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Impact of tillage and nutrient management practices on soil microbial population under diverse rice-based cropping systems in Eastern Vidarbha zone of Maharashtra

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Abstract
A field investigation was conducted during 2020-21 and 2021-22 to study on 'impact of tillage and nutrient management practices on soil microbial count under rice-based cropping systems at Sindewahi block, Chandrapur district, Maharashtra, India'. The experiment laid out in split-split plot design with 24 treatment combinations (6 cropping systems, 2 tillage practices, and 2 nutrient management practices) replicated thrice. Rice-chickpea cropping systems exhibited the highest populations of bacteria, fungi, and actinomycetes compared to rice-rice and rice-wheat cropping systems. Other diversified systems *viz*., rice-lathyrus, rice-vegetables, and l rice-linseed also showed greater microbial populations than rice-rice and rice-wheat cropping systems. The integrated nutrient management (INM) practices significantly increased bacterial and fungal populations compared to sole reliance on chemical fertilizers. This study suggests that, incorporating legumes into rice-based cropping systems alongside INM practices can significantly promote soil microbial communities. These findings highlight the potential of these practices to contribute to improved soil health and productivity in the Sindewahi block of Chandrapur district.

Keywords: Rice based cropping systems, tillage practices, nutrient management practices, soil microbial count

Introduction
Soil is a fundamental building block of nature, providing essential services for countless ecosystems that ultimately benefit humanity. Unfortunately, the damage we inflict on soil through degradation and loss is so severe that, it cannot be fully recovered within a human lifespan. Rice (*Oryza sativa* L.) is the staple food for a significant portion of the global population, particularly in Asia. In the Eastern Vidarbha region of Maharashtra, rice cultivation dominates agricultural practices and plays a crucial role in ensuring food security. However, intensive agricultural practices focused solely on maximizing rice yield have led to unintended consequences for soil health. One of the most concerning issues is the decline in soil microbial populations. Mechanization, which has revolutionized agriculture, often relies on practices like tillage that disrupt soil structure and aeration. This disruption can negatively impact the delicate balance of soil microbes, including bacteria, fungi and actinomycetes (Kumar *et al.,* 2020) [4, 5]. These microbes play a vital role in maintaining soil fertility by decomposing organic matter, fixing nitrogen, and enhancing nutrient availability for plants (Banerjee *et al.*, 2016) [2].
Chemical fertilization, another cornerstone of modern agriculture, while promoting short-term yield increases, can have detrimental long-term effects on soil health. Excessive and imbalanced use of chemical fertilizers can suppress beneficial microbial populations and lead to soil degradation (Kumar *et al.,* 2020) [4, 5]. The decline in soil microbial populations poses a significant threat to the sustainability of rice-based cropping systems in the Eastern Vidarbha region. A critical strategy for addressing this challenge lies in diversifying rice-based cropping systems. Moving away from monoculture practices, which involve cultivating only rice year after year, towards incorporating legume crops holds immense potential.

Moreover, the monoculture of rice crop exacerbates the depletion of soil microbial diversity and function. Hence, there is a growing recognition of the importance of diversifying rice-based cropping systems by incorporating legume crops. This diversification strategy holds promise for revitalizing soil health and promoting sustainable agricultural practices. Legumes have a symbiotic relationship with nitrogen-fixing bacteria. These bacteria convert atmospheric nitrogen into a form usable by plants, reducing dependence on synthetic fertilizers. Additionally, legume residues left in the soil after harvest act as a source of organic matter, promoting the growth and activity of beneficial soil microbes (Yadav *et al.*, 2017) [11].

Recent trends in rice production underscore the urgency of addressing soil health concerns. India, being one of the largest producers and consumers of rice globally, has witnessed a steady increase in rice production over the years. According to the Food and Agriculture Organization (FAO), India's rice production reached approximately 118 million metric tons in 2022, contributing significantly to global rice supplies. However, the sustainability of this production trajectory is threatened by declining soil microbial populations and the consequent degradation of soil health. Excessive use of chemical fertilizers has been associated with altered soil pH, nutrient imbalance, and toxicity, further influencing microbial communities negatively. Consequently, there has been a gradual decline in soil microbial populations, including bacteria, fungi, and actinomycetes, in rice-based cropping systems.

