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Original Research Article

Impact of Different Sources of Organic Manures in Comparison with TRRI Practice, RDF and INM on Growth, Yield, Soil Microbial Populations and Enzymatic Activities in Rice- Greengram Cropping System under Site-Specific Organic Farming Situation

Alagappan Sankaramoorthy[1], Venkitaswamy Rangasamy[2] and Mariappan Gurusamy[1]

[1]Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore - 641 003, Tamil Nadu, India
[2]Directorate of Crop Management, Tamil Nadu Agricultural University, Coimbatore - 641 003, Tamil Nadu, India
**Corresponding author*

A B S T R A C T

Field experiments were carried out at Tamil Nadu Agricultural University, Coimbatore, India during samba (August-December) season of 2012 and 2013 to study the effect of different sources of organic manures in comparison with TRRI practice, RDF and INM on growth, yield and soil microbial populations of rice with succeeding rice fallow residual greengram during summer 2013 and 2014. The experiment consisted of fifteen treatments which were laid out in Randomized Block Design, replicated thrice and square planting with the spacing of 25 x 25 cm was adopted during both the years. Among fifteen treatments, thirteen treatments were organic which were compared with the recommended dose of fertilizer (RDF) an activities d integrated nutrient management practice (RDF + Dhaincha @ 6.25 t ha^{-1}). The effect on growth parameters such as number of productive tillers per square meter, filled grain percentage and grain yield were recorded in both the years. Out of fifteen treatments, INM imposed treatment performed better followed by TRRI practice. Among the organic treatments, TRRI practice followed by 100% RDN through green manure recorded more number of productive tillers per square meter, filled grain percentage and grain yield of rice. The soil microbial populations such as bacterial population, fungal population and actinobacterial/actinomycetes were recorded during both the years of experimentation. The soil enzymatic activities like urease, dehydrogenase and phosphatase activities were recorded after the harvest of rice and the succeeding greengram's harvest during both the years of investigation. The succeeding residual greengram's grain yield was recorded in the entire cropping system in both the years of experimentation. The RDF treatment performed better than all the organic treatments except the TRRI practice during both the years of study. The performance of INM imposed treatment followed by RDF recorded better growth and yield parameters than the organic treatments, whereas the soil microbial population is concerned, the organic treatments such as100% RDN through green manure, TRRI practice and 25% RDN through each organic manures combination recorded better results than RDF and INM imposed treatment during both the years of investigation. Similar results were obtained with respect to soil enzymatic activities also during both the years of study. The 100% RDN through green manure invariably performed better than all the organic, RDF and INM treatment in terms of soil microbial population and soil enzymatic activities after the harvest of rice and after the harvest of residual greengram in the entire cropping system in both the years of study.

Keywords

Organic farming, Growth parameters, Rice-greengram grain yield, Soil microbial populations, Soil enzymatic activities and rice-greengram cropping

Introduction

Rice (*Oryza sativa* L.) is the most important and extensively cultivated food crop, which provides half the daily food for one of every three persons on the earth. In Asia alone, more than two billion people obtain 60 to 70 per cent of their energy intake from rice and its derivatives. Rice-rice-pulse (Greengram/ Blackgram) is the predominant cropping system of major rice growing areas of Tamil Nadu. The cropping sequence of rice-pulse is practically feasible, viable, economical, eco-friendly, water saving technology for sustaining soil fertility and rice productivity. Awareness about crop quality and soil health in- creased the attention of people towards organic farming [37]. Balanced use of nutrients through organic sources like farmyard manure, vermicompost, green manuring, neem cake and biofertilizers are prerequisites to sustain soil fertility, to produce maximum crop yield with optimum input level [12]. The organic manures leave behind sufficient residual effect for the sequence crops. Soil microorganisms are critical to the maintenance of soil function because of their contributions to soil structure formation; decomposition of organic matter, toxin removal; and biogeochemical cycling of carbon, nitrogen, phosphorous and sulphur [22], [14] and [27]. Understanding soil microbial ecology is increasingly recognized as important for the restoration and sustainability of ecosystems [40] and [29]. The extent of soil microbial diversity in agricultural soils is also critical to the maintenance of soil health and quality, restoration and sustainability of ecosystems [16] and [38]. The greatly enhanced microbial activities not only increases the rate of nutrient transformations into forms readily available for plants, but also have effects on plant growth through increased enzymatic activity and disease suppression [15]. These changes, influence on the quality and productive capacity of the soil [1], [7] and [45]. In view of the above facts, field experiment was conducted with the following objectives.

To study the influence of different sources of organic manures in comparison with TRRI practice, RDF and INM on growth and yield of rice- greengram cropping system under site-specific organic farming situation.

To study the influence of different sources of organic manures in comparison with TRRI practice RDF and INM on growth, yield and soil microbial populations and enzymatic activities after the harvest of rice, and,

To study the influence of different sources of organic manures in comparison with TRRI practice, RDF and INM on the soil microbial populations and soil enzymatic activities after the harvest of succeeding rice fallow pulse crop (greengram) in rice-greengram cropping system.

