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Long Term Influence of Manure- Fertilizer Treatments on Soil Biological Health and Yield of Rice Crop

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Authors' contributions

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

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ABSTRACT

Long term manure fertilizer experiments provide valuable information on the impact of long term adoption of nutrient management systems with varying sources, types and combinations of plant nutrient inputs on soil fertility and productivity. A Permanent Manurial Experiment (PME) under rice monoculture is in operation since 1975 at the central farm of the Agricultural College and Research Institute, Madurai. The present study was taken up to evaluate the effects of different manure – fertilizer schedules on certain properties of the soil, available nutrient status, total microbial population and enzyme activities of the soil. In this experiment, four main plot treatments involving three organic manures viz., FYM, GLM and UC @ 12.5 t ha^{-1} with a no manure control and eight sub plot treatments viz., control N,P,K,NP,NK,PK and NPK. The 57th rice crop (Var ADT 49) was raised during *rabi* 2016 with NPK recommended dose of 150:50:50 kg N, P_2O_5 and K_2O respectively. The maximum total bacterial population (128 x 10^6 $CFUg^{-1}$ of dry soil), total fungal population (70 x 10^4 $CFUg^{-1}$ of dry soil) and total actinomycetes population (84 x 10^3 $CFUg^{-1}$ of dry soil) were registered in the plots that received integrated application of GLM @ 12.5 tha^{-1} and 100%

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recommended NPK (150:50:50 kgha^{-1} during this season). However compared to the bacterial population, the inorganic fertilizers did not have much influence on the fungal population as that of the organic manures. Integrated application of GLM @ 12.5 tha^{-1} along with N fertilizer with or without P and K registered the maximum dehydrogenase activity, during tillering stage of rice crop. The maximum yields of rice grain and straw (4790 and 8701 kg ha^{-1}) respectively was recorded in the treatments that received GLM and NPK and it was evident that the inclusion of FYM or GLM or Urban compost along with NPK, N, NP, and NK fertilizers recorded significantly higher yields than their individual applications and unmanured and unfertilized control.

Keywords: Fertilizer; green leaf manure; microbial population; rice crop yield.

1. INTRODUCTION

Globally, rice is grown on 193Mha [1], though its production and consumption is concentrated in Asia, where more than 90% of all rice is consumed. India produced 117.5 million tonnes during 2019-20 from 42.77 million hectare [2]. with an average productivity of 2.9 t ha^{-1} [3]. The yield level of rice has to be hiked by 25 to 30 per cent from the present level, if the country has to remain self-sufficient by 2025. Tamil Nadu contributes 8 per cent to national rice production from an area of 1.87 million ha with the production of 7.65 million tones [4]. However, the intensive cultivation of rice has resulted in heavy depletion of soil nutrients. Thus, the future food and nutritional security of India depends upon the continuous improvement in the productivity of soil and crop on sustainable basis through adequate and balanced management of inputs without degrading the natural resources for which the results of permanent manurial experiment will be of much significance. One such permanent manurial experiment on rice is being conducted at the central farm of the Agricultural College and Research Institute, Madurai, since 1975 to evaluate the response of rice crop to different manure-fertilizer schedules and changes that would take place in the properties and fertility status of soil under rice monoculture. Several findings are continuing to be emanated from these long term studies which could be applied for enhancing soil fertility and crop productivity. The findings of the previous experiments have established that continuous application of organic manures have improved the physical and physico chemical properties of soil. Further the results show that the regular application of inorganic P fertilisers have resulted in accumulation of soil P and to reduce 50 percent of recommended P for rice crop in case of soils reporting high status of available P. It was also observed that the most important problem under continuous cropping is the imbalance of soil microflora.

Soil processes such as mineralization, humification are mediated by microorganisms and they play a significant role in the mechanisms of nutrient availability [5]. Hence it is imperative to have a better understanding of the factors that regulate its size, activity, and structure [6]. Soils containing a high microbial diversity are characteristic of a healthy soil-plant relationship and hence information regarding long-term effect of absence or presence of nutrients on the microbial community is important for the regulation of the microbial population in rice ecosystems. Further, the repeated application of fertilizers to soil can change the soil microbial community directly or indirectly since they change the physical, chemical and biological properties [7]. However limited information is available on microbial diversity under long term experimentation of manure - fertilizer schedules under rice monoculture. Much of the research work on long term fertilizer experiments were focused on soil physico-chemical and chemical properties. Hence the present study was undertaken to assess the total and functional soil microbial population (bacteria,fungi and actinomycetes) as influenced by organic, inorganic and integrated nutrient management (INM) on rice crop and to study the correlation of microbial dynamics on available nutrient status of soil and the yield of rice crop.

