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Effect of different rice based cropping systems on soil health under organic management

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Abstract

Deterioration of soil fertility is the main drawback of monocropping of rice where the system is highly nutrient exhaustive and thus, has depleted inherent soil fertility, causing deficiency of several nutrients. Crop diversification, especially under organic management is an alternative to restore the fertility in the soil and sustain it. The present investigation was conducted during May 2015 to May 2017 at Department of Agronomy, College of Horticulture, Thrissur to study the effect of crop diversification to sustain the soil health under organic management. The experiment was laid out in completely randomized block design and practiced under three replication. Rice was grown under four different cropping systems with and without foliar spray of liquid organic manures (LOMs) along with traditional cropping system (rice-rice-fallow) keeping as control. The rotations followed were rice-rice-njavara rice, rice-rice-salad cucumber, rice-rice-vegetable cowpea, rice-rice-amaranthus and rice-rice-fallow. The management practices were followed as per the Package of Practices Recommendations: (*Ad hoc*) for organic farming: Crops of the Kerala Agricultural University. *Jeevamrurtham, Panchagavyam,* green leaf extract and *fish amino acid* were the liquid organic manures sprayed at fifteen days intervals after planting/ transplanting. The results further indicated that introduction of leguminous crop in the existing rice-rice-rice/ fallow not only increased the system yield but also improved the physical, chemical and biological properties of the soil. It improved the physical characters like bulk density, porosity and water holding capacity, decreased pH, increased organic carbon, available NPK and total microbial biomass.

Keywords: Soil fertility, crop diversification, organic management and organic carbon

Introduction

Monocropping of rice is a highly nutrient exhaustive system and its continuous use has depleted inherent soil fertility, causing deficiency of several nutrients (Zia *et al*., 1997) [15]. The application of chemical fertilizers either in excess or less than optimum rates affects both yield and quality of rice to a greater extent (Meena *et al*., 2003) [6]. Since sustainability of the production system depends on the sustainable use of soil resources, it is necessary to develop and adopt soil management technologies that improve soil physical, chemical and biological properties to keep lands productive on the sustainable bases (Ali *et al*., 2012) [1]. Hence, soil fertility enhancement is vital in sustaining and improving agricultural productivity. Crop diversity especially under organic farming, with holistic nutrient management, is considered as best option for sustaining soil health. Induction of green manuring and leguminous crops in the existing rice monocropping system can improve the soil fertility and crops productivity on sustainable bases. In addition to this, organic nutrient management involving the addition of manures and soil amendments provides an additional benefit by modifying the physical properties of the soil (Nyalemegbe *et al*., 2011) [8]. Recently, liquid organic manures are also becoming popular among the farmers due to their beneficial effects on crop as well as soil. Fermented liquid organic formulations prepared from on-farm wastes such as *Pancha Gavyam, Beej amrutham* and *Jeevamrutham* are rich in beneficial microflora and can be used as efficient plant growth promoters (Devakumar *et al*., 2014) [2]. They are mainly applied as foliar spray and through irrigation water which is meant to enhance soil health by improving biological activity, crop productivity and sustainability of the system. The present study was designed to study the effect of diversification of existing rice monocropping system on soil health and crop productivity.

Materials and Methods

The experiment was laid out during May 2015 to May 2017 at Department of Agronomy, College of Horticulture, Thrissur, Kerala. The soil of the experimental site was slightly acidic in nature (pH 5.83), low in available N (141.15 kg ha^{-1}), medium in phosphorus (37.47 kg ha^{-1}) and high in potassium (287.46 kg ha^{-1}). The experiment was conducted in randomized block block design. Nine cropping systems *viz*., T_1: Rice-rice-njavara rice (*Ad hoc* POP), T_2: rice-rice-njavara rice (*Ad hoc* POP + foliar spray of LOMs), T_3: rice-rice-salad cucumber (*Ad hoc*

POP), T_4: rice-rice-salad cucumber (*Ad hoc* POP + foliar spray of LOMs), T_5: rice-rice-vegetable cowpea (*Ad hoc* POP), T_6: rice-rice-vegetable cowpea (*Ad hoc* POP + foliar spray of LOMs), T_7: rice-rice-amaranthus (*Ad hoc* POP), T_8: rice-rice-amaranthus (*Ad hoc* POP + foliar spray of LOMs) and T_9: rice-rice-fallow (*Ad hoc* POP) were studied in the experiment. Rice was practiced in *virippu* (kharif) and *mundakan* (rabi) seasons while *puncha* (summer) was diversified with medicinal rice, salad cucumber, vegetable cowpea and amaranthus. Recommended manures to each crop were kept optimum as per the *Ad hoc* POP of Kerala Agricultural University for organic farming: Crops (KAU, 2009) and the cultivation practices followed are given in Table 1. Liquid organic manures (LOMs) *viz*., *Jeevamrutham*, *Panchagavya*, Green leaf extract and *Fish amino acid* were sprayed sequentially at fifteen days interval. Soil analysis was made before sowing and after the completion of experiment to determine the effect of crop diversity on soil health. The data on physical, chemical and biological parameters before and after the experiment were statistically analyzed by applying the technique of analysis of variance using the WASP 2.0 package and the significance among the treatments was estimated at 5 per cent of probability (Gomez and Gomez, 1984) [3].