Materials and Methods

Field experiments were carried out at Wetland Farms of "O" block at Tamil Nadu Agricultural University, Coimbatore, India during *samba* (August-December) season of 2012 and 2013 for rice and summer 2013 and 2014 for residual rice fallow pulse crop (greengram). Coimbatore is situated in the Western agro-climatic zone of Tamil Nadu at 11^{o}N latitude and 77^{o}E longitude and at an altitude of 426.7 m above mean sea level. The soil of the experimental field was clay loam in texture belonging to *Typic Haplustalf* with the initial analysis of the soil of the experimental site revealed that the soil was slightly alkaline (pH= 8.0 and 8.1) with low soluble salts (EC= 0.43 and 0.42dSm^{-1}), medium in organic carbon content (0.42 and 0.41%), low in available N (254.0 and 260.0 kg ha^{-1}), low in available P (16.7 and 17.8 kg ha^{-1}) and high in available K (402.0 and 418.0 kg ha^{-1}) during the first and second years respectively. The experiment consisted of fifteen treatments which were laid out in Randomized Block Design and replicated thrice. Out of fifteen treatments, thirteen treatments were organic which were compared with the recommended dose of fertilizer (RDF) and integrated nutrient management practice (RDF + Dhaincha @ 6.25 t ha^{-1}). One treatment is used for the comparison i.e., TRRI Practice (organic rice practice) was already developed by Tamil Nadu Rice Research Institute, Aduthurai. The rice variety CO (R) 48 with field duration of 135 days was used in the trial followed by summer greengram (Co 6) as residual succeeding crop without addition of any manures and fertilizers in both the years of experiment. Separate nurseries were raised for conventional (INM and RDF) treatments and organic nursery for organic treatments. For organic and inorganic treatments separate experimental plots were maintained in both the years of study. Square planting was adopted with the spacing of 25 x 25 cm, transplanted with 14 days old seedlings. All other package of practices were carried out as per recommendation of CPG [11] for INM and RDF treatments.

In the net plot area, five sample hills (plants) were selected randomly and tagged for recording biometric observations. In the tagged plant, the number of productive tillers per square meter, filled grain percentage and grain yield of rice were recorded for both the years. The succeeding greengram's grain yield was recorded. The soil microbial populations and soil enzymatic activities were recorded after the harvest of rice and after the harvest of residual greengram in both the years of experimentation of the entire cropping system.

Growth parameters of rice

Five plants from each plot were recorded chosen by random sampling and tagged. These plants were used for recording important growth parameters such as number of productive tillers per square meter at harvest and fertility percentage during both the years of experimentation [20].

Rice and greengram grain yield

Grain yield was calculated through ten randomly selected plants which were thoroughly sun dried to 14% moisture content, weighed and expressed in gram per plant and expressed in kg $ha^{-1.}$ Similar method was adopted for greengram harvest also.

Soil microbial populations

The microbial population in the soil at harvest stage of the crop was determined. The standard serial dilution plating technique of [30] was adopted for the estimation of microbial population and expressed as colony forming unit (cfu) g^{-1} of soil. The different types of microorganisms were enumerated using differential media favoring the growth of bacteria, fungi and actinobacteria as shown in the following table 2 and 3.

Soil enzymatic activities

The enzyme activity was determined at initial and post-harvest stages of rice and greengram. The substrates and methods followed for enzyme assays were presented in the following table 4 and 5.

Statistical analysis

The data on various characters studied during the course of investigation were statistically analysed [18] for randomized block design. Wherever treatment differences were significant ("F" test), critical differences were worked out at five per cent probability level. Treatment differences that were not significant were denoted as "NS".

Results and Discussion

Productive tillers m^{-2}

The number of productive tillers m^{-2} ranged from 228 to 328 and from 236 to 330 during 2012 and 2013 respectively (Table 1). The INM practice (T_{15}) recorded more number of productive tillers m^{-2} (328 in 2012 and 330 in 2013, respectively) and which was on par with TRRI practice (T_{13}) and recommended NPK fertilizers (T_{14}).

Among the organic treatments, TRRI practice (T_{13}) recorded higher number of productive tillers m^{-2} (316 and 319 during 2012 and 2013, respectively) and it was on par with 100 % RDN through green manure (T_5) and 25% RDN through each organic manure (T_{12}). The least number of productive tillers m^{-2} (228 and 236 in 2012 and 2013, respectively) was associated with the treatment of absolute control (T_1). Similar trend was observed in the conformity trial during 2013 also. Increase in rice grain yield owing to green manure incorporation might be attributed to the release of nutrients to soil slowly for longer duration after decomposition, resulting in better plant growth and yield contributing characters. The enhanced and continuous supply of nutrients by the organics lead to better tiller production and filled grain of rice was reported by [34].

