Impact of different rice-based cropping systems on soil biological properties and soil enzymes under irrigated conditions of Eastern Uttar Pradesh.

ABSTRACT

A field experiment was planned and conducted during the Rainy (Kharif) and winter (Rabi) seasons of 2021-22 and in the Summer (Zaid) season of 2022 at Agronomy Research Farm, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.) to investigate the impact of different rice-based cropping systems on soil biological properties under irrigated conditions of eastern U.P. The experiment was designed using a randomized block design with three replications and ten treatments. T_1 Rice(*Oryza sativa* L.)-Wheat(*Triticum aestivum* L.)-Fallow, T_2 Rice-Wheat-Green gram(*Vigna radiata* L.), T_3 Rice-French bean(*Phaseolus vulgaris* L.)-Green gram, T_4 Rice-Chickpea(*Cicer arietinum* L.)-Cowpea(*Vigna unguiculata* L.), T_5 Rice-Mustard (*Brassica juncea* L.)-Green gram, T_6 Rice-Linseed(*Linum usitissimum* L.)-Black gram(*Vigna Mungo* L.), T_7 Rice-Berseem(*Trifolium alexandrium* L.)-Sorghum(*Sorghum Bicolor* L.), T_8 Rice-Oat(*Avena Sativa* L.)-Maize(*Zea Mays* L.)+Cowpea, T_9 Rice-Cauliflower(*Brassica Oleracea* L.)-Okra(*Abelmoschus esculentus* L.), T_{10} Rice-Potato(*Solanum tuberosum* L.)-Cowpea. The soil of the experimental field was silty loam in texture, soil was slightly alkaline in reaction, low in organic carbon and available nitrogen and medium in available phosphorus and potassium. The growth of bacteria (11.68 x 10^6 cfu g^{-1}), fungi (6.55 x 10^5 sfu g^{-1}) and actinomycetes (7.15 x 10^4 cfu g^{-1}) was found to be highest in T_{10} Rice-Potato-Cowpea cropping system. In this investigation, the microbial population was higher under the treatments in which high doses of nitrogen and crop residues were applied. The activity of dehydrogenase enzyme (153.68 µg TPF g^{-1} soil day^{-1}), urease (217.33 µg urea g^{-1} soil hr^{-1}) and alkaline phosphate (163.96 µg p-nitrophenol g^{-1} hr^{-1}) was found significantly higher in T_4 (Rice-chickpea-cowpea) cropping system in comparison with the other cropping system.

Keywords: Actinomycetes, Alkaline Phosphatase, Bacteria, Cropping system, Dehydrogenase, Fungi, Microbial Population and Urease.

1. INTRODUCTION: Biological characteristics are the most sensitive indicators of soil quality in rice production systems and respond quickly to environmental changes (Lima *et al.,* 2013). Soil microbial communities have a crucial role in regulating below-ground ecological processes, including nutrient availability, especially nitrogen (N) (Coleman and Crossley, 1996). Changes in soil nitrogen supply can impact the microbial community, reducing their function in organic matter turnover.

Changes in soil microbial function and community composition can affect litter and organic matter decomposition rates (Carreiro *et al.* 2000), humus formation (Magill and Aber, 1998), nutrient transformation and cycling (Fisk and Fahey,2001), and plant-microbe interactions. These biological features may be beneficial for analysing soil fertility and quality changes in short-term trials.

Rice fallows are poor crop stands as a result. However, the cultivation of short duration crops like pulses and oilseeds in rice fallows has been considerably better (Lal *et al.*, 2017). With the increasing demand for food due to population growth, it is necessary to improve the production potential of rice-based cropping systems. Under irrigated conditions, rice-based cropping systems have the potential to yield high-quality and high-quantity crops, contributing significantly to food security and economic growth. However, the production potential of rice-based cropping systems under irrigated conditions is influenced by several factors such as soil fertility, water management, crop rotation, and agronomic practices (Ali *et al.* 2012).

A rice-based cropping sequence is a combination of farming techniques that includes rice as the main crop and then the growing of other crops. Rice-based cropping systems help to maintain soil health by reducing soil erosion, improving soil structure, and enhancing soil fertility. Crop rotation with legumes or other non-rice crops can also help to fix nitrogen and increase soil fertility, reducing the need for chemical fertilizers. Rice-based cropping systems, especially those under irrigated conditions, can use water more efficiently than monocropping. Crop rotation with non-rice crops can help to reduce water use by breaking the water-intensive rice monoculture. Rice-based cropping systems provide opportunities for crop diversification, improving farmers' income and food security ((Saroch *et al.* 2005). Crop rotation with vegetables, fruits, or other cash crops can provide additional income streams and improve the nutritional quality of the diet. In many areas, intercropping of rice and other suitable crops is also very common. The rotation of crops involving cereals, pulses, oilseeds, cotton, sugarcane, green manures, vegetables, etc. is one of the main cropping sequences used in India. In eastern India, particularly in Chhattisgarh, Odisha, and portions of Bihar, Rice pulse cropping systems constitute the predominant crop rotation. As they fix atmospheric nitrogen and improve the physical, chemical and biological qualities of soil, pulse crops are prospective candidates for consideration in summer rice fallows (Cassman and Pingali, 1995). They serve as functional foods and are excellent sources of protein with low glycine max and gluten levels (Edwards *et al.* 1992).