Table 1: Cultivation practices of all the crops

Particulars	**Crop- I**	**Crop- II**	**Crop-III**			
Crop	**Rice**	**Rice**	**Medicinal rice**	**Salad cucumber**	**Vegetable cowpea**	**Amaranthus**
Land preparation	Nursery was prepared to raise the seedlings (raised beds of 5-10 cm height, 1-1.5 m width and 2 m length)			Pits with a size 60 cm diameter and 30 cm depth were prepared	Ridges were made 45 cm apart	Shallow trenches of 30 cm width were prepared at 30 cm apart
Variety	Jyothi	Kanchana	Njavara	Pusa Uday	Anaswara	Arun
Seed rate (kg ha^{-1})	80		60	0.50 – 0.75	25	1.50
Seed treatment	*Pseudomonas fluorescens* @ 10 g kg^{-1}			1% *Pseudomonas fluorescens* and PGPR 1	1% PGPR 1	*Pseudomonas fluorescens* @ 10 g kg^{-1}
Spacing (cm)	20 X 15	15 X 10	15 X 10	200 X 150	45 X 30	30 X 20
Sowing	21 days old seedlings were transplanted in the main field		18 days old seedlings were transplanted in the main field	@ 4 seeds per pit	@ 3 seeds per pit at a depth of 5 cm	Seedlings were transplanted in trenches at a distance of 20 cm apart in two rows
Manuring	Vermi compost @ 2.5 t ha^{-1} and neem cake @ 400 kg ha^{-1} as basal application, Groundnut cake @ 400 kg ha^{-1} at active tillering stage			FYM @ 12 t ha^{-1} and vermi compost @ 4 t ha^{-1} as basal application, Cow dung slurry @ 50 kg ha^{-1} at 15 days interval (1 kg 10 L^{-1})	FYM @ 20 t ha^{-1}, vermi compost @ 2 t ha^{-1} and rock phosphate @ 110 kg ha^{-1} as basal application	Compost @ 25 t ha^{-1} as basal application, Top dressing of cow dung slurry @ 50 kg ha^{-1} at 7-10 days interval, Foliar spray of cow urine (1 %) after each harvest
Weeding	20 and 40 DAS		15 and 30 DAT	15 and 30 DAS	20 and 40 DAS	
Irrigation	1.50 cm of water level was maintained during transplanting and gradually increased up to 5 cm until maximum tillering stage. Water was drained out 14 days before harvest			Daily during early period and later once in 3-4 days interval	Twice in a week until pod formation stage and later once in a week	Daily
Plant protection measurements	Trichocards (*Trichogramma japonicum* and *Trichogramma chilonis*) @ 5 cc ha^{-1}, Neem soap @ 10 g L^{-1}			Neem soap @ 10 g L^{-1}, *Beauveria bassiana* 10 g L^{-1}		

DAS- Days after sowing, DAT- Days after transplanting

Table 2: Effect of rice based cropping systems on soil fertility

Treatments	**Physical properties**			**Chemical properties**						**Biological properties**			
	Bulk Density (g cm^{-3})	**Porosity (%)**	**Water holding capacity (%)**	**pH**	**EC (dS m^{-1})**	**OC (%)**	**Available nutrients (kg ha^{-1})**			**DHA (µg TPF formed g^{-1} soil day^{-1})**	**Bacteria (10^6 CFU g^{-1} soil)**	**Fungi (10^3 CFU g^{-1} soil)**	**Actinomycetes (10^4 CFU g^{-1} soil)**
							N	**P_2O_5**	**K_2O**				
T_1: Rice-Rice-Njavara rice (*Ad hoc* POP)	1.33	49.83	40.38	5.77	0.22	1.22	151.88	49.45	310.18	49.65	26.00 (7.40)	31.33 (4.49)	109.33 (6.04)
T_2: Rice-Rice-Njavara rice (*Ad hoc* POP + *foliar spray of LOMs)	1.32	50.09	39.28	5.73	0.22	1.23	156.83	50.40	312.49	51.85	29.67 (7.46)	41.33 (4.61)	110.67 (6.04)
T_3: Rice-Rice-Salad cucumber (*Ad hoc* POP)	1.33	50.28	41.06	5.79	0.23	1.40	162.36	56.02	329.97	52.78	36.67 (7.56)	35.00 (4.54)	115.00 (6.06)
T_4: Rice-Rice-Salad cucumber (*Ad hoc* POP + foliar spray of LOMs)	1.32	51.24	40.75	5.77	0.23	1.42	168.69	55.06	332.78	53.32	44.67 (7.64)	31.67 (4.50)	125.33 (6.10)
T_5: Rice-Rice-Vegetable cowpea (*Ad hoc* POP)	1.33	51.76	42.25	5.63	0.22	1.45	184.51	67.70	327.70	59.65	70.67 (7.85)	52.33 (4.72)	166.67 (6.22)
T_6: Rice-Rice-Vegetable cowpea (*Ad hoc* POP + foliar spray of LOMs)	1.32	53.22	44.45	5.67	0.24	1.46	192.04	71.11	327.40	60.88	75.00 (7.87)	47.33 (4.67)	198.67 (6.30)
T_7: Rice-Rice-Amaranthus (*Ad hoc* POP)	1.32	52.67	43.11	5.80	0.24	1.31	172.85	63.86	318.17	51.55	49.00 (7.69)	22.67 (4.33)	171.33 (6.23)
T_8: Rice-Rice-Amaranthus (*Ad hoc* POP + foliar spray of LOMs)	1.32	52.99	43.47	5.80	0.20	1.31	176.87	66.25	321.68	52.23	59.00 (7.77)	28.33 (4.44)	181.67 (6.26)
T_9: Rice-Rice-Fallow (*Ad hoc* POP)	1.33	51.51	38.05	5.82	0.25	1.10	149.49	41.74	297.33	29.62	14.00 (7.11)	15.33 (4.18)	84.00 (5.92)
SEd±	0.00	0.41	0.46	0.46	0.03	0.05	3.73	2.05	1.76	2.24	5.19	3.06	6.05
CD at 5%	0.01	1.24	1.39	1.39	0.10	0.15	11.20	6.15	5.27	6.73	15.57	9.17	18.14
Initial value	1.33	49.50	37.87	5.83	0.26	1.05	141.15	37.47	287.46	26.30	23.81	20.81	88.57

