Impacts of Different Sources of Organic Manures on Soil Physico-Chemical Properties, Nutrient Balance and Yield of Rice-Greengram Cropping Sequence under Organic Farming

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Abstract: *Field experiments were carried out at Tamil Nadu Agricultural University, Coimbatore, India during Samba (August-December) and Summer (February- May) seasons of 2012-2013 and 2013-2014. This study mainly focus on soil physico-chemical properties, nutrient balance and yield in lowland rice-greengram cropping sequence under organic farming. The test variety of rice CO(R)48 and (Co 6) of greengram variety was used for both the year, under site-specific organic farming condition. The field experiment consisted of fourteen treatments which were laid out in Randomized Block Design, replicated thrice and square planting (25 x 25 cm) was adopted. Twelve organic treatments were compared with RDF and INM. The same layout was maintained for residual greengram for both the years. The soil physical and chemical properties, grain and straw yield of rice and greengram were recorded at harvest. Organic carbon content of soil was significantly increased with 100% RDN through green manure followed by all the organic treatments. The INM and RDF were noticed with lesser organic carbon content and the absolute control recorded with the lowest. The soil nutrient contents like soil available NPK, uptake of NPK by the crops and the nutrient (NPK) balance in the rice-greengam cropping sequence were also recorded. The less bulk density, more percent pore space and water holding capacity were recorded in all organic treatments and the INM recorded at par with 100% RDN through green manure and the higher bulk density, lesser percent pore space and water holding capacity was recorded with RDF. The soil available NPK and uptake of NPK at harvest of rice, was higher recorded with INM followed by RDF, whereas among the organic treatments, 100% RDN through green manure followed, by 25% RDN through each organic manures recorded more soil available and uptake of major nutrients in both the years of study. Similar trend was noticed in grain and straw yield of rice and greengram during two year cropping sequence. The N and P balance at the end of the cropping period was positive in all the treatments except the absolute control, whereas the negative K balance was noticed in the entire cropping sequence.*

Keywords: *soil physico-chemical properties, soil available NPK, uptake of NPK by crops, nutrient balance, organic farming, grain and straw yield of rice-greengram cropping sequence*

I. Introduction

In agriculture, one of the methods is organic farming which protects environment, quality of the food, animal health, natural resources on sustainable bases and is helpful for the social welfare purpose. This ensures to support the market and compensate for the internationalization of externalities (Lampkin, 2003). To ensure the environmental sustainability, organic agriculture is one of the best practices. Basically these practices are very harmless for human health, because they retain the soil fertility of soils and sustain the ecosystems. It depends upon natural biodiversity and locally adapted improved ecological processes or cycles, rather than genetically altered resources and the use of synthetic inputs (Auerbach, 2013).

Rice (*Oryza sativa* L.) is grown over 150 million ha worldwide and is the staple food for around three billion people. While rice provides a source of carbohydrate, in its polished form, it contains low concentrations of protein and key micronutrients needed in the human diet, including zinc (Zn) and iron (Fe) (Impa and Johnson-Beebout, 2012). Organic farming of rice will increase the nutrient values of product and reduce pesticide residues within it and allows the higher price of the crops in market (Rekha and Prasad, 2006).

Despite the past gains in rice production through chemical fertilizers, recent observations of stagnant or declining yields have raised concerns about the long term sustainability of the crop production (Khan *et al*., 2010). Continuous use of inorganic fertilizers leads to deterioration in soil chemical, physical and biological properties, and soil health (Mahajan *et al.*, 2008). The negative impacts of chemical fertilizers, coupled with escalating prices, have led to growing interests in the use of organic fertilizers as a source of nutrients. Organic materials such as FYM have traditionally been used by rice farmers (Satyanarayana *et al.*, 2002). FYM supplies all major nutrients (N, P, K, Ca, Mg, S,) necessary for plant growth, as well as micronutrients (Fe, Mn, Cu and Zn). Hence, it acts as a mixed fertilizer (Dejene *et al.*, 2012). The fact that the use of organic fertilizers improves soil structure, nutrient exchange and maintains soil health has raised interests in organic farming.

The importance of organic manure as a source of humus and plant nutrients to improve the soil fertility and soil health has been well established many (Larson & Clapp, 1984; Doran & Parkin, 1994; Sudha & Chandini, 2003). In recent times, reports on organic manure as a source of plant nutrients for field crops particularly as an alternative to chemical fertilizers in rice cultivation is also increasing (Banik et al., 2006; Siavoshi *et al.*, 2011). Plants acquire nutrients from two principal sources which are the soil, (through commercial fertilizer, manure and/or mineralization of organic matter); and the atmosphere (through symbiotic N fixation) (Vance, 2001; Rahman, 2013). This is because the cereal-legume cropping systems help to minimize excessive loss of N while maximizing N use efficiency and meeting cereal-legume cropping systems in India.

Improvement in the soil structure due to FYM application leads to a better environment for root development (Prasad and Sinha, 2000) and also improves soil water holding capacity (Dejene *et al.*, 2012). The fact that the use of organic fertilizers improves soil structure, nutrient exchange, and maintains soil health has raised interests in organic farming. The use of FYM alone as a substitute to inorganic fertilizer is not be enough to maintain the present levels of crop productivity of high yielding varieties. Therefore, integrated nutrient management in which both organic manures and inorganic fertilizers are used simultaneously is the most effective method to maintain a healthy and sustainably productive soil (Dejene *et al*., 2012). Emerging evidence indicated that integrated soil fertility management involving the judicious use of combined organic and inorganic resources is a feasible approach to overcome soil fertility constrains (Efthimiadou *et al*., 2010).

Keeping the importance of the organic farming, this study was undertaken and used different sources of organic manures on various combinations in comparison with RDF and INM. The main objective of this study was to assess the impact of soil physico-chemical properties, soil available NPK, uptake of NPK by the crops and the nutrient balance (NPK) with crop yields in the rice-greengram cropping sequence under organic farming in Western Zone of Coimbatore in Tamil Nadu, India.

II. Materials and Methods

A. *Description of the study site*

Field experiments were carried out at Tamil Nadu Agricultural University, Coimbatore, India during *Samba* (August-December) and Summer (February- May) seasons of 2012-2013 and 2013-2014 and 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 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.

B. *Materials used for the experiment*

C. *Planting materials*

The rice variety CO(R)48 and the greengram variety (Co 6) was used during *Samba* and *Summer* season as the test crop for both the years of experimentation.

III. Treatments Details

T_1 : Absolute control (No fertilizers / manures)
T_2 : 100% Recommended dose of nitrogen (RDN) through FYM
T_3 : 100% RDN through Vermicompost
T_4 : 100% RDN through Poultry manure
T_5 : 100% RDN through Green manure*
T_6 : 50% RDN through FYM + 50% RDN through Vermicompost
T_7 : 50% RDN through FYM + 50% RDN through Poultry manure
T_8 : 50% RDN through FYM + 50% RDN through Green manure*
T_9 : 50% RDN through Vermicompost + 50% RDN through Poultry manure
T_{10} : 50% RDN through Vermicompost + 50% RDN through Green manure*
T_{11}: 50% RDN through Poultry manure + 50% RDN through Green manure*

T_{12}: 25% RDN each through FYM + Vermicompost + Poultry manure + Green manure*
T_{13}: Recommended Dose of Fertilizers (RDF) through inorganic fertilizers (150:50:50) NPK kg ha^{-1}
T_{14}: Integrated Nutrient Management (INM) practice (RDF + GM @ 6.25 t ha^{-1})

*Green manure: Dhaincha (*Sesbania aculeata*) incorporation as green leaf manure at the time of puddling (two weeks prior to transplanting) .

T_{13} and **T_{14}** involving inorganic fertilizer applied plots were established separately well away from organic treatmental plots.

A. Experimental design

The experiments were laid out in a Randomized Block Design with three replications. The gross and net plot sizes were 5.0 x 4.0 m and 4.5 x 3.5 m, respectively.

IV. A. Organic manure application

On N equivalent basis, required quantities of farmyard manure, decomposed poultry manure, vermicompost were applied in the soil one week before transplanting, whereas the Dhaincha (*Sesbania aculeata*) green manure was applied two weeks prior to transplanting on wet weight basis. Different sources of organic manures nutrient content were furnished in (Table 1), and the quantity applied as per treatment schedule were furnished in (Table 2).

B. Inorganic fertilizer application

Recommended doses of 150:50:50 kg ha^{-1} of N, P and K in the form of urea, single super phosphate and muriate of potash were applied to the rice crop in respect of treatment T_{13}. The N was applied in four equal splits *viz.*, at basal, active tillering, panicle initiation and flowering stages. The entire dose of P and K were applied basally before sowing. Only rice crop was fertilized while greengram was raised as a residual crop without any organic and fertilizer application.

C. Integrated Nutrient Management (INM) application

In INM treatment T_{14}, 6.25 t ha^{-1} of green manure Dhaincha (*Sesbania aculeata*) was incorporated two weeks prior to transplanting along with the recommended doses of 150:50:50 kg ha^{-1} N, P and K in the form of urea, single super phosphate and muriate of potash were applied to the rice crop. In addition to this, application of 5 kg ha^{-1} of *Azospirillum*, 5 kg ha^{-1} of *Phosphobacteria* and 50 kg ha^{-1} of Zinc sulphate were applied as basal prior to transplanting.

D. Water management

The experimental plots were irrigated to 2 cm depth uniformly in all the treatments after the appearance of hair line cracks, upto panicle initiation stage. After panicle initiation, the crop was irrigated to 5 cm depth. Irrigation was stopped 15 days prior to harvesting of the crop. Similarly, for greengram one life irrigation was given immediately after sowing and thereafter 8-10 days interval irrigation was given and the irrigation was stopped 15 days prior to harvest.

E. Weed management

One Cono weeding was given on 15 days after transplanting followed by two hand weeding on 30th and 45th day after transplanting to keep the field under weed free condition. No herbicide was applied for organic treatments whereas for inorganic and INM treatments, Butachlor @ 2.5 lit ha^{-1} as pre emergence herbicide applied on 3 DAT.