2. MATERIALS AND METHODS

The permanent manurial experiment is in operation since 1975 at the Agricultural College and Research Institute, Madurai, Tamil Nadu (95o4' North latitude, 78o0' East longitude and 147 m above MSL) in sandy clay loam soil (Typic Haplustalfs). The main plot comprises of four treatments viz., M1- control (No Manure), M2- Farm yard manure (FYM@12.5 t ha^{-1}),M3- Green leaf manure (GLM) @ 12.5 t ha^{-1}) and M4- Urban compost(UC) @ 12.5 t ha^{-1}).The subplot comprises of eight treatments S1- Control (no N,P and K),S2 - N alone (N), S3- P alone(P),S4-

K alone (K),S5- N+P,S6- N+K, S7 –P+K and S8- N+P+K. The treatments were imposed in split plot design in two replications. A field experiment was conducted in the existing permanent manurial experiment during rabi, 2015- 2016 with ADT 49 rice as test crop.

The organic manures were applied at the rate of 12.5 t ha-1 and incorporated into soil prior to planting. The amount of organic manure needed for the treatment was calculated on the basis of their nitrogen content and incorporated in the soil 15 days prior to transplanting of rice. Nitrogen, phosphorus and potassium are applied at the rates of 150, 50 and 50 kg ha-1, respectively in the form of urea, super phosphate and muriate of potash according to the treatments. Preplanting and post harvest soil samples were collected at 0-15 cm depth and analysed for various properties as per the standard procedures prescribed in Jackson, 1973. Soil microbial population was enumerated by using standard serial dilution plate techniques as given by Waksman and Fred [8] and enzyme activity as suggested by Cassida et. al., [9]. Analysis of variance was calculated as suggested by Panse and Sukhatme [10]. Simple correlation and regression co-efficients were also worked out between certain inter-related pairs of parameters to observe their degree of dependence as suggested by Snedecor and Cochran [11].

3. RESULTS AND DISCUSSION

3.1 Initial Characterization of the Experimental Soil

The soil of the experimental site was sandy clay loam in texture which was analysed for various properties before imposing the treatments for the 57th rice crop. The soil recorded pH 7.24 and electrical conductivity 0.30 dS m-1.The total N, P and K status of the soil were 0.08, 0.06 and 0.11 per cent respectively and the available N, P and K status were 185, 25.5 and 254 kg ha-1 respectively. The cation exchange capacity (CEC) of the soil was 22.8 cmol (p+) kg-1. The experimental soil belonged to the order Alfisol (Typic Haplustalf) as per the soil taxonomy. (Table 1). The manured plots of the previous experiments significantly recorded the maximum microbial population compared to unmanured plots (control). Among the manurial treatments, GLM treated plots registered the highest population of bacteria () fungi (39 x 104 CFU g-1 of dry soil) and actinomycetes (60 x 103 CFU g-1 of dry soil). Among the fertilizer schedules, the maximum population of bacteria (78 x 106 CFU g-1 of dry soil), fungi (40 x 104 CFU g-1 of dry soil) and actinomycetes (58 x 103 CFU g-1 of dry soil) was recorded in the plots that received NPK compared to unfertilized control plots. Among the integrated treatments, plots that received GLM @ 12.5 t ha-1 along with NPK (M3S8) registered the highest bacterial population of 79 x 106 CFU g-1 of dry soil, at preplanting stage. The minimum bacterial population of 46 x 106 CFU g-1 of dry soil was recorded in unmanured and unfertilized control (M1S1). The combined use of organic and inorganic fertilizers has been reported not only to meet the nutrients need of the crop but also has been fund to sustain large scale productivity goals through improving the biological properties of soil [12]

3.2 Long Term Effect of Manure – Fertilizer Schedules on Organic Carbon Content

Organic carbon content ranged between 6.1 g kg-1 in unmanured control and 13.7 g kg-1 with GLM treatment and was significantly higher in the treatments that received manures than in the unmanured control (Table 2). Among the sources of organics, significantly higher organic carbon status was observed with GLM followed by Urban Compost (UC) application. Similar observations were made by Anand Swarup [13] and Dejene and Lemlem, [14]. In case of fertilizer schedules, the organic carbon content of the soil varied from 10.7 mg kg-1 in unfertilized plots to 11.6 mg kg-1 in plots that received recommended NPK of 150:50:50 kg ha-1 Among them, organic carbon content was higher in the treatments that received N with or without P and K due to higher crop residues left in these treatments. The priming effect of inorganic N on fresh organic material in soil stimulates the microbial activity that resulted in organic matter decomposition and increase in the soil organic carbon content.

