International Journal of Plant & Soil Science

34(19): 312-320, 2022; Article no.IJPSS.87580
ISSN: 2320-7035

Fortification of Organic Manures with Iron on Nutrient Release Characteristics

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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: 10.9734/IJPSS/2022/v34i1931118

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/87580

Original Research Article

Received 12 March 2022
Accepted 24 May 2022
Published 02 June 2022

ABSTRACT

Aims: The objective of current study was to examine the nutrient release pattern by enriching different organic manures with iron fertilizer at different ratios in regular sampling intervals.

Study Design: The design used in this current study was Factorial completely randomized block design with six treatments replicated thrice.

Place and Duration of Study: An incubation experiment was carried out in the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, India during December - March 2022.

Methodology: An incubation experiment was carried out by enriching inorganic iron fertilizer with three different organics such as FYM, vermicompost and biocompost in two ratios viz., 1:5 and 1:10 at four different sampling intervals 7, 14, 21 and 28 days after incubation and analyzed for various physical and chemical properties to study the iron release pattern.

Results: The results revealed that the iron content ranged from 5324 to 8823 mg kg^{-1}. Among all the combinations, the highest nutrient release was found in $FeSo_4$ enriched with vermicompost 1:10 ratio at 21 DAI which is followed by $FeSo_4$ enriched with FYM 1:10 ratio.

Conclusion: The present study revealed that the integrated application of organic and inorganic fertilizer significantly improved the iron use efficiency. Only a few work were reported on integrated application of micronutrient at different organic fertilizer rates, however need further studies to validate the reliability.

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Keywords: Iron fertilizer; organic manures; nutrient release; enrichment; iron use efficiency.

1. INTRODUCTION

Micronutrient deficiency in plants is an alarmingly increasing global issue. Among the micronutrients, iron (Fe) is a crucial element for plants due to its role in photosynthetic activity which determines the yield of crops [1]. The total iron content in the earth's crust though is high, it doesn't reflect on supplying capacity of soil and nutrient available pool to plants. Generally, Fe chlorosis occurs as a result of poor availability of Fe for crops [2]. Although Fe is the fourth most abundant nutrient in the earth's crust, it is the third-most scarce element for growth of the plant mainly by the nature of low solubility [3]. Iron plays an indispensable role in numerous pathways in the plant system. It serves as a constituent of several enzymes and is requisite for copious biological actions. It is also involved in chlorophyll synthesis, and prerequisite for chloroplast structure and its function maintenance [4].

Favorable effects of organic manures were already known in the ancient era but the potential of enriching organic manures with inorganic fertilizers has been recognized recently. Chemical fertilization has flourished good results in certain circumstances, and adverse effects have been reduced by using combined application of organic and inorganic fertilizers [5]. Organic manures solitarily do not contribute remarkable surge in crop yields owing to the low nutrient reserves. Consequently, to sustain soil productivity, combined use of inorganic and organic manures needs to be implemented. Continuous applications of organics aggravate to proliferate the beneficial microbes and strengthen the physical characteristics of the soil. However, chemical fertilizers provide certain nutrients and the soil cannot contribute in sufficient amounts. Accordingly, judicious blending of organic manures and inorganic fertilizers support to sustain soil health and its productivity. [6,7] reported that combination of cow dung and inorganic fertilizer was found to improve the efficiency of chemical fertilizers significantly.

