Original Research Article

Micronutrient Dynamics in Soil Under Integrated Thermochemical Organic Fertilizer Pellet Application

ABSTRACT

Aim: To study the micronutrient release dynamics from integrated thermochemical organic fertilizer pellets.

Study Design: The soil incubation study was laid down in completely randomized design with 5 treatments replicated 4 times.

Place and Duration of Study: The experiment was conducted at the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani between May 2023 to July 2023.

Methods: Five kg air dried, 2 mm sieved soil was filled in pots and mixed with pellets required for five kg soil was mixed with soil and pots were maintained at field capacity throughout the study period.

Results: Fe, Mn and Zn exhibited a gradual and progressive release pattern throughout the incubation period. Whereas Cu and b availability showed a decreasing trend from the 15th say onwards. Highest Fe, Mn and Zn availability were observed towards the end of the incubation study. While the Cu and B recorded highest on the initial 15th day of incubation.

Conclusion: TOF based pellets significantly impact the micronutrientavailability in soil compared to the FYM based and control ~~trearment~~treatment.

Keywords: *Thermochemical organic fertilizer, pellets, nutrient release, micronutrients, ~~Iron,~~ Manganese~~, Zinc, Copper, Boron~~.*

1. INTRODUCTION

Micronutrients are essential for plant metabolism, which in turn affects crop production in addition to crop plant growth and development. These micronutrients function as co-factors for a variety of enzymes involved in the metabolism of different organic compounds, including lipids, proteins, carbohydrates, and nucleic acids [6]. Agricultural soils were found to contain concentrations of Fe, Mn, Zn and Cu ranging from 20,000–550,000 mg, 450–4000 mg [20],10–300 mg [5] and 2–100 mg [19],respectively. Regardless of the source, organic manures are preferable for providing soil with vital nutrients and various micronutrients, including Fe, S, Mo, Zn, and Cu. Upon mineralization, soil organic matter releases considerable amount of phosphorus, ~~sulphur~~Sulphur, nitrogen, and a small amount of micronutrients[23, 2].The binding

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ABSTRACT
A soil incubation study was carried out in the Department of Soil Science and Agricultural Chemistry, to assess dynamics of micronutrient release. Soil Pots were filled with 5 kg air-dried, 2 mm sieved soil. The study was laid in Completely Randomized Design with 5 treatments and 4 replications. Treatments were, T_1: Pellet formulation 1; T_2: Pellet formulation 2; T_3: Pellet formulation 3; T_4: FYM+NPK (RDF as per POP) and T5: Control (Soil alone). The collected soil had Fe and Mn content of 10.14 mg kg^{-1} and 8.59 mg kg^{-1}, respectively. Three distinct pellet formulations P1, P2 & P3 were used in study based on thermochemical organic fertilizer (TOF). Fe, Mn and Zn exhibited a gradual and progressive release pattern throughout the incubation period. Whereas Cu and b availability showed a decreasing trend from the 15th say onwards. Highest Fe, Mn and Zn availability were observed towards the end of the incubation study. While the Cu and B recorded highest on the initial 15th day of incubation. We conclusion that TOF based pellets significantly impact the micronutrient availability in soil compared to the FYM based and control treatment.

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of metals to organic matter may cause a decrease in the concentration of free cations in soil solution; however, the dissolution of these organo-metallic complexes increases the ~~phyto~~Phyto-availability of metals at the root-rhizosphere interface by raising the concentration of total dissolved ions. This concentration is dependent on the mobility of the metal-dissolved organic carbon (DOC) complexes and their dissociation kinetics. The increase in root-accessible forms of zinc and iron is mostly caused by chelating these elements with organic matter, which also keeps insoluble forms like carbonates and oxides from forming in the soil [27].Numerous researches have shown the direct and indirect effects of soil organic matter (SOM) on soil availability of micro nutrients and plant absorption [24, 22, 18]. Dhaliwal and Walia [11] observed that incorporation of manures besides giving the macronutrients it also boosts the availability of the micronutrients like Zn, Cu,Fe, and Mn. Integrated application of organic and inorganic fertilizer is considered to be sustainable then the sole use of inorganic fertilizers. The application of mineral ~~fertilisers~~fertilizers and organic manuresover time has a substantial impact on soil characteristics, including pH, organic matter contents, and accessible forms ofmacronutrients, which impacts micronutrient availability to plants [26]. Pellet fertilizer, integrating both organic and inorganic sources of nutrients, has slow-release nutrient capability, can limit leaching losses, and attributes ~~favourable~~favorable outcomes on soil nutrient levels and overall health. Hence the current study was conducted to assess the micronutrient dynamics in soil under integrated thermochemical organic fertilizer pellets.