Filled grain percentage

The per cent of filled grain which indicate the capacity of the plant to convert source to sink in the process of photosynthesis, was significantly influenced by the INM practice, organic manures, TRRI practice and recommended NPK fertilizers in both the years of experimentation (Table 1). Higher percentage of filled grain was recorded under the INM practice (T_{15}) (88.1 and 88.2 during 2012 and 2013, respectively) and it was comparable with TRRI practice (T_{13}) and recommended NPK fertilizers (T_{14}). Among the organic treatments, TRRI practice (T_{13}) recorded higher filled grain per cent (83.5 and 83.7 during 2012 and 2013, respectively) and was comparable with 100% RDN through green manure (T_5) and it was followed by 25% RDN through each organic manure (T_{12}) each other during both the years. The lower filled grain per cent was noticed in the absolute control treatment (T_1) (52.2 in 2012 and 53.1 in 2013). The proper partitioning might have occurred from source to sink and as a result the panicle weight and filled grain percentage could have improved [43].

Rice grain yield

The effect of treatment variables on grain yield (kg ha^{-1}) of rice are furnished in Table 1. The treatments imposed had direct influence on rice grain yield in both the years of experimentation. The grain yield of rice extended from 3602 to 6235 kg ha^{-1} during 2012 and from 3646 to 6270 kg ha^{-1} during 2013. The INM practice (T_{15}) recorded higher grain yield (6235 and 6270 kg ha^{-1} in 2012 and 2013, respectively) and was found to be on par with TRRI practice (T_{13}) and recommended NPK fertilizers (T_{14}), which were on par with each other during both the years. Among the organic treatments, TRRI practice (T_{13}) recorded higher grain yield (5628 and 5684 in 2012 and 2013, respectively) and was followed by 100% RDN through green manure (T_5) (5084 and 5140 in 2012 and 2013, respectively). Lower grain yield 3602 and 3646 kg ha^{-1} during 2012 and 2013 was obtained with absolute control (T_1), which did not receive organic manures and recommended NPK fertilizers. This was significantly inferior to the grain yield obtained with 100% RDN through farm yard manure (T_2). During the conformity trial also similar nature of results were noticed. This was evidenced with the findings of yield attributes of rice [33].

Grain yield of residual greengram

During 2013 and 2014, the residual greengram recorded higher grain yield (kg ha^{-1}) with INM practice (T_{15}) (642 and 698) followed by RDF treatment (437 and 502), among the organic treatments, higher grain yield was recorded with TRRI practice (T_{13}) (428 and 496) followed by 100% RDN through green manure (T_5) (410 and 476) in both the years of study. The least grin yield was recorded from the absolute control (T_1) (251 and 258) in both the years of experimentation. The superiority of residual effect of organic manures and green manure was attributed to its slow decomposition, which probably released the nutrients slowly as compared to other organic materials [36]. The grain and haulm yield of rice fallow blackgram was higher with different organic manures were used on equi nutrient basis in rice-blackgram cropping sequence. The superiority of *Sesbania aculeata* in improving the growth characters observed among the organic manures which were followed by FYM, poultry manure and vermicompost. This would have been also due to the better residue addition in rice based cropping system. Similar observations have been made by [32]. The efficient utilization of mineralized N from the incorporated *Sesbania aculeata* and other organic sources along with fertilizer N would have increased the availability of N throughout the growth period increasing the growth characters and yield attributes of greengram in summer indicating higher residue management. Similar increase in yield attributes of greengram due to combined application of inorganic fertilizer and organics applied to previous crops and in INM practice applied to previous crops has been reported by [39], [31] and [17].

Soil microbial load

During both the years, the INM practice, different sources of organic manures, TRRI practice and recommended NPK fertilizers (RDF) had significantly influenced bacterial, fungal and actinobacterial population all stages of the crop. The bacterial population was expressed in 10^6 cfu (colony forming units) per gram of dry soil, the soil fungal population was expressed in 10^3 cfu per gram of dry soil and the actinobacterial population was expressed in 10^4 cfu per gram of dry soil.

Bacterial population

The bacterial population had increased as the crop growth advances in both the years of experimentation. The bacterial population after harvest of rice during *samba* 2012 and *samba* 2013 was more recorded with 100% RDN through green manure (T_5) (38.2 and 42.4) followed by TRRI practice (T_{13}) (38.0 and 42.2). The INM practice recorded with the bacterial population of 32.2 and 34.4 and the recommended dose of fertilizers (RDF) (T_{14}) recorded with the bacterial population of 29.8 and 31.4 during both the years of study. The least bacterial population was recorded with the absolute control (T_1) (20.9 and 20.2) which had not received any source of organic or inorganic fertilizers during both the years of study. The bacterial population after the harvest of residual greengram was more with 100% RDN through green manure (T_5) (59.2 and 61.6) followed by TRRI practice (T_{13}) (59.0 and 61.4). The INM practice recorded with the bacterial population of 58.6 and 60.2 and the recommended dose of fertilizers (RDF) (T_{14}) recorded with the bacterial population of 24.8 and 24.2 during both the years of study. The least bacterial population was recorded with the absolute control (T_1) (17.5 and 17.9) which had not received any source of organic or inorganic fertilizers during both the years of study.

