ORGANIC NUTRIENT MANAGEMENT STUDIES IN RICE – BLACKGRAM CROPPING SEQUENCE

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Thesis submitted in part fulfillment of the requirements for the degree of

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CERTIFICATE

This is to certify that the thesis entitled "**ORGANIC NUTRIENT MANAGEMENT STUDIES IN RICE – BLACKGRAM CROPPING SEQUENCE**" submitted in part fulfillment of the requirement for the degree of **DOCTOR OF PHILOSOPHY in AGRONOMY** to the Tamil Nadu Agricultural University, Coimbatore, is a bonafide record of research work carried out by **S.P. SANGEETHA,** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, fellowship or other similar titles of prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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(S.P. SANGEETHA)

ABSTRACT

ORGANIC NUTRIENT MANAGEMENT STUDIES IN RICE -
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By

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Degree	:	**Doctor of Philosophy (Agriculture) in Agronomy**
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Field experiments were conducted at wetland farm of Tamil Nadu Agricultural University, Coimbatore during *rabi* and summer seasons of 2007 - 2008 and 2008 - 2009 to evaluate the organic nutrient management practices in rice-blackgram cropping sequence. The field experiments were laid out in randomized block design with three replications. The experiment consisted of eight treatments comprising six treatments of organic manures and their combinations (enriched FYM compost, vermicompost, FYM + neem cake, enriched FYM compost + vermicompost + FYM, composted poultry manure and enriched poultry manure compost) and recommended NPK fertilizers and absolute control (without organic and inorganic).

The pre-season green manuring of *Sesbania aculeata* (Dhaincha) was incorporated before transplanting of rice. The consumer preference rice variety, Improved white ponni was raised during *rabi* while in summer, blackgram variety T9 was raised. The recommended dose of 75: 50: 50 kg ha^{-1} of NPK was applied for *rabi* rice. Based on the equal N basis, required quantities of organic manures were incorporated in the soil one week before transplanting of rice. The P and K were not applied. The recommended NPK fertilizers treatment received full dose of NPK through inorganic fertilizers.

Appreciable improvement in growth parameters and yield attributes of rice were evidenced due to the application of enriched poultry manure compost, which was closely

followed by the application of composted poultry manure. Application of enriched poultry manure compost resulted in higher grain yield (4675 kg ha^{-1} during *rabi* 2007 and 4953 kg ha^{-1} during *rabi* 2008) and straw yield (6568 kg ha^{-1} during *rabi* 2007 and 6725 kg ha^{-1} during *rabi* 2008), which was however comparable with composted poultry manure.

Organic manure incorporation showed favourable residual effect on the growth parameters, yield attributes and yield, besides nutrient uptake in rice fallow blackgram. The effect was more pronounced with enriched poultry manure compost and composted poultry manure than the residual effect of recommended NPK through fertilizer.

Improvement in macro (N, P and K) and micronutrient (Fe, Mn, Zn and Cu) uptake and enrichment in soil available N, P and lower decline in K, higher soil exchangeable Ca, Mg and Na and soil available Fe, Mn, Zn and Cu status at the end of two year cropping sequence were observed with the application of enriched poultry manure compost and composted poultry manure. Among the organic manures, higher net gain in soil available N of 66 kg ha^{-1} and 15.4 kg ha^{-1} of P at the end of two years of cropping sequence was recorded with enriched poultry manure compost followed by composted poultry manure. In general, composted poultry manure (both enriched and not enriched) performed better than the recommended NPK fertilizers.

The application of enriched poultry manure compost and composted poultry manure heightened the agronomic efficiency and apparent nitrogen recovery as compared to recommended NPK fertilizer. Higher system productivity and per day production were recorded with enriched poultry manure compost and composted poultry manure, which were comparable with each other.

The application of enriched poultry manure compost and composted poultry manure improved the soil health coupled with considerable build up in soil organic carbon content at the end of two year cropping sequence.

The microbial (bacteria, fungi and actinomycetes) and enzyme (urease, dehydrogenase and phosphatase) activity were greater due to enriched poultry manure compost and composted poultry manure. The recommended NPK fertilizer and absolute control registered lesser microbial population and soil enzyme activity.

The application of organic manures *viz.*, FYM + neem cake, enriched poultry manure compost and composted poultry manure markedly improved the soil physical properties (reduced soil bulk density and increased pore space and water holding capacity) at the end of two years of cropping sequence.

Improved milling characteristics of paddy, chemical composition and cooking characteristics of milled rice were observed in recommended NPK fertilizer and enriched poultry manure compost. The application of enriched poultry manure compost and composted poultry manure improved the colour, texture, taste and overall acceptability score than recommended NPK fertilizer.

Considering the cropping sequence as a whole during 2007 - 2008 and 2008 - 2009, the net income and B: C ratio of enriched poultry manure compost outshone the existing recommended NPK fertilizers. The net return and B: C ratio (Rs. 47,843 ha^{-1} and 2.67 during 2007 - 2008; Rs. 51,550 ha^{-1} and 2.80 during 2008 - 2009) were highest in enriched poultry manure compost followed by composted poultry manure.

From the above results, it could be concluded that the application of enriched poultry manure compost is the best nutrient management practice in rice-blackgram cropping sequence for higher growth, yield attributes and yield through improved soil fertility, physical and biological characteristics of soil, rice grain quality and desirable economical incentives. For farmers without sufficient inputs for the preparation of enriched poultry manure compost, the composted poultry manure is suggested as the next alternative nutrient management package in rice-blackgram cropping sequence.

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CHAPTER I
INTRODUCTION

Rice (*Oryza sativa* L.) is the most important and extensively cultivated food crop, which provides half the daily food for one out of every three persons on the earth. In Asia alone, more than 2 billion people obtain 60 to 70 per cent of their energy intake from rice and its derivatives. India has the largest area among rice growing countries and it stands second in production. It produces 96.43 million tonnes of rice in an area of 43.77 million hectares with a productivity of 2.2 t ha^{-1} (www.indiastat.com). In Tamil Nadu, rice occupies an area of 2.05 million hectares with an annual production of 5.2 million tonnes and productivity of 2.53 t ha^{-1} (Season and Crop Report of Tamil Nadu, 2005-2006).

Until the middle of 20^{th} century, agriculture all over the world was based on the principles of eco-friendly organic farming system, which ensured crop and animal food production as well as environmental safety to the human beings and other forms of domestic and non-domestic animals. However, since the commencement of green and industrial revolutions, people in some advanced agricultural countries and developing countries like India abandoned the traditional means of agriculture and stressed the need for more food production and economic growth through chemical inputs without environmental consideration, which led to environmental degradation and ecological imbalance. Energy crisis, higher fertilizer cost, sustainability in agri-production system and ecological stability are the important issues which renewed the interest of farmers and research workers in non-chemical sources of plant nutrients like biofertilizers, farmyard manure, green manure, composts etc. Awareness about crop quality and soil health increased the attention of people towards organic farming (Sharma *et al*., 2008).

Indian soils have rapidly degraded in their nutrient status. Motsara (2002) estimated that 90% of the soils are presently deficient in available N, 80% in P_2O_5 and 50% in K_2O. The depletion of secondary nutrients and micronutrients like Zn, Mn, B and Fe has also become more conspicuous in decreasing the productivity of crops. One of the major causes for decline in the productivity of the soils is low organic matter content.

Wherever the fertilizers have been continuously used without adequate supply of organic manure, the decline is faster in addition to creating new problems of insect, pest and diseases. To reverse this trend, one of the possible means is to go for organic agriculture.

Therefore, augmenting soil resources is inevitable in rice based cropping system. Organic sources of nutrition has a great scope to increase the productivity by proper management, this not only sustains the soil fertility and productivity but also keeps the environment free from pollution (Swaminathan, 1987). 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 (Dahiphale *et al*., 2003). In addition to supply of nutrients, organic sources improve the physical condition and biological health of soil, which improves the availability of applied and native nutrients (Dick and Gregorich, 2004).

Since the organo-foods are getting a fast boost up in the world export market, the potential of pure organic farming can be exploited (Sharma, 2002). Although the organic manures contain plant nutrients in small quantities as compared to the chemical fertilizers, presence of growth promoting principles like enzymes and hormones, besides plant nutrients make them essential for improvement of soil fertility and productivity (Bhuma, 2001).

Green manuring, which is of organic origin, helps to keep soil quality and fertility enhancement as a whole meeting a part of nutrient need of crops. The pre-season green manuring of *Sesbania aculeata* (Dhaincha) and its *in situ* incorporation had improved growth and productivity of succeeding cereals, particularly rice. There is ample scope to fit in short duration pulses to a considerable extent in the rice fallows of Tamil Nadu. The beneficial effects of including a pulse crop in rice based cropping system have been well documented (Chinnusamy *et al*. 1997).

Against the backdrop of diminishing organic and mounting inorganic use, the concept and practice of organic farming has assumed center stage in rice farming. Among the organic sources, farmyard manure, enriched farmyard manure compost, vermicompost, composted poultry manure, enriched poultry manure compost and neem cake provide a good amount of organic matter and plant nutrients. Most studies describe the effect of inorganic alone or combination of organic and inorganic fertilizer under various rates of substitution usually not exceeding 50 per cent of inorganic nutrient level. But studies on exclusive use of organic sources and combination of different organic sources in various proportions are very few. The effect of complete exclusion of inorganic nutrient sources in rice nutrition needs to be studied in depth to make meaningful recommendation on organic nutrient management for rice-blackgram cropping sequence. Considering the importance of the above aspects, field studies were carried out with the following objectives

1. To study the effect of organic nutrient management practices on growth, yield attributes and yield of rice and blackgram
2. To study the impact of organic manures on soil fertility components
3. To know the effect of organic manuring on quality of rice grain
4. To evaluate the economics of various nutrient management practices in rice-blackgram cropping sequence.

CHAPTER II

REVIEW OF LITERATURE

Present intensive agricultural practices lead to mining of the soil by extracting nutrients for crop growth. These losses are being offset by increased fertilizer application. Application of inorganic fertilizer alone in large quantities over a long period of time may cause depletion of certain nutrients in soil and certain others would generally accumulate in excess resulting in nutrient imbalance.

One such system which will help to alleviate the problems of soil and environmental degradation is "Organic farming" - which aims at co-operating rather than confronting with the nature. Masonobu Fukooka of Japan, considered as the father of natural farming, says that organic farming is the only answer to bring sustainability to agriculture in future. However, more comprehensive and analytical approach based on large volume of on-farm trial data is essential to examine the comparative feasibility and economics of organic farming versus modern farming (Gunjal, 1991). Therefore available literature on organic manures for organic farming in relation to crop growth, soil health, crop quality and economics pertaining to wetland cropping system are reviewed and presented in this chapter.

2.1. Organic Agriculture - definitions and concepts

The term "Organic Agriculture" refers to a process that uses methods respectful of the environment from the production stages through handling and processing. Organic production is not merely concerned with a product, but also with the whole system used to produce and deliver the product to the ultimate consumer.

Two main sources of general principles and requirements apply to organic agriculture at the international level. One is the Codex Alimentarius Guidelines for the production, processing, labelling and marketing of organically produced foods. According to Codex, "Organic agriculture is a holistic production management system, which promotes and enhances ecosystem health, including biological cycles and soil biological activity". Organic agriculture is based on minimising the use of external inputs, avoiding the use of synthetic fertilizers and pesticides. The primary goal of organic agriculture is to optimize the health and productivity of interdependent communities of soil life, plants, animals and people. The other is the International Federation of Organic Agriculture Movements (IFOAM), a private sector international body, with some 750-member organizations in over 100 countries. IFOAM defines and regularly reviews, in consultation with its members, the basic standards. “Organic agriculture is a whole system approach based upon a set of processes resulting in a sustainable ecosystem, safe food, good nutrition, animal welfare and social justice. Organic production therefore is more than a system of production that includes or excludes certain inputs” (FAO, 2004).

Organic farming is not mere non-chemicalism in agriculture, but it is a system of farming based on integral relationship with nature (Lampkin, 1990). The principal elements to be considered while practicing organic farming are:

i. Creating a healthy soil.

ii. Making nutrient and energy flow in soil ecosystem.

iii. Keeping the biological life in the cycle and providing sustainable yield.

According to U.S. Department of Agriculture report (USDA, 1980), organic farming is a production system, which avoids and largely excludes the use of synthetic compounds, fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent possible organic farming system rely upon crop rotations, crop residues, animal manures, legumes, green manures, off farm organic wastes, mechanical cultivations, mineral bearing rocks and biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weed and other pests.

Eventhough concept of organic farming has gained the confidence of farmers, scientists, extension workers and policy makers, systematic research work has been started only recently. Organic farming is focused on the whole farm system and its interaction with climate, environment, social and economic conditions, rather than considering the farm as comprising of individual enterprises.

2.2. Organic farming and crop productivity

The long term addition of organic materials to soil resulted in increased organic matter, crop productivity and soil biological activity (Collins *et al*., 1992). Wang *et al*. (1994) opined that the yields were higher with organic cultivation in both early and late rice varieties. The rice crop yields ranged from 2.2 to 4.6 t ha^{-1} for the early crop and 3.4 to 5.5 t ha^{-1} for late crop in China.

Khatik and Dikshit (2001) indicated that the application of organic manures helped to sustain crop productivity besides maintaining the soil health. Martini *et al*. (2004) reported that increase in crop yield over the first few years of organic farming (especially during the 3-year 'transitional' period established in US law) have been attributed to gradual improvements in soil properties, such as the capacity of the soil microbial community to mineralize N or to suppress diseases.

2.3. Organic manures in organic farming

Use of organic manures and green manuring is an age-old practice in Indian farming. Organic manures are valued and stressed to be included in rice nutrition. Organic manure in a broad sense includes composts from rural and urban wastes, crop residues, agro industrial bio wastes and green manures, apart from the commonly used FYM. Organic manure improves soil physical condition including soil porosity and water holding capacity and microbial environment, replenishes essential micronutrients in soil, increases the utilization efficiency of applied fertilizers and favours micronutrient availability to the plant. Organic manure is of paramount importance not only in augmenting the crop production but also for making the agriculture sustainable as an eco-friendly means of soil health management.

Organic recycling and use of organic manure to previous crop considerably influence the nutrient supply to the succeeding crop (Mohanty and Sharma, 2000). The conventional organic manures rich in plant nutrients could replace the inorganic fertilizers on equal nutrient basis (Krishnakumar and Jawahar, 2001).

2.4. Availability of organic manures

The organic manures have been used as a means of maintaining and increasing soil fertility all along the history of farming. Organic manures are bulky in nature but supply the nutrients in small quantities (Alok *et al*., 1995). The organic manures are available in the form of green and dry plant residues, fresh animal wastes, decomposed materials of plants and animal origin and biologically active preparations (Palaniappan *et al*., 1995). Use of manures and biologically active preparations of animal and plant origin was most commonly used by those farmers who aimed for sustainable production in Tamil Nadu (Somasundaram, 2002).

The major sources of organic plant nutrients in India are farmyard manure, rural and urban compost, poultry manure, sewage, sludge, pressmud, green manure, crop residues, forest litter, industrial waste water and by-products, etc. Some estimates indicate that their potential source is about 16.9 million tonnes (Shukla and Mathus, 2000). Efficient collection and application of those resources will go a long way in reducing our dependence on fertilizers (Palaniappan, 2002).

2.5. Organic farming in relation to soil properties and crop nutrition

A major objective of organic farming is to encourage a high level of biological activity in the soil, in order to sustain its quality and thereby promote metabolic interactions between the soil and plants (Stolze *et al*., 2000). Soil quality enhancement required improvement in soil structure, available nutrient status, soil organic matter content and soil biodiversity (Subbian *et al*., 2000).

2.5.1. Effect of organic manures on soil physical properties

Soil structure is assumed to be positively altered by organic farming as a consequence of the high level of biological activity in these systems. A well-structured soil is an important asset for sustaining high crop yields and controlling erosion, and is crucial for organic farming. The high level of biological activity in organically managed systems encourages good soil structure and *vice versa*. Soil structure is improved by the incorporation of organic matter, the gums and mucilages formed during its breakdown by bacteria helping to bind the peds together (Bridges, 1978).

Manickam (1993) concluded that the added organic residues to the soil undergo microbial decomposition and in this process, various organic acids and other products of decay are released which act as strong binding agents in the formation of large and arable aggregates. The application of green manure, FYM and crop residue helped to improve the soil physical conditions through microbial cells, decomposition products and penetration of fine roots (Meelu *et al*., 1994). Chakraborty (1998) studied that the application of organic manure enhances microbial decomposition resulting in the formation of humus which exerts a positive influence on the physical properties by improving the bulk density and water holding capacity of soil and reduce the leaching loss in coarse soils and in general, application of organics had a favourable effect in building up of the soil structure (Hariharane *et al*., 2002).

The post harvest soil analysis of organics applied plots revealed that application of organics favourably improved the physical properties of soil, this might be due to higher addition of humus through organics (Malewar *et al*., 2000) and also improves physical properties of soil i.e., structure and permeability (Sharma and Bali, 2000). The soil treated with manure was found to be loose, which probably provided adequate aeration into the soil and improved soil microbial activities and the post harvest soil analysis of organics applied plots revealed that the application of organics favourably improved the physical properties of the soil (Natarajan, 2007).

2.5.2. Effect of organic manures on soil biological properties

Higher population of microbes under organic treatments acted as an index of soil fertility because it serves as temporary sink of nutrients flux as found by Hassink *et al.* (1991). Organic farmers do not use synthetic fertilizers and pesticides and aim at keeping a closed nutrient cycle on their farms, striving to protect environmental quality and to enhance beneficial biological interactions and processes (Vandermeer, 1995). Plant production in organic farming mainly depends on nutrient release as a function of mineralization processes in soils. An active soil microflora and a considerable pool of accessible nutrients, therefore, is an important priority in organic farming. Fertilizing the soil rather than the plant is an organic farmer’s goal to assure sufficient nutrient mineralization to meet his economic needs.

Microbial and physico-chemical mechanism linked to nutrient availability to the rice-rhizosphere was studied by Berthelin and Giudici (1993). Microbial populations were higher in organic applied area than in conventional area. The lowest soil microbial load was found in recommended NPK fertilizers which might be due to inhibitory nature of chemical fertilizers on the growth and development of microbes (Singh, 1998).

Permanent manurial experiments indicated that the organic matter build up occurred at an increased rate under organic farming as compared to conventional farming. Evidently this confers increased biological activity and cation exchange capacity in soil besides ensuring soil structural stability (Reddy and Reddy, 1999). Soil microbial population (Actinomycetes, Bacteria, Fungi and BGA) enhanced due to the application of organic amendments in comparison to absolute control as well as recommended fertilizer application that in turn resulted in a notable enhancement in soil dehydrogenase and phosphatase enzyme activity (Singh *et al*., 2007).

2.5.3. Effect of organic manures on soil chemical properties

The build up of organic carbon in the soil due to organics could be ascribed to the supply of needed energy and nutrient by the inorganic fertilizer for the decomposition of complex organic matter and converting these to mineralized organic colloid which in turn added to the organic matter reserves and rapid multiplication of microbial population (Ganeche, 1999).

Raju *et al*. (1991) detected that the available soil N after the crop harvest increased considerably as compared to initial level due to organic manure incorporation. Buchner (1993) viewed the increase in available nitrogen due to organic materials application could also be attributed to the greater multiplication of soil microbes which could convert organically bound N to inorganic form.

Sharma (1999) opined that application of organic manure increased the available P content of the soil due to the production of some organic acids during decomposition which caused release of P from insoluble phosphorous compounds. Appreciable build up in available P in soil with organic manure and inorganic may be attributed to the influence of organic manure in increasing the labile P through complexion of cations like Ca^+ and Mg^+ which are responsible for fixation of P (Vyas *et al*., 2003).

Srikanth *et al*. (2000) showed that the decrease in soil pH with application of farmyard manure could be ascribed to the effect of organic acids produced during the decomposition of farmyard manure. The applied organics considerably reduced the soil pH as against the initial pH at all the stages of crop growth. The reduction in pH may be attributed to the higher production of CO_2 and organic acids due to addition of organics (Yaduvanshi, 2001). The significant reduction in EC due to organics application might be due to leaching of salts by the organic acid released by the organic sources

(Anand, 1992). The organic manured plot had a relatively higher cation exchange capacity (CEC) as compared to inorganic fertilized plot. Cation exchange capacity estimated after FYM treatment was significantly higher compared to treatments with commercial manures. Addition of organic manures are increased the CEC. This was due to improvement in organic matter content of soil (Prakash *et al*., 2002).

Appavu *et al*. (2000) showed that incorporation of organic manures (Coir pith, poultry manure, goat manure and FYM) increased the available Zn and Fe content. The application of enriched organic manure increased the availability of micronutrients in the soil (Chitdeswari and Krishnasamy, 2000).

2.6. Organic farming in relation to rice grain quality

Lampkin (1990) stated that organic farming system have higher protein contents in the cereals. The average value of 1000 grain weight and eating quality in rice were higher under organic farming than conventional farming (Nakai, 1994). The 'bio' products differed little from conventional products either in nutrition or taste as reported by Hagner (1994).

Higher and proper nutrition through the organic matter resulted with ensured supply of nutrients might have lead to increase in total amylose content and crude protein (Radha, 1996; Omar Hattab *et al*., 1998). Quality parameters like hulling percentage, milling percentage, protein and amylose contents also increased due to use of NPK fertilizers, FYM and BGA inoculation either alone or in combination (Dixit and Gupta, 2000). Farmers entertained a deep conviction that organically produced foods possess better keeping quality and organoleptic properties than conventionally produced food (Senthil Kumaran and Vadivel, 2001). Organic manures and biodynamic preparation improved the organoleptic properties of food grains (Pathak, 2002). In order to produce good eating quality of rice, it was important to restrict the nitrogen absorption from organic fertilizers at the ripening period (Saitoh *et al*., 2002). The rice grain quality characters *viz*., total amylose content and gruel loss were significantly influenced by the incorporation of organics over no organics (Natarajan, 2007).

2.7. Effect of organic manures on soil, growth and yield of rice

Research work on pre-season green manuring and organic nutrient supplementing manures like FYM, enriched FYM compost, composted poultry manure, enriched poultry manure compost, vermicompost and neem cake on the response of soil health, crop growth, quality and economics in rice based cropping system are reviewed in the following sections.

2.7.1. Green manure

2.7.1.1. Effect of green manuring on soil fertility

Green manuring is a practice of turning green biomass in the soil to improve physical, physico-chemical as well as biological properties suitable for plant growth. It is a convenient mean to furnish higher amount of nitrogen to the beneficiary crops. Green manures, particularly legumes are comparatively high in N, low in C: N and behave almost like chemical nitrogenous fertilizers. Besides N, they mobilize S, P, Si, Zn, Cu, Mn and other nutrient elements as a result of increased microbial activity (CO_2 formation) and decreased redox potential (Becker, 1990).

Sesbania aculeata as green manure crop had wider acceptance among all green manure crops and it occupies prime place in India from early times (Domnergues, 1982). Saradhamani *et al*. (1989) reported that dhaincha accelerates the rate of reclamation, besides increasing the productivity status of the soil. *Sesbania aculeata* accumulated the higher amount of biomass (26.3 t ha^{-1}) followed by *Sesbania rostrata* (24.9 t ha^{-1}) but in terms of N contribution, both were comparable contributing 145 and 146 kg of N ha^{-1} respectively (Siddeswaran, 1992).

Green manure substituted about 100 per cent of N requirement of rice crop (Matiwade and Sheelavantar, 1994). Bindra and Thakur (1995) reported that *Sesbania aculeata* was a better green manure than other green manures. 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).

2.7.1.2. Effect of green manuring on growth, yield components and yield of rice

Becker *et al*. (1991) found that green manuring increased grain yield through increase in number of panicles $hill^{-1}$, length of panicles, and number of filled grains $panicle^{-1}$ and test weight. Incorporation of dhaincha @ 5 t ha^{-1} increased grain yield by 42.8 per cent (Sharma and Kuhad, 1993). Budhar (1994) reported that plant height, LAI, RGR, CGR, number of tillers m^{-2}, DMP, number of grains $panicle^{-1}$ and test weight of rice increased upon green manuring at a dose equivalent to 200 kg ha^{-1}.

Various green manures raised during pre-season rice gave higher yield of succeeding rice by increasing the values of yield determinants *viz*., number of grains $panicle^{-1}$ and test weight than rice following preceded fallow (Solaiappan *et al*., 1996). On decomposition, green manuring was found to release on an average of 70 kg N ha^{-1} during rice cropping season and increased the yield up to 20-50 per cent (Rangaswamy *et al*., 1997). Green manures raised during pre-season rice recorded higher values of growth parameters and yield of succeeding rice than pre-season fallow (Subbalakshmi *et al*., 1999).

Narayana and Surekha (2001) provided evidence that rice receiving green manures recorded (14-38%) higher grain yields over no green manure due to N supplying effect of green manures. Application of green manures along with organic compost gave significantly higher LAI than chemical fertilizer alone (Sujathamma and Srinivasulu, 2004).

2.7.2. Farmyard manure (FYM)

Farmyard manure is a store house of several plant nutrients and act as a good soil conditioner. Farmyard manure is the commonly used organic manure and it proved its ability in enhancing crop production. Farmyard manure, a traditionally important source of nutrient, lost its relative importance with widespread use of fertilizers. Meena *et al.* (2007) reported that FYM had 0.46 per cent N, 0.18 per cent P_2O_5 and 1.32 per cent K_2O.

2.7.2.1. Effect of FYM on soil physical properties

The role of farmyard manure is multidimensional ranging from building up of organic matter, maintaining favourable soil physical properties and balanced supply of nutrients (Prihar and Sandhu, 1987).

Organic inputs and plant residues stimulated the production of polysaccharides and other compounds that favoured soil aggregation (Hendrix *et al*., 1992). The application of FYM not only improved the physicochemical properties of soil like bulk density, maximum water holding capacity and organic carbon content but also had a little effect on residual phosphorus and potassium in the soil (Panda, 1995). Green manuring and FYM incorporation increased water soluble aggregates, infiltration rate and reduced the bulk density of the soil and helped to improve the physical conditions (Meelu, 1996). Application of FYM and vermicompost decreased the bulk density and increased the water holding capacity than NPK application alone (Maheswarappa *et al*., 1999). Several workers reported the favourable influence of FYM on soil physical properties such as improved soil aggregation, infiltration rate, total porosity and hydraulic conductivity (Rabindar *et al*., 1986; Loganathan, 1990).

The farmyard manure seems to act directly by increasing the crop yield either by accelerating the respiratory process through cell permeability or by hormone growth action. It supplies nitrogen, phosphorus and sulphur in available forms to the plants through biological decomposition. Indirectly, it improves the physical properties of soil such as aggregation, aeration, permeability and water holding capacity (Chandramohan, 2002). Application of 90 kg N ha^{-1} in the form of FYM + neem cake, conspicuously reduced the bulk density and increased the pore space, water holding capacity and saturated hydraulic conductivity (Krishnakumar *et al*., 2007a).

2.7.2.2. Effect of FYM on soil chemical properties

2.7.2.2.1. Effect of FYM on organic carbon

Sud *et al*. (1990) reported that application of FYM in long term run resulted in increased organic carbon content by about 140 per cent. Mishra and Sharma (1997) observed an increase in organic carbon content with application of FYM @ 10 t ha^{-1} before transplanting of rice and BGA @ 13 kg algal crust ha^{-1} one week after transplanting of crop. According to Kenchaiah (1997), continuous application of organic manures especially FYM over a period of time increased the organic carbon content of the soil.

Satheesh (1998) noted that FYM when applied along with neem cake enhanced the organic carbon content of soil. Maheswarappa *et al*. (1999) observed that the organic carbon content was increased to a greater extent at 0-25 cm depth with FYM and vermicompost application than the other organic sources. The FYM received treatments resulted in increased organic carbon content of the soil from 1.72 to 3.92 per cent was reported by Katkar *et al*. (2002).

2.7.2.2.2. Effect of FYM on N availability

Higher available N content of soil under FYM addition could be due to favourable microbial activity and enhanced biomass addition to the soil and also as a result of improved soil physical properties (Muthuvel *et al*., 1990).

Kamelesh *et al*. (1991) reported that application of FYM @ 90 t ha^{-1} annually for 20 years increased the available N in soils. Satheesh (1998) detected that application of FYM + neem cake and FYM + poultry manure left significantly higher soil available N after the harvest of both *rabi* and *kharif* rice crop. Increase in available N status due to FYM addition was recorded by Bhakiyathusalina *et al*. (2002). Decomposition of organic matter added through FYM by mineralization increased the available nitrogen status of the soil, due to increase in microbial activity in the presence of organic matter (Singh *et al*., 2006).

2.7.2.2.3. Effect of FYM on P availability

Singh and Mandal (1997) reported that the available N and P of the post harvest soil increased considerably as compared to initial level due to FYM incorporation. Radha *et al*. (1999) observed that incorporation of FYM improved the phosphorus status of soil through slow decomposition of FYM. The application of FYM @ 12.5 t ha^{-1} increased the available phosphorus content in paddy field (Sudhakar, 2000).

2.7.2.2.4. Effect of FYM on K availability

Math *et al*. (1998) and Sharma (1999) noticed that application of FYM significantly increased the available potassium status in the soil. This might be attributed to the direct addition of potassium to the available pool of the soil besides the reduction of K fixation and release of K due to the interaction of organic matter with clay. The higher available K due to the application of 10 t ha^{-1} of FYM or compost was also reported by Khatik and Dikshit (2001).

2.7.2.2.5. Effect of FYM on micronutrient availability

Ranganathan and Selvaseelan (1997) reported that macro and micro nutrient availability were increased considerably by the application of farmyard manure. Subramanian *et al*. (2000) opined that the inclusion of organic manures *viz*., FYM and sunnhemp in the fertilizer schedule not only increased the yield but also improved the soil moisture storage by 31.4, 31.2 and 31.4 per cent at 0-15, 15-30 and 30-60 cm soil depth, respectively. Farmyard manure is the best external organic source of micronutrients, it supplied the largest amount of Zn and Cu to the soil gave the highest concentration of these elements in rice grain (Mishra *et al*., 2006).

2.7.2.2.6. Effect of FYM on nutrient uptake

Verma and Bhagat (1994) found that the incorporation of FYM increased significantly the NPK contents in grain and straw of rice. Kamalakumari and Singaram (1996) found increased N, P and K uptake of rice plant due to higher DMP. The uptake of nutrient was more under FYM when it was applied in combination with pig manure, poultry manure and pressmud (Hedge, 1996). Application of FYM + Neem cake recorded significantly higher N, P and K uptake over control (Satheesh, 1998). NPK fertilizer in combination with FYM registered the higher uptake of N, P and K by both grain and straw (Nagarajan *et al*., 2000).

2.7.2.3. Effect of FYM on biological properties

Kamelesh *et al*. (1991) reported that application of FYM at the rate of 90 t ha^{-1} annually increased the organic carbon, total N and total microbial biomass. Application of farmyard manure and vermicompost increased the soil microbial population. The organic manure produced more microbial biomass than inorganic and increased the proportion of labile carbon and nitrogen by directly stimulating the activity of the microorganism (Maheswarappa *et al*., 1999).

The application of FYM + neem cake registered maximum population of bacteria, fungi and actinomycetes. The soil microbes continue to increase with the advancement of crop growth. The attributed reason was the enhanced organic carbon content of the soil as a result of organic manure application as compared to inorganic fertilizers. Besides this, the FYM + neem cake would have resulted in increased secondary and micronutrients in the soil which might have helped to increase the microbial population (Krishnakumar *et al*., 2007b).

2.7.2.4. Effect of FYM on growth, yield components and yield of rice

The highest growth and grain yield of rice was obtained by the application of FYM both @ 10 t ha^{-1} and 20 t ha^{-1} (Gupta *et al*., 1995). According to Singh *et al*. (1996) application of FYM @ 20 t ha^{-1} significantly increased the plant height, LAI and tillers $hill^{-1}$ and FYM application @ 10 t ha^{-1} significantly increased the growth components *viz*., number of leaves $plant^{-1}$ and tillers $hill^{-1}$.

Bijay *et al*. (1998) found that amending the soil with FYM @ 12 t ha^{-1} increased the yield of rice in the absence of fertilizer by 22 per cent. Udayasoorian (1998) also observed a positive influence of FYM on rice plant height, number of tillers $hill^{-1}$ and dry matter production with increased yield attributes and yield.

Channabasavanna *et al*. (2000) found that the incorporation of FYM @ 7.0 t ha^{-1} improved grain yield of rice compared to no incorporation. Shanmugam and Veeraputhiran (2001) revealed that application of FYM @ 12.5 t ha^{-1} + Azospirillum @ 2 kg ha^{-1} increased the productive tillers m^{-2}, filled grains $panicle^{-1}$, panicle length, finally grain yield and straw yield of *rabi* rice. The basal incorporation of FYM @ 10 t ha^{-1} produced a significant increase of rice yield against the control, which was 27.5 per cent higher than the control. FYM produced more number of effective tillers, heavier test weight, more number of filled grains $panicle^{-1}$ and more straw yield (Sumarjit and Bidur, 2005).

2.7.3. Enriched FYM compost

FYM is bulky and low in major plant nutrients such as N and K. Hence, there is a need to improve its quality. Conventional FYM commonly contains about 75% water and very low concentrations of nutrients. As a result, large quantities are needed to supply an appreciable part of the nutrient requirement of the plant. Hence, the bulky organic manure requires improvement in quality with reference to its nutrient content through enrichment (Tolessa and Friesen, 2001).

Karuppaiah (1983) noted during *rabi*, the combined application of rock phosphate 50 kg P_2O_5 ha^{-1} + 10 t of FYM registered highest grain and straw yield. The residual effect of the rock phosphate is more pronounced in the presence of organic manure in a rice-rice cropping system (Panda, 1989). The composted FYM with rock phosphate recorded the highest grain and straw yield, harvest index and N, P and K uptake of rice (Pazhanivelan *et al*., 2006). Treating rock phosphate with FYM is found effective in steady release of P from rock phosphate and consequent increase in crop yields even in neutral and calcareous soils (Kaleeswari *et al*., 2007).

Application of enriched FYM has been reported to increase P availability in the soil which ultimately leads to increased P use efficiency. This has been attributed to increased solubilization of insoluble P and reduced P fixation in the soil during the process of humification due to the protective action of the manure (Tomer *et al*., 1984). Application of pre-incubated rock phosphate with cow dung to wheat crop increased the P availability and P use efficiency (Tomer *et al*., 1983). The application of P enriched FYM ensured continuous availability of plant nutrients and increased grain yields over straight fertilizer application and thus improved fertilizer use efficiency (Pushpanathan, 1987).

2.7.4. Neem cake

Eighty per cent of the seed remaining as residue after oil extraction is called "Neem cake". Neem cake serves as nitrification inhibitor and a biopesticide in controlling insect, pests and diseases (Parmar and Singh, 1993). Bains *et al*. (1971) found that neem seed crush extract treated urea increased number of effective tillers and influenced number of filled grains and thousand grain weight. Jadhav *et al*. (1983) stated that neem cake application increased the productive tillers hill^{-1}, number of grains panicle^{-1}, total dry matter production. Prameela (1996) reported that the growth and dry matter production of rice cv. ASD 18 in *kharif* season was highest due to application of neem cake + urea (1:3 N basis).

The influence of neem cake in increasing yield of lowland rice when blended with urea over untreated urea has been reported by many workers and the yield increase was reported to be 10 to 24 per cent (Bains *et al*., 1971; Jadhav *et al*., 1983; and Prameela, 1996).

2.7.5. Vermicompost

Vermicompost is blackish brown humus like coarse, granular material which is loose, fine, soft to touch, light in weight and free from any foul smell, having electrically charged particles meant for improved adsorption of plant nutrients in the soil (Neena and Battish, 2005). Marinari *et al.* (2000) also observed that vermicompost had pH 7.7, 2.0 per cent of N, 34.2 per cent total carbon, 813.0 μg N g^{-1} NO_3-N, 133.7 μg N g^{-1} NH_4-N, and 47.0 μg P g^{-1} available P. Vermicompost, being a rich source of macro and micro nutrients, vitamins, plant growth regulators and beneficial microflora, appeared to be the best organic source in maintaining soil fertility on sustainable basis towards an eco-friendly environment (Edwards and Arancon, 2004).

2.7.5.1. Effect of vermicompost on soil physical properties

Martin (1991) reported that earthworm casts had increased the proportion of macro-aggregates significantly from 25.4 to 31.2 per cent. Kale *et al*. (1992) found that the application of earthworm casts to fields can improve the physical-chemical and biological properties of the soil. Earthworms make the soil porous and help in better aeration and water infiltration. The infiltration capacity is said to increase up to 130 mm hr^{-1} against 10 mm hr^{-1} of a conventional farm. This ensures ground water retention and prevents soil erosion. Apart from raising the water table, the earthworm act as bio-pump by transporting moisture from lower layers to upper ones (Bhawalkar, 1993). The increased macropore formation due to earthworm burrows which could increase preferential flow path ways, and movement of N through the soil profile (Lanchnicht *et al*., 1997).

2.7.5.2. Effect of vermicompost on soil chemical properties

2.7.5.2.1. Effect of vermicompost on organic carbon

Casts deposited by earthworms may participate in the accumulation of organic matter through increased organic matter produced in the ecosystem and the protection of soil organic matter in structures of the drillosphere (Martin, 1991). The organic carbon content is increased by 4.1 to 21.0 per cent for burrow wall material and by 21.1 to 43.0 per cent for worm casts.

Kale (1994) reported that vermicasting replenished the organic matter content of soils. The organic matter content in worm casts was about four times higher than in surface soil, with mean values of 48.2 and 11.9 g kg^{-1} respectively (Khang *et al*., 1994). The application of vermicompost @ 5 t ha^{-1} significantly increased organic carbon in soil (Srikanth *et al.*, 2000).

2.7.5.2.2. Effect of vermicompost on N availability

The earthworm output comprises almost assimiable products of excretion such as ammonia and urea which is rapidly mineralized. Thus it represents a potentially significant source of rapidly available nutrient for plant growth. Increased availability of N in worm casts compared to non ingested soil has been reported by (Hullugalle and Ezumah, 1991).

Blair *et al*. (1997) suggested possible mechanism whereby earthworm microbial interactions can increase soil N availability by reducing microbial immobilization and enhancing mineralization. Bouche *et al*. (1997) found that the worm activity can increase potential net N mineralization rates and is to accelerate the transformation of N, after increasing availability. The cast that earthworms excrete contains a much higher amount of inorganic-N than the soil around the earthworms (Wilcox *et al*., 2002). The available NPK status of the post harvest soil was higher in application of vermicompost @ 5 t ha^{-1} when compared to FYM @ 10 t ha^{-1} (Sudha and Chandini, 2005).

2.7.5.2.3. Effect of vermicompost on P availability

The availability of P was enhanced in casts compared to non ingested soil (Mansel *et al*., 1980; Devleeschauwer and Lal, 1981) due to increased solubility of P by high phosphatase activity (Syers and Springett, 1984).