Organic sources have the ability to complex Fe and increase its solubility and mobility [8]. Organic amendments contain organic compounds which are highly capable of chelating Fe. These chelators of Fe in organic sources are mostly humic acids, amino acids, phenolics, hydroxamates and catechol siderophores [9]. Organic sources not only help in increasing Fe solubility by providing chelators but also stimulate the microbial activities which results in powerful siderophore production [10,11]. Although $FeSO_4$ is extensively applied fertilizers for nature of quick solubility, and affordability in the market, nutrient fixation is the crucial issue in soil. Under such circumstances augmented methods like synthetic chelates usage can be approved to aggravate the insubstantial utilization of micronutrients. Besides using synthetic chelates like Fe-EDTA, EDDHA-Fe which is costly, making use of organic manures that act as natural chelates for enrichment sounds to be economically viable. Many iron fertilizers are available for controlling of iron chlorosis, but their high costs generally restrict wide use of iron sources in agriculture [12]. And hence, by using combined application of manures and inorganic fertilizers paves the way for higher nutrient release. There are few studies that were reported on integrated application of micronutrients at different organic fertilizer rates. Hence, a laboratory incubation experiment was carried out with an objective to study the nutrient release pattern with the addition of fortified organic manure with inorganic iron fertilizer viz., $FeSO_4$.

2. MATERIALS AND METHODS

An incubation experiment was carried out in the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, India during Dec 2021-March 2022, to study the nutrient release pattern of organic manure fortified with inorganic iron fertilizer. Three types of organics, *viz*., FYM, Vermicompost and biocompost were collected from the farm at the Tamil Nadu Agricultural University and used for the study. Different sources of organics were air dried, powdered to pass 2-mm mesh and mixed thoroughly and were enriched with inorganic iron fertilizer (Ferrous sulphate - $FeSO_4.7H_2O$) @ two different ratios. The enrichment treatments consisted of 1:5 and 1:10 ratio of ferrous sulphate with three different organics i.e., FYM, vermicompost and biocompost studied at four different incubation intervals such as 7, 14, 21 and 28 days. The mixture was turned over periodically (weekly) and moisture level was maintained till the completion of the study. The enrichment study was conducted as per the treatment schedule, water was added to maintain 65% moisture holding capacity and sampling was done periodically at 7, 14, 21 and 28 days of incubation. The enriched samples were air dried, powdered and sieved through 2 mm sieve and analyzed for various physical properties and chemical properties by adopting standard procedures.

2.1 Physical Properties of Enriched Samples

The physical properties like pH, EC (Electrical Conductivity), bulk density, particle density and porosity were analyzed. The enrichment samples were analyzed for pH and EC in 1:5 ratio manure - water suspension [13]. The bulk density, particle density and porosity of the enriched samples were analyzed by cylindrical method [14].

2.2 Chemical Properties of Enriched Samples

Chemical properties like DTPA (Diethylenetriaminepentaacetic acid) extractable micronutrient Fe was analyzed in Atomic Absorption Spectrophotometer as per the procedure of [15].

2.3 FTIR- Fourier Transform Infrared Spectroscopy

FTIR is a promising technique for identification of functional groups in the fortified organic manures. The use of instrumental technique like FTIR analysis reveals the featured changes in the characteristics of functional groups during the process of enrichment.

2.4 Statistical Analysis

The data obtained from the experiment were subjected to statistical analysis using AGRESS software version 7.01. The level of significance used was $P < 0.05$. Critical difference (CD) values were calculated for the $P < 0.05$ whenever "F" test was found significant [16].