Application of 12.5 t ha-1of GLM resulted in 15.5% and 12% increase in organic carbon over the application of 12.5 t FYM and urban compost respectively. This is in line with the findings of Bayu et al. [15] and Francis Rayns and Anton Rosenfeld, [16] who reported that the green manure crops improves and incorporates the organic matter content of soil by adding larger biomass and stimulating the microbial activity in soil . A marginal increase (0.4 g kg-1) in the soil organic carbon content was observed from preplanting to post harvest stage due to manure-fertilizer application.

3.3 Long Term Effect of Manure – Fertilizer Schedules on Soil Microbial Activity

Biological activity of soil is an important factor of productivity from agricultural and ecological stand points and the amount of organic matter present influences the soil biological activity than any other factor. Microbial activity helps in recycling of energy and nutrients which is influenced by the application of organic manures and inorganic fertilisers as established through this study. It was observed that over the experimentation period, the microbial population (bacteria, fungi and actinomycetes) was significantly influenced by the manure-fertilizer treatments.

Table 1. Basic properties of the experimental soil

i) Mechanical analysis	**Values**
Coarse sand (%)	29.2
Fine sand (%)	34.8
Silt (%)	7.8
Clay (%)	27.0
Texture class	Sandy clay loam
ii) Physico-chemical properties	
pH	7.24
EC (dSm^{-1})	0.30
CEC (c mol(p^+) kg^{-1})	22.8
iii) Chemical properties	
Total N (%)	0.08
Total P (%)	0.06
Total K (%)	0.11
Organic carbon (g kg^{-1})	6.4
Alkaline $KMnO_4$ – N (kg ha^{-1})	185
Olsen P (kg ha^{-1})	25.5
N N NH_4 OAc-K (kg ha^{-1})	254

3.4 Total Bacterial Population

Application of organic manures and fertilizers significantly influenced the total microbial population of soil. Among the organic manures, application of GLM at 12.5 tha-1 registered the maximum bacterial population (108 x 106 CFUg-1 of dry soil) followed by application of UC at 12.5 tha-1 (96 x 106 CFUg-1 of dry soil) compared to that of unmanured control (69 x 106 CFUg-1 of dry soil). Among the fertilizer schedules, application of NPK at 150:50:50 kg ha-1 recorded the maximum total bacterial population (110 x 106 CFUg-1 of dry soil) compared to that of unfertilized control (74 x 106 CFUg-1 of dry soil). Integrated application of manures and fertilizers recorded significantly higher total bacterial population, the highest with GLM + NPK compared to other combinations. (Fig. 1). It may be due to the continuous addition of biomass and organic matter through the application of GLM and the effect of higher crop residues due to the application of 100% recommended NPK fertilizers.

The results also suggested that organic manure application had a stronger influence on soil bacterial population. Long term applications of organic manure may play an important role in sustaining soil microbial activities [17]. Further, the microorganisms occurring naturally in organic manures could also be contributing to the enhanced bacterial activity in soil. In this study, application of NPK fertilizers along with GLM had a positive impact on the total bacterial population (128 x 106 CFU g-1 of dry soil) compared to other combinations of manure-fertilizers. The GLM application neutralizes the soil pH, improves aggregate stability and soil aeration which inturn increases the bacterial population in soil. It was also evident that long term absence in input of any one major nutrient element significantly reduced the total bacterial population. Accordingly throughout the crop growth stages, the treatments N alone, P alone, K alone, N+P, N+K and P+K registered on an average 15 to 20% lesser bacterial population compared to that of application of NPK fertilizers. This was in accordance with the findings of Naher [18] indicating that balanced fertilization resulted in higher bacterial activity.

The total soil bacterial population as recorded during preplanting, tillering, flowering and post harvest stages showed significant variations with the manure-fertilizer treatments Among the crop growth stages, total bacterial population was the maximum in tillering stage (108 x 106 CFUg-1 of dry soil) which decreased to 93 x 106 CFUg-1 and 76 x 106 CFUg-1 during flowering and post harvest stages respectively.(Fig.1) This may be due to decrease in organic carbon content of soil with the advancement of crop growth stages. Similar observation was made by Meena et al. [19].

