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Effect of organic manures and lime on nutrient availability and soil enzyme activity under upland rice in North Eastern Himalayan Region

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ABSTRACT

A field experiment was conducted to evaluate the effect of various nutrient sources and lime on nutrient availability and soil enzymatic activities in upland rice in North Eastern Himalayan region, Meghalaya. The experiment was laid out in FRBD (Factorial Randomized Block Design), with three replications and twelve treatment combinations (Control, 100% RDN through inorganic means, 100%RDN through FYM, 50%RDN through FYM+50%RDN through Vermicompost (VC), 50%RDN though FYM+50%RDN through Poultry manures (PM), 50%RDN though FYM+50%RDN through Pig Manures (SM), each treatment alternatively supplemented with lime @ 400 kg/ha). Available N, P, K, Fe, Zn were significantly higher in 50% FYM + 50% SM followed by 50% FYM + 50% PM over control. Enzyme activities as observed for dehydrogenase, fluorescein diacetate and soil microbial biomass carbon were significantly higher by 78.6%, 47.0% and 44.5% in 50% FYM + 50% SM at harvest. Urease enzyme activity was highest in 100% inorganic at flowering. The increase in enzyme activity due to liming was not found.

Introduction

Production oriented agriculture practices contrasts modern agriculture that aims at balance input use, reduced cost of cultivation and minimal environmental impact. The type of nitrogen fertilizer used may affect the growth, yield and grain quality of rice (Chaturvedi, 2005). Rice is widely consumed staple food and India is the largest consumer and producer of rice (115.63 mt). The whole grains are rich in calorie, fibre, thiamin, magnesium, phosphorous, selenium and manganese, dietary fiber and bioactive compounds.

Livestock holds an important place in the rural farm economy giving additional income and bears risk of crop failure. Livestock population in India

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counts to 535.78 million (20th livestock census, 2019). Northeast states hold 6.7% of cattle, 1% of sheep, 5% goat, 40% pigs and 5% livestock population from the national share. The traditional practice of using organic manures has changed in recent past because of readily available cheaper chemical fertilizers. Organic manures undoubtedly enhance soil health, plant growth and are important in sustainable agriculture.The labile soil microbial biomass makes up 1–3% of total soil organic matter. Soil organic matter affects crop growth and yield by influencing the supply of available plant nutrients. Microbial biomass nitrogen makes up to 5% of total soil N, which contributes to most labile carbon and nitrogen pools in soils (Luce *et al.,* 2011). N immobilised in microbial biomass has a ten-fold faster turnover time than N obtained from plant material (Rastetter *et al.,* 2021). Organic matter, whether in the form of crop residues or farmyard manures, has been shown to improve soil structure, water retention capacity, infiltration rates, and bulk density (Bhagat and Verma, 1991). Long-term soil management is reflected in soil quality (Ramphisa and Davenport, 2020). The importance of physical, chemical, and microbiological indicators in crop production, as well as how they are affected by nutrient management strategies, are highlighted by the quality and functioning of soil in crop production. Microbial and enzyme activity are very sensitive to changes induced by fertilisation that makes them superior indicators for soil quality assessment (Ramphisa and Davenport, 2020). Microbial biomass carbon, nitrogen and extra cellular enzymes produced by soil microorganisms are the key to nutrient cycling, fertility and functionality of soil ecosystem (Sinsabaugh and Follstad Shah, 2012). As a result, the size and activity of the microbial biomass have a significant impact on nutrient cycling, availability, and production in agroecosystems (Friedel *et al.,* 1996). An index of general microbiological activity of the soil is given by soil dehydrogenases belonging to oxidoreductase class (Gu *et al.,* 2009), reflecting the rate of transformations occurring in the soil. Soil phosphatase levels regulate the biotic pathways of phosphorus, often the limited plant available nutrient (Chadwick *et al.,* 2003). Therefore, phosphatase play a fundamental role in transforming phosphorous in soil organic matter to available forms. Bacteria, fungi and plant roots produce phosphatase enzymes that cleave phosphate group from unavailable recalcitrant organic form to assimilable phosphate (Brady and Weil, 2008; Margalef. *et al.,* 2017). Urease (Urea amidohydrolase) degrades urea, is considered a good proxy of nitrogen mineralization. Lime and decomposed organic manure increases the urease enzyme activity (Adetunji *et al.,* 2020). The number of active fungus and bacteria in a soil sample is determined by fluorescein diacetate (FDA) hydrolysis, which only distinguishes between active and inactive biomasses and does not show the level of activity of the active biomass.The type and number of microorganisms are subjected to soil pH change. India being a tropical country has about 49 million ha of arable land under pH < 6.5 (Majji *et al.,* 2012). North Eastern region covers 21 million ha of acid soil both arable and non arable owing to heavy annual rainfall of > 2500mm. This leaches down and washes off tonnes of soluble nutrient from soil. Most micronutrients precipitate at low pH and become unavailable to plants, or they may be present in hazardous levels. To combat the negative effects of pH on plant growth, lime should be added to the soil prior to cultivation. Liming benefits plants in a variety of ways, including lowering the risk of Mn2+ and Al3+ toxicity. It boosts microbial activity, physical structure, symbiotic nitrogen fixation, forage palatability, and provides a low-cost supply of Ca^{2+} and Mg^{2+}. It also boosts P and Mo nutritional availability. An experiment was undertaken to evaluate the simultaneous influence of organic sources of fertilisers and lime on soil fertility in upland rice, taking into account the above available resources and limits. As a result, the focus of this experiment is on the impact of organic manure sources and lime on soil nutrition and health in an upland rice setting.