3. RESULTS AND DISCUSSION

Organic manure fortified with inorganic iron fertilizer significantly influenced the pH and EC of the enriched manure. The results showed that pH during the incubation ranged from 5.09 to 5.7, 4.94 to 5.65, 4.88 to 5.47 and 4.77 to 5.38 respectively on 7th day, 14th day, 21st day and 28th DAI. Among the different treatments, minimum pH reduction of 5.11 was observed in the manure FYM @ 1:5 ratio, and maximum pH reduction of 5.47 was observed in vermicompost @ ratio of 1:10. The pH of the enriched manure showed a declining trend with incubation period in all treatments irrespective of the manures. Among all the treatments, T_4 - $FeSO_4$ enriched with vermicompost at 1:10 ratio accounted for a higher reduction in pH with the value of 5.47 at 21 DAI. [17] reported that soil pH gradually decreased with increasing incubation time. In the proposed incubation experiment, the influence of enriched organic manure with micronutrients decreases the EC and it was clearly demonstrated. Changes in EC during the incubation ranged from 3.76 to 6.52 dS m^{-1}, 3.69 to 6.36 dS m^{-1}, 3.56 to 6.14 dS m^{-1} and 3.48 to 5.85 dS m^{-1} on 7th day, 14th day, 21st day and 28thday respectively. Minimum EC reduction of 5.38 dS m^{-1} was noticed in the vermicompost @ ratio of 1:10, and maximum EC reduction (5.46 dS m^{-1}) in vermicompost @ ratio of 1:10. As the incubation period progressed from 7 to 28 days, the electrical conductivity began to decline. Among all the treatments, higher reduction in EC was observed in treatment T_4, with the value of 5.46 dS m^{-1} at 21 DAI. Vermicompost or worm manure is rich in plant growth regulators and enhances more microbial load [18]. Microbial activity is more because of the increased and exposed surface area that favors the decomposition much faster [19,20]. Additionally, earthworms ingest huge quantity of organic materials rich in nitrogen and enhances N mineralization [21]. This might be the reason for reduction in pH and EC. This finding supports [22]'s earlier findings. The drop in EC could be related to the production of organic acid during the decomposition of inorganic iron fertilizer-enriched manures. Organic matter induced leaching of excessive ions by enhancing the physical property of soil, which also results in lower EC [23].

3.1 Bulk Density, Particle Density and Porosity

Fortification of organic manure with inorganic fertilizer also plays a vital role in influencing bulk density, particle density and porosity of the enriched products. The bulk density of the Fe-enriched manure showed a declining trend and particle density and porosity showed an increasing trend over incubation period. The results revealed that changes in bulk density

Table 1. Effect of Fe fortified organic manure on the pH and EC (dS m^{-1})

Treatments	pH				Mean	EC				Mean
	7th DAI	14th DAI	21st DAI	28th DAI		7th DAI	14th DAI	21st DAI	28th DAI	
T_1	5.25	5.18	5.10	5.06	5.15	5.79	5.66	5.42	5.11	5.50
T_2	5.09	4.94	4.88	4.77	4.92	6.52	6.36	6.14	5.85	6.22
T_3	5.51	5.39	5.26	5.17	5.33	4.98	4.84	4.70	4.56	4.77
T_4	5.75	5.65	5.47	5.38	5.56	6.10	5.98	5.46	5.38	5.73
T_5	5.64	5.52	5.39	5.23	5.45	3.76	3.69	3.56	3.48	3.62
T_6	5.19	5.09	4.95	4.80	5.01	4.85	4.44	4.33	4.25	4.47
SEd	0.06	0.04	0.04	0.04		0.21	0.02	0.04	0.05	
CD (.05)	0.12	0.09	0.09	0.09		0.46	0.05	0.09	0.11	

**SEd-standard error of difference and CD-critical difference*

Table 2. Effect of Fe-fortified organic manure on the bulk density, particle density and porosity

Tr	Bulk density (g/cm^3)				Mean	Particle density (g/cm^3)				Mean	Porosity (%)				Mean
	7th DAI	14th DAI	21st DAI	28th DAI		7th DAI	14th DAI	21st DAI	28th DAI		7th DAI	14th DAI	21st DAI	28th DAI	
T_1	1.13	1.12	1.11	1.09	1.11	2.54	2.56	2.60	2.65	2.59	55.5	56.3	57.3	58.9	57.0
T_2	1.19	1.17	1.16	1.15	1.16	2.55	2.57	2.59	2.61	2.58	53.3	54.5	55.2	55.9	54.7
T_3	1.10	1.08	1.06	1.05	1.07	2.57	2.59	2.61	2.63	2.60	57.2	58.3	59.4	60.1	58.7
T_4	1.17	1.16	1.13	1.12	1.10	2.80	2.85	2.92	2.97	2.89	58.2	59.3	61.3	62.3	60.3
T_5	1.20	1.18	1.17	1.16	1.17	2.54	2.56	2.57	2.59	2.57	52.8	53.9	54.5	55.2	54.1
T_6	1.21	1.20	1.19	1.18	1.10	2.57	2.62	2.65	2.68	2.63	52.9	54.2	55.1	56.0	54.5
SEd	0.02	0.02	0.02	0.03		0.04	0.06	0.06	0.06		1.26	1.06	1.31	1.16	
CD (0.05)	0.04	0.05	0.04	0.07		0.09	0.14	0.14	0.14		2.74	2.31	2.85	2.53	