Table 2. Effect of manure-fertilizer schedules on organic carbon (g kg1) content of the soil

Treatments	Pre planting stage					Post Harvest stage					
Sub/Main	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**	**Sub plot mean**
S_1	5.5	10.9	13.6	12.8	10.7	5.7	10.7	13.7	13.0	10.7	10.7
S_2	6.4	11.5	13.9	13.1	11.2	6.5	12.1	14.6	13.2	11.6	11.4
S_3	5.9	10.8	13.7	12.7	10.7	6.3	11.3	14.0	13.1	11.1	10.9
S_4	5.6	9.9	13.5	12.4	10.3	5.8	10.5	13.9	12.7	10.7	10.5
S_5	6.0	11.9	13.9	12.9	11.1	6.6	12.3	14.5	13.5	11.7	11.4
S_6	6.9	11.9	13.7	13.2	11.4	6.9	12.3	14.3	13.6	11.7	11.6
S_7	6.4	10.8	13.7	12.2	10.7	6.6	11.4	14.3	12.6	11.2	11.0
S_8	6.8	12.0	13.9	12.9	11.4	6.9	12.4	14.5	13.5	11.8	11.6
Mean	6.1	11.2	13.7	12.7	10.9	6.4	11.6	14.2	13.1	11.3	
Main plotmean	M_1 – 6.3			M_2 – 11.4			M_3 – 14.0			M_4 – 12.9	

	Pre planting stage		Post Harvest stage	
	SEd	**CD(P=0.05)**	**SEd**	**C.D(P=0.05)**
M	0.22	0.43	0.23	0.43
S	0.26	0.51	0.27	0.52
M at S	0.62	1.22	0.88	1.75

3.5 Total Fungal Population

The long term presence or absence of major nutrient elements significantly influenced the total microbial populations in the wetland rice cultivation system. Among the organic manures, application of GLM at 12.5 tha-1 registered the maximum fungal population (50 x 104 CFUg-1 of dry soil) followed by application of FYM at 12.5 tha-1 (39 x 104 CFUg-1 of dry soil) compared to that of unmanured control (30 x 104 CFUg-1 of dry soil) (Table 3.). The larger biomass and subsequent decomposition of GLM improved the soil properties that supported good crop growth. The addition of C and N improved the microbial population whose addition was lesser from other manures and hence highest numbers were recorded in this treatment. Among the fertilizer schedules, application of NPK at 150:50:50 kg ha-1 recorded the maximum total fungal population (47 x 104 CFUg-1 of dry soil) compared to that of unfertilized control (27 x104 CFUg-1 of dry soil). Integrated application of manures and fertilizers recorded significantly higher total fungal population, the highest with GLM + NPK compared to other combinations. This agrees with the findings Hongwuyang et al. [20]. Among the crop growth stages, total fungal population was the maximum in tillering stage (43 x 104 CFUg-1 of dry soil) which decreased to 37 x 104 CFUg-1 and 35 x 104 CFUg-1 during flowering and post harvest stages respectively. Compared to bacterial population, the effect of inorganic fertilizers did not have much influence on fungal population. The fungal population was also found to decrease at harvest due to lack of availability of nutrients and organic matter compared to tillering and flowering stages of the rice crop. Similar findings were also reported by Nedunchezhiyan et al. [21].

3.6 Total Actinomycetes Population

Application of organic manures and fertilizers significantly influenced the total microbial population of soil. Among the organic manures, application of GLM at 12.5 tha-1 registered the maximum actinomycetes population (64 x 103 CFUg-1 of dry soil) followed by application of urban compost at 12.5 t ha-1 (53 x 103 CFUg-1 of dry soil) compared to that of unmanured control (41 x 103 CFU g-1 of dry soil) (Table 4.). Higher soil actinomycetes population may probably be due to higher available carbon substrates from these treatments and their nutrient contents. This finding is in accordance to the findings of Zak et al. [22]. Among the fertilizer schedules, application of NPK at 150:50:50 kg ha-1 recorded the maximum total actinomycetes population (62 x 103 CFUg-1 of dry soil) compared to that of unfertilized control (34 x 103 CFUg-1 of dry soil). Plots that received N or P or K or NP, NK, PK and NPK fertilizers recorded significantly higher actinomycetes population compared to that of unfertilized control. This may be due to the fact that fertilizers directly stimulates microbial growth and may affect the composition of individual microbial communities. Similar observation was made by Naher et al. [18]. Among the crop growth stages, total actinomycetes population was the maximum in tillering stage (59 x 103 CFUg-1 of dry soil) which decreased to 51 x 103 CFUg-1 and 40 x 103 CFUg-1 during flowering and post harvest stages respectively.

3.7 Long Term Effect of Manure – Fertiliser Schedules on Soil Dehydrogenase Activity

Application of organic manures and fertilizers significantly influenced the dehydrogenase activity of soil (Table 4) Enzymes play key role in the cycling of nutrients in nature and their activity is sensitive to nutrient management practices and considered as an index of soil fertility [23].Dehydrogenase is an enzyme that occurs in all intact microbial cells and can be used as a measure of microbial respiration and a reliable index of microbial activity in soil [24] The higher dehydrogenase activity (132 TPF Mg g-1) due to addition of GLM could be attributed to increased microbial activity which is known to stimulate the dehydrogenase activity. Similar findings were reported by Watts et al. [25].

