Original Research Article

Impact of organic and inorganic sources of nutrients on root architecture, soil microbial biomass and yield on low land rice ecosystem

ABSTRACT

To study the impact of vermicompost, arbuscular mycorrhizae and FYM application on the rice ecosystem at low land, a field experiment was conducted with rice CO(R) 51 at the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University in Coimbatore during the winter of 2020. The experiment was framed in RBD comprising of 8 treatments viz., RDF STCR approach (T_1), RDF 75 % + FYM @ 12.5 t ha^{-1} (T_2), T_2 + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi (T_3), RDF 75 % + Vermicompost @ 5 t ha^{-1} (T_4), T_4 + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi (T_5), FYM @ 12.5 t ha^{-1} + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi (T_6), Vermicompost @ 5 t ha^{-1}+ Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi (T_7) and Absolute control (T_8) and replicated thrice. The maximum microbial population were registered in the plots that received integrated nutrient application of RDF 75 % STCR approach + Vermicompost 5 t ha^{-1} + seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi. Rice root architecture has changed significantly as a result of mycorrhizal inoculation. Mycorrhizal rice plants have more root volume, length, and spread than plants without mycorrhizae. Nutrient retention and availability influenced the presence of microbial-mediated metabolic activities and nutrient transformations during crop growth. Bacteria, fungus, and actinomycetes became less abundant as the crop reached harvest. The population density of mycorrhizospheres that utilize both organic and inorganic fertilizers is higher. The treatments that received Vermicompost or FYM with VAM and NPK fertilizers obtained the highest yields of rice grain and straw (6740 and 7840 kg ha^{-1}) respectively, and it was clear that the combination of Vermicompost or FYM, VAM and along with NPK fertilizers produced significantly higher yields than their individual applications and absolute control.

***Key words**: Arbuscular mycorrhizae, FYM, Microbial population, Root architecture, Vermicompost*

1. INTRODUCTION

Rice is grown other 193 million hectares worldwide [6] but production and consumption are focused in Asia, where more than 90% of all rice is consumed. From 42.77 million hectares, India produced 117.5 million tonnes in 2019-20 [3], with a 2.9 t ha^{-1} average production [18]. If the country is to remain self-sufficient by 2025, rice yields must be increased by 25 to 30 percent from existing pace. Tamil Nadu produces 7.65 million tonnes of rice on to an area of 1.87 million hectares, accounting for 8% of national rice output [6]. Instead, rice production has lost significant amounts of soil nutrients. Thus, India's future food and nutritional security is dependent on continual increase in soil and crop productivity on a long-term basis through sufficient and balanced input management without depleting natural resources, for which the outcomes of integrated nutrient management would be essential.

Microorganisms influences the soil activities such as mineralization and humification, and they play an important role in nutrient availability [16]. As a result, a better insight into the mechanisms that influence its size, activity, and structure is essential [10]. Soils with higher microbial diversity are indicative of an improved soil plant relationship, hence research on the long-term effects of nutrient absence or presence on the microbial community is important for the regulation of rice ecosystem. Additionally, even though continuous application of fertilizers alter the physical, chemical, and biological properties of soil, they can change the soil microbial population directly or indirectly [1]. To enhance crop yields, organic manures must be used in association with inorganic fertilizers to develop a soil rich in organic matter in the form of readily available nutrients [15]. This study investigated the soil microbial community (bacteria, fungi, and actinomycetes) as influenced by organic, inorganic, and integrated nutrient management (INM) on rice crop yield and AM resulted in an increase in microbial biomass and a change in the root architecture in the rhizosphere region of lowland rice fields.

2. MATERIALS AND METHODS

The experiment was conducted in the Wetland, Central Farm of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. The experimental site is geographically located at 11^{o}00’ N latitude and 76.92’ E longitude at an elevation of 426.72 m above mean sea level. The soil of the experimental site was clay loam with pH of 8.15, EC of 0.63 dSm^{-1} and medium in organic carbon (0.62 %), medium in available nitrogen (268 kg ha^{-1}), high in available phosphorus (22.5 kg ha^{-1}) and high in available potassium (780 kg ha^{-1}) (Table 2).

