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Research Article

Effect of Integrated Use of Organic and Inorganic Amendments on Nutrient Dynamics in Typic Haplaquept Soil of West Bengal

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Abstract: Balanced nutrition guided by soil test values is essential for maintaining and enhancing soil productivity. An integrated approach combining organic inputs, secondary and micronutrients, and inorganic fertilizers is necessary to prevent a decline in soil fertility, crop yields, and overall sustainability. The present study evaluated the effect of farmyard manure (FYM), sulfur (S), and zinc (Zn) applied alone or in combination with inorganic NPK fertilizers on soil nutrient availability. It was found that FYM amendment enhanced soil organic carbon content and nutrient availability when compared to non-amended soils or soils that received only inorganic fertilizers. The combination of FYM with S and Zn enhanced its positive effects further.

Keywords: Organic, secondary, micronutrient, farmyard manure

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1. Introduction

The use of inorganic fertilizers has expanded very rapidly to respond to the increased needs of modern agriculture for nutrients. However, an overreliance on these inorganic inputs has caused many imbalances in the nutrient pool available to soil, with likely adverse effects on both soil health and crop productivity. Balanced applications of secondary and micronutrients have been shown to ensure optimal crop yield and sustainable management of soils. Organic resources, such as farmyard manure (FYM), are essential for maintaining soil health. They provide a dual benefit by meeting immediate nutrient requirements and contributing to the long-term enhancement of soil organic matter (SOM), as pointed out by Palm et al. (2001). Incorporation of organic sources like FYM with chemical fertilizers is an effective strategy to ensure a steady supply of macro- and micronutrients while simultaneously improving soil properties. Studies have demonstrated that this combination not only supports plant nutrition but also sustains soil fertility over time (Arbad and Ismail, 2011). For example, sulfur-containing fertilizers have been reported to increase the availability of the most critical nutrients such as nitrogen (N), phosphorus (P), and potassium (K) by Klikocka et al. (2017). Zinc (Zn), another essential micronutrient that is deficient in the soils of West Bengal (AICRPMSPE, 2015), is an important micronutrient for a variety of physiological and biochemical processes in plants. Zn is essential for protein and starch biosynthesis (Marschner, 1995) and acts as an antioxidant protecting the cell membranes against oxidative stress produced by superoxide radicals (Cakmak, 2000). Zinc deficiency has been identified as a common problem in rice cultivation where it has greatly affected plant health and yield (Niraj et al., 2014). Based on these factors, the aim of the present study is to determine the effects of adding organic and inorganic fertilizers to alluvial soils, along with sulfur and zinc on the monitoring and improvement of the nutrient status of the soil. The proposed approach ensures an optimal balance between short-term nutrient needs and the long-term sustainability of the soil-a key need with respect to modern agriculture.

2. Materials and Methods

Soil Sample Collection

A composite soil sample was collected from a farmer's field situated in Ghentugachhi under Chakdah block, Nadia district of West Bengal. The soil, according to National Bureau of Soil Science and Land Use Planning (NBSS & LUP), comes under the typic Haplaquept category. Fields are mainly of rice-mustard cropping cycle, and hence, the soils were sampled preceding the rice cropping season. The soil collected was air-dried, crushed using a wooden pestle and mortar into fine pieces, and passed through an 80-mesh sieve. The following standard analytical procedures were followed in the study: physical and chemical properties were studied, which were summarized (Table 1).

Table 1. Soil Analysis Parameters and Results

Sl. No	Parameter	Result	Reference	Method
1	pH	7.41	Jackson, 1973	Glass electrode method
2	Electrical Conductivity (dS m^{-1})	0.23	Jackson, 1973	Conductometric method
3	Mechanical Separates			
	i) Sand (%)	16.8	Piper, 1966	Hydrometer method
	ii) Silt (%)	18		
	iii) Clay (%)	65.2		
	Textural class	Clay loam	USDA, 1975	Textural triangle method
4	Organic Carbon (%)	0.51	Walkley and Black, 1934	Wet oxidation method
5	Water Holding Capacity (%)	48.3	Baruah and Barthakur, 1997	Gravimetric method
6	Total Nitrogen (%)	0.089	Stevenson, 1996	Kjeldahl method
7	Available NH_4^+ (mg kg^{-1})	132.41	Bremner and Keeney, 1966	Steam distillation method
8	Available NO_3^- (mg kg^{-1})	27.65		Phenoldisulfonic acid method
9	Available Phosphorus (kg ha^{-1})	36.39	Olsen et al., 1954	Sodium bicarbonate extraction method
10	Available Potassium (kg ha^{-1})	162.74	Jackson, 1973	Flame photometric method
11	Available Sulfur (mg kg^{-1})	6.45	Chesnin and Yien, 1951	Turbidimetric method
12	Available Zinc (mg kg^{-1})	0.58	Lindsay & Norvell, 1978	DTPA extraction method

Experimental Setup and Methodology

The laboratory experiment was conducted from September to November 2022-2023 under controlled conditions at the polyhouse of BCKV. Three kilograms of soil samples were placed in pots and incubated for 90 days. During the incubation period, the soil moisture was maintained at 60% of its water-holding capacity. Moisture loss due to evaporation was replenished every alternate day by weighing and adjusting as needed. To study the effect of supplemented secondary and micronutrients along with NPK fertilizers and FYM on yield, a completely randomized design was developed and six treatment combinations were prepared. All the treatments were replicated thrice for reliable results.