during the incubation ranged from 1.10 to 1.21 g/cm^3, 1.08 to 1.20 g/cm^3, 1.06 to 1.19 g/cm^3 and 1.05 to 1.18 g/cm^3 respectively during 7th day, 14th day, 21st day and 28th day after incubation. Minimum bulk density reduction of 1.18 g/cm^3 was recorded in the biocompost @ ratio of 1:10, and maximum bulk density reduction (1.13 g/cm^3) was noticed in vermicompost @ ratio of 1:10. Among the various treatments, T_4 -$FeSO_4$ enriched with vermicompost @1:10 ratio accounted for a higher reduction in bulk density (1.13 g/cm^3) at 21 DAI. With regard to particle density during the incubation, it ranged from 2.54 to 2.80 g/cm^3, 2.56 to 2.85 g/cm^3, 2.57 to 2.92 g/cm^3 and 2.59 to 2.97 g/cm^3 respectively during 7th day, 14th day, 21st day and 28thday of incubation. Minimum particle density increment (2.57 g/cm^3) was registered in the vermicompost @ ratio of 1:5, and maximum particle density increment (2.92 g/cm^3) was observed in vermicompost @ ratio of 1:10. Similar results were recorded with respect to porosity also and, during the incubation it ranged from 52.8 to 58.2 %, 53.9 to 59.3%, 55.2 to 61.3 % and 55.2 to 62.3 % at 7th day, 14th day, 21st day and 28th day of incubation respectively. Minimum porosity raise of 54.5 % was observed in the FYM @ ratio of 1:10, and maximum porosity raise (61.3 %) was recorded in vermicompost @ ratio of 1:10. The particle density and porosity were found to be high in T_4 -$FeSO_4$ enriched with vermicompost 1:10 ratio having value of 2.92 g/cm^{3}and 61.3 % respectively at 21 DAI. Due to organic manures decomposition that increases microbial load and the spaces between particles and thus increases the void ratio. The results are in accordance with those of [24],

who found that using organic manure in combination with chemical fertilizer reduced soil bulk density, increased particle density, and increased total porosity.

3.2 Iron Content

The use of fortified organic manure with inorganic iron fertilizer greatly increased the availability of DTPA extractable iron in the current investigation. The DTPA - Fe showed an increasing trend of availability from 7 DAI to 21 DAI and thereafter declined at 28 DAI. Changes in iron content during the incubation ranged from 5324 to 6968 mg kg^{-1},6744 to 8531 mg kg^{-1}, 7084 to 8823 mg kg^{-1} and 6917 to 8609 mg kg^{-1} respectively at 7th day, 14th day, 21st day and 28th day of incubation. Minimum iron content of 5324 mg kg^{-1} was observed in the biocompost @ ratio of 1:5, and maximum iron content of 8823 mg kg^{-1} was recorded in vermicompost @ ratio of 1:10.

