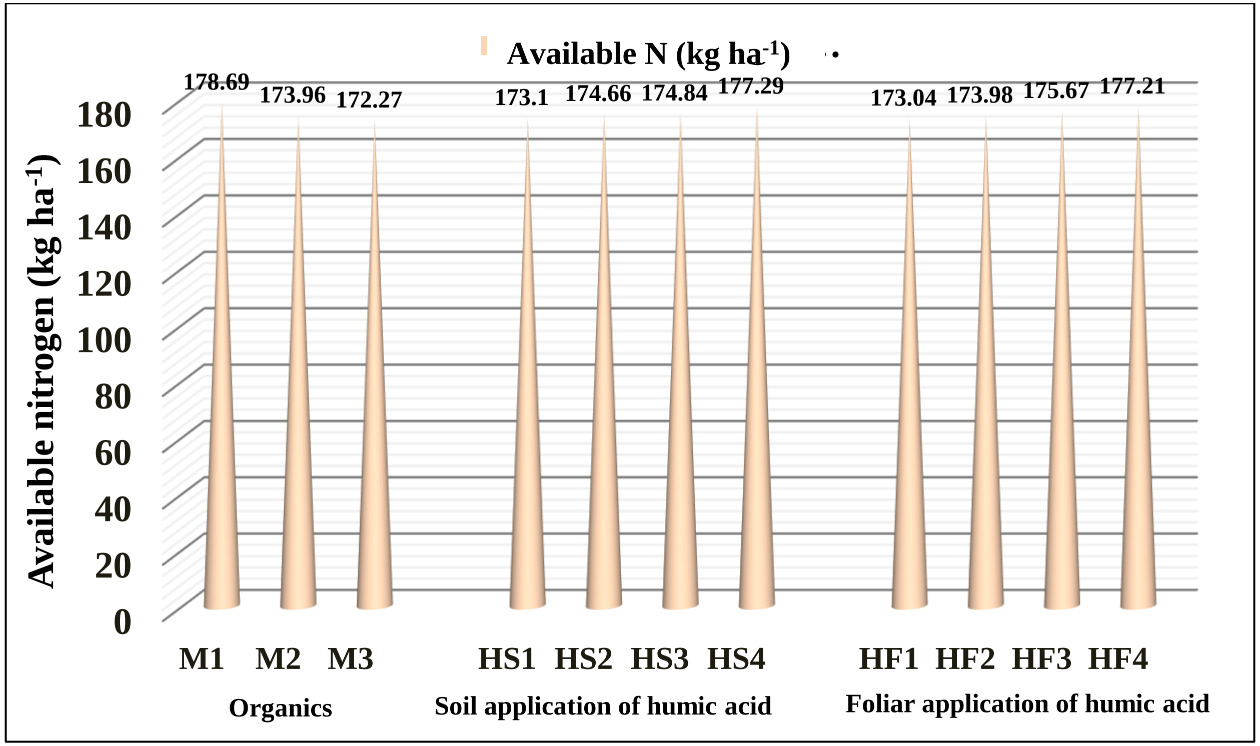

Fig. 2. Available nitrogen in soil after harvest of chickpea as influenced by residual effect organics and humic acid

