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Effect of integrated nutrient management practices on soil chemical and biological properties under rice (*Oryza sativa* L.) cultivation

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Abstract
A field experiment was conducted in 2014-15 and 2015-16 in *kharif* season at agricultural research farm at B.H.U. Varanasi to study the effect of different integrated nutrient management on the chemical and biological properties of soil under rice cultivation. The trial consisting of different levels of RDF, *Azospirillum*, phosphate solubilising bacteria (PSB), 30 kg N through dhaincha and crop residue was laid out in randomized block design with four replications. The significant effect of different treatments was seen with treatment T_4: RDF + *Azospirillum* + PSB + 30 kg nitrogen through dhaincha + residue mulch @ 2 t ha^{-1} regarding pH, EC, available N, available P_2O_5 and soil microbial biomass carbon (SMBC). It directly associated with the good fertility level band soil health and finally it affects the yield of the crop.

Keywords: Integrated, nutrient management, chemical, biological properties, soil, rice etc.

Introduction

Rice (*Oryza sativa* L.) is the staple food of more than 60 % of world population, which is grown in 112 countries covering every continent and it is consumed by 2500 million people in developing countries, mostly in Asia (90%) and rest (10%) in America, Africa, Australia and Europe. Anonymous. (2017) [1]. It plays a unique role in producing calories to majority of Asian and Latin America countries. In India, it is cultivated in an area of 43.38 million hectare with total annual production of 104.32 million tonnes. The productivity of rice in India is about 2.40 t ha^{-1}, Anonymous. (2017) [1]. Rice is grown in many regions across India. West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Bihar, Orissa, Assam and Haryana are the major rice producing states. The slogan “Rice is Life” is most appropriate for the country as the crop plays a vital role in national food security contributing about two third calories to the people in humid and sub humid Asia. (Wang *et al*., 2013) [17].

The environmental implications of rice ecosystem, heavy use of agrochemicals and flooded conditions could lead to substantial water use and pollution (Wang *et al.*, 2013) [17], high dependence on energy, and considerable GHG emissions. In contrast, mulch improves edaphological environment (Aniekwe *et al*., 2007) [2], moderates soil temperature (Sarkar *et al*., 2007) [12]. Fresh residues (mulches) are C source for microbial activity and form nucleation centres for aggregation, and the attendant enhanced microbial activity accentuates formation of macroaggregates Dorodnikov *et al*. (2009) [5].

Phosphorus is important for the plant growth and promotes root development, tillering, early flowering, and performs other functions like metabolic activities, particularly in synthesis of protein (Tanwar and Shaktawat, 2003) [15]. The rhizosphere microorganisms play a significant role for P solubilization in many crops especially under P deficiencies (Khan *et al*., 2009) [7]. Among the soil microorganisms, PSB play an important role in solubilizing P for the plants and allowing more efficient use of Phosphatic fertilizers. The different biofertilizers can colonize the root surface and some of them have been shown to colonize endophytically (Naher *et al*., 2009) [10]. The association and colonization of different phosphate solubilising bacteria on the surface the crop roots involve direct competition with other microorganisms into the rhizosphere, while the endophytic population of phosphate solubilising bacteria strains may give more comprehensive effects on the plants due to the less competition.

Sesbania is a legume crop used as a green manure as well as the brown manure in the rice cultivation. fast-growing, flood-tolerant legumes can be used as green manures in the short period prior to the planting of rice (*Oryza sativa* L.), thereafter referred to as the pre-rice period, and can add substantial quantities of biologically fixed nitrogen to lowland rice cropping systems (Ladha *et al*., 2003) [9]. The minimum microbial biomass carbon recorded under application of inorganic treatment alone 100% NPK at both 0-15 cm and 15-30 cm soil depths. Use of organic sources of nutrients in combination with chemical fertilizers significantly increased the soil microbial biomass carbon (SMBC). It might be due to the additional utilization of mineralizable and readily hydrolysable carbon due to organic matter incorporation resulted in higher microbial activity and in higher soil microbial biomass carbon. (Datt *et al*., 2013) [4].

Materials and Methods

The agricultural research farm is situated in the south- eastern part of Varanasi. Geographically, experimental site falls under sub-tropical zone of Indo-Gangatic plains and lies on the left bank of river Ganga. It is located on 25°15'19.7"N latitude, 82°59'34.2"E longitude and at an altitude of 76 meters above mean sea level. The total rainfall received during the cropping period was 870.7 mm during 2014-15 and 793.5 mm during 2015-16 with the distribution being normal during the experimental period. The highest rainfall (142.7 mm) was recorded in the meteorological week 32 during 2014-15 and 261.5 mm in the meteorological week no. 29 during 2015-16.