Fungal population

The fungal population had increased as the crop growth advances in both the years of experimentation. The fungal population after harvest of rice during *samba* 2012 and *samba* 2013 was more recorded with 100% RDN through green manure (T_5) (17.6 and 17.9) followed by TRRI practice (T_{13}) (17.4 and 17.7). The INM practice recorded with the fungal population of 12.9 and 13.8 and the recommended dose of fertilizers (RDF) (T_{14}) recorded with the fungal population of 11.6 and 12.4 during both the years of study. The least fungal population was recorded with the absolute control (T_1) (4.9 and 4.6) which had not received any source of organic or inorganic fertilizers during both the years of study. The fungal population after the harvest of residual greengram (rice fallow pulse) was more with 100% RDN through green manure (T_5) (19.4 and 19.0) followed by TRRI practice (T_{13}) (19.3 and 18.8). The INM practice recorded with the fungal population of 18.8 and 18.6 and the recommended dose of fertilizers (RDF) (T_{14}) recorded with the fungal population of 6.5 and 7.2 during both the years of study. The least fungal population was recorded with the absolute control (T_1) (3.5 and 3.9) which had not received any source of organic or inorganic fertilizers during both the years of study.

Actinobacterial population

The actinobacterial population had increased as the crop growth advances in both the years of experimentation. The actinobacterial population after harvest of rice during *samba* 2012 and *samba* 2013 was more recorded with 100% RDN through green manure (T_5) (13.9 and 16.4) followed by TRRI practice (T_{13}) (13.7 and 16.2). The INM practice recorded with the actinobacterial population of 10.4 and 12.6 and the recommended dose of fertilizers (RDF) (T_{14}) recorded with the actinobacterial population of 9.8 and 12.1 during both the years of study. The least actinobacterial population was recorded with the absolute control (T_1) (6.2 and 5.8) which had not received any source of organic or inorganic fertilizers during both the years of study. The actinobacterial population after the harvest of residual greengram (rice fallow pulse) was more with 100% RDN through green manure (T_5) (18.8 and 18.4) followed by TRRI practice (T_{13}) (18.6 and 18.2). The INM practice recorded with the actinobacterial population of 18.4 and 18.0 and the recommended dose of fertilizers (RDF) (T_{14}) recorded with the actinobacterial population of 5.8 and 5.6 during both the years of study. The least actinobacterial population was recorded with the absolute control (T_1) (3.9 and 3.2) which had not received any source of organic or inorganic fertilizers during both the years of study.

Soil enzyme activities

The soil enzyme activities were significantly influenced by the INM practice, different organic manures, TRRI practice and recommended NPK fertilizers application in both the years of experimentation (Table 4 and 5) in this rice- greengram cropping system, site-specific organic farming study..

Soil urease activity

Higher urease activity was observed with 100% RDN though green manure (T_5) (46.8 µg NH^+ g^{-1} soil 24 h^{-1} in 2012 and 46.0 in 2013) and it was comparable with TRRI Practice (T_{13}) (46.6 and 45.8) and 25% RDN through each organic manure (T_{12}) (45.9 and 45.6) during both the years of study. The INM practice (T_{15}) recorded higher urease activity (38.0 during 2012 and 40.2 during 2013, respectively) whereas, it was on par with recommended dose of NPK fertilizers (T_{14}) (36.5 and 34.5) and it was inferior to all the other organic (T_2 to T_{12}) treatments and superior to absolute control (T_1) during both the years of study. Similar trend was observed after the harvest of greengram.

Soil dehydrogenase activity

Higher soil dehydrogenase activity was observed with 100% RDN though green manure (T_5) (36.8 µg of TPF released g^{-1} of soil 24 h^{-1} in 2012 and 36.9 in 2013) and it was comparable TRRI practice (T_{13}) (36.6 and 36.7) and 25% RDN through each organic manure (T_{12}) (36.1 and 35.5) during both the years of study. Invariably, all the organic treatments from T_2 to T_{12} registered higher soil dehydrogenase activity when compared to recommended NPK fertilizers (T_{14}) and absolute control (T_1). The recommended NPK fertilizers (T_{14}) produced lower soil dehydrogenase (25.3 and 24.5 in 2012 and 2013, respectively) than all the organic treatments from (T_2 to T_{12}) whereas the INM practice (T_{15}) (27.4 and 30.4) produced higher soil dehydrogenase activity than the recommend NPK fertilizers. The lowest soil dehydrogenase activity was observed with absolute control (T_1) (22.5 and 21.7 in 2012 and 2013) in both the years of study. Similar trend was noticed after the harvest of greengram.