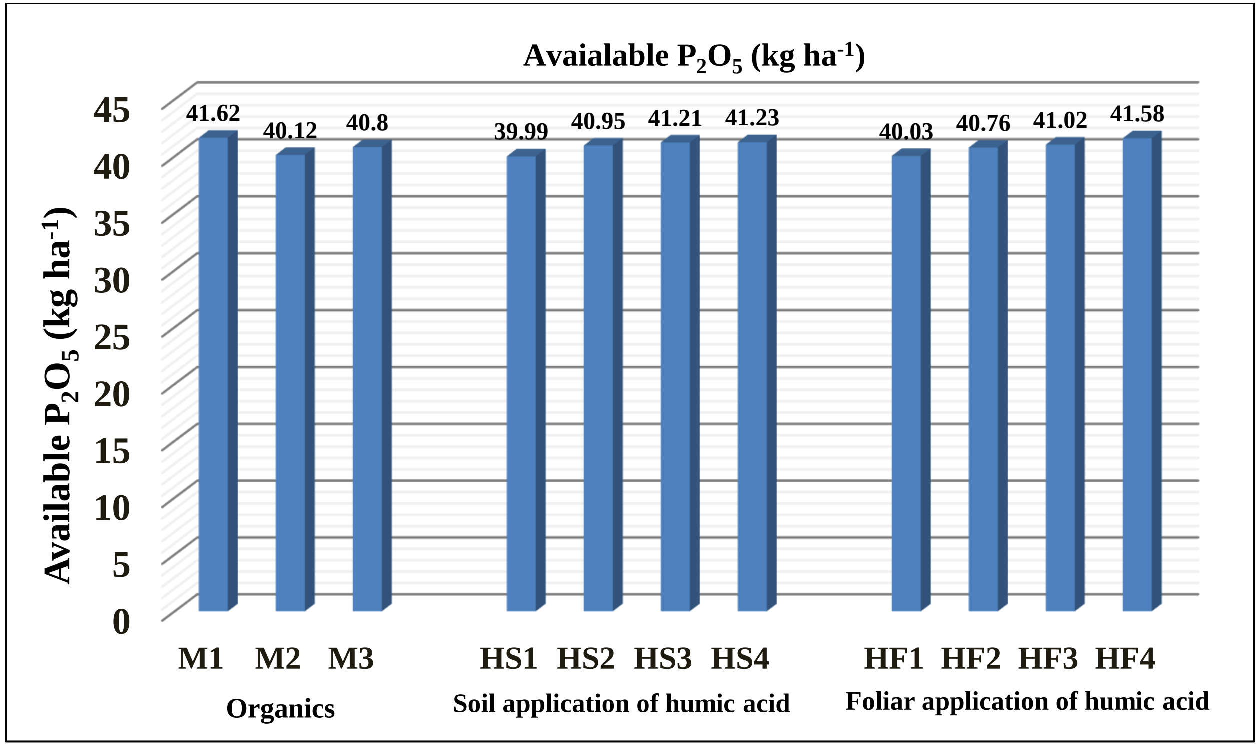

Fig. 3. Available phosphorus in soil after harvest of chickpea as influenced by residual effect organics and humic acid

Table 4. DTPA-extractable iron and manganese in soil after harvest of chickpea as influenced by residual effect organics and humic acid

Treatments	Fe (mg kg^{-1})			Mn (mg kg^{-1})		
	2022-23	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**
Levels of organics (M)						
M_1: FYM @ 10 t/ha	4.42	4.45	4.44	7.22	7.28	7.25
M_2: Vermicompost @ 5 t/ha	4.39	4.41	4.40	7.20	7.29	7.25
M_3: Castor shell compost @ 5 t/ha	4.40	4.43	4.41	7.10	7.27	7.19
S.Em. ±	0.03	0.04	0.03	0.05	0.07	0.04
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS
Levels of soil application of humic acid (HS)						
HS_1:00 kg/ha	4.34	4.41	4.37	7.13	7.21	7.17
HS_2:10 kg/ha	4.37	4.42	4.39	7.14	7.27	7.19
HS_3:20 kg/ha	4.45	4.44	4.44	7.20	7.31	7.26
HS_4:30 kg/ha	4.45	4.45	4.45	7.24	7.33	7.28
S.Em. ±	0.04	0.05	0.03	0.06	0.08	0.05
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS
Levels of foliar application of humic acid (HF)						
HF_1:00 PPM	4.38	4.40	4.39	7.12	7.21	7.17
HF_2:10 PPM	4.39	4.42	4.41	7.16	7.28	7.22
HF_3:20 PPM	4.41	4.45	4.43	7.19	7.30	7.25
HF_4:30 PPM	4.44	4.45	4.44	7.23	7.34	7.28
Mean	4.40	4.43	4.42	7.18	7.28	7.23
S.Em. ±	0.04	0.05	0.03	0.062	0.077	0.049
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS
Year						
S.Em. ±	-	-	0.0219	-	-	0.035
C.D. (P= 0.05)	-	-		-	-	NS
Y × M × HS × HF						
S.Em. ±	-	-	0.1520		-	0.242
C.D. (P= 0.05)	-	-	NS	-	-	NS
Sig. interactions(S)	-	-	-	-	-	-
CV%	4.97	6.81	5.96	5.20	6.33	5.80
Initial	4.241			7.159		

3.4 Biological Properties

3.4.1 Total bacterial count

3.4.1.1 Residual effect of organic manures

The residual effect of organic manures on total bacterial count in soil after harvest of chickpea was not affected significantly during both the individual years but in pooled analysis found signficalty affected on total bacterial count in soil after harvest of chickpea significantly the higher bacterial count was recorded under the treatment FYM @ 10 t ha^{-1} over rest of the treatment during pooled analysis.

Organic manure *viz*., FYM releases nutrients more slowly than mineral nutrients which might contribute to the residual pool of organic nitrogen, phosphorus and potassium in the soil and reduced nutrient loss from the soil by improving soil organic matter. Organic manure of plant nutrients thus exerted long lasting residual effect on next crop by improving physico-chemical and biological properties of the soil. These results are in the lines of those reported by Solanki et al. (2023).