Among the fertilizer schedules, the dehydrogenase activity was minimum in control (96 TPF Mg g-1 of dry soil h-1) and maximum in NPK treated plots (128 TPF Mg g-1 of dry soil h-1). The data on integrated application showed maximum activity at combined application of GLM with NPK which may be due to higher organic matter addition through GLM and the priming effect of inorganic N. Similar findings were reported by De Forest et al. [26]. This treatment was followed by GLM with P+K which was also on par with GLM with N+K application. Among the stages, the maximum dehydrogenase activity was registered in tillering stage (138 TPF Mg g-1 of dry soil h-1) followed by flowering (109 TPF Mg g-1 of dry soil h-1) and post harvest stages of rice crop (91 TPF Mg g-1 of dry soil hz-1). This may be due to the microbial biomass variation that might have occured with a change in growth stage.

Table 3. Long term effect of manures and fertilizers on total fungal population of the soil

Treatments Sub/Main	Total fungal population (x 10^4 CFU g^{-1} of dry soil)															
	Tillering					Flowering					Post Harvest					
	M1	M2	M3	M4	Mea n	M1	M2	M3	M4	Mea n	M1	M2	M3	M4	Mea n	Sub plot mea n
S_1	24	36	45	30	34	15	25	33	22	24	12	23	30	25	23	27
S_2	34	47	57	38	44	30	41	51	33	39	29	38	46	34	37	40
S_3	41	42	50	34	42	36	38	47	30	38	31	36	42	30	35	38
S_4	33	45	53	36	42	29	39	48	32	37	27	37	40	33	34	38
S_5	38	38	61	40	44	32	36	53	35	39	30	34	52	34	38	40
S_6	31	50	63	44	47	27	43	55	39	41	25	40	50	37	38	42
S_7	32	40	48	32	38	28	37	45	29	35	23	33	42	29	32	35
S_8	44	53	70	48	54	38	47	58	42	46	33	41	53	38	41	47
Mean	35	44	56	38	43	29	38	49	33	37	26	35	44	33	35	
Main plot mean	M_1 - 30				M_2 - 39				M_3 - 50				M_4 - 35			

	Tillering		Flowering		Post harvest	
	SEd	CD(p=0.05)	SEd	CD(p=0.05)	SEd	CD(p=0.05)
M	0.78	2.48	1.83	3.14	1.76	3.43
S	1.51	3.10	2.12	3.65	1.94	3.87
M at S	2.94	6.26	3.843	7.23	4.12	7.93

Table 4. Long term effect of manures and fertilizers on total actinomycetes population of the soil

Treatment s Sub/Main	Total actinomycetes population (x 10^3 CFU g^{-1} of dry soil)															
	Tillering					Flowering					Post Harvest					
	M1	M2	M3	M4	Mea n	M1	M2	M3	M4	Mea n	M1	M2	M3	M4	Mea n	Sub plot mea n
S_1	30	43	52	41	42	22	36	45	34	34	15	27	39	25	25	34
S_2	50	64	72	62	62	41	55	66	55	54	35	46	60	45	45	54
S_3	45	57	64	55	55	38	49	56	51	49	33	40	49	41	41	48
S_4	49	61	70	58	60	41	53	64	48	52	36	43	57	38	38	50
S_5	52	50	75	50	57	44	41	68	43	49	39	33	60	34	34	47
S_6	55	69	79	66	67	47	66	71	60	61	40	52	65	50	50	59
S_7	47	54	67	52	55	39	47	60	46	48	36	39	53	36	36	46
S_8	56	73	84	70	71	48	65	78	61	63	42	57	71	52	52	62

Treatment s Sub/Main	Total actinomycetes population (x 10^3 CFU g^{-1} of dry soil)															
	Tillering					Flowering					Post Harvest					
	M1	M2	M3	M4	Mea n	M1	M2	M3	M4	Mea n	M1	M2	M3	M4	Mea n	Sub plot mea n
Mean	48	59	70	57	59	40	52	64	50	51	35	42	57	52	40	50
Main plot mean	M_1 - 41				M_2 - 51				M_3 - 64				M_4 - 53			

	Tillering		Flowering		Post harvest	
	SEd	CD(p=0.05)	SEd	CD(p=0.05)	SEd	CD(p=0.05)
M	0.45	1.45	2.46	4.79	2.46	4.21
S	0.89	1.83	2.96	4.83	2.82	4.65
M at S	1.73	3.69	4.17	7.97	3.54	7.24

3.8 Effect of Manure Fertilizer Schedules on Grain and Straw Yield of Rice

Application of manures and fertilizers significantly influenced the grain and straw yields of rice crop at 5 percent level of significance (Table 6).