Soil phosphatase activity

Higher soil phosphatase activity was observed with 100% RDN though green manure (T_5) (38.8 µg of p - nitrophenol released g^{-1} of soil 24 h^{-1} in 2012 and 38.6 in 2013) and it was comparable with TRRI practice (T_{13}) (38.6 and 38.4) and 25% RDN through each organic manure (T_{12}) (37.4 and 37.2) during both the years of study. Invariably, all the organic treatments from T_2 to T_{12} registered higher soil phosphatase activity when compared to recommended NPK fertilizers (T_{14}) and absolute control (T_1). The recommended NPK fertilizers (T_{14}) produced lower soil phosphatase (27.4 and 26.6 in 2012 and 2013, respectively) than all the organic treatments from (T_2 to T_{12}) whereas the INM practice (T_{15}) (30.6 and 32.2) produced higher soil phosphatase activity than the recommend NPK fertilizers. The lowest soil phosphatase activity was observed with absolute control (T_1) (24.9 and 23.4 in 2012 and 2013) in both the years of study. Similar trend was noticed after the harvest of greengram. This could be due to enhanced organic carbon content of the soil as a result of organic manure application as compared to inorganic fertilizers [23].

The poultry manure also had secondary and micronutrients which might have helped to increase the microflora as reported by [44]. High organic carbon content in soil applied with poultry manure stimulated the soil microorganisms by serving as source of carbon, energy and other nutrients essential for their growth and multiplication and the increased the soil enzyme activities.

Table.1 Effect of organic manures, RDF, INM and TRRI practice on number of productive tillers m^{-2}, fertility percentage, grain yield of rice and greengram

Treatments	*Samba* 2012	Summer -2013			*Samba* 2013	Summer - 2014		
	Productive tillers (No. m^{-2})	Fertility percentage	Rice yield (kg ha^{-1})	Greengram Yield (kg ha^{-1})	Productive tillers (No. m^{-2})	Fertility percentage	Rice Yield (kg ha^{-1})	Greengram Yield (kg ha^{-1})
T_1 : Absolute control	228	52.2	3602	251	236	53.1	3646	258
T_2 : 100% RDN through FYM	271	79.2	4164	325	272	78.3	4190	386
T_3 : 100% RDN through VC	278	79.2	4296	335	280	78.6	4380	398
T_4 : 100% RDN through PM	288	80.7	4377	341	292	80.1	4550	406
T_5 : 100% RDN through GM	310	80.9	5084	410	308	81.2	5140	476
T_6 : 50% RDN each of through FYM + VC	259	78.6	3910	305	260	77.8	3980	370
T_7 : 50% RDN each of through FYM + PM	299	80.6	4721	368	300	80.6	4833	432
T_8 : 50% RDN each of through FYM + GM	274	79.1	4236	331	276	78.3	4316	394
T_9 : 50% RDN each of through VC + PM	301	80.7	4923	384	304	80.1	4986	448
T_{10} : 50% RDN each of through VC + GM	264	78.8	4079	318	268	78.1	4140	382
T_{11} :50% RDN each of through PM + GM	282	79.6	4322	338	284	78.9	4430	401
T_{12} : 25% RDN each of through FYM + VC + PM + GM	306	80.8	5004	390	308	80.9	5120	452
T_{13} : TRRI Practice*	316	83.5	5628	428	319	83.7	5684	496
T_{14} : RDF : (150 : 50 : 50) NPK kg ha^{-1}	312	81.2	5603	437	316	82.1	5680	502
T_{15} : INM Practices (RDF + GM @ 6.25 t ha^{-1})	328	88.1	6235	642	330	88.2	6270	698
SEd	**29**	**7.9**	**463**	**38**	**28**	**7.9**	**470**	**42**
CD (p=0.05)	**60**	**16.6**	**972**	**79**	**58**	**16.6**	**987**	**88**

FYM: Farm Yard Manure, VC: Vermicompost, PM: Poultry manure, GM: Green manure (Dhaincha) *Sesbania aculeata*
TRRI Practice*: (poultry manure @ 5 t/ha + 1000 kg/ha Azolla + 8 kg/ha Azospirillum + 8 kg/ha Phosphobacteria + 100 kg/ha Groundnut oil cake on 50 DAT)
RDN: Recommended Dose of Nitrogen, RDF: Recommended Dose of Fertilizers, INM: Integrated Nutrient Management
TRRI: Tamil Nadu Rice Research Institute, Aduthurai. TRRI practice*: (Organic practice for rice was developed by TRRI, Aduthurai).

Table.2 Residual effect of organic manures, TRRI practice, RDF and INM on soil microbial population at harvest of rice

