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Monitoring of Soil Properties and Crop Performance (Rice) under Different Rice-based Cropping Systems

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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

An experiment on rice-based cropping systems to monitor the soil properties and crop performance (Rice) was conducted at Agronomy Research Farm in Acharya Narendra Deva University of Agriculture and Technology, Kumarganj (Ayodhya, U.P.) during 2020-21 in Complete Randomized Block Design with seven treatments and three replications. Seven cropping patterns viz; rice-wheat-fallow, rice-wheat-green gram, rice-frenchbean-green gram, rice-berseem-sudan chari, rice-cauliflower-okra, rice-potato-cowpea, rice-mustard-green gram were compared with rice-rice cropping pattern. The cropping systems were evaluated for their productivity & to assess their effect on the soil properties like soil pH, EC, organic carbon contents, soil organic matter, and available soil NPK. The results revealed that the green manuring and leguminous cropping patterns gave higher paddy yield as compared to the commonly practiced rice-rice cropping pattern. The maximum yield of rice (43.15q/ha) was obtained from a rice-mustard-green gram cropping pattern which was comparatively higher than those of a rice-rice cropping pattern. As regards the cost-benefit ratio, the highest ratio was received in the case of the rice-mustard-green gram (1:1.77) cropping system followed by the rice-frenchbean- green gram (1:1.65) and rice-wheat-green gram (1:1.52) as against the existing cropping system rice-rice. The results further indicated that the introduction of green manuring or leguminous crops in the existing rice-wheat system increased grain yields and improved the physio-chemical properties, organic matter contents, and nutrient availability in the soil. Soil pH lowered from 8.3 to 7.97 and organic carbon increased from 0.38 % to 0.39 %.

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1. INTRODUCTION

Rice (*Oryza sativa* L.), cultivation started nearly 11500 years ago [1] and more than 60 % of the total world's population consumed rice as like staple food (Ma et al., 2007). If we want to ensure food security for the expanding population, rice production should be increased by 50 % in rice-consuming countries [2]. In Uttar Pradesh, rice production is 15.66 million Tonnes and shares 12.81 % of production in India. The cumulative percent share of production is 26.43 [3]. India ranks first in the area and second in production after China. West Bengal is the top producing state and other dominant states in production are Uttar Pradesh, Punjab, and Chhattisgarh. In India, it is grown over an area of 43.78 million ha. having production of 118.43 million tonnes and average productivity of 2705 kg/ha [4]. The continuous growing of rice has led to a deterioration in soil quality, resulting in some serious threats to agricultural sustainability in the high rainfall zones in India. Therefore, crop diversification with a wider choice in the production of crop varieties is being promoted to restore of quality of the soil [5]. Rice-based cropping sequence can be described as a mix of farming practices that comprises rice as the major crop followed by subsequent cultivation of other crops. Various rice-based cropping sequences have been reported from different parts of India ranging from rice-rice-rice to rice followed by different cereals, pulses, oilseeds, vegetables, and fibre crops. The prominent rice-based cropping sequences in India are rice-rice, rice-wheat, rice-pulse, and rice-potato. The predominance of the rice-wheat system in the whole Indo-Gangetic plains zone is particularly due to the compatibility of the two crops mainly during sowing times [6].

In rice-pulse based cropping sequence legume crops in the rotation with cereals not only fix atmospheric Nitrogen through biological nitrogen fixation (BNF) but also enrich soil fertility, nutrient recycling from deeper soil layers, minimize the soil compaction, increase the organic matter, reduces pest and disease incidence, promote mycorrhizal colonization, and sustain the productivity of cereal-based cropping patterns [7]. The use of legume crops has enhanced their physical and chemical properties. The legume residues contain about 20–80 kg N ha^{-1} (about 70% of it is derived from BNF) depending upon the type and maturity of the crop and the full Nitrogen benefits will be realized if all the residues of the crop are incorporated after harvesting the seed yield [8]. In the cropping sequences including pulses, the preceding pulse may add about 20-70 kg N ha^{-1} to the soil, and thereby a considerable quantity of N supply to the succeeding crop could be reduced [9]. The rice-rice system is followed in irrigated cropping while the rice-pulse system is adopted in rainfed lowlands leaving land fallow during the pre-Kharif/summer season. Cropping sequences, including crop diversification, crop rotation and intercropping, and related agronomic practices used in agriculture impact soil health and quality from various spatial and temporal aspects [10], Cropping sequences were initially designed to maximize the yield by the agro-systems, but modern agriculture has become increasingly concerned about the environmental sustainability of cropping sequences [11]. The present study was designed for monitoring Soil properties like physical (sand, silt, and clay percentage) and chemical changes (organic carbon, pH ,EC, CEC)in soil and crop performance, like increase in yield, productivity, and economy (Rice) under different Rice-based cropping sequences.

