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Influence of integrated nitrogen and phosphorus management practices on soil microbial population dynamics

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Abstract

Soil microbial populations are highly responsive to nutrient management practices and play a vital role in nutrient cycling and soil fertility. A field experiment was conducted during two consecutive seasons (2022-23 and 2023-24) to evaluate the influence of integrated nitrogen and phosphorus management practices on soil fungal, bacterial, and actinomycetes populations at different crop growth stages. The experiment was laid out in a factorial randomized block design with six nitrogen management options and three phosphorus management options, replicated thrice. Soil samples were collected at 30 days after transplanting (DAT), 60 DAT, and at harvest, and microbial populations were estimated using standard dilution plate count techniques. Pooled analysis of two years' data revealed significant variation in microbial populations due to nutrient management practices. Among nitrogen management options, integrated application of organic residues along with bio-consortium and recommended nitrogen dose recorded significantly higher fungal, bacterial, and actinomycetes populations at all growth stages. Microbial populations increased from 30 DAT to 60 DAT and declined slightly at harvest, indicating peak microbial activity during the active vegetative phase. Phosphorus management involving 100 per cent recommended dose applied as basal consistently recorded higher microbial populations compared to reduced phosphorus levels with bio-inoculants. Interaction effects between nitrogen and phosphorus management practices were found to be non-significant. Enhanced microbial populations under integrated nutrient management may be attributed to improved substrate availability, increased organic carbon input, and favorable soil environment for microbial proliferation. The consistency of results across years highlights the sustainability of integrated nutrient management practices. The study concludes that balanced and integrated application of nitrogen and phosphorus is essential for improving soil microbial health and sustaining long-term soil fertility.

Keywords: Integrated nutrient management, soil microbes, fungi, bacteria, actinomycetes, nitrogen and phosphorus

Introduction

Soil microorganisms play a crucial role in maintaining soil fertility by regulating organic matter decomposition, nutrient mineralization, and nutrient availability to plants. The size and activity of soil microbial populations are highly sensitive to changes in nutrient management practices and therefore serve as important indicators of soil biological health. Among soil microorganisms, fungi, bacteria, and actinomycetes contribute significantly to carbon and nutrient cycling processes.

Excessive reliance on chemical fertilizers often leads to deterioration of soil biological properties, whereas integrated nutrient management involving organic residues, bio-fertilizers, and inorganic fertilizers improves microbial activity and diversity. Nitrogen and phosphorus are major nutrients influencing both plant growth and microbial metabolism. Organic amendments provide readily available carbon sources that stimulate microbial proliferation, while balanced phosphorus nutrition supports microbial energy transfer and cellular functions.

Previous studies have reported increased microbial populations under integrated nutrient management systems compared to sole fertilizer application (Masto *et al.*, 2006; Mandal *et al.*, 2007) [4, 3]. However, information on the combined influence of integrated nitrogen and phosphorus management practices on soil microbial populations at different crop growth

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stages is limited. Hence, the present investigation was undertaken to study the effect of nitrogen and phosphorus management practices on soil fungal, bacterial, and actinomycetes populations.

Materials and Methods

A field experiment was conducted during the agricultural years 2022-23 and 2023-24 at the experimental farm under irrigated conditions. The experiment was laid out in a factorial randomized block design with six nitrogen management options and three phosphorus management options, replicated three times.

Soil samples were collected from the rhizosphere at 30 DAT, 60 DAT, and at harvest. Fungal, bacterial, and actinomycetes populations were enumerated using the serial dilution and plate count technique as described by Waksman and Fred (1922) [7] and Parkinson *et al.* (1971) [6]. The results were expressed as colony forming units (CFU) per gram of soil. Data were statistically analyzed using analysis

of variance (ANOVA) as outlined by Gomez and Gomez (1984) [2], and year-wise data were pooled for interpretation.

Results and Discussion

Fungal Population: Fungal population data (Table 1) indicated significant differences due to nitrogen and phosphorus management practices at all growth stages. Pooled data revealed that nitrogen management treatment T₅ recorded the highest fungal population at 30 DAT (24.22), 60 DAT (33.71), and at harvest (26.49). The increase in fungal population under integrated nutrient management may be attributed to enhanced organic matter availability and improved soil micro-environment. Similar findings were reported by Mandal *et al.* (2007) [3].

Among phosphorus management options, application of 100% RDP as basal recorded significantly higher fungal populations at all stages. Interaction effects were non-significant, indicating independent effects of nitrogen and phosphorus treatments.