Reatments	*Samba* 2012			*Samba* 2013		
	Bacteria ($x10^6$ CFU g^{-1}) of dry soil	Fungi ($x10^3$ CFU g^{-1}) of dry soil	Actinobacteria (x 10^4 CFU g^{-1}) of dry soil	Bacteria ($x10^6$ CFU g^{-1}) of dry soil	Fungi ($x10^3$ CFU g^{-1}) of dry soil	Actinobacteria (x 10^4 CFU g^{-1}) of dry soil
T_1 : Absolute control	*20.9*	4.9	6.2	*20.2*	4.6	5.8
T_2 : 100% RDN through FYM	*33.4*	13.4	10.8	*39.1*	14.2	13.6
T_3 : 100% RDN through VC	*35.4*	14.2	11.3	*40.2*	15.6	14.6
T_4 : 100% RDN through PM	*36.4*	15.1	12.4	*41.2*	15.8	15.4
T_5 : 100% RDN through GM	*38.2*	17.6	13.9	*42.4*	17.9	16.4
T_6 : 50% RDN each of through FYM + VC	*34.2*	14.5	11.2	*38.5*	15.5	13.4
T_7 : 50% RDN each of through FYM + PM	*34.6*	14.8	12.5	*38.7*	16.0	13.6
T_8 : 50% RDN each of through FYM + GM	*34.8*	15.6	12.7	*38.9*	16.2	14.2
T_9 : 50% RDN each of through VC + PM	*35.4*	15.8	12.9	*39.4*	16.4	15.2
T_{10} : 50% RDN each of through VC + GM	*35.6*	15.9	13.1	*39.8*	16.8	15.4
T_{11} : 50% RDN each of through PM + GM	*36.2*	16.2	13.4	*40.8*	17.2	15.6
T_{12} : 25% RDN each of through FYM + VC + PM + GM	*37.2*	16.5	13.6	*41.5*	17.4	15.9
T_{13} : TRRI Practice*	38.0	17.4	13.7	42.2	17.7	16.2
T_{14} : RDF (150 : 50 : 50) NPK kg ha^{-1}	*29.8*	11.6	9.8	*31.4*	12.4	12.1
T_{15} : INM Practice (RDF + GM @ 6.25 t ha^{-1})	*32.2*	12.9	10.4	*34.4*	13.8	12.6
SEd	**3.4**	**1.4**	***1.1***	**3.7**	**1.5**	***1.3***
CD (p=0.05)	**7.2**	**2.9**	***2.3***	**7.8**	**3.1**	***2.7***

FYM: Farm Yard Manure, VC: Vermicompost, PM: Poultry manure, GM: Green manure (Dhaincha) *Sesbania aculeata*
TRRI Practice*: (poultry manure @ 5 t/ha + 1000 kg/ha Azolla + 8 kg/ha Azospirillum + 8 kg/ha Phosphobacteria + 100 kg/ha Groundnut oil cake on 50 DAT)
RDN: Recommended Dose of Nitrogen, RDF: Recommended Dose of Fertilizers, INM: Integrated Nutrient Management
TRRI: Tamil Nadu Rice Research Institute, Aduthurai. TRRI practice*: (Organic practice for rice was developed by TRRI, Aduthurai).

Table.3 Residual effect of organic manures, TRRI practice, RDF and INM on soil microbial population at harvest of greengram

Treatments	Summer 2013			Summer 2014		
	Bacteria ($x10^6$ CFU g^{-1}) of dry soil	Fungi ($x10^3$ CFU g^{-1}) of dry soil	Actinobacteria (x 10^4 CFU g^{-1}) of dry soil	Bacteria ($x10^6$ CFU g^{-1}) of dry soil	Fungi ($x10^3$ CFU g^{-1}) of dry soil	Actinobacteria (x 10^4 CFU g^{-1}) of dry soil
T_1 : Absolute control	17.5	3.5	3.9	17.9	3.9	3.2
T_2 : 100% RDN through FYM	42.0	14.8	14.1	42.0	14.1	13.8
T_3 : 100% RDN through VC	43.2	16.0	15.6	42.1	15.5	15.8
T_4 : 100% RDN through PM	46.2	17.2	17.0	44.0	16.3	16.6
T_5 : 100% RDN through GM	59.2	19.4	18.8	61.6	19.0	18.4
T_6 : 50% RDN each of through FYM + VC	40.7	13.3	12.0	40.0	12.5	12.0
T_7 : 50% RDN each of through FYM + PM	50.0	17.6	17.4	48.2	17.0	16.8
T_8 : 50% RDN each of through FYM + GM	42.8	15.6	15.2	42.0	14.9	14.0
T_9 : 50% RDN each of through VC + PM	52.1	18.0	17.6	50.0	17.2	17.1
T_{10} : 50% RDN each of through VC + GM	41.2	14.2	13.4	41.4	14.1	13.2
T_{11} : 50% RDN each of through PM + GM	44.0	16.6	16.4	43.0	16.4	16.2
T_{12} : 25% RDN each of through FYM + VC + PM + GM	54.8	18.2	18.0	53.8	18.0	17.6
T_{13} : TRRI Practice*	59.0	19.3	18.6	61.4	18.8	18.2
T_{14} : RDF (150 : 50 : 50) NPK kg ha^{-1}	24.8	6.50	5.80	24.2	7.20	5.60
T_{15} : INM Practice (RDF + GM @ 6.25 t ha^{-1})	58.6	18.8	18.4	60.2	18.6	18.0
SEd	**4.48**	**1.56**	**1.43**	**4.42**	**1.53**	**1.48**
CD (p=0.05)	**9.43**	**3.28**	**2.99**	**9.29**	**3.21**	**3.11**

FYM: Farm Yard Manure, VC: Vermicompost, PM: Poultry manure, GM: Green manure (Dhaincha) *Sesbania aculeata*
TRRI Practice* : (poultry manure @ 5 t/ha + 1000 kg/ha Azolla + 8 kg/ha Azospirillum + 8 kg/ha Phosphobacteria + 100 kg/ha Groundnut oil cake on 50 DAT)
RDN: Recommended Dose of Nitrogen, RDF: Recommended Dose of Fertilizers, INM: Integrated Nutrient Management
TRRI : Tamil Nadu Rice Research Institute, Aduthurai. TRRI practice* : (Organic practice for rice was developed by TRRI, Aduthurai).

