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RESPONSES OF BENEFICIAL SOIL MICROBIAL POPULATION TO INTEGRATED NUTRIENT MANAGEMENT IN TRANSPLANTED SUMMER RICE (*Oryza sativa* L.)

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ABSTRACT

An investigation was carried out at the Agricultural Experimental Farm of University of Calcutta, Baruipur, West Bengal during *boro* season of 2022-2024 (December-April) to evaluate the effect of integrated nutrient management on soil beneficial microflora in transplanted summer rice viz., fungi, actinomycetes and total bacteria. The experiment was laid out in Randomized Block Design replicated thrice with ten treatments, T₁-50% RDF N P₂O₅ K₂O + FYM @ 5 t ha⁻¹, T₂-75% RDF N P₂O₅ K₂O + FYM @ 5 t ha⁻¹, T₃-50% RDF N P₂O₅ K₂O + FYM @ 7 t ha⁻¹, T₄-75% RDF N P₂O₅ K₂O + FYM @ 7 t ha⁻¹, T₅-50% RDF N P₂O₅ K₂O + Vermicompost @ 2 t ha⁻¹, T₆-75% RDF N P₂O₅ K₂O + Vermicompost @ 2 t ha⁻¹, T₇-50% RDF N P₂O₅ K₂O + Vermicompost 3 t ha⁻¹, T₈-75% RDF N P₂O₅ K₂O + Vermicompost @ 3 t ha⁻¹, T₉-100% RDF N P₂O₅ K₂O (120:60:60) kg ha⁻¹, T₁₀-Control. The soil condition was medium fertile, clay loam in texture with slightly acidic reaction having pH of 6.0. The analysis of soil microflora was carried out with respective media preparation i.e., Martin's Rose Bengal Streptomycin Agar Medium for fungi, Jensen's Agar Medium for actinomycetes and Thornton's agar medium for total bacteria and recorded in cfu g⁻¹ soil. The soil sampling was done at initial stage (before application of treatments) and after harvest of rice crop. The treatment T₈-75% RDF N P₂O₅ K₂O + Vermicompost @ 3 t ha⁻¹ recorded highest colony count of fungi, actinomycetes and total bacteria followed by T₆-75% RDF N P₂O₅ K₂O + Vermicompost @ 2 t ha⁻¹ whereas, on the other hand the treatment T₁₀-Control indicated lowest colony compared to other treated plots. The availability of optimum amount of organic nutrients in soil provided healthy and conducive environment for soil microbial population in treatment with INM to multiply and improve crop productivity.

Key words : Boro, FYM, INM, Microflora, Vermicompost.

Introduction

Rice is known as "Global Grain" due to its cultivation in around 117 nations and considered as a staple food for over 50% of population worldwide. Recently, India became largest producer of rice with 150.18 million metric tonnes surpassing China (IBEF, 2026). It is one of the instant energies giving food with less content of protein 6-7% and carbs percent ranging 72-75% (Bhosale and Jondhale, 2019). Rice is cultivated in each and every states of India but Uttar Pradesh followed by Telangana and West Bengal are major rice producing hubs in the country

(PIB, 2026). To maintain the production and productivity of rice nutrient management plays a very crucial role in the background. Mostly, farmers rely on inorganic nutrients as they supply the crops with readily available nutrient in mineralized form but too much dependency on inorganic sources causes heavy impact on the soil and its micro-environment. Both organic manures and inorganic fertilizers must be applied to achieve required yields and the soil for cropping will also be enriched with optimum amount of necessary nutrients resulting in better and maintained soil health. The wetland paddy with high grain