Table 1. Treatment schedule for field experiment at Western zone of Tamil Nadu

T_1	RDF STCR approach
T_2	RDF 75 % + FYM @ 12.5 t ha^{-1}
T_3	RDF 75 % + FYM @ 12.5 t ha^{-1} + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi
T_4	RDF 75 % + Vermicompost @ 5 t ha^{-1}
T_5	RDF 75 % + Vermicompost @ 5 t ha^{-1} + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi
T_6	FYM @ 12.5 t ha^{-1} + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi
T_7	Vermicompost @ 5 t ha^{-1}+ Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi
T_8	Absolute control

Table 2. Initial soil parameters of the experimental site at Western zone of Tamil Nadu

Sl. No	Particulars	Values
I. Physical Properties		
1.	Sand (%)	42.3
2.	Silt (%)	21.5
3.	Clay (%)	45.9
4.	Textural class	Clay loam
5.	Bulk density (Mg m^{-3})	1.32
6.	Particle density (Mg m^{-3})	2.16
7.	Total porosity (%)	38.8
II. Physico-chemical properties		
8.	pH	8.15
9.	EC (dSm^{-1})	0.63
10.	Organic carbon (%)	0.62
III. Chemical properties		
11.	Available nitrogen (kg ha^{-1})	268
12.	Available phosphorous (kg ha^{-1})	22.5
13.	Available potassium (kg ha^{-1})	780

Fertilizers were recommended based on soil test value. Following three STCR equations developed for rice crop with a targeted yield. FN = 4.39 T – 0.59 SN – 0.80 ON, FP_2O_5 = 2.22 T – 3.63 SP - 0.98 OP, FK_2O = 2.44 T – 0.39 SK – 0.72 OK. The required fertilizer nitrogen (FN), fertilizer phosphorus (FP) and fertilizer potassium (FK) for rice were calculated by substituting the initial soil values of N, P, K and target yield in STCR equation of rice. Average yield of CO 51 is 7 t ha^{-1}. The experiment was laid out in randomized block design having 8 treatments viz, RDF STCR approach (T_1), RDF 75 % + FYM @ 12.5 t ha^{-1} (T_2), RDF 75 % + FYM @ 12.5 t ha^{-1} + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi (T_3), RDF 75 % + Vermicompost @ 5 t ha^{-1} (T_4), RDF 75 % + Vermicompost @ 5 t ha^{-1} + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi (T_5), FYM @ 12.5 t ha^{-1} + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi (T_6), Vermicompost @ 5 t ha^{-1}+ Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi (T_7) and Absolute control (T_8) and replicated thrice (Table 1). Fertilizer was applied in soil as per STCR recommendation of 108, 37.35, and 25 kg ha^{-1} of N, P_2O_5, and K_2O respectively as per recommendation were applied through Urea, DAP and muriate of potash as per treatments. Half dose of nitrogen and full dose of phosphorus and potassium were applied basally. Remaining half N dose was applied in two equal splits once at tillering and rest panicle initiation stages. However, vermicompost was applied three days before transplanting and soil application of vesicular arbuscular mycorrhiza at the time of transplanting (Table 3). Seedlings of 25 days were transplanted, 2 to 3 seedling/hill at 20 x 10 cm spacing in a plot size of 20 sq.m (5 × 4 m) under puddled conditions.

