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Effect of Integrated Nutrient Management Practices and Rice Establishment Techniques on Soil Chemical and Biological Properties in Rice-Toria-Greengram Cropping Sequence

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ABSTRACT

A field experiment was conducted at Instructional-cum-Research Farm of Assam Agricultural University, Jorhat during 2016-17 and 2017-18. The experiment was laid out in split-plot design with three replications. The treatments consisted of two different establishment techniques of rice *viz.*, Transplanted rice (M_1) and Direct seeded rice (M_2) in main plot and five different nutrient management practices *viz.*, Control(N_1), 100% RDF (N_2), 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer (N_3), 75% RDN as inorganic + 25% RDN as vermi-compost + bio-fertilizer (N_4) and 100% N as vermi-compost + bio-fertilizer (N_5) in sub-plots. Result of the experiment revealed that in rice 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer, in toria 75% RDN as inorganic + 25% RDN as vermi-compost + bio-fertilizer and in greengram 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer recorded the highest value of available N, P_2O_5, K_2 O and organic carbon content of the soil. Significantly, the highest SMBC, fungal and bacterial population after two years cropping cycle was found in 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer.

Introduction

Intensive agriculture involving exhaustive high yielding varieties of rice lead to heavy withdrawal of nutrients from soil. Imbalanced & indiscriminate use of chemical fertilizer has resulted in deterioration of soil health (John *et al.,* 2001). This decline in soil quality results in a decrease in factor productivity and overall crop productivity. On the other hand most of the cultivated soil have organic matter content of below 1.5% and addition of organic matter is very low. Therefore, suitable combination of organic and inorganic sources of nutrient is necessary for suitable crop yield. Integrated use of organic matter and chemical fertilizers would be quite promising not only in providing greater stability, but also maintaining better soil fertility status. The appropriate combination of mineral fertilizers, organic manures and crop residues varies according to the system, land use, ecological, social and economic conditions. Inspite of increased use of fertilizer nutrients, there is a gap between the nutrients applied and nutrients harvested, which is likely to widen further with the achievement of targets, leading to mining of soil. Over use of certain potential areas and sub-optional use of larger areas are crucial issues. Experiences from long term fertilizer experiments revealed that integrated use of farm yard manures, vermin-compost, bio-compost, *etc.* with graded levels of chemical fertilizers is promising not only in maintaining higher productivity but also in providing maximum stability in crop production. The response of N as chemical fertilizer generally increases when it is used in combination with FYM, vermi-compost, *etc.* and saves N fertilizer.

Materials and Methods

The experiment was carried out at Instructional-cum-Research Farm of Assam Agricultural University, Jorhat during 2016-17 and 2017-18 to study the effect of integrated nutrient management practices and rice establishment techniques on Soil chemical and biological properties in rice-toria-greengram cropping sequence. The soil of the experimental plot was sandy loam, acidic in reaction (pH 5.8), medium in organic carbon content (0.61%), available N (299.67kg ha^{-1}), available K_2O (139.71 kg ha^{-1}) and low in available P_2O_5 (21.59kg ha^{-1}).The experiment was laid out in split-plot design with three replications. The treatments consisted of two different establishment techniques of rice *viz.*, Transplanted rice (M_1) and Direct seeded rice (M_2) in main plot and five different nutrient management practices *viz.*, Control(N_1), 100% RDF (N_2), 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer (N_3), 75% RDN as inorganic + 25% RDN as vermi-compost + bio-fertilizer (N_4) and 100% N as vermi-compost + bio-fertilizer (N_5) in sub-plots.

The Soil samples collected from 0-15cm and 15-30 cm soil depth in each plot were used for estimation of available nitrogen, phosphorus, potassium, organic carbon and pH. Available nitrogen was estimated by Modified Kjeldahl method and expressed in kg/ha. Available phosphorus was estimated by Bray I method, Potassium was estimated by Flame photometric method and organic carbonic (%) was estimated by wet digestion method. The pH of the soil solution was estimated by 1.25 (soil: water) suspension glass electrode pH meter method as described by Jackson (1973). For counting of soil microbial population *viz.*, Fungal and bacterial, soil samples from 0-15 cm depth from three spots of each plot were collected before transplanting of rice and at harvest of third crop and then fungal and bacterial populations in soil were enumerated by following the standard serial dilution technique and pour plate method using different media. Microbial biomass carbon was determined by chloroform fumigation extraction technique following the methods of Vance *et al.*, (1987).