A variety of cropping systems can benefit from proper agronomic management, the use of biofertilizers, and mechanical cultivation, which can increase production and cover a large area with pulses (Sekhon *et al.* 2007).

The widespread use of this approach will also be crucial for future planning to maintain the self-sufficiency of food grains because of their high productivity, stability, and low risk (Singh *et al.* 2012).

The incorporation of leftover pulse crop wastes into soil improves biological activity (Saviozzi *et al.* 1999). Microbial activity and soil fertility are linked since biomass mineralizes key organic elements (C, N, and P) (Ros *et al.* 2003).

Microbial adaptation to environmental circumstances allows microbial analyses to be discriminating in soil health evaluation, and changes in microbial populations and activities may therefore operate as a good indication of change in soil health (Pankhurst *et al*, 1995).

Soil enzymes play a crucial role in soil ecology, regulating physical and chemical processes, and releasing nutrients. Soil microbes use several enzymes to decompose organic materials. In organically treated soil, dehydrogenase activity and soil biomass are substantially associated (Garcia *et al.* 2008).

Therefore, the purpose of this study was to develop and evaluate the effects of various rice-based cropping systems on the biological characteristics of the soil in Eastern Uttar Pradesh under irrigated conditions.

2. MATERIALS AND METHODS

A field experiment was conducted from the rainy season (*Kharif*) 2021 to summer (*Zaid)* 2022 at Agronomy Research Farm, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya 26^0 47^0 N latitude and 82^0 12^0 E longitude on an elevation of about 113 meters above mean sea level in the Indo-Gangetic alluvial soil belt of Eastern Uttar Pradesh. The area falls under the subtropical zone which is characterized by hot and dry summers with cold winters. Rain is more often confined to the period from July to September with occasional winter and summer rain. The soil of the experimental field is alluvial, developed from the alluvium deposited by rivers. The partially reclaimed sodic soil belongs to the order inceptisol with silt loam texture, low in organic carbon (0.29%), available nitrogen
(150 kg ha^{-1}), medium in available phosphorus (14.11 kg ha^{-1}) and potassium (245.43 kg ha^{-1}) and alkaline in reaction (pH 8.2). A field experiment on various rice-based cropping systems for increasing the production potential was started in 2021 with ten treatments in rice-based cropping systems in randomized block design with three replications. The treatments

included 10 cropping systems, Viz. Rice Wheat-Fallow, Rice-Wheat-Green gram, Rice-French bean-Green gram, Rice-Chickpea-Cowpea, Rice Mustard -Green gram, Rice-Linseed-Black gram, Rice-Berseem-Sorghum, Rice-Oat-Maize+Cowpea, Rice-Cauliflower-Okra, Rice-Potato-Cowpea. The net plot size of each treatment was 22.5 m^2. Varieties and hybrids which were popular with the local farmers for their yield potential and low infestation of insect pests and diseases were used. All the crops were grown successfully with recommended packages of practices. The crops were irrigated optimally as and when required. Each of the following treatments was thoughtfully developed to separate apart a primary set of nutrient supplementation and organic inputs with bacterial aid.