T_1: Soil
T_2: Soil + NPK (N-P_2O_5 –K_2O at 60-30-30 Kg ha^{-1})
T_3: Soil +NPK +FYM (FYM at 1% dry wt. of soil)
T_4: Soil +NPK +FYM+S (S at 20 mg kg^{-1})
T_5: Soil +NPK +FYM +Zn (Zn at 10 mg kg^{-1})
T_6: Soil +NPK+ FYM +S (S at 20 mg kg^{-1}) + Zn (Zn at 10 mg kg^{-1})

The soils in the experiment were amended with nitrogen (N), phosphorus (P), and potassium (K) at rates of 60, 30, and 30 kg ha^{-1}, respectively, supplied in the forms of urea, single super phosphate (SSP), and muriate of potash (MOP). Well-decomposed farmyard manure (FYM) was added as an organic amendment at a rate equivalent to 1% of the soil's dry weight. Elemental sulfur with a purity of 95% was used at a concentration of 20 mg kg^{-1} for sulfur (S), and Zn EDTA with 12% Zn was applied at a rate of 10 mg kg^{-1} for zinc (Zn). All the treatment materials were mixed well into the soil as basal applications on the first day of the experiment. Soil samples were collected and assessed at four-time intervals, these being the 15th, 30th, 60th, and 90th days of incubation. Evaluated parameters of soil were those for organic carbon available nitrogen, phosphorus, potassium, sulfur and DTPA extractable Zn. The soils were analyzed on statistical methods related to Federer (1927) for analysis of mean values to establish that there is the presence of different treatment means values during the various phases of the observation of the experimentation.

3. Results and Discussion

Organic Carbon

Figure 1 depicts changes in oxidizable organic carbon content in soil treated with different combinations of inorganic and organic fertilizers. Results indicate that there is progressive increase in oxidizable organic carbon with incubation time. This increase was much more significant in treatments involving organic matter, as any organic inputs by nature contain carbon for the soil. Among the treatments, T5 recorded the maximum amount of accumulation of oxidable organic carbon, while the second one was T6. Balanced fertilization not only favors microbial activities and proliferation but also contributes towards the buildup of microbial biomass carbon that later leads to an improvement in the soil's oxidable organic carbon. Sarkar 1997). The increase of oxidizable organic carbon during later incubation stages is attributed to the increase in microbial populations and the decomposition of their dead cells, which enhances the soil's organic carbon (Premi, 2003).

Similar studies by Abraham and Lal (2003) found that the integration of various nutrient sources increases the organic carbon percentage in soil. The statistical analysis showed significant differences among treatments and demonstrated the impact of nutrient management strategies on organic carbon dynamics

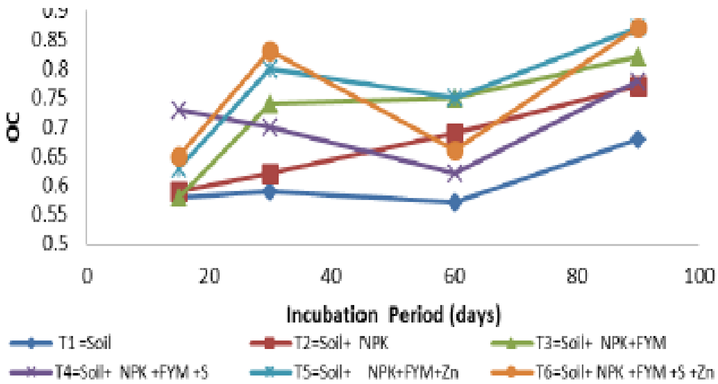

Fig 1: Influence of inorganic and organic amendments on changes in Organic Carbon (%)

Available Nitrogen (N)

Throughout the treatments, available nitrogen (N) was generally declining up to the 60th day of incubation except for treatment T3. Thereafter, it started increasing and peaked on the 90th day of incubation (Table 2). The decline in available N at the onset can be attributed to microbial consumption and losses through denitrification and volatilization processes (Burger and Venterea, 2008). The following rise is because of the transformation of exchangeable ammonium ($NH4^+$) into microbial biomass N, which at the time of microbial turnover is released back in the system as available N (Kanchikerimath and Singh, 2001). N fertilizer inputs did, of course, have a response in all treatments-thus it's obvious that N maintains soil nitrogen pools.