yield quality tend to uptake a good amount of macro and micro soil nutrients in order to produce better yield and if deficiency of any nutrient occurs then it will result in low yield (Pawar *et al.*, 2017; Shankar *et al.*, 2018). Use of major organic sources like FYM, vermicompost, poultry manure etc are being given value today for improving soil health. Different organic and inorganic sources of nutrients improve the soil physical, chemical and biological properties of soil and also improves porosity and enzymatic activity. Various studies have been carried out which concluded that INM practices lessen denitrification and leaching loss, reduces mineralization and improves fertilizer use efficiency thus restoring soil health and productivity attaining sustainability (Kumar *et al.*, 2013). Soil comprises of different microbes present in the rhizospheric zone. They mostly perform certain chemical reaction on the soil carbon available and the organic sources applied to crop as a nutrient that undergoes mineralization process with the help of soil microbes and ultimately the organic carbon obtained serves as an energy source for their multiplication that enables in production of certain enzymes and hormones suitable for crop growth and development (Kikuchi *et al.*, 2007). Keeping this point in view, an experiment was performed for two consecutive years in the Agricultural Experimental Farm of University of Calcutta from 2022-2024 to evaluate the effect of different INM practices in transplanted rice on soil microbial population during *boro* season.

Materials and Methods

A field experiment conducted during *boro* season of 2022-2024 at the Agricultural Experimental Farm of University of Calcutta located at Baruipur, West Bengal (22° 21' 56" N latitude and 88° 26' 14" E longitude) and 9 m altitude. The topography of the experimental plot was low land, more or less uniform with a drainage condition. The soil was medium fertile, clay loam in texture with slightly acidic reaction representative of the new Gangetic alluvial soil of West Bengal. The initial available soil N, P₂O₅ and K₂O recorded was 175.95 kg ha⁻¹, 31.83 kg ha⁻¹ and 261.29 kg ha⁻¹. The experiment was set in randomized block design with ten integrated nutrient management treatments replicated thrice *viz.*, T₁-50% RDF N P₂O₅ K₂O + FYM @ 5 t ha⁻¹, T₂-75% RDF N P₂O₅ K₂O + FYM @ 5 t ha⁻¹, T₃-50% RDF N P₂O₅ K₂O + FYM @ 7 t ha⁻¹, T₄-75% RDF N P₂O₅ K₂O + FYM @ 7 t ha⁻¹, T₅-50% RDF N P₂O₅ K₂O + Vermicompost @ 2 t ha⁻¹, T₆-75% RDF N P₂O₅ K₂O + Vermicompost @ 2 t ha⁻¹, T₇-50% RDF N P₂O₅ K₂O + Vermicompost 3 t ha⁻¹, T₈-75% RDF N P₂O₅ K₂O + Vermicompost @ 3 t ha⁻¹, T₉-100% RDF N P₂O₅ K₂O (120:60:60) kg ha⁻¹, T₁₀-Control.

The rice variety MTU-1153 (Chandra) was transplanted in the main field during the second week of January in both the experimental years maintaining a spacing of 20cm × 20cm. The source of chemical fertilizers applied was urea, SSP and MOP respectively broadcasted with the required quantity of FYM and vermicompost as per the treatments respectively. The urea was applied in 3 split doses *viz.*, 1/4th as basal before transplanting and then top dressing twice (1/2 and 1/4th) was done, while the rest SSP and MOP was broadcasted fully before transplanting along with FYM and vermicompost, respectively.

The soil samples collection from the rhizosphere was done at various intervals *viz.*, before sowing and at harvest. The count of the microbial population was performed by using their respective agar medium following serial dilution technique and pour plate method. The plates were incubated at 30°C in an incubator. The data on colony counts were done at 15 days of incubation. The fungi count was made using Martin's rose bengal streptomycin agar medium (Table 1). Sterile streptomycin was added just prior to plating to the medium. Jensen's agar medium (Table 2) was used for actinomycetes to take the colony of total actinomycetes. A pH of 6.5-6.6

Table 1 : Martin's rose bengal streptomycin agar medium (for fungi).