Results and Discussion

Soil chemical properties

The establishment techniques of rice revealed non-significant effect on the available N, P_2O_5, K_2O and organic carbon content of the soil after harvest of rice but different nutrient management practices brought significant effect on the available N, P_2O_5 and K_2 O content of the soil (Table 1). Nutrient management with 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer recorded the highest available N, P_2O_5 and K_2 O content of the soil which was significantly higher than all the treatments and the lowest value was found under control (Table 1). The highest available soil N under the treatment might be due to direct addition of N through fertilizer and organic materials and greater multiplication of soil microbes, which converts organically bound nitrogen to inorganic form. The result was in agreement with the findings of Harikesh *et al.*, (2017). Pandey, (2001) also reported that application of organic manures could reduce N losses and conserve soil N by mineralization, thus maintaining a continuous availability of N in entire life cycle of rice plant. Similarly, greater mobilization of native soil P under the treatment by reducing the P fixation capacity of soil due to the release of organic acids during decomposition process might be the reason for increased availability of phosphorus in soil. Application of organics and bio-inoculants in rice increased the phosphorus availability in soil (Selvamani *et al.,* 2011). Mehdi *et al.,* (2011) also reported the increase in availability of phosphorus due to release of organic acids during decomposition of organic manures. The organic materials form a protective cover on sesquoxide, thus also reduce the phosphate fixing capacity of soil and hence, increase available P status of soil. The result was in full agreement with the findings of Singh *et al.,* (2006) and Harikesh *et al.,* (2017).

The increase in available potassium under 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer might be due to addition of K through organic manures and the solubilization of K from native source during the process of decomposition of organic sources. The organic manures have greater capacity to hold K in available form and reduced K-fixation due to interaction of organic matter with clay. The results corroborate with the findings Harikesh *et al.,* (2017). The nutrient management with 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer recorded the highest organic carbon content in soil which was significantly higher than all other treatments being at par with 75% RDN as inorganic + 25% RDN as vermi-compost + bio-fertilizer (Table 1). Addition of inorganic fertilizer along with organic manure helps in mineralization which resulted in rapid conversion of organically bound forms of nutrients to organic forms and ultimately organic carbon content in the soil increased.

In toria available N, P_2O_5, K_2O and organic carbon content were non-significant due to different establishment techniques of rice. The nutrient management practices reported significant effect on available N, P_2O_5 and K_2O content in soil (Table 2). Nutrient management with 75% RDN as inorganic + 25% RDN as vermi-compost + bio-fertilizer recorded the highest available N and P_2O_5 which was significantly higher than all the treatments and the lowest value was found under control. The increase in available N under the treatment might be because of slow release of nutrients due to organic sources. Similar results were also reported by Shaikh *et al.,* (2011) and Kulkarni *et al.,* (2019).The highest available P under the treatment might be due to release of organic acids *viz.,* chiefly maleic and citric acid on decomposition of organic manures which helps in solubulization of unavailable P. The result was in agreement with the findings of Singh *et al.,*(2011).The available K_2O content in soil was significant due to different nutrient management treatments (Table 2). Nutrient management with 75% RDN as inorganic + 25% RDN as vermi-compost + bio-fertilizer revealed the highest available K_2 O being at par with 100% RDF and 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer. The direct K addition to the soil, addition of organic manures may be ascribed to the reduction of K-fixation and release of K due to interaction of organic matter with clays and this might be the reason for increased available K_2O content in soil under the treatment. Similar beneficial effects of organic sources as well as the integration of different sources of nutrients on soil fertility were also reported by Tamboli *et al.,* (2014).Nutrient management practices recorded significant effect on the organic carbon content in the soil (Table 2). The highest organic carbon content was found in 75% RDN as inorganic + 25% RDN as vermi-compost + bio-fertilizer. The treatment was significantly higher than all other treatments being at par with 100% RDF (Table 2). The increase in organic carbon content might be due to the build up of humus and higher microbial population by vermi-compost, bio-fertilizer and crop residue.