Table 1: Influence of Nitrogen and Phosphorus Management Practices on Fungi activity in soil

Table: Fungi activity in soil ()									
Treatments	30 DAT			60 DAT			At Harvest		
Nitrogen Management Option (T)									
	2022-23	2023-24	pooled data	2022-23	2023-24	pooled data	2022-23	2023-24	pooled data
T ₁	18.75	17.55	18.15	28.08	28.11	28.09	21.25	19.40	20.32
T ₂	20.62	19.18	19.90	30.01	29.50	29.75	23.07	20.95	22.01
T ₃	21.18	20.01	20.59	30.28	29.75	30.02	23.26	21.28	22.27
T ₄	21.48	20.44	20.96	30.74	30.10	30.42	23.86	21.91	22.89
T ₅	24.83	23.62	24.22	34.30	33.13	33.71	27.57	25.42	26.49
T ₆	23.20	22.02	22.61	32.49	31.46	31.98	25.75	23.74	24.75
SE(m)±	0.556	0.506	0.547	0.586	0.430	0.536	0.565	0.508	0.492
CD	1.598	1.454	1.572	1.686	1.237	1.540	1.623	1.459	1.415
Phosphorus Management Options (P)									
100%RDP(Basal)	23.13	21.84	22.49	33.07	32.38	32.72	25.75	23.60	24.67
75%RDP(Basal) + PSB@ 2kg/ac	20.58	19.44	20.01	29.41	28.81	29.11	22.91	21.00	21.95
50%RDP(PT) + 25%RDP(Basal)	21.32	20.13	20.72	30.47	29.84	30.15	23.73	21.75	22.74
SE(m) ±	0.393	0.358	0.387	0.415	0.304	0.379	0.399	0.359	0.348
CD	1.130	1.028	1.111	1.192	0.875	1.089	1.147	1.031	1.000
Interaction (TxP)									
SE(m) ±	0.963	0.876	0.947	1.016	0.746	0.928	0.978	0.879	0.853
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS
T ₁ -Burning +100% RDN (33.3% DT, 33.3% at MT and 33.3% at PIS), T ₂ - Incorporation + PJTAU Consortium+100% RDN (33.3% DT, 33.3% at MT and 33.3% at PIS), T ₃ - Incorporation + PUSA Decomposer+100% RDN (33.3% DT, 33.3% at MT and 33.3% at PIS),T ₄ - Incorporation + PJTAU Consortium+100% RDN (20% DT, 20% at 15 DAT, 30% at MT and 30% at PIS(60DAT)), T ₅ -Incorporation + PJTAU Consortium + Incorporation of Gliricidia leaves(15% RDN) +100% RDN (20% DT, 20% at 15 DAT, 30% at MT and 30% at (60DAT)) T ₆ - Incorporation +115% RDN (20% DT, 30% at 15 DAT, 35% at MT and 30% at PIS).									

Bacterial Population

Bacterial population showed trends similar to fungal population (Table 2). Treatment T₅ recorded significantly higher pooled bacterial population at 30 DAT (14.39), 60 DAT (19.58), and at harvest (15.72). Increased bacterial population under integrated treatments may be due to higher

availability of labile carbon and nutrients. These results are in agreement with Dick *et al.* (1996) [1] and Masto *et al.* (2006) [4].

Phosphorus management with 100% RDP (basal) significantly enhanced bacterial population compared to other treatments. Interaction effects were non-significant.

Table 2: Influence of Nitrogen and Phosphorus Management Practices on Bacteria population

Treatments	30DAT			60DAT			Harvest		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Nitrogen Management Option (T)									
T ₁	11.31	7.51	9.41	14.55	12.60	13.57	12.92	10.16	11.54
T ₂	13.28	8.65	10.96	16.86	13.93	15.39	14.67	11.63	13.15
T ₃	13.69	9.07	11.38	17.14	14.56	15.85	14.85	11.72	13.28
T ₄	14.10	9.31	11.70	18.09	14.99	16.54	15.15	11.83	13.49
T ₅	17.51	11.28	14.39	21.96	17.21	19.58	18.07	13.36	15.72
T ₆	16.34	10.61	13.47	20.79	16.31	18.55	17.50	12.72	15.11
SE(m) ± (A)	0.48	0.25	0.38	0.58	0.37	0.46	0.47	0.26	0.32
CD (P=0.05)	1.37	0.71	1.10	1.67	1.06	1.33	1.36	0.74	0.92
Phosphorus Management Options (P)									