F. Plant protection

Neem seed kernel extract @ 3% and *Panchagavya* @ 3% were sprayed at 35 and 50 days after transplanting as a prophylactic measure against rice leaf folder and stem borer. *Panchagavya* @ 3% was again sprayed at 70 days after transplanting along with liquid formulation of *Pseudomonas fluorescens* @ 500 ml ha^{-1} against the neck blast, leaf spot diseases and grain discoloration. For the inorganic treatments (T_{13} and T_{14}), the chemical plant protection measures were taken on need based.

G. Harvesting and threshing

Harvesting was done manually using hand sickles and for the rice crop, border rows in the plots were harvested first and the net plots were then harvested and threshed, cleaned and dried to 14% moisture level and the grain yield from net plot was calculated and expressed in kg ha^{-1} (Hemalatha *et al*., 2000). For determining seed yield of greengram, all the pods were harvested separately and threshed manually by beating with sticks, cleaned and dried to 12% moisture level and the grain yield from net plot was calculated and expressed in kg ha^{-1} .

H. Data collection and measurements

a). Soil physical analysis

Pre and post harvest soil physical analysis was done before and after rice greengram for bulk density and particle density following core method suggested by Gupta and Dakshinamoorthi (1981).The percentage of pore space and water holding capacity were determined by the pressure plate apparatus method suggested by Richards (1954).

b). Soil chemical analysis

1) Soil nutrients

Soil samples were taken before the start of experiment, during the experiment and harvest of rice and greengram. Soil samples were taken from each treatment plots at five places and composite soil sample was kept for analysis, replication wise at active tillering, panicle initiation, flowering and harvest stages of rice for analysis. Pre-sowing composite soil sample was analysed for mechanical and chemical properties (Table 1). The soil samples were collected from each plot at 0-15 cm depth, dried under shade, powdered, sieved through 2 mm sieve and analysed for pH, EC, organic carbon and macro-nutrients with following the standard procedures as shown in Table 3.

Table 3. Soil physico-chemical characteristics of the pre experimental field.

2) Nutrient uptake by plants

Green manure (Dhaincha) sample at the time of incorporation and rice plant samples collected at active tillering, panicle initiation, flowering and harvest stages and greengram at harvest stage for DMP were chopped, dried and ground into fine powder in a Willey mill and used for chemical analysis. For calculating nutrient uptake at harvest, nutrient content of grain and straw was multiplied with respective dry weights. The methods used for plant analysis are furnished in Table 4.

$$\text{Nutrient uptake} = \frac{\text{Nutrient content} \times \text{Total dry matter production } (\text{kg ha}^{-1})}{100} \quad (1)$$

Table 4. Analytical methods employed in plant and organic manure analysis

Parameters	Methods	Reference
Di acid extract	Sulphuric acid: Perchloric acid (5:2)	Biswas et al. (1977)
Tri acid extract	Nitric acid: Sulphuric acid: Perchloric acid (9:2:1)	Piper (1966)
Organic carbon	Chromic acid wet digestion	Walkley and Black (1934)
Total N	MicroKjeldahl's method using di acid extract	Humphries (1956)
Total P	Vanadomolybdophosphoric yellow colour method using tri acid extract	Piper (1966)
Total K	Flame photometry using tri acid extract	Piper (1966)
Total Ca	Versanate titration method using tri acid extract	Jackson (1973)
Total Mg	Versanate titration method using tri acid extract	Jackson (1973)
DTPA extractable Micronutrients	0.005 M DTPA using Atomic Absorption Spectrophotometry	Lindsay and Norvell (1978)

3) Soil physical analysis

Just after harvesting the crop, composite surface (0-20 cm) soil samples were collected from five spots for each plot for determination of total N, available P, bulk density, particle density, percent pore space, organic matter content as well as the water contents of the soil at field capacity and permanent wilting point. Available water capacity (AWC) is defined the water held between field capacity and the water content at permanent wilting point (PWP), and is the amount water a soil can store that is available for use by plants (Lipsius, 2002). The AWC therefore was calculated as using the following formula:

$$AWC = FC - Ø\ PWP$$

where FC is the water content at field capacity and Ø PWP is the water content at permanent wilting point.

4) Nutrient (NPK) Balance

Soil available nutrient (N, P_2O_5 and K_2O) balance in the cropping system was computed for the treatments as per the specific nutrient added to the rice crop and the nutrient added by the residual crop was put together computed as the total quantity of the nutrient added and the same manner the total quantity of nutrient removal was also computed. The specific nutrient's computed balance was derived from total quantity of the specific nutrient added was subtracted from the total quantity of the specific nutrient removed. The specific nutrient balance was computed from the soil specific nutrient status at harvest was subtracted from the specific nutrient status at initial as per the procedure suggested by Sadanandan and Mahapatra (1973) and the nutrient balance (either positive or negative) was expressed in kg ha^{-1}.

The nutrient balance exercises may serve as an instrument to provide indicators for sustainability of agriculture systems (Tiwari *et al*., 2010). However, the nutrient balance did not account for the addition of nutrients from rainfall, dry deposition, biological nitrogen fixation, nor gaseous losses of N, or weed uptake of nutrients from the soil (Tiwari *et al*., 2010). These external factors are uncontrollable during the field experimentation. Hence, the measurement of these inputs and output were beyond the scope of this study. The experimental field is rich with available potash, but it is unavailable to crops hence the negative balance is expressed at the end of the cropping sequence at all the treatments.

I. Statistical Analysis

The data on various characters studied during the course of investigation were statistically analyzed by using the procedure given by Gomez and Gomez (2010), for randomized block design, replicated thrice. Wherever treatment differences were significant ("F" test), critical differences were worked out at 5% probability level. Treatment differences that were not significant were denoted as "NS". "AGRESS" statistical software was used to analyze the collected field data from all the treatments, replication wise for both the years of experimentation.

V. Results and Discussion

A. Soil available nitrogen

The soil available nitrogen extended from 210 to 307, 202 to 284 and 208 to 298 kg ha^{-1} during 2012 and from 208 to 306,201 to 302, and 206 to 308 kg ha^{-1} during 2013, respectively at panicle initiation, flowering and harvest stages. The INM (T_{14}) registered higher available N (307, 284 and 298 kg ha^{-1} respectively) at panicle initiation, flowering and harvest stages of the crop and was comparable with RDF (T_{13}). Among the organic treatments, 100% RDN through green manure (T_5) registered higher available soil N (276, 253 and 267 kg ha^{-1} in 2012, and 275, 271 and 278 kg ha^{-1} in 2013, respectively) and which was comparable with 25% RDN through each organic manure (T_{12}) (274, 251 and 265 kg ha^{-1} in 2012 and 274, 269 and 276 kg ha^{-1} in 2013) followed by 50% RDN through vermicompost and green manure (T_9). The least availability of soil available N was with (T_1) (210, 202 and 208 kg ha^{-1}; 208, 201 and 206 kg ha^{-1} respectively) at panicle initiation, flowering and harvest stages of crop growth during both the years (Table 5 & 6).

Studies on available N status of the soil showed that the INM recorded maximum soil available N as compared to RDF and 100% RDN through green manure at all the stages of rice during both the years. This might be due to lower amount of residual nutrient in inorganic fertilizer applied field. Inorganic fertilizers cause immediate release of nutrients, which will be utilized by the crop or might have lost the environment through leaching or identification process. Similar results were also noted by Singh *et al.* (2006). Higher N availability in the organic manures such as poultry manure, vermicompost, FYM might be due to higher N content and continuous and slow release of nutrients from organic manure and increased biomass and accumulated soil organic matter. Similar findings were also reported by Amanullah *et al.* (2006) and Prasanthrajan *et al.* (2008). The soil available N was higher with different organic manures application than NPK fertilizer after harvest of greengram. 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 (Dalal *et al*., 1998; Pilbeam *et al*. 1998). 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 Ahmed *et al*. (2001). Higher soil available N due to legume in rice based cropping system was also observed by Chandrasekaran and Sankaran (1995). Rice-pulses cropping system prevailed protective cover to the soil aggregates which in turn led to improvement of physical properties and available nutrient status (Prakash *et al*., 2008).

B. Soil available Phosphorus

The soil available P ranged from 14.4. to 34.2, 14.0 to 32.4 and 13.9 to 31.8 kg ha^{-1} and from 14.9 to 35.7, 14.4 to 33.4 and 14.0 to 35.8 kg ha^{-1} during 2012 and 2013, respectively at panicle initiation, flowering and harvest stages (Table 5 & 6). The INM (T_{14}) improved soil available P status (34.2, 32.4 and 31.8 kg ha^{-1} in 2012 and 35.7, 33.4 and 35.8 kg ha^{-1} in 2013, respectively) and which was on par with RDF(T_{13}). Among the organic treatments, application of 100% RDN through green manure (T_5) recorded higher available soil P (30.3, 29.3 and 27.7 kg ha^{-1} in 2012; and 31.7, 29.2 and 31.6 kg ha^{-1} in 2013, respectively) and which was on par with 25% RDN through each organic manure (T_{12}) (30.1, 29.1 and 27.4 kg ha^{-1} in 2012 and31.3, 29.0 and 31.3 kg ha^{-1} in 2013, respectively). Lower soil available P was registered by absolute control treatment (T_1) (14.4, 14.0 and 13.9 kg ha^{-1}; 16.0, 14.9, 14.4 and 14.0 kg ha^{-1} in 2012 and 2013, respectively).

After harvest of rice, there was appreciable build up in available P status in soil due to application of organic manures during both the years which is largely attributed to minimization of P from fixed phosphorous. The INM practice registered higher available soil P and which was comparable with recommended NPK fertilizes and 100% RDN through green manure in both the years at all the stages of the crop. This might be due to the fact that during the mineralization of enriched organics, a number of organic acids, especially the hydroxyl ions (product of microbial metabolism) are produced, which release P through chelation or by removal of metal ions from the insoluble metal phosphates as observed by Mohandas and Appavu (2000).