Potassium dihydrogen phosphate	KH ₂ PO ₄	1.0 g
Magnesium sulphate	MgSO ₄ ·7H ₂ O	0.5 g
Dextrose	C ₆ H ₁₂ O ₆	10.0 g
Peptone		5.0 g
Agar		10.0 g
Rose Bengal (1:300 aq)		10.0 ml
Distilled water		1000 ml
Streptomycin		30 µg ml ⁻²

Table 2 : Jensen's agar medium (for actinomycetes).

Dextrose	C ₆ H ₁₂ O ₆	2.0 g
Casein [dissolved in 10 ml of 0.1 (N) NaOH]		5.0 g
Dipotassium hydrogen phosphate	K ₂ HPO ₄	0.2 g
Magnesium sulphate	MgSO ₄ ·7H ₂ O	0.2 g
Yeast extract		0.5g
Potassium chloride	KCl	0.2g
Ferrous sulphate	FeSO ₄ ·2H ₂ O	
Trace Agar		15.0 g
Distilled water		1000 ml

Table 3 : Thornton's agar medium (for total bacteria).

Dipotassium hydrogen phosphate	K_2HPO_4	1.0 g
Calcium chloride	$CaCl_2$	0.1 g
Magnesium sulphate	$MgSO_4 \cdot 7H_2O$	0.2 g
Sodium chloride	$NaCl$	0.1 g
Ferric chloride	$FeCl_3 \cdot 6H_2O$	0.002g
Potassium nitrate	KNO_3	0.5g
Asparagine	$C_4H_8N_2O_4$	0.5g
Mannitol	$C_6H_8(OH)_6$	1.0g
Agar		15.0 g
Distilled water		1000ml

was maintained for the medium and sterilization was done at 15 lbs pressure for 20 minutes. The total bacteria count was done using Thornton's agar medium (Table 3) with the pH of the medium at 7.4 and sterilized for 20 minutes at 15 lbs pressure. The count was recorded as cfu g⁻¹ soil.

Statistical analysis of the collected data was evaluated utilizing the methods as suggested by Gomez and Gomez (1984).

Results and Discussion

Effect of INM practices on fungi population

Table 4 for beneficial soil fungi recorded as cfu g⁻¹ soil revealed that during the initial stages in both the years of the experiment showed no significant variation. But at harvest in both the years indicated that, T₈ (75% RDF N-P₂O₅-K₂O+Vermicompost @ 3 t ha⁻¹) acquired the highest fungi colony while T₁₀ (Control) recorded the lowest colony. The treatment T₈ (75% RDF N-P₂O₅-K₂O+Vermicompost @ 3 t ha⁻¹)-(55.67) × 10⁴ was statistically at par with T₆ (75% RDF N-P₂O₅-K₂O+Vermicompost @ 2 t ha⁻¹)-(53.33) × 10⁴ followed by T₇ (50% RDF N-P₂O₅-K₂O+Vermicompost @ 3 t ha⁻¹)-(51.00) × 10⁴ and T₄ (75% RDF N-P₂O₅-K₂O+FYM @ 7 t ha⁻¹)-(48.00) × 10⁴ but differs significantly with T₅ (50% RDF N-P₂O₅-K₂O+Vermicompost @ 2 t ha⁻¹)-(45.33) × 10⁴ followed by other treatments respectively in the first year. In the second year, T₈ (75% RDF N-P₂O₅-K₂O+Vermicompost @ 3 t ha⁻¹)-(59.33) × 10⁴ was statistically at par with T₆ (75% RDF N-P₂O₅-K₂O + Vermicompost @ 2 t ha⁻¹)-(56.67) × 10⁴ but differs significantly with T₇ (50% RDF N-P₂O₅-K₂O + Vermicompost @ 3 t ha⁻¹) - (49.67) × 10⁴ followed by other treatments, respectively. The T₁₀ (Control)-(18.67 and 16.00) × 10⁴ showed the lowest count of fungal colony, respectively. The increase in fungal population might be due to addition of organics as they require organic source

of carbon as nutrition as well as oxidation of organic substances provides energy all of which made favourable condition for fungi to thrive and colonize the rhizosphere region of soil. Hence, increasing their population in soil. Symbiotrophic fungi, including AMF, makes mutual relationships with plant roots that improves nutrient uptake, particularly phosphorus and other micronutrients. Similar findings were observed by (Ingle *et al.*, 2014; Khaliq *et al.*, 2022).