Basker *et al*. (1994) registered that the available P was higher compared to the surrounding soil due to soil ingestion by earthworm. Vasanthi and Kumaraswamy (1999) reported that the organic carbon content, available status of N, P, K, Ca, Mg and micro nutrients were higher in treatment that received vermicompost plus N, P and K than in the treatment with N, P and K alone.

2.7.5.2.4. Effect of vermicompost on K availability

The earthworm casts contained two to three times more available K than surrounding soils (Hullugalle and Ezumah, 1991). Basker *et al*. (1993) showed that the availability of K was enhanced significantly following soil ingestion by earthworm and this must be due to the changes in the distribution of K between exchangeable and non exchangeable K forms.

Earthworms can not increase the total amount of nutrient in the soil but can make them more available and they may increase the rate of nutrient cycling, there by increasing the quantity of nutrients available (Sharpley and Syres, 1997).

2.7.5.2.5. Effect of vermicompost on nutrient uptake

Kale *et al*. (1987) observed an increase in the rates uptake of nutrients with the increase in symbiotic microbial association in cereal and ornamental plants on using vermicompost as a source of organic manure. Jadhav *et al.* (1997) concluded considerable increase in the uptake of major and secondary nutrients such as N, P, K, Ca, and Mg by rice under vermicompost treatment than FYM. Earthworms accelerated the mineralization rate and converted the wastes into casting with higher nutritional value (Albanel *et al*., 1998). Lal *et al.* (2003) stated that vermicompost contain major and minor plant nutrients in available form that in turn improved the uptake of nutrients by the plants. The application of vermicompost enhanced the availability of nutrients in the soil and uptake by the plants (Usha *et al*., 2006).

2.7.5.3. Effect of vermicompost on biological properties

Elliott *et al*. (1990) noted that the earthworm casts had higher numbers of cellulolytic aerobes and hemicellulolytic, amylolytic, nitrifying and denitrifying bacteria than the soil in which they lived. Presently, vermicompost as an organic manure has been popularized, supplies a good amount of different nutrient elements but also contains beneficial microbes like nitrogen fixing bacteria and mycorrhizae and also releases growth promoting substances for betterment of crops (Kale *et al.*, 1992). The micro organisms in worm casts may fix atmospheric N in quantities that are significant for the earthworm metabolism and as a source of nitrogen for plant growth (Lee, 1992).

The highest bacterial and fungal population was associated with the application of 75 per cent N as vermicompost with azospirillum, which was five times higher than the 100 per cent urea received plot (Kannan *et al.*, 2005). This might be attributed to the vermicompost containing higher amount of growth promoting substances, vitamins, and enzymes, which in turn increased the microbial population and the addition of azospirillum increased the root biomass production, which resulted in higher production of root exudates increasing the beneficial bacteria, fungi and actinomycetes population in rhizosphere region (Gunadi *et al*., 1999 and Masciandaro *et al*., 2000). Vermicompost is a potential source due to the presence of readily available plant nutrients, plant growth hormones, vitamins, enzymes, antibiotics and number of beneficial micro-organisms (Usha *et al*., 2006).

2.7.5.4. Effect of vermicompost on growth, yield components and yield of rice

Kale *et al*. (1992) revealed that in low land rice, applying vermicompost improved uptake of nutrients, increased levels of N, P and microbial load and higher level of symbiotic association resulted in increased effect on growth and yield. Application of vermicompost to crops had immediate benefits as the nutrient can be directly absorbed, when applied to direct sown rice, the seedlings turned dark green immediately after emergence (Gunathilagaraj, 1994).

Angadi and Radder (1996) indicated that the use of vermicompost @ 2.5 t ha^{-1} increased grain and straw yield of rice and could save 50 per cent of recommended NPK fertilizers in upland rice. Jadhav *et al*. (1997) stated that vermicompost was found to be a better source for increased plant growth, dry matter production and yield. Application of vermicompost improved the yield components and yield in rice (Sudhakar *et al*., 2002). Vermicompost favourably influenced the growth of rice (Meena, 2003; Anitha and Prema, 2003). Norman *et al.* (2005) reported that potential of vermicompost to improve plant growth may be due to the changes in physico-chemcial properties of soils, overall effects of plant growth regulators produced by micro-organisms. Roy and Singh (2006) found that increase in growth and yield components of crops due to application of vermicompost is mainly because of microbial stimulation effect and N supplied through gradual mineralization in a steady manner throughout the crop growth period and vermicompost was also effective in maintaining higher fertility status of the soil at residual stages was considered to be beneficial for cultivation of succeeding crops.

2.7.6. Composted poultry manure

Poultry manure is rich organic manure since solid and liquid excreta are excreted together resulting in no urine loss. In fresh poultry excreta uric acid or urate is the most abundant N compound (40-70% of total N) while urea and ammonium are present in small amounts (Krogdahl and Dahlsgard, 1981). The poultry manure can be effectively used by composting to increase the available soil N progressively, thus enabling the manure to release the nutrients steadily and make it available to the plants for a longer period of time without much loss (Amanullah *et al*., 2006b).

Composting or controlled biological decomposition of organic waste has been investigated as a method or stabilizing poultry litter and manure prior to land application. This process produced a material with several advantages with respect to handling by reducing volume, mass of dry matter, odours, fly attraction and breeding weed seed viability (Sweeten, 1980). Composting poultry manure under anaerobic conditions helps for greater recovery of final product and negligible loss of nutrients especially nitrogen (Kirchmann and Witter, 1989).

During the composting process the conversion of organic matter was carried out by different groups of heterotrophic microorganisms like bacteria, fungi, actinomycetes and protozoa. These microorganisms derive their energy and carbon requirement from the carbonaceous materials. For every ten parts of carbon, one part of nitrogen was assimilated for building up of cell protoplasm (Gaur, 1982). The lowering of C:N ratio brought about the fact that two-thirds of carbon consumed was given off as CO_2 while the other one-third was combined with nitrogen in the living cells (Golueke, 1991).

Nodar *et al*. (1990) made a detailed study on characters of poultry excreta. It was explained that the total carbon content in the poultry droppings ranged from 44.7 to 46.9 per cent with C: N ratio 10 to 11. The total nitrogen was 4.45 per cent, organic nitrogen 3.67 per cent, ammoniacal nitrogen 0.74 per cent and nitrate nitrogen 0.1 per cent. The total P content in the form of P_2O_5 was 2.62 per cent. Poultry manure invariably contains an appreciable amount of K. The potassium in manure is considered as being available as its fertilizer equivalent (Tunney, 1981). Poultry excreta contains less carbon and iron than mixed litter, but higher concentration of nitrogen, phosphorus, chlorine, calcium, sodium, copper, zinc and water (Edwards and Daniel, 1992). Composting poultry manure and poultry carcasses, with straw (a carbon source) successfully decomposed the manure and carcasses and produced a stable organic material physically and chemically similar to the manure used in the composting process (Sims *et al*., 1992). The manure would be a nitrogen source that could be added to high carbon wastes to create favourable C: N ratios. The gradual darkening or melanisation of the material takes place and the final product was found to be dark brown colour during the end of composting (Haider, 1992).

Twenty one trace, minor and major elements including aluminium, barium, calcium, cadmium, chromium, copper, iron, potassium, magnesium, molybdenum, sodium, nickel, lead, rubidium, sulphur, vanadium and zinc have been detected in poultry manure and litter (Inhar and Fernandes, 1996). The heat generated during composting may also destroy pathogens (Golueke, 1997). Amanullah (2002) analysed that deep litter poultry manure contains 1.70-2.20, 1.41-1.81, 0.93-1.30 per cent total N, P_2O_5, K_2O respectively and in addition to these nutrients 930-1380 ppm Fe, 90-308 ppm Zn, 24-42 ppm Cu, 210-380 ppm Mn, 0.90 - 1.10 per cent Ca and 0.45-0.68 per cent Mg. Nitrogen, phosphorus and potassium content in poultry manure were 2.42 per cent, 0.81 per cent and 0.74 per cent respectively (Nagaraj *et al.*, 2004).

2.7.6.1. Effect of composted poultry manure on physical properties

Soil physical properties such as bulk density, water holding capacity and percent stable aggregation were noted to be favourably influenced by poultry waste addition to soil (Weil and Kroontje, 1979). The poultry manure significantly decreased bulk density and increased total and macro porosity, infiltration capacity and available water as reported by Mbagulu (1992). In contrast to mineral fertilizer, poultry manure adds organic matter to soil which improves soil structures, nutrient retention, aeration, soil moisture holding capacity and water infiltration (Deksissa *et al*., 2008).

2.7.6.2. Effect of composted poultry manure on chemical properties

2.7.6.2.1. Effect of composted poultry manure on organic carbon

Application of poultry manure increased the soil organic carbon content of residual wheat crop in rice-wheat cropping system (Maskina *et al*., 1988). Poultry manure owing to its higher organic matter content could have increased moisture holding capacity of the soil and resulted in considerable residual carbon, leading to higher soil organic matter and its fractions (Ramesh and Chandrasekaran, 2004).

2.7.6.2.2. Effect of composted poultry manure on N availability

Poultry manure is an excellent organic fertilizer, as it contains high nitrogen, phosphorus, potassium and other essential nutrients. The concentration of N from various organic manures was comparable on equivalent N basis in which poultry manure proved to be a better source (Kettar, 1993). Further the poultry waste had both urinary and fecal excretion, hence the fertilizer value was nearly three times higher than FYM (Devegowda, 1997). Maximum N uptake was noticed when the plot was treated with recycled poultry manure as fish pond silt and FYM (Sumathi, 1998). Canali *et al*. (2000) reported the nitrogen availability was same in poultry manure applied plots compared with inorganic fertilizer. Subha (2000) reported that application of more than 6 t ha^{-1} of animal manure namely poultry manure or cattle manure increased the soil N status. The applied dairy cattle waste and poultry waste composts released approximately equal to 31.5 and 51.3 per cent nitrogen respectively and also had decreased nitrate leaching to deeper soil layer in Kyushu area (Yanwang *et al*., 2002). The higher N uptake in the grain of rice fertilized with poultry manure reflected the extent and pattern of N release for absorption by the plant from seedling stage to grain-filling stages (Norman *et al*., 2005).

2.7.6.2.3. Effect of composted poultry manure on P availability

In a field experiment conducted to find out the effect of poultry manure on phosphorus availability and uptake, it was seen that soluble phosphorus in soil solution was higher when poultry manure was added to crop yield (Warncke and Siregar, 1992). Warnecke and Fonteno (1993) reported that the application of poultry manure to loamy sand soil had increased the available phosphorus status. It was also indicated that poultry manure more readily supplies P to plants than other organic manure sources (Garg and Bahla, 2008).

2.7.6.2.4. Effect of composted poultry manure on K and micronutrient availability

Madhumita *et al*. (1991) reported that a marked increase in the exchangeable K due to application of poultry manure up to 24^{th} day after incubation was observed in an incubation study. The organic manure amendments (Poultry manure, farmyard manure, maize straw and cotton waste) registered higher potassium availability than inorganic amendments, improvement of water availability and reduction of bulk density was also noticed by Mathan *et al*. (2000). The increases in soil fertility is consistent with findings of previous studies that amendment of soil using poultry manure improved soil organic matter, N, P, K, Ca and Mg (Adeniyan and Ojeniyi, 2005; Adenawoola and Adejoro, 2005).

The higher concentration of macro and micronutrients in the composted poultry manure and higher and steady nutrient release compared to other organic manures could make it to perform well and increased soil organic matter and cation exchange capacity from composted poultry manure applications may improve nutrient retention in soils. The application of poultry manure with inorganic fertilizers increased the available Fe, Mn, Cu and Zn gradually from tillering to harvesting stage (Suvarna and Sankara, 2001).

2.7.6.3. Effect of composted poultry manure on biological properties

Wang and Chao (1995) reported that chicken manure used in the organic farming treatment enhanced the bacterial and fungal population greater than conventional farming. Application of poultry manure and dhaincha increased bacterial, fungal and actinomycetes population in soil (Boomiraj, 2003; Somasundaram, 2003). Yadav and Lourduraj (2007) observed that application of 50% N through composted poultry manure + 50% N through green leaf manure increased significantly the microbial population and enzymes activity, which was superior to recommended NPK through fertilizers. The maximum microbial population and enzyme activity was recorded in soil applied with poultry manure (Prasanthrajan *et al*., 2008).

2.7.6.4. Effect of composted poultry manure on growth, yield components and yield of rice

Budhar *et al*. (1991) reported that plant height was markedly influenced by poultry manure. The yield attributing character like panicles m^{-2} and filled grains were more in poultry manure but it was not significant among manures tried like FYM and biogas slurry. Rainy *et al*. (1992) observed that composted poultry litter applied at the rate of 2000 kg ha^{-1} (dry weight basis) increased rice yields in Arkansas, USA. In order to evaluate feasibility of organic farming, experiment was carried out in Tiwan, to compare rice yields from conventional (chemical) farming with those from organic farming, as well as intermediate system (a mixture of chemical and organic fertilizer). A high quality rice variety Taichung 189 was used. Results indicated that application of composted poultry manure gave similar grain yield (7.43 t $ha^{-!}$) as that from conventional farming

(7.43 t ha^{-1}) which depend solely on chemical fertilizer (Sun and Hsieh, 1993). The plant growth parameters and yield contributing characters were affected positively by the incorporation of poultry manure and FYM resulting in the highest grain and straw yield of rice was studied by Verma and Bhagat (1994).

Gupta *et al*. (1995) concluded that there was a 55 per cent increase in yield over control and 5.2 per cent increase in yield over recommended fertilizers due to poultry manure application. Prasad (1999) reported higher rice grain yield following application of poultry manure. Khan and Shaukat (2000) found that application of poultry manure increased rice shoot weight, root weight and grain yield. Application of poultry manure @ 5 t ha^{-1} to rice at Pantnagar recorded higher rice yield over control in all the years of experiments (Singh *et al*., 2000). Poultry manure is efficient organic manure in improving and sustaining rice productivity. Poultry manure increased grain yield by 6.4 per cent and 20.5 per cent over FYM and no organic manure respectively (Channabasavanna *et al*., 2000). In a case study of rice growing farmers, Nagarajan (2003) found that farmers using poultry manure + inorganic fertilizer had got more net income with quality grain than inorganic fertilizers alone. Application of poultry manure (9 t ha^{-1}) produced grain yield in paddy was at par with that of recommended dose of fertilizer (RDF) + 10 t FYM (Ananda *et al*., 2006).

2.7.7. Enriched poultry manure compost

Studies have shown that composting process immobilizes N in the manure and produces humus that can be used as source of organic material and slow down the release of nutrients. The enhanced and continuous supply of nutrients by the enriched organics leading to better tiller production, enhanced panicle length and thousand grain weight of rice was reported by Shanmugam and Veeraputhiran (2001). The application of rock phosphate with poultry manure to soils with earthworms stimulated microbial proliferation and subsequent enzyme synthesis activity leading to faster hydrolysis of ester-bound P to plant available P thereby increase the crop growth (Dinesh *et al*., 2003). The application of organic manures, along with rock phosphate (Rajphos), enhanced the solubility of Rajphos by producing organic acids, which, in turn, improved P availability at the later stages of crop growth and thus increased the grain yield (Selvi *et al*., 2003).

Datta *et al*. (1992) reported that poultry manure at the rate of 5 t ha^{-1} + 21.8 kg P as Mussoorie rock phosphate + inoculation with *Bacillus* sp. gave high yield of 4.17 t ha^{-1} as compared to control (3.17 t ha^{-1}). The granulated enriched poultry manure appears to be potentially better source of N than other organic sources (Prasanthrajan *et al*., 2004).

2.8. Rice based cropping system

Rice-rice, rice-rice-pulses, rice-cotton in South India, rice-wheat-greengram, rice-potato-rice, rice-potato-groundnut in North India and jute-rice-wheat in Eastern India are some of the examples of intensive cropping systems (Chinnusamy *et al*., 1997). Rice-rice-pulse (Greengram/ Blackgram) is the predominant cropping system of major rice growing areas of Tamil Nadu. The possibility of including green manure in rice based cropping systems has been extremely studied by a number of workers (Siddeswaran, 1992; Geethalakshmi, 1996). In all the above studies green manure one of the component crops, neither preceding nor succeeding rice. Cultivation of pulses under rice fallow as relay cropping is a unique system in coastal and deltaic areas of India (Sathyanarayana, 1998).

2.8.1. Green manure-rice-pulse cropping sequence

2.8.1.1. Green manure-rice sequence

More and effective utilization of solar energy and temperature following green manure incorporation in rice based cropping system was reported (Jin, 1984). Kulkarni and Pandey (1987) reviewed that scope and feasibility of including green manure in rice based cropping system and concluded that either a green manure crop or dual purpose grain legumes could be successfully fitted into rice based cropping system. Green manuring before transplantation of rice has been advocated to improve yields and to partially substitute the N requirement of the crop (Swarup, 1987). Regular practice of green manuring over a long period not only improves the soil fertility, but also resulted with noticeable residual effect in intensive cropping system (Palaniappan and Reddy, 1990 and Ghosh and Sharma, 1996).

Pradhan and Mondal (1997) reported that the recommended does of N, P and K may safely be reduced by 25 per cent if green manure is provided to both the rice crops in sequence. Subbalakshmi *et al*. (1999) opined that incorporations of green manure like

Sesbania speciosa and *Sesbania aculeata* increased the total growth yield and productivity of rice-rice cropping system at Madurai. *In situ* green manuring system of on-site nutrient resource generation is most prevalent in northern and southern parts of India where rice is the major crop in the existing cropping system (Bisen *et al*., 2008).

2.8.1.2. Rice-pulse sequence

Growing pulses after rice is beneficial in improving physical, chemical and biological properties of soil. The cropping sequence of rice-pulse is practically feasible, viable, economical, eco-friendly, water saving technology for sustaining soil fertility and rice productivity. The pulse crop production in rice fallow should be viewed as a system (rice-pulse) but not individually. The pulse crop yields were influenced by the duration of the rice, fertilizer applied to the rice, their residual effect, etc. Thus, rice fallow pulses were not only location specific but also system specific and hence the requirements were also specific (Yadav, 1992). Improvement in organic carbon, CEC, porosity and water holding capacity and drastic reduction in bulk density was observed with rice-pulse cropping system as compared to rice-rice cropping system (Prakash *et al*., 2008).

Sushama *et al.* (1993) stated that blackgram cv T9 grown in rice-pulse cropping system increased the efficiency of P-fertilizers. Legume in rice based cropping system results in higher soil N and higher uptake of P (Chandrasekaran and Sankaran, 1995). Setty and Gowda (1997) indicated significant increase in soil fertility status due to incorporation of green manure or legumes under rice-based cropping system in coastal Karnataka.

Legumes with their adaptability to different rice-based cropping patterns and their ability to fix N may offer opportunities to increase and sustain productivity and income in rice based cropping system (Premsekhar, 1993). Sarkar *et al.* (2000) stated that for producing higher yields and to obtain good net profit, farmers can successfully adopt rice-blackgram sequence on rainfed uplands of eastern India. Inclusion of blackgram in the cropping system increased the productive tillers of 412 m^{-2} and filled grains of 80.1 $panicle^{-1}$, which resulted in higher grain yield of 4.57 t ha^{-1} of succeeding pishanam rice (Subramani *et al*., 2005). The mean of 10 years research results revealed that growing pulses after or before rice in rice-pulses sequence recorded maximum grain yield (5550 kg ha^{-1}) as compared to rice-rice cropping system of 5160 kg ha^{-1} (Prakash *et al*., 2008).

2.9. Nutrient balance in cropping sequence

Raju and Reddy (2000) reported a positive balance when full dose of recommended level of N was applied to each rice crop and the balance was negative when only half of the recommended N was applied to either of the rice crops. Geethalakshmi (1996) found a net loss in soil available N balance when either fertilizer N alone or Green Leaf Manures (GLM) alone was added. The application of 40 kg N ha^{-1} either through *Ipomea reptans* or *Calotropis gigantea* (green leaf manures) showed a slight improvement in N balance. In the case of *Sesbania aculeata*, 80 kg N ha^{-1} showed a positive N balance. The application of FYM + Neem cake released the N steadily and hence losses were minimum (99.1% net gain) as observed by Kenchaiah (1997). .

Chandrasekaran and Sankaran (1995) recorded maximum nitrogen balance of 214.6 kg ha^{-1} under rice-cotton cropping sequence. Rajarathinam (2002) indicated that application of 100 per cent recommended N with green manure + Azolla to both the rice crops resulted in a net gain of soil available N. According to Sharma and Sharma (2002) N balance was found to be positive in rice-wheat-greengram and rice-potato-greengram cropping systems. The addition of organic manures in rice based cropping system tended to improve the soil available N status, thus indicating a net gain (Ramesh, 2002). Amanullah *et al*. (2007) observed that application of composted poultry manure had positive N balance due to its steady N release pattern.

2.10. Economics of organic farming

Studies in North America, at the Mennonites and Amish farms, showed that, net returns on investment was usually higher under organic nutrition because they consumed less inputs and when environmental costs were taken into account, the organic alternative is clearly superior (Dahama, 1996). Higher net income by application of vermicompost in rice was obtained by Nagarajan (1997).

In most of the occasions, the total income from organic farming was lower than inorganic farming but the net profit was higher. Because of the use of no or low cost inputs, biological means of weed, pest and disease control, the cost of cultivation was lowered which in turn resulted in higher net profit (Sundararaman *et al*., 2001). Eco-friendly organic farming gave 23 per cent expenditure saving and 73 per cent more profit than chemical farming (Jayasheelan and Rameshkumar, 2002). The investment: income ratio was same under both chemical and organic farming (Somasundaram, 2002). Number of case studies showed that organic and agro-ecological approaches are presently being proven successful in meeting a range of diverse objectives, improving yields, farmer's income and soil health status and reversing established patterns of land degradation (Parrott and Marsden, 2002). Yadav and Lourduraj (2006a) reported that application of 50% N through composted poultry manure + 50% N through green leaf manure along with panchagavya recorded highest net return (Rs. 22273 ha^{-1}) in rice which was on par with recommended NPK through fertilizers along with panchagavya spray (Rs. 21853 ha^{-1}). Application of 150 kg nitrogen as poultry manure recorded the highest net and gross return and benefit-cost ratio may be due to increased yield and decreased cost of cultivation (Prabakaran, 2008).

2.10.1. Economics of rice based cropping sequence

Nallaiah (1996) revealed that the rice (short duration) in *kar* season green manure-rice (short duration) in *pishanam*-blackgram or gingelly in summer fetched a higher net return of Rs. 46373 and Rs. 46535 ha^{-1} with B: C ratio of 3.71 over other cropping sequences.

Chinnusamy *et al*. (1997) revealed that the rice-gingelly-maize sequence with the application of recycled poultry manure @ 5 t ha^{-1} to rice coupled with recommended dose of NPK fertilizers to each crop fetched higher net returns. Rice-rice sequence recorded significantly higher net return of Rs. 33699 ha^{-1} $year^{-1}$ and rice-wheat (Rs. 26528 ha^{-1} $year^{-1}$) (Nagalikar *et al*., 1999). Verma and Warsi (1999) concluded that rice-pulses- oilseeds cropping system increases the productivity with monetary return and benefit cost ratio. The crop sequence *viz.,* rice-rice-greengram gave consistently higher net return of Rs. 40754 to 42513 ha^{-1} with increased B: C ratio was recorded by Rajarathinam (2002).

2.11. Residual effects of organic manures

The organic manures leave behind sufficient residual effect for the sequence crops (Singh *et al*., 1996; Hegde, 1998). The positive carry over effect of organic sources probably owed to the decomposition and release of several nutrients for a long time period (Raju *et al*., 1993). Organic manures, besides supplying some amount of the essential nutrients to the current crop often leave substantial residual effect on the succeeding crops in the system and this residual effect lasts for several seasons. The addition of organic manure in different cropping systems build up the soil fertility over a period of time and the nutrient supply was increased. Ofori *et al*. (2005) obtained higher yield in the second season compared with the first, which could be due to residual effects of previous organic amendments and rice root biomass left after the harvest of the first crop. Application of inorganic fertilizer did not improve soil fertility, which was almost similar to that of the native fertility level of the soil (Vinod Kumar *et al*., 2007).

Kapur and Rana (1980) reported that only 30% of N and 66% of P from FYM were likely to be used by the first crop and the remaining nutrients may become available to the second crop and to a little extent to the subsequent crop which may be the reason for lower yields of paddy with FYM. Residual effect of organic manures on soil fertility is related with their ability to promote soil organic carbon content (Wong *et al*., 1999). Seshadri *et al*. (2005) concluded that poultry manure, sewage sludge and enriched urban garbage compost have higher residual effect on succeeding crops compared to farmyard manure. The important property of organic manure is the residual effect that is by and large beneficial. It points out the long-term advantages in nutrient availability and enhanced moisture retention (Gedam *et al*., 2008).

2.11.1. Residual effect of crop residues

Residual effects of green manures have been reported by a number of workers. Green manures, which decomposes slowly and release little of its N for immediate crop use, would have a large residual effect in the organic matter build up. According to Bouldin *et al*. (1988) 65 per cent of the green manure decomposes during the first crop period and 14.0 and 3.3 per cent of the residual N decomposes during the second and each successive crop respectively.

Panda *et al.* (1991) recorded substantial increase in organic carbon and total nitrogen in the soil after harvest of rice due to green manure, which benefited the succeeding rice crop. Residual effect of applied pre-season green manure *Sesbania* sp was observed through increased N, P and K uptake in the second rice in rice-ratoon rice system and the nitrogen applied through chemical fertilizers alone did not show any residual effect (Kumaresan, 2001).

In general, roots accumulate significant amounts of major, secondary and micronutrients (Viswanathan *et al*., 1978). Under intensive cropping, if the stubbles are ploughed back into the soil, significant quantities of nutrients would be returned to the soil, which gradually become available to the subsequent crops on decomposition. Thangamuthu (1985) found that by rice stubbles (45 cm long) incorporation, fertilizer nitrogen could be reduced by 50 per cent. Ramaswamy (1982) observed that incorporation of rice stubble in the summer rice had a favourable residual effect on the following monsoon rice in terms of better growth, nutrient uptake and yield. About 25% of N and P, 50% of S and 75% of K taken up by cereal crops are retained in the crop residue, making them viable nutrient sources (Singh, 2003). Also, residues return carbon (C) to the soil, which improves soil structure, the ability of the soil to hold nutrients, and water holding capacity and residues provide potassium as well as other nutrients that may not be available in inorganic fertilizers (Navneet and Benipal, 2006).

CHAPTER III

MATERIALS AND METHODS

Field experiments were conducted at wetland farm of Tamil Nadu Agricultural University, Coimbatore during 2007 - 2008 and 2008 - 2009 to investigate the organic nutrient management on the growth and yield of rice and to assess their residual effect on the succeeding blackgram in rice-blackgram cropping sequence through pre-season green manuring of *Sesbania aculeata* Poir. The details of the experiments, the materials used and the methodology adopted are furnished in this chapter.

3.1. MATERIALS

3.1.1. Field location

The field experiments were conducted in 'N' block of the wetland farm, Tamil Nadu Agricultural University, Coimbatore. The farm is situated in Western Agro-climatic Zone of Tamil Nadu at 11° North latitude and 77° East longitude with an altitude of 426.7 m above MSL.

3.1.2. Weather and climate

The experimental farm lies under Semi Arid Tropics (SAT). The normal weather condition of Coimbatore based on the 50 years weather data indicated that a mean annual rainfall of 674.2 mm is received in 45.8 rainy days. The mean annual maximum and minimum temperature ranged from 29.2 to 35.2°C and 17.9 to 23.8°C, respectively. The mean relative humidity ranged from 50 to 77 per cent. The mean sunshine hours per day ranged from 4.6 to 9.9. The mean solar radiation was 429.2 cal cm^{-2} day^{-1}. Weekly weather conditions that prevailed during the cropping periods are furnished in Appendix I and II and depicted in Fig 1 and 2.

3.1.3. Soil and water characteristics of experimental site

The soil of the experimental field was clay loam belonging to Noyyal series. The soil is classified taxonomically as *Typic haplustalf* in USDA classification. The composite soil samples collected prior to the experiment were analysed for various physico-chemical and biological characteristics. The initial analysis of the soil of the experimental site revealed that the soil was slightly alkaline (pH = 8.1) with low soluble salts (EC = 0.45 dS m^{-1}), medium organic carbon content (0.62 per cent), low in available N (262 kg ha^{-1}), medium in P (18.2 kg ha^{-1}) and high in K (576 kg ha^{-1}). Detailed physico-chemical and biological characteristics of the soil are presented in Table 1. The irrigation water was found to be neutral in reaction (pH = 7.60) with medium level of the soluble salts (EC = 1.18 dS m^{-1}). As a whole, the irrigation water was found to be good for irrigation. The procedure followed for the soil and irrigation water analyses are furnished in Table 2.

3.1.4. Crop variety and seasons

The medium duration rice variety Improved white ponni was grown during *rabi* seasons (August - January), while blackgram variety, T9 was used as rice fallow pulse during summer in both the years (2007 - 2008 and 2008 - 2009) of study (Plate 3). The details of crop varieties used for the study are given in Table 3.

3.1.5. Green manure incorporation

Dhaincha (*Sesbania aculeata* Poir.), a leguminous green manure crop (Plate 3), local variety was used as pre-season green manure *S. aculeata* is an indigenous and familiar green manure crop traditionally grown by Indian farmers in lowland rice. It is a root nodulating, quick growing, and succulent green manure, capable of producing 20 to 25 t ha^{-1} biomass accumulating 80-120 kg N ha^{-1} in 55 days. It is tolerant to flooding, salinity and does not require pretreatment of seeds.

Good quality seeds of dhaincha were obtained from Central Farm Unit of Tamil Nadu Agricultural University. The field was thoroughly ploughed with tractor and the seeds were sown at a seed rate of 25 kg ha^{-1} and *in situ* incorporated using tractor drawn cage wheel before transplanting of rice at the age of 51 and 47 days during 2007 and 2008, respectively. The manurial value of *Sesbania aculeata* is furnished in Table 4.

Table 1. Physico-chemical and biological characteristics of soil and irrigation water characteristics of the experimental field

Particulars	Values
A. Soil characteristics	
I. Physical properties	
Mechanical Analysis	
Clay (%)	34.4
Silt (%)	22.1
Coarse sand (%)	16.4
Fine sand (%)	26.8
Textural class	Clay loam
Bulk density (Mg m^{-3})	1.22
Particle density (Mg m^{-3})	2.58
Pore space (%)	54.63
Water holding capacity (%)	36.5
II. Chemical characteristics	
pH	8.1
Electrical conductivity (dS m^{-1})	0.45
Organic carbon (%)	0.62
Available N (kg ha^{-1})	262
Available P (kg ha^{-1})	18.2
Available K (kg ha^{-1})	576
Cation exchange capacity (c mol (P^+) kg^{-1})	20.8
Exchangeable Ca (c mol (P^+) kg^{-1})	9.72
Particulars	**Values**

Exchangeable Mg (c mol (P^+) kg^{-1})	5.81
Exchangeable Na (c mol (P^+) kg^{-1})	2.65
DTPA-Fe (mg kg^{-1})	28.2
DTPA-Cu (mg kg^{-1})	3.1
DTPA-Mn (mg kg^{-1})	3.7
DTPA-Zn (mg kg^{-1})	5.2
III. Biological properties	
Total bacteria (CFU x 10^6 g^{-1} soil)	17
Total fungi (CFU x 10^3 g^{-1} soil)	9
Total actinomycetes (CFU x 10^4 g^{-1} soil)	5
Dehydrogenase (µg of TPF released g^{-1} of soil 24 h^{-1})	8.20
Urease (µg NH_4^+ g^{-1} soil 24 h^{-1})	27.73
Phosphatase (µg of p-nitrophenol released g^{-1} of soil h^{-1})	12.04
B. Irrigation water characteristics	
pH	7.60
Electrical conductivity (dS m^{-1})	1.18

Table 2. Methods employed for soil and irrigation water analysis

Particulars	Method	Reference
I. Physical characteristics of soil		
Mechanical Analysis	Robinson's international pipette method	Piper (1966)
Bulk density	Core method	Gupta and Dakshinamoorthi (1981)
Particle density		
Per cent pore space	Pressure plate apparatus method	Richards (1954)
Water holding capacity	Pressure plate apparatus method	Richards (1954)
II. Chemical characteristics of soil		
pH (Soil: Water = 1: 2)	Using glass electrode in the "ELICO" pH meter	Jackson (1973)
Electrical conductivity (Soil: Water = 1: 2)	Using "ELICO" conductivity bridge	Jackson (1973)
Organic carbon	Chromic acid wet digestion method	Walkley and Black (1934)
Available N	Alkaline permanganate method	Subbiah and Asija (1956)
Available P	Using 0.5 M $NaHCO_3$ of pH 8.5 using colorimeter	Olsen *et al*. (1954)
Available K	Flame photometric method using neutral normal ammonium acetate extract	Stanford and English (1949)
Cation exchange capacity	Neutral normal ammonium acetate	Jackson (1973)
Exchangeable Ca	Versenate method	Jackson (1973)

Particulars	Method	Reference
Exchangeable Mg	Versenate method	Jackson (1973)
Exchangeable Na	Flame photometer	Jackson (1973)
DTPA extractable micronutrients	0.005 M DTPA using Atomic Absorption Spectrophotometry	Lindsay and Norvell (1978)
III. Biological properties of soil		
Soil microbial population		
Total bacteria	Nutrient agar	Collings and Lyne (1968)
Total fungi	Martin’s rose Bengal agar	Martin (1950)
Total actinomycetes	Kenknight’s medium	Kenknight and Muncie (1939)
Soil enzyme activity		
Dehydrogenase	Spectrophotometer at 485 nm	Casida *et al*. (1964)
Urease	Spectrophotometer at 630 nm	Tabatabai and Bremner (1969)
Phosphatase	Spectrophotometer at 420 nm	Halstead (1964)
Irrigation water characteristics		
pH	Potentiometry	Jackson (1973)
Electrical conductivity	Conductometry	Jackson (1973)

Table 3. Characteristics of varieties used in the experiment

A. Particulars	**Rice (Improved white ponni)**
Parentage	Taichung 65/2 X Mayang Ebos-80
Duration (days)	135 - 140
Average yield (kg ha^{-1})	5000
1000 grain weight (g)	16.4
Grain L/B ratio	2.84
Grain type	Medium slender
Morphological Characters	
Habit	Medium tall, erect
Leaf sheath	Green
Panicle	Long drooping
Rice colour	White
Grain size (mm)	
Length	8
Breadth	3
Thickness	2
B. Particulars	**Blackgram (T9)**
Parentage	Selection from Bareilly, U.P
50% flowering (days)	30 - 35
Maturity duration (days)	65 - 70
Grain yield (kg ha^{-1}) (Irrigated)	1000
Height (cm)	35 - 40
Clusters	10 - 12
100 grain weight (g)	4.0

(CPG, 2005)

3.1.6. Organic manures

Well decomposed farmyard manure was collected from the wetland farm, Tamil Nadu Agricultural University, Coimbatore. Poultry manure, vermicompost and neem cake (Plate 1a) were obtained from Central Farm Unit of Tamil Nadu Agricultural University. Nutrient contents of manures were analysed and furnished in Table 4. The quantity of manures required for the experiment was worked out based on equal N basis and presented in Table 5.

3.1.6.1. Enriched farmyard manure compost preparation

For enriched FYM compost (Plate 1a), 10 kg of rock phosphate and 10 kg of each biofertilizers *viz*., Azospirillum, Azotobacter and Phosphobacteria were thoroughly mixed with 1000 kg of well decomposed and powdered FYM on dry weight basis and made into a heap like structure. The heap was kept for 60 days for composting under the shade with 60% moisture. The manurial value of enriched FYM compost was analysed and furnished in Table 4. The quantity of compost required for the experiment was worked out based on equal N basis and presented in Table 5.

3.1.6.2. Composted poultry manure preparation

For composting poultry manure (Plate 1a), 100 kg of bits of chopped rice straw was mixed with 1000 kg of poultry manure on dry weight basis and made into a heap like structure. The heap was kept for 60 days for composting under the shade with 60% moisture as suggested by Sims *et al*. (1992). The manurial value of composted poultry manure was analysed and furnished in Table 4. The quantity of compost required for the experiment was worked out based on equal N basis and presented in Table 5.

3.1.6.3. Enriched poultry manure compost preparation

The enriched poultry manure compost (Plate 1a) was prepared by using 20 kg of rock phosphate and 10 kg of each biofertilizers *viz*., Azospirillum, Azotobacter and Phosphobacteria which were thoroughly mixed with 1000 kg of poultry manure on dry weight basis and made into a heap like structure. The heap was kept for 60 days for composting under the shade with 60% moisture as suggested by Sims *et al*. (1992). The manurial value of enriched poultry manure compost was analysed and furnished in Table 4.

The quantity of compost required for the experiment was worked out based on equal N basis and presented in Table 5.

Table 5. Quantity of organic manures added (kg ha^{-1}) on equal N basis

Organic manures	Quantity added to substitute 100% recommended N for rice (75 kg ha^{-1})	
	***Rabi* 2007 - 2008**	***Rabi* 2008 - 2009**
T_1 : Enriched FYM compost	5319	5682
T_2 : Vermicompost (VC)	3927	4310
T_3 : FYM + Neem cake (1/2+1/2)	6250 + 893	7500 + 987
T_4 : Enriched FYM compost + VC + FYM (1/3+1/3+1/3)	1773 + 1309 + 4167	1894 + 1437 + 5000
T_5 : Composted poultry manure	3304	3363
T_6 : Enriched poultry manure compost	2344	2329

Table 6. Quantity of P and K (kg ha^{-1}) added through organic sources in different treatments (*Rabi* 2007 - 2008)

Treatments	P		K	
	Quantity	**Total**	**Quantity**	**Total**
T_1: Enriched FYM compost	58.51	58.51	37.76	37.76
T_2: Vermicompost (VC)	24.74	24.74	47.91	47.91
T_3: FYM + Neem cake (1/2+1/2)	26.25+6.07	32.32	42.5+7.68	50.18
T_4: Enriched FYM compost + VC + FYM (1/3+1/3+1/3)	19.50+8.25+ 17.50	45.25	12.58+15.97+ 28.34	56.89
T_5: Composted poultry manure	47.91	47.91	41.63	41.63
T_6: Enriched poultry manure compost	49.69	49.69	42.66	42.66

Table 7. Quantity of P and K (kg ha^{-1}) added through organic sources in different

treatments (*Rabi* 2008 - 2009)

Treatments	P		K	
	Quantity	Total	Quantity	Total
T_1: Enriched FYM compost	52.27	52.27	69.32	69.32
T_2: Vermicompost (VC)	24.14	24.14	57.75	57.75
T_3: FYM + Neem cake (1/2+1/2)	28.50+ 6.91	35.41	54.00+7.50	61.50
T_4: Enriched FYM compost + VC + FYM (1/3+1/3+1/3)	17.42+8.05+ 19.00	44.47	23.11+19.26 + 36.00	78.37
T_5: Composted poultry manure	50.11	50.11	43.38	43.38
T_6: Enriched poultry manure compost	50.77	50.77	45.42	45.42

3.2. Methods

3.2.1. Experimental details

The experiments were laid out in a randomized block design with three replications. The layout plan of the experiment is depicted in Fig 3. The field was kept undisturbed throughout the period of investigation for residual study. Particulars on date of sowing, transplanting, harvest, incorporations of green manure and plot sizes are presented in Table 8.

