EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND YIELD OF AEROBIC RICE (*Oryza sativa* L.)

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Affectionately

Dedicated to

My beloved parents

Sri. Jayaram Kamble

Smt. Ranamma, Sisters

Chandrakala, Sushma

& Brothers Chandrashekar,Vinod

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE, SHIVAMOGGA
UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES, SHIVAMOGGA

CERTIFICATE

This is to certify that the thesis entitled **'EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND YIELD OF AEROBIC RICE (*Oryza sativa* L.)'** submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture) in AGRONOMY** of the University of Agricultural and Horticultural Sciences, Shivamogga, is a record of research work done by **Mr. KIRAN KUMAR, ID. NO. MA1TAC017** during the period of his study in the University under my guidance and supervision and that no part of thesis has been submitted for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Shivamogga
July, 2015 ***(KIRAN KUMAR)***

EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND YIELD OF AEROBIC RICE (*Oryza sativa* L.)

KIRAN KUMAR

ABSTRACT

A field experiment was conducted during *Kharif* 2014 at agriculture and Horticulture Research Station (AHRS), Bavikere to know the combined effect of organic and inorganic fertilizers on growth and yield of aerobic rice. The experiment was laid out in a randomized complete block design (RCBD) with eleven treatments replicated thrice.

Application of RDF + Vermicompost + PSB + 25 % Nitrogen through glyricidia recorded higher plant height (65.10 cm), number of leaves (103.32 $plant^{-1}$), leaf area (2323.60 cm^2 $plant^{-1}$), leaf area index (3.72), number of tillers (31.63 $plant^{-1}$), total dry matter accumulation (96.46 g $plant^{-1}$), grain yield (4241 kg ha^{-1}) and straw yield (5487 kg ha^{-1}) which was on par with the application of RDF + FYM + PSB + 25 % Nitrogen through glyricidia grain yield (4111 kg ha^{-1}) straw yield of (5248 kg ha^{-1}), respectively.

Application of RDF + Vermicompost + PSB + 25 % Nitrogen through Glyricidia resulted in higher total nitrogen, phosphorus and potassium uptake by aerobic rice (131.32, 26.95 and 113.07 kg ha^{-1}, respectively) which was on par with the application of RDF + FYM + PSB + 25 % Nitrogen through glyricidia (125.54, 25.28 and 111.97 kg ha^{-1}, respectively). Lower uptake of nitrogen, phosphorus and potassium (86.93, 13.26 and 85.46 kg ha^{-1}, respectively) was observed with application recommended dose of fertilizer (RDF) alone.

The available nitrogen, phosphorus and potassium (272.62, 86.95 and 221.30 kg ha^{-1}, respectively) after the crop harvest were observed with the application of RDF + Vermicompost + PSB + 25 % Nitrogen through glyricidia which was on par with application of RDF + FYM + PSB + 25 % Nitrogen through glyricidia (271.30, 85.69, and 201.25 kg ha^{-1}, respectively). Lower available nitrogen, phosphorus and potassium (265.14, 76.81 and 164.82 kg ha^{-1}, respectively) were observed with application of recommended dose of fertilizer (RDF) alone.

Department of Agronomy
UAHS, Shivamogga
July, 2015

C. J. Sridhara
(Major advisor)

ಅರೆನೀರಾವರಿ ಭತ್ತದ ಬೆಳವಣಿಗೆ ಹಾಗೂ ಇಳುವರಿಯ ಮೇಲಾಗುವ ಸಮಗ್ರ ಪೋಷಕಾಂಶ ನಿರ್ವಹಣೆಯ ಪರಿಣಾಮಗಳು

ಕಿರಣ ಕುಮಾರ

ಸಾರಾಂಶ

ಅರೆನೀರಾವರಿ ಭತ್ತದ ಬೆಳವಣಿಗೆ ಹಾಗೂ ಇಳುವರಿಯ ಮೇಲಾಗುವ ಸಮಗ್ರ ಪೋಷಕಾಂಶ ನಿರ್ವಹಣೆಯ ಪರಿಣಾಮದ ಅದ್ಯಾಯನ ಮಾಡಲು ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕೆ ಸಂಶೋಧನ ಕೇಂದ್ರ ಬಾವಿಕೆರೆ ಅವರಣದಲ್ಲಿ ೨೦೧೪ ರ ಮುಂಗಾರು ಹಂಗಾಮಿನಲ್ಲಿ ಒಂದು ಕ್ಷೇತ್ರ ಪ್ರಯೋಗವನ್ನು ತೆಗೆದುಕೊಳ್ಳಲಾಯಿತು. ಈ ಪ್ರಯೋಗವನ್ನು ಒಟ್ಟು ಹನ್ನೊಂದು ಸಂಯುಕ್ತ ಉಪಚಾರಗಳನ್ನೊಳಗೊಂಡ ಯಾದೃಚ್ಚಿಕ ಸಂಪೂರ್ಣ ಬ್ಲಾಕ್ ವಿನ್ಯಾಸದ ಮಾದರಿಯಲ್ಲಿ ಮೂರು ಪ್ರತಿಕೃತಿಗಳೆಂಬಂತೆ ಪ್ರತಿರೂಪಿಸಲಾಯಿತು.

ವಿವಿಧ ಸಮಗ್ರ ಪೋಷಕಾಂಶಗಳ ಬಳಕೆಯ ಪರಿಣಾಮಗಳಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಗೊಬ್ಬರ + ಎರೆಹುಳು ಗೊಬ್ಬರ + ರಂಜಕ ಕರಿಗಿಸುವ ದುಂಡಾಣು + ಗ್ಲಿರಿಸೀಡಿಯಾ ಮೂಲಕ ಒದಗಿಸಿದ ೨೫ % ರಷ್ಟು ಸಾರಜನಕ ಉಪಚಾರದಲ್ಲಿ ಹೆಚ್ಚು ಎತ್ತರದ ಸಸಿಗಳು (೬೫.೧೦ ಸೆ.ಮೀ) ಅಧಿಕ ಸಂಖ್ಯೆಯ ಎಲೆಗಳು (೧೦೩.೩೨) ಎಲೆಯ ವಿಸ್ತೀರ್ಣ (೨೩೨೩.೬೦ ಚ.ಸೆ.ಮೀ) ಮತ್ತು ತೆಂಡೆಗಳ ಸಂಖ್ಯೆ (೩೧.೬೩) ಒಟ್ಟು ಒಣ ತೂಕ (೯೬.೪೬ ಗ್ರಾಂ) ಬೀಜದ ಇಳುವರಿ (೪೨೪೧ ಕೆಜಿ/ಹೆ) ಮೇವಿನ ಇಳುವರಿ (೫೪೮೭ ಕೆಜಿ/ಹೆ) ಪಡೆಯಲಾಯಿತು.