Available Phosphorus (P)

For most treatments (except the control), available phosphorus followed a clear trend: it declined up to the 30th day, increased up to the 60th day, and declined slightly at the final stage of incubation (Table 2). This peak accumulation of available phosphorus on the 60th day is due to the mineralization of organic phosphorus, besides the fact that crop uptake did not occur in the experiment. The subsequent reduction in some treatments may be attributed to the consumption of phosphorus by microorganisms and its eventual conversion into other inorganic or organic forms with time (Clark, 1998; Antil and Singh, 2007). Incorporation of organic and inorganic fertilizers with micronutrients increased the population of phosphorus-solubilizing microorganisms, which improved the availability of phosphorus in the soil further (Buurash, 1997; Fraser, 1994). These results point out the necessity of integrated nutrient management to ensure phosphorus availability.

Available Potassium (K)

Available potassium (K) content decreased continuously throughout the incubation period, irrespective of treatment (Table 2). Available K, however increased significantly on the 15th day in the treatments where potassium fertilizer was applied. Treatment T3 noted the highest K content available at the end on the 30th day with the likely liberation of potassium from FYM and inorganic sources with healthy microbial growth. Antil and Singh (2007) stated that the potassium levels were retained in the soil due to both organic and inorganic amendments applied.

Available Sulfur (S)

The amount of available sulfur (S) in the soil, as presented in Table 2, peaked on the 30th day of incubation for all treatments. This increase is due to the mineralization of organic matter in the soil. However, sulfur levels declined slightly between the 30th and 60th days before increasing again during the final stage of incubation, except in treatments T4 and T5. The changes in sulfur availability are closely related to the dynamics of organic matter mineralization and the particular treatment combinations used (Saren and Saha, 2018). The statistical analysis indicated that there were significant differences between treatments, sampling stages, and their interactions.

DTPA-Extractable Zinc (Zn)

The DTPA-extractable zinc (Zn) concentrations increased with incubation time for all treatments except the control (Table 2). The highest extractable Zn was recorded in treatment T6 at all sampling stages. Dash (2015) reported that the interaction of Zn with other nutrients, especially sulfur, is synergistic and thereby increases its availability. The effect of Zn plus S was additive, which further added to the increment in extractable Zn levels. Statistical analysis confirmed significant differences among treatments, sampling stages, and their interactions, highlighting the critical role of nutrient management in enhancing zinc availability in soils.

Table 2: Influence of inorganic and organic amendments on different soil parameters

Treatments	Incubation Period (Days)	Av. N (kg ha^{-1})	Av. P (kg ha^{-1})	Av. K (kg ha^{-1})	Av. S (mg kg^{-1})	DTPA Zn (mg kg^{-1})
T1 = Soil	15	234.13	65.92	189.06	5.34	0.78
	30	174.14	64.43	166.5	11.12	0.84
	60	173.46	85.73	154.29	10.22	0.6
	90	162.91	81.72	139.02	15.8	0.56
T2 = Soil + NPK	15	245.5	81.15	220.09	6.65	0.88
	30	175.06	52.28	240.48	19.58	1.02
	60	168.13	94	175.12	12.36	0.74
	90	226.79	83.13	173.62	18.25	0.78
T3 = Soil + NPK + FYM	15	274.73	167.38	263.41	10.22	0.98
	30	210.58	107.19	257.01	19.06	1.2
	60	240.7	159.34	218.09	14.96	1.32
	90	252.73	144.81	207.33	19.6	1.84

T4 = Soil + NPK + FYM + S	15	256.28	146.55	259.07	16.74	1.1
	30	203.96	132.35	205.63	33.28	1.32
	60	194.46	157.98	224.05	28.22	1.24
	90	237.23	160.2	182.26	26.84	1.02
T5 = Soil + NPK + FYM + Zn	15	252.76	116.75	256.23	13.32	1.22
	30	194.76	97.29	218.76	25.24	1.4
	60	185.03	172.66	205.32	24.52	1.02
	90	261.36	157.02	218.68	23.19	2.12
T6 = Soil + NPK + FYM + S + Zn	15	266.4	100.69	218.83	18.55	1.56
	30	196.06	109.25	205.9	28.5	1.92
	60	202.88	194.21	197.27	25.67	1.34
	90	238.95	158.2	189.35	30.32	2.48
SEm (Tr x Days)		4.56	2.8	0.96	0.91	0.02
CD (P = 0.05)		12.97	7.96	2.75	2.6	0.04

5. Conclusions

The integrated use of organic and inorganic amendments significantly improves soil nutrient dynamics and fertility in Typic Haplaquept soils of West Bengal. The addition of farmyard manure (FYM), sulfur (S), and zinc (Zn) with NPK fertilizers proved highly effective in improving organic carbon content and the availability of key nutrients such as nitrogen (N), phosphorus (P), potassium (K), sulfur (S), and zinc (Zn). T3 (NPK + FYM) and T6 (NPK + FYM + S + Zn) were the treatments that showed most remarkable results, as they increased the availability of oxidizable organic carbon and micronutrients, indicating their synergistic effects. The results show that balanced fertilization is not just a short-term nutrient supplement but also enhances the activity of microbes along with the entire long-term soil health. The study further emphasizes the role of micronutrients such as Zn in alleviating deficiencies commonly observed in the region's soils, thereby supporting crop productivity. This integrated approach provides a sustainable solution to nutrient management, ensuring both agricultural productivity and soil sustainability for the long term.

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