The influence of organic manure in increasing the label P through complexing of cations like Ca^{2+} and Mg^{2+} responsible for P fixation has been reported by Balaguravaiah *et al.* (2005). Pazhanivelan *et al.* (2006) and Kaleeswari *et al.* (2007) reported that rock phosphate enriched manures maintain higher levels of P in soil solution for a longer period than the inorganic fertilizer. Higher soil available P could be attributed to decomposition of organic manures in the production of organic acids which in turn stabilize native insoluble P and led to available for longer period. Further, the higher quantity of crop residues would also contributed P to the soil. Lower soil available P observed after harvest of rice fallow greengram could be attributed to oxidation of the system. Greengram, being a pulse would have remove considerable quantity of P, bringing the soil available P to lower level. However, intensive cropping with uniformly applied P to both the rice crops of the cropping system resulted in buildup of soil P. The magnitude of soil P build up was commensurate with the quantity of N used in the cropping system.

C. Soil available potassium

The soil available K was extended from 388 to 582, 392 to 400 and 602 to 602 kg ha^{-1} during 2012 and from 384 to 580, 388 to 581 and 396 to 588 kg ha^{-1} during 2013, respectively at panicle initiation, flowering and harvest stages showing the influence due to INM, RDF and addition of organic manures in improving the soil available K. The INM (T_{14}) registered higher amount of soil available K (582, 575 and 602 kg ha^{-1} during 2012 and 580, 581 and 588 kg ha^{-1} during 2013, respectively) and which was comparable with RDF (T_{13}) (Table 5 & 6). Among the organic treatments, 100% RDN through green manure (T_5) recorded higher available soil K (529, 522 and 548 kg ha^{-1} in 2012; 527, 528 and 535 kg ha^{-1} in 2013, respectively) and which was comparable with 25% RDN through each organic manure (T_{12}) (528, 521 and 547 kg ha^{-1} in 2012; and 526, 527 and 534 kg ha^{-1} in 2013, respectively). Lower soil available K was registered with absolute control (T_1) (388, 392 and 400 kg ha^{-1} in 2012; 384, 388 and 396 kg ha^{-1} in 2013, respectively).

Higher soil available K was reported in the INM followed by RDF and 100% RDN through green manure. The lowest soil available K was registered with absolute control in both the years at all stages of the crop. The beneficial effect of available K may be ascribed to the reduction in K fixation and release of K due to interaction of organic matter. This is in accordance with the findings of Balaguruvaiah *et al.* (2005) and Agbede *et al.* (2008). The residual soil K status was reduced after harvest of greengram in all the treatments, which might be due to a higher depletion of K by the crop as reported by Barik *et al.* (2006). The removal of K by the crops might have exceeded the total addition of the fertilizer resulting in a decline in soil available K and the heavy demand of the rice-greengram system on soil K might be the other reason for the available K status. However, the magnitude of decrease in available K content might have been lesser than cumulative K removal by crops evidencing recuperation of the exchange K from other forms of soil K. Organic manures like FYM, Dhaincha (*Sesbania aculeata*), vermicompost, poultry manure, however, improved the available K status of soil marginally. Even greengram, haulms as organic source N exerted considerable influence or the soil fertility and its effect was similar to that of green manure though the magnitude was much less.

D. NPK uptake of rice

a). Nitrogen uptake

The N uptake was progressively increased with advancement in the growth stages *i.e* from active tillering to harvest stage. The uptake of N varies from 37.1 to 68.7, 49.8 to 84.8 and 61.1 to 104.0 kg ha^{-1} during 2012; 31.5 to 60.2, 52.1 to 89.7 and 63.0 to 106.0 kg ha^{-1} during 2013, respectively at panicle initiation, flowering and harvest stages of the crop. The increased N uptake was observed in the INM (T_{14}) (68.7, 84.8 and 104.0 in 2012 and 60.2, 89.7 and 106.0 kg ha^{-1} in 2013, respectively) at panicle initiation, flowering and harvest stages of the crop growth during both the years of study, and it was comparable with RDF (T_{13}), 100% RDN through green manure (T_5) and 25% RDN through each organic manures (T_{12}). The N uptake was lower in absolute control (T_1) (37.1, 49.8 and 61.1 kg ha^{-1} in 2012; 31.5, 52.1 and 63.0 kg ha^{-1} in 2013, respectively) (Table 7 & 8). N uptake was recorded maximum in the INM which was comparable with RDF and 100% RDN through green manure in both the years of the study. The reason for increased N uptake may be due to the fact that in lowland rice soils, organic manure and green manure incorporation undergoes decomposition at a steady rate resulting in the release of N – NH_4^+ into soil solution which is readily available to rice plant. Similar results were indicated by Sudha and Chandini (2005). The increased available N resulted in better N uptake which in turn improved the vegetative growth as indicated by taller plants, more number of tillers and increased leaf size leading to higher leaf area index (LAI) (Padmaja Rao, 1988).

b). Phosphorus uptake

During 2012 and 2013 the INM (T_{14}) recorded higher P uptake (15.0, 23.6 and 25.9 kg ha^{-1}; 16.8, 24.6 and 28.4 kg ha^{-1}, respectively) at panicle initiation, flowering and harvest stages, and it was on par with RDF (T_{13}), 100% RDN through green manure (T_5) and 25 % RDN through each organic manure (T_{12}). The lower P uptake was observed in absolute control (T_1) (6.3, 11.7 and 14.0 kg ha^{-1}; 7.1, 12.3 and 14.7 kg ha^{-1} respectively) (Table 7 & 8). Higher P uptake was recorded with the INM practice followed by RDF and 100% RDN through green manure. Increased P availability might be due to solubilisation of native P by the organic acids produced during organic manure decomposition, thus leading to better utilization of available P. The organic manure which besides N, might have increased the soil organic P content leading to increased P availability (Singh *et al*., 1981) and consequently higher P uptake of rice plants.

c) Potassium uptake

The highest K uptake was associated with the INM (T_{14}) (64.8, 104 and 137 kg ha^{-1} in 2012; 70.6, 107 and 145 kg ha^{-1} in 2013) and it was comparable with RDF (T_{13}) at panicle initiation, flowering and harvest stages. Among the organic treatments, the higher K uptake was recorded with 100% RDN through green manure (T_5) (58.0, 98.2 and 131kg ha^{-1} and 64.8, 101 and 138 kg ha^{-1} during 2012 and 2013, respectively) and was followed by 25% RDN through each organic manures (T_{12}). The lower K uptake was observed in absolute control (T_1) (33.5, 60.9 and 85 kg ha^{-1}; 39.9, 65.2 and 88 kg ha^{-1}, respectively) (Table 7 & 8).

d) Potassium uptake

The highest K uptake was associated with the INM (T_{14}) (64.8, 104 and 137 kg ha^{-1} in 2012; 70.6, 107 and 145 kg ha^{-1} in 2013) and it was comparable with RDF (T_{13}) at panicle initiation, flowering and harvest stages. Among the organic treatments, the higher K uptake was recorded with 100% RDN through green manure (T_5) (58.0, 98.2 and 131kg ha^{-1} and 64.8, 101 and 138 kg ha^{-1} during 2012 and 2013, respectively) and was followed by 25% RDN through each organic manures (T_{12}). The lower K uptake was observed in absolute control (T_1) (33.5, 60.9 and 85 kg ha^{-1}; 39.9, 65.2 and 88 kg ha^{-1}, respectively) (Table 7 & 8).

The highest K uptake was registered with the INM followed by RDF and 100% RDN through green manure in both the years of study. The enhanced K availability irrespective of the season coupled with higher K uptake due to organic manure incorporation could be attributed to higher DMP and K absorption, evidencing the priming effect of K contribution by organic manure.

Among the organic manures, *Sesbania aculeata* played a vital role in improving the uptake of NPK followed by poultry manure, vermicompost and FYM irrespective of the season in both the years of investigation. This might be due to the fact that quick release of N from the added green manure with increased availability of P through the mechanism of reduction, chelation and favorable changes in soil pH and K through the priming effect and besides the direct contribution of K by green manure. Higher K uptake in rice might be due to the increase in available K which may contributed to mineralization of organic manures or solubilization of nutrients from native sources during decomposition as reported by Walia and Kler (2005).

E. Soil chemical properties at harvest of rice

a) Soil pH and EC

The INM practice, organic manures and recommended NPK fertilizers application did not showed any significant difference on soil pH and EC as compared to initial and post harvest stage of the soil during both the years of study (Table 9).

b) Soil organic carbon

The soil organic carbon at post harvest stage ranged from 0.46 to 0.63 and 0.47 to 0.64% during 2012 and 2013, respectively (Table 9). At post harvest stage, higher organic carbon content was recorded with100% RDN through green manure (T_5) (0.63 and 0.64% during 2012 and 2013, respectively) and which was on par with 25% RDN through each organic manure (T_{12}) (0.61 and 0.62%). Invariably, all the organic treatments (T_2 to T_{12}) registered with the organic carbon content ranged from 0.52 to 0.63% and 0.53 to 0.64% during 2012 and 2013, respectively. The INM (T_{14}) registered with the organic carbon content of 0.51 and 0.52% in 2012 and 2013, respectively) and it was on par with the RDF (T_{13}) (0.50 and 0.51%). The absolute control (T_1) (0.46 and 0.47%) registered with lower organic carbon content in both the years of study.

F. Rice grain yield

The effect of treatment variables on grain yield (kg ha^{-1}) of rice are furnished in Table 9. 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 (T_{14}) recorded higher grain yield (6235 and 6270 kg ha^{-1} in 2012 and 2013, respectively) and was followed by RDF (T_{13}) during both the years of study. Among the organic treatments, 100% RDN through green manure (T_5) recorded higher grain yield (5628 and 5684 in 2012 and 2013, respectively) and was followed by 25% RDN through each organic manure (T_{12}) (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 (Ramesh *et al*., 2005).

G. Straw yield

The straw yield was significantly influenced by the treatments imposed in both the years of study. The straw yield ranged from 4907 to 7470 kg ha^{-1} and from 4939 to 7490 kg ha^{-1} during 2012 and 2013, respectively (Table 9). The INM (T_{14}) enhanced the straw yield (7470 and 7490 kg ha^{-1} in 2012 and 2013, respectively) which was on par with RDF (T_{13}). In organic treatments, 100% RDN through green manure (T_5) recorded higher straw yield (6445 and 6467 during 2012 and 2013 respectively) and was followed by 25% RDN through each organic manure (T_{12}) with 6376 kg ha^{-1} and 6455 kg ha^{-1} of straw yield during 2012 and 2013. In both the years of study, lower straw yield (4907 and 4939 during 2012 and 2013) was recorded in T_1 *viz*., absolute control. Physiologically proper partitioning might have occurred from source to sink, as a result improved the yield attributes. The results are similar to the findings of Vijay Kumar and Singh (2006). Mohandas *et al*. (2008) observed that the enhanced and continuous supply of nutrients by the enriched organics leading to better tiller production enhanced panicle length and filled grain of rice which ultimately leads to higher total biomass production of rice.