ಇದೇ ಉಪಚಾರದಲ್ಲಿ ಅರೆನೀರಾವರಿ ಭತ್ತದ ಸಾರಜನಕದ ಗ್ರಹಿಕೆ (೧೩೧.೩೨ ಕೆಜಿ/ಹೆ) ರಂಜಕದ ಗ್ರಹಿಕೆ (೨೬.೯೫ ಕೆ.ಜಿ/ಹೆ) ಮತ್ತು ಪೋಟ್ಯಾಷ್ ಗ್ರಹಿಕೆ (೧೧೩.೦೭ ಕೆ.ಜಿ/ಹೆ) ಹೆಚ್ಚಾಗಿ ಕಂಡು ಬಂದಿದೆ ಈ ಗ್ರಹಿಕೆಯು ಸಂಖ್ಯಾ ಶಾಸ್ತ್ರಕ್ಕೆ ಅನುಗುಣವಾಗಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಗೊಬ್ಬರ + ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ + ರಂಜಕ ಕರಿಗಿಸುವ ದುಂಡಾಣು + ಗ್ಲಿರಿಸೀಡಿಯಾ ಮೂಲಕ ಒದಗಿಸಿದ ೨೫ % ರಷ್ಟು ಸಾರಜನಕ ಉಪಚಾರದಲ್ಲಿ (೧೨೫.೫೪, ೨೫.೨೮ ಮತ್ತು ೧೧೧.೯೭ ಕೆಜಿ/ಹೆ) ಎಂಬತ್ತೆ ಕ್ರಮವಾಗಿ ಕಂಡು ಬಂದಿದೆ ಹಾಗೂ ಕಡಿಮೆ ಸಾರಜನಕ, ರಂಜಕ ಮತ್ತು ಪೋಟ್ಯಾಷ್ ಗ್ರಹಿಕೆಯು ಕೇವಲ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಉಪಚಾರದಲ್ಲಿ ಕಂಡು ಬಂದಿದೆ, ಬೆಳೆಯ ಕಟಾವಿನ ನಂತರ ಅಧಿಕವಾದ ಸಾರಜನಕ ಲಭ್ಯತೆ (೨೭೨.೬೨ ಕೆಜಿ/ಹೆ), ರಂಜಕ (೮೬.೯೫ ಕೆಜಿ/ಹೆ) ಮತ್ತು ಪೋಟ್ಯಾಷ್ (೨೨೧.೩೦ ಕೆಜಿ/ಹೆ) ಲಭ್ಯತೆಗಳನ್ನು ಶಿಫಾರಸ್ಸು ಮಾಡಿದ + ಎರೆಹುಳು ಗೊಬ್ಬರ + ರಂಜಕ ಕರಿಗಿಸುವ ದುಂಡಾಣು + ಗ್ಲಿರಿಸೀಡಿಯಾ ಮೂಲಕ ಒದಗಿಸಿದ ೨೫ % ರಷ್ಟು ಸಾರಜನಕ ಉಪಚಾರದಲ್ಲಿ ಹೆಚ್ಚಗಿ ಪಡೆಯಲಾಯಿತು, ಈ ಗ್ರಹಿಕೆ ಸಂಖ್ಯಾ ಶಾಸ್ತ್ರಕ್ಕೆ ಅನುಗುಣವಾಗಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ + ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ + ರಂಜಕ ಕರಿಗಿಸುವ ದುಂಡಾಣು + ಗ್ಲಿರಿಸೀಡಿಯಾ ಮೂಲಕ ಒದಗಿಸಿದ ೨೫ % ರಷ್ಟು ಸಾರಜನಕ ಉಪಚಾರದಲಿ (೨೧೧.೩೦, ೮೫.೬೫ ಮತ್ತು ೨೦೧.೨೫ ಕೆಜಿ/ಹೆ) ಎಂಬತ್ತೆ ಕ್ರಮವಾಗಿ ಕಂಡು ಬಂದಿದೆ ಹಾಗೂ ಕಡಿಮೆ ಸಾರಜನಕ ಲಭ್ಯತೆ (೨೫.೧೪ ಕೆಜಿ/ಹೆ) ರಂಜಕ (೭೬.೮೧ ಕೆಜಿ/ಹೆ) ಮತ್ತು ಪೋಟ್ಯಾಷ್ (೧೬೪.೮೨ ಕೆಜಿ/ಹೆ) ಲಭ್ಯತೆಗಳನ್ನು ಕೇವಲ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಉಪಚಾರದಲ್ಲಿ ಪಡೆಯಲಾಯಿತು.

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(ಮುಖ್ಯ ಸಲಹೇಗಾರರು.)

ಬೇಸಾಯ ಶಾಸ್ತ್ರ ವಿಭಾಗ,
ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕೆ ವಿಶ್ವವಿದ್ಯಾಲಯ,
ಶಿವಮೊಗ್ಗ.

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Introduction

I INTRODUCTION

Rice (*Oryza sativa*. L.) is the staple food for nearly half of the world's population and most of them living in developing countries. The crop occupies one third of the world total area and provides, 35-60 per cent of the calories consumed by 2.7 billion people. Rice occupies the enviable prime place among the food crops cultivated around the world, and is cultivated in an area of 161.4 million hectare with a production of 730.2 million tonnes and average productivity of 4480 kg per hectare (Anon, 2014a). In India, rice occupies an area of 43.95 million hectare with production of 106.54 million tonnes with an average productivity of 2424 kg per hectare (Anon, 2014b), which is half of the global average. In Karnataka, it is grown in an area of 1.33 million hectare with an annual production of 3.76 million tonnes with productivity of 2828 kg ha^{-1} (Anon., 2014b).

Rice normally requires 3000–5000 liters of water to grow one kilogram traditionally, which is almost 2 to 3 times higher than any other cereal crops such as wheat and maize (Cantrell and Hettel, 2004). Rice is cultivated under four major ecosystems *viz.*, irrigated (57 per cent), rainfed lowland (31 per cent), rainfed upland (9 per cent) and deepwater (3 per cent). With emerging water scarcity in many part of the world, the traditional way of lowland rice cultivation can no longer be sustained.

Rice is the single biggest user of freshwater. It is mostly grown under submerged soil conditions and requires more water compared to other crops. Asia's irrigated rice consumes more than 40per cent of the worlds freshwater that is used for agriculture (Bouman, 2001). Food and water are two of the most important necessities for survival, but, with an increasing demand for food and a looming water crisis, a shortage of both may be on the horizon unless innovative technologies are developed. Water, especially, is fast becoming a precious commodity, as more and more people continue to use water for the household, industry, and agriculture. Scientists are now taking a challenge to develop rice production systems that can cope with water scarcity. More than 75 per cent of the rice production comes from 79 million ha of irrigated lowland. Over 17 million ha of Asia's irrigated rice may experience "physical water scarcity" and 22 million ha may experience "economic water scarcity" by 2025 (Tuong and Bouman 2003).

The declining availability and increasing costs of water threaten the traditional way of producing irrigated rice. Moreover, lack of rainfall is a major production constraint in rain-fed areas where many poor rice farmers live. Under these circumstances, new technologies and methods need to be developed to help farmers cope with water shortages for rice production.

Aerobic rice production is a revolutionary way of growing rice in well-drained, non-puddled, and non-saturated soils without ponded water. The total water requirement from sowing to harvest is estimated about 650 to 830 mm under aerobic condition and water productivity will be increased from 20 to 40 per cent (Castaneda *et al*., 2005). Further, water use in aerobic rice about 60 per cent less than that of low land rice and the total water productivity being 1.6 to 1.9 times higher. This system uses input-responsive specialized rice cultivars such as MAS 946-1 and MAS 26 varieties which are the progenies of the cross between upland and lowland cross having high yielding traits from lowland rice and stress tolerant character of the upland line and maintains rapid growth at field capacity or below. They have good root traits, crop stand and vigour and tolerant to water stress at both vegetative and reproductive stages. They mature in 115 to 120 days and yield 5.5 t ha^{-1} of grain and 6 t ha^{-1} of fodder yields per ha using only 50-70per cent of the water required for irrigated rice production (Atlin *et al*., 2004). This is recommended in areas where water is too scarce or expensive to allow traditional irrigated rice cultivation. In Asia, upland rice is aerobically grown with minimal inputs and it is usually planted as a low yielding subsistence crop in the adverse upland conditions (Lafitte *et al*., 2002).