2. MATERIAL AND METHODS

2.1 Soil incubation study

A soil incubation study was carried out in the Department of Soil Science and Agricultural Chemistry, to assess dynamics of micronutrient release. Soil Pots were filled with 5 kg air-dried, 2 mm sievedsoil.The study was laid in Completely Randomized Design with 5 treatments and 4 replications. Treatments were, T_1: Pellet formulation 1; T_2: Pellet formulation 2; T_3: Pellet formulation 3; T_4: FYM+NPK (RDF as per POP) and T_5: Control (Soil alone). The collected soilhad Fe and Mn content of 10.14 mg kg^{-1} and 8.59 mg kg^{-1}, respectively.Three distinct pellet formulations P_1, P_2 & P_3 were used in study based on thermochemical organic fertilizer (TOF). P_1, P_2 & P_3 were prepared by blending of TOF with125%, 100% and 75% of NPK nutrients based on blanket recommendation for tomato by package of practices of KAU (KAU, 2016). The pellets were mixed with soil and incubated for 75 days and the pots were maintained at field capacity throughout the study period.Soil samples were drawn at 15th, 45th and 75th day. Samples were ~~analysed~~analyses for available Fe, Mn, Zn and Cu, by 0.1 N HCl extraction and atomic absorption spectrophotometry [28].

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2.2 Statistical analysis

A completely ~~randomised~~randomized design (CRD) was used for the soil incubation experiment. ~~The table values were compared with the F values for the treatments~~. Critical differences were computed with a 5% significance level in order to facilitate mean comparisons if the effects were significant. Data analysis was done using the R-package grapesAgri1 [14].

3. RESULTS AND DISCUSSION

3.1 Micronutrient dynamics in the soil

The Fe and Mn content of the soil showed an increasing trend in all the treatments throughout the incubation period (Table 1). Highest available Fe was recorded in T_1 on 75^{th} day (21.93 mg kg^{-1}) followed by T_2 (21.82 mg kg^{-1}). FYM based treatment showed highest Fe content of 20.70 mg kg^{-1}, unlike treatments amended with pellets which maintained highest availability of Fe throughout the period.Also control showed an increasing trend in Fe release.

Manganese also exhibits a steady and progressive rate of release throughout, in all the treatments (Table 1). T_1 displayed the highest available Mn (12.76 mg kg^{-1}) on 75^{th} day, followed by T_4 (12.13 mg kg^{-1}) on 75^{th} day (Table 1). Similar to Fe release, control showed similar pattern in Mn release.

The micronutrients Fe and Mn, exhibited a steady and progressive rate of mineralization all throughout the incubation period (Fig. 1, Fig. 2). Citrate, oxalate, malate, malonate, and succinate are all capable of acting as chelators for iron, copper, and zinc, according to Cline et al. [9]. Solubility of plant-available Fe, Mn, Zn, and Cu rises with decreasing soil pH [3]. The genesis of chelating compounds with organic components may be responsible for the steady rise in Fe content over time, as this leads to a slow release throughout the processes of the decomposition and ~~mineralisation~~mineralization[12]. The gradual, prolonged release of Fe from organic additions may result from the formation of organic complexes with higher stability with Fe [4] that will likely break down more slowly. The levels of exchangeable Fe and Mn in the soil treated with cow manure increased, according to Rostami and Ahangar [25].

The rise in Mn release that was observed is consistent with the findings of a study conducted by Radhakrishnan and Suja [21], which showed that Mn and Fe availability increased over many days. The increase in Mn availability from TOF-based treatments up to 12 weeks of incubation was also observed by Ajayan [1]. According to Leno and Sudharmaidevi [18]thermochemical organic ~~fertiliser~~fertilizer performed better in the soil at supplying plant-available micronutrients than conventional farmyard manure-based ~~fertilisers~~fertilizers.

Zn availability exhibited a slight decline on day 45 and it increased subsequently. The highest value of available zinc was recorded in T1 on day 15 (5.32 mg kg^{-1}) and day 75 (5.28 mg kg^{-1}) followed by T2 (5.07 mg kg^{-1}) on day 15 and T1 (5.06 mg kg^{-1}) on day 45 (Table 2).Whereas, the release of copper showed a decreasing trend after the 15^{th} day of incubation. On day 15 the highest available copper was recorded in T_1 (5.61 mg kg^{-1}) which was significantly on par with T_2 (5.40 mg kg^{-1}) followed by T_3 (5.11 mg kg^{-1}) (Table 2).