Material and Methods

Experimental site

The field trail was taken up with upland rice (Local ruling variety Bhalum 3) on the terraces at the ICAR Research Complex for North Eastern Himalayan Region (ICAR–RCNEH), Barapani, Meghalaya. The nutrient status of soil is given in Table 1.

Table 1. Nutrient status of the experiment soil

Soil chemical properties	Content	Method of analysis
Soil organic carbon (%) (0–15 cm)	1.62 %	Walkley and Black (1934)
Available N (kg/ha) ($KMnO_4$-oxidizable N)	256 kg/ha	Subbiah and Asija (1956)
Available P (kg/ha) (0.03 N NH_4F extractable P)	6.3 kg /ha	(Bray and Kurtz, 1945)
Available K (kg/ha) (0.1N NH_4OAc exchangeable K)	354 kg /ha	Hanway and Heidal (1952)
Soil pH (Initial)	3.8	0.01M $CaCl_2$

Treatment details

With three replications, the experiment was conducted in a factorial randomised block design (3 m * 4 m). Factor A: N0- Control; N1- 100% RDN inorganic; N2- 100% RDN through FYM; N3- 50% RDN through FYM + 50% RDN through Vermicompost (VC); N4- 50% RDN though FYM + 50% RDN through Poultry manures (PM); N5- 50% RDN though FYM + 50% RDN through Pig manures (SM). Factor B: L0- No Lime; L1- Lime (400kg/ha). Each of Factor A was alternated with Factor B making 12 treatment combinations. For inorganic treatment N was applied in two splits at basal and tillering stage. P and K were applied as basal @ 60–40–40 N–P_2O_5–K_2O kg/ha or @ 60–17.5–35.7 (N–P–K). Organic manure was applied at recommended dose of nitrogen (Table 2).

Soil sampling and nutrient estimation

Soil samples were collected randomly following quartering method from each plot from 0–15 cm depth using core sampler. The samples were analysed for soil organic carbon (SOC), available NPK. Micronutrients were estimated by atomic absorption spectrophotometer (AAS).

Soil microbial properties

Fresh soil samples collected from 0–15 cm depth were analysed for following parameters:

Soil microbial biomass carbon (SMBC)

Vance *et al*., (1987) described a strategy for estimating microbial biomass carbon. 17.5 g soil samples were taken in duplicate in sealed vials and fumigated with 1 ml chloroform. As non-fumigated samples, another set of 17.5g soil was stored in a 250 ml conical flask. Both sets were held at 37.5°C for 24 hours of incubation. Chloroform was evaporated for 2 hours at 37°C, after which 70 ml 0.5 M K_2SO_4 was added to both sets and shaken for 30 minutes. Whatman No. 42 filter paper was used to remove the supernatant. At 280nm, the filtrate's OD value was measured. On a soil dry weight basis, soil microbial biomass carbon (SMBC) was estimated by subtracting the titre values of non–fumigated from fumigated samples.