3.2.2. Treatment details

T_1 : Enriched farmyard manure compost

T_2 : Vermicompost

T_3 : Farmyard manure + Neem cake (1/2+1/2)

T_4 : Enriched farmyard manure compost + Vermicompost + Farmyard manure (1/3+1/3+1/3)

T_5 : Composted poultry manure

T_6 : Enriched poultry manure compost

T_7 : Recommended NPK (75: 50: 50 N, P_2O_5 and K_2O kg ha^{-1} through fertilizers)

T_8 : Absolute control (No organics and inorganics)

Table 8. Details of date of sowing, transplanting, harvest and plot size

Particulars	First cropping cycle (2007 - 2008)	Second cropping cycle (2008 - 2009)
I. Pre-season green manure		
Date of sowing	19.06.07	23.06.08
Date of incorporation	08.08.07	08.08.08
Field duration (days)	51	47
II. *Rabi* Rice		
Date of sowing	09.08.07	04.08.08
Date of transplanting	07.09.07	01.09.08
Date of harvest	29.12.07	24.12.08
Field duration (days)	114	115
III. Summer blackgram		
Date of sowing	06.02.08	02.02.09
Date of harvest	19.04.08	13.04.09
Field duration (days)	74	71
Gross plot size	12 x 7 (84 m^2)	12 x 7 (84 m^2)
Net plot size	8.4 x 4.9 (41.2 m^2)	8.4 x 4.9 (41.2 m^2)

3.3. Cultivation practices

Cultural operations other than the treatments were done as per the recommended practices (CPG, 2005).

3.3.1. Main field preparation

The field was thoroughly puddled with tractor drawn cage wheel after green manure incorporation and levelled with bullock drawn wooden plank. The layout was taken providing with buffer channels all round the plot to minimize the movement of nutrients and water. Final levelling was done with hand to ensure uniform stand of water. General view of the experimental field was shown in Plate 4.

After the harvest of rice, the residual crop of blackgram was raised without any field preparation. Prior to sowing, water was let into the field to wet the soil. After obtaining the optimum moisture condition, seeds of blackgram were hand-dibbled as per treatment.

3.3.2. Seeds and sowing

The paddy seeds were obtained from the Central Farm Unit of Tamil Nadu Agricultural University. The seeds were sown at a seed rate of 40 kg ha^{-1} after treating with *Pseudomonas fluorescence* at 10 g kg^{-1} of seeds and Azospirillum 600 g ha^{-1} of seeds for raising nursery. The seeds were soaked in water for 24 hours and incubated. The sprouted seeds were used for raising nursery.

3.3.3. Nursery

Separate nursery was raised for organic treatments with organic manure application (Plate 2a). The nursery area was puddled and recommended quantities of farmyard manure, vermicompost and neem cake were applied before sowing and leveled well with wooden plank. The sprouted seeds were broadcasted uniformly with a thin film of standing water. The nursery was managed well with irrigation. Neem oil (1.5%) and panchagavya (3%) were used as protection measures. For the inorganic treatment (T_8), nursery was raised with the application of inorganic fertilizers (Plate 2b).

3.3.4. Transplanting

Transplanting was done in the main field with a spacing of 20 x 10 cm at two seedlings $hill^{-1}$. After harvesting of rice, the residual crop of blackgram was sown in the same plots by adopting a seed rate of 25 kg ha^{-1} with a spacing of 30 x 10 cm.

3.3.5. Organic manure application

Based on the equal N basis, required quantities of farmyard manure, enriched FYM compost, vermicompost, composted poultry manure, enriched poultry manure compost and neem cake, were incorporated in the soil one week before transplanting of rice (Plate 1b). Different sources of organic manures were applied as per treatment schedule. For Improved white ponni, N @ 75 kg ha^{-1} was applied (CPG, 2005). The N, P and K contents of the organic sources are given in Table 4. The P and K requirement was not supplied separately and whatever contained in the organic sources are taken into account except T_7 and T_8 (Table 6 and 7).

3.3.6. Inorganic fertilizer application

In treatment T_8, recommended doses of 75: 50: 50 kg ha^{-1} of N, P and K in the form of urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) were applied to the rice crop. The N was applied in four equal splits 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 blackgram was grown as a residual crop without any organic and fertilizer application.

3.3.7. Water management

The plots were irrigated with one cm of water for one week after transplanting. The depth of water was increased from one cm to five cm as the crop advanced in age. Irrigation was given with five cm depth of water after the establishment stage one day after the disappearance of ponded water. Irrigation was stopped 15 days before harvest.

3.3.8. Weed management

Two hand weeding were done to manage the weeds in the rice field. One hand weeding was given on 25th day and other at 45th days after transplanting to keep the field in weed free condition. No herbicide was used.

3.3.9. Plant protection

Neem oil and Panchagavya were sprayed as prophylactic measure against insects. Neem oil @ 3% was sprayed at 45 and 50 days after transplanting in order to keep rice leaf folder population below ETL. Panchagavya @ 3% was sprayed at 55 days after transplanting. The bio control agent *Beauveria* sp. @ 2% was also used to control the leaf folder. For the inorganic treatment (T_8), the chemical plant protection measures were taken as recommended in CPG (2005) on need basis.

3.3.10. Harvesting and threshing

For the rice crop, border rows in the plots were harvested first and the net plots were then harvested and threshed. Grain yield from net plots was brought to 14 per cent moisture by shade drying and expressed in kg ha^{-1}. Straw was sun dried thoroughly, weighed and expressed as kg ha^{-1}.

3.4. Biometric observation

3.4.1. Biometrics on green manure

3.4.1.1. Plant height

Plant height of green manure was recorded at the time of incorporation of green manure and expressed in cm.

3.4.1.2. Fresh biomass and dry biomass

The biomass of green manure crop was recorded at the time of incorporation and expressed in t ha^{-1} of fresh biomass. The samples were air dried followed by oven drying at 70°C to attain constant weight and dry weight was recorded and expressed in t ha^{-1}.

3.4.1.3. Nodule number

Total number of nodules of green manure at the time of incorporation was counted and expressed as nodule number $plant^{-1}$.

3.4.1.4. Nutrient contribution by green manure

Green manure plant samples were analysed for nutrient content following the standard procedure as shown in Table 10. Nutrient content was multiplied with the biomass and the nutrient contribution of the green manure was assessed and presented in Table 4.

3.4.2. Biometric observation on rice

3.4.2.1. Growth components

Five plants in each plot were selected at random and tagged. These plants were used for recording biometric observation at different stages of crop growth as follows.

3.4.2.1.1. Plant height

Plant height was measured from ground level to the tip of the longest leaf stretched was measured at active tillering, panicle initiation, flowering and harvest stages of rice and expressed as cm.

3.4.2.1.2. Number of tillers

Total number of tillers was counted at active tillering, panicle initiation, flowering and harvest stages and expressed as tillers m^{-2}.

3.4.2.1.3. Dry matter production (DMP)

From the sampling area in each plot, five plants were removed randomly at active tillering, panicle initiation, flowering and harvest stages. These samples were first air dried in shade and then oven dried at 70°C to constant weight and dry weight was recorded and reported as kg ha^{-1}.

3.4.2.2. Root studies

Studies taken up on rice root system are explained here under.

3.4.2.2.1. Root length

Root length was estimated at active tillering, panicle initiation, flowering and harvest stages. For this, five hills were removed from each plot carefully from sampling area, without much loss of roots as far as possible and root length was measured from the base to the tip of the largest root and expressed in cm.

3.4.2.2.2. Root volume

After measuring the root length, the roots were separated from the plants and were washed with water and the root volume was measured by water displacement method (Karthikeyan, 1999). The root volume $hill^{-1}$ was measured and expressed in cubic centimeter (cc).

3.4.2.2.3. Root dry matter

After measuring the root volume, the roots were dried in shade and then oven dried at 70°C till the attainment of constant weight and expressed in g $hill^{-1}$.

3.4.2.3. Growth analysis

3.4.2.3.1. Leaf Area Index (LAI)

The maximum length and breadth of the 3rd leaf from the top of five tagged plants were measured at active tillering, panicle initiation, flowering and harvest stages and the mean value was multiplied with total number of leaves plant^{-1}. The LAI was worked out using the formula suggested by Yoshida *et al.* (1976).

$$LAI = \frac{K\,(L \times W) \times \text{Number of leaves per hill}}{\text{Land area occupied by the plant}}$$

Where,

K - Constant factor (0.73 for *rabi* season rice)

L - Maximum length of the 3rd leaf blade from the top (cm)

W - Maximum width of the leaf blade (cm)

3.4.2.3.2. Leaf N content

A chlorophyll meter (SPAD 502, Soil Plant Analysis Division section, Minolta Camera Co., Osara, Japan) was used to obtain SPAD values of intact leaves as described by Peng *et al.* (1993). Observations were recorded at active tillering, panicle initiation and flowering stages by taking five observations per leaf around the mid point of each leaf blade, 30 cm apart on upper (dorsal) side of midrib. Readings from five plants i.e. 25 readings, were averaged to represent the mean SPAD values of each plot.

3.4.2.3.3. Crop Growth Rate (CGR)

The CGR indicates an increase in dry matter per unit land area per unit time. It was calculated by using the formula suggested by Watson (1958). It was estimated at active tillering to panicle initiation, panicle initiation to flowering and flowering to harvest stages and expressed in g m^{-2} day^{-1}

$$CGR = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

Where,

W_1 and W_2 - Whole plant dry weight at time t_1 and t_2 respectively

P - Ground area occupied by the plant (m^2)

t_1 and t_2 - Time interval in days.

3.4.2.3.4. Net Assimilation Rate (NAR)

The NAR is the measure of photosynthetic product that is partitioned to form the plant materials. The NAR during the crop growth period (active tillering to panicle initiation, panicle initiation to flowering and flowering to harvest) was estimated by using the following formula suggested by Williams (1946) and expressed in mg cm^{-2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{Log_e L_2 - Log_e L_1}{L_2 - L_1}$$

Where,

L_1 and L_2 - Leaf area of plant at time t_1 and t_2 respectively

W_1 and W_2 - Whole plant dry weight at time t_1 and t_2 respectively

t_1 and t_2 - Time intervals in days.

3.4.2.4. Yield components

The following yield components were measured at harvest from the tagged plants.

3.4.2.4.1. Number of productive tillers m^{-2}

The ear bearing tillers were counted from the five-tagged plants and the mean number of productive tillers m^{-2} was calculated.

3.4.2.4.2. Panicle length

Panicle length was measured from the point of scar to the tip of the panicle obtained from five primary panicles of the tagged hills and mean length of panicle was calculated and expressed in cm.

3.4.2.4.3. Panicle weight

Five primary panicles collected for measuring panicle length were weighed using an electronic balance and the mean weight of the panicle was calculated and expressed in g.

3.4.2.4.4. Thousand grain weight

One sample of 1000 filled grains was taken from each plot and the test weight was recorded and expressed in g.

3.3.2.4.5. Number of spikelets and filled grains panicle^{-1}

The total number of spikelets from each of five primary panicles were separated and sorted into filled and ill-filled grains and the mean values of filled grains panicle^{-1} was worked out.

3.3.2.4.6. Fertility percentage

The percentage of spikelets fertility was worked out using the following formula.

$$\text{Fertility percentage} = \frac{\text{Number of filled grains panicle}^{-1}}{\text{Number of spikelets panicle}^{-1}} \text{ X } 100$$

3.4.2.5. Yield

3.4.2.5.1. Grain and straw yield

The harvested produce from each net plot was threshed, sun dried, winnowed separately and the grain yield was recorded at 14 per cent moisture content and expressed in kg ha^{-1}.

The straw yield of rice was recorded from the net plot area after enough sun drying and expressed in kg ha^{-1}.

3.4.2.5.2. Harvest Index (HI)

Harvest index was calculated by using the following formula as suggested by Yoshida *et al*. (1976).

$$\text{HI} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})}$$

3.4.2.6. Stubble biomass

Stubble was cut at ten cm height from ground level uniformly during harvest. To estimate the amount of biomass of stubbles added after rice crop, the soil was dug out up to 30 cm depth in an area of one quadrate (0.25 m^2) and the sample was washed treatment wise in a drum with a continuous flow of water as per the procedure suggested by Long (1951). The stubbles along with the root system were separated, dried, weighed and expressed in kg ha^{-1}.

3.4.2.7. Biometric observations on blackgram

The following growth and yield attributes were recorded from the tagged plants

i. Plant height (cm)

ii. Leaf area index

iii. Dry matter production (kg ha^{-1})

iv. Number of clusters $plant^{-1}$

v. Number of pods $plant^{-1}$

vi. Length of pod (cm)

vii. Number of seeds pod^{-1}

viii. 100 grain weight (g)

The grain and haulm yield were recorded from net plot and grain yield was expressed as kg ha^{-1} at 12 per cent seed moisture level.

3.5. Compost sample analysis

Standard methods were followed for the analysis of compost materials as shown in Table 10.

3.6. Soil analysis

Physical, chemical and biological analysis made on soil samples are detailed below.

3.6.1. Soil physical analysis

Post harvest soil of rice and blackgram was analysed for bulk density and particle density following core method suggested by Gupta and Dakshinamoorthi (1981). The per cent pore space and water holding capacity were determined by the pressure plate apparatus method suggested by Richards (1954).

3.6.2. Soil chemical analysis

3.6.2.1. Soil nutrients

Soil samples were taken before the start of experiment, during the experiment and after harvest of rice and blackgram. Soil samples were taken 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, macro, secondary and micronutrients following the standard procedures as shown in Table 2.

3.6.2.2. Nitrogen use efficiency

Various parameters used to study the use efficiency of nitrogen are as follows.

3.6.2.2.1. Agronomic efficiency (AE)

The agronomic efficiency i.e. the response in yield per unit input as indicated by the following formula (Yoshida, 1981).

$$AE = \frac{\text{Grain yield in fertilized plot (kg ha}^{-1}\text{) - Grain yield in unfertilized plot (kg ha}^{-1}\text{)}}{\text{Quantity of fertilizer N applied (kg ha}^{-1}\text{)}}$$

3.6.2.2.2. Apparent N recovery (ANR)

Apparent N recovery, also known as recovery fraction was computed as per the formula suggested by Pillai and Vamadevan (1978).

$$\text{ANR (\%)} = \frac{Y_t - Y_o}{N_t} \times 100$$

Where,

Y_t - uptake of N in particular treatment (kg ha^{-1})

Y_o - uptake of N in unfertilized plot (kg ha^{-1}) and

N_t - quantity of N applied for the treatment (kg ha^{-1})

3.6.2.3. Nutrient balance in the cropping system

Soil available nutrient (N, P and K) balance in the cropping system was computed for the treatments as per the procedure suggested by Sadanandan and Mahapatra (1973).

3.6.3. Soil biological analysis

3.6.3.1. Assessment of microbial population

The microbial population in the soil at different stages of the crop was determined. The standard serial dilution plating technique of Pramer and Schemidt (1965) was adopted for the estimation of microbial population and expressed as colony forming unit (CFU) g^{-1} soil. The different types of microorganisms were enumerated using differential media favouring the growth of bacteria, fungi and actinomycetes as shown in Table 2.

3.6.3.2. Assessment of enzyme activity

The enzyme activity was determined at initial and post harvest stages of rice and blackgram. The substrates and methods followed for enzyme assays as shown in Table 9. were adopted.

Table 9. Standard methods followed for soil enzyme analysis

Enzyme	Substrate	Method	Reference
Dehydrogenase	2,3,5-Triphenyl tetrazolium chloride	Spectrophotometer at 485 nm	Casida *et al*. (1964)
Urease	10% urea solution	Spectrophotometer at 630 nm	Tabatabai and Bremner (1969)
Phosphatase	p-nitrophenol phosphate	Spectrophotometer at 420 nm	Halstead (1964)

3.7. Plant analysis

Green manure sample at the time of incorporation and rice plant samples collected at active tillering, panicle initiation, flowering and harvest stages and blackgram at harvest stage for DMP were chopped 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 10.

$$\text{Nutrient uptake}(\text{kg ha}^{-1}) = \frac{\text{Percentage of nutrient x Total dry matter production}(\text{kg ha}^{-1})}{100}$$

Table 10. Analytical methods employed in plant, green manure and compost 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	Vanado molybdophosphoric 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)

3.8. Quality characteristics

3.8.1. Milling quality

The rough rice (paddy) was cleaned, dried to 12 to 14 per cent moisture and dehulled with a McGill laboratory sheller. After hulling, the brown rice was milled and polished in a Kett polisher for a standard time to find out the milling percentage and head rice recovery.

3.8.1.1. Milling recovery percentage

Milling recovery percentage is estimated as

$$\text{Milling recovery (\%)} = \frac{\text{Total milled rice}}{\text{Total rough rice}} \times 100$$

3.8.1.2. Head rice recovery percentage

Head rice recovery percentage is estimated as

$$\text{Head rice recovery (\%)} = \frac{\text{Total head rice}}{\text{Total rough rice}} \times 100$$

3.8.1.3. Broken percentage

Broken rice percentage is defined as the percentage of broken rice to the weight of total quantity of rice obtained by shelling.

$$\text{Broken rice (\%)} = [W_2/(W_1+W_2)] \times 100$$

Where,

W_1 - Weight of whole rice in the sample (g)

W_2 - Weight of broken rice in the sample (g)

3.8.1.4. Co-efficient of shelling

Co-efficient of shelling (C) was calculated with the following formula

$$C = (W-W_1)/W$$

Where,

W - Total quantity of sample (g)

W_1 - Weight of unshelled paddy (g)

3.8.1.5. Effectiveness of shelling

The effectiveness of shelling (ES) was calculated with the following formula

$$ES = C \times H$$

Where,

C = Co-efficient of shelling

H = Head rice percentage

3.8.2. Physical parameters

The rice grains were cleaned manually to remove foreign matters such as stones, sand, clay particles, shriveled, discoloured and infected grains. The following physical parameters were studied to evaluate the quality of rice.

3.8.2.1. Length

The length was estimated by the method described by Khan and Ali (1985). Ten rice grains of uniform size were kept length-wise on a graph paper and the mean length was measured and expressed in mm.

3.8.2.2. Breadth

The breadth was estimated by the method described by Khan and Ali (1985). Ten rice grains of uniform size were kept breadth-wise on a graph paper and the mean breadth was measured and expressed in mm.

3.8.2.3. L: B ratio

Using the measured length and breadth, L: B ratio was calculated for individual grain of the different samples.

3.8.2.4. 1000 kernel weight (g)

One thousand kernels each of the milled rice was counted randomly in duplicate and weighed in a single pan balance and expressed in grams.

3.8.3. Chemical parameters

Rice samples of each treatment were cleaned by removing stones and other foreign particles. Good grains were powdered and used for chemical analysis.

3.8.3.1. Moisture (ISTA, 1999)

Five grams samples were placed in moisture weighing bottle and kept in a hot air oven maintained at 105°C. After 16±1 hours of drying, they were cooled in a desiccator for 30 minutes. The weight of the seeds before and after drying was recorded and expressed in gram. The moisture content of the seed was calculated using the following formula.

$$\text{Moisture content (\%)} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where,

M_1 - Weight of weighing bottle alone

M_2 - Weight of bottle + seed sample before drying

M_3 - Weight of bottle + seed sample after drying

3.8.3.2. Fat content (A.O.A.C., 1980)

Fat was estimated as crude ether extract of the dry material. Fat content in per cent was calculated by the following formula.

$$\text{Fat content (\%)} = \frac{\text{Weight of ether extract}}{\text{Weight of the sample}} \times 100$$

3.8.3.3. Protein

Protein content of rice sample was estimated as per the method suggested by Lowry *et al*. (1951). The estimation of protein was based on the development of blue colour by the hydroxyl groups present in the amino acids with the folin-ciocalteau phenol reagent. The protein content of sample was expressed as percentage.

3.8.3.4. Carbohydrate

Carbohydrate content was estimated from the samples of each treatment by anthrone method as suggested by Hedge and Hofreiter (1962) and expressed as percentage.

3.8.3.5. Amylose content

The method suggested by Sadasivam and Manickam (1996) was followed in determining amylose content.

3.8.3.6. Fibre

The method suggested by Sadasivam and Manickam (1996) was followed in determining fibre content.

3.8.3.7. Total ash (A.O.A.C., 1980)

Ash content percent was calculated by using the following formula.

$$\text{Ash content percent} = \frac{\text{Weight of the ash}}{\text{Weight of the sample taken}} \times 100$$

3.8.4. Cooking Quality

3.8.4.1. Optimum cooking time

The time taken for cooking was estimated by the method described by Jayachandran (1997). Five gram of sample was taken in a boiling test tube. To this 35 ml of water was added and placed in a boiling water bath. A few rice grains were periodically withdrawn and pressed between two slides and the cooking time was adjusted to be complete when white chalky spots had disappeared.

3.8.4.2. Volume expansion ratio

The volume expansion ratio was estimated by the method described by Khan and Ali (1985). It is the ratio between the cooked volume to the uncooked. Five gram of rice was added in a boiling test tube and the level was marked. It was cooked by adding water and the level of rice was also marked. The volume was measured by using water displacement method.

3.8.4.3. Water absorption ratio

The water absorption ratio was estimated by the method described by Khan and Ali (1985). It is the ratio between the weight of the cooked rice to the uncooked.

3.8.4.4. Kernel length and breadth after cooking

Ten normal milled grains are presoaked to 10-30 minutes and placed directly into boiling water either by direct dropping or in a wire cage or basket until its optimum cooking time. The length and breadth of cooked rice are measured and the average worked out.

$$\text{Linear Elongation Ratio (LER)} = \frac{\text{Length of cooked rice}}{\text{Length of raw rice}}$$

$$\text{Breadth wise Expansion Ratio (BER)} = \frac{\text{Breadth of cooked rice}}{\text{Breadth of raw rice}}$$

$$\text{Length Breadth Ratio After Cooking (LBAC)} = \frac{\text{Kernel length after cooking}}{\text{Kernel breadth after cooking}}$$

3.8.5. Sensory evaluation

Plain cooked rice was evaluated by a trained panel of judges for their sensory attributes consisting of colour, texture, taste and overall acceptability using a score card (Appendix IV), with nine point Hedonic scale (Watts *et al*., 1989).

3.9. Production potential of system

Production potential of system was done from total grain production in systems (system productivity). Per day production was obtained by dividing with corresponding crop duration.

3.10. Economic evaluation

Cost of cultivation for all the treatments was worked out on the basis of prevailing input cost and market price of produce at the time of experimentation. The economics for organic rice grain was worked out based on premium price. The details of cost of cultivation of green manure-rice-blackgram cropping sequence are furnished in Appendix III. The net income was calculated by deducting the cost of cultivation from the gross return. Benefit Cost Ratio (BCR) was worked out as follows.

$$\text{BCR} = \frac{\text{Gross return ha}^{-1}\text{(Rs.)}}{\text{Cost of cultivation ha}^{-1}\text{(Rs.)}}$$

3.11. Statistical analysis

The data on various characters studied during the course of investigation were statistically analysed as suggested by Gomez and Gomez (1984) 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’.

CHAPTER IV

RESULTS

Towards realizing the objectives enumerated in Chapter I, field experiments were conducted during June, 2007- April, 2009 and the salient findings are reported herein.

4.1. Performance of green manure crop *Sesbania aculeata* (Table 11)

Pre-season green manuring with *Sesbania aculeata* had uniform growth throughout the field in both 2007 and 2008. On an average, it recorded 62.6 and 60.3 cm of plant height, 40.5 and 38.2 root nodules plant^{-1}. The green manure registered 10.6 and 9.8 t ha^{-1} of fresh biomass and 2.72 and 2.53 t ha^{-1} of dry biomass, through which 72.6 and 66.8 kg N ha^{-1}; 14.1 and 12.7 kg P ha^{-1}; 32.1 and 29.1 kg K ha^{-1} were accumulated in 2007 and 2008, respectively at the time of *in situ* incorporation.

4.2. Growth parameters of rice

4.2.1. Plant height (Table 12)

The plant height was measured at active tillering, panicle initiation, flowering and harvest stages in both *rabi* 2007 and 2008. Rice plant height increased as the crop growth advanced from active tillering and it was maximum at harvest stage. Application of organic manures and recommended NPK fertilizer exerted marked influence on the plant height.

During *rabi* 2007 and 2008, the taller plant height was recorded with recommended NPK fertilizer application (T_7) at active tillering (48.2 and 51.2 cm) and panicle initiation (71.2 and 72.5 cm) stages, respectively and it was comparable with enriched poultry manure compost (T_6) and composted poultry manure (T_5).

The application of enriched poultry manure compost (T_6) was found to be the best in enhancing the plant height (107.5 and 108.2 cm) for flowering and harvest (115.6 and 118.8 cm) stages, respectively in both the years and it was on par with composted poultry manure (T_5) whereas, recommended NPK through fertilizer (T_7) was comparable with composted poultry manure (T_5).

The absolute control (T_8) treatment registered shorter plants (38.4, 52.2, 86.4 and 88.5 cm during *rabi* 2007; 38.2, 53.8, 87.5 and 89.6 cm during *rabi* 2008, respectively) at all the four stages of crop growth.

4.2.2. Number of tillers m^{-2} (Table 13)

During *rabi* 2007 and 2008, the number of tillers produced m^{-2} was more with enriched poultry manure compost (T_6) at active tillering (382 and 397) and panicle initiation (403 and 410) stages respectively, which was however on par with composted poultry manure (T_5) and recommended NPK fertilizer application (T_7).

Application of enriched poultry manure compost (T_6) recorded conspicuously higher number of tillers m^{-2} (359 and 355 in *rabi* 2007; 365 and 359 in *rabi* 2008, respectively) at flowering and harvest stages. However, it was found to be on par with composted poultry manure (T_5) whereas, recommended NPK fertilizer application (T_7) was comparable with composted poultry manure (T_5). These treatments were followed by FYM + neem cake (T_3), vermicompost (T_2), enriched FYM compost + vermicompost + FYM (T_4) and enriched FYM compost (T_1). Absolute control (T_8) produced minimum number of tillers m^{-2} (275, 284, 250 and 248 in *rabi* 2007; 275, 284, 254 and 252 in *rabi* 2008, respectively) at active tillering, panicle initiation, flowering and harvest stages.

4.2.3. Dry matter production (DMP) (Table 14)

During both the years of study, the DMP increased steadily with advancement of age, attaining its peak at harvest in all the treatments. The DMP was favourably increased at all the stages, due to organic manure and recommended NPK fertilizer application.

In *rabi* 2007 and 2008, enriched poultry manure compost (T_6) application recorded significantly higher DMP (2131 and 4148 kg ha^{-1}; 2345 and 4348 kg ha^{-1} at active tillering and panicle initiation stages, respectively), which was however comparable with composted poultry manure (T_5) and recommended NPK fertilizer application (T_7).

At flowering and harvest stages, the treatment T_6 *viz*., enriched poultry manure compost produced the maximum dry matter (8721 and 11363 kg ha^{-1} during *rabi* 2007; 9096 and 11861 kg ha^{-1} during *rabi* 2008, respectively) and it was on par with that composted poultry manure (T_5) whereas, it was comparable with recommended NPK fertilizer application (T_7) and these treatments were followed by addition of FYM + neem cake (T_3).

The lower dry matter production at all the stages of crop growth period was associated in absolute control (T_8) (1198, 2567, 5231 and 6723 kg ha^{-1}; 1366, 2625, 5424 and 6987 kg ha^{-1} respectively). This was significantly inferior to the dry matter produced with the addition of vermicompost (T_2), enriched FYM compost + vermicompost + FYM (T_4) and enriched FYM compost (T_1) during both the years of study.

4.2.4. Root length (Table 15)

It was found that the root length was significantly influenced by the application of organic manures and recommended NPK fertilizer in both the years throughout the crop growth.

The development of root system under various organic manure treatments was observed in this study. During *rabi* 2007 and 2008, enriched poultry manure compost (T_6) recorded longer root length (19.0, 26.5, 25.7 and 24.9 cm; 19.1, 28.0, 28.5 and 27.3 cm respectively) at active tillering, panicle initiation, flowering and harvest stages and which was however on par with composted poultry manure (T_5) and recommended NPK fertilizer application (T_7) at all the four stages. The decreased root length (14.3, 19.5, 18.3 and 17.9 cm in *rabi* 2007; 14.2, 20.5, 20.2 and 19.6 cm in *rabi* 2008, respectively) at all the four stages was observed in absolute control (T_8).

4.2.5. Root volume (Table 16)

The root volume increased significantly in the treatment T_6 *viz*., enriched poultry manure compost (16.5, 26.6, 26.3 and 24.2 cc hill^{-1} in *rabi* 2007; 17.2, 27.3, 26.7 and 25.2 cc hill^{-1} in *rabi* 2008, respectively) at active tillering, panicle initiation, flowering and harvest stages and which was on par with composted poultry manure (T_5) and recommended NPK fertilizer application (T_7). In both the years of study, lower root volume was registered (11.2, 16.8, 16.0 and 15.6 cc hill^{-1} in *rabi* 2007; 11.4, 17.5, 17.2 and 15.9 cc hill^{-1} in *rabi* 2008, respectively) in absolute control (T_8) at all the stages of crop growth.

4.2.6. Root dry weight (Table 17)

During *rabi* 2007 and 2008, the application of enriched poultry manure compost (T_6) enhanced root dry weight at active tillering (1.65 and 1.73 g hill^{-1}), panicle initiation (3.34 and 3.50 g hill^{-1}), flowering (3.32 and 3.38 g hill^{-1}) and harvest stages (3.23 and 3.22 g hill^{-1}) and it was comparable with composted poultry manure (T_5) and recommended NPK fertilizer application (T_7) at all the four stages of crop growth. The lower root dry weight (0.98, 1.92, 1.96 and 1.92 g hill^{-1} during *rabi* 2007; 1.02, 2.12, 2.05 and 1.96 g hill^{-1} during *rabi* 2008) at all the stages of crop growth period was recorded in absolute control (T_8).

4.3. Physiological parameters

4.3.1. Leaf area index (LAI) (Table 18)

In general, with advancement of crop growth, the LAI increased up to flowering stage and there after showed a decline towards harvest in all the treatments.

In *rabi* 2007 and 2008, the higher LAI of rice was observed in the treatment T_6 *viz*., enriched poultry manure compost (2.94, 4.28, 6.50 and 6.25; 3.15, 4.78, 6.92 and 6.62 respectively) at active tillering, panicle initiation, flowering and harvest stages. Whereas it was on par with that of composted poultry manure (T_5) and recommended NPK fertilizer application (T_7) at all the four stages. These treatments were followed by FYM + neem cake (T_3) and vermicompost (T_2).

During the course of investigation, LAI was least in the treatment T_8 (absolute control), the values being 1.82, 2.77, 4.04 and 3.83 during *rabi* 2007 and 1.94, 2.96, 4.14 and 3.95 during *rabi* 2008, respectively at active tillering, panicle initiation, flowering and harvest stages. The application of enriched FYM compost (T_1) was superior to absolute control in enhancing the LAI and it was on par with enriched FYM compost + vermicompost + FYM (T_4) at all the stages of crop growth in both the years.

4.3.2. Rice leaf N content (SPAD value) (Table 19)

The various treatments significantly influenced leaf nitrogen content (SPAD values) during both the years. Application of enriched poultry manure compost (T_6) observed higher SPAD values (29.0, 31.4 and 32.3; 29.3, 32.6 and 33.2 in *rabi* 2007 and

2008, respectively) at active tillering, panicle initiation and flowering stages and it was on par with composted poultry manure (T_5) and recommended NPK fertilizer application (T_7) at active tillering. Whereas, composted poultry manure (T_5) was comparable with recommended NPK fertilizer application (T_7) at panicle initiation and flowering stages. Absolute control (T_8) registered lower SPAD values (23.1, 23.8 and 25.0; 23.6, 24.0 and 25.5 during *rabi* 2007 and 2008, respectively) at active tillering, panicle initiation and flowering stages.

4.3.3. Crop growth rate (CGR) (Table 20)

During *rabi* 2007 and 2008, the CGR found to increase from AT-PI to PI-F phase with a decline at F-H phase.

Application of enriched poultry manure compost (T_6) recorded higher CGR (8.40, 15.88 and 6.88 g m^{-2} day^{-1} in *rabi* 2007; 8.35, 16.55 and 7.20 g m^{-2} day^{-1} in *rabi* 2008, respectively) at AT-PI, PI-F and F-H phases. However, it was comparable with composted poultry manure (T_5) at AT-PI and PI-F stages during both the years. These were followed by recommended NPK fertilizer application (T_7). The lower values of CGR were evident with absolute control (T_8) (5.70, 9.25 and 3.89 g m^{-2} day^{-1} in *rabi* 2007; 5.25, 9.72 and 4.07 g m^{-2} day^{-1} in *rabi* 2008, respectively) at AT-PI, PI-F and F-H phases.

4.3.4. Net assimilation rate (NAR) (Table 21)

The application of enriched poultry manure compost (T_6) recorded higher values of NAR (1.317, 3.839 and 1.059 mg cm^{-2} day^{-1} in *rabi* 2007; 1.326, 3.856 and 1.078 mg cm^{-2} day^{-1} in *rabi* 2008, respectively) at AT-PI, PI-F and F-H phases. However, it was comparable with composted poultry manure (T_5). The absolute control (T_8) registered lower values of NAR (0.896, 1.092 and 0.876 mg cm^{-2} day^{-1} in *rabi* 2007; 1.168, 1.099 and 0.898 mg cm^{-2} day^{-1} in *rabi* 2008, respectively) at AT-PI, PI-F and F-H phases.

4.4. Yield attributes

The foremost important yield attributes *viz*., number of productive tillers m^{-2}, panicle weight (g), panicle length (cm), test weight of grain (g), total spikelets $panicle^{-1}$, filled spikelets panicle^{-1} and filling percentage of spikelets were recorded and the results are presented.

Appreciable improvement was observed with organic manures and recommended NPK fertilizer application on all the yield attributes except the test weight of grain.

4.4.1. Panicle parameters (Table 22)

4.4.1.1. Productive tillers m^{-2}

The number of productive tillers m^{-2} ranged from 228 to 312 and from 234 to 319 during *rabi* 2007 and 2008, respectively. The enriched poultry manure compost (T_6) recorded more number of productive tillers m^{-2} (312 in *rabi* 2007 and 319 in *rabi* 2008) and which was on par with composted poultry manure (T_5) (308 in *rabi* 2007 and 314 in *rabi* 2008). Whereas, the application of recommended NPK fertilizer (T_7) produced comparable number of productive tillers m^{-2} (299 in *rabi* 2007 and 302 in *rabi* 2008) with composted poultry manure (T_5) in both the years. These were followed by addition of FYM + neem cake (T_3), vermicompost (T_2) and enriched FYM compost + vermicompost + FYM (T_4). The least number of productive tillers m^{-2} (228 in *rabi* 2007 and 234 in *rabi* 2008) was associated with the treatment of absolute control (T_8). The application of enriched FYM compost (T_1) was superior to absolute control in respect of the number of productive tillers m^{-2} in both the years of experiments.

4.4.1.2. Panicle weight (g)

The panicle weight ranged from 1.62 to 2.25 g during *rabi* 2007 and from 1.67 to 2.32 g during *rabi* 2008. The application of enriched poultry manure compost (T_6) registered higher panicle weight (2.25 and 2.32 g during *rabi* 2007 and 2008, respectively) and it was comparable with composted poultry manure (T_5) (2.23 g during *rabi* 2007 and 2.26 g during *rabi* 2008) in both the years. These were followed by recommended NPK fertilizer (T_7) and FYM + neem cake (T_3), which were on par with each other. However, the application of recommended NPK fertilizer (T_7) was on par with composted poultry manure (T_5) in *rabi* 2008. Plants without organic manure and recommended NPK fertilizer application (T_8) recorded lesser panicle weight (1.62 g in *rabi* 2007 and 1.67 g in *rabi* 2008, respectively).

4.4.1.3. Panicle length (cm)

The panicle length extended from 19.02 to 22.35 cm during *rabi* 2007 and from 19.18 to 22.62 cm during *rabi* 2008. The length of the panicle was found to increase with the application of enriched poultry manure compost (T_6) (22.35 cm in *rabi* 2007 and 22.62 cm in *rabi* 2008) and which was comparable with composted poultry manure (T_5), recommended NPK fertilizer (T_7) and FYM + neem cake (T_3) during both the years. The absolute control (T_8) noted shorter panicle length (19.02 and 19.18 cm in *rabi* 2007 and *rabi* 2008, respectively).

4.4.1.4. Test weight (g)

With regard to test weight, the effect due to the application of organic manures or fertilizer NPK was not statistically significant during *rabi* 2007 and 2008. However, the test weight ranged from 16.0 to 16.4 g in *rabi* 2007 and from 16.0 to 16.3 g in *rabi* 2008.

4.4.2. Grain / Spikelet filling (Table 23)

4.4.2.1. Total spikelets panicle^{-1}

More number of total spikelets panicle^{-1} were produced with the application of enriched poultry manure compost (T_6) (141.2 and 144.5 during *rabi* 2007 and *rabi* 2008, respectively) and composted poultry manure (T_5) (138.6 in *rabi* 2007 and 140.2 in *rabi* 2008), which were on par. These were followed by recommended NPK fertilizer (T_7) (134.2 and 136.7 spikelets panicle^{-1} during *rabi* 2007 and 2008, respectively). The absolute control (T_8) recorded the lesser number of total spikelets panicle^{-1} (110.2 during *rabi* 2007 and 118.8 during *rabi* 2008).

4.4.2.2. Filled spikelets panicle^{-1}

The number of filled spikelets panicle^{-1} ranged from 73.1 to 111.3 in *rabi* 2007 and from 80.2 to 115.9 in *rabi* 2008. The application of enriched poultry manure compost (T_6) enhanced filled spikelets panicle^{-1} (111.3 and 115.9 in *rabi* 2007 and 2008, respectively) and which was comparable with composted poultry manure (T_5) (108.5 and 112.4 in *rabi* 2007 and 2008, respectively). These were followed by recommended NPK fertilizer application (T_7) (104.9 in *rabi* 2007 and 109.5 in *rabi* 2008) whereas, it was on par with composted poultry manure (T_5). However, the application of FYM + neem cake

(T_3) produced comparable number of filled spikelets panicle^{-1} (100.5 in *rabi* 2007 and 104.2 in *rabi* 2008) with recommended NPK fertilizer (T_7). The absolute control (T_8) registered lower number of filled spikelets panicle^{-1} (73.1 and 80.2 respectively) in *rabi* 2007 and 2008.