Results and Discussion

Soil physical characters did not differ significantly. The bulk density of the soil after the experiment slightly decreased when compared to initial value (1.33 g cm^{-3}). However, a decreasing trend revealed the improvement in bulk density with time which in turn improved the porosity and water holding capacity of all the cropping systems. Among the different cropping systems, rice-rice-vegetable cowpea and rice-rice-amaranthus (with/ without LOMs) improved the physical parameters to the maximum extent. This was due to the strong relationship between bulk density and organic matter where the bulk density decreased due to the addition of organic matter in the form of crop residue and FYM. In another hand, strong binding agents released from the decay of polysaccharides formed large and stable aggregates which in turn improved the bulk density. The observations were in line with Koushal *et al*. (2011) [5]. The chemical parameters like pH and EC also did differ significantly. Soil pH was reduced to a maximum extent in rice-rice-vegetable cowpea (with/ without LOMs) system. This was mainly due to the acidic nature of added manures. Due to high biomass production nature, cowpea supplied a greater amount of organic matter in the form of residue and its decomposition released fulvic acid humic acid which in turn might have also decreased the pH. Similar findings were also noticed by Yaduvamshi (2000) [14] and Patil *et al.* (2003) [10]. Improved soil physical characters leached down the salts and as a result, rice-rice-amaranthus cropping system with LOMs decreased EC to the maximum extent (0.20 dS m^{-1}) while rice-rice-fallow decreased slightly (0.25 dS m^{-1}) when compared to initial value (0.26 dS m^{-1}). **S**arwar *et al*. (2008) [11] also reported the slight change in EC in compost applied rice-wheat cropping system. Addition of organic matter increased the soil organic carbon content and consequently, rice-rice-vegetable cowpea with LOMs had the highest organic carbon content (1.46%), while rice-rice-fallow recorded the lowest value (1.10%) when compared to initial value of 1.05%. Intensification of cropping system enhanced the nutrient status (available N, P and K) of the soil. Among all the cropping system, available N and P contents of the soil were found to be the highest in rice-rice-vegetable cowpea with LOMs (192.04 and 71.11 kg ha^{-1} respectively) while rice-rice-salad cucumber with LOMs had the highest available K content (332.78 kg ha^{-1}). The increase in available N in the soil was due to the addition of organic manures as well as incorporation of crop residue. The leguminous effect cannot be ignored with this system where symbiotic nitrogen fixation by cowpea has also contributed to soil available N (Van Kessel and Hartley, 2000) [13]. The increase in P content could be due to the increased activity of phosphorus solubilizing bacteria particularly in association with legume rhizosphere, which in turn increased the availability of P as reported by Ninan *et al* (2013) [7]. On the other hand, increase in K content in rice-rice-salad cucumber could be due to lesser quantity of K uptake by salad cucumber leaving behind a larger quantity of K in the soil. Organic carbon triggers the enzyme and microbial activities. Therefore, increase in organic carbon in all the systems, increased the dehydrogenase activity and total microbial biomass (bacteria, fungi and actinomycetes) in all the cropping systems being the highest in rice-rice-vegetable cowpea. Among all the microbes, the population of bacteria was found to be the highest which could be due to the favourable condition of pH. The stimulation of dehydrogenase activity and increased microbial load due to increased organic C content were also noticed by Takeda *et al*. (2009) [12] and Parmar *et al*. (2016) [9] respectively. It was concluded that soil fertility could be sustained by diversifying the cropping system with the inclusion of leguminous crops.

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