Effect of INM practices on actinomycetes population

The actinomycetes population from the Table 4 recorded as cfu g⁻¹ soil showed no variation among the treatments in the initial stage as the colony count was more or less similar in all the plots but varied significantly after harvest. The data at harvest indicated the treatment T₈ (75% RDF N-P₂O₅-K₂O +Vermicompost @ 3 t ha⁻¹) with the highest actinomycetes colony and T₁₀ (Control) was found with the lowest count during both the years. during the first year, T₈ (75% RDF N-P₂O₅-K₂O + Vermicompost @ 3 t ha⁻¹)-(68.67) × 10⁵ was statistically at par with T₆ (75% RDF N-P₂O₅-K₂O+Vermicompost @ 2 t ha⁻¹)-(66.33) × 10⁵, T₇ (50% RDF N-P₂O₅-K₂O + Vermicompost @ 3t ha⁻¹)-(65.00) × 10⁵, but differs significantly with T₂ (75% RDF N-P₂O₅-K₂O + FYM @ 5 t ha⁻¹)-(57.00) × 10⁵ followed by other treatments in the first year. In the second year, similarly T₈ (75% RDF N-P₂O₅-K₂O+Vermicompost @ 3 t ha⁻¹)-(72.33) × 10⁵ was statistically at par with T₆ (75% RDF N-P₂O₅-K₂O+Vermicompost @ 2 t ha⁻¹) - (69.67) × 10⁵, T₇ (50% RDF N-P₂O₅-K₂O+Vermicompost @ 3 t ha⁻¹)-(63.67) × 10⁵ but differs significantly with T₄ (75% RDF N-P₂O₅-K₂O+FYM @ 7 t ha⁻¹)-(60.67) × 10⁵ and followed by other treatments, respectively. The T₁₀ (Control) showed the lowest colony of (26.67 and 23.00) × 10⁵, respectively. The organic matter form vermicompost helped in improving the soil physio-chemical condition also the good amount of organic matter concentration supplied to soil through vermicompost has influenced better growth of actinomycetes colony in soil. The organic compounds added might have created favourable environment in the rhizosphere of the soil through secretion of various metabolites upon decomposition resulted in multiplication of soil actinomycetes. Such findings were observed by (Niohi, 1975; Somasundaram *et al.*, 2003; Nagaraju *et al.*, 2022).

Effect of INM practices on total bacteria population

Table 4 for total bacterial population recorded as cfu g⁻¹ soil at initial stage had no significant difference in both the years. The counts were almost close to each other at all days of observations taken. The data at harvest recorded as cfu g⁻¹ soil showed significant variations

Table 4 : Effect of Integrated nutrient management on the population of fungi ($\times 10^4$), actinomycetes ($\times 10^5$) and total bacteria ($\times 10^6$) in cfu g^{-1} soil.