In response to these challenges, there is a growing recognition of the need for sustainable agricultural practices that promote soil health and biodiversity. Diversification of rice-based cropping systems emerges as a viable strategy to mitigate the adverse effects of mechanization and chemical fertilization on soil microbial populations. By integrating legume crops into the cropping system, farmers can harness the benefits of biological nitrogen fixation, enhance soil fertility, and promote microbial diversity. Moreover, legume-rice rotations offer the potential for improved resilience to pests and diseases, reduced reliance on synthetic inputs, and enhanced overall productivity.

Materials and Methods

A field experiment was conducted during the year 2020-21 and 2021-22 to study on "Dynamics of soil organic carbon as influenced by tillage and nutrient management practices under rice based cropping systems in eastern Vidarbha zone of Maharashtra" at Sindewahi block of Chandrapur district. Chandrapur district is located between 16° 40' to 22° 10' North latitude and 72° 60' to 80° 90' East longitude. Site selection for sampling undertaken after survey on farmers field and discussion with farmers with the help of 'Krishi Vigyan Kendra', Sindewahi during *Rabi* 2020. The farmer's field were selected based on similar type of tillage and nutrient management practices since at least 10 cycles of rice- based cropping systems. The experiment was laid out in a split-split plot design with 24 treatment combinations, replicated thrice. The tillage practices which carried out by bullock drawn implements were considered as conventional tillage and farmers who used tractor drawn implements or machinery to complete tillage operations on their field were considered as mechanized tillage.

The treatment wise total 72 surface soil samples (0-15 cm) were collected at mid *Rabi* season and at proper moisture condition during 2020-21 and 2021-22, stored at the 4 ^{0}C temperature. Details regarding experimental treatments presented in table 1. For isolation of bacteria, fungi and actinomycetes from soil three different media were used for specific group of micro flora. For isolation of bacteria, fungi and actinomycetes from soil, nutrient agar, rose Bengal agar and ken knight medium used respectively. One gram of soil was serial diluted to 10^7, 10^4 and 10^4 for bacterial, fungi and actinomycetes respectively. These data statistically analyzed and appropriately interpreted as per method described in 'Statistical procedures for agricultural research' by Gomez and Gomez (1984) [3]. Appropriate standard error and critical differences worked out at 5 per cent probability level and the values were furnished.

Table 1: Detail of experimental treatments

Symbols	Treatment details
Main plot treatment: Rice based cropping systems	
C_1	Rice-Rice
C_2	Rice-Wheat
C_3	Rice-Chickpea
C_4	Rice-Lathyrus
C_5	Rice- Linseed
C_6	Rice-Vegetables
Sub-plot treatments: Tillage practices	
T_1	Conventional tillage
T_2	Mechanized tillage
Sub-sub plot treatments: Nutrient management	
N_1	Integrated Nutrient Management
N_2	Chemical fertilizers only

Table 2: Analytical methods employed in microbial analysis

Parameters	Method	Reference
Total bacteria	Serial dilution method using Nutrient Agar medium	Allen (1953)
Total fungi	Serial dilution method using Rose Bengal Agar medium	Martin (1950)
Total actinomycetes	Serial dilution method using Ken Knights Agar medium	Allen (1953)

Results and Discussions

Effects of tillage and nutrient management practices on bacterial population under rice-based cropping systems

The data pertaining to the impact of tillage and nutrient management practices on soil bacterial count under rice-based cropping systems presented in table 3. The average bacterial population ranged from 50.33 to 54.29 CFU x 10^7 g^{-1} (pooled mean). Among the six rice based cropping systems, the highest value of bacterial population was found under rice-chickpea cropping systems (54.29 CFU x 10^7 g^{-1}) which found to be at par with rice-lathyrus (52.54 CFU x 10^7 g^{-1}), rice-vegetables (52.00 CFU x 10^7 g^{-1}) and rice-linseed (51.88 CFU x 10^7 g^{-1}) and found superior over rice-rice (50.33 CFU x 10^7 g^{-1}) and rice-wheat cropping systems (51.04 CFU x 10^7 g^{-1}).

Additionally, integrated nutrient management practices exhibited a notable impact on soil bacterial population, with a recorded count of 53.33 CFU x 10^7 g^{-1} compared to chemical fertilizer application 50.69 CFU x 10^7 g^{-1} at Sindewahi block. Whereas, tillage practices and the interaction between cropping systems, tillage and nutrient management practices found to be non-significant.