Dehydrogenase enzyme activity

Casida *et al*., (1964) established a technique for calculating dehydrogenase activity in soil samples. Triphenyl Tetrazolium Chloride (TTC), Methanol (AR grade), and Triphenyl Formazon (TPF-100 g/mL) were administered as reagents. In a screw-capped test tube, 6 g fresh air dried soil sample and 60 mg CaCO3 were completely mixed with 1.0 ml freshly made TTC (3 percent w/v) solution and vortexed for 1 minute. These test tubes were incubated for 24 hours at 37°C. The following day, 10 mL methanol was added and vortexed for 1 minute. TPF (pink layer) was filtered. This procedure was followed once again. At 485 nm, the absorbance of the supernatant was measured using a Spectrophotometer. TPF (0–50 g/ml) was used to create a standard curve. The standard curve was used to calculate the concentration of TPF in the sample. The activity of dehydrogenase was calculated and expressed in terms of g TPF liberated g TPF/g of soil/24 hr.

Acid phosphatase activity

The activity of acid phosphatase in soil was measured using Tabatabai and Bremner's method (1969). Toluene, p-Nitrophenyl phosphate (0.115 M), calcium chloride (0.5 M), and sodium hydroxide reagents (0.5 M) were used in a modified universal buffer (MUB; pH 6.5). 1 g of fresh soil sample was taken in triplicate in screw cap tubes and mixed thoroughly with 4 ml MUB, 0.25 ml toluene, and 1 ml p-Nitro phenyl phosphate solution. After 1 hour of incubation at 37 °C, 1 ml 0.5 M $CaCl_2$ and 4 ml 0.5 M NaOH were added to the solution. Whatman No.42 filter paper was used to filter the supernatant. The absence of p-nitrophenol phenyl phosphate was used as a control. The amount of p-nitro phenol in the sample was measured using a spectrophotometer at 420 nm, and acid phosphatase activity was calculated as g p-NP/g of soil/24 hr.

Table 2. Nutrient content of manures (manure applied w.r.t recommended dose of N given in bracket)

Manures	N (%)	P (%)	K (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)
FYM	0.5 (12t/ha)	0.3	0.5	1400	212	57
Vermicompost (VC)	3.5 (1.8t/ha)	1.2	2.0	1300	109	64
Poultry manure (PM)	3.5 (1.8t/ha)	3.0	3.0	1450	215	91
Pig manure (SM)	4.2 (1.5t/ha)	2.9	3.8	1500	110	80

Urease activity

To determine urease activity, two reagents were required. Reagent A was made with a 1:4 dilution of Phenol @50g/l and Na-nitroprusside-0.25g/l (reagent:water). Reagent B was freshly made by combining 25g/l NaOH and 2.1g/l Na-hypochlorite. In triplicate, 1 g of soil was weighed and placed in a screw-capped bottle. 500 l of 0.8M urea solution was added to it, and it was incubated for 2 hours at 37 °C. After that, 10 mL 1N KCl was added and shaken for 30 minutes. Following filtration, 1 mL of filtrate was pipetted into a test tube, followed by 5 mL of each reagent, and the OD was measured at 625 nm. It was calculated as g p-NP/g soil/24 hours.

FDA hydrolysis

A spectrofluorometer is used to measure FDA. 5mg FDA was dissolved in 10ml reagent grade acetone to make a new FDA stock solution. Dissolving 8.7g dipotassium phosphate in 400ml distil water and 1.3g potassium dihydrogen phosphate in 400ml distil water yielded a 60mM phosphate buffer (pH 7.6). Both solutions were mixed and brought to a volume of 1 litre. 5ml of 60mM potassium phosphate buffer and 10ul FDA stock solution were added to 1g of soil in triplicate. After vortexing, it was incubated at 37°C for 2 hours. The process was then abruptly stopped with the addition of 0.2ml acetone. After that, it was vortexed and filtered using Whatman No.42 filter paper, and the OD value was measured at 490nm with Fluoresein standard. It was calculated as g p-NP/g soil/24 hours. Strong enzymatic activity is indicated by a bright yellow-green glow.