It is estimated that the NPK removal by crops in India was about 28 million tons against the fertilizer consumption of 18 million tonnes creating a gap of 10 million tonnes in 2000 (Tiwari, 2002). The higher the grain yield targeted, the greater the amount of nutrient required for rice plant. It is reported that the nutrient use efficiency of N, P and K is 30-50, 15-20 and 60-70 per cent, respectively (Pathak, *et al.,* 2002). Further the NPK ratio of 4:2:1 considered optimum but in reality a wide ratio of 10:2.9:1 is prevalent in the country (Tandon, 2001).

Use of fertilizer in conventional rice cultivation has been reported to have poor nutrient use efficiency due to excessive use of water and loss of nutrients by leaching and volatilization. But total replacement of fertilizes by manures to avoid such losses may not be an easy alternative as manures contain lower nutrient content. Hence it is desirable to adopt integrated approach in meeting the nutrient demand of the crop. This approach involves application of chemical fertilizers, organic manures or crop residues to bridge the gap between nutrient demand and supply to improve the grain yield. Integrated nutrient management (INM) is the adoption of technically appropriate and managerially efficient in achieving the objectives of judiciously utilizing all the major sources of plant nutrients in an integrated manner so as to attain optimum economic yield from a specific cropping system (Sarkar, 2000).

Using organic sources such as FYM, vermicompost, and green manuring deserves priority for sustained production and better resource utilization in integrated nutrient management. INM technology is sustainable as compared to modern chemical farming as the farmer relies more on organic sourcs (Muneshwar Singh *et al.*, 2001). Addition of organic manure improves overall physical condition of the soil which is very essential under aerobic condition.

Animal manures are valuable sources of nutrients and yield-increasing effect of manure is well established (Wakene *et al.,* 2005; Silvia *et al.,* 2006). Organic matter in the soil improves soil physical conditions by improving soil structure, increases water holding capacity, and improves soil structure and aeration, as well as regulating the soil temperature.

At present, information on the adoption of integrated nutrient management practices in aerobic rice cultivation is meager. Keeping these points in view a field experiment entitled “Effect of integrated nutrient management on growth and yield of aerobic rice” was carried out during *Kharif* 2014 at Agriculture and Horticulture Research Station (AHRS) Bavikere, University of Agriculture and Horticulture Sciences, Navile, Shivamogga with the following objectives.

1. To study the effect of integrated nutrient management practices on growth and yield of aerobic rice.

2. To study the effect of integrated nutrient management practices on nutrient status in soil and crop and

3. To study the economics of integrated nutrient management in aerobic rice cultivation.

Review of literature

II REVIEW OF LITERATURE

A field experiment was conducted to study the "Effect of Integrated Nutrient Management on Crop Growth and Yield of Aerobic Rice (*Oryza sativa* L.)" at Agriculture and Horticulture Research Station (AHRS) Bavikere, during *Kharif* 2014. A brief review of the research work on various aspects related to the integrated nutrient management on aerobic rice has been compiled and presented in this chapter under the following headings.

2.1. Performance of aerobic rice cultivation.

2.2. Yield potential of aerobic rice and its constraints.

2.3. Effect of different organic manures on growth and yield of aerobic rice.

2.4. Effect of inorganic fertilizers on growth and yield of aerobic rice.

2.5. Effect of bio-fertilizers on growth and yield of aerobic rice.

2.6. Effect of Integrated Nutrient Management on growth and yield of aerobic rice.

2.7. Effect of Integrated Nutrient Management on nutrient uptake.

2.8. Effect of Integrated Nutrient Management on economics of aerobic rice.

2.1 Performance of aerobic rice cultivation.

Increased competitions for water and climate change are reducing the amount of water available for agriculture in the world. Rice is the major staple food for the large and growing population of the world, and the major user of water. Therefore, new ways must be sought to produce more rice with less water and aerobic rice with micro irrigation practices leads to sustainable rice production methodology for immediate future to address water scarcity with more benefits and environmental safety in the scenario of global warming by reduced methane emission is an added advantage.

Ganesh and Jayadevahakkali (2000) revealed that irrigation once in 5 days consumed least water (89.5 cm) and saved 39 per cent irrigation water compared to farmer's practice of continuous irrigation (230.8 cm).

Bouman (2001) opinioned that the aerobic rice system involves growing input-responsive, drought-tolerant rice varieties in non-flooded and non-puddled soil using supplementary irrigation and fertilizers to achieve high yields.

Castaneda *et al*. (2002) observed that yield of rice crop under aerobic condition were 2.4 t ha^{-1}, which were 14 to 40 per cent lower than under flooded conditions. The total water input from sowing or transplanting up to harvest was 650 to 830 mm under aerobic condition and about 1,350 mm under flooded conditions. Water productivity under aerobic cultivation was increased by 20 to 40 per cent over that flooded condition.

Wang *et al.* (2002) reported that in aerobic rice water productivity is more, however the water use was reported to be about 60 per cent less than that of lowland rice with total water productivity 1.6 to 1.9 times higher and net returns to water use two times higher.

Bouman *et al.* (2005) reported that aerobic rice utilizes only 450-500 mm water and resulted in increased water productivity of 32 to 88 per cent compared to flooded conditions.

Aerobic rice saved 73 per cent of irrigation water for land preparation and 56 per cent during the crop growth stage (Ambracio *et al.*, 2004; Parthasarathi *et al.*, 2012) and On an average, aerobic fields used 190 mm less water in land preparation, 250-300 mm less seepage and percolation, 80 mm less evaporation, and 25 mm less transpiration than flooded fields (Peng *et al*., 2006).

Changying *et al.* (2008) reported that water productivity with respect to total water input (irrigation plus rainfall) was 0.89 - 1.05 g grain kg^{-1} water, and with respect to evapotranspiration, 1.28 - 1.42 g grain kg^{-1} water.

Amudha *et al.* (2009) reported that Water inputs of aerobic rice were more than 50 per cent lesser (470-650 mm) and 64-88 per cent water productivities were higher than the lowland rice.

Tabbal *et al.* (2009) observed that reduced water input and increased water productivity of rice grown under just saturated soil condition compared with traditional flooded rice.

Maragatham *et al.* (2010) reported 5.66 kg ha^{-1} mm^{-1} in alternate wetting and drying system of cultivation. Chan *et al.* (2012) opined that aerobic rice cultivation used much less water for production. This in turn improved water productivity from 0.4 to 0.6 kg m^{-3} compared to irrigated wetland rice.

2.2. Yield potential of aerobic rice and constraints.

2.2.1 Yield potential of aerobic rice.

Rice does not require flooded conditions for higher yield levels (De Datta., 1975).

George and Virmani (2001) while working at IRRI, Philippines, reported that higher yield of 8 t ha^{-1} could be obtained under aerobic rice genotypes.