2. MATERIALS AND METHODS

The experiment was laid out during 2020-21 at the agronomy research farm of the Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya, (UP). The experimental site is situated on the main campus of the university, about 42 km away from Ayodhya district headquarters on Ayodhya-Raebareili Road at 26047 N latitude and 82012 E longitudes and an altitude of 113 meters above mean sea level. The soil of the experimental field was ''Sandy Loam'' in textural, low in organic carbon and available nitrogen while the medium in phosphorus and rich in potassium. Seven cropping systems viz; rice-wheat-fallow, rice-wheat-green gram, rice-frenchbean-green gram, rice-berseem-sudanchari, rice cauliflower-okra, rice-potato-cowpea, rice-mustard-green gram were studied in the experiment. Rice variety NDR-2065 was transplanted using a randomized block design with seven treatments and three replications with a net plot size of 5.5 m x 4.5m = $24.75m^2$ and a gross plot size of 6m x 5m = $30m^2$. Recommended fertilizer to the crop was applied at the appropriate time. The recommended rate of nutrients (N, P, K 120, 60, and 60 kg/ha) were applied in the form of urea,diammonium phosphate, and muriate of potash The available amounts of nitrogen in DAP were deducted from dose of Urea. The data recorded during the investigation were subjected to statistical analysis using the analysis of variance technique (ANOVA) for RBD as prescribed by Cochran and Cox (1963).

Each crop's production costs were computed, and crop yields were estimated based on current market values. The cost-benefit ratio of each cropping pattern was also calculated. Before and after crop harvest, the soil was analyzed to establish its nutrient status.

2.1 Initial Physico-Chemical Proportion of the Soil of Investigational Field

Table 1.

S.NO	Soil properties	Value obtained	Methods employed
A	**Physical properties**		
I	Sand (%)	78.29	Hydrometer method
II	Silt (%)	9.73	(Bouyoucous, 1936)
III	Clay (%)	11.98	
IV	Textural classes	Sandy loam	Triangular method (Lyon et al., 1952)
B	**Chemical properties**		
I	Soil pH & Soil water ratio (1:2.5)	8.3	Glass electrode pH meter [12]
II	EC (dS m^{-1}) & soil water ratio (1:2.5)	0.25	Electrical conductivity bridge method [12]
III	Organic carbon (%)	0.38	Walkley and Black's rapid titration method [13]
IV	Available N (kg ha^{-1})	166.00	Alkaline permanganate method (Subbiah and Asija, 1956)
V	Available P (kg ha^{-1})	17.05	Olsen's method (Olsen et al. 1954)
VI	Available K (kg ha^{-1})	279.80	Flame photometer method [12]

3. RESULTS AND DISCUSSION

3.1 Effect on Crop Height and Dry Matter Accumulation

During the experiment 2020-21, the growth attributes of rice (viz; dry matter accumulation, and crop growth rate) at different growth stages were influenced significantly by crop diversification in various rice-based cropping systems (Table 2). The data presented in (Table 2) revealed that the maximum plant height at 30 DAS (11.66 cm), 60 DAS (59.44 cm),90 DAS (93.06 cm), and at the harvest stage (91.27 cm) under treatment T_7. The plant height recorded under treatments T_1 and T_2 were found statistically at par with T_7 at 30, 60, 90 DAS and harvest stage. The lower value of plant height was recorded under treatment T_4. In this experiment, data shows the height of the plant increases after 60 DAS. This might be attributed to the fact that the higher dose of the nutrients resulted in increasing the plant activities and reactions which increased the plant height. Similar observations have also been reported by Kumar et al. [14]. Dry matter accumulation found a maximum of under 30 DAS (251.03) in T6,60 DAS (273.80),90 DAS (344.99), and at harvest stage (476.08) under treatment T_7 and statistically at par with T_2 (456.78) and T_1 (443.92). The lowest dry matter was recorded at 30 DAS (231.44), 60 DAS (244.20), 90 DAS (278.69), and at the harvest stage (384.60) under the treatments T_1, T_5, T_4, and T_4, respectively. This shows that the dry matter of the crop is affected by the nutrient doses applied during the experiment because it enhanced elongation, chlorophyll, as well as various metabolic activities which increases the dry matter of the crop. The results are in agreement with those of Kumar et al. [14].

3.2 Effect on Chemical Properties of Examined Soil

In this experiment, we observed the data about pH presented in (Table-3) revealed that the maximum pH in rice was observed in T_2 (8.12) (Rice-Wheat-Green Gram) which was significantly superior over T_6 (8.05) and statistically at par with T_5 (8.03) and T_1 (8.01). The least pH was observed under T_3 (7.97) during the investigation. The declines in the pH might be the production of acids due to the decomposition of crop residues. Similar findings have also been observed by Jackson et al. [12].