The release pattern of B is similar to the pattern of Cu. The highest available boron content was recorded in in T_1 on days 45 (0.570 mg kg^{-1}), 15 (0.560 mg kg^{-1}) and 60 (0.555 mg kg^{-1}) followed by T_2 on days 15 (0.545 mg kg^{-1}) and 45 (0.525 mg kg^{-1}) (Table 1).

A consistent decrease and increase pattern in Zn release was observed from 15th day (Fig. 3). The decomposition of OM facilitates an increase in the availability of Zn. This process may be attributed to the presence of various functional groups, such as phenolic, carboxyl, and amino groups, which interact with labile organic compounds and create strong chelation, as stated by Fuente *et al.* [13]. Behera and Thiyagarajan [7] reported similar results. However, the availability of Zn was reduced because it formed strong bonds with inorganic soil colloids, primarily Fe and Al oxides, through specific adsorption [25].

Cu release increased on initial days and thereby kept on decreasing from 15thday (Fig. 4). The increase soil Cu content following the application of OM can be attributed to the adsorption of Cu^{2+} ions onto the OM. The sorption and complexation processes with OM significantly influence the availability of Cu, as copper tends to form strong inner-sphere complexes with SOM [8]. Additionally, the application of organic manures increases the organic-bound fraction of Cu, while simultaneously reducing its soluble and extractable fractions [9] which eventually decrease the Cu availability for plant absorption.

Despite of high mineralization of B from TOF based pellets, it was deficient in the soil and exhibited a decreasing trend during incubation (Fig. 5). According to Tlili et al. [29], organic matter is one of the main sources of B in acid soils since relatively little B adsorption on the mineral fraction happens at low pH values. Soil organic matter serves as a significant source of B reserves. Jacoby et al. [15] have demonstrated that organic ~~fertilisation~~fertilization has a beneficial effect on B absorption and that B is more prevalent in soils with organic matter than in the mineral component.

Kamaraj *et al.*[16] found that fortifying organic manures with micronutrients provides greater benefits due to the chelation of these nutrients by organic matter, facilitates a gradual release tailored to crop requirements. The progressive increase observed in the control treatment, which did not receive any amendments, can be attributed to the dissolution of inherent nutrients. This phenomenon occurred because the soil was maintained at field capacity for the entire duration of the study period.

Table 1. Effects of integrated thermochemical organic fertilizer ~~treatments~~on Fe (mg kg^{-1}) and Mn (mg kg^{-1}) at various days of incubation

Treatment ~~details~~	Fe (mg kg^{-1})			Mn (mg kg^{-1})		
	Days of incubation			Days of incubation		
	15 Days	45 Days	75 Days	15 Days	45 Days	75 Days
~~T1: Pellet formulation 1~~ (P1)	19.65	19.80	21.93	6.50	8.81	12.76
~~T2: Pellet formulation 2~~ (P2)	19.33	19.50	21.82	6.52	7.68	10.89
~~T3: Pellet formulation 3~~ (P3)	16.27	19.00	21.23	6.34	7.55	11.15
~~T4:~~ FYM+NPK	13.24	20.70	21.75	8.28	8.28	12.13
~~T5:~~ Control	12.80	17.24	17.27	5.55	6.73	9.28
SEm (±)	0.719	0.653	0.607	0.156	0.251	0.099
CD (0.05)	2.168	1.970	1.828	0.471	0.756	0.298

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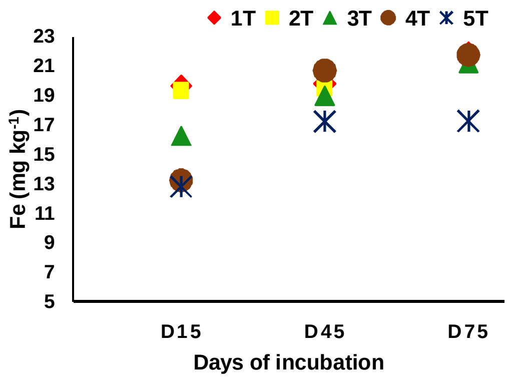
	B (mg kg^{-1})		
	Days of incubation		
	15 Days	45 Days	75 Days
~~T1: Pellet formulation 1~~ (P1)	0.560	0.570	0.490
~~T2: Pellet formulation 2~~ (P2)	0.545	0.525	0.467
~~T3: Pellet formulation 3~~ (P3)	0.518	0.515	0.440
~~T4:~~ FYM+NPK	0.518	0.488	0.440
~~T5:~~ Control	0.470	0.470	0.402
SEm (±)	0.012	0.014	0.005
CD (0.05)	0.037	0.042	0.016

Table 2. Effects of integrated thermochemical organic fertilizer pellets~~treatments~~ on Zn (mg kg^{-1}), Cu (mg kg^{-1}) and B (mg kg^{-1}) at various days of incubation