4.4.2.3. Grain filling 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 organic manure and fertilizer NPK application. During *rabi* 2007 and 2008, the higher percentage of filled grain was recorded under the application of enriched poultry manure compost (T_6) (78.8 and 80.2 respectively) and it was comparable with that composted poultry manure (T_5) (78.3 during *rabi* 2007 and 80.2 during *rabi* 2008) and recommended NPK fertilizer (T_7) (78.2 during *rabi* 2007 and 80.1 during *rabi* 2008). These were followed by FYM + neem cake (T_3) registered higher percentage of filled grain (75.3 and 76.5 in *rabi* 2007 and 2008, respectively). However, these treatments were superior to the application of vermicompost (T_2), enriched FYM compost + vermicompost + FYM (T_4) and enriched FYM compost (T_1). The lower filled grain per cent was noticed in T_8 treatment i.e. without organic and fertilizer NPK application (66.3 in *rabi* 2007 and 67.5 in *rabi* 2008).

4.5. Rice yield

4.5.1. Grain yield (Table 24)

The grain yield of rice extended from 2550 to 4675 kg ha^{-1} during *rabi* 2007 and from 2635 to 4953 kg ha^{-1} during *rabi* 2008. Application of enriched poultry manure compost (T_6) recorded higher grain yield (4675 and 4953 kg ha^{-1} in *rabi* 2007 and *rabi* 2008, respectively), which was found to be on par with composted poultry manure (T_5) (4482 kg ha^{-1} in *rabi* 2007 and 4784 kg ha^{-1} in *rabi* 2008) (Plate 5 and 6). These were followed by recommended NPK fertilizer (T_7) (Plate 7) (4340 kg ha^{-1} during *rabi* 2007 and 4538 kg ha^{-1} during *rabi* 2008), which was however comparable with composted poultry manure (T_5) in both the years. These treatments were followed by T_3 *viz*. FYM + neem cake, whereas it was on par with recommended NPK fertilizer (T_7) during *rabi* 2008 but superior to the application of vermicompost (T_2) and enriched FYM compost + vermicompost + FYM (T_4), which were on par with each other during both the years.

The lower grain yield (2550 and 2635 kg ha^{-1} in *rabi* 2007 and 2008, respectively) obtained with the treatment (T_8) (Plate 8) which did not receive organic manures and recommended NPK addition. This was significantly inferior to the grain yield obtained with the application of enriched FYM compost (T_1) in both the years of study.

4.5.2. Straw yield (Table 24)

The straw yield of rice during *rabi* 2007 and 2008 was also influenced by the application of organic manures and recommended NPK fertilizer. The straw yield ranged from 3983 and 6568 kg ha^{-1} and from 4089 to 6725 kg ha^{-1} during *rabi* 2007 and 2008, respectively. The application of enriched poultry manure compost (T_6) enhanced straw yield (6568 and 6725 kg ha^{-1} in *rabi* 2007 and 2008, respectively) which was on par with composted poultry manure (T_5) (6310 kg ha^{-1} in *rabi* 2007 and 6556 kg ha^{-1} in *rabi* 2008). However, composted poultry manure (T_5) application was on par with the recommended NPK fertilizer (T_7) (6012 and 6223 kg ha^{-1} during *rabi* 2007 and 2008, respectively) which was comparable with FYM + neem cake (T_3). These were followed by vermicompost (T_2) and enriched FYM compost + vermicompost + FYM (T_4), which did not differ significantly from each other and proved their superiority over the application of enriched FYM compost (T_1). In both the years of study, lower straw yield (3983 kg ha^{-1} during *rabi* 2007 and 4089 kg ha^{-1} during *rabi* 2008) was recorded in T_8 *viz*. absolute control.

4.5.3. Harvest index (Table 25)

The application of organic manures and recommended NPK did not significantly influence the harvest index during *rabi* 2007 and 2008. However, harvest index ranged from 0.390 to 0.419 in *rabi* 2007 and from 0.392 to 0.424 in *rabi* 2008.

4.6. Rice stubble at harvest (Table 26)

During *rabi* 2007 and 2008, the application of enriched poultry manure compost (T_6) added higher quantity of stubble dry weight (1987 and 2154 kg ha^{-1} respectively) and it was comparable with composted poultry manure (T_5) and recommended NPK fertilizer (T_7) while the later two were comparable with FYM + neem cake (T_3). The lower stubble dry weight (1412 kg ha^{-1} in *rabi* 2007 and 1585 kg ha^{-1} in *rabi* 2008) was recorded in absolute control (T_8).

The added nutrients were to the tune of 12.12 kg N, 1.68 kg P and 4.89 kg K ha^{-1} during *rabi* 2007; 13.18 kg N, 1.77 kg P and 5.23 kg K ha^{-1} during *rabi* 2008 for enriched poultry manure compost (T_6) treatment, which was on par with composted poultry manure (T_5) and recommended NPK fertilizer (T_7). Lower level of 8.60 kg N, 1.13 kg P and 3.43 kg K ha^{-1} during *rabi* 2007 and 9.23 kg N, 1.26 kg P and 3.84 kg K ha^{-1} during *rabi* 2008 was noted in absolute control (T_8).

4.7. Plant nutrient uptake

4.7.1. Nitrogen uptake (Table 27)

The N uptake was influenced by organic manuring and recommended NPK fertilizers at all the stages of crop growth during both the years of study. The N uptake progressively increased with advancement in the growth stages i.e. from active tillering to harvest stage.

The uptake of N varied from 18.9 to 34.0, 27.3 to 50.2, 49.9 to 84.2 and 61.2 to 103.9 kg ha^{-1} during *rabi* 2007 and from 21.9 to 38.9, 31.5 to 55.7, 52.1 to 88.2 and 63.0 to 107.3 kg ha^{-1} during *rabi* 2008, respectively, at active tillering, panicle initiation, flowering and harvest stages. The increased N uptake was observed with the treatment T_6 *viz*., enriched poultry manure compost (34.0 and 50.2 kg ha^{-1} in *rabi* 2007 and 38.9 and 55.7 kg ha^{-1} in *rabi* 2008, respectively) at active tillering and panicle initiation stages, while it was comparable with composted poultry manure (T_5) and recommended NPK fertilizer (T_7). These were followed by FYM + neem cake (T_3) application registered higher N uptake.

At flowering and harvest stages, the application of enriched poultry manure compost (T_6) enhanced N uptake (84.2 and 103.9 kg ha^{-1} during *rabi* 2007; 88.2 and 107.3 kg ha^{-1} during *rabi* 2008, respectively) and which was on par with composted poultry manure (T_5) (83.3 and 100.0 kg ha^{-1} in *rabi* 2007; 87.8 and 104.0 kg ha^{-1} in *rabi* 2008, respectively). However, composted poultry manure (T_5) was comparable with recommended NPK fertilizer (T_7) application whereas, it was on par with FYM + neem cake (T_3) and superior to vermicompost (T_2) and enriched FYM compost + vermicompost + FYM (T_4) in both the years. The N uptake was lower in absolute control (T_8) (18.9, 27.3, 49.9 and 61.2 kg ha^{-1} in *rabi* 2007; 21.9, 31.5, 52.1 and 63.0 kg ha^{-1} in *rabi* 2008, respectively) at all four stages of both the years of study but inferior to the application of enriched FYM compost (T_1).

4.7.2. Phosphorus uptake (Table 28)

The P uptake was also influenced by the application of organic manures and recommended NPK fertilizer. During *rabi* 2007 and 2008, enriched poultry manure compost, T_6 recorded the higher P uptake (6.7 and 10.5 kg ha^{-1}; 7.7 and 11.7 kg ha^{-1} respectively) at active tillering and panicle initiation stages and it was on par with composted poultry manure (T_5) and recommended NPK fertilizer (T_7). These treatments were followed by FYM + neem cake (T_3).

At flowering, the application of enriched poultry manure compost (T_6) registered higher P uptake (19.3 and 20.5 kg ha^{-1} during *rabi* 2007 and *rabi* 2008, respectively) and which was comparable with composted poultry manure (T_5). These treatments were followed by recommended NPK fertilizer (T_7) during both the years of study.

During harvest stage, the higher P uptake was recorded with the application of enriched poultry manure compost (T_6) (24.0 kg ha^{-1} in *rabi* 2007 and 24.8 kg ha^{-1} in *rabi* 2008) and it was on par with composted poultry manure (T_5) (22.7 kg ha^{-1} in *rabi* 2007 and 24.3 kg ha^{-1} in *rabi* 2008). These were followed by recommended NPK fertilizer (T_7) however, it was comparable with the application of FYM + neem cake (T_3) and enriched FYM compost (T_1) in both the years. The lower P uptake was observed in absolute control (T_8) (without organic and recommended NPK) (3.7, 6.1, 11.5 and 13.8 kg ha^{-1}; 4.3, 6.9, 12.1 and 14.5 kg ha^{-1} respectively) at the four stages of crop growth of *rabi* 2007 and 2008.

4.7.3. Potassium uptake (Table 29)

During *rabi* 2007 and 2008, the positive influence of treatments on K uptake by rice was evidenced. Highest K uptake was associated with enriched poultry manure compost (T_6) (38.8 and 60.4 kg ha^{-1} in *rabi* 2007; 43.9 and 66.9 kg ha^{-1} in *rabi* 2008) and which was comparable with composted poultry manure (T_5) and recommended NPK fertilizer (T_7) at active tillering and panicle initiation stages. These treatments were followed by FYM + neem cake (T_3).

Application of enriched poultry manure compost (T_6) increased K uptake (103.7 and 140.9 kg ha^{-1} in *rabi* 2007; 108.0 and 148.6 kg ha^{-1} in *rabi* 2008) and which was on par with composted poultry manure (T_5) (100.8 and 135.9 kg ha^{-1} during *rabi* 2007; 106.8 and 143.4 kg ha^{-1} during *rabi* 2008, respectively) at flowering and harvest stages. The composted poultry manure (T_5) was on par with recommended NPK fertilizer (T_7). However, which was comparable with FYM + neem cake (T_3) application. The above treatments (T_6, T_5, T_7 and T_3) were superior to vermicompost (T_2), enriched FYM compost + vermicompost + FYM (T_4) and enriched FYM compost (T_1) in enhancing the K uptake by rice. Lower uptake of K was recorded under absolute control (T_8) (without organic manures and fertilizer NPK) (19.4, 33.3, 60.7 and 82.7 kg ha^{-1} in *rabi* 2007; 19.8, 37.9, 63.2 and 85.5 kg ha^{-1} in *rabi* 2008, respectively) at all stages of the crop growth.

4.7.4. Micronutrient uptake

4.7.4.1. Iron uptake (Table 30)

The application of enriched poultry manure compost (T_6) recorded maximum uptake of Fe (0.739 and 3.159 kg ha^{-1} in *rabi* 2007; 0.753 and 3.234 kg ha^{-1} in *rabi* 2008, respectively) and which was on par with composted poultry manure (T_5) (0.728 and 3.124 kg ha^{-1} in *rabi* 2007; 0.747 and 3.212 kg ha^{-1} in *rabi* 2008, respectively) at panicle initiation and harvest stages. These treatments were followed by recommended NPK fertilizer (T_7) and FYM + neem cake (T_3). The absolute control (T_8) registered lower uptake of Fe (0.321 and 1.732; 0.348 and 1.843 kg ha^{-1} in *rabi* 2007 and 2008, respectively) at panicle initiation and harvest stages.

4.7.4.2. Manganese uptake (Table 30)

During *rabi* 2007 and 2008, the higher uptake of Mn was observed under enriched poultry manure compost (T_6) (0.389 and 1.983 kg ha^{-1}; 0.376 and 1.992 kg ha^{-1} respectively) at panicle initiation and harvest stages. Whereas, it was on par with composted poultry manure (T_5). The lower Mn uptake was noted in absolute control (T_8) (0.158 and 1.134; 0.212 and 1.134 kg ha^{-1} in *rabi* 2007 and 2008, respectively) at panicle initiation and harvest stages.

4.7.4.3. Zinc uptake (Table 31)

Maximum Zn uptake was recorded in enriched poultry manure compost (T_6) (0.070 and 0.302 kg ha^{-1} in *rabi* 2007; 0.074 and 0.308 kg ha^{-1} in *rabi* 2008), which was on par with that composted poultry manure (T_5) (0.068 and 0.294 kg ha^{-1} in *rabi* 2007; 0.074 and 0.302 kg ha^{-1} in *rabi* 2008, respectively) at panicle initiation and harvest stages. These were followed by recommended NPK fertilizer (T_7) and FYM + neem cake (T_3). The absolute control (T_8) registered lower uptake of Zn during both the years of experiments.

4.7.4.4. Copper uptake (Table 31)

At panicle initiation and harvest stages, application of enriched poultry manure compost (T_6) registered higher uptake of Cu (0.060 and 0.148 kg ha^{-1} in *rabi* 2007; 0.068 and 0.154 kg ha^{-1} in *rabi* 2008, respectively), which was comparable with composted poultry manure (T_5). These were followed by recommended NPK fertilizer (T_7) and FYM + neem cake (T_3), which were on par with each other. The lower uptake of Cu was registered under absolute control (T_8) during both the years.

4.8. Use efficiency

4.8.1. Agronomic efficiency (AE) (Table 32)

The Agronomic efficiency (AE) extended from 9.3 to 28.3 in *rabi* 2007 and from 11.0 to 30.9 in *rabi* 2008.

The treatment T_6 (enriched poultry manure compost) resulted higher AE of 28.3 and 30.9 in *rabi* 2007 and 2008, respectively. The next best was observed with the application of composted poultry manure (25.8 in *rabi* 2007 and 28.7 in *rabi* 2008) T_5, recommended NPK fertilizer (23.9 and 25.4 during *rabi* 2007 and 2008, respectively) T_7 and FYM + neem cake (19.5 in *rabi* 2007 and 22.2 in *rabi* 2008) T_3. The enriched FYM compost (T_1) recorded the least agronomic efficiency of 9.3 and 11.0 during *rabi* 2007 and 2008, respectively.

4.8.2. Apparent N recovery (ANR) (Table 33)

The application of enriched poultry manure compost (T_6) recorded higher apparent nitrogen recovery (ANR) (56.9 and 59.1% during *rabi* 2007 and 2008, respectively). This was followed by composted poultry manure (T_5) (51.7% in *rabi* 2007 and 54.7% in *rabi* 2008), recommended NPK fertilizer (T_7) (46.5% in *rabi* 2007 and

48.2% in *rabi* 2008) and FYM + neem cake (T_3) (39.4 and 40.5% in *rabi* 2007 and *rabi* 2008, respectively). The lower apparent nitrogen recovery was recorded in T_1 viz., enriched FYM compost (17.5 and 16.7%) in both the years, respectively.

4.9. Soil chemical properties

4.9.1. Soil available nutrients

4.9.1.1. Soil available nitrogen (Table 34)

Results on soil available N showed the significant influence of organic manures and recommended NPK fertilizer application in sustaining nutrient availability. The soil available nitrogen extended from 221 to 318, 212 to 307, 200 to 296 and 206 to 310 kg ha^{-1} during *rabi* 2007 and from 227 to 325, 224 to 317, 204 to 303 and 212 to 324 kg ha^{-1} during *rabi* 2008, respectively at active tillering, panicle initiation, flowering and harvest stages. In *rabi* 2007 and 2008, the application of enriched poultry manure compost (T_6) registered higher soil available N (318 and 307 kg ha^{-1}; 325 and 317 kg ha^{-1} respectively) and which was comparable with composted poultry manure (T_5) (306 and 294 kg ha^{-1}; 310 and 302 kg ha^{-1}) and FYM + neem cake (T_3) (297 and 289 kg ha^{-1}; 304 and 292 kg ha^{-1} respectively) at active tillering and panicle initiation stages. These were followed by recommended NPK fertilizer (T_7), vermicompost (T_2), enriched FYM compost + vermicompost + FYM (T_4) and enriched FYM compost (T_1) during both the years.

At flowering and harvest stages, maximum soil available N was recorded with enriched poultry manure compost (T_6) (296 and 310 kg ha^{-1}; 303 and 324 kg ha^{-1}) and it was comparable with composted poultry manure (T_5) (283 and 295 kg ha^{-1}; 296 and 310 kg ha^{-1} respectively). Whereas, composted poultry manure (T_5) was on par with FYM + neem cake (T_3) application. These were superior to recommended NPK fertilizer (T_7), vermicompost (T_2), enriched FYM + vermicompost + FYM (T_4) and enriched FYM (T_1) and did not differ significantly with each other. The treatment T_8 (absolute control) recorded the least availability of soil available N (221, 212, 200 and 206 kg ha^{-1}; 227, 224, 204 and 212 kg ha^{-1} respectively) at all the stages of crop growth during both the years of experiments.

4.9.1.2. Soil available phosphorus (Table 35)

The soil available P status was also influenced owing to the addition of organic manures and recommended NPK fertilizer. The soil available P ranged from 15.3 to 31.6, 14.2 to 30.5, 13.8 to 29.0 and 13.7 to 30.4 kg ha^{-1} and from 15.8 to 32.0, 14.7 to 31.8, 14.2 to 31.2 and 14.0 to 32.1 kg ha^{-1} during *rabi* 2007 and 2008, respectively at active tillering, panicle initiation, flowering and harvest stages. In *rabi* 2007 and 2008, the addition of enriched poultry manure compost (T_6) improved soil available P status (31.6 and 30.5 kg ha^{-1}; 32.0 and 31.8 kg ha^{-1} respectively) at active tillering and panicle initiation stages and which was on par with composted poultry manure (T_5) (29.7 and 28.9 kg ha^{-1}; 31.4 and 30.1 kg ha^{-1}) and FYM + neem cake (T_3) in both the years.

Application of enriched poultry manure compost (T_6) recorded higher soil available P at flowering and harvest stages (29.0 and 30.4 kg ha^{-1} in *rabi* 2007; 31.2 and 32.1 kg ha^{-1} in *rabi* 2008, respectively) and it was comparable with composted poultry manure (T_5) (27.7 and 28.6 kg ha^{-1} in *rabi* 2007; 29.3 and 30.2 kg ha^{-1} in *rabi* 2008). Lower soil available P was registered by absolute control treatment (T_8) (15.3, 14.2, 13.8 and 13.7 kg ha^{-1}; 15.8, 14.7, 14.2 and 14.0 kg ha^{-1} in *rabi* 2007 and 2008, respectively) at all four stages of crop growth.

4.9.1.3. Soil available potassium (Table 36)

The soil available K was extended from 469 to 591, 446 to 587, 440 to 574 and 465 to 603 kg ha^{-1} during *rabi* 2007 and from 477 to 587, 456 to 599, 451 to 585 and 450 to 601 kg ha^{-1} during *rabi* 2008, respectively at active tillering, panicle initiation, flowering and harvest stages showing the influence of organic manure and recommended NPK fertilizer addition in improving the soil available K. The application of enriched poultry manure compost (T_6) registered higher amount of soil available K (591, 587, 574 and 603 kg ha^{-1} in *rabi* 2007; 587, 599, 585 and 601 kg ha^{-1} in *rabi* 2008, respectively) and it was comparable with composted poultry manure (T_5) and FYM + neem cake (T_3) at active tillering, panicle initiation, flowering and harvest stages. The addition of vermicompost (T_2), recommended NPK fertilizer (T_7), enriched FYM compost + vermicompost + FYM (T_4) and enriched FYM compost (T_1) were inferior to that of enriched poultry manure compost (T_6) and composted poultry manure (T_5) application and which did not differ significantly each other at all the four stages of both the years. The lower soil available K was observed in absolute control (T_8) (469, 446, 440 and 465 kg ha^{-1}; 477, 456, 451 and 450 kg ha^{-1} respectively) at all the stages of crop growth during both the years of study.

4.9.1.4. Soil exchangeable nutrients (Table 37)

4.9.1.4.1. Soil exchangeable Calcium

Application of enriched poultry manure compost (T_6) registered higher exchangeable Ca (17.72 and 17.92 c mol (P^+) kg^{-1} in *rabi* 2007 and 2008, respectively) however, it was on par with composted poultry manure (T_5), FYM + neem cake (T_3) and enriched FYM compost + vermicompost + FYM (T_4). These were superior to enriched FYM compost (T_1) and recommended NPK fertilizer (T_7). The absolute control (T_8) recorded lesser exchangeable Ca during both the years of study.

4.9.1.4.2. Soil exchangeable Magnesium

Maximum soil exchangeable Mg was registered under enriched poultry manure compost (T_6) (8.04 and 8.12 c mol (P^+) kg^{-1} in *rabi* 2007 and *rabi* 2008, respectively) and which was however comparable with composted poultry manure (T_5). Whereas, composted poultry manure (T_5) was on par with that FYM + neem cake (T_3). These treatments were superior to enriched FYM compost (T_1), enriched FYM compost + vermicompost + FYM (T_4) and recommended NPK fertilizer (T_7). The lower soil exchangeable Mg was obtained under absolute control (T_8).

4.9.1.4.3. Soil exchangeable Sodium

Higher soil exchangeable Na was recorded with enriched poultry manure compost (T_6) (3.73 and 3.82 c mol (P^+) kg^{-1} in *rabi* 2007 and 2008, respectively) and composted poultry manure (T_5) (3.65 and 3.73 c mol (P^+) kg^{-1} in *rabi* 2007 and 2008, respectively), which were comparable with each other. These were superior to vermicompost (T_2), enriched FYM compost + vermicompost + FYM (T_4) and recommended NPK fertilizer (T_7). The absolute control (T_8) left lower soil exchangeable Na, whereas it was on par with enriched FYM compost (T_1).

4.9.1.5. Soil available micronutrients (Table 38)

4.9.1.5.1. Soil available Iron

During both the years, higher soil available Fe was recorded with the application of enriched poultry manure compost (T_6) (31.6 mg kg^{-1} in *rabi* 2007 and 34.8 mg kg^{-1} in *rabi* 2008) and composted poultry manure (T_5) (30.2 mg kg^{-1} in *rabi* 2007 and 33.4 mg kg^{-1} in *rabi* 2008), which were on par with each other. These were followed by FYM + neem cake (T_3) and enriched FYM compost (T_1). The lower available Fe was registered under absolute control (T_8) in both the years.

4.9.1.5.2. Soil available Manganese

Higher Mn was available with the application of enriched poultry manure compost (T_6) (4.2 mg kg^{-1} in *rabi* 2007 and 4.4 mg kg^{-1} in *rabi* 2008) and which was however, comparable with composted poultry manure (T_5) and FYM + neem cake (T_3). The absolute control (T_8) recorded lower soil available Mn during both the years.

4.9.1.5.3. Soil available Zinc

Application of enriched poultry manure compost (T_6) left more soil available Zn (6.4 and 6.6 mg kg^{-1} in *rabi* 2007 and *rabi* 2008 respectively) and it was comparable with composted poultry manure (T_5) (6.2 and 6.4 mg kg^{-1} in *rabi* 2007 and 2008, respectively). These were followed by FYM + neem cake (T_3) and it was however, on par with that composted poultry manure (T_5). In both the years, absolute control (T_8) registered lower available Zn.

4.9.1.5.4. Soil available Copper

Maximum Cu availability was recorded with the application of enriched poultry manure compost (T_6) (4.0 mg kg^{-1} in *rabi* 2007 and 4.2 mg kg^{-1} in *rabi* 2008) and which was on par with composted poultry manure (T_5) and FYM + neem cake (T_3). The lower soil available Cu was registered under absolute control (T_8) during both the years of study.

4.9.2. Soil organic carbon (Table 39)

In general, organic manures and recommended NPK fertilizer application significantly influenced the organic carbon content of the soil at panicle initiation, flowering and harvest stages.

The soil organic carbon ranged from 0.61 to 0.73, 0.62 to 0.76 and 0.62 to 0.73 per cent and from 0.64 to 0.76, 0.65 to 0.80 and 0.63 to 0.78 per cent during *rabi* 2007 and 2008, respectively at panicle initiation, flowering and harvest stages. At panicle initiation stage, the higher organic carbon content was registered by the application of enriched poultry manure compost (T_6) (0.73 and 0.76 per cent during *rabi* 2007 and 2008, respectively), composted poultry manure (T_5) (0.72 per cent in *rabi* 2007 and 0.76 per cent in *rabi* 2008) and FYM + neem cake (T_3) (0.69 per cent in *rabi* 2007 and 0.74 per cent in *rabi* 2008), which were on par with each other. However, the application with FYM + neem cake (T_3) was comparable with enriched FYM compost + vermicompost + FYM (T_4), vermicompost (T_2) and enriched FYM compost (T_1) in both the years of experiment.

During flowering stage, maximum content of organic carbon was associated with enriched poultry manure compost (T_6) (0.76 and 0.80 per cent during *rabi* 2007 and 2008, respectively) and which was on par with composted poultry manure (T_5) and FYM + neem cake (T_3). However, the latter two treatments were comparable with enriched FYM compost + vermicompost + FYM (T_4) and vermicompost (T_2) in both the years.

At harvest stage, higher organic carbon content was recorded with the application of enriched poultry manure compost (T_6) (0.73 per cent in *rabi* 2007 and 0.78 per cent in *rabi* 2008), composted poultry manure (T_5) (0.72 per cent in *rabi* 2007 and 0.77 per cent in *rabi* 2008) and FYM + neem cake (T_3) (0.71 per cent in *rabi* 2007 and 0.75 per cent in *rabi* 2008) which were on par. These were followed by enriched FYM compost + vermicompost + FYM (T_4), vermicompost (T_2) and enriched FYM compost (T_1) in both the years. These treatments were superior to that observed with the application of recommended NPK fertilizer (T_7) which registered a value of 0.62, 0.64 and 0.62 per cent; 0.65, 0.66 and 0.64 per cent in *rabi* 2007 and 2008, respectively at panicle initiation, flowering and harvest stages and it was found to be comparable with absolute control (T_8) (0.61, 0.62 and 0.62 per cent; 0.64, 0.65 and 0.63 per cent in *rabi* 2007 and 2008, respectively) at panicle initiation, flowering and harvest stages in both the years of study.

4.9.3. Soil pH (Table 40)

Organic manuring and recommended fertilizer NPK application treatments significantly influenced soil pH except at active tillering stage of *rabi* 2007.

At active tillering stage of *rabi* 2008, lesser soil pH was observed with the application of enriched poultry manure compost (T_6) (8.12), composted poultry manure (T_5) (8.13), FYM + neem cake (T_3) (8.09), enriched FYM compost + vermicompost + FYM (T_4) (8.29), vermicompost (T_2) (8.31) and enriched FYM compost (T_1) (8.30) than recommended NPK fertilizer (T_7) (8.51) and absolute control (T_8) (8.51). However, the latter three were comparable with recommended NPK fertilizer (T_7) and absolute control (T_8). At panicle initiation stage, enriched poultry manure compost (T_6) registered less soil pH (8.12 and 8.04 in *rabi* 2007 and *rabi* 2008, respectively) and which was on par with composted poultry manure (T_5) and FYM + neem cake (T_3) during both the years.

At flowering stage, enriched poultry manure compost (T_6) reduced soil pH (8.06 in *rabi* 2007 and 8.00 in *rabi* 2008) which was on par with composted poultry manure (T_5), FYM + neem cake (T_3). At harvest stage, the application of enriched poultry manure compost (T_6) registered lesser soil pH (8.04 and 7.80 in *rabi* 2007 and 2008, respectively) and it was comparable with composted poultry manure (T_5), FYM + neem cake (T_3) and enriched FYM compost + vermicompost + FYM (T_4). Higher soil pH was noticed with absolute control (T_8) (8.60, 8.57, 8.54 and 8.53 during *rabi* 2007; 8.51, 8.53, 8.50 and 8.45 during *rabi* 2008, respectively) at all the stages of crop growth.

4.9.4. Soil EC (Table 41)

The various treatments significantly influenced soil EC except at active tillering stage of *rabi* 2007.

Application of enriched poultry manure compost (T_6) observed reduced EC (0.40 dS m^{-1}) which was however comparable with composted poultry manure (T_5), FYM + neem cake (T_3), enriched FYM compost + vermicompost + FYM (T_4), vermicompost (T_2) and enriched FYM compost (T_1) at active tillering stage of *rabi* 2008.

During *rabi* 2007 and 2008, enriched poultry manure compost (T_6) recorded lesser soil EC (0.40, 0.38 and 0.36 dS m^{-1}; 0.37, 0.32 and 0.28 dS m^{-1} respectively), which was comparable with composted poultry manure (T_5) and FYM + neem cake (T_3) at panicle initiation, flowering and harvest. Whereas, higher soil EC was noticed under the treatments of recommended NPK fertilizer (T_7) and absolute control (T_8) at all the stages during both the years.

4.10. Soil microbial load

During both the years, organic manure and recommended NPK treatments significantly influenced bacteria, fungal and actinomycetes population at active tillering, panicle initiation, flowering and harvest stages.

4.10.1. Bacteria (Table 42)

At active tillering stage, the application of enriched poultry manure compost (T_6) registered higher population of bacteria (20.3 and 21.7 x 10^6 CFU g^{-1} of soil in *rabi* 2007 and 2008, respectively) and which was comparable with FYM + neem cake (T_3) and composted poultry manure (T_5). These were followed by enriched FYM compost + vermicompost + FYM (T_4), vermicompost (T_2) and enriched FYM compost (T_1), which were on par with each other.

Application of enriched poultry manure compost (T_6) recorded maximum bacterial population (41.0, 54.0 and 52.0 in *rabi* 2007; 47.0, 61.0 and 58.7 in *rabi* 2008 respectively) at panicle initiation, flowering and harvest stages whereas, it was on par with that composted poultry manure (T_5). This was followed by FYM + neem cake (T_3) and it was comparable with composted poultry manure (T_5) at panicle initiation, flowering and harvest stages. These were superior to enriched FYM compost + vermicompost + FYM (T_4), enriched FYM compost (T_1) and vermicompost (T_2) at all the stages.

The recommended NPK fertilizer (T_7) registered lower bacterial population (13.3, 22.3, 28.3 and 28.0 in *rabi* 2007; 12.7, 24.3, 28.0 and 24.7 in *rabi* 2008) and it was inferior to all other treatments and superior to absolute control (T_8) (10.0, 18.0, 22.3 and 20.7 in *rabi* 2007; 11.0, 17.0, 23.7 and 20.0 in *rabi* 2008, respectively) at all the stages of crop growth.

4.10.2. Fungi (Table 43)

During *rabi* 2007 and 2008, the application of enriched poultry manure compost (T_6) had higher fungal population (12.7 and 15.7; 13.0 and 16.0 x 10^3 CFU g^{-1} of soil, respectively) at active tillering and panicle initiation stages, which was comparable with composted poultry manure (T_5). This was followed by FYM + neem cake (T_3) and it was however on par with composted poultry manure (T_5) at active tillering stage of both the years.

At flowering and harvest stages, higher fungal population was recorded with enriched poultry manure compost (T_6) (17.7 and 16.7 in *rabi* 2007; 17.0 and 17.0 in *rabi* 2008 respectively) and it was on par with composted poultry manure (T_5). Whereas, composted poultry manure (T_5) was however comparable with FYM + neem cake (T_3). These treatments were superior to enriched FYM compost + vermicompost + FYM (T_4), vermicompost (T_2) and enriched FYM compost (T_1) and did not differ significantly with each other at all the stages in both the years of study.

The recommended NPK fertilizer (T_7) registered lower fungal population (6.0, 6.3, 7.0 and 6.7 during *rabi* 2007; 6.3, 7.0, 7.7 and 7.0 during *rabi* 2008, respectively) at active tillering, panicle initiation, flowering and harvest stages and it was inferior to above treatments and superior to absolute control (T_8) (5.3, 5.0, 5.7 and 4.7; 4.0, 5.3, 5.0 and 4.3 during *rabi* 2007 and 2008, respectively) at all the stages of crop growth in both the years of experiments.

4.10.3. Actinomycetes (Table 44)

The enriched poultry manure compost (T_6) application registered higher actinomycetes population (10.3, 13.0, 14.3 and 13.0 x 10^4 CFU g^{-1} of soil in *rabi* 2007; 11.0, 14.7, 16.7 and 16.0 in *rabi* 2008, respectively) at active tillering, panicle initiation, flowering and harvest stages, which was found to be on par with composted poultry manure (T_5). This was followed by FYM + neem cake (T_3), however it was comparable with composted poultry manure (T_5) at all the stages of crop growth except active tillering stage of *rabi* 2007. These were followed by vermicompost (T_2), enriched FYM compost + vermicompost + FYM (T_4) and enriched FYM compost (T_1) and which did not differ significantly each other at all the four stages of both the years.

The recommended NPK fertilizer (T_7) registered lower actinomycetes population (4.3, 6.7, 8.0 and 7.3; 5.0, 7.0, 9.0 and 7.0 during *rabi* 2007 and 2008, respectively) at active tillering, panicle initiation, flowering and harvest stages and it was inferior to above treatments and superior to absolute control (T_8) which recorded the least actinomycetes population (3.0, 5.0, 6.7 and 6.0; 3.7, 5.7, 7.0 and 5.0 during *rabi* 2007 and 2008, respectively) at all the stages of crop growth during both the years of study.

4.10.4. Soil enzyme activity (Table 45)

4.10.4.1. Soil urease activity

During both the years, higher urease activity was observed with the application of enriched poultry manure compost (T_6) (43.6 µg NH_4^+ g^{-1} soil 24 h^{-1} in *rabi* 2007 and 45.3 in *rabi* 2008) and composted poultry manure (T_5) (42.6 in *rabi* 2007 and 43.6 in *rabi* 2008), which were on par with each other. These treatments were followed by FYM + neem cake (T_3), enriched FYM compost (T_1), vermicompost (T_2) and enriched FYM compost + vermicompost + FYM (T_4). The recommended NPK fertilizer (T_7) registered lower urease activity (35.5 and 33.5 during *rabi* 2007 and 2008, respectively) but superior to absolute control (T_8).

4.10.4.2. Soil dehydrogenase activity

Higher dehydrogenase activity was observed under enriched poultry manure compost (T_6) (28.2 µg of TPF released g^{-1} of soil 24 h^{-1} in *rabi* 2007 and 30.0 in *rabi* 2008) and which was comparable with composted poultry manure (T_5) and FYM + neem cake (T_3). These were followed by enriched FYM compost (T_1) and enriched FYM compost + vermicompost + FYM (T_4), which were on par. The recommended NPK fertilizer (T_7) registered lower dehydrogenase activity but superior to absolute control (T_8).

4.10.4.3. Soil phosphatase activity

The enriched poultry manure compost (T_6) registered higher phosphatase activity (32.3 µg of p-nitrophenol released g^{-1} of soil h^{-1} in *rabi* 2007 and 33.4 in *rabi* 2008) and it was on par with enriched FYM compost (T_1) (31.5 in *rabi* 2007 and 32.4 in *rabi* 2008). These were followed by enriched FYM compost + vermicompost + FYM (T_4) and composted poultry manure (T_5). The recommended NPK fertilizer (T_7) and absolute control (T_8) recorded lower phosphatase activity during both the years.

4.11. Soil physical properties at post harvest of rice (Table 46)

The organic manures and recommended NPK significantly influenced the soil physical properties *viz*., bulk density (Mg m^{-3}), per cent pore space and water holding capacity (%) except particle density (Mg m^{-3}) in both the years of experiments.

4.11.1. Bulk density

The reduced bulk density was observed with the application of FYM + neem cake (T_3) (1.14 and 1.12 Mg m^{-3} during *rabi* 2007 and 2008, respectively) and which was comparable with enriched poultry manure compost (T_6) and composted poultry manure (T_5). The applications of enriched FYM compost + vermicompost + FYM (T4), enriched FYM compost (T_1) and vermicompost (T_2) were recorded comparatively lower bulk density than recommended NPK fertilizer (T_7). Highest bulk density was registered with recommended NPK fertilizer (T_7) (1.27 Mg m^{-3} in *rabi* 2007 and 1.25 Mg m^{-3} in *rabi* 2008) and absolute control (T_8) (1.27 and 1.26 Mg m^{-3} in *rabi* 2007 and 2008, respectively) and which were on par with each other.

4.11.2. Pore space

The enriched poultry manure compost (T_6) recorded significantly higher pore space per cent (56.9 and 57.0 per cent during *rabi* 2007 and 2008, respectively) which was however, comparable with that composted poultry manure (T_5) and FYM + neem cake (T_3). The reduced pore space was noticed under the treatment T_7 *viz*., recommended NPK fertilizer (52.8 per cent in *rabi* 2007 and 53.0 per cent in *rabi* 2008) whereas, it was on par with absolute control (T_8) which registered the lower pore space per cent (52.8 and 53.0 per cent respectively) in both *rabi* 2007 and 2008.

4.11.3. Water holding capacity (WHC) (%)

During *rabi* 2007 and 2008, improved water holding capacity was observed in FYM + neem cake (T_3) (42.0 and 43.5% respectively), enriched poultry manure compost (T_6) (41.7 and 42.3%) and composted poultry manure (T_5) (39.5 and 41.7%) and which did not differ significantly with each other during both the years. These were superior to recommended NPK fertilizer (T_7) (34.8% in *rabi* 2007 and 35.2% in *rabi* 2008) however, it was at par with absolute control (T_8) which recorded lower water holding capacity of 34.7% during *rabi* 2007 and 35.0% during *rabi* 2008.

4.12. Residual effect of organic manures and recommended NPK on blackgram

The residual blackgram during summer 2008 and 2009 did not receive any sufficient rainfall during crop growth and only two irrigations could be given to the crop. Subsequently, the growth of blackgram was substantial with only mature pods which were harvested. The entire haulms were incorporated into the soil.

4.12.1. Growth components (Table 47)

The residual effects of organic manure treatments in enhancing the growth components were superior when compared to that of absolute control in both summer 2008 and 2009. The residual effect of enriched poultry manure compost (T_6) on growth components *viz*., plant height (31.3 cm in summer 2008 and 33.5 cm in summer 2009) at maturity, Leaf area index at flowering (2.46 in summer 2008 and 2.50 in summer 2009) and dry matter production (3386 and 3402 kg ha^{-1} during summer 2008 and 2009, respectively) at maturity stage of blackgram was higher and which was however comparable with composted poultry manure (T_5) (30.7 cm, 2.45 and 3275 kg ha^{-1} in summer 2008; 32.4 cm, 2.48 and 3376 kg ha^{-1} in summer 2009, respectively) and FYM + neem cake (T_3) (30.4 cm, 2.45 and 3228 kg ha^{-1} in summer 2008; 31.5, 2.47 and 3324 kg ha^{-1} in summer 2009, respectively). These were followed by enriched FYM compost (T_1), vermicompost (T_2), enriched FYM compost + vermicompost + FYM (T_4) and recommended NPK fertilizer (T_7). The treatment T_8 (absolute control) recorded lower value of plant height, LAI and dry matter production (23.7 cm, 2.00, 2387 kg ha^{-1} in summer 2008; 23.4 cm, 2.05, 2378 kg ha^{-1} in summer 2009, respectively).