Table 3. Nutrient composition and Quantity of organics used in the experimental site at western zone of Tamil Nadu

Crop	Organics	Nutrient composition (%)			Quantity applied ($t\ ha^{-1}$)
		N	P	K	
Rice	Vermicompost	3.0	1.0	1.5	5
	FYM	0.5	0.2	0.5	12.5
	Vesicular Arbuscular Mycorrhizae	100g/ 10,000 spores			1

Five plots were selected randomly and root length was measured from the base of the root to the tip of the primary root at the time of active tillering, panicle initiation and flowering expressed in cm. For measuring root volume, water was poured into a clean measuring cylinder (nearly three fourth of its volume) and the level of water was noted. To avoid parallel error, reading was taken at the lowest level of the meniscus or curved surface of the liquid. A string was attached to the root and lowered into water and the new level of water was noted. The difference in the above readings was calculated and expressed as root volume in cc $hill^{-1}$. Soil samples were collected and stored at a temperature of 4^{0}C until they were taken for the study. The different types of microorganisms were enumerated using different media favouring the growth of bacteria, fungi and actinomycetes. The standard serial dilution and plating technique of Pramer and Schemidt (1965) [14] was adopted and expressed as Colony Forming Unit (CFU) g^{-1} soil. The data pertaining to microbial population were subjected to log transformation ($\log_{10}$) and analyzed statistically. The data on various characters studied during the course of the investigation were statistically analyzed as suggested by Gomez and Gomez (1984) [7].

3. RESULTS AND DISCUSSION

3.1. Root Parameters (Root Length (cm) and Root Volume (cc $hill^{-1}$))

The impact of Vermicompost, Farm yard manure, and Arbuscular mycorrhiza application on low land rice ecosystems was explored in this study. Rice root architecture has been considerably altered by mycorrhizal inoculation. Mycorrhizal plants have greater root volume, length, and spread than non-mycorrhizal plants. At diverse pheonophases of rice, root length, which shows the temporal trend of growth, was measured. As a result of vermicompost application, root volume and length were also increased (Fig. 1). Canellas *et al*. (2002) [2] reported that the humic substances extracted from earthworm compost were capable of inducing lateral root growth in maize plants by stimulation of the plasma membrane H^+-ATPase activity, thus producing similar effects such as the exogenous application of IAA.

Besides, the positive influences of humic acids on plant growth and productivity, which give the impression to be concentration specific, could be mainly due to hormone like activities of humic acids through their involvement in cell respiration, photosynthesis, oxidative phosphorylation, protein synthesis and various enzymatic reactions [23].

Fig 1. Effect of organic and inorganic nutrients on root length (cm) of rice in western zone of Tamil Nadu