Results and Discussion

Available N

The nutrient sources showed higher available N concentration over control (300 kg/ha). 100% inorganic had the lowest (247 kg/ha) and 50% FYM + 50% SM had the maximum available N (276 kg/ha). 50% FYM + 50% SM, 50% FYM + 50% PM and 50% FYM + 50% VC were 11.7%, 10.1% and 8.0% significantly higher over 100% inorganic. Though 50% FYM + 50% SM, 50% FYM + 50% PM and 50% FYM + 50% VC are at par with each other 50% FYM + 50% SM was 3.3% and 1.4% higher over the later two respectively. Liming had no significant effect on available N however, 4.6% increase in available N was recorded in limed treaments (Table 3).

Available P

Available P recorded was higher in soil for nutrient sources over control (5.38 kg/ha). The nutrient sources were mostly at par with each other however, 50% FYM + 50% SM had maximum available P (8.27 kg/ha) and was 5.0%, 5.7%, 12.3% and 22.3% higher over 100% inorganic. Liming did not have a significant effect but was 9.1% higher in the available P (7.48 kg/ha) over no lime (6.85 kg/ha) (Table 3).

Available K

Available K was favourable for nutrient sources over control (322 kg/ha). 50% FYM + 50% SM (370 kg/ha) was promisingly 6.6% higher over 100% inorganic (347 kg/ha). 50% FYM + 50% SM, 50% FYM + 50% PM, 50% FYM + 50% VC and 100% FYM were at par with each other however 50% FYM + 50% SM was 1.6%, 3.3% over 4.5% higher over the later three respectively. Liming increased 4.5% available K however the increase was not significant (Table 3).

Available micronutrients

Availability of Fe and Zn responded significantly to the nutrient sources and liming whereas available Mn did not. Control (207 mg/kg) and 100% inorganic (202 mg/kg) were at par with each other. 50% FYM + 50% SM (238 mg/kg) and 50% FYM + 50% PM (234 mg/kg) were similar to each other in available Fe but promisingly higher over 50% FYM + 50% VC by 8.6% and 6.8%, and 100% inorganic by 17.8% and 15.8% respectively. Similarly, control (4.65 mg/kg) and 100% inorganic (4.29 mg/kg) were at par with each other. Available

Table 3. Effect of different nutrient sources and lime on the chemical properties (available N, P, K, Fe, Mn & Zn) of soil at harvest of rice

Treatment	Available N (Kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Available Fe (mg/kg)	Available Mn (mg/kg)	Available Zn (mg/kg)
Sources of Manure (A)						
Control	235	5.38	322	207	35.5	4.65
100% inorganic	247	7.82	347	202	33.2	4.29
100% FYM	264	6.56	354	228	37.8	5.32
50% FYM + 50% VC	267	7.34	358	219	36.3	5.53
50% FYM + 50% PM	272	7.57	364	234	37.2	5.60
50% FYM + 50% SM	276	8.27	370	238	36.1	5.61
SEm(±)	6.11	0.59	7.78	4.06	1.25	0.28
CD (P=0.05)	17.85	1.72	22.79	11.71	NS	0.80
Lime (B)						
No Lime	258	6.85	351	225	35.6	5.14
Lime (400 kg/ha)	270	7.48	367	234	36.5	5.50
SEm(±)	5.57	0.24	6.94	3.19	0.89	0.15
CD (P=0.05)	NS	NS	NS	8.87	NS	NS