The experiment was laid out in randomized block design with four replications. The seven treatments containing different nutrient sources with the integrated approach were given to the experimental units. The treatments regarding the INM was as follows: T_1: Recommended dose of NPK fertilizers (RDF), T_2: RDF + *Azospirillum* + PSB, T_3: RDF + *Azospirillum* + PSB + 30 kg nitrogen through Dhaincha, T_4: RDF + *Azospirillum* + PSB + 30 kg nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}, T_5: 25% RDF + *Azospirillum* + PSB + 30 kg nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}, T_6: 50% RDF + *Azospirillum* + PSB + 30 kg nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}, T_7: 75% RDF + *Azospirillum* + PSB + 30 kg nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}. *Azospirillum* and PSB is used as the seedling dip method before transplanting. Processed samples were analysed for pH and EC in 1:2.5 soil-water suspensions by using glass electrode pH meter and Systronics Digital Electrical Conductivity Meter, respectively. Organic carbon was estimated by wet digestion method of Walkley and Black.

Results and Discussion

Soil pH, EC and organic matter

Soil pH is an important chemical property of the soil which are presented in Table 1. Soil reaction is directly related to the nutrient availability of the soil. The application of RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha + residue mulch @ 2 t ha^{-1} was reduced the pH towards the neutral pH. There was no significant difference was recorded with the treatments. Application of the 100 % RDF recorded highest pH (7.43 and 7.42 in 2014 and 2015 respectively) due to only use of the chemical fertilizer. Use of the green leaf manure with Dhaincha along with biofertilizers reduces the pH due to decomposition of the organic materials. Similar results were also seen in the experiment by Patra *et al*., (2017) [11]. The highest value of OC (0.40 and 0.41 d S m^{-1} in 2014 and 2015 respectively) was recorded with the T_4 and found on par with the T_3 and T_7. Sushma *et al*. (2007) [14] and Gogoi *et al*. (2015) [6] also found the similar result and the higher organic matter under different INM treatments could be due to the direct application of carbon input, which could be enhanced further through root exudates and the root residue and biofertilizers application in rice. (Banswasi and Bajpai, 2006). Soil electrical conductivity was significantly influenced by the integrated nutrient management treatments during both the years (Table 1). However, significantly highest soil electrical conductivity was observed at harvest of rice with the treatment T_4 (RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha + residue mulch @ 2 t ha^{-1}) over other treatments during both the years followed by the T_7 (75 % RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha + residue mulch @ 2 t ha^{-1}) and T_3 (RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha). It is mainly due to the decomposition of the organic matter. The similar result was also recorded by Gogoi *et al*. (2015) [6].

Available nitrogen and available phosphorus

Different integrated nutrient management influenced the available nitrogen in soil during both the years (Table 1). The highest available nitrogen (224.50 & 229.47 kg ha^{-1} during 2014 and 2015, respectively) in soil was recorded with the application of T_4 (RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha + residue mulch @ 2 t ha^{-1}) in rice and found statistically on par with T_3 (RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha) and T_7 (75 % RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha + residue mulch @ 2 t ha^{-1}). Similarly, the highest available phosphorus (23.95 & 25.84 kg ha^{-1} during 2014 and 2015, respectively) in soil was recorded with the application of T_4 (RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha + residue mulch @ 2 t ha^{-1}) in rice and found statistically on par with T_3 (RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha) and T_7 (75 % RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha + residue mulch @ 2 t ha^{-1}). Plant available phosphorus is usually deficient in the soil because it is fixed in soil layers, (Khan *et al*., 2014) [8]. This insoluble phosphorus is fixed in different forms with calcium $(Ca_3PO_4)_2$, aluminium (Al_3PO_4) and iron (Fe_3PO_4) and can be turned to soluble forms by P-solubilizing micro-organisms (Sharma *et al*., 2013) [13].

Soil Microbial Biomass Carbon (SMBC)

The soil organic biomass carbon (µg C g^{-1} soil) was analysed at the different stages of the rice *viz*. vegetative, reproductive and at harvest stage in (Table no 2). Closer examination of the data revealed that the application of the treatment T_4 (RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha + residue mulch @ 2 t ha^{-1}) produced highest soil organic biomass carbon (125.32, 186.11 and 172.95 µg C g^{-1} soil at vegetative, reproductive and at harvest respectively) in 2014. Similar trend was also observed in 2015 where the highest soil organic biomass carbon (127.25, 189.00 and 174.14 µg C g^{-1} soil at vegetative, reproductive and at harvest respectively) was recorded with treatment T_4 followed by treatment T_3 (RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha). The treatment T_4 was found on par with T_3 at vegetative and at harvest stage while, at reproductive stage the variation was found up to the level of significance. It might be due to the supply of additional mineralizable and readily hydrolysable carbon due to organic sources of nutrient application resulted in higher microbial activity and in higher soil microbial biomass carbon (SMBC). (Thakare and Bhoyar. 2012 and Datt *et al*., 2013) [4].