In greengram the different establishment techniques of rice reported non-significant effect on the available N, P_2O_5, K_2O and organic carbon content on soil after harvest of greengram (Table 3). The available N, P_2O_5, K_2O and organic carbon content of the soil were significant due to nutrient management practices (Table 3). Nutrient management with 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer recorded the highest available N and P_2O_5 followed by 100% RDN and the lowest value was found under control. The highest available N in the soil after harvest of greengram might be due to mineralization of fixed nitrogen due positive effect of vermi-compost and bio-fertilizer on the soil properties due to the production of organic acids. Similar result was also reported by Uma and Malathi (2009).The highest P_2O_5 availability in the treatment might be due to minimization of phosphorus fixation and organic recycling. Legume crops add large amount of organic residues through leaf fall and rhizodeposition that resulted the production of intermediate acids that solubilize fixed forms of phosphorus in soil resulting increased available phosphorus in soil. The result was in full agreement with the findings of Henri *et al.,* (2008).

The available K_2O content in soil was found to be significant due to different nutrient management practices (Table 3). Nutrient management with 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer reported the highest available K_2O in soil which was at par with 100% RDF. Higher available K_2 O in the treatment might be due to acidulation as a result of decomposition of organic matter which released of K_2 O in soil solution. The result was in agreement with Bandopadhyay and Puste (2002) and Maiti *et al.,* (2006). The nutrient management practices also revealed the significant effect on organic carbon content in the soil (Table 3). The highest organic carbon content in soil was recorded in nutrient management with 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer which was at par with 100% RDF and 75% RDN as inorganic + 25% RDN as vermi-compost + bio-fertilizer. The highest value under the treatment might be due to addition of more amount of organic matter in the soil through vermi-compost and leaf fall of legume crop that resulted in rise of organic carbon content in soil. The result was similar with the findings of Porpavai *et al.,* (2011) and Kar *et al.,* (2012).

Biological properties

Establishment techniques of rice showed non-significant effect on fungal, bacterial population and biomass carbon in soil after two years cropping cycle (Table 4). The nutrient management practices brought significant effect on soil fungal and bacterial population. Significantly, the highest fungal and bacterial population was found in nutrient management practice with 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer being at par with 100% RDF and 75% RDN as inorganic + 25% RDN as vermi-compost + bio-fertilizer in fungal population and with 100% RDF in bacterial population. Nutrient management with 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer recorded the increased of 67.96% and 123.64% fungal and bacterial population after two years cropping cycle than the initial population. The increase in fungal and bacterial population might be due to the inclusion of leguminous crop in cropping sequence that helped soil health in multiplication and growth of soil microorganism including fungus and bacteria. Similar result was also observed by Kumar *et al.,* (2012). However, the increase in highest number of bacterial population might be due solid manure that introduces a high amount of beneficial microflora and phytohormones in the soil which increased the organic matter content and water air relationships in the soil. The result was in accordance with the findings of Mandal *et al.,* (2007) and Zhong *et al.,* (2010).The increase in bacterial population with bio-fertilization may be attributed to supplementation of soil with beneficial bacteria through bio-fertilizer inoculation which supported bacterial growth due to their role in phytohormone production, detoxification of soils contaminated with heavy metals and high salt levels, extracellular polysaccharide synthesis and other processes.

Table.1 Effect of establishment techniques and nutrient management on available N, P_2O_5, K_2O, and Organic carbon content in soil after harvest of rice

Treatment	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Organic Carbon (%)
Establishment techniques (M)				
Transplanted rice (M_1)	287.03	22.23	141.82	0.58
Direct seeded rice (M_2)	283.17	21.14	138.98	0.56
SEm±	1.29	0.52	1.25	0.01
CD(P=0.05)	NS	NS	NS	NS
Nutrient management (N)				
Control (N_1)	276.88	20.06	132.70	0.52
100% RDF (N_2)	285.47	21.53	141.68	0.57
50% RDN as inorganic + 50% RDN as VC + bio-fertilizer (N_3)	292.22	23.45	144.24	0.61
75% RDN as inorganic + 25% RDN as VC + bio-fertilizer (N_4)	289.38	22.26	142.31	0.60
100% N as VC + bio-fertilizer (N_5)	281.56	21.11	141.05	0.56
SEm±	2.02	0.44	1.63	0.02
CD(P=0.05)	6.05	1.32	4.87	0.06
Interaction (M×N)	NS	NS	NS	NS

Table.2 Effect of establishment techniques and nutrient management on available N, P_2O_5, K_2O, and Organic carbon content in soil after harvest of toria