H. Soil physical properties at harvest of rice

a). Bulk density

Higher bulk density was observed with absolute control (T_1) (1.28 and1.27 Mg m^{-3} during 2012 and 2013, respectively) and which was comparable with RDF (T_{13}) (1.52 Mg m^{-3} in 2012 and 1.53 Mg m^{-3} in 2013 respectively and which were on par with each other. Lower bulk density was observed with 100% RDN through green manure (T_5) (1.15 and 1.14) followed by 25% RDN through each organic manure (T_{12}) (1.16 and 1.16) in both the years of study. Invariably all the organic treatments registered with lower bulk density when compared to INM. Higher bulk density was registered with RDF (T_{13}) (1.52 and 1.53) and it was inferior to absolute control and superior to the INM (T_{14}) (1.50 and 1.52) during both the years of study (Table 10).

b) Pore space

Higher pore space was registered with 100% RDN through green manure (T_5) (64.2 and 64.1%), followed by 25% RDN through each green manures (T_{12}) (56.6 and 57.0%). The INM (T_{14}) registered (54.6 and 54.9% during 2012 and 2013, respectively) and it was comparable with RDF (53.4% in 2012 and 53.6% in 2013). Lower pore space per cent was observed with absolute control (T_1) (52.9 and 53.1) in both 2012 and 2013. Invariably all the organic treatments from T_2 to T_{12} registered with higher pores pace per cent over INM during both the years of study.

c) Water holding capacity

Higher percentage of water holding capacity was registered with 100% RDN through green manure (T_5) (42.9 and 43.5), followed by 25% RDN through each green manures (T_{12}) (42.1 and 42.6). The INM (T_{14}) registered 39.4 and 40.2 during 2012 and 2013, respectively and it was comparable with RDF (35.4 in 2012 and 35.5 in 2013). Lower percentage of water holding capacity was observed with absolute control (T_1) (34.8 and 35.1) in both 2012 and 2013. Invariably all the organic treatments from T_2 to T_{12} registered with higher percentage of water holding capacity when compared to INM during both the years of study.

I. Soil pH, EC and organic carbon at harvest of greengram

a) Soil pH and EC

The INM, RDF and organic manures application did not showed any significant difference on soil pH and EC as compared to initial and post harvest stage of the soil after the harvest of residual greengram during both the years of study. However, the INM and RDF increased the soil pH when compared to all the organic treatments. This could be ascribed to the acidifying effect due to various organic acids (amino acid, glycine, cysteine and humic acid) or acid forming compounds and CO_2 that were released from decomposition of organic manures. Similar reasons were attributed by Brady and Weil (2005) and Natarajan (2007). Higher soil pH and EC was noticed with absolute control during both the years of study. The soil pH was reduced in the treatments where poultry manure was used and this might be due to lower or acidic pH of poultry manure. The electrical conductivity (EC) of soil was decreased due to application of organic manure treatments during both the years. The reduction in EC might be due to leaching of salts by the organic acids released by the organic sources. Anand (1992) was also corroborated the results.

The soil organic carbon at post harvest stage ranged from 0.45 to 0.62 and 0.44 to 0.63% during 2013 and 2014, respectively (Table 11).. At post harvest stage, higher organic carbon content was recorded with100% RDN through green manure (T_5) (0.62 and 0.63% during 2013 and 2014, respectively) and which was on par with 25% RDN through each organic manure (T_{12}) (0.60 and 0.61). Invariably all the organic treatments (T_2 to T_{12}) registered with the organic carbon content ranged from 0.51 to 0.62% and 0.52 to 0.63% during 2013 and 2014, respectively. The INM (T_{14}) registered with the organic carbon content of 0.50% and 0.51% in 2013 and 2014, respectively) and it was on par with RDF (T_{13}) (0.51% and 0.50%). The absolute control (T_1) (0.45% and 0.44%) registered with lower organic carbon content in both the years of study.

Organic carbon content of soil was significantly increased with 100% RDN through green manure and it was followed by all the other organic treatments. The INM and RDF were noticed with lesser organic carbon content and the absolute control recorded with the lowest soil organic carbon content in both the years of study. This is in conformity with the results noted by Sheeba and Kumarasamy (2001) and Singh *et al.* (2007). This might be ascribed to the fact that organic manures

The introduction of green manure improved the organic carbon content of soil due to that fraction of green manure which is fairy resistant to decomposition but mineralizes at a slower rate (Bouldin *et al.* 1988) and the land submergence resulting in anerobiosis, led to slower decomposition and buildup of soil organic carbon. This corroborates the descriptions of Doberman and Witt (2000). Further, the addition of stubbles of rice would add substantial quantity of organic matter. Similar increase in soil organic carbon due to incorporation of green manure and pulses residue in a crop sequence has been reported by Palaniappan, (1985). There was slight increase in soil organic carbon status in all the organic treatments, INM and RDF at the end of second cropping cycle from initial level, probably due to the incorporation of higher quantities of crop residues to the soil. The incorporation of higher quantities of crop residues resulted in increased soil organic carbon content in rice-greengram cropping sequence.

J. Grain and haulm yield of residual greengram

During 2013 and 2014, the residual greengram recorded higher grain yield (kg ha^{-1}) with INM (T_{14}) (642 and 698) followed by RDF treatment (T_{13}) (437 and 502), Among the organic treatments, higher grain yield was recorded with 100% RDN through green manure (T_5) (428 and 496) followed by 25% RDN through each organic manure (T_{12}) (410 and 476) in both the years of study (Table 11). The least grain 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 was evidenced by Seshadri *et al.*, 2005. 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

like poultry manure owing to its higher organic matter content could have increased moisture holding capacity of the soil and resulted in considerable residual carbon. Further, improved physical properties might have provided a conductive environment for humus formation. This overlaps with the views of Ramesh and Chandrasekarn (2004) and Andesodun *et al.* (2005). The additive effect of FYM with other organic manures maintaining higher organic carbon level might be due to its less rapid decomposition. Similar, results were also reported by Ranjan *et al.* (2004). The results revealed that the cropping sequence of greengram – rice had favorable effect towards build up of organic carbon in the soil.

organic manures which was followed by FYM, poultry manure and vermicompost. This would have been also due to the better residue addition in rice based cropping system. 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 has been reported by Gedam *et al*., (2008).

K. Soil physical properties at harvest of greengram

a). Bulk density

Higher bulk density was observed with RDF followed by the INM (1.54 and 1.52; 1.53 and 1.52 Mg m^{-3} during 2013 and 2014, respectively).

Among each organic manure treatment and which were on par with each other. Invariably all the organic treatments registered with lower bulk density when compared to RDF and INM (Table 12).Mg m^{-3} during 2013 and 2014, respectively). Among the organic treatments, 100 % RDN through green manure recorded the lower bulk density (1.15 and 1.14 during 2013 and 2014, respectively) and which was comparable with 25% RDN through each organic manure treatment and which were on par with each other. Invariably all the organic treatments registered with lower bulk density when compared to RDF and INM (Table 12).

b). Pore space

Higher pore space was registered with 100% RDN through green manure (T_5) (63.4 and 63.5%), followed by 25% RDN through each green manures (T_{12}) (56.5 and 56.3%). The INM practice (T_{14}) registered (54.6 and 54.4% during 2013 and 2014, respectively) and it was comparable with RDF (52.3% in 2013 and 52.1% in 2014). Lower pore space per cent was observed with absolute control (T_1) (52.4 and 52.6%) in both 2013 and 2014. Invariably all the organic treatments from T_2 to T_{12} registered with higher pore space per cent over INM during both the years of study.

c). Water holding capacity

Higher percentage of water holding capacity was registered with 100% RDN through green manure (T_5) (46.2 and 45.8), followed by 25% RDN through each green manures (T_{12}) (40.6 and 41.8). The INM (T_{14}) registered (37.8 and 40.4 during 2013 and 2014, respectively) and it was comparable with RDF (34.5 in 2013 and 34.7 in 2013). Lower percentage of water holding capacity was observed with absolute control (T_1) (34.3 and 34.6) in both 2013 and 2014.

Invariably all the organic treatments from T_2 to T_{12} registered with higher percentage of water holding capacity when compared to INM during both the years of study. Application of 100% RDN through green manure followed by all the other organic treatments recorded improved soil physical properties in rice-pulse system over the INM and RDF. The absolute control resulted with reduced soil physical properties during both the years of experiments.

Several studies (Kannan *et al.*, 2005 Natarajan 2007) revealed that organic manures increases water holding capacity, pore space and decreases bulk density of soil. Manickam (1993) concluded that the added organic residues to the soil undergo microbial decomposition and in this process, various organic acids other products of decay like polysaccharides are released which act as strong binding agents in the formation of large and arable aggregates.

The reduced bulk density with the organic manures application was due to the improvement of soil aggregation, soil structural improvement and increased porosity (Agbede *et al.*, 2008). Application of organic manures increased moisture content of the soil better than the chemical fertilizers due to its high organic carbon content and addition of organic matter of the soil.

Organic matter has the ability to retain appreciable amounts of soil moisture as suggested by Agyenim *et al*. (2006). Application of organic manures increased moisture content of the soil better than the chemical fertilizers due to its high organic carbon content and addition of organic matter of the soil. Organic matter has the ability to retain appreciable amounts of soil moisture as suggested by Agyenim *et al.* (2006). The FYM application reduced bulk density of soil due to higher organic matter content of soil added through FYM and increased water holding capacity due to humic substances penetrated the inter lamella space of clay minerals and influenced the interaction of clay with other soil constituents and ultimately increased the water holding capacity of the soil (Singh *et al.*, 2006). The recommended NPK fertilizers treatment showed higher bulk density and lower water holding capacity and pore space. This might be attributed to deterioration of soil structure by inorganic fertilizers. Kannan *et al.* (2005) and Krishnakumar (2007) also reported similar results. In the present investigation, rice-greengram cropping sequence improved the physical condition. It might be due to readily decomposable huge organic matter from greengram, had an advantage of releasing various humic fractions and thus, enhanced nutrient release, apart from that greengram exerted their root system into deeper horizons of soil and may enable the absorption of nitrates, sulphates to avoid buildup of P in the soil and helped soil particles to bind together extensively which in turn led to improvement of physical properties. Prakash *et al.*, (2008) also opined the same nature of results.