Treatments	Fungi ($\times 10^4$) cfu g^{-1} soil				Actinomycetes ($\times 10^5$) cfu g^{-1} soil				Total Bacteria ($\times 10^6$) cfu g^{-1} soil			
	Initial		At Harvest		Initial		At Harvest		Initial		At Harvest	
	2022-2023	2023-2024	2022-2023	2023-2024	2022-2023	2023-2024	2022-2023	2023-2024	2022-2023	2023-2024	2022-2023	2023-2024
T ₁ -	3.76(13.67)	3.67(13.00)	6.09(36.67)	5.81(33.33)	4.64(21.00)	4.41(19.00)	7.27(52.33)	7.10(48.00)	4.95(24.33)	5.05(25.00)	8.15(66.00)	7.95(62.67)
T ₂ -	3.39(11.00)	3.58(13.67)	6.59(43.00)	6.42(40.67)	4.42(19.00)	4.60(20.67)	7.57(57.00)	7.49(55.67)	5.01(24.67)	4.94(24.00)	8.59(73.33)	8.44(71.00)
T ₃ -	3.81(13.33)	3.63(12.67)	6.23(38.33)	6.28(39.00)	4.53(19.67)	4.34(18.33)	7.15(49.67)	7.33(53.33)	5.15(26.00)	4.95(24.00)	8.27(68.00)	8.36(69.33)
T ₄ -	3.62(12.67)	3.67(13.00)	6.96(48.00)	6.84(46.33)	4.33(18.33)	4.53(20.00)	7.89(62.00)	7.82(60.67)	5.08(25.33)	5.05(25.00)	8.74(76.00)	8.69(75.33)
T ₅ -	3.81(14.33)	3.63(12.67)	6.75(45.33)	6.67(44.00)	4.71(21.67)	4.49(19.67)	7.80(60.67)	7.67(58.33)	5.18(26.33)	5.05(25.00)	8.71(75.33)	8.57(73.00)
T ₆ -	3.63(12.67)	3.67(13.00)	7.34(53.33)	7.56(56.67)	4.41(19.00)	4.56(20.33)	8.17(66.33)	8.37(69.67)	4.98(24.33)	5.15(26.00)	9.06(81.67)	9.31(86.33)
T ₇ -	3.53(12.00)	3.89(14.00)	7.22(51.00)	7.07(49.67)	4.56(20.33)	4.60(20.67)	8.09(65.00)	8.01(63.67)	4.92(23.67)	5.15(25.67)	8.92(79.33)	8.80(77.00)
T ₈ -	3.72(13.33)	3.92(15.00)	7.49(55.67)	7.73(59.33)	4.49(19.67)	4.41(19.00)	8.31(68.67)	8.51(72.33)	5.14(26.00)	4.84(23.00)	9.26(85.33)	9.49(89.67)
T ₉ -	3.76(13.67)	3.67(13.33)	5.66(31.67)	5.24(27.33)	4.30(18.00)	4.53(20.00)	6.80(46.00)	6.49(41.67)	5.08(25.33)	4.85(23.00)	7.79(60.33)	7.56(56.67)
T ₁₀ -	3.67(13.00)	3.89(14.33)	4.35(18.67)	4.02(16.00)	4.49(19.67)	4.64(21.00)	5.21(26.67)	4.85(23.00)	5.02(24.67)	5.15(26.00)	5.97(35.33)	5.72(32.67)
SEm($\pm$)	NS	NS	0.20	0.23	NS	NS	0.25	0.22	NS	NS	0.26	0.28
CD at 5%	NS	NS	0.59	0.69	NS	NS	0.74	0.65	NS	NS	0.76	0.82

Values in parentheses are original. Data showed are $\sqrt{x+0.5}$ transformed.

Notations used: T₁-50% RDF N-P₂O₅-K₂O + FYM @ 5 t ha⁻¹, T₂-75% RDF N-P₂O₅-K₂O + FYM @ 5 t ha⁻¹, T₃-50% RDF N-P₂O₅-K₂O + FYM @ 7 t ha⁻¹, T₄-75% RDF N-P₂O₅-K₂O + FYM @ 7 t ha⁻¹, T₅-50% RDF N-P₂O₅-K₂O + Vermicompost @ 2 t ha⁻¹, T₆-75% RDF N-P₂O₅-K₂O + Vermicompost @ 2 t ha⁻¹, T₇-50% RDF N-P₂O₅-K₂O + Vermicompost @ 3 t ha⁻¹, T₈-75% RDF N-P₂O₅-K₂O + Vermicompost @ 3 t ha⁻¹, T₉-100% RDF N-P₂O₅-K₂O (120:60:60) kg ha⁻¹, T₁₀-Control.