Though, all the levels of iron enrichment were efficient in increasing the iron availability, among the different manures, T_4- enrichment of $FeSO_4$ with vermicompost 1:10 ratio accounted for the high Fe availability. It was found to be high at 21 DAI with DTPA- Fe content of 8823 mg kg^{-1} which was followed by T_2- enrichment of $FeSO_4$ with FYM 1:10 ratio with the value of 8274 mg kg^{-1}. It is well known that the availability of micronutrients in soil is mostly determined by soil pH and organic matter level. The increased iron availability might be due to the role of humic substances in the manure which increased micronutrients availability by preventing their transformation as insoluble hydroxides, chelation action and releasing them in labile forms [25]. A similar finding was also reported in soil by [26] and they found significant influence of Fe-fortified vermicompost on availability of iron due the complexation or chelation action, contribution from manures and prevention from fixation of iron.

3.3 FT-IR

The infrared spectroscopy of raw manure sources and the best result of the enriched manure was characterized by main absorbance bands at 1739 cm$^{−1}$ (C=O stretch), 1228 and 1216 cm$^{−1}$ (C–O stretch & O-H stretch), 1367 cm$^{−1}$ (C–O stretch), 2970 and 2946 cm$^{−1}$ (C-H stretch), 3016 cm$^{−1}$ (NH_2 stretch), 1438 cm$^{−1}$ (COO- stretch) and 3456 cm$^{−1}$ (C-H stretch). The presence of aliphatic C–H stretching, stretching vibration of –OH and CO- bonds, and COO- stretching were highly remarkable in the enriched samples and this indicates the mineralization of nutrients through the enrichment process. The highest peak intensity was observed in the best enrichment manure i.e., inorganic fertilizer (ferrous sulphate) enriched with vermicompost at the ratio of 1:10. As compared to all other raw manure sources, the high intense peak was observed in the region of 1739 cm$^{−1}$, vibration of C=O stretch which is the functional groups of carboxylic acids, aldehyde and ketone [27].

The highest nutrient release in the enriched manure might be due to the functional group of carboxylic acids released from the decomposition process. The acid chelates and increases the available form to labile and the similar findings were also in accordance with the results of [29].