Table 2.

Treatment	Plant height (cm)				Dry matter accumulation (g/plant)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1: Rice-Wheat-Fallow	10.85	55.43	86.77	85.61	231.44	13.15	16.85	443.92
T_2: Rice-Wheat-Green Gram	11.16	57.03	89.29	87.80	237.68	6.12	14.51	456.78
T_3: Rice-Frenchbean- Green Gram	11.40	58.24	91.18	89.92	250.43	6.13	14.54	466.43
T_4: Rice-Berseem-Sudan Chari	9.40	48.02	75.02	73.64	249.69	6.24	14.80	384.60
T_5: Rice-Cauliflower- Okra	10.38	53.02	83.00	81.63	231.50	6.34	15.04	424.61
T_6: Rice-Potato-Cowpea	10.61	54.22	84.89	83.15	251.03	6.55	15.61	434.27
T_7: Rice-Mustard – Green Gram	11.66	59.44	93.06	91.27	242.64	6.87	16.28	476.08
SEM ±	0.18	0.73	1.32	1.37	3.48	7.03	16.67	5.02
CD(P=0.05)	0.58	2.23	4.13	4.27	10.89	14.65	10.95	15.66

Table 3.

Treatment	pH	EC (dSm^{-1})	CEC	Organic carbon (%)	Soil organic matter (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1: Rice-Wheat-Fallow	8.01	0.35	11.97	0.36	0.63	160.02	13.43	232.70
T_2: Rice-Wheat-Green Gram	8.12	0.39	12.47	0.37	0.64	175.03	15.43	247.80
T_3: Rice-Frenchbean- Green Gram	7.97	0.37	13.01	0.38	0.66	183.3	16.17	243.70
T_4: Rice-Berseem-Sudan Chari	7.98	0.34	09.83	0.31	0.54	173.07	13.73	237.10
T_5: Rice-Cauliflower- Okra	8.03	0.36	10.39	0.35	0.60	168.72	14.69	245.10
T_6: Rice-Potato-Cowpea	8.05	0.38	11.14	0.35	0.61	171.04	13.65	256.70
T_7: Rice-Mustard – Green Gram	7.98	0.35	13.69	0.39	0.67	164.02	14.19	251.08
SEM ±	0.29	0.005	0.17	0.006	0.01	1.93	0.19	2.98
CD (P=0.05)	NS	NS	0.53	0.02	0.03	6.02	0.61	9.30

Table 4.

Sr. No	Treatments	Tillers	Grain per panicles	Grain Yield	Straw Yield	Harvest Index (%)
T_1	Rice-Wheat-Fallow	20.73	85.14	41.45	55.75	42.64
T_2	Rice-Wheat-Green Gram	21.36	86.23	42.20	56.73	42.65
T_3	Rice-Frenchbean- Green Gram	22.07	87.65	42.40	54.00	43.98
T_4	Rice-Berseem-Sudan Chari	18.83	79.10	39.20	52.90	42.56
T_5	Rice-Cauliflower- Okra	19.24	81.98	40.50	54.80	42.49
T_6	Rice-Potato-Cowpea (Veg.)	20.01	83.03	40.80	55.65	42.30
T_7	Rice-Mustard – Green Gram	23.12	89.27	43.15	58.80	42.32
	SEM ±	0.29	1.38	0.81	0.54	0.73
	CD(P=0.05)	0.92	4.32	2.52	1.68	NS

Table 5.

Sr. No.	Treatments	Cost of Cultivation	Gross Return	Net Return	B: C
T_1	Rice-Wheat-Fallow	35849	86314	50465	1.40
T_2	Rice-Wheat-Green Gram	35134	88732	53598	1.52
T_3	Rice-Frenchbean- Green Gram	32738	86967	54229	1.65
T_4	Rice-Berseem-Sudan Chari	37564	79437	41873	1.11
T_5	Rice-Cauliflower- Okra	36848	82434	45586	1.23
T_6	Rice-Potato-Cowpea	36207	83036	46829	1.29
T_7	Rice-Mustard – Green Gram	33738	93650	59912	1.77