among the treatments where T₈(75% RDF N-P₂O₅-K₂O+Vermicompost @ 3 t ha⁻¹) registered the highest colony followed by T₆(75% RDF N-P₂O₅-K₂O + Vermicompost @ 2 t ha⁻¹) and T₁₀(Control) recorded the lowest count. T₈(75% RDF N-P₂O₅-K₂O + Vermicompost @ 3 t ha⁻¹)-(85.33) $\times 10^6$ was statistically at par with T₆(75% RDF N-P₂O₅-K₂O + Vermicompost @ 2 t ha⁻¹)-(81.67) $\times 10^6$ cfu followed by T₇(50% RDF N-P₂O₅-K₂O+Vermicompost @ 3 t ha⁻¹)-(79.33) $\times 10^6$ and other treatments while significant difference was observed with T₃(50% RDF N-P₂O₅-K₂O + FYM @ 7 t ha⁻¹)-(68.00) $\times 10^6$ followed by other treatments respectively in the first year. The second year showed that T₈(75% RDF N-P₂O₅-K₂O + Vermicompost @ 3 t ha⁻¹)-(89.67) $\times 10^6$ was statistically at par with T₆(75% RDF N-P₂O₅-K₂O + Vermicompost @ 2 t ha⁻¹)-(86.33) $\times 10^6$ followed by T₇(50% RDF N-P₂O₅-K₂O + Vermicompost @ 3 t ha⁻¹)-(77.00) $\times 10^6$, but had significant difference with T₄(75% RDF N-P₂O₅-K₂O + FYM @ 7 t ha⁻¹)-(75.33) $\times 10^6$ followed by other treatments, respectively. The T₁₀(Control) revealed (35.33 and 32.67) $\times 10^6$ colony count respectively. The increase in total bacteria may be linked with the increase in fungi population as the organic acids released by fungi changes the soil chemical structure which supports and enhances the bacterial population in soil. The organic fertilizers applied boosted the plant growth and stimulated root carbon flow, which acted as a source of nutrients for the bacterial population to multiply rapidly and flourish in the paddy soil increasing the richness and diversity of bacterial colony, which might be due to addition of organics in soil and enhanced soil microbial biomass. Similar findings were reported by Higa (1995), Biswas *et al.* (2018), He *et al.* (2008) and Islam *et al.* (2011).

Conclusion

The vermicompost applied in T_8 (75% RDF $N-P_2O_5-K_2O$ +Vermicompost @ 3 t ha⁻¹) served as a substrate for beneficial microflora, and the phytohormones released helped to improve soil organic carbon, which is a source of nutrient for biological activity. This results in improved water-air relationships in the soil, higher root exudate production by the crop due to improved root biomass as there was availability of good quantity of nutrients from organic sources and better nutrient cycling by the vermicasts present in the vermicompost, which in turn increased the colony of microbes. Also, T_4 (75% RDF $N-P_2O_5-K_2O$ +FYM @ 7 t ha⁻¹) though ranked behind T_8 (75% RDF $N-P_2O_5-K_2O$ +Vermicompost @ 3 t ha⁻¹) provided suitable nutrition in carbon form to soil microbes so that they can thrive and colonize in soil that helped in recycling of nutrients for crop uptake and improved the soil health as the soil microbial produced certain enzymes essential for maintaining soil physio-chemical condition. The treatment T_9 (100% RDF $N-P_2O_5-K_2O$) indicated lowest soil microbial colony compared to other integrated treatments due to low availability or non-addition of organic carbon in the soil that would support soil microbes to flourish more, but the root exudates produced from the crop provided some source of energy to the microbes to increase in colony that was not sufficient as compared to other treatments. In the T_{10} (Control) plots as there was non- addition of external nutrient input, microbial colony at post-harvest stage of the crop was indicated as the lowest compared to treated plots.