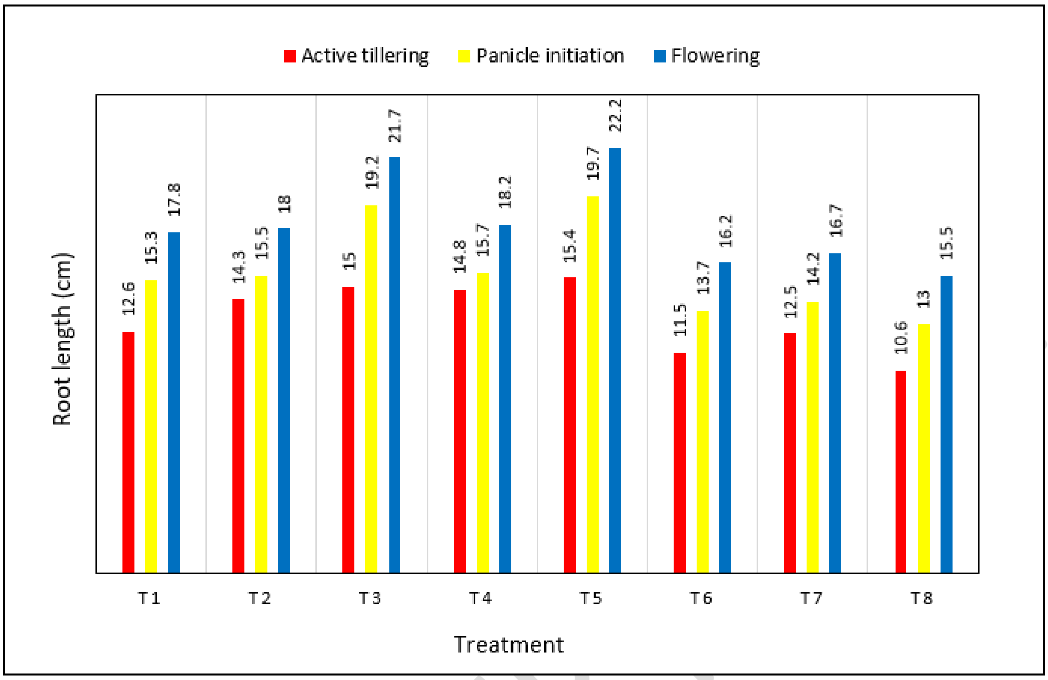
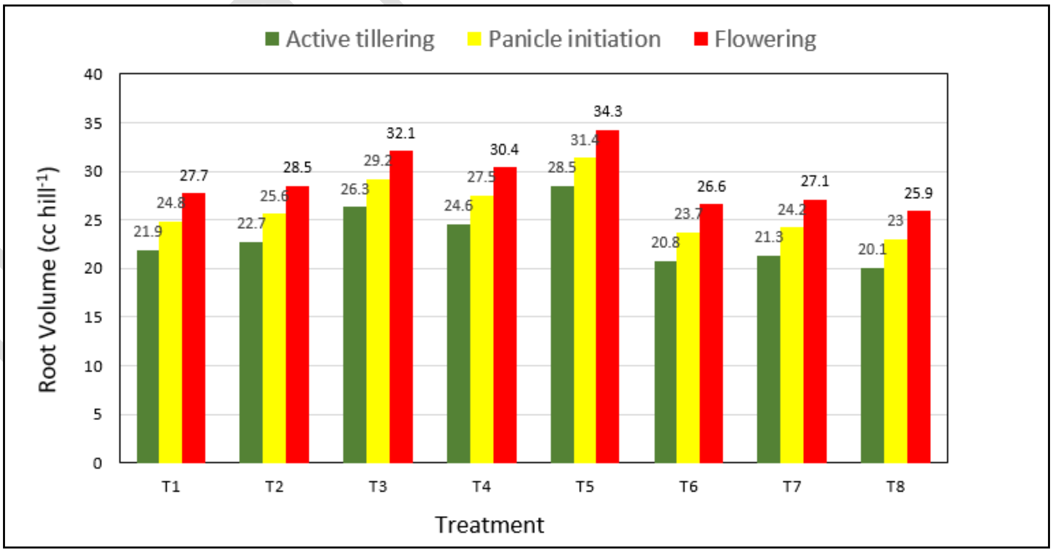


Fig 2. Effect organic and inorganic nutrients on root volume (cc hill^{-1}) of rice in western zone of Tamil Nadu



In the present study, the treatment T_5 had registered higher root volume (28.5 cc hill^{-1}), which was statistically on par with T_3 (26.3 cc hill^{-1}) and the lowest value was recorded under T_8 (20.1 cc hill^{-1}) on Active tillering stage. A similar trend of results was also observed in panicle initiation and flowering stage. (Fig 2). Parmesh *et al.* (2013) [13] reported that application of chemical fertilizer with vermicompost could lead to a massive root system, with roots encroaching onto large soil surfaces and absorbing more moisture and nutrients supplied from both organic and inorganic sources. Yadav *et al.* (2005) [22] reported that in *Oryza sativa* L, the application of vermicompost recorded a favourable effect on soil structure, texture and tilth and thus facilitates quick and greater availability of plant nutrients and offers a more favourable environment for root evolution, resulting in a larger site of absorption for nutrient uptake.