Table.4 Effect of organic manures, TRRI Practice, RDF and INM on soil enzyme activity at post-harvest soil of rice

Treatments	*Samba* 2012			*Samba* 2013		
	Urease[1]	Dehydrogenase[2]	Phosphatase[3]	Urease[1]	Dehydrogenase[2]	Phosphatase[3]
T_1 : Absolute control	32.7	22.5	24.9	30.5	21.7	23.4
T_2 : 100% RDN through FYM	39.0	28.0	32.0	41.0	31.8	33.0
T_3 : 100% RDN through VC	41.0	31.0	33.0	42.0	32.0	34.0
T_4 : 100% RDN through PM	43.4	33.6	35.0	43.0	33.8	35.0
T_5 : 100% RDN through GM	46.8	36.8	38.8	46.0	36.9	38.6
T_6 : 50% RDN each of through FYM + VC	39.6	28.6	32.5	41.5	32.4	34.2
T_7 : 50% RDN each of through FYM + PM	42.2	33.4	32.9	42.5	32.6	35.6
T_8 : 50% RDN each of through FYM + GM	42.6	33.8	34.2	44.6	34.6	35.8
T_9 : 50% RDN each of through VC + PM	43.7	35.2	36.2	44.8	34.8	36.2
T_{10} : 50% RDN each of through VC + GM	44.2	35.6	36.4	45.2	34.9	36.4
T_{11} : 50% RDN each of through PM + GM	44.6	32.9	36.6	45.4	35.2	36.8
T_{12} : 25% RDN each of through FYM + VC + PM + GM	45.9	36.1	37.4	45.6	35.5	37.2
T_{13} : TRRI Practice*	46.6	36.6	38.6	45.8	36.7	38.4
T_{14} : RDF (150 : 50 : 50) NPK kg ha^{-1}	36.5	25.3	27.4	34.5	24.5	26.6
T_{15} : INM Practice (RDF + GM @ 6.25 t ha^{-1})	38.0	27.4	30.6	40.2	30.4	32.2
SEd	**3.91**	**2.97**	**3.16**	**3.95**	**3.04**	**3.21**
CD (p=0.05)	**8.20**	**6.23**	**6.63**	**8.29**	**6.39**	**6.71**

Urease (µg NH_4^+ g^{-1} of soil 24 h^{-1}), 2. Dehydrogenase (µg of TPF released g^{-1} of soil 24 h^{-1}) and 3. Phosphatase (µg of p-nitrophenol released g^{-1} of soil 24 h^{-1})
FYM: Farm Yard Manure, VC: Vermicompost, PM: Poultry manure, GM: Green manure (Dhaincha) *Sesbania aculeata*
TRRI Practice*: (poultry manure @ 5 t/ha + 1000 kg/ha Azolla + 8 kg/ha Azospirillum + 8 kg/ha Phosphobacteria + 100 kg/ha Groundnut oil cake on 50 DAT)
RDN: Recommended Dose of Nitrogen, RDF: Recommended Dose of Fertilizers, INM: Integrated Nutrient Management
TRRI : Tamil Nadu Rice Research Institute, Aduthurai. TRRI practice*: (Organic practice for rice was developed by TRRI, Aduthurai).

Table.5 Residual effect of organic manures, TRRI Practice, RDF and INM on soil enzyme activity at post-harvest soil of greengram

Treatments	Summer 2013			Summer 2014		
	Urease 1	**Dehydrogenase** 2	**Phosphatase** 3	**Urease** 1	**Dehydrogenase** 2	**Phosphatase** 3
T_1 : Absolute control	28.0	20.3	22.6	26.9	19.6	21.6
T_2 : 100% RDN through FYM	35.0	26.0	31.4	38.2	26.2	32.4
T_3 : 100% RDN through VC	36.4	28.0	31.8	39.0	28.2	34.2
T_4 : 100% RDN through PM	37.0	31.0	32.0	39.6	32.0	33.8
T_5 : 100% RDN through GM	43.6	36.8	38.4	44.8	37.4	38.8
T_6 : 50% RDN each of through FYM + VC	33.6	24.5	30.7	37.5	24.6	31.8
T_7 : 50% RDN each of through FYM + PM	38.2	32.1	33.2	40.0	33.4	34.0
T_8 : 50% RDN each of through FYM + GM	36.2	27.0	31.7	38.6	27.1	33.8
T_9 : 50% RDN each of through VC + PM	39.8	33.0	34.6	41.2	34.8	35.6
T_{10} : 50% RDN each of through VC + GM	34.4	25.2	31.2	37.9	25.4	32.0
T_{11} : 50% RDN each of through PM + GM	36.6	29.2	31.9	39.4	30.8	33.6
T_{12} : 25% RDN each of through FYM + VC + PM + GM	42.8	35.6	37.4	43.6	36.2	37.2
T_{13} : TRRI Practice*	43.4	36.6	38.2	44.6	37.2	38.6
T_{14} : RDF (150 : 50 : 50) NPK kg ha^{-1}	30.6	28.7	25.1	30.2	21.8	24.2
T_{15} : INM Practice (RDF + GM @ 6.25 t ha^{-1})	40.6	33.4	35.8	41.8	35.2	36.1
SEd	**3.47**	**2.51**	**3.04**	**3.66**	**2.78**	**3.14**
CD (p=0.05)	**7.13**	**5.56**	**6.24**	**7.53**	**5.71**	**6.46**