100%RDP(Basal)	15.30	9.87	12.58	19.31	15.79	17.55	16.43	12.63	14.53
75%RDP(Basal) + PSB@ 2kg/ac	13.66	9.04	11.35	17.38	14.25	15.81	14.81	11.34	13.07
50%RDP(PT)+25%RDP(Basal)	14.15	9.30	11.73	18.00	14.76	16.38	15.34	11.74	13.54
SE(m)± (B)	0.34	0.18	0.27	0.41	0.26	0.33	0.33	0.18	0.23
CD (P=0.05)	0.97	0.50	0.78	1.18	0.75	0.94	0.96	0.52	0.65
Interaction (TxP)									
SE(m)±	0.82	0.43	0.66	1.01	0.64	0.80	0.82	0.45	0.56
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Actinomycetes Population

Actinomycetes population (Table 3) was significantly influenced by nutrient management practices. Treatment T5 recorded the highest pooled actinomycetes population at all stages, followed by T₆. Actinomycetes populations

increased from 30 DAT to 60 DAT and declined at harvest, reflecting their preference for stable organic substrates. These findings corroborate earlier reports by Nannipieri *et al.* (2003) ^[5].

Table 3: Influence of Nitrogen and Phosphorus Management Practices on Actinomycetes activity in soil

Table: Actinomycetes activity in soil									
Treatments	30 DAT			60 DAT			At Harvest		
Nitrogen Management Option									
	2022-23	2023-24	pooled data	2022-23	2023-24	pooled data	2022-23	2023-24	pooled data
T ₁	32.73	38.10	35.42	39.29	49.18	44.24	46.89	41.53	44.21
T ₂	35.55	41.02	38.28	43.12	53.77	48.45	49.60	44.17	46.88
T ₃	36.33	41.71	39.02	44.17	54.99	49.58	50.22	45.29	47.76
T ₄	37.16	42.16	39.66	45.08	55.56	50.32	51.05	45.69	48.37
T ₅	40.49	45.59	43.04	49.54	60.90	55.22	54.49	48.83	51.66
T ₆	39.95	44.95	42.45	48.75	60.19	54.47	53.65	48.39	51.02
SE(m) ±	0.915	0.908	0.702	1.065	1.361	1.274	0.623	0.858	0.864
CD	2.629	2.609	2.018	3.061	3.913	3.662	1.789	2.466	2.482
Phosphorus Management Options									
100%RDP(Basal)	39.52	45.13	42.33	48.01	59.51	53.76	54.41	48.76	51.59
75%RDP(Basal) + PSB@ 2kg/ac	35.16	40.04	37.60	42.72	52.94	47.83	48.40	43.26	45.83
50%RDP(PT) + 25%RDP(Basal)	36.42	41.59	39.01	44.25	54.84	49.55	50.14	44.93	47.53
SE(m) ±	0.647	0.642	0.496	0.753	0.963	0.901	0.440	0.607	0.611
CD	1.859	1.845	1.427	2.165	2.767	2.589	1.265	1.744	1.755
Interaction (TxP)									
SE(m) ±	1.584	1.572	1.216	1.845	2.358	2.207	1.078	1.486	1.496
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS
T ₁ -Burning +100% RDN (33.3% DT, 33.3% at MT and 33.3% at PIS), T ₂ - Incorporation + PJTAU Consortium+100% RDN (33.3% DT, 33.3% at MT and 33.3% at PIS), T ₃ - Incorporation + PUSA Decomposer+100% RDN (33.3% DT, 33.3% at MT and 33.3% at PIS), T ₄ - Incorporation + PJTAU Consortium+100% RDN (20% DT, 20% at 15 DAT, 30% at MT and 30% at PIS(60DAT)), T ₅ -Incorporation + PJTAU Consortium + Incorporation of Gliricidia leaves (15% RDN) +100% RDN (20% DT, 20% at 15 DAT, 30% at MT and 30% at (60DAT)) T ₆ - Incorporation +115% RDN (20% DT, 30% at 15 DAT, 35% at MT and 30% at PIS).									

Conclusions: The study demonstrated that integrated nitrogen and phosphorus management practices significantly enhanced soil fungal, bacterial, and actinomycetes populations at all crop growth stages. Treatments involving combined application of organic residues, bio-consortium, and recommended nitrogen dose proved superior to sole chemical fertilizer application. Phosphorus application at 100% recommended dose as basal consistently supported higher microbial populations. The non-significant interaction effects suggest independent contributions of nitrogen and phosphorus. Integrated nutrient management can be recommended as a sustainable strategy for improving soil microbial health and long-term soil fertility.

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