3.2. Microbial population of bacteria (CFU 10^6/g of dry soil), fungi (CFU 10^4/g of dry soil) and actinomycetes (CFU 10^3/g of dry soil).

Soil biological activity is a key element in agricultural and ecological production, and the amount of organic matter present has a greater impact on soil biological activity than any other factor. As indicated by this study, microbial activity contributes to the recycling of energy and nutrients, which are influenced by the application of organic manures and inorganic fertilizers. The microbial community (bacteria, fungus, and actinomycetes) was profoundly changed by the manure-fertilizer treatments throughout the experimentation period.

The microbial population viz., bacteria, fungi and actinomycetes significantly were affected with application of different organic and inorganic sources as compared to control. The application of application of RDF 75 % + Vermicompost @ 5 t ha^{-1} + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi T_5 resulted in maximum microbial population of bacteria (28.3, 41.5 and 39.6 cfu10^6 g^{-1} soil), fungi (15.7, 21.0 and 15 cfu10^4 g^{-1} soil) and actinomycetes (14.7, 16.3 and 15.6 cfu10^3 g^{-1} soil) at active tillering, flowering and harvest stage respectively (Table 4) and it was closely followed by by the application of RDF 75 % + FYM @ 12.5 t ha^{-1} + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi T_3 resulted in microbial population of bacteria (28.3, 41.5 and 39.6 cfu10^6 g^{-1} soil), fungi (15.7, 21.0 and 15 cfu10^4 g^{-1} soil) and actinomycetes (14.7, 16.3 and 15.6 cfu10^3 g^{-1} soil). The lowest microbial population was recorded under control (T_8). The addition of organic inputs enhanced the microbial counts in soil, which might be due to carbon addition and changes in physico-chemical properties of soil. Microbial populations were more numerous in the application of either through vermicompost (T_5) or FYM (T_3) probably due to the bioavailability of growth-promoting substances.

Table 4. Effect of organic and inorganic sources of nutrients on the microbial population in rice rhizosphere soil at different growth stages in the western zone of Tamil Nadu.

Treatment	Bacteria (10^6 CFU/g of dry soil)			Fungi (10^4 CFU/g of dry soil)			Actinomycetes (10^3 CFU/g of dry soil)		
	Active Tillering	Flowering	Harvest	Active Tillering	Flowering	Harvest	Active Tillering	Flowering	Harvest
T_1	23.9 (1.38)	31.8 (1.50)	30.0 (1.48)	12.3 (1.09)	15.3 (1.18)	11.6 (1.06)	11.1 (1.05)	12.1 (1.08)	10.8 (1.03)
T_2	26.3 (1.42)	37.1 (1.57)	34.6 (1.54)	13.0 (1.11)	15.7 (1.20)	11.9 (1.08)	11.5 (1.06)	14.0 (1.15)	12.5 (1.10)
T_3	27.7 (1.44)	39.4 (1.60)	37.4 (1.57)	14.0 (1.15)	19.0 (1.28)	14.7 (1.17)	14.0 (1.15)	15.1 (1.18)	13.4 (1.13)
T_4	26.6 (1.42)	38.0 (1.58)	35.2 (1.55)	13.9 (1.14)	17.0 (1.23)	13.4 (1.13)	12.3 (1.09)	14.2 (1.15)	13.0 (1.11)
T_5	28.3 (1.45)	41.5 (1.62)	39.6 (1.60)	15.7 (1.20)	21.0 (1.32)	15.0 (1.18)	14.7 (1.17)	16.3 (1.21)	15.6 (1.19)
T_6	23.0 (1.36)	29.3 (1.47)	26.6 (1.42)	10.7 (1.21)	13.7 (1.14)	10.0 (1.00)	7.9 (0.90)	9.8 (0.99)	9.2 (0.96)
T_7	23.4 (1.37)	30.5 (1.48)	27.3 (1.44)	11.2 (1.05)	14.0 (1.15)	10.4 (1.02)	9.6 (0.98)	10.0 (1.00)	9.3 (0.97)
T_8	22.5 (1.35)	28.7 (1.46)	25.5 (1.41)	8.7 (0.94)	12.5 (1.10)	8.8 (0.94)	4.8 (0.68)	7.4 (0.87)	6.6 (0.82)
SEd	0.4610	0.6536	0.6027	0.2383	0.3122	0.2508	0.2332	0.2510	0.2109
CD p=(0.05)	0.9889	1.4019	1.2929	0.5112	0.6698	0.5380	0.5003	0.5383	0.4524