Yield varies from season to season and place to place, tropical aerobic rice yielded 4.0-5.7 t ha^{-1} and 3.5-4.2 t ha^{-1} in dry and wet season (Peng *et al*., 2006).

In Karnataka aerobic rice can yield up to 7 and 6.61 t ha^{-1} in *kharif* and 10.08 and 9.21 t ha^{-1} in summer season with increasing yield parameters like number of productive tillers m^{-2} (428), number of grains $panicle^{-1}$ (140.1), 1000 seed weight (24.5 g) and harvest index (0.40) (Ajaya Kumar., 2008).

Wang *et al*. (2009) revealed that yield of aerobic rice varied from 4.5 to 6.5 t ha^{-1}, which was about double than that of traditional upland varieties.

2.2.2 Constraints of aerobic rice production.

Aerobic rice system of cultivation needed good management practices, due to drying of paddy soil, increased denitrification and nitrate leaching, indeed a drastic reduction in plant uptake of fertilized –N (Lin *et al*., 2002), and sink size was identified as the limitation of aerobic rice yield, because its spikelet number m^{-2} was too low compared with the lowland rice. The nitrate nitrogen (N) and ammonium N supplied at early growth stages provided the first evidence for aerobic rice (Guang-hui *et al*., 2008).

Weather parameters also causes decreased yield due to high atmospheric temperature during flowering period, which results in poor grain setting in panicle and most of them became chaffy due to spikelet sterility. Ultimately, it produced low grain yield of rice in aerobic situation during summer season due to high temperature at flowering period, grain formation and grain ripening stages (Jana *et al*., 2013).

2.3. Effect of different organic manures on growth and yield of aerobic rice.

2.3.1 Effect of Farm yard manure on growth and yield of aerobic rice.

Ravindra Babu and Reddy (2000) reported that Improving the Farm yard manure increased the number of panicles, filled spike lets, panicle length and grain yield. FYM is a good amendment which improves soil fertility status and it is the source and store house of nutrients in soil as it improves the organic carbon content of soil.

Shanmugam and Veeraputhram (2000) revealed that application of FYM at 12.5 t ha^{-1} increased the growth attributes of rice (plant height and tiller per square meter).

Brar *et al*. (2001) reported from a field trial on maize conducted at Ludhiana during *Kharif* season that application of FYM at 2.5 t ha^{-1} alone resulted in better grain yield than glyricidia green leaf manure incorporation at 5 t ha^{-1}.

Datta *et al.* (2001) reported that application of FYM significantly increased plant height, dry matter accumulation and number of tillers as compared to control.

Muneshwar Singh *et al.* (2001) analyzed the nutrient content of FYM and reported that FYM has 0.62 per cent of nitrogen (N), 0.13 per cent of phosphorous (P) and 0.71 per cent of potassium (K).

Beena and Balachandraan (2002) reported that the grain and straw yield of rice which received a combination of 100 per cent NPK+FYM in *Kharif* season was significantly higher (3119 and 3956 kg ha^{-1} , respectively) compared to treatments receiving NPK fertilizers only (2548 and 2293 kg has^{-1}, respectively).

Satyanarayana *et al*. (2002) reported that application of farmyard manure at 10 t ha^{-1} increased grain yield of rice by 25 per cent compared to no farmyard manure control. Similar observations were also made on straw yield, tiller number, filled grains per panicle, and 1000-grain weight. There were significant interactions between farmyard manure and inorganic fertilizer treatments.

Higher grain (5939 kg ha^{-1}) yield of rice was recorded with the application of 25 per cent of N through FYM + 100 per cent fertilizer management through urea and was significantly superior to 100 per cent RDF (5487 kg ha^{-1}) during both years. Integrated application of inorganic fertilizer and FYM increased productive tillers $hill^{-1}$, panicle length and number of grains $panicle^{-1}$ (Malla Reddy *et al*., 2003).

Manish Kumar *et al.* (2003) reported that integrated use of wheat straw (10 t ha^{-1}), 100 per cent RDF and farm yard manure resulted in higher grain yield of 4.5 t ha^{-1}.

Rana and Shivran (2003) conducted a field trial at Indian Agriculture Research Institute, New Delhi on maize and reported that number of cobs $plant^{-1}$, cob length, grains cob^{-1}, grains weight cob^{-1} and weight of cobs per plot were significantly higher in the treatment FYM at 5 t ha^{-1} along with dust mulch or straw mulch than to that of no mulch.

The per cent increase in grain yield with 100 per cent recommended dose of nitrogen (RDN) mixed with FYM, 100 per cent RDN along with 5 tonnes of FYM and 100 per cent RDN through urea along with FYM over 100 per cent RDN were 13.4, 14.2 and 8.2 per cent respectively (Roul and Sarawgi., 2005).

Balyan *et al.* (2006) reported that in maize application of 10 t FYM ha^{-1} significantly increased the plant height (10.26 per cent) and dry matter per plant (18.36 per cent) compared to without FYM application

Godhawale and Dahipale (2007) reported that among different organic treatments, Green leaf manure (5 t ha^{-1}) along with FYM (10 t ha^{-1}) recorded significantly higher grain yield (2771 kg ha^{-1}) and production efficiency (22.17 kg ha^{-1} day^{-1}) in rice.

Pandey and Tripathi (2007) reported that application of two third nitrogen through farm yard manure and remaining one third through inorganic fertilizer recorded higher grain yield (3.7 t ha^{-1}) as compared to no fertilizer (2.16 t ha^{-1}).

The higher grain yield (58.4 q ha^{-1}) and straw yield (7.87 t ha^{-1}) of rice was recorded by combined application of 10 t ha^{-1} each of fly ash and FYM, which was on par with 15 t ha^{-1} of fly ash along with 10 t ha^{-1} of FYM (Prabhakar Reddy *et al*., 2007).

Mandal *et al.* (2008) observed that dry matter production, yield components and yield (6.2 t ha^{-1}) of rice improved significantly when the crop was applied with 75 per cent recommended NPK along with 10 tonnes of FYM ha^{-1} as compared to 100 per cent recommended NPK.

Rathore *et al*. (2008) observed that rice grain yield (5.57 t ha^{-1}) was significantly higher with the application of FYM at 5 tonnes ha^{-1} along with NPK (60:37.5:22.5 kg ha^{-1}) as compared to control. Further increase in plant was observed at harvest stage.

Jana and Ghosh (2009) conducted a field experiment to study the effect of integrated nutrient management through organic and inorganic sources of fertilizer in rice-rice crop sequence. They reported that grain yield of rainy season crop was higher under 100 per cent recommended dose of NPK (4.76 t ha^{-1}) supplied as 75 per cent through inorganic and 25 per cent through organic sources (4.45 t ha^{-1}). The uptake of the nutrients such as, N, P and K was more when 75 per cent of the fertilizers were applied as inorganic and 25 per cent as organic sources.

Siddaram *et al.* (2010) revealed that application of recommended dose of fertilizer (100:50:50 kg N:P:K ha^{-1}) + 10 tonnes of FYM ha^{-1} recorded significantly higher growth parameters like plant height (63.1 cm), number of tillers (36.2 $hill^{-1}$), leaf area (1602 cm^2 $hill^{-1}$) and dry matter production at harvest (151.1 g $hill^{-1}$).

Tilahun-Tadesse *et al*. (2013) reported that application of FYM at 15 t ha^{-1} combined with 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} increased grain yield by 123 per cent and 38 per cent compared to the negative (00-0 kg ha^{-1}FYM-N-P_2O_5) and positive (0-120-100 kg ha^{-1} FYM-N-P_2O_5) controls, respectively.