Table 3: Effects of cropping systems, tillage and nutrient management practices on bacterial population (CFU x 10^7 g^{-1}) at Sindewahi block (Pooled mean).

Treatments	Conv. tillage (T_1)		Mean	Mech. tillage (T_2)		Mean	Mean C
	INM (N_1)	Chem fert. (N_2)		INM (N_1)	Chem fert. (N_2)		
C_1-R-R	56.67	52.33	54.50	54.17	38.17	46.17	50.33
C_2-R-W	50.00	60.33	55.17	45.67	48.17	46.92	51.04
C_3-R-C	52.00	58.83	55.42	64.33	42.00	53.17	54.29
C_4-R-L	59.67	50.83	55.25	57.67	42.00	49.83	52.54
C_5-R-Lin.	50.67	61.83	56.25	52.00	43.00	47.50	51.88
C_6-R-V	48.00	50.33	49.17	49.17	60.50	54.83	52.00
Mean	52.83	55.75		53.83	45.64		
Mean N	53.33(N_1)			50.69(N_2)			
Mean T	54.29			49.74			

	C	T	N	C x T	C x N	T x N	C x T x N
S.E.(m) ±	0.90	2.09	0.93	4.14	3.90	3.69	3.22
C.D. at 5%	2.65	NS	2.60	NS	NS	NS	NS

The increase in microbial population in soil might be due to greater availability of organic carbon and mineralized nutrients for their proliferation and development. The legume crops can solubilize different nutrients quickly by secreting root exudates that enhance the growth and activities of wide range of bacteria. The results indicated that the application of FYM in combination with chemical fertilizers proved better than use of only chemical fertilizers in helping the multiplication of bacterial population.

Results are confirmed with the findings of Upadhaya *et al.*, (2022) [10] they reported that, the bacterial population was higher where more legume crops were taken, because of the availability of the growth substances for bacteria was higher from the root exudates, which led to increased bacterial growth. Organic manure with NPK fertilizer excreted a stimulating influence on the preponderance of soil microbial community. This might be ascribed to the decomposed food material available from organic sources (Meshram *et al.* 2016) [7].

Effects of tillage and nutrient management practices on fungal population under rice based cropping systems

The fungal population at Sindewahi block of Chandrapur district was notably affected by both, rice-based cropping systems and nutrient management practices, as presented in Table 4. The mean values of fungal population ranged from 22.96 – 28.75 CFU x 10^4 g^{-1} (pooled mean).

Meanwhile, the highest fungal population was observed in rice-chickpea cropping systems (28.75 CFU x 10^4 g^{-1}) which were comparable to rice-lathyrus (27.00 CFU x 10^7 g^{-1}), rice-vegetables (26.96 CFU x 10^4 g^{-1}) and rice-linseed (24.88 CFU x 10^4 g^{-1}) These values surpassed those of rice-rice (22.96 CFU x 10^4 g^{-1}) and rice-wheat cropping systems (23.96 CFU x 10^4 g^{-1}). Additionally, The INM practices recorded the significant fungal population 26.31 CFU x 10^4 g^{-1} over chemical fertilizer application 25.19 CFU x 10^4 g^{-1}.

Table 4: Effect of cropping systems, tillage and nutrient management practices on soil fungal population (CFU x 10^4 g^{-1}) at Sindewahi block (Pooled mean).

Treatments	Conv. tillage (T_1)		Mean	Mech. tillage (T_2)		Mean	Mean C
	INM (N_1)	Chem fert. (N_2)		INM (N_1)	Chem fert. (N_2)		
C_1-R-R	23.67	22.00	22.83	22.33	23.83	23.08	22.96
C_2-R-W	25.33	22.67	24.00	24.67	23.17	23.92	23.96
C_3-R-C	28.50	33.50	31.00	28.33	24.67	26.50	28.75
C_4-R-L	27.67	28.17	27.92	27.00	25.17	26.08	27.00
C_5-R-Lin.	27.50	25.33	26.42	22.33	24.33	23.33	24.88
C_6-R-V	22.67	25.00	23.83	35.67	24.50	30.08	26.96
Mean	25.89	26.11		26.72	24.28		
Mean N	26.31(N_1)			25.19(N_2)			
Mean T	26.00			25.50			