L. Soil available NPK balance in the cropping system

a) Total soil available N balance at the end of two years (2012 – 14)

The INM (T_{14}) positively influenced post harvest available N and its balance (Table 13). Net N loss was high (-4.0 kg ha^{-1}) in T_1, *viz.*, without INM, organic manures and RDF, whereas, net N gain was maximum recorded with the INM (T_{14}) (85.0 kg ha^{-1}). The 100% RDN through green manure (T_5) (46.0 kg ha^{-1}), 25% RDN through each organic manure (T_{12}) (42.0 kg ha^{-1}), 50% RDN through vermicompost and poultry manure (T_9) (40.0 kg ha^{-1}) and 50% RDN through FYM and poultry manure (T_7) (36.0 kg ha^{-1}) at the end of experiment. RDF (T_{13}) recorded the soil available N balance of 10.0 kg ha^{-1} during the cropping sequence 2012-14. The INM increased soil available N balance. The balance was positive, indicating net gain, when rice crop received organic manures.

All the organic treatments showed positive N balance at the end of second year cropping cycle. Higher N balance was observed with 100% RDN through green manure (46.0 kg ha^{-1}) at the end of cropping sequence 2012-14. Among the organic treatments, 100% RDN through green manure recorded higher N balance (46.0 kg ha^{-1}) followed by 25% RDN through each organic manures (42.0 kg ha^{-1}). The lowest N balance was recorded with absolute control (-4.0 kg ha^{-1}) at the end of the two year cropping sequence. The increased N balance might be due to the slow decomposition of organic manures led to steady N release to meet the requirement of crops of initial stages. Even after completion of growing period, mineralization of N could be continued to the soil pool (Bouldin *et al.*, 1988). This might have helped in maintaining the soil available N in spite of depletion by the crops. Similar observations have been earlier made by Amanullah *et al.* (2007). The net loss of soil available N was observed when N was not applied through either organic manures or inorganic fertilizers (absolute control) end of two years. This might be due to susceptibility of inorganic fertilizers to various losses during after mineralization in addition to uptake by crops.

b) Total soil available P balance at the end of two years (2012-14)

The INM and the addition of organic manures increased available soil P balance (Table 14). Organic manuring positively influenced post harvest available P and its balance N and P loss was high in (-2.5) absolute control (T_1) *viz.*, without INM, organic manures and RDF, whereas net P gain was maximum recorded with the INM (T_{14}) (5.1 kg ha^{-1}), followed by 25% RDN through each organic manures(T_{12}) (3.1 kg ha^{-1}), 100% RDN through green manure (T_5) (3.0 kg ha^{-1}) 50% RDN through FYM and green manure (T_8) (3.0 kg ha^{-1})) and 50% RDN through vermicompost and poultry manure (T_9) (2.9 kg ha^{-1}). The available soil P balance was observed with RDF (T_{13}) (2.8 kg ha^{-1}) at the end of the experiment. The net gain of available P was observed with organic manure treatments during both the years.

Maximum gain of available P was registered with the INM (5.1 kg ha^{-1}) which was followed by 25% RDN through each organic manures (3.1 kg ha^{-1}). This might be due to the slow decomposition of organic manures and more mobilization of native P and uptake by the crop. This was inconformity with results observed by Pazhanivelan *et al.* (2006). The absolute control (-2.5 kg ha^{-1}) recorded net negative balance of P during both the years.

c) Total oil available K balance at the end of two years (2012-14)

The INM and the addition of organic manures have increased available soil K balance (Table 15). The INM, addition of organic manures and RDF resulted net negative K balance. The net K loss was higher in absolute control (T_1) (-118.0 kg ha^{-1}) followed by 50% RDN with FYM and vermicompost(T_6) (-85.0 kg ha^{-1}), 50% RDN through vermicompost and green manure (T_{10}) (-82.0kgha^{-1}), 50% RDN through poultry manure and green manure (T_{11}) (-66.0 kg ha^{-1}), 25% RDN through each organic manures (T_{12}) (-50.0 kg ha^{-1}), 100% RDN through green manure (T_5) (-46.0 kg ha^{-1}), RDF (T_{13}) (-44.0 kg ha^{-1}) and INM (T_{14}) resulted with the net loss of K (-16.0 kg ha^{-1})) at the end of two years cropping sequence 2012-14. The net negative balance of K was noted in all the treatments at the end of two year cropping sequence. The net K loss was higher in absolute control (-118.0 kg ha^{-1}) followed by 50% RDN through FYM and vermicompost (-85.0 kg ha^{-1}). The lowest net negative balance was observed with INM (-16.0 kg ha^{-1}). This was attributed to luxurious consumption of K by crops (Barik *et al.*, 2008).

VI. Conclusion

The grain and straw yield of rice and greengram was higher recorded with INM followed by RDF, whereas among the organic treatments, 100% RDN through green manure followed by 25% RDN through each organic manure recorded the maximum during both the years of study. Similar trend was noticed in the available soil N and uptake of N status on rice crop. The same trend was noticed in soil available and uptake of P and K on rice crop. The least soil available NPK and uptake of NPK of rice was observed with absolute control. Organic carbon content of soil was significantly increased with 100% RDN through green manure and it was followed by all the other organic treatments. INM and RDF were noticed with lesser organic carbon content and the absolute control recorded with the lowest soil organic carbon content in both the years of study. INM, different organic manures and RDF application did not showed any significant difference on soil pH and EC as compared to initial and post harvest stage of the soil during both the years of study. Application of 100% RDN through green manure followed by all the other organic treatments improved soil physical properties in rice-pulse system over INM and RDF. The absolute control resulted with reduced soil physical properties during both the years of experiments.

The soil available N and P balance was positive with INM (85.0 and 5.10 kg ha^{-1}) at the end of two year of cropping system. Among the organic treatments, 100% RDN through green manure recorded the highest N balance (46.0 kg ha^{-1}) followed by 25% RDN through each organic manures (42.0 kg ha^{-1}) at the end of the cropping system (2012 -14). Similarly, the highest P balance was recorded with 25% RDN through each organic manures (3.1 kg ha^{-1}) and which was followed by 100% RDN through green manure (3.0 kg ha^{-1}). The least N and P balance was noticed with absolute control (-4.0 and -2.5 kg ha^{-1}). This may be due to the faster uptake of soil available nutrients by the plants which did not received the fertilizers or manures in the entire cropping period. Invariably, all the treatments recorded net negative K balance in both the years of cropping system. To improve the K balance continuous usage of crop residues, rice stubbles and greengram haulms incorporation and supplementations of mineral K application is required to sustain the availability of soil K.

In general, during the period of field experimentation the pre-season green manuring and application of organic manures and the implementation of INM showed favorable response towards improvement in soil fertility status and soil health when compared with their initial values except absolute control. The inclusion of green manure (*Sesbania aculeata*) in rice based cropping sequence reduced the loss of native nitrate N accumulated during aerobic cycle of the rice based cropping sequence and also conserved it, which would be lost upon flooding. Further, the biological N fixation (BNF) also improved the soil fertility status. The addition of organic manure of rice crop can build up the soil fertility over a period of time and the nutrient supply was increased at slower rate.

The incorporation of greengram haulms as the source of organic manure also improved the soil fertility and soil health over a period of time. Similar results were supported by (Sangeetha *et al*., 2013) in rice -blackgram cropping sequence. Green manures have a good potential to maintain soil fertility, supplement nutrient supply to rice crop and could contribute to greater food security (Palaniappan, 2000), which found to be optimum for enhancing rice production for promoting organic rice farming in Western agro-climatic zone of Coimbatore.

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Abbreviations: The following abbreviations are used in this manuscript.

FYM: Farmyard manure, VC: Vermicompost, PM: Poultry manure and GM: Green manure, Dhaincha (*Sesbania aculeata*), INM: Integrated Nutrient Management, RDF: Recommended Dose of Fertilizers, RDN: Recommended Dose of Nitrogen, Absolute control: No fertilizers / manures, N: Nitrogen, P: Phosphorus, K: Potassium, PI: Panicle Initiation, F: Flowering, H: Harvest. EC: Electrical Conductivity, OC: Organic Carbon, and WHC: Water Holding Capacity, DAT: Days After Transplanting, LAI: Leaf Area Index, AWC: Available Water Capacity, PWP: Permanent Wilting Point, FC: Field Capacity.

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Table 1. Nutrient content of organic manures used in the field experiment on dry weight basis

Organic manures	Samba 2012 : Nutrient content (%)						Samba 2013:; Nutrient content (%)					
	N	P	K	Ca	Mg	C : N Ratio	N	P	K	Ca	Mg	C : N Ratio
Farm yard manure	0.60	0.42	0.64	0.21	0.18	20:96	0.58	0.40	0.68	0.18	0.17	23:00
Vermicompost	1.91	0.64	1.20	0.31	0.27	18:98	1.88	0.68	1.24	0.33	0.28	18:82
Poultry manure	2.27	1.42	1.24	4.22	0.65	17:36	2.25	1.45	1.22	4.01	0.62	17:41
Green manure (Dhaincha) Sesbania aculeata	2.67	0.68	1.26	1.17	0.75	18:91	2.65	0.66	1.28	1.07	0.77	18:64

Table 2. Quantity of organic manures added on N equivalent basis and quantity of P_2O_5 and K_2O substituted (kg ha^{-1}).