Log transformation values*

The increase in microbial population following the application of organic manure might be attributed to the stimulation of soil microorganism growth and activity [21]. The crop plant's roots released a variety of organic acids, which are a readily available source of food for soil microorganisms [4]. The composition and density of microbial populations in soil organic matter is an essential indicator of the soil's capacity to retain and recycle nutrients and energy.

3.3. Grain and Straw yield (kg ha^{-1})

The yield of grain and straw were influenced significantly due to application of Vermicompost, FYM, Arbuscular mycorrhizae and along with NPK fertilizers (Table 5).

Among the various organic and inorganic nutrients tested, application of RDF 75 % + Vermicompost @ 5 t ha^{-1} + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi T_5 (6740 and 7840 kg ha^{-1}) significantly recorded the higher grain and straw yield along with harvest index (46.2 %). The increase in grain and straw yield over control were 12 and 13.5 %, respectively and it was closely followed by the application of RDF 75 % + FYM @ 12.5 t ha^{-1} + Seed treatment with Azospirillum and Phosphobacteria + Soil application of AM fungi T_3 (6625 and 7725 kg ha^{-1}) respectively. A combination of inorganic fertilizers and vermicompost application was found to be increased in grain production, possibly by regulating the release of nutrients in the soil through mineralization [17]. Similar results were also reported by Thakur *et al*. (2021) [20]: Kamaleshwaran and Elayaraja (2021) [8].

However, the FYM treatment recording higher root growth and yield parameters was mainly due to balanced and continuous supply of macro and micro-nutrients from FYM throughout the growing period [12]. Singh *et al*. (2012) [19] reported that application of 100% RDF through inorganic fertilizers being on par with 50% RDF as inorganic fertilizers + 50% RDN as farm yard manure but produced significantly higher straw yield (2.23 t ha^{-1}) over rest of the fertility treatments. Farmyard manure might have supplied the essential minerals and worked as a catalyst for efficient use of applied nutrients in increasing the yield attributes. The research findings were supported by Kumar *et al.* (2014) [9].

Table 5. Grain and Straw yield of rice Co 51 in western zone of Tamil Nadu

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T_1	6180	7490	45.2
T_2	6285	7520	45.5
T_3	6625	7725	46.2
T_4	6480	7615	46.0
T_5	6740	7840	46.2
T_6	5960	6975	46.1

T_7	6120	7325	45.5
T_8	5935	6780	46.7
SEd	111.275	132.57	0.8210
CD (p=0.05)	238.68	284.27	1.7610

4. CONCLUSION

Integrated use of organic and inorganic fertilizers improved the microbial population of bacteria, fungi and actinomycetes population in soil. From this study it can be concluded that FYM and vermicompost application have on par effect with respect to soil biological properties. Decomposition of organic matter and recycling of carbon have substantial effect on the activity of soil enzymes evolved during the mineralization of crop plant nutrients, which would have improved the soil health and microbial population in soil. Higher rice grain yield and harvest index (6740 kgha^{-1} and 46.2 % respectively) were significantly associated with RDF 75% (STCR approach) + Vermicompost @ 5t ha^{-1}along with Arbuscular mycorrhizae, a best sustainable nutrient management practice for lowland rice environment for getting sustainable yield and higher returns.

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