2.3.2 Effect of vermicompost on growth and yield of aerobic rice.

A study conducted by Ravi and Srivasthava (1997) revealed that combined application of vermicompost and inorganic fertilizer recorded significantly higher plant height, effective tillers $hill^{-1}$, higher grain and straw yield of rice as compared to application of inorganic fertilizers alone, which resulted in a saving of inorganic fertilizer to an extent of 30 per cent.

Rajkhowa *et al.* (2000) reported that vermicompost had 1.15 per cent of organic carbon, 1.3 per cent of total nitrogen, 1.3 per cent of phosphorous and 2.6 per cent of potassium. Srikanth *et al*. (2000) revealed that in addition to 1.52 per cent of organic carbon, vermicompost contained sizeable amounts of N (1.4 per cent), P_20_5 (0.36 per cent) and K_20 (0.60 per cent).

Application of vermicompost at the rate of 5 t ha^{-1} combined with NPK at 150-75-75 kg ha^{-1} had recorded significantly higher yield (4889 kg ha^{-1}) as compared to no vermicompost application (4070 kg ha^{-1}). Increased grain yield with vermicompost was because of significantly higher yielding attributes like number of panicles $hill^{-1}$ (10.91) and number of grains $panicle^{-1}$ (186.82) due to increased availability of nutrients in vermicompost treatment (Murali and Setty, 2001).

Sudha and Chandini (2003) conducted an experiment using vermicompost at the rate of 5 t ha^{-1} had positive influence on growth and yield of rice, resulted in a better grain yield of 4.54 t ha^{-1} and straw yield of 5.15 t ha^{-1} along with the NPK dose of 105:52.5:52.5 kg ha^{-1} supplied through inorganic sources. The increase in yield in the study was due to the promotion of tiller and panicle with the supply of vermicompost. Further, they observed that supply of secondary nutrients like Mg as well as micronutrients through vermicompost improved the chlorophyll content and caused reduction of chaff percentage.

Pandu *et al.* (2005) reported that N management using leaf color chart at critical value 3 with vermicompost seemed to be promising in respect of nitrogen use efficiency (NUE) and rice grain yield. An increase in nitrogen use efficiency and 20 per cent saving of chemical fertilizer N could be attained with incorporation of vermicompost and N management using leaf color chart at critical value 3 significant reduction in yield.

Singh *et al.* (2005) proved that effective substitution of the recommended N dose of rice could be done up to 33 per cent by vermicompost.

Rajashekhara Reddy (2006) reported that higher rice yield (66.58 q ha^{-1}) was obtained by applying 75 per cent inorganic fertilizers (RDF) with 25 per cent organic nutrients (through FYM, vermicompost and poultry manure in equal proportion) over control treatment.

Godhawale and Dahipale (2007) reported that application of vermicompost at 2.5 t ha^{-1} recorded higher grain yield of rice (1348 kg ha^{-1}) as compared to control treatment (925 kg ha^{-1}).

Jadhav *et al*. (2008) reported that application of vermicompost increased the uptake of primary and secondary nutrients such as N, P, K, Ca and Mg by rice and maximum nitrogen uptake was recorded by the conjunctive use of 75 kg N ha^{-1} through urea along with 25 kg N ha^{-1} through vermicompost.

Vasanthi and Kumaraswamy (2008) in their study with vermicompost obtained from various organic materials, found that the grain yield of rice was significantly higher in treatments that received vermicompost, irrespective of the type of organic material along with recommended NPK compared to that of recommended NPK application alone. Vermicompost at 5 t ha^{-1} was suggested to be sufficient for rice when applied with recommended levels of NPK.

Adhikari and Mishra (2009) indicated that rice varieties like Basmati 370 and Pusa Sugandh 3 gave higher yields with 60 kg N through prilled urea, 60 kg N through vermicompost along with 40 kg N through farm yard manure ha^{-1}.

Siddaram *et al*. (2009) reported that application of recommended dose of fertilizer (100:50:50 kg N:P:K ha^{-1}) along with 10 tonnes of FYM ha^{-1} was found to be superior in giving maximum grain (40.8 q ha^{-1}) and straw yield (46.6 q ha^{-1}). However, it was on par with 200 per cent RDN equivalent through vermicompost ha^{-1} grain (39.9 q ha^{-1}) and straw (45.8 q ha^{-1}) yield.

Anburani (2010) revealed that the growth parameters were significantly influenced due to the application of soil and foliar application of organic nutrients. The highest plant height (54.43 cm), number of tillers (5.12), number of leaves per plant (17.77), leaf area (145.79 cm^2) and dry matter production (9.43 g $plant^{-1}$) of onion were recorded in the treatment that received with Vermicompost at 1 kg pot^{-1} combined with vermiwash (1:5) foliar spray.

2.3.3 Effect of Green manure on growth and yield of aerobic rice.

Narayanreddi *et al*. (1972) repotted that the highest grain yield and straw yield of rice were obtained with glyricidia (15 t ha^{-1}) plus RDF (100:60:60 kg NPK ha^{-1}) when compared to same dose of NPK alone. The yield parameters viz., productive tiller per hill, test weight, number of filled grains per panicle were also higher with Glyricidia plus NPK treatment.

Anwarulla and Chadrashekar (1996) reported that there was no significant difference both in grain and straw yield in the four green leaf manures viz., Glyricidia, pongamia, sesbania and eupatorium when used in combination with 50 per cent of inorganic nitrogen compared to 100 per cent RDF.

Haravade *et al.* (1996) reported that highest grain yield (6.5 t ha^{-1}) was obtained with glyricidia plus 200:75:75 kg NPK plus 1kg Zinc ha^{-1}.

Application of either green manure or FYM along with recommended NPK produced significantly higher grain yield of rice than only NPK fertilizer as per the report of Subbaiah and Kumaraswamy (1996).

Singh *et al.* (1998) reported that application of 50 per cent N either through green manure or FYM supplemented with 50 per cent NPK through fertilizers gave highest grain yield of rice in rice-rice system compared to only NPK fertilizers.

Talathi *et al.* (2000) reported that application of 50 per cent recommended NPK through fertilizers + 50 per cent N through glyricidia recorded higher plant height (115.24 cm), No of tillers hill^{-1} (13.86) and No of leaves hill^{-1} (62.07) in rice compared to RDF only.

Ghodake *et al.* (2005) application of glyricidia 2 t ha^{-1} + goat manure 6 t ha^{-1} recorded higher grain yield of 4598 kg ha^{-1} and straw yield of 5342 kg ha^{-1} compared to application of FYM 4 t ha^{-1}.

Dass and Patnaik (2007) reported that application of 50 per cent NPK through fertilizers along with 50 per cent N through glyricidia recorded highest fingermillet grain yield of 18.7 q ha^{-1} and total biomass yield of 60 q ha^{-1} compared to only fertilizer except the grain yield obtained with 50 per cent NPK through fertilizers + 50 per cent N through FYM and 50 per cent NPK through fertilizers + 25 per cent N through Glyricidia + 25 per cent N through FYM.

Sridhar *et al.* (2007) reported that application of FYM 10 t ha^{-1} + Glyricidia 5 t ha^{-1} recorded higher plant height (85.90 cm), No of tillers hill^{-1} (15.93) and grain yield (46.8 q ha^{-1}) of rice compared to RDF alone.