3. RESULTS AND DISCUSSION

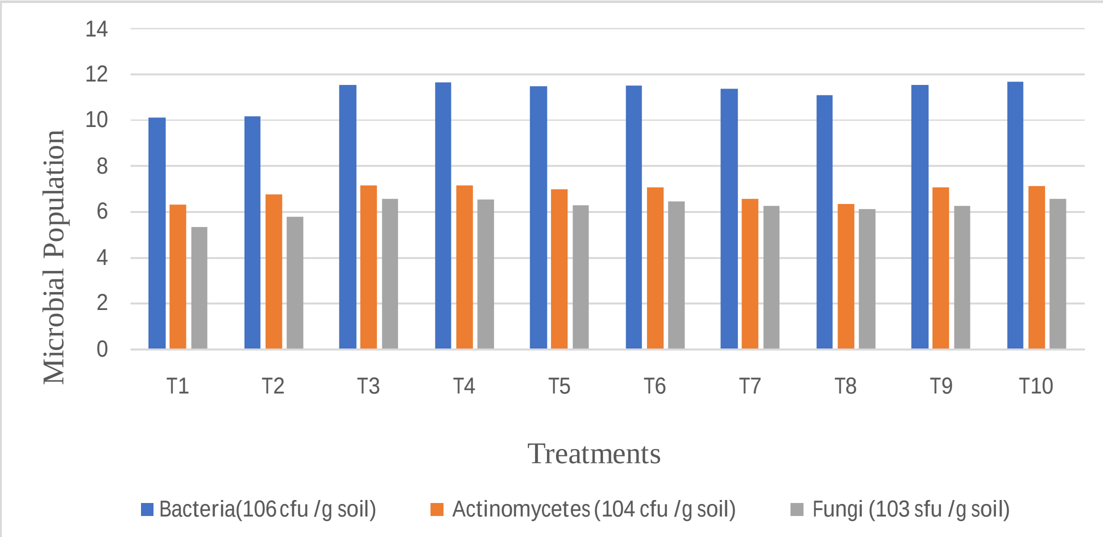
3.1 Soil Microbial Population (Bacteria, Fungi, Actinomycetes)

The data shows in Table 1 and Fig.1 that different rice-based cropping system treatments have a significantly higher impact on soil microbial populations. The total microbial population i.e., bacteria, actinomycetes and fungi are found to be maximum (11.68 x 10^6 cfu g^{-1} soil bacterial population, 7.15 x 10^4 cfu g^{-1} soil actinomycetes population, and 6.55 x 10^5 sfu g^{-1} soil fungi population) under the treatment T_{10} (Rice-Potato-Cowpea) and the lowest (10.12 x 10^6 cfu g^{-1} soil bacterial population, 6.31 x10^4 cfu g^{-1} soil actinomycetes population and 5.33 x10^5 sfu g^{-1} soil fungi population) microbial population was found under the treatment T_1 (Rice-Wheat-Fallow). Also the data showed that there insignificant differences between T10 and T4 treatments in Soil Microbial Population (Bacteria, Fungi, Actinomycetes) . In this investigation, the microbial population was higher under the treatments in which high doses of nitrogen and crop residues were applied. Arcand *et al.* (2016) have observed similar findings.

Table 1 Impact of different rice-based cropping system in irrigated conditions on soil microbial population.

Treatments	Bacteria (10^6 cfu g^{-1} soil)	Actinomycetes (10^4 cfu g^{-1} soil)	Fungi (10^3 sfu g^{-1} soil)
T_1 Rice-Wheat-Fallow	10.12	6.31	5.33
T_2 Rice-Wheat-Green gram	10.19	6.75	5.79
T_3 Rice-French bean-Green gram	11.54	7.15	6.57
T_4 Rice-Chickpea-Cowpea	11.67	7.16	6.56
T_5 Rice-Mustard-Green gram	11.51	7.01	6.28
T_6 Rice-Linseed-Black gram	11.53	7.08	6.44
T_7 Rice-Berseem-Sorghum	11.40	6.57	6.26
T_8 Rice-Oat-Maize + Cowpea	11.11	6.34	6.14
T_9 Rice-Cauliflower-Okra	11.54	7.09	6.27
T_{10} Rice-Potato-Cowpea	11.68	7.12	6.57
SEm (±)	4.611	0.021	0.026
CD (P=0.05)	NS	0.061	0.076

Fig. 1 Impact of different rice-based cropping system in irrigated conditions on soil microbial population.



3.2 Activity of soil enzymes

The data presented in table 2 and figure 2. Shows that the activity of dehydrogenase enzyme was recorded at maximum (153.68 µg TPF g^{-1} soil day^{-1}) under the treatment T_4 (Rice-Chickpea-Cowpea) compared with other cropping systems and the lowest (116.2 µg TPF g^{-1} soil day^{-1}) activity of dehydrogenase enzymes is found in the T_1 (Rice-Wheat-Fallow). The activity of urease was significantly higher (217.33 µg urea g^{-1} soil hr^{-1}) T_4 (Rice-chickpea-cowpea cropping system in comparison with the other cropping system. The lowest activity of urease was found under the T_1 (Rice-Wheat-Fallow) cropping system in comparison to other systems of cropping. Data from this investigation revealed that urease activity was influenced by the nutrient status of the soil. higher activity of urease was observed where higher doses of nitrogen were applied. Similar findings have been reported by Singh *et al.* (2018) and Li, J. Xie et al. (2021). Significantly the higher (163.96 µg p-nitrophenol g^{-1} hr^{-1}) amount of alkaline phosphatase activity was observed under the treatment T_3 (Rice-French bean-Green gram) in comparison to the other treatments of different cropping systems. Treatment T_1 (Rice-Wheat-Fallow) resulted in low (159.36 µg p-nitrophenol g^{-1} hr^{-1}) alkaline phosphatase activity. The data from this investigation revealed that the activity of dehydrogenase and alkaline phosphatase was higher under the treatment in which legume crops have been sown and which after the harvesting have been incorporated inside the soil for green manuring purposes. Singh *et al.* (2018) and Meena *et al.* (2014) have reported similar findings.