Zn was maximum in 50% FYM + 50% SM (5.61 mg/kg). 50% FYM + 50% PM (5.60 mg/kg) was promisingly 30% high over 100% inorganic. Liming increased available Fe significantly by 4% but had no effect on Manganese and zinc availability (Table 3). 50% FYM + 50% SM and 50% FYM + 50% PM had maximum available N, P, K, Fe and Zn because pig manure and poultry manure had sufficiently higher nutrient concentration. Pig manure in Meghalaya are richer in plant essential nutrients over FYM because they make an important animal component of every household and are part of their cuisine. Hazarika *et al.,* (2020) also reported similar results. Organic manures enhance the physical, chemical, and biological qualities of the soil. Organic manures added as per recommended dose of nitrogen was sufficient to ameliorate acid soils and reduce the fixed nutrients like Fe and Mn from their higher oxide form to their lower oxide that is available to plants for uptake. Nitrogen loss as denitrification, runoff, leaching and volatilization was very meagre from the organic matter than the fertilizers where nutrients are in readily available form. The well–decomposed manures could synchronise phosphorous mineralisation with plant uptake so that fixation is minimal (Kumar *et al.,* 2021). In case of fertilizer treatment readily available phosphorous gets fixed soon in acid soil as insoluble iron and aluminium phosphates and availability is lower than organic manures (Syers *et al.,* 2008). FYM owing to its low nutrient status could supply nutrient in low concentration (Hopmans, 2019). Available Fe, Mn and Zn were slightly lower in 100% inorganic treatment over control may be because only recommended dose of N, P and K were added in former treatment. 100% inorganic treatment had better growth compared to control because of readily available plant available nutrients that might have helped in higher uptake of micronutrients from soil. Many phenolic, carboxylic, and enolic groups are found in partially decomposed organic materials, which can consume protons at their normal pH (Wong *et al.,* 1998). Their ability to neutralize acidity when added to acid soils is partly due to their buffering capacity, which is due to their ability to consume protons. Similarly, protons can be used by simple organic acid anions found in organic materials (Naramabuye and Haynes, 2007). That is, if the pH of the soil is less than the pKa of the weak acid groups on added organic matter, the pH of the soil will rise due to H^+ from the soil interacting with the organic anions (Ritchie and Dolling, 1985). This increase in pH with manure application is consistent with Ramphisa and Davenport's (2020) findings, which found that adding organic manures to soil resulted in an increase in soil pH and a decrease in Al ions in soil solution. Liming is well known for increasing soil pH by exchanging H^+ from clay complexes with Ca^{2+} ions and forming OH^-, neutralising active acidity. Liming is the process of adding mineral calcium and magnesium compounds to acidic soils, mostly carbonates, oxides, hydroxides, or a mixture of them, and, less commonly, silicates, to reduce the concentration of protons (Yadesa *et al.,* 2019). Amount of lime applied did not raise the pH of the soil to neutral but the slight increase in pH to 5.2 could show its effect faintly and without any promising result. The slight increase in available Zn due to liming may be because of high Zn concentration in manures. Zhang *et al.,* (2020) had also reported the same from Meghalaya. The meagre effect of liming may be because the quantity of lime applied was not sufficient to raise the soil pH of experimental plot to neutral.

Effect of nutrient sources and liming on the soil microbiological properties at flowering and after the harvest of rice crop

Data on the subject of, dehydrogenase activity, acid phosphatase activity, FDAase activity, urease and soil microbial biomass carbon of rice.

Dehydrogenase enzyme activity

Dehydrogenase activity was slightly higher at flowering than at harvest. In terms of nutritional sources, it outperformed the control (188 g TPF/g soil/24 hr). Among the nutrient sources highest dehydrogenase enzyme activity at harvest was observed in 50% FYM + 50% SM (377 µg TPF/g soil/24 hr) that is 16%, 28.6%, 45% and 78.6% high over 50% FYM + 50% PM, 50% FYM + 50% VC, 100% FYM and 100% inorganic respectively. There was no significant effect of lime on dehydrogenase enzyme activity just 4.4% higher activity was due to liming. The trend was also similar at flowering stage (Figure 1).

Acid phosphatase activity

Acid phosphatase activity was higher at harvest than at flowering stage. At flowering stage nutrient sources had promising enzyme activity over control (140 µg p-NP/g soil/24 hr). 50% FYM + 50% SM, 50% FYM + 50% PM, 50% FYM + 50% VC and 100% FYM were at par with each other. However, 50% FYM + 50% SM (159 µg p-NP/g soil/24 hr) had 8.9% higher activity over 100% FYM. At flowering, liming (151 µg p-NP/g soil/24 hr) favourably increased acid phosphatase activity by 6.3%. At harvest, nutrient sources and lime were at par with control and no lime respectively but had similar trend as at flowering (Figure 2).