	C	T	N	C x T	C x N	T x N	C x T x N
S.E.(m) ±	1.34	0.63	0.34	2.75	2.69	1.32	2.17
C.D. at 5%	3.98	NS	0.98	NS	NS	NS	NS

This might be due to rice-legume cropping systems receiving greater organic root exudates and organic acids in the rhizosphere caused a higher build-up of fungal density as compared to cereals. The availability of readily decomposed food material from organic source (FYM). However, application of inorganic fertilizers also leads to an improvement in fungal population over control. Fresh air and nutrition in to top soil benefits the soil microbial growth. Such an increase was not purely due to nutrient response but it was due to microbial oxidation of ammonium salt present in inorganic fertilizers which leads to formation of nitric acid pre disposing condition for fungal proliferation as reported by Meshram *et al.* (2016) [7].

The increase in microbial population in soil might be due to greater availability of organic carbon and mineralized nutrients for their proliferation and development (Kumari *et al.*, 2020) [4, 5].

Effect of tillage and nutrient management practices on actinomycetes population under rice based cropping systems: In Sindewahi block of Chandrapur district, rice-based cropping systems exerted a significant influence on the population of actinomycetes, as detailed in Table 5. The mean values of actinomycetes ranged from 29.42- 36.42 CFU x 10^4 g^{-1}. Among the rice based cropping system, highest value of actinomycetes population were found in rice-chickpea cropping systems 36.42 CFU x 10^4 g^{-1}) over rice-rice (29.42 CFU x 10^4 g^{-1}) and rice-wheat cropping systems (32.75 CFU x 10^4 g^{-1}) and was at par with rice-lathyrus (35.83 CFU x 10^4 g^{-1}), rice-vegetables (35.08 CFU x 10^4 g^{-1}) and rice-linseed (33.33 CFU x 10^4 g^{-1}) at Sindewahi block of Chandrapur district. The nutrient and tillage management practices, along with their interactions, did not found statistically significant differences.

Table 5: Effect of cropping systems, tillage and nutrient management practices on soil actinomycetes population (CFU x 10^4 g^{-1}) from Sindewahi block (Pooled mean).

Treatments	Conv. tillage (T_1)		Mean	Mech. tillage (T_2)		Mean	Mean C
	INM (N_1)	Chem fert. (N_2)		INM (N_1)	Chem fert. (N_2)		
C_1-R-R	29.33	31.33	30.33	29.50	27.50	28.50	29.42
C_2-R-W	34.33	27.33	30.83	35.67	33.67	34.67	32.75
C_3-R-C	46.00	30.17	38.08	34.67	34.83	34.75	36.42
C_4-R-L	36.83	34.17	35.50	30.00	42.33	36.17	35.83
C_5-R-Lin.	36.00	32.33	34.17	33.00	32.00	32.50	33.33
C_6-R-V	33.50	33.67	33.58	40.67	32.50	36.58	35.08
Mean	36.00	31.50		33.92	33.81		
Mean N	34.96(N_1)			32.65(N_2)			
Mean T	33.75			33.86			

	C	T	N	C x T	C x N	T x N	C x T x N
S.E.(m) ±	1.28	0.50	0.89	3.88	3.65	2.69	2.96
C.D. at 5%	3.65	NS	NS	NS	NS	NS	NS

The additions of legumes in cropping systems enhance the soil microbial activity as well as increase microbial diversity and small changes in the concentration of nitrogen, cellulose, lignin content and C: N ratio of residue trigger the divergence of soil microbial status.

The similar findings were also reported by Kumar *et al*. (2017) [11] and Sharma *et al*. (2011) [8] they reported that, the degradation of crop residues and slow release of nutrients with balanced C:N ratio and ensured the faster microbial proliferation. Microorganism's play an important role in degrading complex organics such as cellulose, lignin and protein and enhanced the soil microbial population under the effect of organic manure (Shashidhar *et al.* 2009) [9]

Conclusion
Agricultural practices that promote crop diversification, particularly by incorporating legumes in rice based cropping systems. Such as chickpea and lathyrus along with integrated nutrient management (INM) practices, were found to significantly improve soil microbial populations compared to rice-rice and rice-wheat cropping systems and those reliant solely on chemical fertilizers. These findings suggest that adopting such practices can contribute positively to soil health and productivity in the Sindewahi block of Chandrapur district.

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