4.12.2. Yield attributes (Table 48 and 49)

During summer 2008 and 2009, the residual effect of enriched poultry manure compost (T_6) improved significantly the yield attributes *viz*., number of clusters $plant^{-1}$ (7.8 in summer 2008 and 7.7 in summer 2009), number of pods $plant^{-1}$ (15.13 in summer 2008 and 16.07 in summer 2009) and number of seeds pod^{-1} (7.56 in summer 2008 and 7.92 in summer 2009) except the pod length (4.56 in summer 2008 and 4.55 in summer 2009) and 100 grain weight (4.58 in summer 2008 and 4.57 in summer 2009) and it was on par with composted poultry manure (T_5) and FYM + neem cake (T_3) except for number of pods $plant^{-1}$. These treatments were superior to enriched FYM compost + vermicompost

+ FYM (T_4), enriched FYM compost (T_1), vermicompost (T_2) and recommended NPK fertilizer (T_7). The lower yield attributes were registered in absolute control (T_8) (4.0 clusters plant^{-1}, 7.03 pods plant^{-1} and 6.02 seeds pod^{-1} in summer 2008; 4.0 clusters plant^{-1}, 7.80 pods plant^{-1} and 6.07 seeds pod^{-1} in summer 2009).

4.12.3. Grain and haulm yield (Table 50)

Grain yield was higher (507 kg ha^{-1} during summer 2008 and 514 kg ha^{-1} during summer 2009) in the residual effect of enriched poultry manure compost (T_6) and which was comparable with that composted poultry manure (T_5) (485 in summer 2008 and 502 kg ha^{-1} in summer 2009) (Plate 9) and FYM + neem cake (T_3) (476 and 492 kg ha^{-1} in summer 2008 and 2009, respectively). These were followed by enriched FYM compost (T_1), enriched FYM compost + vermicompost + FYM (T_4) and vermicompost (T_2). The residual effect of recommended NPK fertilizer (T_7) (410 in summer 2008 and 416 kg ha^{-1} in summer 2009) was inferior to the above treatments (T_6, T_5, T_3, T_1, T_4 and T_2) but superior to T_8 (absolute control) which recorded lower grain yield of 355 and 348 kg ha^{-1} in summer 2008 and 2009, respectively.

Haulm yield was also maximum with the residual effect of enriched poultry manure compost (T_6) (2598 kg ha^{-1} in summer 2008 and 2617 kg ha^{-1} in summer 2009) whereas, it was on par with composted poultry manure (T_5) and FYM + neem cake (T_3). These were followed by the residual effect of enriched FYM compost + vermicompost + FYM (T_4), enriched FYM compost (T_1), vermicompost (T_2) and recommended NPK fertilizer (T_7), being on par with each other were superior to absolute control (T_8) (1846 and 1854 kg ha^{-1} during summer 2008 and 2009, respectively) in respect of haulms yield.

4.13. Nutrient uptake of blackgram (Table 51)

During summer 2008 and 2009, the uptake of nutrients (NPK) was influenced by residual effect of the different treatments tried. The uptake of N, P and K was significantly higher in the residual effect of enriched poultry manure compost (T_6) (43.3 kg N ha^{-1}, 12.6 kg P ha^{-1} and 44.5 kg K ha^{-1} in summer 2008 and 45.2 kg N ha^{-1}, 12.6 kg P ha^{-1} and 44.9 kg K ha^{-1} in summer 2009) and it was on par with composted poultry manure (T_5). This was followed by FYM + neem cake (T_3) whereas, it was comparable with composted poultry manure (T_5) and enriched poultry manure compost

(T_6) for N and K uptake. These were followed by the residual effect of enriched FYM compost (T_1), enriched FYM compost + vermicompost + FYM (T_4), vermicompost (T_2) and recommended NPK fertilizer (T_7) and which did not differ significantly with each other. The minimum uptake of N, P and K was recorded with absolute control (T_8) (31.7 kg N ha^{-1}, 8.6 kg P ha^{-1} and 32.9 kg K ha^{-1} in summer 2008 and 33.6 kg N ha^{-1}, 8.9 kg P ha^{-1} and 34.0 kg K ha^{-1} in summer 2009).

4.14. Soil available nutrient at post harvest stages of blackgram

4.14.1. Soil available N at post harvest of blackgram (Table 52)

The different treatments imposed to the preceding rice crop exerted a significant influence on the soil available N after harvest of blackgram.

During summer 2008 and 2009, the soil available N status varied from 214 to 308 kg ha^{-1} and 212 to 328 kg ha^{-1} respectively. The application of enriched poultry manure compost (T_6) to the previous rice considerably enhanced the soil available N (308 kg ha^{-1} during summer 2008 and 328 kg ha^{-1} during summer 2009) and it was on par with composted poultry manure (T_5) (305 and 315 kg ha^{-1} in summer 2008 and 2009, respectively). Whereas, it was also comparable with that FYM + neem cake (T_3). These treatments (T_6, T_5 and T_3) were superior to vermicompost (T_2), enriched FYM compost + vermicompost + FYM (T_4), enriched FYM compost (T_1) and recommended NPK fertilizer (T_7) and which were on par. Lower soil available N status was recorded in absolute control (T_8) (214 and 212 kg ha^{-1} respectively) in summer 2008 and 2009.

4.14.2. Soil available P at post harvest of blackgram (Table 52)

The post harvest soil available phosphorus extended from 14.7 to 30.7 kg ha^{-1} and from 14.2 to 33.6 kg ha^{-1} for different treatments during summer 2008 and 2009 respectively.

The treatment T_6 (enriched poultry manure compost) applied to the preceding rice crop resulted in significantly higher soil available phosphorus of 30.7 and 33.6 kg ha^{-1} in summer 2008 and 2009, respectively and which was comparable with composted poultry manure (T_5) (29.1 kg ha^{-1} during summer 2008 and 31.8 kg ha^{-1} during summer 2009). The composted poultry manure (T_5) was on par with FYM + neem cake (T_3). The application of enriched FYM compost (T_1) was next best and it was on par with that enriched FYM compost + vermicompost + FYM (T_4) but superior to recommended NPK fertilizer (T_7). The soil available P status was least in T_8 (without organic manure and recommended NPK fertilizer) (14.7 and 14.2 kg ha^{-1} respectively) in both summer 2008 and 2009.

4.14.3. Soil available K at post harvest of blackgram (Table 52)

The various treatments significantly influenced the soil available K status, which ranged from 428 to 575 kg ha^{-1} and from 416 to 567 kg ha^{-1} in summer 2008 and 2009, respectively.

The residual effect of enriched poultry manure compost (T_6) increased the soil available potassium (575 kg ha^{-1} in summer 2008 and 567 kg ha^{-1} in summer 2009) and which was on par with composted poultry manure (T_5). This was followed by FYM + neem cake (T_3), vermicompost (T_2), enriched FYM compost (T_1), enriched FYM compost + vermicompost + FYM (T_4) and recommended NPK fertilizer (T_7). The lower soil available K was obtained with treatment T_8 (absolute control) (428 and 416 kg ha^{-1} in summer 2008 and 2009, respectively).

4.14.4. Soil exchangeable nutrients at post harvest of blackgram (Table 53)

4.14.4.1. Soil exchangeable calcium

The residual effect of enriched poultry manure compost (T_6) recorded maximum exchangeable Ca (15.64 and 15.76 c mol (P^+) kg^{-1} in summer 2008 and 2009, respectively) and it was on par with composted poultry manure (T_5) and FYM + neem cake (T_3). These were followed by enriched FYM compost + vermicompost + FYM (T_4) and it was found to be on par with the FYM + neem cake (T_3). The recommended NPK fertilizer (T_7) was recorded lower exchangeable Ca and was superior to absolute control (T_8) during both the years.

4.14.4.2. Soil exchangeable magnesium

The soil exchangeable Mg was higher with residual effect of enriched poultry manure compost (T_6) (6.83 c mol (P^+) kg^{-1} in summer 2008 and 6.87 c mol (P^+) kg^{-1} in summer 2009) and which was comparable with composted poultry manure (T_5) and FYM + neem cake (T_3). These treatments were found to be superior to recommended NPK fertilizer (T_7) and absolute control (T_8) during both the years of study.

4.14.4.3. Soil exchangeable sodium

Higher soil exchangeable Na (3.16 and 3.35 c mol (P^+) kg^{-1} in summer 2008 and 2009, respectively) was recorded in enriched poultry manure compost (T_6) and it was on par with composted poultry manure (T_5). These were followed by FYM + neem cake (T_3), however, it was comparable with composted poultry manure (T_5). The residual effect of recommended NPK fertilizer (T_7) recorded lower exchangeable Na and inferior to above treatments but superior to absolute control (T_8) during both the years of experiments.

4.14.5. Soil available micronutrients at post harvest of blackgram (Table 54)

4.14.5.1. Soil available iron

During both the years, residual effect of enriched poultry manure compost (T_6) recorded higher soil available Fe (29.8 mg kg^{-1} in summer 2008 and 33.4 mg kg^{-1} in summer 2009) which was comparable with composted poultry manure (T_5) (29.6 mg kg^{-1} in summer 2008 and 32.9 mg kg^{-1} in summer 2009). These were followed by FYM + neem cake (T_3). The recommended NPK fertilizer (T_7) recorded lower available Fe but superior to absolute control (T_8) in both the years.

4.14.5.2. Soil available manganese

Higher Mn was available with the residual effect of enriched poultry manure compost (T_6) (4.1 mg kg^{-1} in summer 2008 and 4.1 mg kg^{-1} in summer 2009) and which was however, comparable with composted poultry manure (T_5). This was followed by FYM + neem cake (T_3) and it was found to be on par with composted poultry manure (T_5). The absolute control (T_8) recorded lower soil available Mn during both the years.

4.14.5.3. Soil available zinc

The residual effect of enriched poultry manure compost (T_6) registered higher soil available Zn (6.1 mg kg^{-1} in summer 2008 and 6.2 mg kg^{-1} in summer 2009), which was on par with composted poultry manure (T_5) and FYM + neem cake (T_3). The above treatments were superior to recommended NPK fertilizer (T_7). In both the years, absolute control (T_8) registered lower available Zn.

4.14.5.4. Soil available copper

During both the years, the residual effect of enriched poultry manure compost (T_6) recorded higher Cu availability (3.7 mg kg^{-1} in summer 2008 and 4.0 mg kg^{-1} in summer 2009) and which was on par with composted poultry manure (T_5) and FYM + neem cake (T_3). The recommended NPK fertilizer (T_7) recorded lower available Cu but superior to absolute control (T_8) in both the years.

4.15. Soil organic carbon in the post harvest soil of blackgram (Table 55)

Soil organic carbon content increased significantly with the application of organic manure and recommended NPK to the preceding rice crop, thus, expressing the residual effect during 2008 and 2009. The range of organic carbon content among the treatments was from 0.63 to 0.76 and from 0.64 to 0.80% during summer 2008 and 2009, respectively. In both the years, the residual effect of enriched poultry manure compost (T_6) was significantly higher in enhancing the content of soil organic carbon (0.76% in summer 2008 and 0.80% in summer 2009) and it was comparable with composted poultry manure (T_5) (0.73 and 0.78% during summer 2008 and 2009, respectively) and FYM + neem cake (T_3) (0.73% in summer 2008 and 0.78% in summer 2009). These were followed by enriched FYM compost + vermicompost + FYM (T_4), vermicompost (T_2) and enriched FYM compost (T_1) and which were on par with each other.

The application of recommended NPK fertilizer (T_7) registered lower value of 0.64 and 0.65% of organic carbon during summer 2008 and 2009, respectively and was found to be on par with absolute control (T_8) (0.63% in summer 2008 and 0.64% in summer 2009).

4.16. Soil pH and EC at post harvest soil of blackgram (Table 56)

During summer 2008 and 2009, the residual effect of enriched poultry manure compost (T_6) registered lesser soil pH (8.09 and 7.95 respectively) and which was on par with composted poultry manure (T_5) (8.11 and 8.00), FYM + neem cake (T_3) (8.13 and 8.07) and enriched FYM compost + vermicompost + FYM (T_4) (8.23 and 8.06) in summer 2008 and 2009, respectively. The recommended NPK fertilizer (T_7) recorded higher soil pH (8.55 and 8.52) and it was however comparable with absolute control (T_8) (8.57 and 8.56) in summer 2008 and 2009, respectively.

The residual effect of enriched poultry manure compost (T_6) recorded lesser soil EC (0.37 and 0.30 dS m^{-1}) and it was on par with composted poultry manure (T_5) (0.38 and 0.32 dS m^{-1}) and FYM + neem cake (T_3) (0.38 and 0.32 dS m^{-1}) in summer 2008 and 2009, respectively. The higher soil EC was observed under recommended NPK fertilizer (T_7) (0.45 dS m^{-1} in summer 2008 and 0.42 dS m^{-1} in summer 2009) and it was however comparable with absolute control (T_8) (0.46 and 0.44 dS m^{-1} in summer 2008 and 2009, respectively).

4.17. Soil microbial population at post harvest of blackgram (Table 57)

In summer 2008 and 2009, the residual effect of organic manures and recommended NPK fertilizer could be observed effectively in respect of microbial load in the post harvest soil of blackgram.

4.17.1. Bacteria (Table 57)

The bacterial population of the post harvest soil was higher (58.7 x 10^6 CFU g^{-1} of soil in summer 2008 and 62.3 in summer 2009) in T_6 (enriched poultry manure compost) and which was on par with composted poultry manure (T_5) whereas, it was comparable with FYM + neem cake (T_3). These were followed by enriched FYM compost (T_1), vermicompost (T_2) and enriched FYM compost + vermicompost + FYM (T_4) and were superior to recommended NPK fertilizer (T_7) (24.0 and 23.3 during summer 2008 and 2009, respectively). The absolute control (T_8) recorded least bacterial population (17.3 and 17.7 in summer 2008 and 2009, respectively).

4.17.2. Fungi (Table 57)

The residual effect of enriched poultry manure compost (T_6) improved the fungal population in post harvest soil (18.0 x 10^3 CFU g^{-1} of soil during summer 2008) and (18.3 during summer 2009). However, it was comparable with composted poultry manure (T_5) and FYM + neem cake (T_3). These were superior to enriched FYM compost + vermicompost + FYM (T_4), vermicompost (T_2) and enriched FYM compost (T_1) and which were on par. The lower fungal population was recorded with recommended NPK fertilizer (T_7) (5.7 and 6.3 during summer 2008 and summer 2009, respectively) but superior to absolute control (T_8) which registered least population of 3.3 in summer 2008 and 3.7 in summer 2009.

4.17.3. Actinomycetes (Table 57)

During summer 2008 and 2009, the actinomycetes population was higher in T_6 (enriched poultry manure compost) (14.3 and 17.0 x 10^4 CFU g^{-1} of soil respectively) and it was on par with that composted poultry manure (T_5) and FYM + neem cake (T_3) but were superior to recommended NPK fertilizer (T_7) (5.0 in summer 2008 and 4.6 in summer 2009). The actinomycetes population was, however, least in absolute control (T_8) (3.7 and 3.0 respectively) in both the years.

4.17.4. Soil enzyme activity at post harvest of blackgram (Table 58)

4.17.4.1. Soil urease activity

Higher urease activity was observed with the residual effect of enriched poultry manure compost (T_6) (40.3 µg NH_4^+ g^{-1} soil 24 h^{-1} in summer 2008 and 42.2 in summer 2009) and composted poultry manure (T_5) (39.6 in summer 2008 and 40.7 in summer 2009), which were on par. These were followed by FYM + neem cake (T_3), enriched FYM compost (T_1), vermicompost (T_2) and enriched FYM compost + vermicompost + FYM (T_4). The recommended NPK fertilizer (T_7) registered lower urease activity (30.1 and 29.4 during summer 2008 and 2009, respectively) but superior to absolute control (T_8).

4.17.4.2. Soil dehydrogenase activity

The higher dehydrogenase activity was observed under enriched poultry manure compost (T_6) (27.8 µg of TPF released g^{-1} of soil 24 h^{-1} in summer 2008 and 29.0 in summer 2009), which was comparable with composted poultry manure (T_5) and FYM + neem cake (T_3). These were followed by enriched FYM compost + vermicompost + FYM (T_4), enriched FYM compost (T_1) and vermicompost (T_2). The recommended NPK fertilizer (T_7) registered lower dehydrogenase activity but superior to absolute control (T_8).

4.17.4.3. Soil phosphatase activity

The enriched poultry manure compost (T_6) registered higher phosphatase activity (32.8 µg of p-nitrophenol released g^{-1} of soil h^{-1} in summer 2008 and 33.0 in summer 2009), which was on par with that enriched FYM compost (T_1) (31.7 in summer 2008 and 31.8 in summer 2009). These were followed by enriched FYM compost +

vermicompost + FYM (T_4) and it was comparable with enriched FYM compost (T_1). The recommended NPK fertilizer (T_7) and absolute control (T_8) recorded lower phosphatase activity during both the years.

4.18. Soil physical properties at post harvest of blackgram (Table 59)

The residual effect of organic manures and recommended NPK significantly influenced the soil physical properties *viz*., bulk density (Mg m^{-3}), per cent pore space and water holding capacity (%) except particle density (Mg m^{-3}) in both the years of experiments.

4.18.1. Bulk density

The reduced bulk density was observed with the residual effect of enriched poultry manure compost (T_6) (1.17 and 1.16 Mg m^{-3} during summer 2008 and 2009, respectively) and which was comparable with composted poultry manure (T_5), enriched FYM compost + vermicompost + FYM (T_4), FYM + neem cake (T_3), vermicompost (T_2) and enriched FYM compost (T_1). The recommended NPK fertilizer (T_7) registered higher bulk density (1.27 Mg m^{-3} in summer 2008 and 1.26 Mg m^{-3} in summer 2009) and it was on par with absolute control (T_8) during both the years.

4.18.2. Pore space

The enriched poultry manure compost (T_6) recorded higher pore space per cent (56.7 and 57.4 per cent during summer 2008 and 2009, respectively), which was however, comparable with that composted poultry manure (T_5) and FYM + neem cake (T_3). The reduced pore space was noticed under the treatment T_7 *viz*., recommended NPK fertilizer (52.0 per cent in summer 2008 and 51.8 per cent in summer 2009) whereas, it was on par with absolute control (T_8) which registered the lower pore space per cent (52.2 and 52.4 per cent respectively) in both summer 2008 and 2009.

4.18.3. Water holding capacity (WHC)

During summer 2008 and 2009, improved water holding capacity was observed in FYM + neem cake (T_3) (41.5 and 43.0% respectively), enriched poultry manure compost (T_6) (41.0 and 42.0%) and composted poultry manure (T_5) (40.7 and 41.0%) and which did not differ significantly with each other during both the years, respectively.

These were superior to recommended NPK fertilizer (T_7) (34.2% in summer 2008 and 34.3% in summer 2009) however, it was on par with absolute control (T_8) which recorded lower water holding capacity of 34.1% during summer 2008 and 34.4% during summer 2009.

4.19. Soil available N balance in the cropping system

4.19.1. Soil available N balance in first cropping cycle 2007 - 2008 and second cropping cycle 2008 - 2009 (Table 60 and 61)

The application of organic manures and recommended NPK in the first and second cropping system of green manure-rice-blackgram altered the balance of soil available nitrogen. Application of organic manures increased available soil N balance. The balance was positive, indicating a net gain, when, both rice crops received organic manures. During first cropping cycle 2007 - 2008, the net gain in respect of available N was the maximum with the application of enriched poultry manure compost (T_6) (46 kg ha^{-1}), composted poultry manure (T_5) (43 kg ha^{-1}), FYM + neem cake (T_3) (26 kg ha^{-1}) when compared to vermicompost (T_2) (13 kg ha^{-1}), enriched FYM compost + vermicompost + FYM (T4) (8 kg ha^{-1}), recommended NPK fertilizer (T_7) (6 kg ha^{-1}) and enriched FYM (T_1) compost (5 kg ha^{-1}). The net loss of soil available N was observed (-48 kg ha^{-1}), when N was not applied through either organic manures and recommended N fertilizer (absolute control) T_8.

In the second cropping cycle 2008 - 2009, soil available N balance ranged from -8 kg ha^{-1} in T_7 (recommended NPK fertilizer) to 20 kg ha^{-1} (enriched poultry manure compost) in T_6. The application of recommended N alone to preceding rice was not sufficient to meet the needs of the succeeding crop and resulted in sharp depletion of the soil available N status in recommended NPK fertilizer (T_7).

4.19.2. Total soil available N balance at the end of 2 years (2007 - 2009) (Table 62)

Organic manuring positively influenced post harvest available N and its balance. Net N loss was feebly high (-50 kg ha^{-1}) in T_8 *viz.*, without organic manures and recommended fertilizer N, whereas, net N loss was -2 kg ha^{-1} in T_7 (recommended NPK fertilizer). The organic manure application through enriched poultry manure compost (T_6) recorded a net gain of 66 kg N ha^{-1} at the end of the experiment.

4.19.3. Soil available P balance in first cropping cycle 2007 - 2008 and second cropping cycle 2008 - 09 (Table 63 and 64)

The application of organic manures registered net gain of P, whereas, the recommended NPK fertilizer (T_7) (-0.2 and -0.4 kg P ha^{-1} in 2007 - 2008 and 2008 - 2009, respectively) and absolute control (T_8) had net negative P (-3.5 kg P ha^{-1} during 2007 - 2008 and -0.5 kg P ha^{-1} during 2008 - 2009). Among the organic manures, the enriched poultry manure compost (T_6) recorded higher net gain of P (12.5 and 2.9 kg ha^{-1} in 2007 - 2008 and 2008 – 2009, respectively).

4.19.4. Total soil available P balance at the end of 2 years (2007 - 2009) (Table 65)

Organic manuring positively influenced post harvest available P and its balance. The recommended NPK fertilizer (T_7) recorded higher net P loss (-0.6 kg ha^{-1}) whereas, net P loss was -4.0 kg ha^{-1} in absolute control (T_8). The organic manure application through enriched poultry manure compost (T_6) recorded a net gain of 15.4 kg P ha^{-1} at the end of the experiment.

4.19.5. Soil available K balance in first cropping cycle 2007 - 2008 and second cropping cycle 2008 - 2009 (Table 66 and 67)

During both the years of cropping system, the application of organic manures and recommended NPK fertilizer resulted net negative K balance. The higher net loss of K was recorded with absolute control (T_8) (-148 kg ha^{-1} during 2007 - 2008) and recommended NPK fertilizer (T_7) (-16 kg ha^{-1} during 2008 - 2009). Among the organic manure application, lower net negative K balance was noted under enriched poultry manure compost (T_6) (-1 kg ha^{-1} in 2007 - 2008) and enriched FYM compost (T_1) (-3 kg ha^{-1} in 2008 - 2009).

4.19.6. Total soil available K balance at the end of 2 years (2007 - 2009) (Table 68)

The application of organic manures and recommended NPK fertilizer resulted net negative K balance. The net K loss was higher in absolute control (T_8) (-160 kg ha^{-1}) followed by enriched FYM compost + vermicompost + FYM (T_4) (-88 kg ha^{-1}), enriched FYM compost (T_1) (-86 kg ha^{-1}), recommended NPK through fertilizer (T_7) (-84 kg ha^{-1}), vermicompost (T_2) (-84 kg ha^{-1}) and FYM + neem cake (T_3) (-52 kg ha^{-1}). The enriched poultry manure compost (T_6) had relatively lower net loss of K (-9 kg ha^{-1}) and composted poultry manure (T_5) (-24 kg ha^{-1}).

4.20. Rice quality parameters

4.20.1. Milling characteristics of paddy (Table 69 and 70)

4.20.1.1. Milling recovery (%)

The recommended NPK fertilizer (T_7) recorded higher milling recovery (67.8% during *rabi* 2007 and 68.6% during *rabi* 2008) and it was on par with enriched poultry manure compost (T_6) (67.3 and 67.6%) and composted poultry manure (T_5) (66.5 and 67.4% respectively) during *rabi* 2007 and 2008. Lower milling recovery was registered in absolute control (T_8) (61.9 and 60.8% respectively) in both the *rabi* 2007 and 2008.

4.20.1.2. Whole rice (g)

Application of recommended NPK fertilizer (T_7) had given higher whole rice (42.5 and 43.0 g during *rabi* 2007 and 2008 respectively) and it was on par with enriched poultry manure compost (T_6) whereas, it was comparable with that composted poultry manure (T_5). The absolute control (T_8) recorded lowest whole rice of 34.5 g in *rabi* 2007 and 33.6 g in *rabi* 2008.

4.20.1.3. Unshelled paddy (g)

The highest unshelled paddy was observed in absolute control (T_8) (12.4 g during *rabi* 2007 and 13.5 g during *rabi* 2008) followed by enriched FYM compost (T_1) and enriched FYM compost + vermicompost + FYM (T_4). However, the recommended NPK fertilizer (T_7) recorded lower unshelled paddy (7.5 g in *rabi* 2007 and 7.0 g in *rabi* 2008) and it was on par with enriched poultry manure compost (T_6) and composted poultry manure (T_5).

4.20.1.4. Head rice recovery (%)

The recommended NPK fertilizer (T_7) had recorded higher head rice per cent (64.5% in *rabi* 2007 and 65.2% in *rabi* 2008) and which was comparable with enriched poultry manure compost (T_6) and composted poultry manure (T_5). The absolute control (T_8) registered lower head rice percentage of 58.7% in *rabi* 2007 and 57.5% in *rabi* 2008.

4.20.1.5. Broken rice (%)

The absolute control (T_8) had shown higher broken rice percentage of 41.3 and 42.5 during *rabi* 2007 and 2008, respectively. Lower broken percentage was recorded with recommended NPK fertilizer (T_7) (35.5 and 34.8%), enriched poultry manure compost (T_6) (36.2 and 35.5%) and composted poultry manure (T_5) (36.5 and 36.0%) in both *rabi* 2007 and 2008, respectively.

4.20.1.6. Co-effficient of shelling

Application of recommended NPK fertilizer (T_7) had observed higher co-efficient of shelling (0.85 at *rabi* 2007 and 0.86 at *rabi* 2008) and it was on par with enriched poultry manure compost (T_6) and composted poultry manure (T_5). The lower co-efficient of shelling (0.75 during *rabi* 2007 and 0.73 during *rabi* 2008) recorded in absolute control (T_8).

4.20.1.7. Effectiveness of shelling (%)

Higher effectiveness of shelling was registered in recommended NPK fertilizer (T_7) (54.83% during *rabi* 2007 and 56.07% during *rabi* 2008) and it was comparable with enriched poultry manure compost (T_6). The absolute control (T_8) registered lower effectiveness of shelling of 44.03 and 41.98% in *rabi* 2007 and 2008, respectively.

4.20.2. Physical characteristics of raw rice grain (Table 71)

4.20.2.1. Grain length

Grain length was maximum in recommended NPK fertilizer (T_7) (5.72 mm during *rabi* 2007 and 5.70 mm during *rabi* 2008) and it was statistically on par with grain length recorded under enriched poultry manure compost (T_6), composted poultry manure (T_5) and FYM + neem cake (T_3). Minimum grain length was recorded in absolute control (T_8) (5.43 and 5.42 mm respectively) in both the *rabi* 2007 and 2008.

4.20.2.2. Grain breadth

The recommended NPK fertilizer (T_7) observed higher grain breadth of 2.04 mm in *rabi* 2007 and 2.02 mm in *rabi* 2008 and it was at par with enriched poultry manure compost (T_6) and composted poultry manure (T_5). The absolute control (T_8) registered lower grain breadth (1.88 mm in *rabi* 2007 and 1.90 mm in *rabi* 2008) and it was comparable with vermicompost (T_2).

4.20.2.3. L/B ratio

Higher L/B ratio was recorded for absolute control (T_8) (2.89 and 2.85 during *rabi* 2007 and 2008, respectively) and it was comparable with following treatments vermicompost (T_2), enriched FYM compost (T_1), FYM + neem cake (T_3), enriched FYM compost + vermicompost + FYM (T_4) and composted poultry manure (T_5). Lower L/B ratio was recorded in recommended NPK fertilizer (T_7) (2.80 in *rabi* 2007 and 2.82 in *rabi* 2008).

4.20.2.4. 1000 grain weight (g)

The various treatments failed to influence the 1000 grain weight (g).

4.20.3. Chemical composition of rice (Table 72 and 73)

4.20.3.1. Moisture content (%)

Moisture content did not differ significantly among the treatments studied in both the years.

4.20.3.2. Protein (%)

The enriched poultry manure compost (T_6) significantly improved protein content (7.13% in *rabi* 2007 and 7.15% in *rabi* 2008) and it was on par with recommended NPK fertilizer (T_7) and composted poultry manure (T_5). Low protein content was recorded in absolute control (T_8) (5.82 and 6.16% during *rabi* 2007 and 2008, respectively).

4.20.3.3. Carbohydarte (%)

Carbohydrate per cent was higher in recommended NPK fertilizer (T_7) (77.57 and 77.87% during *rabi* 2007 and 2008, respectively) and which was comparable with enriched poultry manure compost (T_6) and composted poultry manure (T_5). The absolute control (T_8) registered lower per cent of carbohydrate (74.50% in *rabi* 2007 and 74.00% in *rabi* 2008) and it was on par with vermicompost (T_2) and enriched FYM compost (T_1).

4.20.3.4. Amylose content (%)

The enriched poultry manure compost (T_6) had higher amylose content (25.47% during *rabi* 2007 and 25.11% during *rabi* 2008) and it was comparable with composted poultry manure (T_5) and recommended NPK fertilizer (T_7). The absolute control (T_8) had lower amylose content of 19.00 and 19.30% in *rabi* 2007 and 2008, respectively.

4.20.3.5. Fat (%)

The recommended NPK fertilizer (T_7) recorded improved fat content (0.57 and 0.57% during *rabi* 2007 and 2008, respectively) and which was comparable with enriched poultry manure compost (T_6), composted poultry manure (T_5) and FYM + neem cake (T_3). The absolute control (T_8) registered lower fat content (0.51% in *rabi* 2007 and 0.52% in *rabi* 2008).

4.20.3.6. Fibre (%)

The enriched poultry manure compost (T_6) had more fibre content (0.217% during *rabi* 2007 and 0.216% during *rabi* 2008) and it was comparable with composted poultry manure (T_5). The absolute control (T_8) had lesser fibre content of 0.182 and 0.185% in *rabi* 2007 and 2008, respectively, whereas, it was on par with enriched FYM compost + vermicompost + FYM (T_4).

4.20.3.7. Total ash content (%)

The recommended NPK fertilizer (T_7) registered higher total ash content (0.878% in *rabi* 2007 and 0.875% in *rabi* 2008) however, it was comparable with enriched poultry manure compost (T_6), composted poultry manure (T_5) and FYM + neem cake (T_3). The lower total ash content was recorded in absolute control (T_8) (0.833 and 0.835% during *rabi* 2007 and 2008, respectively) and which was on par with vermicompost (T_2) and enriched FYM compost (T_1).

4.20.4. Cooking quality of milled rice (Table 74)

4.20.4.1. Cooking time

The different treatments did not significantly influence the cooking time (minutes) during both *rabi* 2007 and 2008.

4.20.4.2. Volume expansion ratio

The recommended NPK fertilizer (T_7) had higher volume expansion ratio (2.97 and 3.08 during *rabi* 2007 and 2008, respectively) and was comparable with enriched poultry manure compost (T_6) and composted poultry manure (T_5). The absolute control (T_8) was observed lower volume expansion ratio (2.50 in *rabi* 2007 and 2.47 in *rabi* 2008) and it was on par with vermicompost (T_2).

4.20.4.3. Water absorption ratio

Improved water absorption ratio was observed under enriched poultry manure compost (T_6) (4.33 in *rabi* 2007 and 4.27 in *rabi* 2008), whereas, it was on par with recommended NPK fertilizer (T_7) and composted poultry manure (T_5). The lower water absorption ratio was observed in absolute control (T_8) (4.13 and 4.15 during *rabi* 2007 and 2008, respectively).

4.20.5. Cooking characteristics of milled rice (Table 75)

4.20.5.1. Kernel Length after Cooking (KLAC)

The recommended NPK fertilizer (T_7) had increased KLAC (10.02 and 10.02 mm during *rabi* 2007 and 2008, respectively) and was comparable with enriched poultry manure compost (T_6) and composted poultry manure (T_5). The absolute control (T_8) observed lower KLAC (9.40 mm in *rabi* 2007 and 9.53 mm in *rabi* 2008).

4.20.5.2. Kernel Breadth after Cooking (KBAC)

Maximum KBAC was recorded in recommended NPK fertilizer (T_7) (2.47 and 2.50 mm during *rabi* 2007 and 2008, respectively) and which was on par with enriched poultry manure compost (T_6) and composted poultry manure (T_5). The lower KBAC was observed in absolute control (T_8) (2.30 mm in *rabi* 2007 and 2.32 mm in *rabi* 2008).

4.20.5.3. Linear Elongation Ratio (LER)

The higher LER was registered in enriched poultry manure compost (T_6) (1.76 in *rabi* 2007 and 1.77 in *rabi* 2008) and it was comparable with composted poultry manure (T_5). The absolute control (T_8) recorded lower LER (1.73 and 1.76 during *rabi* 2007 and 2008, respectively).

4.20.5.4. Breadth wise Expansion Ratio (BER)

The FYM + neem cake (T_3) recorded higher BER (1.24 and 1.24 during *rabi* 2007 and 2008, respectively) and it was on par with enriched FYM compost + vermicompost + FYM (T_4) and vermicompost (T_2). The lower BER was observed in enriched FYM compost (T_1) (1.21 in *rabi* 2007 and 1.23 in *rabi* 2008) and it was comparable with enriched poultry manure compost (T_6) and composted poultry manure (T_5).

4.20.5.5. Length Breadth ratio after Cooking (LBAC)

The increased LBAC was observed in enriched FYM compost (T_1) (4.18 in *rabi* 2007) and composted poultry manure (T_5), vermicompost (T_2) and FYM + neem cake (T_3) were recorded more LBAC in *rabi* 2008. The lesser LBAC was registered in recommended NPK fertilizer (T_7) (4.06) during *rabi* 2007 and absolute control (T_8) (3.97) during *rabi* 2008.

4.20.6. Sensory characteristics of cooked rice (Table 76)

4.20.6.1. Colour

The enriched poultry manure compost (T_6) had influenced (8.4 during *rabi* 2007 and 8.4 during *rabi* 2008) colour of cooked rice and it was similar to composted poultry manure (T_5). The recommended NPK fertilizer (T_7) (7.8 and 7.8) and vermicompost (7.8 and 7.8) noted lower mean score in both the years respectively.

4.20.6.2. Texture

The enriched poultry manure compost (T_6) also influenced the texture (8.2 during *rabi* 2007 and 8.2 during *rabi* 2008) of cooked rice and it was followed by to composted poultry manure (T_5), enriched FYM compost + vermicompost + FYM (T_4), FYM + neem cake (T_3) and absolute control (T_8). The lower mean score was observed in recommended

NPK fertilizer (T_7) and vermicompost (T_2) (7.6 and 7.2 in *rabi* 2007; 7.2 and 7.6 in *rabi* 2008, respectively).

4.20.6.3. Taste

The enriched poultry manure compost (T_6) recorded acceptable taste (8.6 in *rabi* 2007 and 8.42 in *rabi* 2008) and composted poultry manure (T_5) (8.4 2 in *rabi* 2007 and 8.22 in *rabi* 2008). Lower mean score for taste was registered for vermicompost (T_2) and recommended NPK fertilizer (T_7) (7.8 and 8.0 respectively) during *rabi* 2007. The recommended NPK fertilizer (T_7) and enriched FYM compost + vermicompost + FYM (T_4) observed lesser mean score for taste (7.8 and 7.8 respectively) in *rabi* 2008.

4.20.6.4. Overall acceptability

The enriched poultry manure compost (T_6) (8.6 during both *rabi* 2007 and 2008) and composted poultry manure (T_5) (8.4 in *rabi* 2007 and 8.6 in *rabi* 2008) registered higher score than other treatments. These were followed by FYM + neem cake (T_3). The lower score was noted in recommended NPK fertilizer (T_7) (8.0 in both *rabi* 2007 and 2008) and also with absolute control (T_8), vermicompost (T_2) and enriched FYM compost (T_1).

4.21. Production potential of system (Table 77)

4.21.1. System productivity

Higher system productivity was recorded under enriched poultry manure compost (T_6) (5182 and 5467 kg ha^{-1} in 2007 - 2008 and 2008 – 2009, respectively) and composted poultry manure (T_5) (4967 kg ha^{-1} in 2007 - 2008 and 5286 kg ha^{-1} in 2008 - 2009), which were comparable with each other. These were followed by recommended NPK fertilizer (T_7) (4750 kg ha^{-1} in 2007 - 2008 and 4954 kg ha^{-1} in 2008 - 2009) and it was superior to FYM + neem cake (T_3), vermicompost (T_2), enriched FYM compost + vermicompost + FYM (T_4) and enriched FYM compost (T_1). The absolute control (T_8) registered lower system productivity (2905 and 2983 kg ha^{-1} respectively) during 2007 - 2008 and 2008 - 2009.

4.21.2. Per day production (Crop duration)

During 2007 - 2008 and 2008 - 2009, enriched poultry manure compost (T_6) registered higher per day production (23.77 kg ha^{-1} in 2007 - 2008 and 25.43 kg ha^{-1} in 2008 - 2009) and which was on par with that composted poultry manure (T_5). These were followed by recommended NPK fertilizer (T_7) and it was superior to FYM + neem cake (T_3), vermicompost (T_2), enriched FYM compost + vermicompost + FYM (T_4) and enriched FYM compost (T_1). The absolute control (T_8) registered lower per day production of 13.33 kg ha^{-1} during 2007 - 2008 and 13.87 kg ha^{-1} during 2008 - 2009.

4.22. Economics of green manure-rice-blackgram cropping sequence (Table 78 and 79)

Gross return per hectare during 2007 - 2009, extended from Rs. 39,336 to Rs. 76,564 for the green manure-rice-blackgram cropping sequence. Higher gross return (Rs. 76,564) and net return (Rs. 47,843) were associated with enriched poultry manure compost (T_6) and it was corresponded to that observed with T_5 *viz*., composted poultry manure for gross return (Rs. 73,382) and net return (Rs. 46,395). These were followed by the application of recommended NPK fertilizer (T_7) (Rs. 60,510 and net return of Rs. 35,572) and FYM + neem cake (T_3). The absolute control (T_8) recorded lower gross return (Rs. 39,336) and net return (Rs. 16,899).

Higher B: C ratio (2.67) was registered in enriched poultry manure compost (T_6) and composted poultry manure (T_5) (2.65) followed by recommended NPK fertilizer (T_7) (2.43) and FYM + neem cake (T_3) (2.06). The lower B: C ratio (1.53) was recorded in vermicompost (T_2).

During 2008 - 2009, the gross return and net return of the green manure-rice-blackgram cropping sequence varied from Rs. 40,061to Rs. 80,236 and from Rs. 17,264 to Rs. 51,550 respectively. The application of enriched poultry manure compost (T_6) recorded higher gross return Rs. 80,236 and net return Rs. 51,550 followed by composted poultry manure (T_5) (gross return of Rs. 77,713 and net return of Rs. 50,611). The recommended NPK fertilizer (T_7) registered gross return of Rs. 62,838 and net return of Rs. 37,900 ha^{-1}. The lowest gross return of Rs. 40,061and net return of Rs. 17,264 was registered in absolute control (T_8).