The grain yield ranged from 2365 kg ha-1 in unmanured control to 4790 kg ha-1 in GLM treatment. The increase in grain yields in the treatments that received continuous supply of organic manures like FYM or GLM or UC may be attributed to the overall influence of organic matter added through these manures on the properties and fertility status of the soil. The straw yield of rice varied between 3713 kg ha-1 in control and 8701 kg ha-1 in the GLM treatment. The slow release of nutrients from the green manures and greater addition of organic matter improves the richness of the soil and consequently promotes better crop growth, enhances the yield attributes and ultimately reflects in grain yield. The green or green leaf manuring and its positive effect on rice grain yield was reported by several workers [27-29].Among the fertilizer schedules the grain yield ranged from 4733 kg ha-1 in control to 7909 kg ha-1 in balanced NPK treatment. Lower yields were recorded in the treatments without N due to poor vegetative growth in the absence of Nitrogen. Similar observations were made by Brar et al. [30].

Also the biological health of the soil improved considerably in terms of population of bacteria, fungi and actinomycetes as evidenced in this experiment contributed to better soil quality thus enhancing the nutrient uptake and grain yield of rice. Similar observations were made by Shinde et al. (2013) who reported a favourable soil environment due to organic carbon, root activity and rhizo deposition of organic manures preferably GLM. Among the fertilizer schedules, the grain yield of rice ranged from 2998 kg ha-1 in control to 4205 kg ha-1 in NPK treatment. The treatments NP (3927 kg ha-1) and NK (4030 kg ha-1) were on par in influencing the grain yield. The data emphatically indicated that the highest response was observed for N application. Similar results were reported by Tilahun Tadesse et al. [31]. However the highest yields were registered with combined application of GLM @ 12.5 t ha-1 and 100% recommended NPK at 150:50:50 kg ha-1. Similar findings were reported by Amod Thakur et al. [32].

The higher yields associated with higher population of bacteria, fungi and actinomycetes in the treatments that received GLM and NPK was well established in their positive correlation (r =0.84, r = 0.85 and r = 0.76 respectively) that existed between these factors (Soil microbes vs grain yield). Application of 100% recommended NPK in combination with organic manures facilitated active participation of bacteria, fungi and actinomycetes in carbon assimilation, photosynthesis, starch formation and translocation of protein and sugar etc., Similar correlation was established by Arun Kumar et al. [33]. Hence in order to derive maximum benefit in terms of higher yields as well as maintaining soil fertility and fertilizer use efficiency, the rice-rice cropping system has to be adopted with integrated nutrient supply.

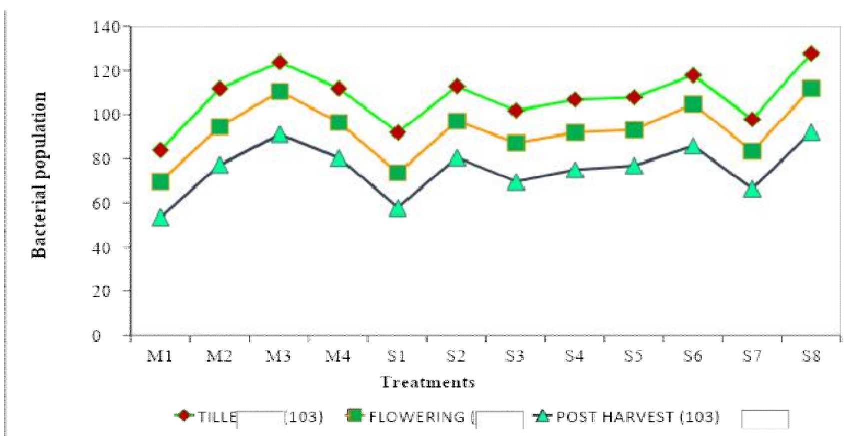

Fig. 1. Effect of manure - fertilizer schedules on total bacterial population (106 CFU g-1 of dry soil)

Table 5. Effect of manures - fertilizer schedules on grain and straw yield (kgha-1) of rice crop

Treatments Sub/Main	Grain Yield					Straw Yield				
	M_1	M_2	M_3	M_4	MEAN	M_1	M_2	M_3	M_4	MEAN
S_1	2365	2840	3560	3230	2998	3713	4865	5717	4639	4733
S_2	2690	3840	4300	4100	3732	5865	7900	8145	7970	7470
S_3	2510	3360	3910	3960	3435	4591	6715	6912	6002	6055
S_4	2450	3240	3850	3640	3295	3818	7005	7540	7305	6417
S_5	3060	3780	4620	4250	3927	5427	6328	8360	6171	6571
S_6	3180	4050	4510	4380	4030	6280	8020	8270	8235	7701
S_7	2850	3760	4480	3950	3760	4530	6453	6188	7193	6091
S_8	3190	4300	4790	4540	4205	6390	8073	8701	8475	7909
Mean	2786	3646	4252	4006	3672	5076	6919	7479	6998	6618