Fluorescein diacetate activity (FDA)

Higher FDA was observed at flowering than harvest stage. 100% inorganic (1.98 µg fluorescein/g/hr) and control (1.65 µg fluorescein/g /hr) were similar to each other. Among the nutrient sources highest FDA was observed in 50% FYM + 50% SM (2.91 µg fluorescein/g/hr) that is promisingly 8.8%, 14.5% and 47% higher over 100% FYM, 50% FYM + 50% VC and 100% inorganic respectively. Liming had 12.6% significantly high FDA. Similar trend was at harvest stage for nutrient sources only (Figure 3).

Urease enzyme activity

At flowering, significantly maximum urease activity was in 100% inorganic treatment (40.4 µg NH_3/g/hr). 50% FYM + 50% SM, 50% FYM + 50% PM and 50% FYM + 50% VC were similar in urease activity. 50% FYM + 50% SM was 37% higher over 100% FYM. 100% inorganic was 39.7% higher over 50% FYM + 50% SM. Liming raised urease activity by 13.8% at flowering. However, at harvest all the nutrient sources had a slightly higher urease enzyme activity over flowering except for control and 100% inorganic treatment. Liming slightly increased urease activity at harvest over flowering. 18.2% higher urease activity was due to liming at harvest (Figure 4).

Soil microbial biomass carbon (SMBC)

Higher SMBC was at flowering over harvest. At flowering, control (226 µg/g/dry soil) and 100% inorganic (200 µg/g/dry soil) had then lowest SMBC and were at par with each other. 50% FYM + 50% SM, 50% FYM + 50% PM and 50% FYM + 50% VC were at par with each other. 50% FYM + 50% SM (289 µg/g/dry soil) was 12.8% and 44.5% higher over 100% FYM and 100% inorganic. Liming did not have promising effect on SMBC however, 8.5% increase was seen. At harvest the trend was similar to flowering except for control (184 µg/g/dry soil) was significantly higher over 100% inorganic (136 µg/g/dry soil). Liming did not have significant effect at harvest though it gave 15% higher SMBC (Figure 5).

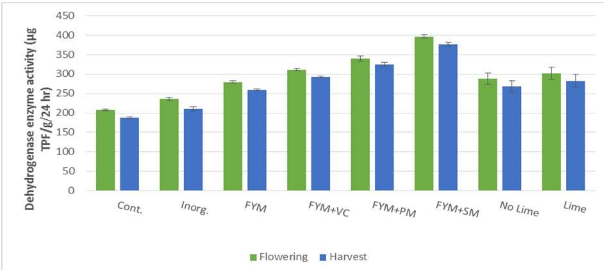

Figure 1: Effect of nutrient sources on dehydrogenase activity of soil at harvest of rice.

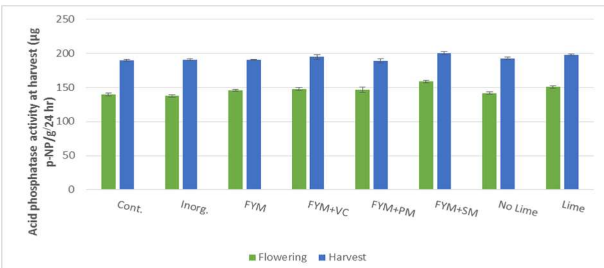

Figure 2: Effect of nutrient sources on acid phosphatase activity of soil at harvest of rice.

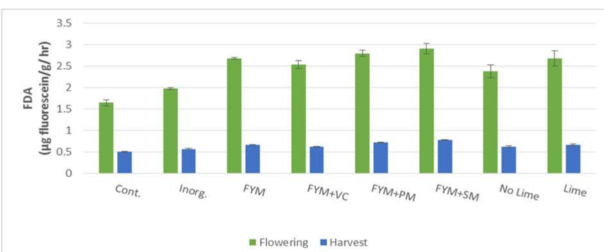

Figure 3: Effect of nutrient sources on FDA activity of soil at harvest of rice.