Treatments	Quantity added for 100 % N		P_2O_5 and K_2O		P_2O_5 and K_2O	
	2013	2014	Substituted during 2013		Substituted during 2014	
T_1: Absolute control	-	-	-	-	-	-

T_2: 100% RDN through FYM	25000	25862	105.00	160.00	103.00	176.00
T_3: 100% RDN through VC	7853	7979	50.30	94.24	54.26	98.94
T_4: 100% RDN through PM	6608	6667	93.83	81.94	96.67	81.34
T_5: 100% RDN through GM	25281	25470	38.20	70.79	37.36	72.45
T_6: 50% RDN each of FYM + VC	12500 +3927	12931 + 3990	77.65	127.12	78.63	137.47
T_7: 50% RDN each of FYM + PM	12500 + 3304	12931 + 3334	99.42	120.97	99.84	128.67
T_8: 50% RDN each of FYM + GM	12500 +12640	12931 + 2735	71.60	115.40	70.18	124.23
T_9: 50% RDN each of VC+ PM	3927 + 3304	3990 + 3334	72.07	88.09	75.47	90.14
T_{10} : 50% RDN each of VC+ GM	3927 + 2640	3990 + 2735	44.25	82.52	45.81	85.70
T_{11} : 50% RDN each of PM + GM	3304 + 12640	3334 + 2735	66.02	76.37	67.02	76.90
T_{12} : 25% RDN each of FYM + VC + PM + GM	6250 + 1963 + 1653 + 6320	6466 + 1995 + 1666 + 368	71.86	101.75	72.83	107.19
T_{13} : RDF : (150 : 50 : 50) NPK kg ha^{-1}	-	-	-	-	-	-
T_{14} : INM Practice (RDF+GM @ 6.25 t ha^{-1})	-	-	-	-	-	-

FYM: Farmyard manure, VC: Vermicompost, PM: Poultry manure and GM: Green manure Dhaincha (*Sesbania aculeata*), INM: [(150:50:50) NPK kg ha^{-1}, *Azospirillum*@ 2.5 kg ha^{-1}, *Phosphobacterium*@ 2.5 kg ha^{-1}, Zinc sulphate @ 50 kg ha^{-1} and Green manure 6.25 t ha^{-1}] all put together, RDF : (150 : 50 : 50) NPK kg ha^{-1}.

3.2. Layout plan of experimental field (2012-2014)

I. Organic treatments (Fig. 1)

Main irrigation channel

5 m ↔ ; 4m ↕

REPLICATION I		REPLICATION II		REPLICATION III	
T_2	**T_6**	**T_{12}**	**T_4**	**T_1**	**T_{11}**
T_5	**T_3**	**T_{10}**	**T_3**	**T_3**	**T_8**
T_{12}	**T_8**	**T_8**	**T_5**	**T_5**	**T_{12}**
T_{10}	**T_1**	**T_{11}**	**T_7**	**T_2**	**T_6**
T_4	**T_9**	**T_9**	**T_2**	**T_{10}**	**T_9**
T_7	**T_{11}**	**T_1**	**T_6**	**T_4**	**T_7**

Min irrigation channel

REPLICATION I **REPLICATION II** **REPLICATION III**

II. Inorganic treatments (Fig. 2)

Main irrigation channel

R_1 T_{13}	**R_2 T_{14}**	**R_3T_{13}**
R_3T_{14}	**R_2T_{13}**	**R_1T_{14}**

4 m ↕ ; 5m ↔

Main irrigation channel

Table 3. Soil physico-chemical characteristics of the pre experimental field.

Particulars	Value	Method	Reference
A. Soil physical properties			
I. Mechanical analysis			
Clay (%)	47.5	Robinson's International Pipette Method	Piper (1966)
Silt (%)	22.3	"	Piper (1966)
Coarse sand (%)	11.9	"	Piper (1966)
Fine sand (%)	18.3	"	Piper (1966)
Textural class	Clay loam	"	Piper (1966)
Bulk density (Mg m^{-3})	1.23	Core method	Gupta and Dakshinamoorthy (1981)
Particle density (Mg m^{-3})	2.56	Core method	
Pore space (%)	54.20	Pressure plate apparatus method	Richards (1954)
Water holding capacity (%)	36.60	Pressure plate apparatus method	Richards (1954)
II.Chemical characteristics			
PH	8.0	Glass electrode in the "ELICO" pH meter	Jackson (1973)
Electrical conductivity (dS m^{-1})	0.43	Using "ELICO" conductivity bridge	Jackson (1973)
Organic carbon (%)	0.45	Chromic acid wet digestion method	Walkley and Black (1934)
Available N (kg ha^{-1})	214	Alkaline permanganate method	Subbiah and Asija 1956)
Available P_2O_5 (kg ha^{-1})	16.7	Olsen method using colorimeter	Olsen et al. (1954)
Available K_2O (kg ha^{-1})	536	Flame photometric method	Stanford and English (1949)

Table 4. Analytical methods employed in plant and organic manure analysis

Parameters	Methods	Reference
Di acid extract	Sulphuric acid: Perchloric acid (5:2)	Biswas et al. (1977)
Tri acid extract	Nitric acid: Sulphuric acid: Perchloric acid (9:2:1)	Piper (1966)
Organic carbon	Chromic acid wet digestion	Walkley and Black (1934)
Total N	MicroKjeldahl's method using di acid extract	Humphries (1956)
Total P	Vanadomolybdophosphoric yellow colour method using tri acid extract	Piper (1966)
Total K	Flame photometry using tri acid extract	Piper (1966)
Total Ca	Versanate titration method using tri acid extract	Jackson (1973)
Total Mg	Versanate titration method using tri acid extract	Jackson (1973)
DTPA extractable Micronutrients	0.005 M DTPA using Atomic Absorption Spectrophotometry	Lindsay and Norvell (1978)

Table 5. Impact of different organic manures on soil available NPK (kg ha^{-1}) at different growth stages of rice *Samba* 2012

Treatments	N			P			K		
	PI	F	H	PI	F	H	PI	F	H
T_1 : Absolute control	210	202	208	14.4	14.0	13.9	388	392	400
T_2 : 100% RDN through FYM	254	242	255	19.5	18.2	22.3	507	498	528
T_3 : 100% RDN through VC	258	243	256	21.5	18.8	23.1	514	508	532
T_4 : 100% RDN through PM	266	245	259	22.9	19.8	23.7	519	512	538
T_5 : 100% RDN through GM	276	253	267	30.3	29.3	27.7	529	522	548
T_6 : 50% RDN each of through FYM + VC	250	240	253	17.9	17.1	21.8	498	488	524
T_7 : 50% RDN each of through FYM + PM	269	246	260	23.5	20.2	24.1	523	516	542
T_8 : 50% RDN each of through FYM + GM	256	242	255	20.9	18.6	22.7	510	504	530
T_9 : 50% RDN each of through VC+ PM	271	248	262	23.8	20.4	24.4	526	519	545
T_{10} : 50% RDN each of through VC+ GM	252	241	254	18.5	17.8	21.4	502	494	526
T_{11} : 50% RDN each of through PM + GM	260	244	258	21.4	19.4	23.4	516	510	536

T_{12} : 25% RDN each of through FYM + VC + PM + GM	274	251	265	30.1	29.1	27.4	528	521	547
T_{13} : RDF (150 : 50 : 50) NPK kg ha^{-1}	278	255	269	30.4	29.5	27.8	530	523	550
T_{14} : INM Practice (RDF + GM @ 6.25 t ha^{-1})	307	284	298	34.2	32.4	31.8	582	575	602
SEd	**25**	**23**	**24**	**2.2**	**2.0**	**2.2**	**49**	**48**	**51**
CD (p=0.05)	**52**	**48**	**50**	**4.6**	**4.2**	**4.6**	**103**	**101**	**106**

Table 6. Impact of different organic manures on soil available NPK (kg ha^{-1}) at different growth stages of rice *Samba* 2013

Treatments	**N**			**P**			**K**		
	PI	**F**	**H**	**PI**	**F**	**H**	**PI**	**F**	H
T_1 : Absolute control	208	201	206	14.9	14.4	14.0	384	388	396
T_2 : 100% RDN through FYM	266	254	263	19.9	19.8	20.4	510	507	521
T_3 : 100% RDN through VC	269	258	265	21.9	21.0	21.4	514	512	524
T_4 : 100% RDN through PM	273	264	269	23.3	22.0	22.6	518	519	528
T_5 : 100% RDN through GM	275	271	278	31.7	29.2	31.6	527	528	535
T_6 : 50% RDN each of through FYM + VC	265	252	261	18.5	18.7	19.8	507	501	518
T_7 : 50% RDN each of through FYM + PM	272	266	271	23.9	22.4	23.0	520	521	530
T_8 : 50% RDN each of through FYM + GM	265	256	264	20.7	20.6	21.0	512	510	522
T_9 : 50% RDN each of through VC+ PM	273	268	274	24.3	22.6	23.3	524	525	532
T_{10} : 50% RDN each of through VC+ GM	266	253	262	19.3	19.4	20.0	508	504	520
T_{11} : 50% RDN each of through PM + GM	271	260	267	22.5	21.5	22.2	516	516	526
T_{12} : 25% RDN each of through FYM + VC + PM + GM	274	269	276	31.3	29.0	31.3	526	527	534
T_{13} : RDF (150 : 50 : 50) NPK kg ha^{-1}	277	273	280	31.8	29.4	31.8	528	529	536
T_{14} : INM Practice (RDF + GM @ 6.25 t ha^{-1})	306	302	308	35.7	33.4	35.8	580	581	588
SEd	**25**	**24**	**25**	**2.2**	**2.2**	**2.2**	**49**	**49**	**50**
CD (p=0.05)	**52**	**50**	**52**	**4.6**	**4.6**	**4.6**	**103**	**103**	**105**

Table 7. Impact of different organic manures on NPK uptake (kg ha^{-1}) at different growth stages of rice during *Samba* 2012

Treatments	**N**			**P**			**K**		
	PI	**F**	**H**	**PI**	**F**	**H**	**PI**	**F**	**H**
T_1 :Absolute control	37.1	49.8	61.1	6.3	11.7	14.0	33.5	60.9	85.1
T_2 :100% RDN through FYM	40.1	67.2	80.4	8.3	16.3	19.5	50.8	81.2	104.2
T_3 :100% RDN through VC	42.2	68.1	84.2	9.1	16.3	19.6	46.8	84.0	110.3
T_4 :100% RDN through PM	42.2	69.8	88.6	9.9	16.8	19.6	50.1	88.4	118.1
T_5 :100% RDN through GM	60.6	78.6	96.4	13.2	20.5	22.4	58.0	98.2	131.4
T_6 :50% RDN each of through FYM + VC	42.5	65.9	76.3	7.6	16.1	19.4	40.9	79.5	100.1
T_7 :50% RDN each of through FYM + PM	48.9	70.4	90.4	10.3	17.1	19.6	53.1	92.8	124.2
T_8 :50% RDN each of through FYM + GM	44.3	67.9	82.4	8.7	16.3	19.5	44.6	82.6	107.3