Avudaithai and Somasundaram (2009) reported that application of Glyricidia 8.3 t ha^{-1} + vermicompost 4.2 t ha^{-1} recorded higher grain (3.75 t ha^{-1}) and straw yield (5.92 t ha^{-1}). Vijaymahantesh (2012) reported that application of 100 per cent N through organic source (50 per cent N through FYM and 50 per cent N through Glyricidia) recorded higher fingermillet grain (3849 kg ha^{-1}) and straw (7009 kg ha^{-1}) yield compare to control.

2.4. Effect of fertilizers on growth and yield of aerobic rice.

2.4.1 Effect of N levels on growth and yield of aerobic rice.

Nitrogen is extensively involved in plant metabolism having great impact on growth and yield of any crop. Rice is no exception to this dictum. Literature relevant to N response and uptake presented in this chapter amply support the importance of N for rice.

Application of nitrogenous fertilizer increased number of tillers, number of grains $panicle^{-1}$ number of spikelets per panicle (Munda, 1989) panicle length, filled grains per panicle, 1000 grain weight (Rafey *et al.*, 1989).

Maske *et al*. (1993) reported that application of nitrogen at different levels (at 0, 40, 80 and 120 kg N ha^{-1}) results in difference in height, number of functional leaves per hill, leaf area and dry matter per hill. They observed that with increase in nitrogen content all the above parameters increased.

Rao *et al*. (1996) reported that application of 100 kg N ha^{-1} in three splits (25 per cent basal + 50per cent tillering stage + 25 per cent panicle initiation stage) recorded maximum plant height, LAI, number of tillers per hill and dry matter.

Rao and Moorthy (1997) reported that with the increase in N application from 0-90 kg ha-1, plant height showed a significant increase.

Devasenamma *et al.* (1999) reported that nitrogen application caused significant variation in total dry matter production over control at all the crop growth stages. There was significant increase in total dry matter production with successive increase in levels of nitrogen up to 180 kg ha^{-1} at all stages of crop growth.

Kumari *et al.* (2000) conducted a field experiment to study the effect of different levels of nitrogen on growth of rice. They observed taller plants at higher level of nitrogen application *i.e*. 120 kg ha^{-1}. Dry matter production also increased with increased level of nitrogen.

Muhammad Mqsood *et al*. (2000) conducted a field experiment to study the effect of different levels of nitrogen on yield and yield component on BAS-385. They observed higher plant growth (98.1cm) at high levels of nitrogen *i.e* 120 kg ha^{-1}.

Rammohan *et al*. (2000) studied the influence of different levels of nitrogen on growth and yield of rice in coastal saline soils and reported that increase in nitrogen level increased the growth parameters and yield of rice.

Fageria and Baligar (2001) reported that nitrogen fertilizer application significantly increased dry matter of rice crop.

Pradhan *et al*. (2001) studied response of varieties (JK - 8, BG -1, RLM - 36 and OLM -203) by employing three nitrogen levels (0, 20 and 40 kg N ha^{-1}). The yield potential of little millet (*Panicum sumatrense*) OLM - 203 attained significantly taller plant, more tillers $hill^{-1}$, panicle $plant^{-1}$ including the panicle length in consecutive years of experimentation while test weight was not differed significantly in all years and significant increased yields were observed under 40 kg ha^{-1} in all 4 years.

Shivay *et al.* (2002) revealed that the application of 120 kg N ha^{-1} recorded significantly higher cob number, cob length, cob diameter, grains per cob, test weight and grain yield (32.7 q ha^{-1}) over no fertilizer application.

Somasundaram *et al.* (2002) observed significant increase in plant height, leaf area index and dry matter accumulation with each successive increase in N level from 0 to 150 kg ha^{-1}. Addition of N from 100 to 150 kg ha^{-1} did not significantly improve the above parameters. However, maximum values for growth parameters were recorded at 125 kg N ha^{-1}.

Grazia *et al.* (2003) observed that application of 200 kg N ha^{-1} recorded significantly higher leaf area, plant height, cob diameter and biomass production of maize when compared to no nitrogen application.

Jayaprakash *et al.* (2003) reported that dry matter production, length of cobs, number of grains per cob, grain and stover yield were significantly higher with 150 kg N ha^{-1} over control.

Indira Chaturvedi (2005) reported that dry matter accumulation increased significantly with N-fertilizer application of Ammonium Sulphate Nitrate (ASN) in rice at all growth stages of the crop.

Different levels of nitrogen significantly influenced on yield and yield attributing parameters. The highest grain yield (3.70 t ha^{-1}) was recorded with 150 kg N ha^{-1} (Hossain *et al.*, 2006).

Manzoor *et al*. (2006) studied the effect of nine different nitrogen levels i.e. 0, 50, 75, 100, 125, 150, 175, 200 and 225 kg ha^{-1} on paddy yield and yield components. Plant height, number of productive tillers per hill, panicle length, number of grains per panicle, 1000 grain weight and paddy yield showed increasing trend from 0 kg N ha^{-1} up to 175 kg N ha^{-1}. The yield parameters including paddy yield, number of grains per panicle and 1000 grain weight at 200 kg N ha^{-1} level and above. Maximum paddy yield (4.2 t ha^{-1}) was obtained from 175 kg ha^{-1} nitrogen application treatment which also produced highest values of number of grains per panicle (130.2) along with a maximum 1000 grain weight (22.92 g). The plant height (139.8 cm) along with number of productive tillers per hill (23.42) and panicle length (29.75 cm) was maximum at 225 kg N ha^{-1} level.

Singh and Kumar Singh (2006) reported that application of nitrogen (80 kg ha^{-1}) along with blue green algae and azolla recorded significantly higher grain yield of rice (46.20 q ha^{-1}) as compared to control (without N).

Senthil Kumar *et al.* (2007) reported that the beneficial effect was evident with increases in the level of nitrogen, 150 per cent recommended dose of nitrogen was better than 125 per cent and 100 per cent dose of nitrogen.

The grain and stover yields were highest under the application of nitrogen at 120 kg ha^{-1} and it was on par with nitrogen at 90 kg ha^{-1} in the case of winter maize as observed by Tripathi *et al*. (2007).

Maheswari *et al.* (2008) opined that N levels increased the chlorophyll content, increasing levels of nitrogen progressively enhanced panicles per m^2, filled grains $panicles^{-1}$, grain and straw yield.

Stalin *et al*. (2008) recorded significantly higher grain yield of rice (5.61 t ha^{-1}) by applying N based on SSNM approach with 115 + 20 kg N ha^{-1} and real-time N management (N applied at 15, 29 and 43 DAT) as compared to other treatments. This was mainly due to more number of productive tillers m^{-2} (475 m^{-2}) and number of grains per panicle (75.5).

Kunjir *et al*. (2009) reported that in sweet corn application of 150 and 225 kg N ha^{-1} recorded significantly higher values for all growth attributes than 75 kg N ha^{-1} and control.

Maragatham *et al. (*2010) revealed that application of 50 per cent of N as Urea + 50 per cent of N as poultry manure recorded higher growth characters, yield attributes and grain yield which was closely followed by application of 100 per cent of N as urea.

Siddaram *et al.* (2010) revealed that the levels of nitrogen increase yield attributes like number of productive tillers $hill^{-1}$, number of filled grains $panicle^{-1}$ and 1000 grain weight differed significantly due to various levels of nitrogen.