Treatment	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Organic Carbon (%)
Establishment techniques (M)				
Transplanted rice (M_1)	283.67	23.27	142.34	0.60
Direct seeded rice (M_2)	279.66	22.23	140.03	0.58
SEm±	1.5	0.32	1.21	0.01
CD(P=0.05)	NS	NS	NS	NS
Nutrient management (N)				
Control (N_1)	272.75	20.90	133.91	0.54
100% RDF (N_2)	284.55	23.48	143.32	0.62
50% RDN as inorganic + 50% RDN as VC + bio-fertilizer (N_3)	282.96	23.00	142.88	0.59
75% RDN as inorganic + 25% RDN as VC + bio-fertilizer (N_4)	288.17	24.18	143.90	0.63
100% N as VC + bio-fertilizer (N_5)	279.89	22.21	141.92	0.57
SEm±	2.50	0.64	1.70	0.02
CD(P=0.05)	6.45	1.92	5.10	0.06
Interaction (M×N)	NS	NS	NS	NS

Table.3 Effect of establishment techniques and nutrient management on available N, P_2O_5, K_2O, and organic carbon content in soil after harvest of greengram

Treatment	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Organic Carbon (%)
Establishment techniques (M)				
Transplanted rice (M_1)	323.70	24.87	144.22	0.62
Direct seeded rice (M_2)	315.94	24.07	142.14	0.6
SEm±	2.45	0.54	0.96	0.02
CD(P=0.05)	NS	NS	NS	NS
Nutrient management (N)				
Control (N_1)	306.13	22.10	135.09	0.55
100% RDF (N_2)	322.30	25.35	145.11	0.63
50% RDN as inorganic + 50% RDN as VC + bio-fertilizer (N_3)	331.88	26.25	146.95	0.65
75% RDN as inorganic + 25% RDN as VC + bio-fertilizer (N_4)	322.04	24.64	144.90	0.63
100% N as VC + bio-fertilizer (N_5)	316.72	24.01	144.19	0.62
SEm±	3.53	0.55	1.86	0.02
CD(P=0.05)	10.60	1.64	5.58	0.06
Interaction (M×N)	NS	NS	NS	NS

Table.4 Effect of establishment techniques and nutrient management on soil microbial populations and biomass carbon after two years crop sequence

Treatment	Fungus (10^5 cfu/g soil)		Bacteria (10^6 cfu/g soil)		SMBC (µg g^{-1} soil)	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**
Establishment techniques (M)						
Transplanted rice (M_1)	26.01	39.87	33.45	71.29	134.95	180.65
Direct seeded rice (M_2)	25.14	39.49	33.05	70.18	134.23	176.89
SEm±	0.17	0.50	0.22	0.95	0.17	2.20
CD(P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
Control (N_1)	23.93	30.52	32.63	59.98	134.05	149.72
100% RDF (N_2)	26.13	42.95	33.47	73.89	135.16	165.82
50% RDN as inorganic + 50% RDN as VC + bio-fertilizer (N_3)	26.00	43.67	34.13	76.17	135.17	201.43
75% RDN as inorganic + 25% RDN as VC + bio-fertilizer (N_4)	26.20	41.80	33.67	72.77	134.25	194.25
100% N as VC + bio-fertilizer (N_5)	25.60	39.48	32.33	70.87	134.30	182.63
SEm±	0.66	0.86	0.75	1.08	0.42	2.50
CD(P=0.05)	NS	2.59	NS	3.23	NS	7.49
Interaction (M×N)	NS	NS	NS	NS	NS	NS

Similarly, nutrient management practices showed significant effect on soil microbial biomass carbon (Table 4). Nutrient management with 50% RDN as inorganic + 50% RDN as vermi-compost + bio-fertilizer recorded the significantly highest soil microbial biomass carbon content in soil being at par with 75% RDN as inorganic + 25% RDN as vermi-compost + bio-fertilizer and lowest soil microbial biomass carbon was noted in control. However, the increase in soil microbial biomass carbon under two treatment were 49.02% and 44.69% higher than their initial value. Similar result was also reported by Chandel *et al.,* (2018). Increase in soil microbial biomass carbon might be due to application of vermi-compost and bio-fertilizer which adds mineralizable and readily hydrolizable carbon which resulted in higher microbial activity and in turn higher soil microbial biomass carbon. Moreover, the SMBC acts as the transformation agent of the organic matter in the soil. Similar result was also reported by Mali *et al.,* (2015).

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