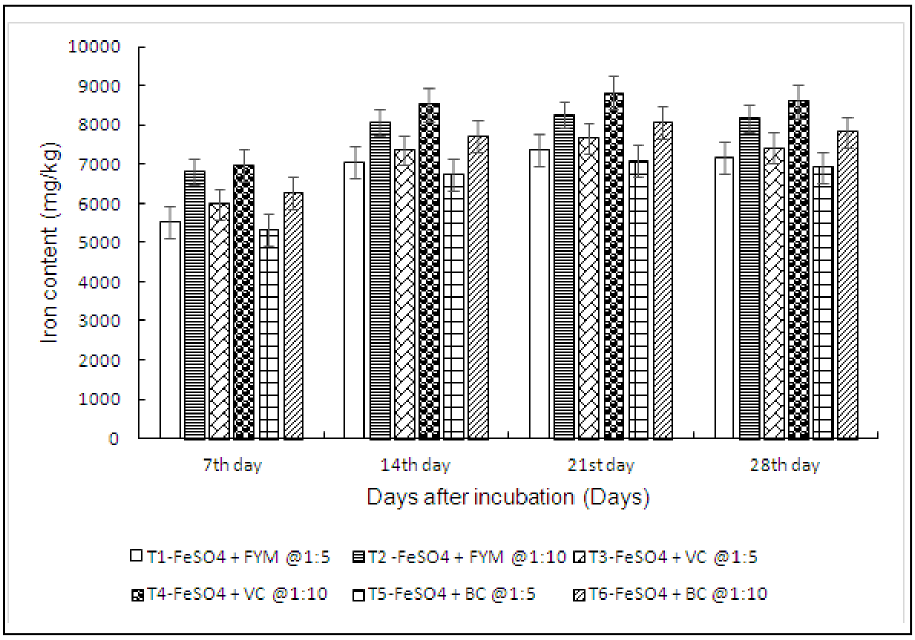
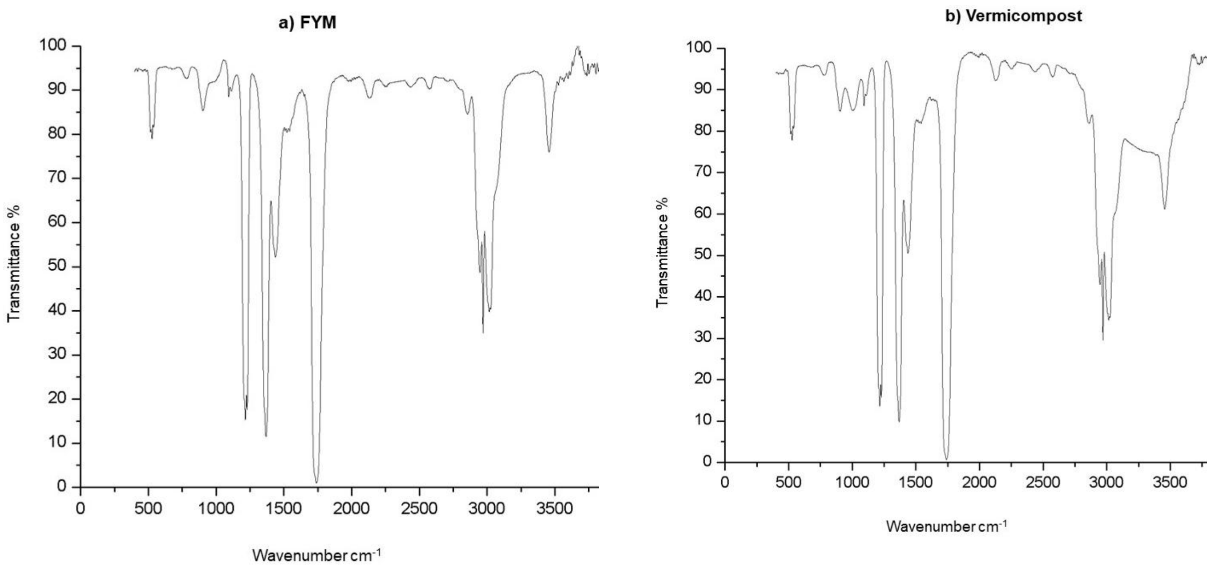


Fig.1. Effect of fortified organic manure on the DTPA- Fe content

Table 3. Assigned values for different peaks in FTIR

Wavenumber cm^{-1}	Vibration	Functional groups
3456	O–H stretch	Phenols and carboxylic groups
3016	NH_2 stretch	Primary amides
2946	C–H stretch	Aliphatic methylene groups of lipids and fats
1739	C=O stretch	Aldehyde, ketone, carboxylic acids and esters
1438	COO− stretch	Carboxylic acids
	C–N stretch	Amide III
1216	C–O stretch	Alcohols, ethers and esters

Source: [28]