T_9 :50% RDN each of through VC+ PM	51.5	74.8	93.1	10.5	17.5	20.4	55.2	95.4	128.3
T_{10} :50% RDN each of through VC+ GM	43.7	66.6	78.4	7.9	16.2	19.4	45.1	80.6	102.1
T_{11} :50%RDNeach of through PM + GM	45.5	68.6	86.5	9.5	16.3	19.6	48.1	86.2	114.2
T_{12} :25%RDNeach of through FYM + VC + PM + GM	53.3	76.8	95.0	13.1	20.4	22.2	57.6	97.8	130.2
T_{13} :RDF (150 : 50 : 50) NPK kg ha^{-1}	60.7	80.6	99.1	13.4	20.6	22.8	59.2	99.8	133.1
T_{14} :INM Practice (RDF + GM @ 6.25 t ha^{-1})	68.7	84.8	104.0	15.0	23.6	25.9	64.8	104.0	137.4
SEd	**4.5**	**6.5**	**8.0**	**0.9**	**1.6**	**1.8**	**4.6**	**8.1**	**10.2**
CD (p=0.05)	**9.6**	**13.6**	**16.8**	**1.9**	**3.4**	**3.8**	**9.6**	**17.0**	**21.5**

Table 8. Impact of different organic manures on NPK uptake (kg ha^{-1}) at different growth stages of rice during Samba 2013

Treatments	**N**			**P**			**K**		
	PI	**F**	**H**	**PI**	**F**	**H**	**PI**	**F**	**H**
T_1 :Absolute control	31.5	52.1	63.0	7.1	12.3	14.7	39.9	65.2	88.1
T_2 :100% RDN through FYM	42.0	72.6	82.0	9.9	17.1	21.8	48.6	83.4	108.2
T_3 :100% RDN through VC	42.6	73.8	86.0	10.7	17.2	22.2	52.6	86.8	116.3
T_4 : 100% RDN through PM	46.6	75.4	91.4	11.5	17.9	23.0	57.1	90.2	126.4
T_5 :100% RDN through GM	54.2	82.5	99.8	14.7	22.4	24.5	64.8	101.0	138.5
T_6 : 50% RDN each of through FYM + VC	41.3	70.1	77.5	9.0	17.0	21.0	47.9	82.9	106.1
T_7 :50% RDN each of through FYM + PM	48.2	76.0	93.2	11.9	19.0	23.4	60.0	94.2	132.2
T_8 :50% RDN each of through FYM + GM	42.4	73.2	84.0	10.3	18.5	22.0	50.4	84.8	112.3
T_9 :50% RDN each of through VC+ PM	50.4	78.4	95.0	12.3	19.1	23.8	62.0	98.6	135.4
T_{10} :50% RDN each of through VC+ GM	41.8	71.4	79.4	9.4	17.0	21.4	48.0	83.1	106.1
T_{11} :50%RDNeach of through PM + GM	44.6	74.8	90.0	11.1	17.3	22.4	54.1	88.8	121.2
T_{12} :25%RDNeach of through FYM + VC + GM	52.0	80.0	97.2	14.6	22.1	24.2	64.0	100.0	137.3
T_{13} :RDF (150 : 50 : 50) NPK kg ha^{-1}	55.0	84.7	102.0	14.8	22.6	24.6	65.4	103.0	139.4
T_{14} :INM Practice (RDF + GM @ 6.25 t ha^{-1})	60.2	89.7	106.0	16.8	24.6	28.4	70.6	107.0	145.5
SEd	**4.3**	**6.9**	**8.2**	**1.1**	**1.7**	**2.1**	**5.1**	**8.3**	**11.2**
CD (p=0.05)	**9.0**	**14.5**	**17.2**	**2.3**	**3.6**	**4.4**	**10.7**	**17.4**	**23.5**

Table 9. Impact of different organic manures on soil pH, EC, organic carbon (OC) at post harvest soil, grain and straw yield of rice.

Treatments	***samba* 2012**					***samba* 2013**				
	Soil pH	**EC dSm-1)**	**OC (%)**	**Grain yield (kg ha-1)**	**Straw yield (kg ha-1)**	**Soil pH**	**EC (dSm-1)**	**OC (%)**	**Grain yield (kg ha-1)**	**Straw yield (kg ha-1)**
T_1: Absolute control	7.98	0.42	0.46	3602	4907	7.96	0.41	0.47	3646	4939
T_2 : 100% RDN through FYM	7.84	0.40	0.52	4164	5424	7.81	0.40	0.53	4190	5425
T_3 : 100% RDN through VC	7..83	0.41	0.56	4296	5549	7.80	0.40	0.57	4380	5618
T_4 : 100% RDN through PM	7.82	0.40	0.57	4377	5608	7.79	0.38	0.58	4550	5760
T_5 : 100% RDN through GM	7.69	0.38	0.63	5084	6445	7.68	0.36	0.64	5140	6467
T_6: 50% RDN each of through FYM + VC	7.80	0.41	0.55	3910	5120	7.75	0.40	0.56	3980	5175
T_7: 50% RDN each of through FYM + PM	7.74	0.39	0.56	4721	6024	7.75	0.39	0.57	4833	6155
T_8: 50% RDN each of through FYM + GM	7.79	0.41	0.57	4236	5494	7.76	0.40	0.58	4316	5568
T_9: 50% RDN each of through VC+ PM	7.79	0.40	0.58	4923	6255	7.77	0.40	0.59	4986	6304
T_{10}: 50% RDN each of through VC+ GM	7.78	0.41	0.59	4079	5321	7.74	0.40	0.60	4140	5385
T_{11}: 50%RDNeach of through PM + GM	7.78	0.41	0.60	4322	5578	7.75	0.40	0.61	4430	5655
T_{12}: 25%RDN each of through FYM + VC + PM + GM	7.77	0.39	0.61	5004	6376	7.74	0.38	0.62	5120	6455
T_{13}: RDF (150 : 50 : 50) NPK kg ha^{-1}	7.86	0.41	0.50	5603	7103	7.84	0.41	0.51	5680	7128

T_{14}: INM Practice (RDF + GM @ 6.25 t ha^{-1})	7.85	0.41	0.51	6235	7470	7.85	0.42	0.52	6270	7490
SEd	**0.73**	**0.04**	**0.05**	**425**	**546**	**0.73**	**0.04**	**0.05**	**432**	**552**
CD (p=0.05)	**NS**	**NS**	**0.11**	**874**	**1123**	**NS**	**NS**	**0.11**	**889**	**1136**

Table 10. Impact of different organic manures on soil physical properties at post harvest of rice

Treatments	***samba* 2012**				***samba* 2013**			
	Bulk density (Mg m^{-3})	**Particle density (Mg m^{-3})**	**Per cent pore space**	**WHC (%)**	**Bulk density (Mg m^{-3})**	**Particle density (Mg m^{-3})**	**Per cent pore space**	**WHC (%)**
T_1: Absolute control	1.28	2.55	52.9	34.8	1.27	2.55	53.1	35.1
T_2: 100% RDN through FYM	1.19	2.54	55.0	40.2	1.17	2.53	55.2	0.7
T_3: 100% RDN through VC	1.18	2.55	55.6	40.6	1.16	2.50	55.8	41.2
T_4: 100% RDN through PM	1.17	2.55	56.2	41.0	1.15	2.54	56.4	41.5
T_5: 100% RDN through GM	1.15	2.55	64.2	42.9	1.14	2.54	64.1	43.5
T_6: 50% RDN each of through FYM + VC	1.17	2.55	55.4	40.5	1.15	2.54	54.5	41.2
T_7: 50% RDN each of through FYM + PM	1.17	2.55	55.6	40.7	1.15	2.54	56.6	41.4
T_8: 50% RDN each of through FYM + GM	1.17	2.54	55.8	40.8	1.16	2.54	56.7	41.2
T_9: 50% RDN each of through VC+ PM	1.16	2.55	56.1	41.2	1.16	2.54	56.8	42.4
T_{10}: 50% RDN each of through VC+ GM	1.16	2.54	56.2	41.4	1.16	2.53	56.9	42.2
T_{11}: 50%RDNeach of through PM + GM	1.16	2.54	56.4	41.6	1.16	2.53	56.0	41.8
T_{12}: 25%RDNeach of through FYM + VC + GM	1.16	2.55	56.6	42.1	1.16	2.54	57.0	42.6
T_{13}: RDF (150 : 50 : 50) NPK kg ha^{-1}	1.52	2.55	53.4	35.4	1.53	2.57	53.6	35.5
T_{14}: INM Practice (RDF + GM @ 6.25 t ha^{-1})	1.50	2.53	54.6	39.4	1.52	2.53	54.9	40.2
SEd	**0.11**	**0.24**	**5.2**	**3.8**	**0.11**	**0.24**	**5.2**	**3.8**
CD (p=0.05)	**0.23**	**NS**	**10.9**	**7.9**	**0.23**	**NS**	**10.9**	**8.0**

Table 11. Impact of different organic manures on pH, EC and organic carbon (OC) of soil at harvest of residual greengram, grain and haulm yield of greengram.