Fig. 2. Dehydrogenase, Urease and alkaline phosphatase activity under various rice-based cropping systems in irrigated conditions.

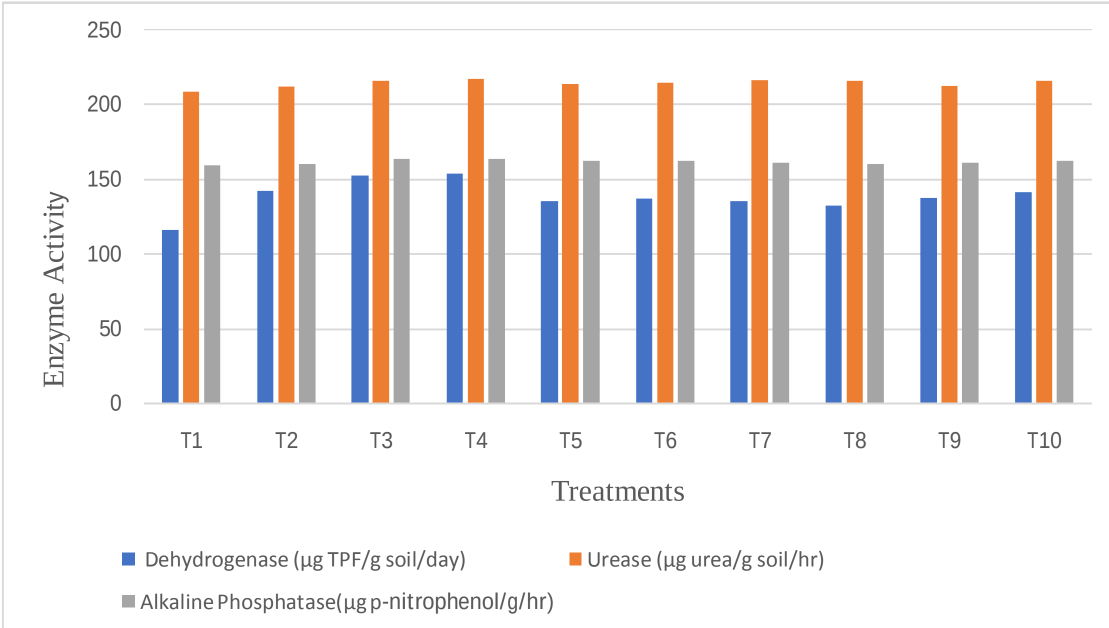


Table 2. Dehydrogenase, Urease and alkaline phosphatase activity under various rice-based cropping systems in irrigated conditions.

Treatments	Dehydrogenase (µg TPF g^{-1} soil day^{-1})	Urease (µg urea g^{-1} soil hr^{-1})	Alkaline phosphatase (µg p-nitrophenol g^{-1} hr^{-1})
T_1 Rice-Wheat-Fallow	116.20	208.37	159.36
T_2 Rice-Wheat-Green gram	142.52	212.32	160.25
T_3 Rice-French bean-Green gram	152.50	216.25	163.96
T_4 Rice-Chickpea-Cowpea	153.68	217.33	163.85
T_5 Rice-Mustard-Green gram	135.67	213.96	162.50
T_6 Rice-Linseed-Black gram	137.20	214.70	162.18
T_7 Rice-Berseem-Sorghum	135.11	216.50	161.22
T_8 Rice-Oat-Maize	132.54	216.10	160.28
T_9 Rice-Cauliflower-Okra	137.88	212.40	161.15
T_{10} Rice-Potato-Cowpea	141.25	216.05	162.55
SEm (±)	0.741	1.044	0.140
CD (P=0.05)	2.225	3.126	0.418

4. CONCLUSION: The results demonstrated that the inclusion of the legume crops in the rice based cropping system is the most desirable in order to improve microbial population and enzyme activities in soil. Thus, it can be concluded from the present study that incorporation of the crop residues of the legume crops in the field can be used as an alternate nutrient source for maintaining soil nutrient availability, microbial population and enzyme activities. It will also increase the fertility status of the soil. These findings underscore the importance of adopting ecofriendly agricultural strategies that reduce reliance on synthetic fertilizers while promoting soil biodiversity and fertility.

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