As in the previous cropping system, the higher B: C ratio was recorded with enriched poultry manure compost (T_6) (2.80) and composted poultry manure (T_5) (2.79). The next best in respect of B: C ratio was recorded with the application of recommended NPK fertilizer (T_7) (2.52). The vermicompost (T_2) recorded the lowest B: C ratio (1.56).

CHAPTER V
DISCUSSION

The field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during 2007 - 2008 and 2008 - 2009 to study the effect of different organic manures on rice and their residual effect on succeeding blackgram and fertility status of soil through pre-season green manuring. The salient findings from the experiments are discussed in this chapter.

5.1. Weather condition during crop period

It was observed from the meteorological data collected from Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, that a total rainfall of 867.8 mm and 606.8 mm was received in 43 and 36 rainy days during the cropping period of 2007 - 2008 and 2008 - 2009, respectively. The mean relative humidity was 87.82 (at 07.22 hrs) and 53.00 per cent (at 14.22 hrs) during 2007 - 2008 and 86.00 (at 07.22 hrs) and 46.95 per cent (at 14.22 hrs) during 2008 - 2009. The mean temperature during the crop growing seasons was 30.4 and 31.4^{0}C for maximum and 21.0 and 21.2^{0}C for minimum during 2007 - 2008 and 2008 - 2009, respectively. The mean sunshine hours was 5.9 during 2007 - 2008 and 6.7 during 2008 - 2009. The mean solar radiation was 355.9 and 385.3 cal cm^{-2} day^{-1} during 2007 - 2008 and 2008 - 2009, respectively. Thus the climatic conditions were found to be normal for growth of *rabi* rice and summer blackgram during both the years of experiments.

5.2. Pre-season green manuring

Pre-season green manuring of *Sesbania aculeata* (Dhaincha) recorded high nodulation, higher green biomass through increased plant height and higher N, P and K accumulation at the time of *in situ* incorporation at 51 DAS during 2007 and at 47 DAS during 2008. This is in accordance with the views of Singh *et al*. (1992), who observed that *Sesbania aculeata* have higher rate of biomass production and can produce green biomass to the tune of 16.0 to 19.0 t ha^{-1} within a short period of 45 - 60 days and an average about 5.0 t ha^{-1} dry matter can easily be produced which is sufficient for meeting the nutritional demand of rice either in *kharif* or *rabi* season.

Green manures raised during pre-season rice and *in situ* incorporation resulted substantial increase in growth parameters, yield attributes and yield of succeeding rice. This increase might be due to the decomposition of green manure, which released NH_4^+-N into the rice rhizosphere system, which was readily usable by the rice plant (Anbumani, 2001) and also possible changes in the rice soil aerobic layer facilitating root aeration associated with the higher growth parameters. In addition, the decomposing green manure might have influenced the photosynthetic activity by rapid evolution of CO_2 (Bhardwaj and Dev, 1985) to promote net assimilation rate (NAR). Similar views were also endorsed by Gracy Mathew and Alexander (1995) and Kanwar *et al*. (2006). Increase in rice grain yield owing to green manure incorporation might be attributed to release of nutrients to soil slowly for longer duration after decomposition, resulting in better plant growth and yield contributing characters as reported by Patra *et al*. (2001).

5.3. Growth and physiological parameters of rice

The results of the present investigation involving organic manures and recommended NPK through fertilizer showed marked impact on the growth and physiological parameters of rice.

Maximum plant height recorded as a result of application of recommended NPK through fertilizer (T_7) at active tillering and panicle initiation stages might be due to the immediate mineralization of inorganic nutrients applied through this treatment and it was comparable with enriched poultry manure compost (T_6) and composted poultry manure (T_5). Due to early mineralization and accumulation of available nutrients, improved plant height resulted with the application of enriched poultry manure compost (T_6) and composted poultry manure (T_5). In the past it was indicated that organic source like poultry manure would require some minimum period to release the nutrients to the soil pool as compared to other organic sources (Verma and Bhagat, 1994). The plant height at flowering and harvest stages was on par between enriched poultry manure compost (T_6) and composted poultry manure (T_5). The application of enriched poultry manure compost or composted poultry manure would have helped in rapid absorption of nutrients by plants because of optimum level of C: N ratio which resulted in better plant growth.

Enriched poultry manure compost (T_6) recorded higher LAI and it was comparable with composted poultry manure (T_5) at all the stages of crop growth during both the years. The next best treatment was recommended NPK fertilizer (T_7). Taller plants usually provide a better ventilated canopy and CO_2 exchange might have improved (Noova and Loomis, 1981). In the present study, better utilization of N resulted in higher leaf surface area and there by higher LAI with enriched poultry manure compost (T_6) and composted poultry manure (T_5). This corroborates with the findings of Amanullah *et al*. (2006c).

During both the years, number of tillers m^{-2} was influenced greatly by the application of enriched poultry manure compost (T_6) and it was on par with composted poultry manure (T_5). The recommended NPK fertilizer application (T_7) was comparable with composted poultry manure (T_5). The enriched poultry manure compost (T_6) increased the number of tillers m^{-2} over absolute control (T_8) and it was 38.9, 41.9, 43.6 and 43.2 per cent during *rabi* 2007 and 44.4, 44.4, 43.7 and 42.5 per cent during *rabi* 2008, respectively at active tillering, panicle initiation, flowering and harvest stages. This might be due to addition of enriched poultry manure compost (T_6) and composted poultry manure (T_5), which add N to the soil helping in enhanced number of tillers m^{-2}. In addition, involvement of certain growth promoting substances also might have accelerated number of tillers. This is in consonance with the findings of Prabhakaran (2000). The biochemical and biophysiological process might have been triggered by enriched poultry manure compost (T_6) and composted poultry manure (T_5), as a result increased tiller number was obtained in the present investigation.

Dry matter accumulation is considered to be the reliable index of crop growth. The enriched poultry manure compost (T_6) registered higher dry matter production and it was on par with composted poultry manure (T_5) at all the stages of both the years (Fig. 4 and 5). This was followed by recommended NPK fertilizer application (T_7), which was comparable with composted poultry manure (T_5). The enriched poultry manure compost (T_6) increased dry matter production than control to the tune of 77.9, 61.6, 66.7 and 69.0 per cent during *rabi* 2007 and 77.7, 65.6, 67.7 and 69.8 per cent during *rabi* 2008, respectively at active tillering, panicle initiation, flowering and harvest stages. The probable reason might be attributed to the continuous slow release of nutrients which might have enabled the leaf area duration to extend, thereby providing an opportunity for plants to increase the photosynthetic rate which in turn, could have led to higher accumulation of dry matter. Similar results were obtained by Amanullah *et al*. (2006a). The higher dry matter observed with the application of poultry manure, might be ascribed partly to its ability to release N synchronously with the demand of rice, compared with cattle manure (Ofori *et al*., 2005).

The root characters are healthier index for vigorous rice plant since it supports the above ground plant parts. The root length, volume and dry weight were greatly influenced by the application of enriched poultry manure compost (T_6) and it was on par with composted poultry manure (T_5) and recommended NPK fertilizer application (T_7) at all the stages during both the years. This may be due to the improvement in soil physical condition which might have provided a better soil environment for root development. The favourable soil physical condition adduced to poultry manure is consistent with earlier findings of Akanni (2005) and Agbede *et al*. (2008).

The enriched poultry manure compost (T_6) registered higher SPAD values (rice leaf N concentration) and it was comparable with composted poultry manure (T_5) at active tillering, panicle initiation and flowering stages. This might be due to the supply of higher nutrients from the incorporated enriched poultry manure compost (T_6) and composted poultry manure (T_5) to the growing tissues which led to the synthesis of more chlorophyll. This is in accordance with the results obtained by Shanthi and Vijayakumari (2005). In addition, prolific root also might have sustained the leaf N concentration at a higher level throughout the crop growth period. The crop growth rate (CGR) and net assimilation rate (NAR) was higher with the application of enriched poultry manure compost (T_6). Plausible reason could be the nutrient richness in enriched poultry manure and its application also improved the soil environment which encouraged proliferous root system resulting in better absorption of water and nutrients from lower layers and thus resulted in increased growth rate. This is consistent with those of Jagdev and Singh (2000) and Seshadri *et al*. (2005).

The beneficial influence of organic manures (T_1, T_2, T_3, T_4, T_5 and T_6) and recommended NPK through fertilizer (T_7) on growth and physiological attributes was observed when compared to absolute control (T_8). In the present study, the non supply of nutrients through any sources resulted in poor performance of rice could be noticed by the lower values of all the growth and physiological parameters in absolute control. When nutrients are not supplied, rice has to obviously depend upon initial soil nutrients, which is not sufficient to produce even reasonable yields. This is agreement with the findings of Natarajan (2003).

5.4. Growth parameters of blackgram

The residual effect of preceding organic manure treatments was more on growth parameters of blackgram when compared to inorganic fertilizer application and absolute control in both the years. Similar observations were made by Britto and Girija (2006). The residual effect of enriched poultry manure compost (T_6) recorded higher growth parameters (plant height, LAI and DMP) of blackgram and it was comparable with composted poultry manure (T_5) and FYM + neem cake (T_3). The rice fallow blackgram survives entirely on residual moisture and fertility left over by the preceding crop of rice. Increased growth components of residual blackgram was due to the residues left behind by the application of enriched poultry manure compost, composted poultry manure and FYM + neem cake and also improvement in soil physical, chemical and biological properties, which led to better uptake of nutrients and crop growth. The results are in agreement with those of Prakash *et al*. (2008).

5.5. Yield attributes of rice

Yield attributes *viz*., productive tillers m^{-2}, panicle weight (g), panicle length (cm), total spikelets $panicle^{-1}$, filled spikelets $panicle^{-1}$ and filling percentage were positively influenced by the application of organic manures and recommended NPK through fertilizer except test grain weight probably, the weight of individual grain is mainly influenced by the genetic make up of the plant as compared to other environmental factors (Bhardwaj *et al*., 1981 and Narayanasamy, 1994).

Application of enriched poultry manure compost (T_6) recorded increased number of productive tillers m^{-2}, panicle weight (g), panicle length (cm), total spikelets $panicle^{-1}$, filled spikelets $panicle^{-1}$ and filling percentage and it was comparable with composted poultry manure (T_5) (Fig. 6 and 7). These were followed by recommended NPK fertilizer (T_7). What was true for growth parameters was also true for yield attributes. This might be due to higher concentration of macro and micronutrients in the enriched poultry manure compost (T_6) and composted poultry manure (T_5) and higher and steady nutrient release compared to other organic manures. Further, the poultry waste had both urinary and fecal excretion, hence the fertilizer value was nearly three times higher than FYM (Devegowda, 1997). The enriched poultry manure compost (T_6) increased productive tillers (35.8 and 36.3 per cent) and filled spikelets panicle^{-1} (54.6 and 65.6 per cent) than absolute control during *rabi* 2007 and 2008, respectively. 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. Because of more number of filled grains under enriched poultry manure compost (T_6) there might be increase in panicle weight and filling percentage. 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).

5.6. Yield attributes of blackgram

Striking improvement in yield attributes (number of clusters plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1} except the pod length and 100 grain weight) of blackgram with organic manure treatments than recommended NPK fertilizer and absolute control. The residues of enriched poultry manure compost (T_6) and composted poultry manure (T_5) influenced the yield attributes and were on par with each other. The efficient utilization of mineralized nutrients from these organic manures has increased the availability of nutrients throughout the growth period which in turn increased the growth and yield attributes of blackgram. Similar increase in yield attributes of residual crop due to application of poultry manure to previous crop has been reported by Gedam *et al*. (2008).

5.7. Grain and straw yield of rice

5.7.1. Grain yield of rice

The grain yield of rice was increased significantly with the application of organic manures and recommended NPK through fertilizer as compared to absolute control (T_8) suggesting the importance of organic manures during both the years. The slightly higher rice grain obtained in *rabi* 2008 compared with *rabi* 2007 could be due to residual effects of previous organic manures and rice root biomass left after harvest of rice and the incorporation of the haulms of residual blackgram in preceding summer season. Similar findings were reported by Natarajan (2003) and Ofori *et al*. (2005).

The beneficial effect in respect of grain yield (4675 kg ha^{-1} during *rabi* 2007 and 4953 kg ha^{-1} during *rabi* 2008) was more prominent with enriched poultry manure compost (T_6) and it was comparable with composted poultry manure (T_5) and better than other organic manure treatments and also inorganic source treatment (Fig. 8 and 9). The comparison of the grain yield obtained under enriched poultry manure compost (T_6) and recommended NPK fertilizer (T_7) revealed that the percentage increase over T_7 was 7.7 per cent during *rabi* 2007 and 9.1 per cent during *rabi* 2008. Similar result was obtained by Kenchaiah (1997). All along, it is known that because of early mineralization of inorganic nutrients there might be spontaneous response of rice within season and it is believed earlier that 30 per cent of the nutrients applied from organic source were available to rice crop within the season, leaving the remaining for subsequent crops in a cropping system. But on contrary in the present investigation, application of enriched poultry manure compost to rice was able to respond greater level compared to inorganic fertilizer application, which might be due to the following reasons. The supremacy of enriched poultry manure compost lies in the fact that it can supply the nutrients in soluble form for a quite longer period by not allowing the entire soluble form into solution, to come in contact with soil and other inorganic constituents, thereby minimizing fixation and precipitation from the enriched manures, the plant roots can very well compete with loss mechanisms and absorb more nutrients leading to better yield. This falls in line with the findings of Mohandas *et al*. (2008).

The application of composted poultry manure (T_5) was on par with recommended NPK fertilizer (T_7) in both the years of study. Similar result was obtained by Ananda *et al*. (2006). Singh *et al*. (2007) reported that rice grain yield registered under organic amendments was on par with the yield recorded under recommended dose of chemical fertilizer application. This might be due to the fact that steady and adequate supply of nutrients by the enhanced biochemical activity of microorganisms coupled with large photosynthesizing surface would have helped in the production of more tillers and dry matter with enhanced supply of assimilate to sink resulting in more number of spikelets, higher filling percentage and higher yield with the addition of enriched poultry manure compost (T_6) and composted poultry manure (T_5). This corroborates with the findings of Ramesh (2002). The next best grain yield was recorded with the application of FYM + neem cake (T_3). The probable reason might be the FYM acts as nutrient reservoir and upon decomposition produces organic acids, thereby adsorbed ions are released slowly for the entire growth (Channabasavanna *et al*., 2001) and the nitrification inhibitory property of neem cake (Prasad *et al*., 1980) and increased NUE leading to higher yields (Kenchaiah, 1997).

The enriched poultry manure compost (T_6) increased grain yield to the tune of 83.3 and 88.0 per cent, while recommended NPK fertilizer (T_7) to the tune of 70.2 and 72.2 per cent over absolute control (T_8) during *rabi* 2007 and 2008, respectively. Lower grain yield of 2550 kg ha^{-1} during *rabi* 2007 and 2635 kg ha^{-1} during *rabi* 2008 was recorded in absolute control (T_8). This was quite natural that the inherent soil available nutrients were not sufficient to meet the crop demand.

5.7.2. Straw yield of rice

In case of straw yield, application of enriched poultry manure compost (T_6) and composted poultry manure (T_5) enhanced the straw yield and were comparable. These were followed by the recommended NPK fertilizer (T_7) whereas, it was on par with composted poultry manure (T_5) (Fig. 8 and 9). All the treatments were significantly superior over absolute control (T_8) during both the years. The enriched poultry manure compost (T_6) increased straw yield over absolute control (T_8) was 64.9 per cent during *rabi* 2007 and 64.5 during *rabi* 2008. This might be due to the adequate biomass production and better nutrient uptake which might have resulted in higher straw yield by the application of enriched poultry manure compost (T_6) and composted poultry manure (T_5). This is in accordance with the results obtained by Yadav and Lourduraj (2006a).

5.7.3. Grain and haulm yield of blackgram

In rice fallow pulse blackgram, the yield (grain and haulm) registered by residual effect of organic treatments were higher than recommended NPK fertilizer (T_7) and absolute control (T_8). The spectacular yield improvement was observed due to incorporation of organic manures could be documented to the cumulative effect of organics in improving the yield appreciably. Research results of AICARP (1978), AICARP (1980) also lend support to the above findings. The result on yield (grain and haulm) of blackgram once again proved the superiority of enriched poultry manure compost (T_6) and composted poultry manure (T_5) and these were on par with FYM + neem cake (T_3), thus revealing the residual effect of organic manures over recommended NPK fertilizer (T_7) and absolute control (T_8) (Fig. 10 and 11). The enriched poultry manure compost (T_6) increased grain yield by 42.8 per cent during *rabi* 2007 and 47.7 per cent during *rabi* 2008 over absolute control (T_8) and haulm yield by 40.7 per cent during *rabi* 2007 and 41.2 per cent during *rabi* 2008 over absolute control (T_8). The superiority of residual effect of enriched poultry manure compost (T_6) and composted poultry manure (T_5) was attributed to its slow decomposition, which probably released the nutrients slowly as compared to other organic materials. This is in accordance with the findings of Seshadri *et al*. (2005).

5.8. Nutrient uptake

5.8.1. Nitrogen uptake

Application of enriched poultry manure compost (T_6) resulted in maximum N uptake followed by composted poultry manure (T_5), which were similar with each other. The composted poultry manure (T_5) was comparable with recommended NPK fertilizer (T_7) at all the stages of crop growth during both the years (Fig. 12 and 13). All the treatments were significantly superior over absolute control (T_8). Accelerated growth in terms of DMP and N content, augmented the N uptake of crops (Sharma *et al*., 2008). These two parameters were higher in enriched poultry manure compost (T_6) which recorded 69.7 and 70.4 per cent higher N uptake over absolute control (T_8) at harvest stage during *rabi* 2007 and 2008, respectively. This might be ascribed to the fact that poultry manure contained 60 per cent of N in the form of uric acid, which changed rapidly to NH_4^+ form for utilization by rice plants (Prabhakaran, 2000). The higher N uptake in the rice grains, fertilized with poultry manure reflected the extent and pattern of N release for absorption by the plant from seedling stage to grain-filling stages as suggested by Norman *et al*. (2003). The higher uptake of N with the application of recommended NPK fertilizer (T_7) might be due to the direct application of nutrients.

5.8.2. Phosphorus uptake

In case of P uptake by rice, application of enriched poultry manure compost (T_6) showed the highest uptake and it was comparable with composted poultry manure (T_5) during both the years (Fig. 12 and 13). The next best treatment was recommended NPK fertilizer (T_7) at all the stages of crop growth during both the years. All the treatments were significantly superior over control. The enriched poultry manure compost (T_6) increased the P uptake by 73.4 per cent during *rabi* 2007 and 71.3 per cent during *rabi* 2008 over absolute control (T_8) at harvest stage. The probable reason might be that the application of rock phosphate with organic manure enhances the dissolution of native P by the organic acids produced during the decomposition, thus leading to better utilization of available P in enriched poultry manure compost (T_6). Similar results were also obtained by Bagavathiammal and Mahimairaja (1999) and Selvi *et al*. (2003). Dinesh *et al*. (2003) also indicated that application of rock phosphate with poultry manure to soils stimulated microbial proliferation and subsequent enzyme synthesis activity leading to faster hydrolysis of ester-bound P to plant available P thereby increase the crop uptake.

5.8.3. Potassium uptake

Potassium uptake by rice showed that the application of enriched poultry manure compost (T_6) and composted poultry manure (T_5) recorded higher value (Fig. 12 and 13). The composted poultry manure (T_5) was on par with recommended NPK fertilizer (T_7) at all the stages of crop growth during both the years. The application of enriched poultry manure compost (T_6) increased K uptake over absolute control (T_8) was 70.3 and 73.9 per cent at harvest stage of crop growth during *rabi* 2007 and 2008, respectively. This might be due to the increase in available K, which may attributed to mineralization of organic manures or solubilization of nutrient from native sources during decomposition as reported by Walia and Kler (2005).

5.8.4. Micronutrient uptake

The application of enriched poultry manure compost (T_6) and composted poultry manure (T_5) registered higher uptake of micronutrients like Fe, Mn, Zn and Cu when compared to recommended NPK fertilizer (T_7) at panicle initiation and harvest stages during both the years of study. This might be due to the higher micronutrient content in organic manure treatments. The results were similar to the findings of Yadav (2004). The application of enriched organic manure resulted in the production of chelating agents from soluble complexes with Zn, which are efficiently utilized by rice plants (Singh *et al*., 1982). These results are in agreement with those observed by Saravana *et al*. (2005).

5.8.5. Nutrient uptake by blackgram

The nutrient (NPK) uptake by blackgram was more due to the residual effect of organic manures when compared to inorganic fertilizers and absolute control. The positive carry over effect of organic sources probably owed to the decomposition and release of several nutrients for a long time and nutrient supply was increased as reported by Raju *et al*. (1993). The residual effect of enriched poultry manure compost (T_6) recorded higher nutrient (NPK) uptake by blackgram and it was comparable with composted poultry manure (T_5) (Fig. 14 and 15). The poultry manure application improved the organic carbon content in the soil which was favourable in supplying the plant nutrient for longer period for better growth and development of succeeding crop. The result further confirms the view of Kalia *et al*. (2004) and Vijay Kumar and Singh (2006).

5.9. Soil fertility

5.9.1. Soil available N

Studies on available N status of the soil showed that the application of enriched poultry manure compost (T_6) and composted poultry manure (T_5) recorded maximum soil available N as compared to application of recommended NPK fertilizer (T_7) at all the stages of rice during both the years (Fig. 16 and 17). The enriched poultry manure compost (T_6) improved the soil available N over recommended NPK fertilizer (T_7) by 16.5 and 21.4 per cent at harvest stage of rice during *rabi* 2007 and 2008, respectively. 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 may be lost into the environment through leaching or denitrification process. Similar results were also noted by Yadav (2004) and Singh *et al*. (2006). The higher N availability with enriched poultry manure compost (T_6) and composted poultry manure

(T_5) might be due to higher N content and continuous and slow release of nutrients from poultry manure, and increased biomass and accumulated soil organic matter. Similar findings were also reported by Amanullah *et al*. (2006b) and Prasanthrajan *et al*. (2008).

The soil available N was higher with organic manures application than recommended NPK fertilizer after harvest of blackgram (Fig. 18 and 19). The incorporation of N fixing legume (blackgram) 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, control the decline of soil N fertility associated with the cropping system as noted by Ahmad *et al*. (2001). Higher soil available N due to legume in rice based cropping system was also observed by Chandrasekaran and Sankaran (1995). Rice-pulse 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).

5.9.2. Soil available P

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 fixation. Application of enriched poultry manure compost (T_6) and composted poultry manure (T_5) had higher soil available P at all stages of rice in both the years of study and which were on par (Fig. 16 and 17). The enriched poultry manure compost (T_6) increased available P by 55.9 and 55.8 per cent compared to recommended NPK fertilizer (T_7) at harvest stage in *rabi* 2007 and 2008, respectively. This might be due to the fact that during the mineralization of enriched organics, a number of organic acids, especially the hydroxyl ones (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 labile 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.

The higher soil available P observed under organic manures than inorganic fertilizers and absolute control (Fig. 18 and 19) after harvest of rice fallow blackgram 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.

5.9.3. Soil available K

The application of enriched poultry manure compost (T_6) registered the higher amount of soil available K and it was comparable with composted poultry manure (T_5) during both the years (Fig. 16 and 17). The enriched poultry manure compost (T_6) improved soil available K over recommended NPK fertilizer (T_7) was 10.2 and 13.0 per cent at harvest stage of rice during *rabi* 2007 and 2008, respectively. The beneficial effect of poultry manure on 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 Balaguravaiah *et al*. (2005) and Agbede *et al*. (2008).

The residual soil K status was reduced after harvest of blackgram in all the treatments (Fig. 18 and 19), which might be due to a higher depletion of K by the crop as reported by Barik *et al*. (2006).

5.9.4. Soil exchangeable Ca, Mg, Na and available micronutrients

The application of organic manures improved exchangeable Ca, Mg and Na and soil available micronutrients compared to inorganic fertilizers and absolute control after harvest of rice during both the years. The application of enriched poultry manure compost (T_6) and composted poultry manure (T_5) registered higher exchangeable Ca, Mg and Na and soil available micronutrients like Fe, Mn, Zn and Cu. Similar results were also reported by Prakash *et al*. (2002) and Agbede *et al*. (2008). Addition of organic materials might have enhanced the microbial activity in the soil and the consequent release of complex organic substances (chelating agents) could have prevented micronutrients from precipitation, fixation, oxidation and leaching and also addition of these nutrients through organic sources. Suvarna and Sankara (2001) stated that poultry manure increased the available Fe, Mn, Zn and Cu gradually from tillering to harvest stage.

The soil exchangeable Ca, Mg and Na and available micronutrients (Fe, Mn, Zn and Cu) were reduced at post harvest soil of blackgram due to uptake of crop.

5.10. Use efficiency

5.10.1. Agronomic efficiency and Apparent N recovery

The agronomic efficiency (AE) which indicates the quantity of rice production per unit quantity of N applied is often expressed as the product of efficiency of absorption and efficiency of utilization. The apparent N recovery (ANR) indicates the efficiency of absorption of applied N. Agronomic efficiency (Fig. 20) and apparent N recovery were improved with the application of enriched poultry manure compost (T_6) followed by composted poultry manure (T_5) than recommended NPK fertilizer (T_7) during both the years. This might be due to the presence of higher macro and micronutrients in these organic manures as observed by Seshadri *et al*. (2005). The application of enriched poultry manure compost (T_6) and composted poultry manure (T_5) might have contributed considerable quantity of N upon mineralization making more N available to plants leading to increased N use efficiency.

5.11. Production potential of system

The higher production potential of system was recorded with enriched poultry manure compost (T_6) and composted poultry manure (T_5), which were comparable with each other. Similar results due to the application of poultry manure was observed by Ramesh (2002) in rice based cropping system.

5.12. Soil pH and EC

Application of organic manures reduced the soil pH when compared to recommended NPK fertilizers and absolute control during both the years of study. This could be ascribed to the acidifying effect due to various organic acids (amino acid, glycine, cystein 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). The reduction in soil pH was found to be less in enriched poultry manure compost (T_6) and composted poultry manure (T_5) compared to other treatments. This might be due to greater pH of composted poultry manure. This was supported by Elias-Azar (1980) who reported that soil pH had reduced due to application 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).

5.13. Organic carbon

Organic carbon content of soil was significantly increased by organic manures application as compared to recommended NPK through fertilizers and absolute control during both the years. This is in conformity with the results noted by Sheeba and Kumarasamy (2001) and Singh *et al*. (2007).

The enriched poultry manure compost (T_6) enhanced the organic carbon content and it was comparable with composted poultry manure (T_5) and FYM + neem cake (T_3) (Fig. 21). The enriched poultry manure compost registered higher soil organic carbon by 20.6 and 25.0 per cent over absolute control at the end of first and second cropping cycle, respectively. This might be ascribed to the fact that 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 conducive environment for humus formation. This overlaps with the views of Ramesh and Chandrasekaran (2004) and Adesodun *et al*. (2005). The additive effect of FYM + neem cake (T_3) in maintaining higher organic carbon level might be due to its less rapid decomposition. Similar result was also reported by Kenchaiah (1997) and Ranjan *et al*. (2004).

The results revealed that the cropping sequence of green manure-rice-blackgram had favourable effect towards build up of organic carbon in the soil. The introduction of green manure improved the organic carbon content of soil due to that fraction of green manure which is fairly resistant to decomposition but mineralizes at a slower rate (Bouldin *et al*., 1988) and the land submergence resulting in anaerobiosis, 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 many authors (Palaniappan, 1985: Rajeswari, 1990 and Natarajan, 2003).

There was slight increase in soil organic carbon status due to the application of inorganic fertilizers at the end of second cropping cycle (4.62 per cent) from initial level, probably due to the incorporation of higher quantities of crop residues to the soil. This is in accordance with the findings of Siddeswaran (1992) who reported that the incorporation of higher quantities of crop residues resulted in increased soil organic carbon content.

5.14. Nutrient balance

Application of organic manures increased soil available N balance. The balance was positive, indicating a net gain, when rice crops received organic manures. Among the organic manures, enriched poultry manure compost (T_6) and composted poultry manure (T_5) recorded higher positive N balance of 46 and 43 kg ha^{-1} during 2007 - 2008 and 20 and 10 kg ha^{-1} during 2008 - 2009, respectively. The enriched poultry manure compost (T_6) registered higher net N gain of 66 kg ha^{-1} at the end of two years cropping sequence (Fig. 22). This might be due to the slow decomposition of organic manures especially enriched poultry manure compost and composted poultry manure led to steady N release to meet the requirement of crops at critical stages. Even after the 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. This was well pronounced with the application of enriched and composted poultry manure. 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) and application of recommended NPK fertilizers at the end of two years. This might be due to susceptibility of inorganic fertilizers to various losses during and after mineralization in addition to uptake by crops. Similar result was recorded by Kenchaiah (1997).

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 application of enriched poultry manure compost (T_6) of 15.54 kg ha^{-1} at the end of two years (Fig. 22). The probable reason might be rock phosphate enriched poultry manure compost maintain higher levels of P in soil solution for a longer period due to more mobilization of native P and desired uptake by the crop. This was in conformity with results observed by Pazhanivelan *et al.* (2006). The recommended NPK fertilizers and absolute control recorded net negative balance of P during both the years.

The net negative balance of K was noted in all the treatments at the end of two year cropping sequence (Fig. 22). The lesser net negative balance was observed in enriched poultry manure compost (T_6) application. This was attributed to luxurious consumption of this nutrient by crops (Barik *et al*., 2008).

In general, during the period of field experimentation, the pre-season green manuring and application of organic manures showed favourable response towards improvement in soil fertility status and soil health when compared with their initial values except in recommended NPK fertilizers and absolute control. The inclusion of pre-season green manuring particularly *Sesbania aculeata* (Dhaincha) 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 nitrogen fixation (BNF) also improved the soil fertility status. The addition of organic manure to 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 blackgram haulms as the source of organic manure also improved the soil fertility and soil health over a period of time.

5.15. Soil microbial population

Application of enriched poultry manure compost (T_6) and composted poultry manure (T_5) had higher influence on the population of bacteria, fungi and actinomycetes as compared to recommended NPK fertilizer (T_7) and absolute control (T_8). The soil microbes continue to increase with the advancement of crop growth. It could be due to enhanced organic carbon content of the soil as a result of organic manure application as compared to inorganic fertilizers (Krishnakumar, 2007b). With application of enriched poultry manure compost and composted poultry manure the population of soil microbes got influenced positively due to many scientific reasons including the presence of higher organic carbon content. The poultry manure also had secondary and micronutrients more than other organics and this might have helped to increase the microflora as reported by

Wang and Chao (1995). They also opined that chicken manure used in the organic farming treatment enhanced the bacterial and fungal population greater than conventional farming. Bolten *et al*. (1982) opined that the soil microbial activity was always higher in organic plots than conventional plots. This is in agreement with those of Singh *et al*. (2007). The lower soil microbial load found in recommended NPK fertilizers might be due to inhibitory nature of chemical fertilizers on the growth and development of microbes (Singh, 1998). Similar findings were reported by Kenchaiah (1997) and Yadav and Lourduraj (2007).

5.16. Soil enzyme activity

The various biochemical processes associated with nutrient recycling are mediated by soil enzymes which are derived from soil microbes and plant roots as reported by Tabatabai (1982). The organic manure application had significant influence on soil enzyme activity than inorganic fertilizers. The higher dehydrogenase and urease activity was observed under enriched poultry manure compost (T_6) and it was comparable with composted poultry manure (T_5). The phosphatase activity was also higher with enriched poultry manure compost (T_6) and enriched FYM compost (T_1). The high organic carbon content in soil applied with poultry manure stimulated the microorganisms by serving as source of carbon, energy and other nutrients essential for their growth and multiplication and thus increased the soil activities. Similar results of increased enzyme activity due to poultry manure application were reported by Boomiraj (2003). These results are in line with the findings of Suryanarayana (2002) and Somasundaram (2003). The higher phosphatase activity was observed with enriched organic manures treated with rock phosphate as noted by Kaleeswari *et al*. (2007).

5.17. Soil physical properties

The application of organic manures significantly improved the physical properties of soil when compared to recommended NPK fertilizers and absolute control during both the years of experiments. Several studies (Kannan *et al*., 2005; Natarajan, 2007) revealed that organic manure 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 and other products of decay like polysaccharides are released which act as strong binding agents in the formation of large and arable aggregates.

Among the organic manures, the enriched poultry manure compost (T_6) had resulted in greater improvement of soil physical properties and it was on par with composted poultry manure (T_5) and FYM + neem cake (T_3). The favourable soil physical condition adduced to poultry manure is consistent with earlier findings (Akanni *et al*., 2005; Amanullah *et al*., 2006a; Akanni and Ojeniyi, 2008). The reduced bulk density with poultry manure application was due to the improvement of soil aggregation and structure (Jegadeswari, 1997) and increased porosity **(**Agbede *et al*., 2008). Application of poultry manure increased moisture content of the soil better than the chemical fertilizers due to its high organic carbon content and addition of organic matter to the soil. Organic matter has the ability to retain appreciable amounts of soil moisture as suggested by Agyenim *et al*. (2006). The FYM + neem cake (T_3) 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 fertilizer treatment showed higher bulk density and reduced water holding capacity and pore space. This might be attributed to deterioration of soil structure by inorganic fertilizers as reported by Kannan *et al*. (2005) and Krishnakumar *et al*. (2007a).

In the present investigation, green manure-rice-blackgram cropping sequence improved the physical condition. It might be due to readily decomposable huge organic matter from blackgram, had an advantage of releasing various humic fractions and thus enhanced nutrient release, apart from that blackgram exerted their root system deep into the deeper horizons of soil and may enable the absorption of nitrates, sulphates and avoid build up of P in the soil helped soil particles to bind together extensively which in turn led to improvement of physical properties as observed by Prakash *et al*. (2008).

5.18. Quality characteristics

5.18.1. Physical characteristics

Physical characteristics namely milling recovery (%), whole rice (g), unshelled paddy (g), head rice (%), broken rice (%), coefficient of shelling (%) and effectiveness of shelling were computed for the treatments studied. The recommended NPK fertilizer (T_7) and enriched poultry manure compost (T_6) recorded high milling rice recovery (%) and increased head rice (%) with lesser broken rice. This might be due to better amenability for shelling, good grain size and less number of chalky grains. Though N was supplied N equivalent basis, the enriched poultry manure compost contains more P, K and micronutrients which might have helped to reduce broken percentage and in turn increased head rice recovery.

In respect of physical characteristics of rice grain invariably the treatments recommended NPK fertilizer (T_7) and enriched poultry manure compost (T_6) had offered good rice quality characters like grain length, grain breadth and L:B ratio. These treatments had better yield components like number of filled grains panicle^{-1} and grain filling percentage and might have influenced these parameters. Application of poultry manure resulted to better physical characteristics of grain, which was also reported by Kenchaiah (1997).

5.18.2. Chemical composition

Application of recommended NPK fertilizers (T_7) recorded higher carbohydrate, fat and total ash content followed by application of enriched poultry manure compost (T_6), which did not differ significantly with each other. However, higher protein, amylose and fibre content were obtained in enriched poultry manure compost (T_6) and it was comparable with recommended NPK fertilizers (T_7). N being an important element and constituent of the amino acids and protein probably, the increased uptake of N might have resulted in the increment of the crude protein content. This might have lead to accumulation of higher quantities of seed components like calcium carbonate and increased the lipid metabolism which helps in increasing the protein content in seed. These results are in accordance with findings of Roy and Singh (2006). Higher and proper nutrition through the organic matter resulted with ensured supply of nutrients might have lead to increase in total amylose content and crude protein (Omar Hattab *et al*., 1998; Radha, 1996 and Natarajan, 2007). Lampkin (1990) also stated that organic farming system have higher protein content in the cereals.

5.18.3. Cooking characteristics of milled rice

The cooking time was not significantly influenced by the different treatments, indicating no relationship of cooking time with the sources of nutrients. The maximum volume expansion ratio and water absorption ratio were recorded in recommended NPK fertilizers (T_7), enriched poultry manure compost (T_6) and composted poultry manure (T_5), which were on par with each other. Bold rice grain was observed in these treatments might be the reason for the higher volume expansion and water absorption ratio. This statement is also supported by Yadav and Lourduraj (2006b).

Generally the grain length and breadth after cooking of rice were markedly influenced by recommended NPK fertilizers (T_7), enriched poultry manure compost (T_6) and composted poultry manure (T_5). The linear elongation ratio was maximum in enriched poultry manure compost (T_6) and breadth wise expansion ratio was more with FYM + neem cake (T_3). The increased L: B ratio after cooking was observed in enriched FYM compost (T_1) and composted poultry manure (T_5). This character is considered as desirable trait in high quality rice. Nguyen *et al.* (2002) reported that the application of organic manures gave a higher L: B ratio of rice after cooking than with inorganic fertilizer.

5.18.4. Sensory characteristics

Application of enriched poultry manure compost (T_6) and composted poultry manure (T_5) recorded high score of comsumer acceptable colour, texture, taste and overall acceptability score as compared to other treatments. Similarly, Hsieh (1995) reported that quality characteristics of rice were improved with application of poultry manure. The eating quality of rice was higher under organic farming than conventional farming (Nakai, 1994). Improved organoleptic properties of organically produced food were also reported by Senthil Kumaran and Vadivel (2001) and Pathak (2002).

In general, good grain quality fetches higher premium price to the farmers with change in income levels and self sufficiency induced shift in the consumer as well as market preference for better rice grain quality. Also grain quality characters are very important parameters for determining consumer acceptance for any rice variety or hybrid. In the present study, the improved grain quality was recorded under organic manuring in respect of chemical and cooking quality. Since, the organically grown rice grain free from pesticide, insecticide and inorganic fertilizers, the consumption of organic rice may have food security in the human diet activities and health aspects.

5.19. Economic evaluation

From the technology recommendation and adaptation point of view, economic evaluation plays a paramount role.

Net return and benefit cost ratio of the rice-blackgram cropping sequence was greatly influenced by the application of organic manures and recommended NPK through fertilizers. Considering the cropping sequence as a whole the higher net return of Rs. 47843 and Rs. 51550 was obtained under enriched poultry manure compost (T_6) during the years 2007 - 2008 and 2008 - 2009, respectively (Fig. 23 and 24). This was followed by the application of composted poultry manure (T_5) and recommended NPK fertilizers (T_7). The reason for the higher net return in enriched poultry manure compost (T_6) and composted poultry manure (T_5) than recommended NPK fertilizers (T_7) was higher product price of organic rice than inorganically produced rice as well as the yield obtained in these treatments was more than inorganic fertilizers treatment. Similar observation was obtained earlier by Yadav and Lourduraj (2006a).

Benefit cost ratio (return per rupee invested), the index for economic sustainability, was higher (2.67 during 2007 - 2008 and 2.80 during 2008 - 2009) in enriched poultry manure compost (T_6) followed by composted poultry manure (T_5) than recommended NPK fertilizer (T_7). This might be due to higher gross return in these treatments than recommended NPK fertilizers (T_7).