Table 1: Effect of integrated nutrient management on soil chemical properties before and after rice crop

Treatment	Soil chemical properties									
	pH		EC (d S m^{-1})		Organic carbon (%)		Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T_1: Recommended dose of NPK fertilizers (RDF)	7.43	7.40	0.19	0.21	0.39	0.38	211.41	216.08	22.42	24.16
T_2: RDF + *Azospirillum* + PSB	7.42	7.39	0.19	0.21	0.40	0.40	216.14	220.92	22.65	24.41
T_3: RDF + *Azospirillum* + PSB + 30 kg Nitrogen through Dhaincha	7.41	7.38	0.20	0.22	0.40	0.41	220.37	225.25	23.32	25.19
T_4: RDF + *Azospirillum* + PSB + 30 kg Nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}	7.42	7.39	0.24	0.25	0.40	0.41	224.50	229.47	23.95	25.84
T_5: 25% RDF + *Azospirillum* + PSB + 30 kg Nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}	7.41	7.38	0.20	0.22	0.40	0.40	191.89	196.13	20.20	21.81
T_6: 50% RDF + *Azospirillum* + PSB + 30 kg Nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}	7.41	7.38	0.19	0.21	0.40	0.40	201.81	206.27	21.91	23.66
T_7: 75% RDF + *Azospirillum* + PSB + 30 kg Nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}	7.40	7.38	0.23	0.23	0.40	0.41	218.54	222.15	23.17	25.03
Sem ±	0.005	0.006	0.003	0.004	0.004	0.008	3.06	3.52	0.44	0.39
CD (P = 0.05)	NS	NS	0.010	0.011	NS	NS	9.08	10.44	1.32	1.17
Initial values (before start of season)	7.43	7.40	0.18	0.20	0.38	0.40	202.60	210.20	19.65	22.71
(RDF: 120-60-60 kg N, P_2 O_5 and K_2O ha^{-1} respectively)										

Table 2: Effect of integrated nutrient management on SMBC (µg C g^{-1} soil) at different stages of rice

Treatment	SMBC (µg C g^{-1} soil)					
	Vegetative Stage		Reproductive Stage		At harvest	
	2014	2015	2014	2015	2014	2015
T_1: Recommended dose of NPK fertilizers (RDF)	111.64	112.58	159.91	161.10	154.04	155.90
T_2: RDF + *Azospirillum* + Phosphate solubilising bacteria (PSB)	115.66	116.64	165.67	166.79	161.94	164.19
T_3: RDF + *Azospirillum* + PSB + 30 kg Nitrogen through Dhaincha	123.72	126.64	179.88	181.22	168.93	171.85
T_4: RDF + *Azospirillum* + PSB + 30 kg Nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}	125.32	127.25	186.11	189.00	172.95	174.14
T_5: 25% RDF + *Azospirillum* + Phosphate solubilising bacteria (PSB) + 30 kg Nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}	100.92	101.61	144.32	145.40	139.83	142.21
T_6: 50% RDF + *Azospirillum* + Phosphate solubilising bacteria (PSB) + 30 kg Nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}	105.57	109.40	155.39	156.55	145.90	148.38
T_7: 75% RDF + *Azospirillum* + Phosphate solubilising bacteria (PSB) + 30 kg Nitrogen through Dhaincha + residue mulch @ 2 t ha^{-1}	123.02	124.51	176.84	178.16	166.21	168.54
SEm ±	1.71	1.43	2.03	1.79	2.33	1.77
CD (P = 0.05)	5.07	4.25	6.03	5.33	6.93	5.25
(RDF: 120-60-60 kg N, P_2O_5 and K_2O ha^{-1} respectively)						

Conclusion

The judicious and effective integration of RDF along with the different biofertilizers, green leaf manure and crop residue is mandatory for maintaining the soil productivity in Indian agriculture. Thus, the concluding results from this study suggest that the application of the RDF + *Azospirillum* + PSB+ 30 kg N through Dhaincha + residue mulch @ 2 t ha^{-1} enhances the edaphological quality *viz*. chemical and biological properties. The use of this combination of treatment also enhances soil microbial biomass carbon which is also the significant indicator of the good soil fertility and productivity. It enhances the quality as well as the sustainability of soil properties in a glorious manner.

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