	SEd	CD(p=0.05)	SEd	CD(p=0.05)
M	90.3	181.1	165.7	328.6
S	92.3	187.8	169.4	335.1
M at S	97.6	196.2	182.6	367.3

Table 6. Correlation co - efficient (r) between important properties of soils treated with manures and fertilizers

	Bacteria	Fungi	Actinomycetes	Dehydrogenase	* OC	* G.Y
Bacteria	*	0.92	0.91	0.60	0.79	0.84
Fungi	0.92	*	0.85	0.79	0.80	0.85
Actinomycetes	0.91	0.90	*	0.56	0.69	0.76
Dehydrogenas e	0.60	0.79	0.56	*	0.62	0.70
OC	0.79	0.80	0.69	0.62	*	0.94
G.Y	0.84	0.85	0.76	0.70	0.94	*

G.Y- Grain Yield, OC- Organic carbon

3.9 Correlation between Important Properties of Soils Treated with Manures and Fertilizers

Correlation between soil organic carbon, total microbes (bacteria, fungi, actinomycetes), enzyme activities (dehydrogenase) and grain yield of rice crop was worked out at 1% significant level. A positive significant relationship was established between microbial and enzyme activities besides a positive correlation between bacteria and organic carbon (r = 0.79) and fungi and organic carbon (r = 0.80). All these parameters of total microbial population and soil enzyme activities were positively correlated with grain yields of rice crop (Table 7).

4. CONCLUSION

The total microbial population in all the treated plots of manures and fertilizers was found higher during the tillering stage of rice crop which gradually decreased during the flowering and post harvest stages. Among the microbes, the total population of bacteria was the highest compared to that of fungi and actinomycetes. The maximum dehydrogenase activity was recorded with integrated application of GLM @ 12.5 tha-1 and NPK (182 TPF µg g-1 of dry soil h-1) at tillering stage of rice crop. The influence of P and K application was on par with NPK in influencing the dehydrogenase activity of the soil.The overall results of the study indicated that continuous application of organic manures (FYM or GLM or urban compost @ 12.5 tha-1 each) is highly essential for improving the biological properties of soil through their contribution to soil organic matter. However higher population of microbes and enzymes exhibited maximum values when combined with balanced application of NPK fertilizers emphasizing the need for integrated application of manures and fertilizers. The poor biological properties in terms of soil microbial population and enzyme activities in unmanured and unfertilized control plots revealed the deterioration of soil biological health without the application of manures and fertilizers over a longer period of time.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. The state of food security and nutrition in the world." Rome, Italy: Food and Agriculture Organization of the United Nations; 2018.
2. DES. Directorate of Economics and Statistics Department of Agriculture, Cooperation & Farmers Welfare Ministry of Agriculture & Farmers Welfare Government of India, New Delhi, database; 2020. March 15 :2021
3. Singh, Anil Kumar, Naresh Chandra, Bharti RC. Effects of genotype and planting time on phenology and performance of rice (*Oryza sativa L*.); 2012.
4. FAOSTAT. Food and agriculture organization statistical database; 2020. Retrieved February 27:2020.
5. Sahu, Nisha, et al. "Strength of microbes in nutrient cycling: A key to soil health." Agriculturally important microbes for sustainable agriculture. Springer, Singapore. 2017;69-86.
6. Masto R, Ebhin, et al. "Changes in soil biological and biochemical characteristics in a long-term field trial on a sub-tropical inceptisol." Soil biology and biochemistry. 2006;38.7:1577-1582.
7. Bodruzzaman M, et al. "Long-term effects of applied organic manures and inorganic fertilizers on yield and soil fertility in a wheat-rice cropping pattern." Proceedings of the 19th World Congress of Soil Science, Brisbane, Australia; 2010.
8. Waksman SA, Fred EB. A tentative outline of the plate method for determining the number of micro-organisms in the soil." Soil Science. 1922;14.1:27-28.
9. Casida Jr, LE, Donald A, Klein, Thomas Santoro. "Soil dehydrogenase activity." Soil science. 1964;98.6:371-376.
10. Panse, Vinayak Govind, and Pandurang Vasudeo Sukhatme. "Statistical methods for agricultural workers." Statistical methods for agricultural workers; 1954.
11. Snedegor GW, William G. Cochran. "Statistical methods." Statistical methods. 6th ed; 1967.
12. Yadav Lalji, Meena RN. Performance of aromatic rice (Oryza sativa) genotypes as influenced by integrated nitrogen management." Indian Journal of Agronomy. 2014;59.2:251-255.
13. Swarup, Anand. "Integrated plant nutrient supply and management strategies for enhancing soil quality, input use efficiency and crop productivity." Journal of the Indian Society of Soil Science. 2010;58.1: 25-31.
14. Mengistu Dejene K, Lemlem S. Mekonnen. "Integrated agronomic crop managements to improve tef productivity under terminal drought." Water Stress. Vienna Tech. 2011;1:235-254.
15. Bayu, Wondimu, et al. "Application of farmyard manure improved the chemical and physical properties of the soil in a semi-arid area in Ethiopia." Biological agriculture & horticulture. 2006;24.3:293-300.
16. Rayns, Francis, Anton Rosenfeld, and Garden Organic. "Green manures–effects on soil nutrient management and soil physical and biological properties." Garden Organic, Horticulture Development Company; 2010.
17. Li, BY, et al. Soil micronutrient availability to crops as affected by long-term inorganic and organic fertilizer applications." Soil and Tillage Research. 2007;96.1-2:166-173.
18. Naher, Umme Aminun, Radziah Othman, and Qurban Ali Panhwar. "Culturable total and beneficial microbial occurrences in long-term nutrient deficit wetland rice soil." Australian Journal of Crop Science. 2013;7.12:1848-1853.
19. Meena VS, et al. Soil microbial population and selected enzyme activities as influenced by concentrate manure and inorganic fertilizer in alluvium soil of Varanasi." Bioscan. 2013;8.3:931-935.
20. Yang, Hongwu, et al. "The impacts of different green manure on soil microbial communities and crop health; 2016.
21. Nedunchezhiyan M, et al. Selected soil enzyme activities, soil microbial biomass carbon, and root yield as influenced by organic production systems in sweet potato." Communications in soil science and plant analysis. 2013;44.8:1322-1339.
22. Zak, Donald R, et al. "Microbial responses to a changing environment: implications for the future functioning of terrestrial ecosystems." Fungal Ecology. 2011;4.6: 386-395.
23. Yang, Lijuan, Yulong Zhang, Fusheng Li. Soil enzyme activities and soil fertility