Ashouri and Amiri (2011) showed that weight of 1000 grain in 150 kg ha^{-1} N fertilizer was 22.2 g in 2008 and 23.3 g in 2009. The highest paddy yield at 200 kg N per hectare might be due to higher number of grains per panicle and 1000-grain weight at this nitrogen rate

Murthy *et al*. (2012) reported that the nitrogen uptake by grain and straw only up to 120 kg ha^{-1}.

2.4.2 Effect of P levels on growth and yield of aerobic rice

Singh and Modgal (1978) found that modern semi dwarf rice removed 16 kg of P from the soil, of which 60per cent was translocated to the grain. For upland rice P is the most limiting factor after water for proper root development.

Mahapatra and Srivastava (1983) reported that N application significantly influenced P uptake in grain and straw. Short duration (100-110 days) upland rice responded to up to 18 kg applied P ha^{-1} in *laterite* soils of eastern India.

Reddy *et al*. (1984) reported that plant height, number of tillers and dry matter increased significantly with increasing level of P_2O_5 from 40 to 60 kg ha^{-1}.

Annadurai and Palaniappan (1994) reported that the rice soil high in available P did not respond to applied P. Application of graded levels of phosphorus (0, 9.5, 19 and 38 kg P_20_5 ha^{-1}) significantly improved the number of productive tillers and 1000 grain weight which in turn increased the yield.

Pawar and Chavan (1996) studied the response of rice to different sources of complex phosphatic fertilizers in lateritic soils and reported that the treatment nitrophosphate produced significantly higher number of tillers per hill. Urea ammonium phosphate and urea + single super phosphate were next in performance and at par with each other.

Kirk *et al.* (1998) reported that deficiency of P mainly noticed in drought prone environment because, mobility of P decreases sharply as soil dries. He also pointed out P fertilization is critical in crop establishment under dry condition.

Plant height, panicle length and grain yield increased significantly up to 30 kg P_20_5 ha^{-1} and difference between 30 and 60 kg P_20_5 ha^{-1} were non significant (Singh *et al.,* 1999).

Singh and Verma (2000) conducted field experiments to study the response of rice to 4 levels of P_2O_5, *viz*., 0, 30, 60 and 90 kg P_2O_5 ha^{-1}. They found that both grain and straw yields increased with graded levels of P_2O_5 application. There was significant response to applied P up to 60 kg P_2O_5 ha^{-1}.

Panhawar and Othman (2011) reported that phosphorus is essential for tillers development and root growth of wheat. Phosphorus is important for plant growth and promotes root development, tillering, early flowering and performs other functions like metabolic activities, particularly in synthesis of protein.

2.4.3 Effect of K levels on growth and yield of aerobic rice.

Mahapatra *et al.* (1980) reported that upland rice responded to 33 kg K_2O ha^{-1} applied at planting. Applying it in equal splits at planting and as a topdressing or foliar application 30 days after sowing was similar to applying a single basal dose, he also concluded applied 33 and 66 kg ha^{-1} in 2, 3, 4, or 5 splits.

Hati and Misra (1982) studied the effect of levels of potash on dry matter of rice. They used four levels of K (0, 30, 60, 90 and 120 kg ha^{-1}) as muriate of potash. They reported that potash treatments effected significant variations in the dry matter at 60 days and at harvest. The dry matter increased significantly with increase in level of potash up to 60 kg ha^{-1}. A decline in the dry matter was observed at 120 kg ha^{-1}.

Ravi and Rao (1992) conducted a field experiment to study the effect of graded levels of potassium and times of application, with three levels of potassium (0, 60 and 120 kg ha^{-1}) and four schedules of application (All basal, half as basal + half at 30 DAT, half as basal + half at PI stage and 1/3 equally as basal, at 30 DAT and at PI stage). They observed that dry matter production significantly increased at 90 DAT and at harvest due to levels of potassium only. A significant superior LAI was obtained.

Bohra and Doerffling (1993) revealed that increasing levels of K application improved plant height, tiller number and shoot dry weight at flowering. However, significant difference was observed only in the sensitive variety IR-28, whereas K_{50} and K_{75} treatments produced significantly higher value than the K_0 treatment.

Poonam *et al.* (1993) reported that grain yield of rice was influenced significantly by the application of 20, 40 and 60 kg K_2O ha^{-1} as basal dose which gave 16.79, 67.17 and 98.57 per cent higher grain yield than control (0 kg K_2O ha^{-1}).

Upadhyay (1995) reported that different levels of potash did not alter significantly various yield components *viz.,* number of productive tillers m^{-2}, number of filled spike lets $panicle^{-1}$, length of panicle and panicle weight, except plant height, which was maximum at 75 kg K_2O ha^{-1} but were at par with 100 kg K_2O ha^{-1} and 125 kg K_2O ha^{-1}.

Panda *et al*. (1999) reported that application of K_2O at 40 kg ha^{-1} recorded significantly higher uptake of N, P and K over control. The additional increase in N, P and K uptake over control was 1, 0.4 and 2.21 kg, respectively.

Raju *et al*. (1999) reported that rice yield and its attributing characters responded favorably to higher dose (60 kg K_2O ha^{-1}) of K, but not at lower doses (40 kg K_2O ha^{-1}) except when the entire dose was applied at panicle initiation stage.

Bhiah *et al.* (2010) studied the effect of potassium on rice lodging under high nitrogen (N) and phosphorus (P) nutrition in the absence of applied potassium (K). Application of K significantly increased tiller number (40-140 per cent), plant height (<30 per cent), shoot (120-140 per cent) and root (80-300 per cent) dry matter production and stem diameter (30-80 per cent) in all varieties, although differences between varieties were observed. Lodging occurred primarily from the base, due to poor root growth in the absence of K. Potassium application successfully overcome lodging incidence in all three varieties. Trials of both K application and seedling planting depth should be investigated in lodging susceptible areas of the Iraqi rice production region.

2.4.4 Effect of Nitrogen, phosphorus and potassium on growth and yield of rice.

Among several factors responsible for increase in rice production, adequate supply of essential nutrients in balanced way is one factor for getting good yield. This is particularly true for high yielding varieties and hybrids. Much of the nutrients required by the rice crop come from the soil but is insufficient to meet the nutrient requirements for high rice yields. Balanced nutrition for direct seeded rice is of much greater importance than application of a single nutrient source to restore the soil fertility over and above increasing the productivity. Some of the research findings for the balanced nutrition to get higher yields were listed bellow.

Venkateshwaralu and Mahatim Singh (1980) opined that yield reached maximum average yield of rice at 120 kg N+ 60 kg P_2O_5 +45 kg K_2O ha^{-1} (35.31 q ha^{-1}). In aerobic rice higher grain yield is attributed to the adequate supply of nutrients and higher uptake and recovery of nutrients from higher levels of nutrient application.

Dwivedi and patel (1988) reported that application of NPK @ 120 + 80 + 60 or 80 + 60 + 40 kg ha^{-1} gave average paddy yield of 5.02 and 4.89 t ha^{-1}, respectively, compared with 3.05 t ha^{-1} without NPK. Crops grown at a spacing of 10 cm in rows 10 or 20 cm apart gave yields of 3.77 and 4.44 t ha^{-1}, respectively.