Treatments	**summer 2013**					**summer 2014**				
	pH	**EC (dSm^{-1})**	**OC (%)**	**Grain yield (kg ha^{-1})**	**Haulm yield (kg ha^{-1})**	**pH**	**EC (dS m^{-1})**	**OC (%)**	**Grain yield (kg ha^{-1})**	**Haulm yield (kg ha^{-1})**
T_1 : Absolute control	7.96	0.41	0.45	251	1142	7.94	0.41	0.44	258	1174
T_2 : 100% RDN through FYM	7.73	0.40	0.51	325	1477	7.71	0.40	0.52	386	1754
T_3 : 100% RDN through VC	7.72	0.41	0.55	335	1524	7.70	0.40	0.56	398	1809
T_4 : 100% RDN through PM	7.71	0.40	0.56	341	1585	7.69	0.39	0.57	406	1845
T_5 : 100% RDN through GM	7.65	0.38	0.62	410	1864	7.74	0.38	0.63	476	2164
T_6 : 50% RDN each of through FYM + VC	7.69	0.41	0.54	305	1386	7.65	0.40	0.55	370	1682
T_7 : 50% RDN each of through FYM + PM	7.68	0.39	0.55	368	1672	7.66	0.39	0.56	432	1964
T_8: 50% RDN each of through FYM + GM	7.68	0.41	0.56	331	1504	7.67	0.40	0.57	394	1790
T_9: 50% RDN each of through VC+ PM	7.68	0.40	0.57	384	1745	7.66	0.40	0.58	448	2036
T_{10}: 50% RDN each of through VC+ GM	7.67	0.41	0.58	318	1445	7.65	0.40	0.59	382	1736
T_{11}: 50%RDNeach of through PM + GM	7.67	0.41	0.59	338	1536	7.64	0.40	0.60	401	1822
T_{12}: 25%RDN each of through FYM + VC + PM + GM	7.67	0.39	0.60	390	1772	7.64	0.39	0.61	452	2054
T_{13}: RDF (150 : 50 : 50) NPK kg ha^{-1}	7.75	0.41	0.51	437	1986	7.74	0.41	0.50	502	2282

T_{14}: INM Practice (RDF + GM @ 6.25 t ha^{-1})	7.74	0.41	0.50	642	2918	7.75	0.41	0.51	698	3172
SEd	**0.72**	**0.04**	**0.05**	**34**	**155**	**0.72**	**0.04**	**0.05**	**39**	**179**
CD (p=0.05)	**NS**	**NS**	**0.11**	**70**	**318**	**NS**	**NS**	**0.11**	**81**	**369**

Table 12. Impact of different organic manures on soil physical properties at harvest of residual greengram

Treatments	summer 2013				summer 2014			
	Bulk density (Mg m^{-3})	**Particle density (Mg m^{-3})**	**Per cent pore space**	**WHC (%)**	**Bulk density (Mg m^{-3})**	**Particle density (Mg m^{-3})**	**Per cent pore space**	**WHC (%)**
T_1 : Absolute control	1.29	2.56	52.4	34.3	1.28	2.56	52.6	34.6
T_2 : 100% RDN through FYM	1.20	2.56	55.4	39.4	1.19	2.56	55.3	39.6
T_3 : 100% RDN through VC	1.19	2.56	55.8	39.8	1.18	2.56	55.7	40.1
T_4 : 100% RDN through PM	1.18	2.55	56.1	40.2	1.17	2.54	56.0	40.4
T_5 : 100% RDN through GM	1.15	2.54	63.4	46.2	1.14	2.55	63.5	45.8
T_6 : 50% RDN each of through FYM + VC	1.21	2.55	53.6	38.4	1.20	2.54	53.4	38.6
T_7 : 50% RDN each of through FYM + PM	1.18	2.54	56.3	40.4	1.17	2.55	56.2	40.6
T_8 : 50% RDN each of through FYM + GM	1.19	2.56	55.6	39.6	1.18	2.56	55.5	39.8
T_9 : 50% RDN each of through VC+ PM	1.17	2.54	56.4	40.5	1.16	2.55	56.4	40.7
T_{10} : 50% RDN each of through VC+ GM	1.20	2.55	55.2	39.0	1.19	2.56	55.2	39.2
T_{11} : 50%RDNeach of through PM + GM	1.18	2.54	56.0	40.0	1.17	2.54	55.8	40.2
T_{12} : 25%RDNeach of through FYM + VC + PM + GM	1.17	2.54	56.5	40.6	1.15	2.53	56.3	41.8
T_{13} : RDF (150 : 50 : 50) NPK kg ha^{-1}	1.54	2.56	52.3	34.5	1.53	2.56	52.1	34.7
T_{14} : INM Practice (RDF + GM @ 6.25 t ha^{-1})	1.52	2.54	54.6	37.8	1.52	2.54	54.4	40.4
SEd	**0.11**	**0.24**	**5.28**	**3.75**	**0.11**	**0.24**	**5.27**	**3.78**
CD (p=0.05)	**0.23**	**NS**	**10.8**	**7.71**	**0.23**	**NS**	**10.8**	**7.76**

Table 13. Impact of different organic manures on soil available N balance (kg ha^{-1}) during the cropping sequence 2012-14

Treatments	**Initial soil N**	**N applied**	**Residual N Added**	**Total N added**	**Total N removal**	**Computed balance**	**Final Soil N**	**Net gain or loss**
T_1 : Absolute control	214	-	80.9	80.9	189.4	-108.5	210	-4.0
T_2 : 100% RDN through FYM	214	300	89.2	389.2	240.7	148.5	234	20.0
T_3 : 100% RDN through VC	214	300	93.1	393.1	248.7	144.4	242	28.0
T_4 : 100% RDN through PM	214	300	96.7	396.7	259.0	137.7	248	34.0
T_5 : 100% RDN through GM	214	300	105.9	405.9	277.1	128.8	260	46.0
T_6 : 50% RDN each of through FYM + VC	214	300	87.1	387.1	231.8	155.3	227	13.0
T_7 : 50% RDN each of through FYM + PM	214	300	97.2	397.2	262.9	134.3	250	36.0
T_8 : 50% RDN each of through FYM + GM	214	300	92.0	392.0	245.1	146.9	238	24.0
T_9 : 50% RDN each of through VC+ PM	214	300	99.4	399.4	267.8	131.6	254	40.0
T_{10} : 50% RDN each of through VC+ GM	214	300	88.8	388.8	236.5	152.3	231	17.0
T_{11} : 50%RDNeach of through PM + GM	214	300	95.6	395.6	255.8	139.8	244	30.0
T_{12} : 25%RDNeach of through FYM + VC + PM + GM	214	300	104.3	404.3	272.1	132.2	256	42.0
T_{13} : RDF (150 : 50 : 50) NPK kg ha^{-1}	214	300	108.0	408.0	278.5	129.5	224	10.0
T_{14} : INM Practice (RDF + GM @ 6.25 t ha^{-1})	214	300	119.3	419.3	294.3	125.0	299	85.0

Table 14. Impact of different organic manures on soil available P balance (kg ha^{-1}) during the cropping sequence 2012-14

Treatments	Initial soil P	P applied	Residual P added	Total P added	Total P removal	Computed balance	Final Soil P	Net gain or loss
T_1 : Absolute control	16.7	-	18.7	18.7	46.2	-27.5	14.2	-2.5
T_2 : 100% RDN through FYM	16.7	208.0	24.5	232.5	62.0	170.5	18.6	1.9
T_3 : 100% RDN through VC	16.7	104.6	25.8	130.4	62.8	67.6	19.0	2.3
T_4 : 100% RDN through PM	16.7	190.5	26.5	217.0	64.1	152.9	19.4	2.7
T_5 : 100% RDN through GM	16.7	75.6	28.7	104.3	68.1	36.2	19.7	3.0
T_6 : 50% RDN each of through FYM + VC	16.7	156.2	23.2	179.4	60.7	118.7	17.7	1.0
T_7 : 50% RDN each of through FYM + PM	16.7	199.2	26.4	225.6	64.7	160.9	19.3	2.6
T_8 : 50% RDN each of through FYM + GM	16.7	141.7	25.4	167.1	62.3	104.8	19.0	3.0
T_9 : 50% RDN each of through VC+ PM	16.7	147.6	27.2	174.8	66.0	108.8	19.6	2.9
T_{10} : 50% RDN each of through VC+ GM	16.7	90.0	24.5	114.5	61.4	53.1	18.9	2.2
T_{11} : 50%RDNeach of through PM + GM	16.7	133.0	26.9	159.9	63.2	96.7	19.4	2.7
T_{12} : 25%RDNeach of through FYM + VC + PM + GM	16.7	144.6	28.2	172.8	67.2	95.3	19.8	3.1
T_{13} : RDF (150 : 50 : 50) NPK kg ha^{-1}	16.7	100.0	29.1	129.1	69.7	59.4	19.5	2.8
T_{14} : INM Practice (RDF + GM @6.25 t ha^{-1})	16.7	100.0	31.9	131.9	84.1	47.8	21.8	5.1

Table 15. Impact of different organic manures on soil available K balance (kg ha^{-1}) during the cropping sequence 2012-14

Treatments	Initial soil K	K applied	Residual K added	Total K added	Total K removal	Computed balance	Final Soil K	Net gain or loss
T_1 : Absolute control	536	-	103.1	103.1	239.9	-136.8	418	-118.0
T_2 : 100% RDN through FYM	536	336.1	124.1	460.2	290.1	170.1	458	-78.0
T_3 : 100% RDN through VC	536	193.1	128.8	321.9	305.1	16.8	464	-72.0
T_4 : 100% RDN through PM	536	163.2	133.6	296.8	323.5	-26.7	474	-62.0
T_5 : 100% RDN through GM	536	143.2	144.5	287.7	349.4	-61.7	490	-46.0
T_6 : 50% RDN each of through FYM + VC	536	264.6	119.9	384.5	281.6	102.9	451	-85.0
T_7 : 50% RDN each of through FYM + PM	536	249.6	133.8	383.4	335.7	47.7	478	-58.0
T_8 : 50% RDN each of through FYM + GM	536	239.6	127.7	367.3	297.8	69.5	496	-40.0
T_9 : 50% RDN each of through VC+ PM	536	178.2	135.2	313.4	342.9	-29.5	482	-54.0
T_{10} : 50% RDN each of through VC+ GM	536	168.2	124.1	292.3	285.9	6.4	454	-82.0
T_{11} : 50%RDNeach of through PM + GM	536	153.3	132.2	285.5	314.3	-28.8	470	-66.0
T_{12} : 25%RDNeach of through FYM + VC + PM + GM	536	208.9	142.7	351.6	347.1	4.5	486	-50.0
T_{13} : RDF (150 : 50 : 50) NPK kg ha^{-1}	536	100.0	143.2	243.2	352.5	-109.3	492	-44.0
T_{14} : INM Practice (RDF + GM @ 6.25 t ha^{-1})	536	227.7	162.1	389.8	371.2	18.6	520	-16.0