dynamics." Advances in citrus nutrition. Springer, Dordrecht. 2012;143-156.
24. Tejada, Manuel, et al. "Use of biostimulants on soil restoration: Effects on soil biochemical properties and microbial community." Applied soil ecology. 2011;49: 11-17.
25. Watts, Dexter B, et al. "Soil microbial community dynamics as influenced by composted dairy manure, soil properties, and landscape position." Soil science. 2010;175.10:474-486.
26. DeForest, Jared L, et al. "Soil microbial responses to elevated phosphorus and pH in acidic temperate deciduous forests." Biogeochemistry. 2012;109.1:189-202.
27. Singh, Amarpreet, Yashbir Singh Shivay, and M. A. Ansari. "Enhancing productivity and Zn-use efficiency of Basmati rice through summer green manuring and Zn fertilisation." Indian Journal of Fertilisers. 2014;10.2:42-48.
28. Baishya LK, et al. Effect of integrated nutrient management on rice productivity, profitability and soil fertility." Annals of Plant and Soil Research. 2015;17.1:86-90.
29. Rupesh T, Singh DP, Meena RH, Yadav KK, Choudhary RS. Effect of Organic and Inorganic Sources of Nitrogen on Growth, Quality Parameters, Yield and Yield Attributes of Sweet Corn (*Zea mays L. sachharata*) in Typic Haplusteps. Ind. J. Pure App. Biosci. 2020;8(4):660-8.
30. Brar BS, Kamalbir Singh, Dheri GS. Carbon sequestration and soil carbon pools in a rice–wheat cropping system: Effect of long-term use of inorganic fertilizers and organic manure." Soil and Tillage Research. 2013;128:30-36.
31. Tadesse, Tilahun, et al. "Effects of farmyard manure and inorganic fertilizer application on soil physico-chemical properties and nutrient balance in rain-fed lowland rice ecosystem; 2013.
32. Thakur Amod K, Krishna G, Mandal, Sachidulal Raychaudhuri. "Impact of crop and nutrient management on crop growth and yield, nutrient uptake and content in rice." Paddy and Water Environment. 2020;18.1:139-151.
33. Kumar, Arun, et al. "Effect of organic and inorganic sources of nutrient on yield, yield attributes and nutrient uptake of rice cv. PRH-10." The Bioscan. 2014;9.2:595-597.

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