Urease (µg NH4+ g^{-1} of soil 24 h^{-1}), 2. Dehydrogenase (µg of TPF released g-1 of soil 24 h^{-1}) and 3. Phosphatase (µg of p-nitrophenol released g-1 of soil 24 h^{-1})
FYM: Farm Yard Manure, VC: Vermicompost, PM: Poultry manure, GM: Green manure (Dhaincha) *Sesbania aculeata*
TRRI Practice*: (poultry manure @ 5 t/ha + 1000 kg/ha Azolla + 8 kg/ha Azospirillum + 8 kg/ha Phosphobacteria + 100 kg/ha Groundnut oil cake on 50 DAT)
RDN: Recommended Dose of Nitrogen, RDF: Recommended Dose of Fertilizers, INM: Integrated Nutrient Management
TRRI: Tamil Nadu Rice Research Institute, Aduthurai. TRRI practice*: (Organic practice for rice was developed by TRRI, Aduthurai).

Soil microbial populations

Soil microbial populations	Method used
Total bacteria (cfu x 10^6 g^{-1} of soil)	Serial dilution method using Nutrient glucose Agar medium [10]
Total fungi (cfu x 10^3 g^{-1} of soil)	Serial dilution method using Martin's Rose Bengal Agar medium [25]
Total actinobacteria(cfu x 10^4 g^{-1} of soil)	Serial dilution method using Kenknight's Agar medium [21]

Soil enzymatic activities

Enzyme	Substrate	Method	Reference
Dehydrogenase	2,3,5- Triphenyl Tetrazolium chloride	Spectrophotometer at 485 nm	Casida *et al.*, [9]
Urease	10 per cent urea solution	Spectrophotometer at 630 nm	Tabatabai and Bremner [42]
Phosphatase	p-nitrophenol phosphate	Spectrophotometer at 420 nm	Halstead [19]

These results are in line with the findings of [35] and [40]. The incorporation of haulms of N fixing legume (greengram) into the soil increased the plant available nitrate N and released more mineral N from legume residues [13] and [28]. Thus, inclusion of legumes in cereal cropping rotations can theoretically increase soil N concentration and at least, reduced the decline of soil N fertility associated with the cropping system and noted by [2]. It could be due to enhanced organic carbon content of the soil as a result of organic manure application as compared to inorganic fertilizers [24]. They also opined that chicken manure used in the organic farming treatments enhanced the bacterial and fungal population greater than conventional farming. [8] opined that the soil microbial activity was always higher in organic plots than conventional plots.

From this study, it was concluded that, higher growth and yield parameters were recorded with the INM practice followed by TRRI practice and recommended dose of fertilizers (RDF) treatment [6]. Among the organic treatments, higher growth and yield parameters were recorded with TRRI practice followed by 100% RDN through green manure in both the years of study. Further, it was concluded that the application of 100 % RDN through green manure recorded more grain yield in both the years of experimentation [3]. Higher bacterial population was recorded with 100% RDN through green manure followed by TRRI practice, the lowest bacterial population was recorded with absolute control. Similar trend was also observed with fungal and actinobacterial population in both the years of study after the harvest of rice. The microbial population after the harvest of residual greengram (rice fallow pulse) was more with 100% RDN through green manure followed by TRRI practice [43]. Similar results were obtained from the soil enzymatic activities also in both the years of study after the harvest of rice and the residual green gram's harvest in the entire cropping system [5]. Invariably, all the organic treatments performed better in terms of building up soil microbial load and the soil enzymatic activities rafter the harvest of the crops in the entire cropping system than RDF and INM practices [4] and [5]. Green manures have a good potential to maintain soil fertility (the enzymatic activities in soil, like urease helps biological nitrogen fixation, phosphatase helps in phosphorous mobilization and increase in phosphorous availability in soil and the dehydrogenase helps in other organic substances production in lowland rice soil ecosystems) supplement nutrient supply to rice greengram cropping system and could contribute to greater food security [26], which found to be optimum for enhancing rice production for promoting organic rice farming in this site-specific Western agro-climatic zone of Coimbatore.

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