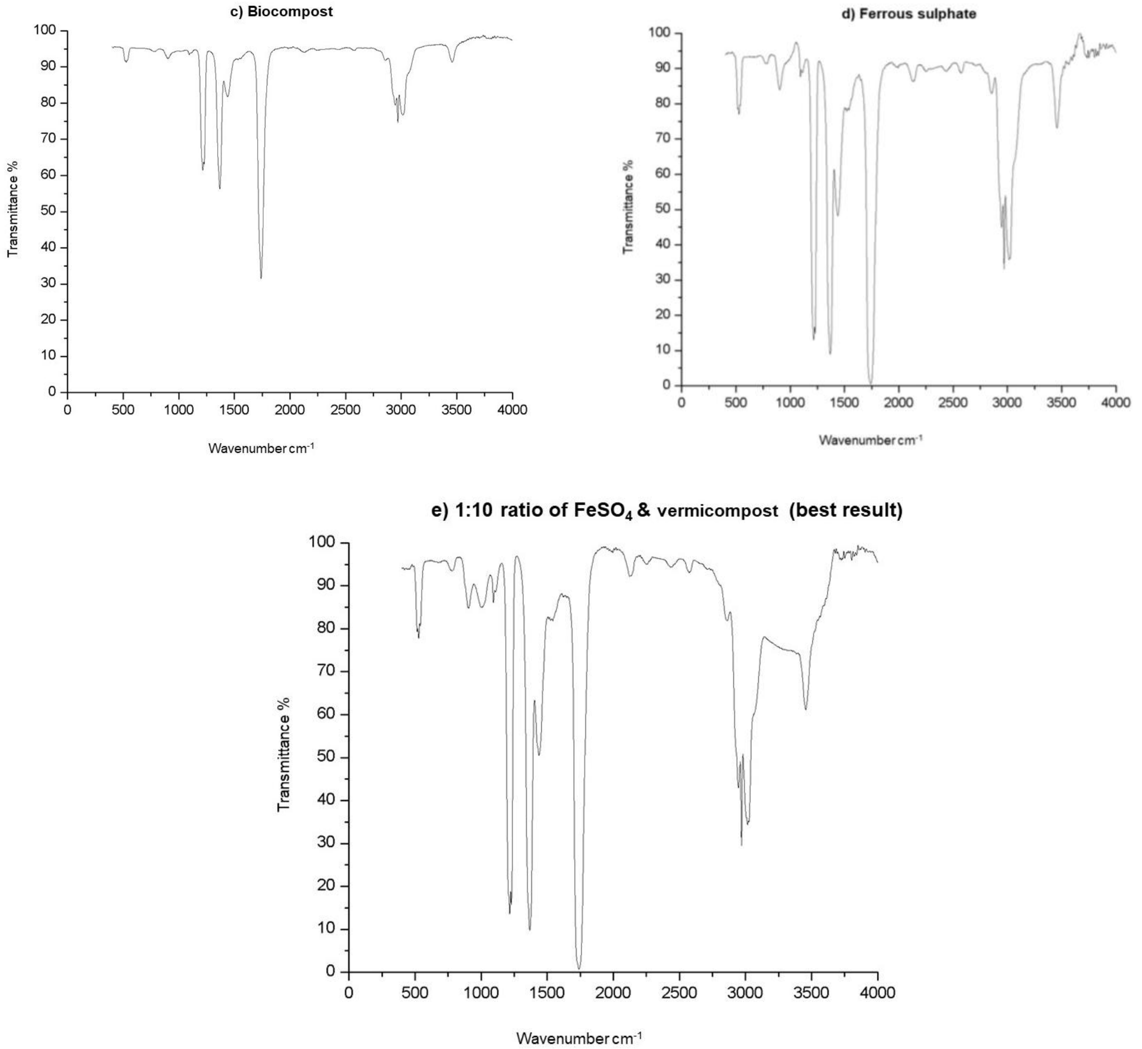


Fig 2. FTIR images of various organic manures, inorganic fertilizer and enriched manure

4. CONCLUSION

A profound influence of fortified organic manure in the iron nutrient release was well evidenced in the present investigation. Furthermore, fortification of organic manure increases the soil fertility and crop production potential possibly by its favorable effects on soil physical and chemical properties including nutrient bioavailability, water holding capacity, soil pH, microbial community and activity etc. The study revealed that the physical properties like pH, electrical conductivity and bulk density were decreased and particle density and porosity were increased throughout the incubation period from 7 to 28 days which favors the higher iron use efficiency. The DTPA-Fe content was also increased from 7 to 21 days and slightly decreased from 21 to 28 days after incubation. In this laboratory incubation experiment, significantly better result was obtained in the treatment of 1:10 ratio of $FeSO_4$ and vermicompost which had reduced pH and EC and increased micronutrient availability which was comparable with the results of 1:10 ratio of $FeSO_4$ and FYM. The results indicated that, 1:10 ratio of $FeSO_4$ and vermicompost at 21 DAI was found to be promising enrichment treatment in regarding iron use efficiency.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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