3.5 Residual Effect of Soil and Foliar Application of Humic Acid

It is evident from the data explicit that residual effect of soil application of humic acid and foliar application of humic acid had no significant effect on organic carbon content, N, P_2O_5, K_2O, DTPA-extractable Fe, Mn, Zn, Cu and total bacterial count in soil after harvest of chickpea during both the years of study and in pooled results. But numerically improve the all parameter as mention above in soil under the soil application of humic acid 30 kg ha^{-1} during both the year and in pooled result.

3.6 Interaction Effect

An evaluation of mean data did not show any significant interaction due to residual effect of organic manures and humic acid on organic carbon content, N, P_2O_5, K_2O, DTPA-extractable Fe, Mn, Zn, Cu and total bacterial count in soil after harvest of chickpea during both the years of study and in pooled results in soil after harvest of chickpea.

Table 5. DTPA-extractable zinc and copper in soil after harvest of chickpea as influenced by residual effect organics and humic acid

Treatments	Zn (mg kg^{-1})			Cu (mg kg^{-1})		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Levels of organics (M)						
M_1: FYM @ 10 t/ha	0.629	0.637	0.633	0.414	0.416	0.415
M_2: Vermicompost @ 5 t/ha	0.626	0.634	0.630	0.416	0.418	0.417
M_3: Castor shell compost @ 5 t/ha	0.620	0.630	0.625	0.412	0.425	0.418
S.Em. ±	0.0051	0.0054	0.0037	0.004	0.003	0.002
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS
Levels of soil application of humic acid (HS)						
HS_1:00 kg/ha	0.611	0.630	0.622	0.410	0.416	0.414
HS_2:10 kg/ha	0.628	0.632	0.631	0.412	0.418	0.416
HS_3:20 kg/ha	0.630	0.634	0.632	0.414	0.421	0.417
HS_4:30 kg/ha	0.632	0.636	0.633	0.418	0.423	0.420
S.Em. ±	0.006	0.006	0.004	0.004	0.003	0.003
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS
Levels of foliar application of humic acid (HF)						
HF_1:00 PPM	0.614	0.630	0.622	0.409	0.416	0.413
HF_2:10 PPM	0.625	0.634	0.629	0.411	0.419	0.414
HF_3:20 PPM	0.631	0.635	0.633	0.416	0.421	0.418
HF_4:30 PPM	0.631	0.635	0.633	0.422	0.423	0.422
S.Em. ±	0.0059	0.0062	0.0043	0.004	0.003	0.003
C.D. (P= 0.05)	NS	NS	NS	NS	NS	NS
Mean	0.625	0.633	0.629	0.414	0.420	0.417
Sig. interactions(S)	-	-	-	-	-	-
CV%	5.70	5.88	5.79	6.51	4.66	5.65
Initial	0.576			0.432		

Table 6. Total bacterial count in soil after harvest of chickpea as influenced by residual effect organics and humic acid

Treatments	Total bacterial count (10^6 cfu/ g soil)		
	2022-23	2023-24	Pooled
Levels of organics (M)			
M_1: FYM @ 10 t/ha	155.39	157.12	156.26
M_2: Vermicompost @ 5 t/ha	152.94	154.88	153.91
M_3: Castor shell compost @ 5 t/ha	151.86	153.29	152.58
S.Em. ±	1.03	1.10	0.75
C.D. (P= 0.05)	NS	NS	2.10
Levels of soil application of humic acid (HS)			
HS_1:00 kg/ha	151.65	152.61	153.13
HS_2:10 kg/ha	153.14	154.28	153.81
HS_3:20 kg/ha	153.42	156.39	154.71
HS_4:30 kg/ha	155.38	157.10	155.34
S.Em. ±	1.19	1.27	0.87
C.D. (P= 0.05)	NS	NS	NS

Treatments	**Total bacterial count (10^6 cfu/ g soil)**		
	2022-23	**2023-24**	**Pooled**
Levels of foliar application of humic acid (HF)			
HF_1:00 PPM	151.26	152.96	152.95
HF_2:10 PPM	152.65	153.97	153.56
HF_3:20 PPM	154.39	156.58	154.62
HF_4:30 PPM	155.27	156.89	155.85
Mean	4.65	4.91	4.78
S.Em. ±	1.19	1.27	0.87
C.D. (P= 0.05)	NS	NS	NS
Sig. interactions(S)	-	-	-
CV%	4.65	4.91	4.78
Initial	96.2	-	-

4. CONCLUSION

On the basis of two years experimental findings, it is concluded that residual effect of application of either FYM @ 10 t ha^{-1} or vermicompost @ 5 t ha^{-1} to significantly improved chemical property (organic carbon, nitrogen and phosphorus) and biological property (Total bacterial count) of soil after harvest of chickpea crop.

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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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/128022