EC recorded (Table 3) a maximum at T_2 (0.39) (Rice-Wheat-Green Gram) which was significantly superior over T_6 (0.38) and statistically at par with T_3 (0.37) and T_5 (0.36). The least EC was observed under T_4 (0.34) during the investigation. Similar findings were reported by Jackson et al. [12] and Kumar et al. [15]. CEC presented in (Table-3) revealed that the maximum CEC in rice was observed in T_7 (13.69) (Rice-Mustard-Green Gram) which was significantly superior over T_3 (13.01) and statistically at par with T_2 (12.47) and T_1 (11.97). Least CEC was observed under T_4 (9.83) during the investigation. Data shows that the cation exchange capacity might be influenced by the crop residues such as legume crop residues which helps the soil in increasing the cation exchange capacity. Similar observations have also been reported by Skidmore et al. [16] and Bhagat et al. [17]. The analyzed data are shown in Table 3 for soil organic matter found to be highest at T_7 (0.67) (Rice-Mustard-Green Gram) which was significantly superior over T_3 (0.66) and statistically at par with T_2 (0.64) and T_1 (0.63). The least Soil Organic Matter was observed under T_4 (0.54) during the investigation. Data shows that the soil organic matter increases with an increase in organic carbon content in the soil. Similar findings were observed by Walkley et al. [13]. The soil's initial availability of nitrogen was 166 kg ha^{-1} (Table-1). With the addition of leguminous crops to the rotation, the status of available N gradually increased. Among the cropping systems tested T_3 (183.30) rice-frenchbean-green gram cropping system significantly improved the soil’s available nitrogen status and the maximum status of nitrogen was recorded under this cropping system which was significantly superior over T_2 (175.03) and statistically at par with T_4 (173.07) and T_6 (171.04). Lowest Available N was observed under T_1 (160.02) during the investigation. This is due to the availability of the nutrients based on the cropping systems, if in the cropping system in which treatment with legumes increases the content of nitrogen in the soil. Similar findings have also been observed by Subbiah et al. (1956). The maximum Phosphorus and Potassium status were recorded under T3(16.17) (Rice-Frenchbean-Green Gram) and T_6 (256.70) (Rice-Potato-Cowpea) respectively.

3.3 Effect on Yield and Yield Attributes

A significant response was found from crop diversification in the rice-based cropping system on yield components of rice. Among different rice-based cropping systems the highest number of tillers and filled grain panicles was found under T_7 (23.12 and 89.27 respectively) (Rice-Mustard – Green Gram) and statistically at par with T_2 (86.23) and T_1 (85.14). The highest grain yield and straw yield were recorded under treatment T_7 (Rice-Mustard – Green Gram) at 43.15q/ha and 53.80q/ha respectively followed by T_1 and T_6 on pooled data basis (Table 4). These treatments were at par with each other. When combined with non-legume crops in rice-based cropping systems, the inclusion of legume crops improved rice yield components, resulting in higher yield. The harvest index of rice was influenced significantly due to crop diversification in different rice-based cropping systems where rice in rice-frenchbean-green gram showed the highest harvest index (43.98%) followed by rice-wheat-green gram (42.65%) and rice-wheat-fallow (42.64%). The inclusion of green gram in the cropping system might have increased the productivity and profitability of rice in the rice–potato–green gram system which conformed with the findings of Gangwar and Ram (2005) and Singh et al. (2007).

3.4 Effect on Economy of Crop

Data about Cost of Cultivation during experimentation and Gross Return, Net Return and Benefit Cost Ratio presented in (Table-5) revealed that the maximum cost of cultivation of rice (Rs. 37564) was incurred in the treatment T_4 (rice-berseem-sudan chari), while the least cost of cultivation of rice (Rs. 32738) was associated with T_3 (rice-frenchbean-green gram). The maximum gross return was noted as (Rs. 93650) under treatment T7 and the lowest (Rs. 79437) in T_4. The maximum net return was observed with (Rs. 59912) T7 while the minimum (Rs. 41873) was found in T_4. The maximum benefit-cost ratio (1.77) was observed with T7 during the investigation and the minimum (1.11) was found in T_4. Chaudhary et al. [18] reported that the intensification of the rice-wheat cropping system by rice proved to be highly remunerative and sustainable by generating income, employment, and protecting the environment in Bihar. Similar findings have also been observed by Mishra et al. [19].

4. CONCLUSION

Based on results presented and discussed in the preceding chapters concluded that maximum yield and productivity and build-up in fertility might be achieved with the application of recommended doses of fertilizer and the performance of the crop enhanced by the use of an integrated form of the organic and inorganic fertilizers along with different rice-based cropping systems. Hence it may be recommended for enhancing the productivity and sustainability of Rice and other related crops under the Rice-based cropping system.

The effect of green manure is shown in the availability of N and P hence it is proven by the monitoring of soil and crop performance on rice-based cropping systems that the use of green manure crops under rice-based cropping increases the availability of the nutrients in the soil which play a vital role in increasing the productivity of the soil and the crop production and it also helps in increasing the net return from the crop under various rice based cropping system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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