APPENDIX III

Details of cost of cultivation

S.No.	Particulars	Inputs	Rate (Rs.)	Total cost (Rs. ha^{-1})
General cost of cultivation				
I	**Green manure sowing and incorporation**			
i	Tractor ploughing twice	1 tractor for 4 hrs	250 hr^{-1}	2000.00
ii	Cost of green manure seed	25 kg	40 kg^{-1}	1000.00
iii	Sowing	½ man day	80 day^{-1}	40.00
iv	Green manure incorporation	1 tractor for 4 hrs	250 hr^{-1}	1000.00
II	**Preparatory cultivation for nursery**			
1	**Land preparation**			
i	Puddling with tractor drawn cage wheel	1 tractor for 1 hr	250 hr^{-1}	250.00
ii	Trimming, plastering and levelling	1 man day	80 day $^{-1}$	80.00
2	**Seeds and sowing**			
i	Cost of paddy seed	40 kg	18 kg^{-1}	720.00
ii	Seed treatment			
	Pseudomonas fluorescence	10 g kg^{-1}	100 kg^{-1}	40.00
	Azospirillum	600 g ha^{-1}	30 kg^{-1}	18.00
	Seed treatment and incubation	½ woman day	80 day^{-1}	40.00
iii	Sowing	½ woman day	80 day^{-1}	40.00
3 a	**Nursery raised with organic manures**			
i	Manure application			
	FYM	1000 kg ha^{-1}	0.50 kg^{-1}	500.00
	Vermicompost	100 kg /20 cents	4 kg^{-1}	400.00
	Neem cake	10 kg /20 cents	5.35 kg^{-1}	53.50
	Application cost	½ woman day	80 day^{-1}	40.00
ii	Plant protection			
	Neem oil	2 spray (1.5%)	110 lit^{-1}.	27.50
	Panchagavya spray	2 spray (3%)	40 lit^{-1}.	20.00
3 b	**Conventional nursery**			
i	Fertilizer application			
	DAP	40 kg /20 cents	9.72 kg^{-1}	388.80
	Urea	16 kg /20 cents	4.90 kg^{-1}	78.40
	Super phosphate	120 kg /20 cents	3.48 kg^{-1}	417.60
4	**Irrigation and guidance**	1 man day	80 day^{-1}	80.00

S.No.	Particulars	Inputs	Rate	Total

			(Rs.)	cost (Rs. ha^{-1})
III	**Main field preparation**			
1	**Land preparation**			
i	Puddling with tractor drawn cage wheel	1 tractor for 4 hrs	250 hr^{-1}	2000.00
ii	Trimming, Plastering, levelling and digging the corner	5 men day	80 day^{-1}	400.00
2 a	**Organic Treatment**			
i	Manure application and spreading	5 women day	80 day^{-1}	400.00
2 b	**Inorganic treatment**			
i	Fertilizer application	3 women day	80 day^{-1}	240.00
3	**Transplanting**			
	Pulling out of seedling, transport and transplanting	30 women day	80 day^{-1}	2400.00
4	**Hand weeding twice**	40 women day	80 day^{-1}	3200.00
5	**Plant protection**			
a	**Organic treatment**			
i	Cost of neem oil, panchagavya and *Boveheria* culture			445.00
ii	Spraying cost	3 men day 3 women day	80 day^{-1}	480.00
b	**Inorganic treatment**			
i	Cost of monocrotophos			374.40
ii	Spraying cost	2 men day 2 women day	80 day^{-1}	320.00
6	**Irrigation and guidance**	5 women day	80 day^{-1}	400.00
7	**Harvesting, threshing and cleaning of paddy**	20 men day 35 women day	80 day^{-1}	4400.00
IV	**Cost of cultivation of Blackgram**			
i	Cost of blackgram seed	25 kg	30 kg^{-1}	750.00
ii	Sowing and irrigation	5 women day	80 day^{-1}	400.00
iii	Harvesting, threshing and cleaning	20 women day	80 day^{-1}	1600.00

Total cost of cultivation excluding organic manures:

- Total cost of cultivation (inorganic) = Rs. 22677
- Total cost of cultivation (organic) = Rs. 23224
- Total cost of cultivation (control) = Rs. 22437

Total cost of cultivation in different treatments (2007-2008)

Treatments	Cost of cultivation excluding organic manures/ fertilizer (Rs. ha^{-1})	Cost of organic manures / fertilizer (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
T_1 : Enriched FYM compost	23224	9175	32399
T_2 : Vermicompost	23224	16513	39737
T_3 : FYM + Neem cake	23224	9255	32479
T_4 : Enriched FYM compost + Vermicompost + FYM	23224	11500	34725
T_5 : Composted poultry manure	23224	4510	27734
T_6 : Enriched poultry manure compost	23224	5497	28721
T_7 : Recommended NPK fertilizer	22677	2261	24938
T_8 : Absolute control	22437	-	22437

FYM : Farmyard manure

Total cost of cultivation in different treatments (2008-2009)

Treatments	Cost of cultivation excluding organic manures/ fertilizer (Rs. ha^{-1})	Cost of organic manures / fertilizer (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
T_1 : Enriched FYM compost	23224	9801	33025
T_2 : Vermicompost	23224	18124	41348
T_3 : FYM + Neem cake	23224	10647	33871
T_4 : Enriched FYM compost + Vermicompost + FYM	23224	12835	36059
T_5 : Composted poultry manure	23224	4590	27815
T_6 : Enriched poultry manure compost	23224	5462	28686
T_7 : Recommended NPK fertilizer	22677	2261	24938
T_8 : Absolute control	22437	-	22437

FYM : Farmyard manure

Cost of composted poultry manure

S.No.	**Particulars**	**Inputs**	**Rates (Rs.)**	**Total cost (Rs.)**
1	Poultry manure	1000 kg	1.00 kg^{-1}	1000.00
2	*Paddy straw*	100 kg	0.80 kg^{-1}	80.00
3	Labour for heap making, and sprinkling water	1 man day 1 woman day	80 day^{-1}	160.00
4	Transport (tractor)	½ hr^{-1}	250.00 hr^{-1}	125.00
			Total cost	1365.00

Cost of enriched poultry manure compost

S.No.	**Particulars**	**Inputs**	**Rates (Rs.)**	**Total cost (Rs.)**
1	Poultry manure	1000 kg	1.00 kg^{-1}	1000.00
2	*Paddy straw*	100 kg	0.80 kg^{-1}	80.00
3	*Biofertilizers* *Azospirillum* Phosphobacteria Azotobacter	10 kg 10 kg 10 kg	30.00 kg^{-1} 30.00 kg^{-1} 30.00 kg^{-1}	300.00 300.00 300.00
4	*Rock phosphate*	20 kg	3.99 kg^{-1}	79.80
5	Labour for heap making, and sprinkling water	1 man day 1 woman day	80 day^{-1}	160.00
6	Transport (tractor)	½ hr^{-1}	250.00 hr^{-1}	125.00
			Total cost	2344.80

Cost of farmyard manure

S.No.	Particulars	Inputs	Rates (Rs.)	Total cost (Rs.)
1	Farmyard manure	1000 kg	0.50 kg^{-1}	500.00
2	Collection and transport	1 man day	80.00 day^{-1}	80.00
3	Tractor	½ hr^{-1}	250.00 hr^{-1}	125.00
			Total cost	705.00

Cost of vermicompost

S.No.	Particulars	Inputs	Rates (Rs.)	Total cost (Rs.)
1	Vermicompost	1000 kg	4.00 kg^{-1}	4000.00
2	Collection and transport	1 man day	80.00 kg^{-1}	80.00
3	Tractor	½ hr^{-1}	250.00 hr^{-1}	125.00
			Total cost	4205.00

Cost of Neem cake

S.No.	Particulars	Inputs	Rates (Rs.)	Total cost (Rs.)
1	Neem cake	1000 kg	5.35 kg^{-1}	5350.00
2	Collection and transport	1 man day	80.00 kg^{-1}	80.00
			Total cost	5430.00

Cost of enriched farmyard manure

S.No.	**Particulars**	**Inputs**	**Rates (Rs.)**	**Total cost (Rs.)**
1	Farmyard manure	1000 kg	0.50 kg^{-1}	500.00
2	*Biofertilizers* *Azospirillum* Phosphobacteria Azotobacter	 10 kg 10 kg 10 kg	 30.00 kg^{-1} 30.00 kg^{-1} 30.00 kg^{-1}	 300.00 300.00 300.00
3	*Rock phosphate*	10 kg	3.99 kg^{-1}	39.90
4	Labour for heap making, and sprinkling water	1 man day 1 woman day	80 day^{-1}	160.00
5	Transport (tractor)	½ hr^{-1}	125.00	125.00
			Total cost	1724.9

Cost of fertilizers (75:50:50 kg NPK ha^{-1})

S.No.	**Particulars**	**Inputs**	**Rates (Rs)**	**Total cost (Rs)**
1	Urea	163 kg	4.90 kg^{-1}	798.70
2	Super phosphate	313 kg	3.48 kg^{-1}	1089.24
3	Muriate of potash	83 kg	4.50 kg^{-1}	373.50
			Total cost	2261.44

Cost of plant protection

S.No.	Particulars	Inputs	Rates (Rs.)	Total cost (Rs.)
	Organic treatments			
1	Neem oil	2.50 lit.	110 lit.$^{-1}$	275.00
2	Panchakavya	3.00 lit	40 lit.$^{-1}$	120.00
3	*Boveheria* culture	500 g	100 kg^{-1}	50.00
			Total cost	445.00
S.No.	**Inorganic treatments**	**Inputs**	**Rates (Rs.)**	**Total cost (Rs.)**
1	Monocrotophos	1 lit	374.4 lit.$^{-1}$	374.40
			Total cost	374.40

Cost of Produce

S.No	Particulars	Rates (Rs. kg^{-1})
1	Paddy grain (Organic)	12.00
2	Paddy grain (Inorganic and absolute control)	10.00
3	Paddy straw	0.80
4	Blackgram grain	30.00

APPENDIX IV

Score card for the evaluation of sensory characteristics

Product name:

Sensory characters	Treatment code 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Colour **1………………..9**														
Texture **1………………..9**														
Taste **1………………..9**														
Overall acceptability **1………………..9**														

Hedonic 9 point scale: 1- Dislike extremely, 2- Dislike very much, 3- Dislike moderately, 4- Dislike slightly,
5- Neither like nor dislike, 6- Like slightly, 7- Like moderately, 8- Like very much, 9- like extremely

Name: Designation : Signature:

APPENDIX I

Weather parameters during the cropping period (2007 - 2008)

Standard week	Month and date	Mean temperature (°C)		Mean relative humidity (%)		Total rainfall (mm)	Rainy days (Nos)	M
		Max.	Min.	07.22 Hrs	14.22 Hrs			
25	June 18-24	29.3	23.3	88	62	40.6	2	
26	June 25-July 1	29.5	23.4	74	65	30.2	2	
27	July 2-8	28.7	23.6	79	66	46.7	4	
28	July 9-15	30.1	24.0	74	60	1.8	-	
29	July 16-22	30.1	22.6	90	63	17.7	2	
30	July 23-29	29.6	22.4	92	64	3.4	-	
31	July 30-Aug 5	29.3	22.4	87	67	6.3	-	
32	Aug 6-12	28.7	22.7	85	61	31.8	3	
33	Aug 13-19	32.2	21.9	91	49	-	-	
34	Aug 20-26	30.8	22.1	94	63	46	2	
35	Aug 27-Sep 2	30.9	22.9	85	58	0.6	-	
36	Sep 3-9	31.3	22.8	84	52	0.2	-	
37	Sep 10-16	32.1	23	91	56	7.6	1	
38	Sep 17-23	30.5	23.9	80	58	4.2	-	
39	Sep 24-30	31.2	22.8	86	54	2.4	-	
40	Oct 1-7	32.2	21.4	80	45	-	-	
41	Oct 8-14	33	22.2	91	49	10.2	1	
42	Oct 15-21	30	22	94	65	87.6	3	
43	Oct 22-28	28	22	96	70	156.1	4	
44	Oct. 29-Nov 4	28.9	22.1	94	68	72.2	5	
45	Nov. 5-11	29.8	22.1	93	58	8.6	1	

Standard week	Month and date	Mean temperature (°C)		Mean relative humidity (%)		Total rainfall (mm)	Rainy days (Nos)	M
		Max.	Min.	07.22 Hrs	14.22 Hrs			
46	Nov. 12-18	29.7	16.4	90	39	-	-	
47	Nov. 19-25	29.5	20.5	87	54	0.6	=	
48	Nov 26-Dec 2	29.4	19.5	87	53	-	-	
49	Dec 3-9	28.4	19.9	86	54	1.0	-	
50	Dec 10-16	28.5	20.9	87	53	0.5	-	
51	Dec 17-23	26.2	20.5	91	71	113.4	3	
52	Dec 24-31	29.7	16.3	92	39	-	-	
1	Jan 1-7 (**2008**)	28.6	16.9	92	46	0.2	-	
2	Jan 8-14	28.7	16.5	92	41	-	-	
3	Jan 15-21	29.7	16.5	92	40	-	-	
4	Jan 22-28	30.9	18.7	90	51	-	-	
5	Jan 29-Feb 4	32.2	21.1	89	46	-	-	
6	Feb 5-11	30	21.7	88	61	49.2	2	
7	Feb 12-18	30.8	22.5	88	47	-	-	
8	Feb 19-25	32.2	17.9	85	32	-	-	
9	Feb 26-Mar 4	32.7	18.8	83	28	-	-	
10	Mar 5-11	32.7	16.4	76	19	-	-	
11	Mar 12-18	30.5	15.9	90	58	46.3	2	
12	Mar 19-25	29	22.1	91	63	13.8	2	
13	Mar 26-April 1	32.5	21.4	92	56	41.6	2	
14	April 2-8	32.2	22.3	92	47	27.0	2	
15	April 9-15	32.8	22.8	87	41	-	-	
16	April 16-22	35.6	22.6	89	40	-	-	

APPENDIX II

Weather parameters during the cropping period (2008 - 2009)

Standard week	Month and date	Mean temperature (°C)		Mean relative humidity (%)		Total rainfall (mm)	Rainy days (Nos)	M
		Max.	Min.	07.22 Hrs	14.22 Hrs			
25	June 18-24	32.1	22.9	84	49	7.0	1	
26	June 25-July 1	30.7	23.3	76	61	10.8	1	
27	July 2-8	31.9	22.8	81	48	-	-	
28	July 9-15	32.3	23.4	81	48	-	-	
29	July 16-22	32.3	22.9	90	56	7.2	1	
30	July 23-29	29.5	23.1	82	43	19.2	2	
31	July 30-Aug 5	31.3	23.4	80	53	1.4	-	
32	Aug 6-12	30.9	23.5	79	53	3.0	-	
33	Aug 13-19	30.4	22.4	92	61	18.4	1	
34	Aug 20-26	31.9	22.1	91	53	2.4	-	
35	Aug 27-Sep 2	32.1	22.5	92	54	50.3	4	
36	Sep 3-9	31.6	22.7	88	60	12.9	2	
37	Sep 10-16	29.8	22.8	76	55	5.6	1	
38	Sep 17-23	32	20.9	87	47	-	-	
39	Sep 24-30	33	20	83	43	-	-	
40	Oct 1-7	33.4	20	85	43	2.0	-	
41	Oct 8-14	31.7	23.1	92	64	71.8	4	
42	Oct 15-21	29.6	22.7	94	71	148.2	6	
43	Oct 22-28	27.1	21.6	93	76	90.9	4	
44	Oct. 29-Nov 4	30.7	17.6	90	40	-	0	
45	Nov. 5-11	31.2	20.5	90	48	-	0	
46	Nov. 12-18	31.1	20.7	89	50	0	0	
47	Nov. 19-25	29.2	22.2	93	65	31.8	4	
48	Nov 26-Dec 2	28.2	22.4	92	70	13.6	1	
49	Dec 3-9	29.5	19.7	93	55	1.5	0	
50	Dec 10-16	28.0	20.7	93	58	7.8	1	
51	Dec 17-23	28.0	18.9	88	50	0	0	
52	Dec 24-31	29.5	16.9	89	38	0	0	

1	Jan 1-7 (**2009)**	29.2	17.5	91	43	-	-
2	Jan 8-14	29.7	19.9	85	41	-	-
3	Jan 15-21	29.1	18.2	88	37	-	-
4	Jan 22-28	31.1	18.9	86	39	-	-
5	Jan 29-Feb 4	32.5	18.9	83	29	-	-
6	Feb 5-11	32.3	18.0	79	28	-	-
7	Feb 12-18	33.3	18.2	81	25	-	-
8	Feb 19-25	33.8	21.2	83	33	-	-
9	Feb 26-Mar 4	34.5	19.4	83	19	-	-
10	Mar 5-11	35.2	20.0	79	31	-	-
11	Mar 12-18	32.9	22.1	84	42	68.0	2
12	Mar 19-25	34.7	22.4	85	36	33.0	1
13	Mar 26-April 1	34.3	22.6	84	36	-	-
14	April 2-8	36.4	23.8	81	26	-	-
15	April 9-15	34.1	24.2	83	42	-	-

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* Originals not seen.

ACRONYMS AND ABBREVIATIONS

AE	-	Agronomic efficiency
ANR	-	Apparent N recovery
AT	-	Active tillering
Ca	-	Calcium
CEC	-	Cation exchange capacity
BCR	-	Benefit cost ratio
C: N ratio	-	Carbon : Nitrogen ratio
CD	-	Critical difference
CCP	-	Composted coir pith
CFU	-	Colony forming unit
CPM	-	Composted poultry manure
Cu	-	Copper
cm	-	centi metre
DAS	-	Days after sowing
DMP	-	Dry matter production
dS m^{-1}	-	deci simen
E longitude	-	East longitude
EC	-	Electrical conductivity
Fig.	-	Figure
FYM	-	Farmyard manure
F	-	Flowering
Fig.	-	Figure
Fe	-	Iron
g	-	gram

GLM	-	Green leaf manure
ha	-	hectare
hr	-	hour
H	-	Harvest
HI	-	Harvest index
K/ K_2O	-	Potassium
kg	-	kilogram
LAI	-	Leaf Area Index
lit.	-	litre
m	-	meter
mg	-	milli gram
Mg m^{-3}		Mega gram
Mg	-	Magnesium
Mn	-	Manganese
ml	-	milliliter
msl	-	mean sea level
N latitude	-	North latitude
N	-	Nitrogen
No	-	Number
Na	-	Sodium
NS	-	Non significant
NUE	-	Nitrogen use efficiency
P/ P_2O_5	-	Phosphorus
pH	-	hydrogen ion concentration
ppm	-	parts per million

PI	-	Panicle initiation
Rs.	-	Rupees
SEd	-	Standard Error of deviation
T max.	-	Temperature maximum
T min.	-	Temperature minimum
t	-	tonne
TPF	-	Triphenyl formazon
Zn	-	Zinc
µg	-	micro gram
°C	-	degree Celcius
%	-	per cent
@	-	at the rate of

Fig. 4. Effect of organic manures and fertilizers on dry matter production (kg ha^{-1}) of rice at different growth stages (*Rabi* 2007)

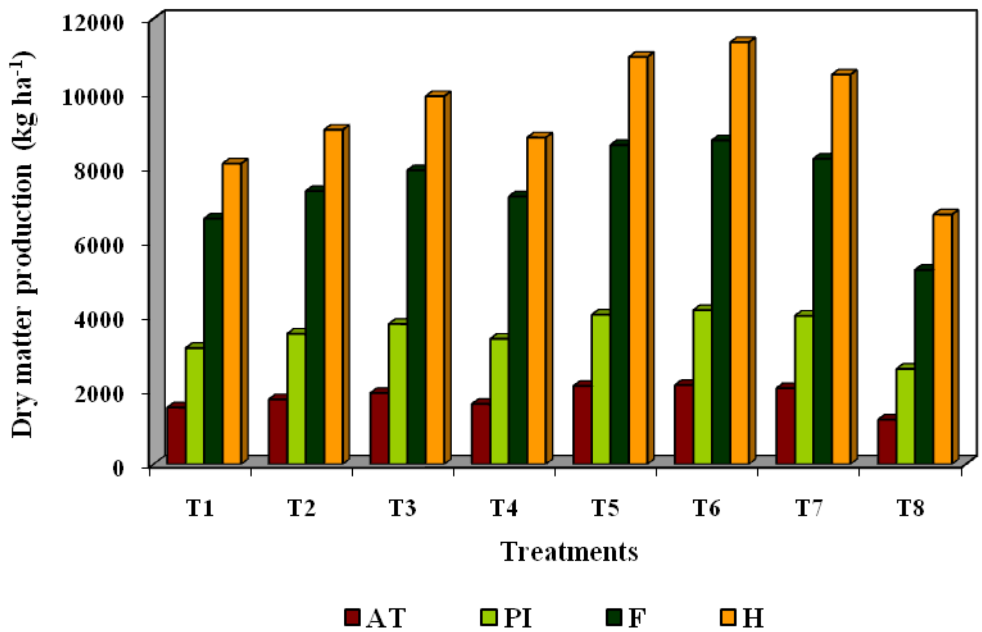


Fig. 5. Effect of organic manures and fertilizers on dry matter production (kg ha^{-1}) of rice at different growth stages (*Rabi* 2008)

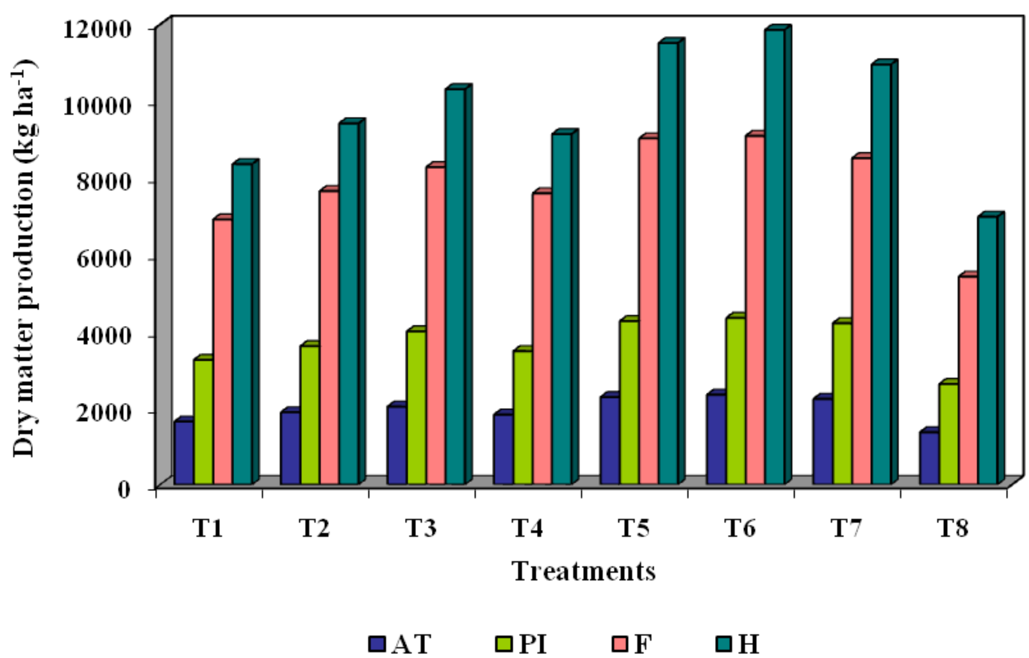


Fig. 6. Effect of organic manures and fertilizers on yield attributes of rice (*Rabi* 2007)

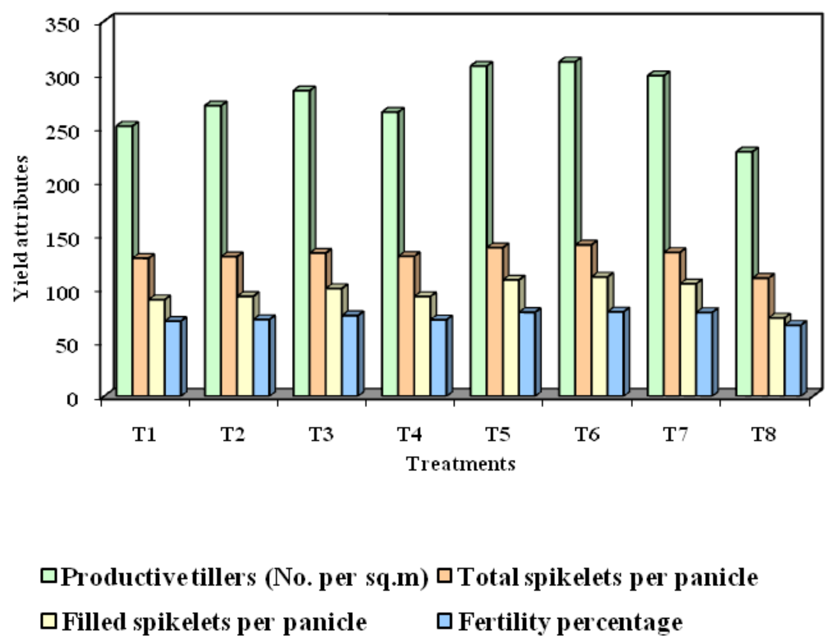


Fig. 7. Effect of organic manures and fertilizers on yield attributes of rice (*Rabi* 2008)

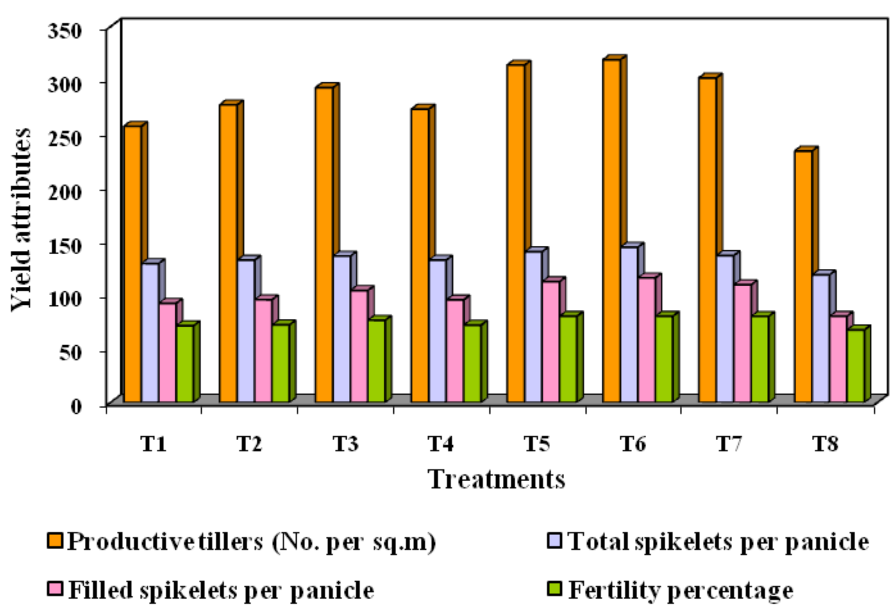


Fig. 8. Effect of organic manures and fertilizers on grain and straw yield (kg ha^{-1}) of rice (*Rabi* 2007)

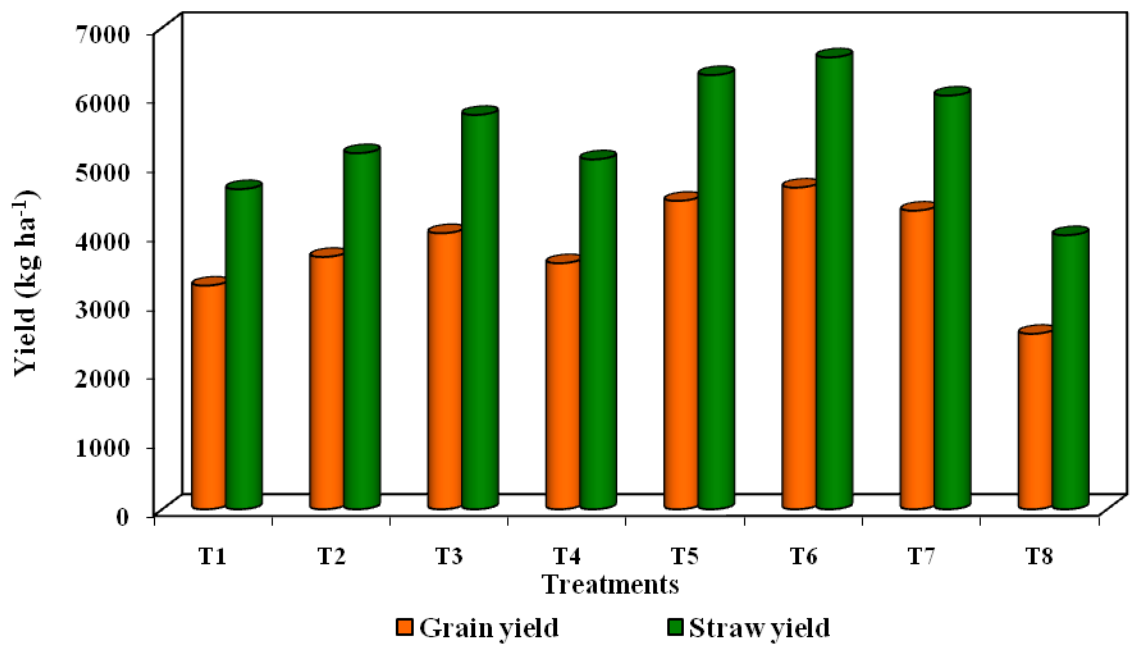


Fig. 9. Effect of organic manures and fertilizers on grain and straw yield (kg ha^{-1}) of rice (*Rabi* 2008)

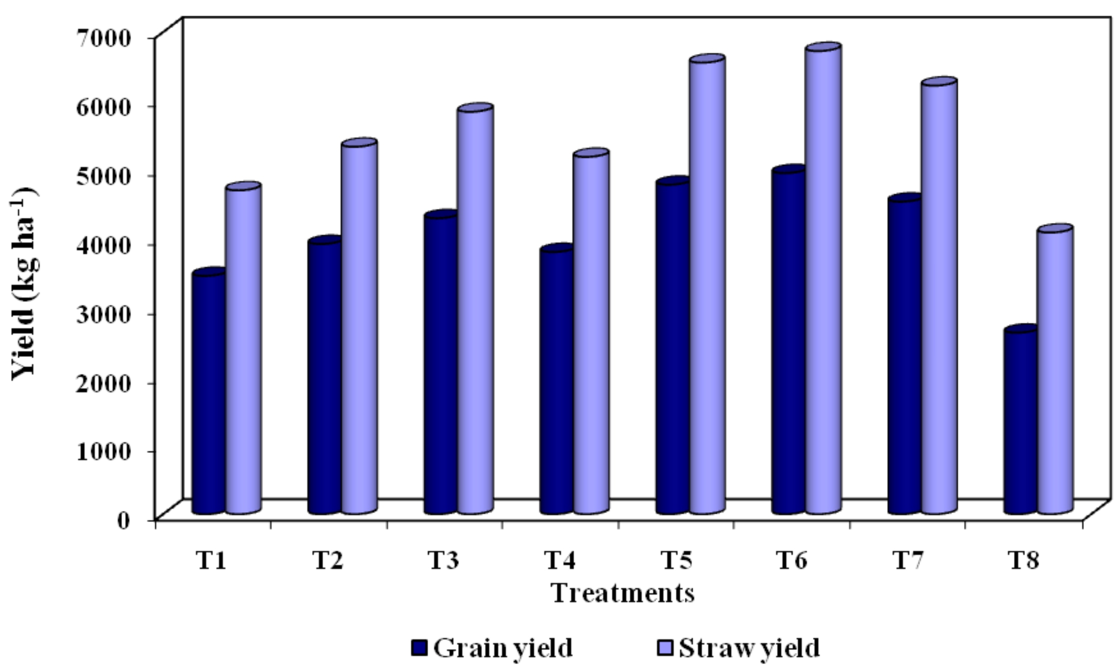


Fig. 10. Residual effect of organic manures and fertilizers on grain and haulm yield

(kg ha^{-1}) of blackgram (Summer 2008)

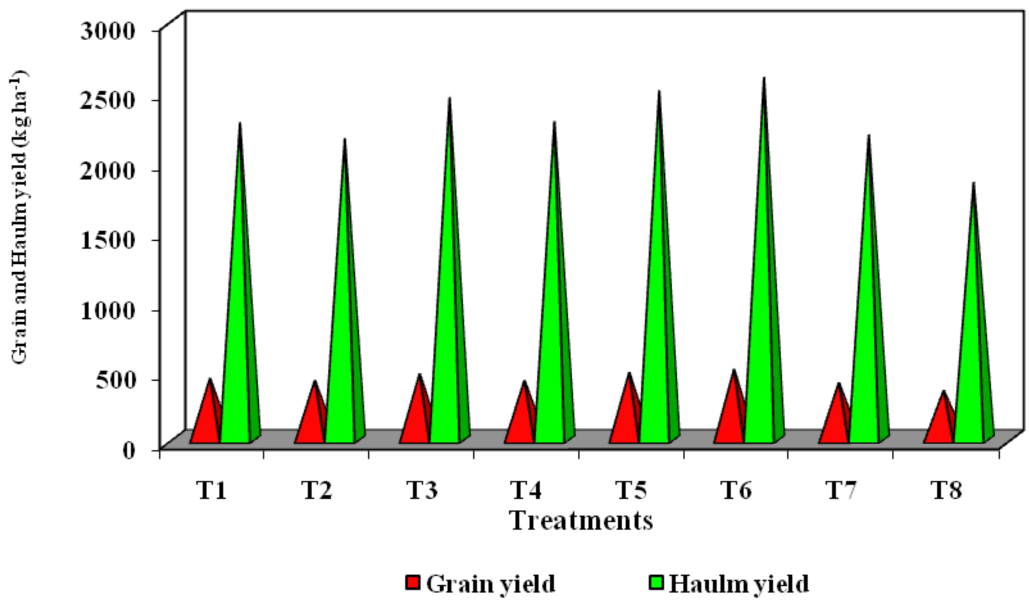


Fig. 11. Residual effect of organic manures and fertilizers on grain and haulm yield (kg ha^{-1}) of blackgram (Summer 2009)

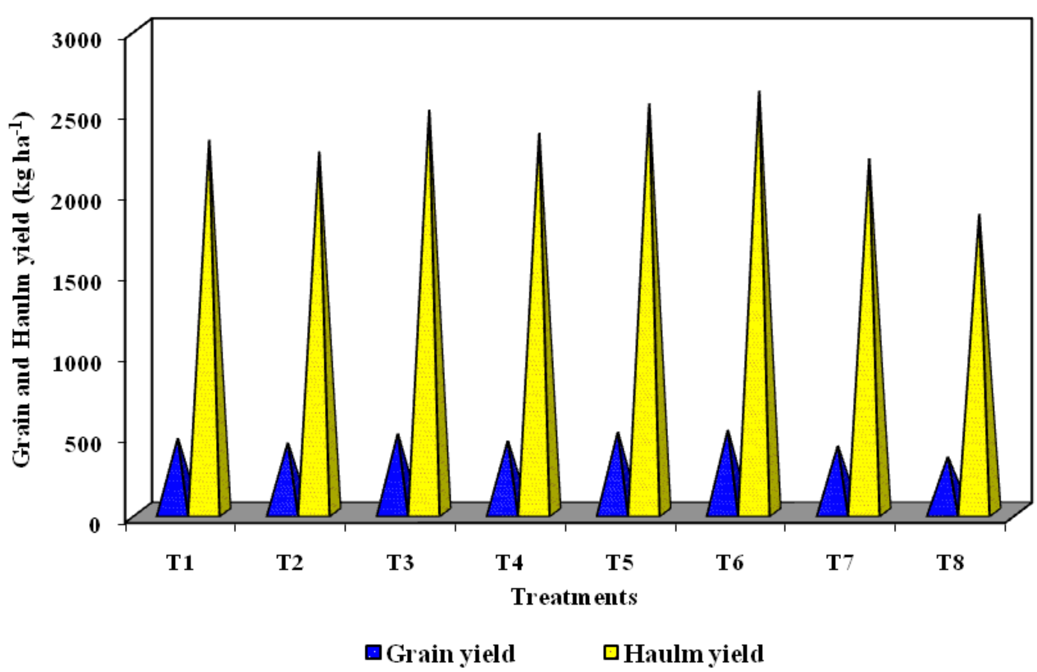


Fig. 12. Effect of organic manures and fertilizers on NPK uptake (kg ha^{-1}) of rice at harvest stage (*Rabi* 2007)

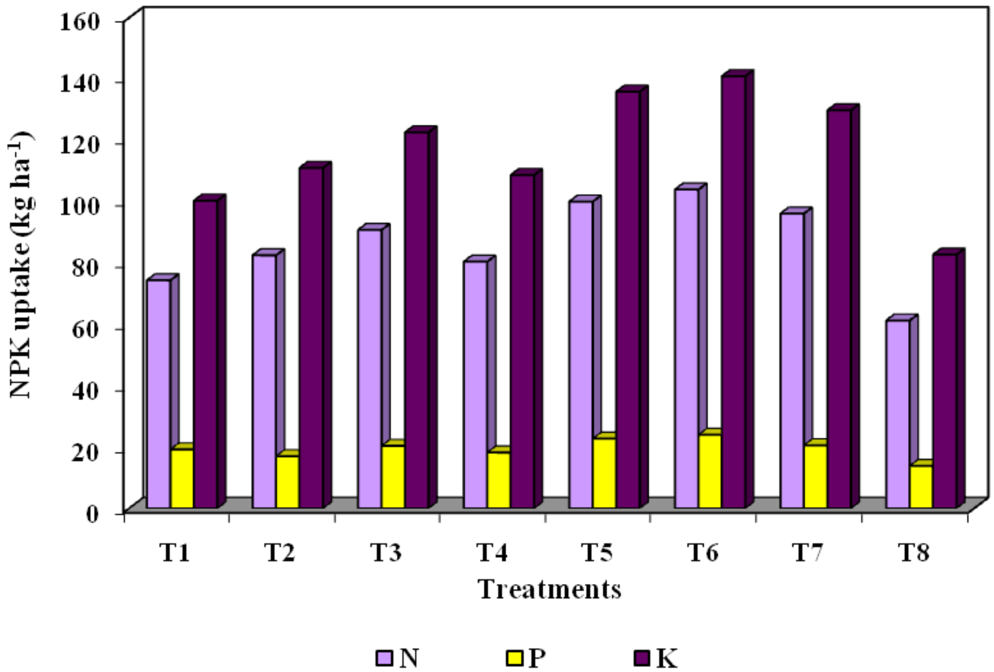


Fig. 13. Effect of organic manures and fertilizers on NPK uptake (kg ha^{-1}) of rice at harvest stage (*Rabi* 2008)