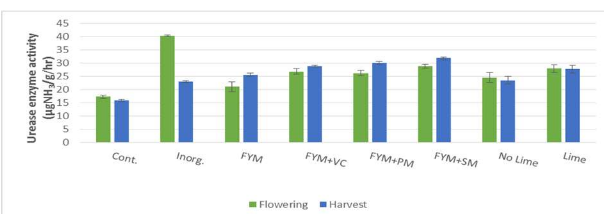

Figure 4: Effect of nutrient sources on Urease activity of soil at harvest of rice.

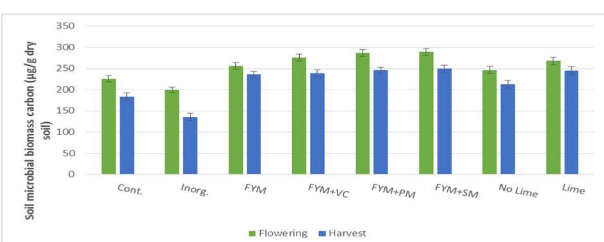

Figure 5: Effect of nutrient sources on soil microbial biomass carbon activity of soil at harvest of rice.

The physical and chemical qualities of the soil, as well as the structure of the microbial population, are affected by the application of organic manure. Wherever organic manure is used, microbial activity improves in the root rhizosphere. Soil microorganisms benefit from organic manure because it provides a suitable habitat, protects them from predation, and improves soil physicochemical qualities (Atkinson *et al.,* 2010; Lehmann and Joseph 2015; Smith *et al.,* 2010). Organic matter acts as an easily degradable substrate by increasing the soil's labile C pool, which aids soil microorganism growth (Das *et al.,* 2017; Zhen *et al.,* 2014). Increased soil microbial biomass carbon, acid phosphatase activity, urease enzyme activity, FDA activity, and dehydrogenase activity all indicate improved soil microbial characteristics. The variation in nutrient composition and indigenous microbial community in manures affect the soil microflora. Microbial community from the gut of livestock, in FYM, may not be as competitive in soil environment but the presence of beneficial and absence of harmful microorganism is favourable to improve soil fertility and productivity (Hartmann *et al.,* 2015; Sun *et al.,* 2015). Due to higher nutrient concentrations that may contribute to faster mineralization, 50% FYM + 50% SM and 50% FYM + 50% PM resulted in more biological activity than solitary application of FYM, inorganic, and control treatments. Kumawat *et al.,* (2009), reported similar observations. FDA, dehydrogenase activity values were higher at flowering over harvest because both of them are highly correlated to microbial respiration when easily degradable C sources, SMBC is high in soil (Lalande *et al.,* 2000). There was slight increase in soil microbial biomass carbon, dehydrogenase activity and FDA owing to utilization of organic substrate during the growing period of rice. Organic matter in the soil is an important predictor of microbial activity. Organic inputs promote microbial biomass carbon and organic carbon in the soil by increasing enzymatic activity (Nath *et al.,* 2012). Baishya *et al.,* (2017) showed the highest dehydrogenase and acid phosphatase enzyme activities under 50 percent FYM + 50 percent SM treatment combinations, which could be related to enhanced oxidative activity of soil microflora. Urease activity was highest for inorganic treatment because of immediate availability of urea as nitrogen substrate for hydrolysis. Acid phosphatase activity was reportedly higher at harvest stage may be due to rise in pH of acid soil which favoured the acid phosphatase activity. Bacteria, fungi, yeasts, protozoa, mycorrhizal fungi and plant roots, produce acid phosphatases. The production of acid phosphatase is optimum at 4.8 pH (Margalef *et al.,* 2017). Similar was the reason for slight higher urease activity at harvest that has optimum activity at 6.4 pH (Tabatabai and Bremner, 1972).

Conclusion

Growing upland rice on acid soils with a combination of FYM and Pig manure is a great way to maintain productivity, profitability, and soil health, according to this study. Application of 50% FYM + 50% SM or 50% FYM + 50% PM is sufficient for management of soil health and supply of essential nutrients in upland acid soils of Meghalaya in North Eastern Himalayan region of India.

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Conflict of interest

The authors declare that they have no conflict of interest.

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