Treatment ~~details~~	Zn (mg kg^{-1})			Cu (mg kg^{-1})		
	Days of incubation			Days of incubation		
	15 Days	45 Days	75 Days	15 Days	45 Days	75 Days
~~T1: Pellet formulation 1~~ (P1)	5.32	5.06	5.28	5.61	4.02	4.28
~~T2: Pellet formulation 2~~ (P2)	5.07	4.52	4.63	5.40	3.92	3.90
~~T3: Pellet formulation 3~~ (P3)	4.46	4.00	4.19	5.11	3.71	3.71
~~T4:~~ FYM+NPK	3.88	3.33	3.89	4.10	2.93	3.80
~~T5:~~ Control	3.48	3.05	3.48	3.45	2.78	3.10
SEm (±)	0.078	0.097	0.295	0.153	0.119	0.151
CD (P=0.05)	0.234	0.294	0.890	0.461	0.358	0.457



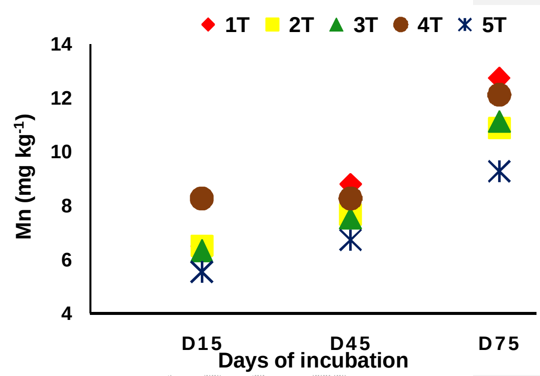


Fig. 1. Temporal variation in available Fe Fig. 2. Temporal variation in available Mn

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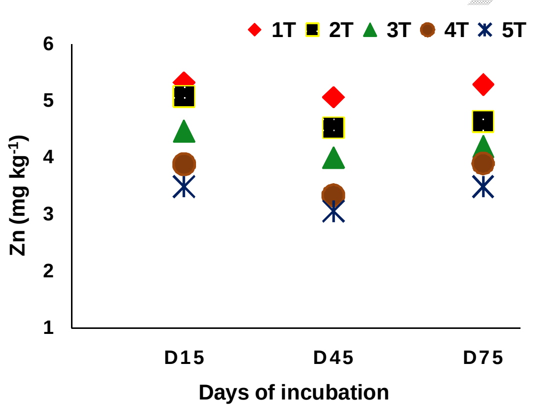

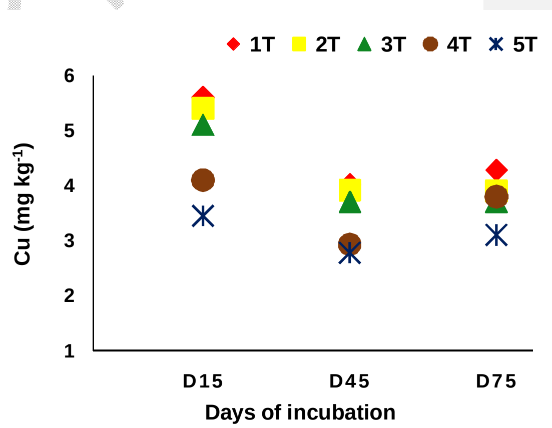

Fig. 3. Temporal variation in available ZnFig.4. Temporal variation in available Cu

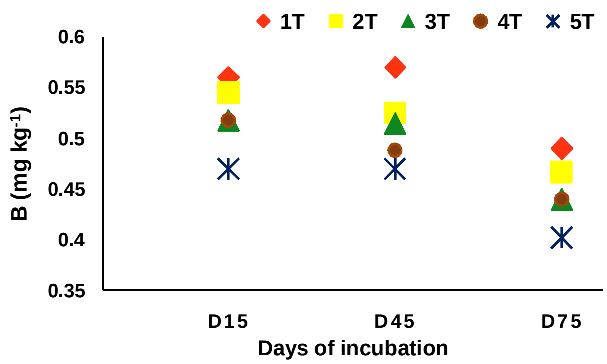

Fig. 5. Temporal variation in available B

4. CONCLUSION

The study can be concluded with the fact that TOF based pellets significantly impact the micronutrient dynamics in soil. Fe, Mn and Zn exhibited a gradual and progressive release pattern throughout the incubation period. Whereas Cu and B availability exhibited a decreasing pattern from 15th day of incubation. The TPF based pellets generally maintained higher micronutrient availability in the course of the incubation study. P_1 (TOF + NPK @ 125%) comes out to be superior in maintaining the micronutrient availability during the study.

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