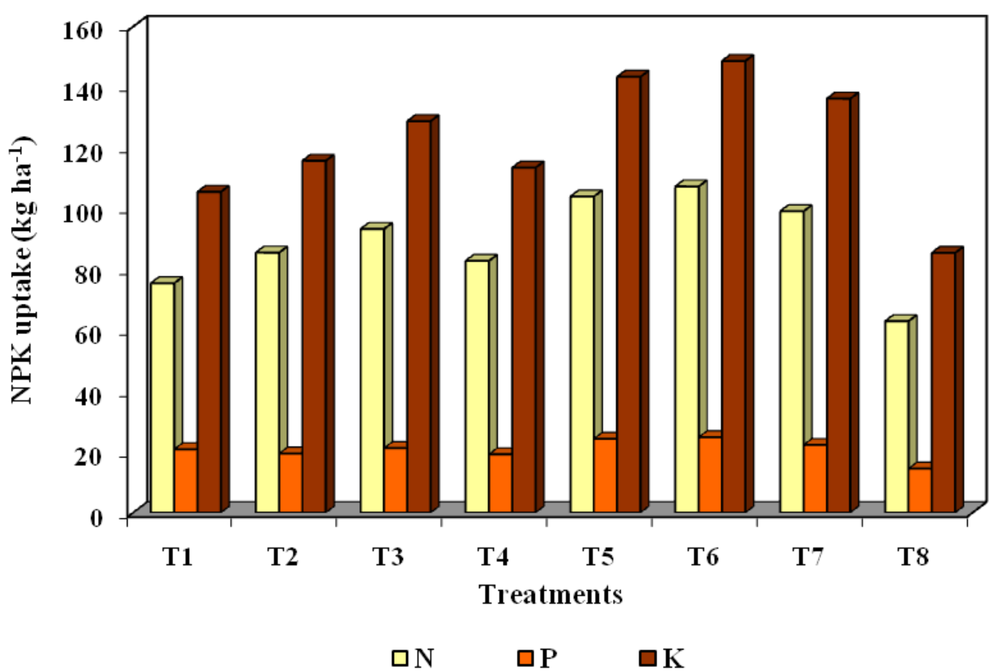


Fig. 14. Residual effect of organic manures and fertilizers on NPK (kg ha^{-1}) uptake of blackgram (Summer 2008)

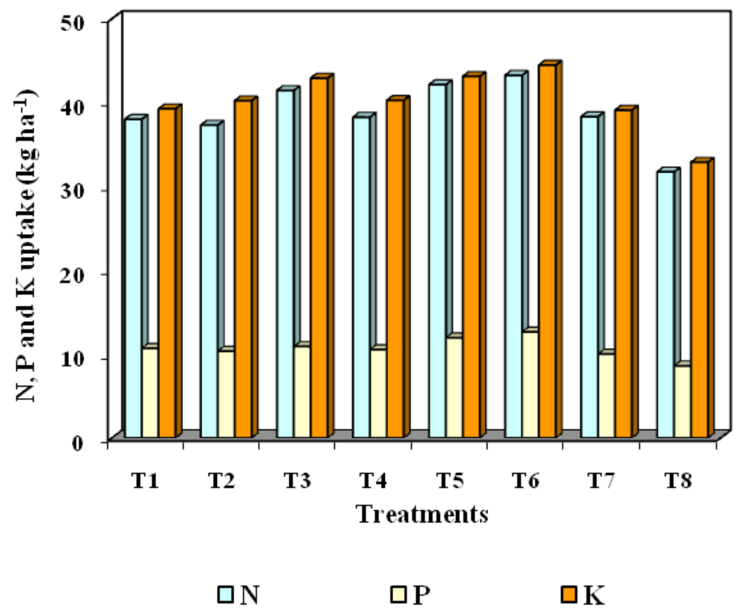


Fig. 15. Residual effect of organic manures and fertilizers on NPK (kg ha^{-1}) uptake of blackgram (Summer 2008)

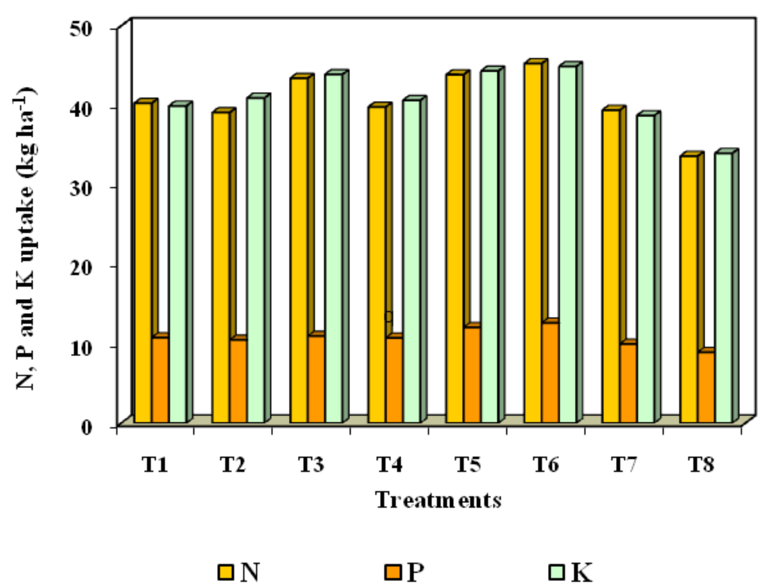


Fig.16. Effect of organic manures and fertilizers on soil available NPK (kg ha^{-1}) at harvest stage of rice (*Rabi* 2007)

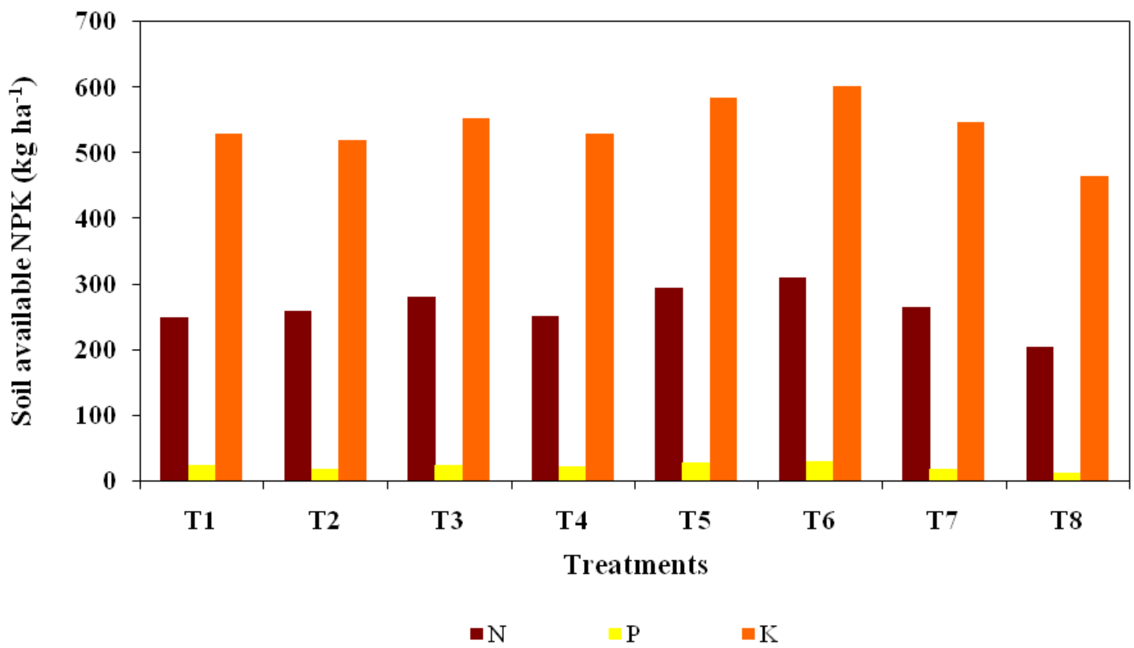


Fig.17. Effect of organic manures and fertilizers on soil available NPK (kg ha^{-1}) at harvest stage of rice (*Rabi* 2008)

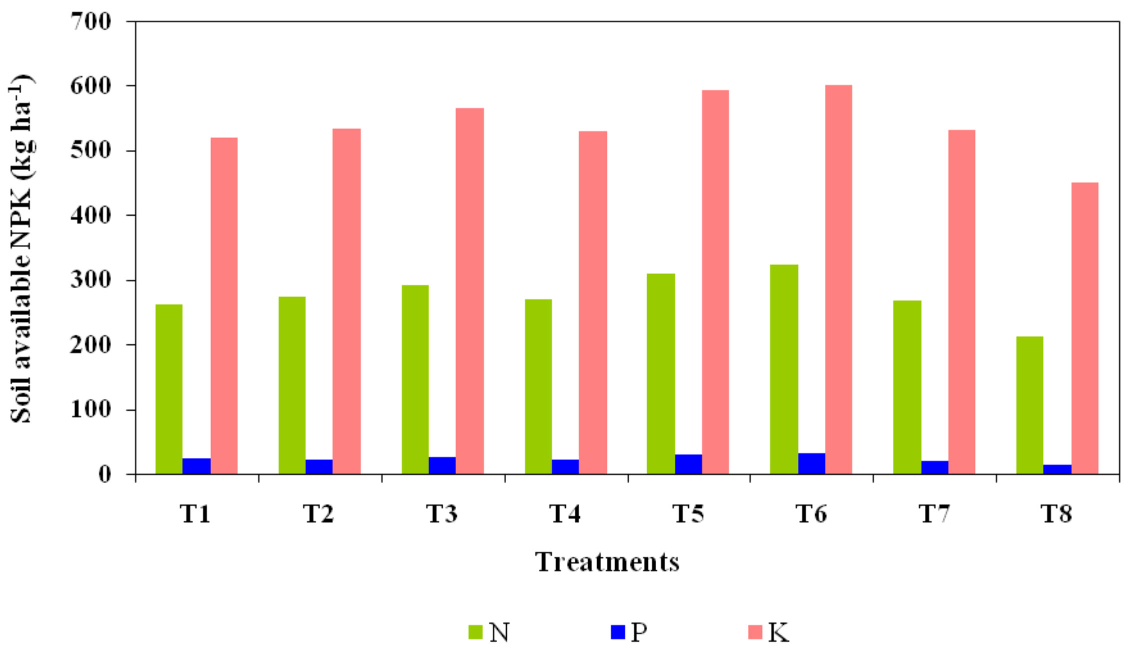


Fig.18. Residual effect of organic manures and fertilizers on soil available NPK (kg ha^{-1}) at post harvest stage of blackgram (Summer 2008)

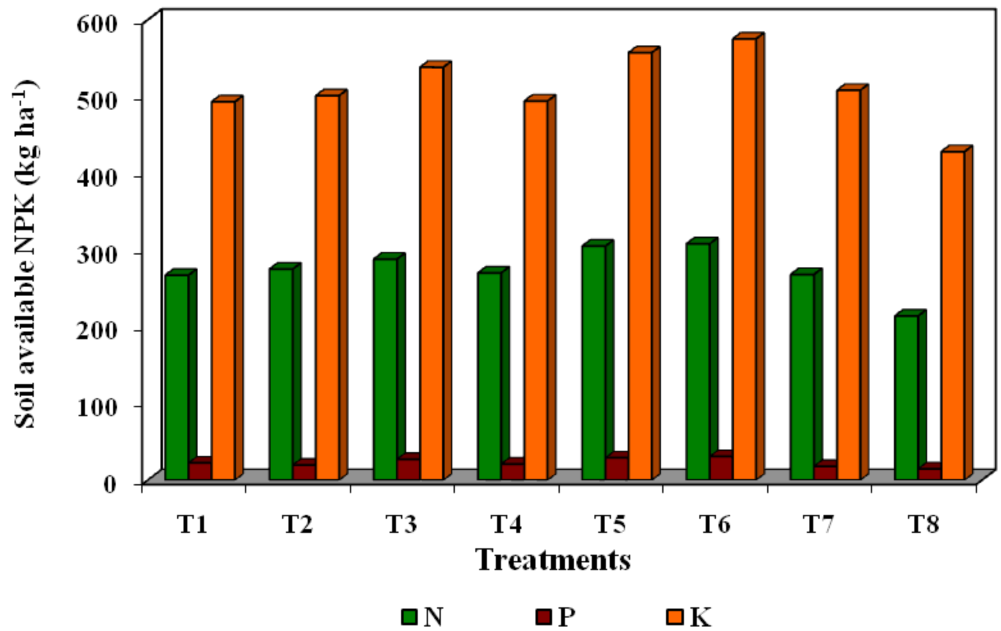


Fig.19. Residual effect of organic manures and fertilizers on soil available NPK (kg ha^{-1}) at post harvest stage of blackgram (Summer 2009)

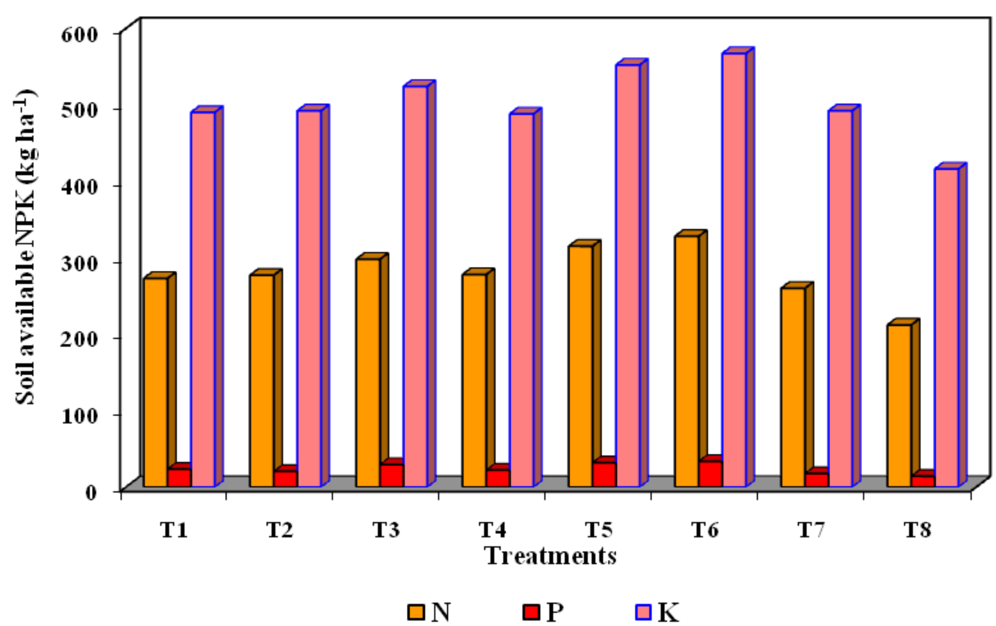


Fig. 23. Economics of rice-blackgram cropping sequence (2007-2008)

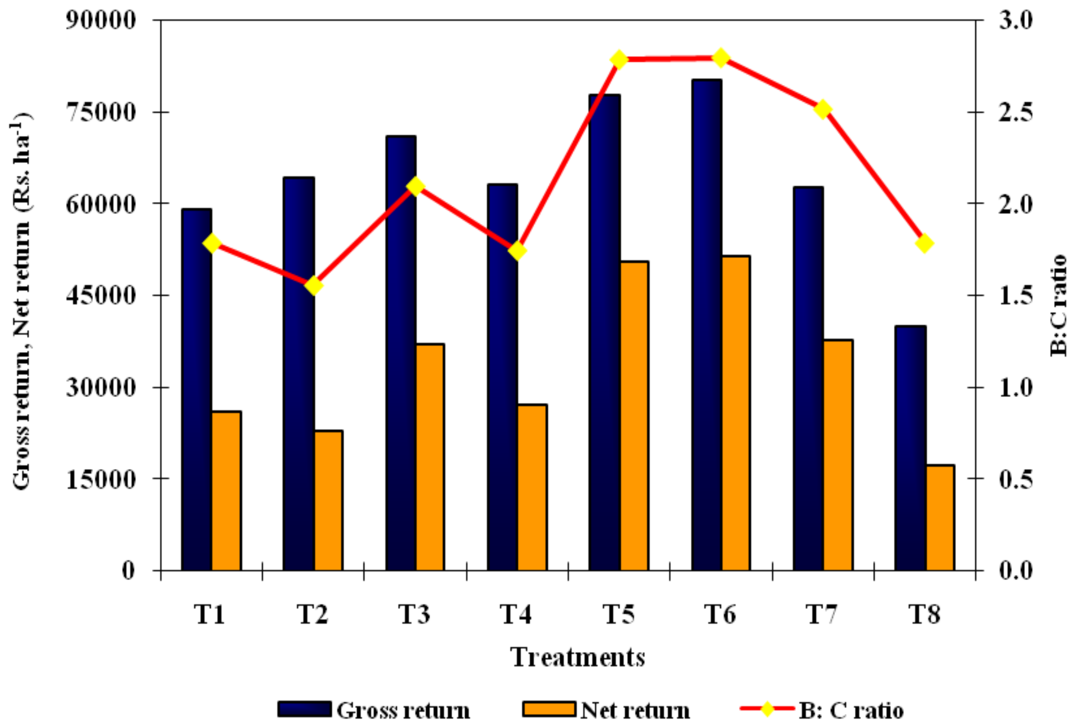


Fig. 24. Economics of rice-blackgram cropping sequence (2008-2009)

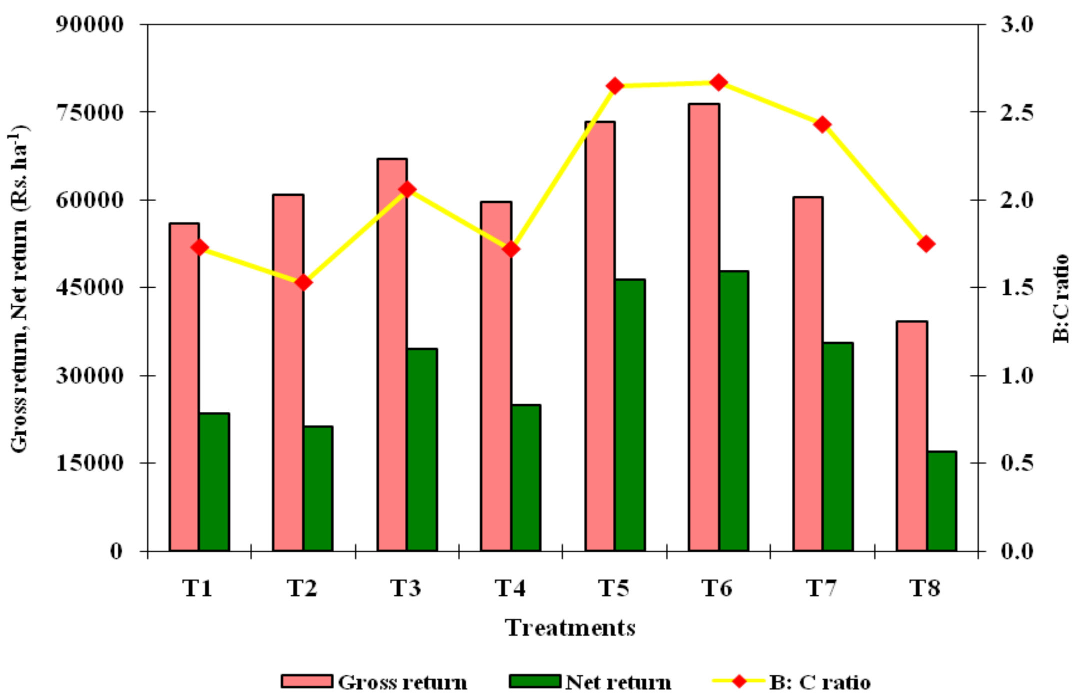
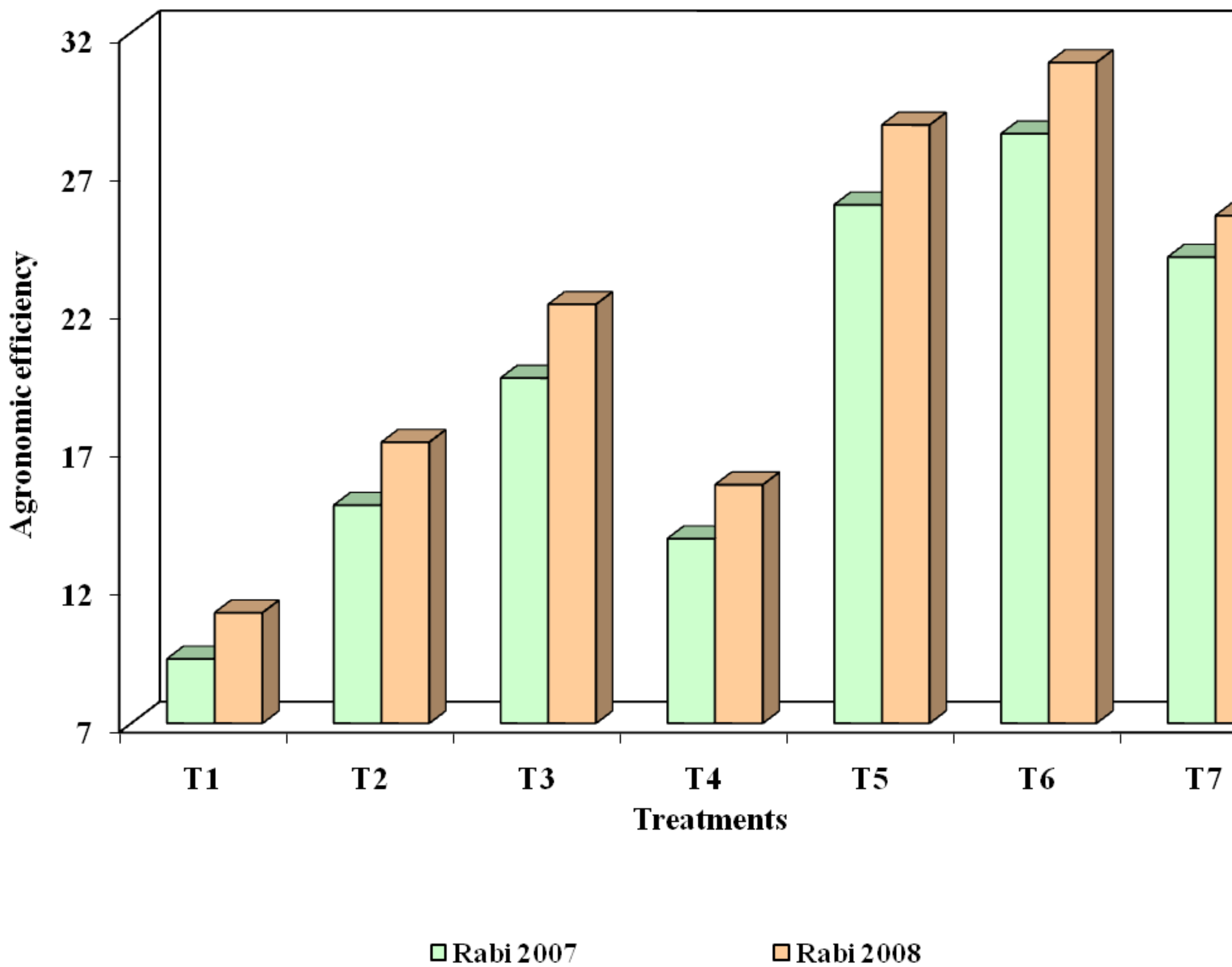
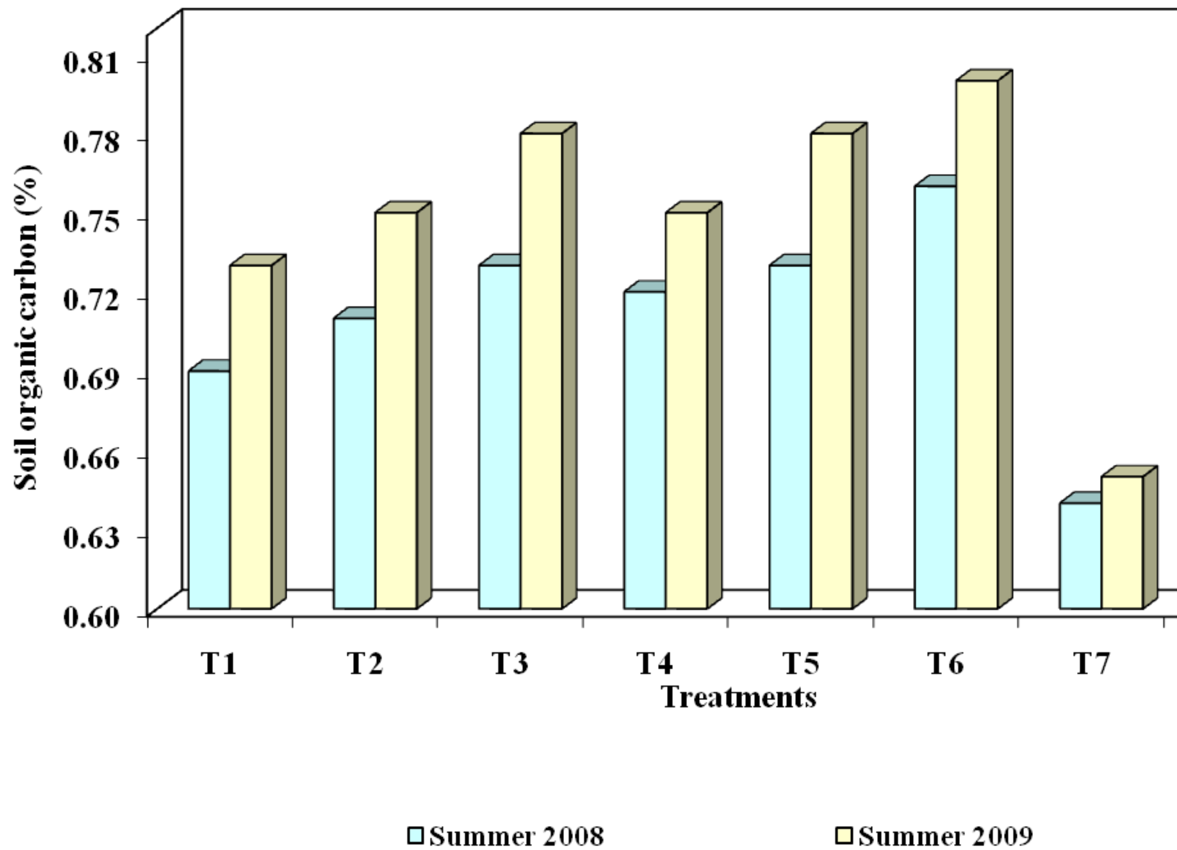


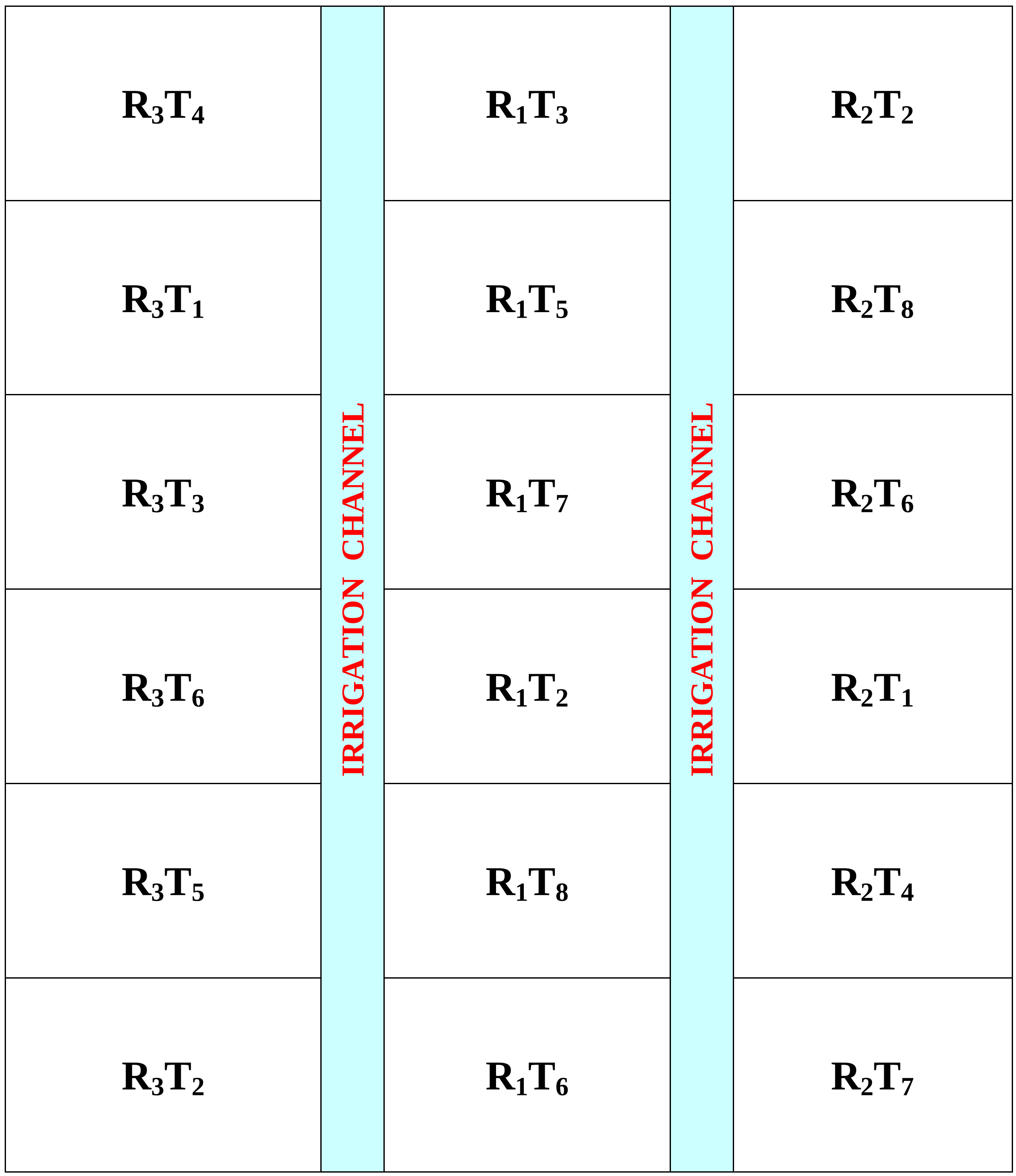
Fig. 20. Effect of organic manures and fertilizers on agronomic efficiency of rice (*Rab*

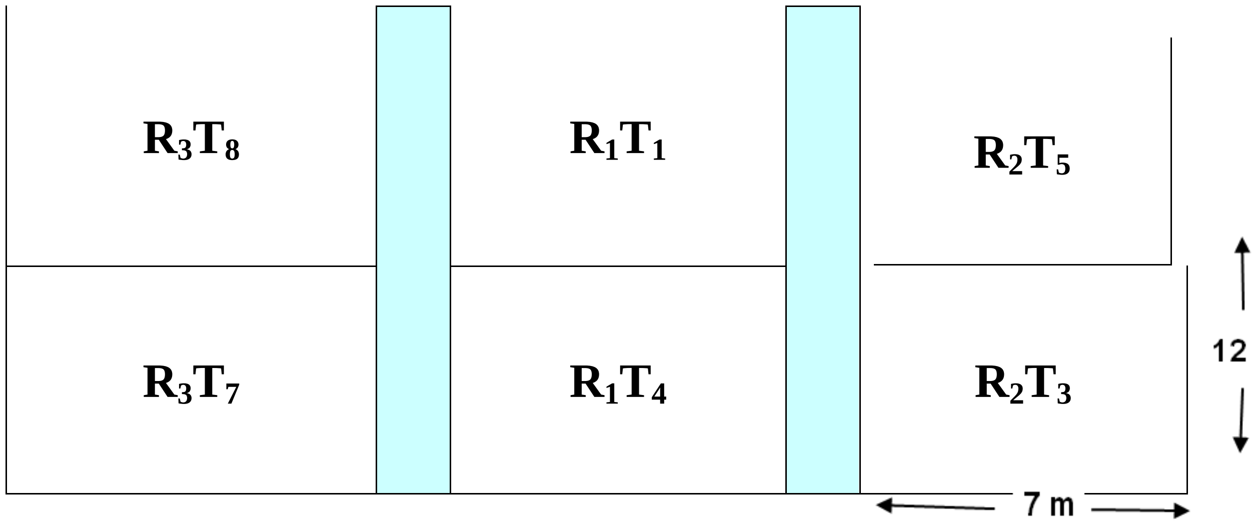




Soil organic carbon (%)
0.81
0.78
0.75
0.72
0.69
0.66
0.63
0.60
T1
T2
T3
T4
T5
T6
T7
Treatments
Summer 2008
Summer 2009

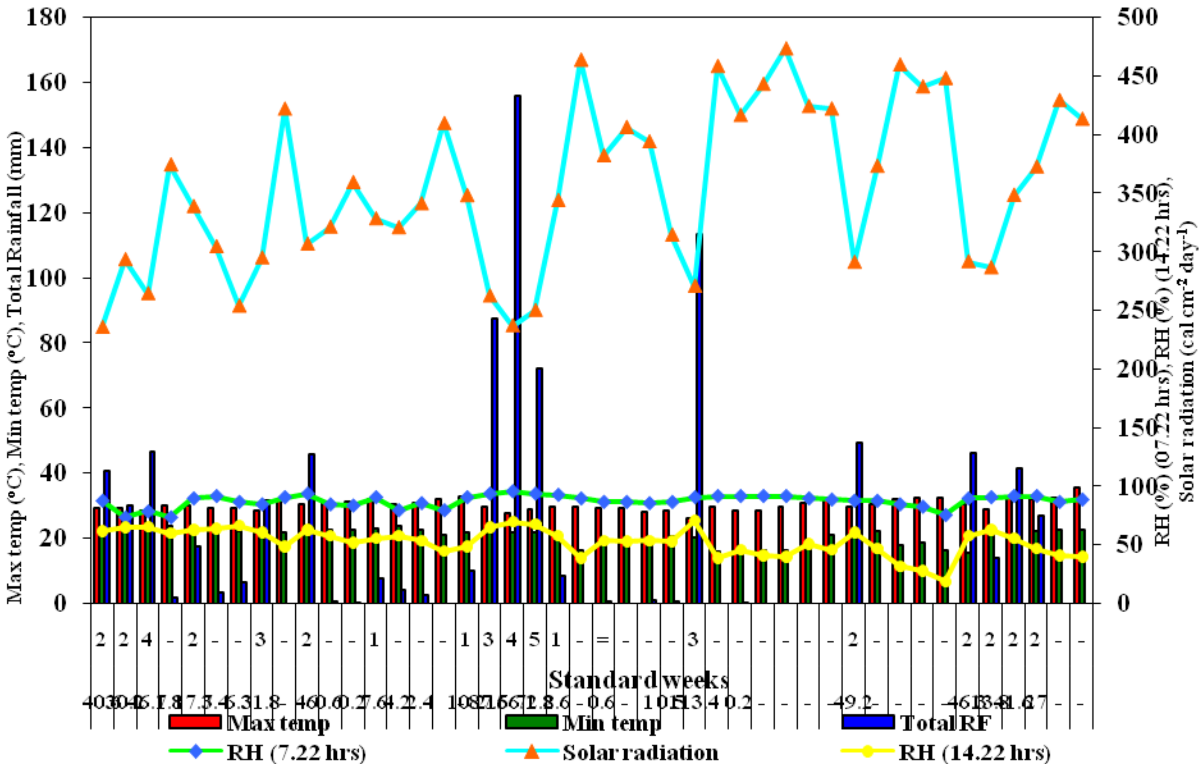
Fig. 3. Lay out of experimental field (2007 - 2008 and 2008 - 2009)

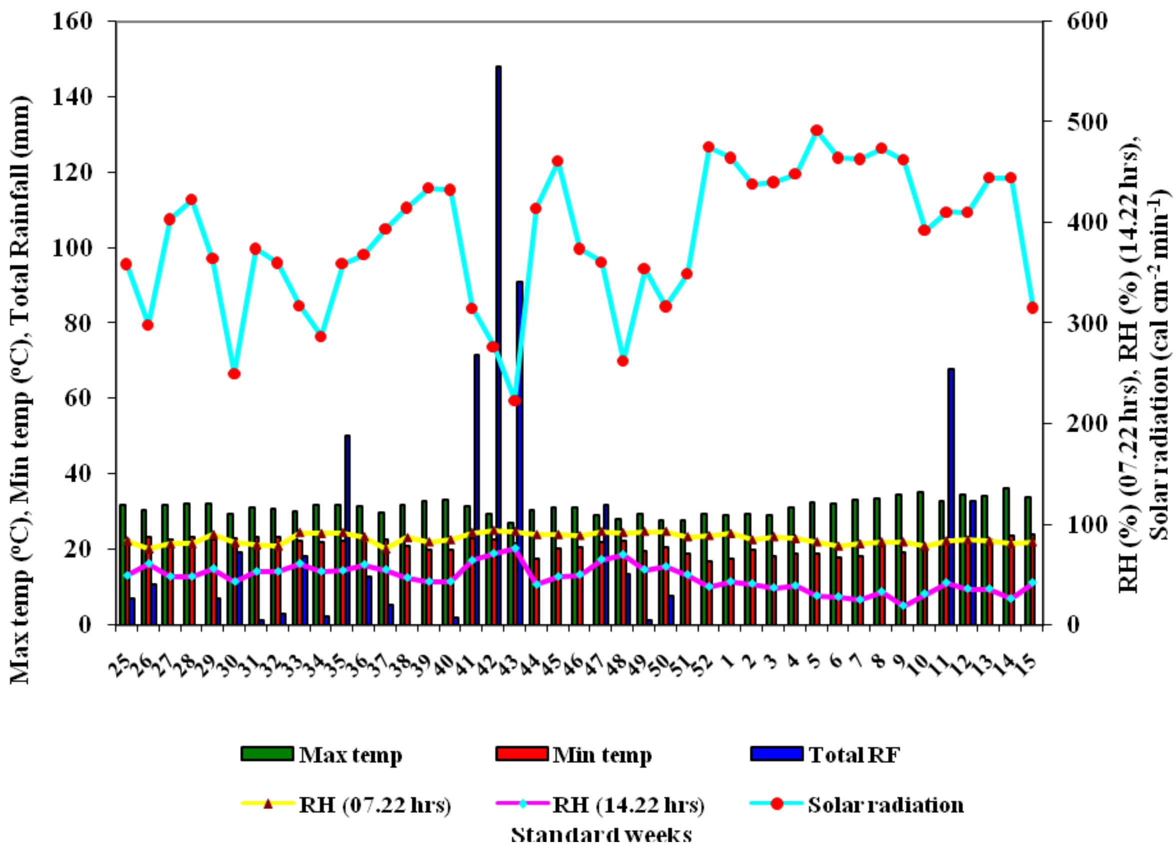




R3T8
R1T1
R2T5
R3T7
R1T4
R2T3
12
7 m

Fig. 1. Weather data during the cropping period (2007 - 2008)





Max temp (ºC), Min temp (ºC), Total Rainfall (mm)
RH (%) (07.22 hrs), RH (%) (14.22 hrs), Solar radiation (cal cm-2 min-1)
Max temp
Min temp
Total RF
RH (07.22 hrs)
RH (14.22 hrs)
Solar radiation
Standard weeks

Fig. 2. Weather data during the cropping period (2008 - 2009)