References

- Bhosale, S.S. and Jondhale D.G. (2019). Long term effect of INM on yield and nutrient uptake of Rice-Rice cropping system in North Konkan. *Int. J. Trend Scientific Res. Devel.*, **4**(1), 513-518.
- Biswas, S., Kundu D.K., Mazumdar S.P., Saha A.R., Majumdar B., Ghorai A.K., Ghosh D., Yadav A.N. and Saxena A.K. (2018). Study on the activity and diversity of bacteria in a New Gangetic alluvial soil (Eutrocept) under rice-wheat jute cropping system. *J. Environ. Biol.*, **39**, 379-386.
- He, J.Z., Zheng Y., Chen C.R., He Y.Q. and Zhang L.M. (2008). Microbial composition and diversity of an upland red soil under long-term fertilization treatments as revealed by culture-dependent and culture-independent approaches. *J. Soils Sediments*, **8**, 349-358.
- Higa, T. (1995). Effective microorganisms: their role kyusei natural farming and sustainable edition: Proceedings of the third international conference on kyusei natural farming U.S. Department of Agriculture, Washington, D.C., U.S.A.
- IBEF (2026). <https://www.ibef.org>.
- Ingle, S.S., Jadhao S.D., Kharche V.K., Sonune B.A. and Mali D.V. (2014). Soil biological properties as influenced by long-term manuring and fertilization under sorghum (*Sorghum bicolor*)-wheat (*Triticum aestivum* L.) sequence in Vertisols. *Indian J. Agricult. Sci.*, **84**, 452-457.
- Islam, M.R., Chauhan P.S., Kim Y., Kim M. and Sa T. (2011). Community level functional diversity and enzyme activities in paddy soils under different long-term fertilizer management practices. *Biol. Fert. Soils*, **47**, 599-604.
- Khaliq, A., Perveen S., Alamer K.H., Zia UlHaq M., Rafique Z., Alsudays I.M., Althobaiti A.T., Saleh M.A., Hussain S. and Attia H. (2022). Arbuscular Mycorrhizal Fungi Symbiosis to enhance Plant-Soil Interaction. *Sustainability*, **14**(13), 7840.
- Kikuchi, H., Watanabe T., Jia Z., Kimura M. and Asakawa S. (2007). Molecular analyses reveal stability of bacterial communities in bulk soil of a Japanese paddy field: Estimation by denaturing gradient gel electrophoresis of 16 Sr RNA genes amplified from DNA accompanied with RNA. *Soil Sci. Plant Nutr.*, **53**, 448-458.
- Kumar, S., Rana S.S. and Chander N. (2013). Mixed weed flora management by bispyribac-sodium in transplanted rice. *Indian J. Weed Sci.*, **45**(3), 151-155.
- Nagaraju, G.S., Vani P.M., Rani P.P. and Venkateswarlu B. (2022). Influence of integrated use of organic and inorganic sources of nutrients on biological properties of soil in sweet corn. *Biological Forum – An Int. J.*, **14**(3), 1041–1044.
- Niohi, L. (1975). Seasonal variation of microorganisms of in forest soils in relation to vegetation and soil type. *J. Soil Manure*, **46**, 369-373.
- Pawar, S.B., Mahadkar U.V., Jagtap D.N. and Jadhav M.S. (2017). Effect of different planting techniques and inputs on yield attributes and yield of rice (*Oryza sativa* L.) during kharif season. *Farming and Management*, **2**, 16-21.
- PIB (2026). <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2248987&reg=3&lang=2>
- Shankar, T., Malik G.C. and Banerjee M. (2018). Effect of nutrient management on yield attributes and yields in rice-based cropping system. *Int. J. Bio-resource, Environ. Agric. Sci.*, **4**, 704-08.
- Somasundaram, E., Sankaranan N., Meena S., Thiagarajan T.M., Chandaragiri K. and Pannerselvam S. (2003). Response of green gram to varied levels of Panchagavya (Organic nutrition) foliar spray. *Madras Agricult. J.*, **90**, 169–172.