Sudha (1990) reported that the maximum rice grain yield (7152 kg ha^{-1}) produced with 125 kg N, 62 kg P_2O_5, 62 kg K_2O ha^{-1}.

Anil kumar *et al.* (1992) noticed that application of NPK fertilizers to rice did not cause significant variations in the micronutrient content of the soil. Soil available Fe and Mn initially increased after submergence and then decreased, while Zn and Cu availability decreased with the period of submergence.

Pandey and Tripathi (2007) observed that the uptake of N, P and K by the crop increased significantly with subsequent increase in the fertilizer levels. This was because of higher availability of these nutrients, which resulted in enhanced nutrient content in plant tissues and higher biomass production at higher fertilizer levels.

Umapathy *et al.* (1994) reported that the growth and yield of grain and straw of drill sown early, medium and late rice genotypes increased significantly upto the fertilizer level of 100: 50: 50 kg NPK ha^{-1} because of fast release of nutrients than organic nutrient sources.

Mahabari *et al.* (1995) reported that rice cv. RDN-185-2 (Gargoti and Bidri) and Dodaga (local, Bhatshirgaon) were given 100 kg N as urea or ammonium sulphate + 50 kg P_2O_5 + 50 kg K_2O ha^{-1} at various application dates. Grain yield was highest with 100 per cent P + 100 per cent K + 50 per cent N applied at sowing + 50 per cent N applied 15 days after germination. Ammonium sulphate gave a higher yield and N use efficiency than urea.

Asif *et al.* (1999) reported that yield were higher with the 2 higher NPK rates than with the lowest rate, with the middle rate giving the best grain quality. Split application of N gave higher yields than a single dose.

Saud *et al*. (1999) rice cv. Bishnuprasad and Jyotiprasad were give 0 to 120: 90: 90 kg N: P_2O_5 : K_2O ha^{-1}. The application of 100: 50: 50 kg N: P_2O_5: K_2O produced a mean grain yield of 4.57 t ha^{-1} and the highest net returns.

Shetty and Naresh (1999) reported that yield was 4.93 t ha^{-1} with 150:75:75 kg N: P_2O_5: K_2O ha^{-1} with NPK, 200:100:100 kg ha^{-1}, and did not increase with further increase in NPK rate. Percentage sterility was higher in the hybrid than in cv. IR-60, and increased with increasing NPK rate.

Cheng- Wang Da *et al.* (2000) reported that application of N at an intermediate rate with an NPK ratio of 1.0:1.2:0.9 had the highest fertilizer use efficiency, crop yield and quality. The rational application of NPK fertilizers increased milled head rate and reduced chalkiness.

Pathak (2000) reported that application of balanced fertilization (250-150-150-40-5, N-P_2O_5-K_2O-S-Zn kg ha^{-1}) recoded significantly highest grain yield of rice (10 t ha^{-1}) than state recommended fertilizer dose (6.87 t ha^{-1}).

Srinivasan and Angayarkanni (2008) reported that higher doses of N, P and K fertilizers increased the N, P and K uptake which might be due to an increase in the nutrient content in the plant.

Shekara *et al.* (2010) reported that application of 75:37.5:50 N P_2O_5 K_2O kg ha^{-1} recorded significantly higher nutrient use (36.32, 35.59 and 34.42 kg grain ha^{-1} nutrients, respectively) efficiency.

Rajanna *et al.* (2012) reported that application of recommended dose of fertilizer (100:50:50 kg N:P:K ha^{-1}) + 10 tonnes of FYM ha^{-1} recorded significantly higher growth indices like plant height (63.2), number of tillers per hill (35.7), leaf area (1509.8 cm^2 $hill^{-1}$), leaf area index (LAI) (2.42), leaf area duration (LAD) (56.49 days), absolute growth rate (AGR) (1.6806 g $p^{-1}day^{-1}$), relative growth rate (RGR) (0.1369 g $g^{-1}day^{-1}$) and dry matter production, similar results were founded by Parashivamurthy *et al.* (2012).

2.5. Effect of bio-fertilizers on growth and yield of aerobic rice.

Taha *et al*. (1969) observed that inoculation of soils with phosphate solubilizers like *Bacillus megatherium*, *Pseudomonas* increased the yield of barley plants.

Gaur and Ostwal (1972) reported inoculation of wheat with *Bacillus polymyxa* significantly increased the grain and straw yield of wheat.

Datta *et al.* (1982) reported that there was an increase in dry matter yield of rice (Jaya and IR-8) due to inoculation with phytohormone producing P solubilizing bacterium *Bacillus firmis* inoculated along with rock phosphate and superphosphate.

Gaur and Singh (1982) obtained increased yield of rice by inoculation of seedling roots with *Bacillus polymyxa* along with rock phosphate. The yield with 60 kg rock phosphate with the above culture was as good as super phosphate applied at 60 kg P_2O_5 ha^{-1}.

Mohod *et al.* (1991) reported that the P-solubilizing cultures (*Pseudomonas striata* and *Bacillus polymyxa*) significantly increased the number of grains per panicle, weight of 1000 grains, grain weight per panicle, grain yield and straw yield of rice variety KJP-184. The cultures were more efficient with rockphosphate than with super phosphate.

Mehta *et al*. (1996) in their experiment on integrated nutrient management of sugarcane recorded an increased cane yield up to 6.6 per cent and sugar yield up to 10.2 per cent when inoculated with *Pseudomonas* over uninoculated control with recommended dose of inorganic fertilizers.

Panhwar *et al.* (2011), revealed that significantly, high P solubilisation (28.7 mg kg^{-1}) and plant uptake (7.94 mg kg^{-1}) was found in PSB16 inoculated treatments at 30 kg ha^{-1} of P_2O_5. In this treatment were also observed high leaf chlorophyll content (34.57), photosynthesis rate (7.59 μ mol CO_2 m^{-2} s^{-1}) and root development. Isolated strains showed potential to make higher availability of P and increase content of organic acids from soil and roots at lower doses of TSP in aerobic rice.

2.6. Effect of Integrated Nutrient Management on growth and yield of aerobic rice.

Kamala Kumari and Singaram (1996) recorded significantly higher grain (47.7 q ha^{-1}) and stover yield (8.85 t ha^{-1}) due to combined application of FYM at 10 t ha^{-1} and 100 per cent NPK over 150, 100 and 50 per cent NPK, 100 per cent NPK + 25 kg $ZnSo_4$ ha^{-1}, 100 per cent N and 100 per cent N and P.

Dwibedi and Singh (1997) revealed that FYM plus urea (50 : 50 per cent) application along with P and K at 50 per cent recommended dose was significantly superior to FYM or NPK and recorded highest grain (23.16 q ha^{-1}) and straw (10.10 t ha^{-1}) yield of finger millet under rainfed hill farming system at Ranichuri, U.P.

Selvakumari *et al*. (1998) reported application of NPK as fertilizers plus compost plus Azospirillum as per STCR technology for an yield target of 60 q ha^{-1} recorded significant increase of 16.0 q ha^{-1} of grain yield over NPK alone and 8.6 q ha^{-1} of additional grain yield over NPK + fly ash at 40 t ha^{-1} in rice.

Shivakumar (1999) reported that application of 50 per cent recommended NPK through fertilizer along with 50 per cent NPK through bio-agro rich produced significantly more number of fingers per ear head (6.51), more grain weight per hill

(16.0 g hill^{-1}) and resulted in higher grain yield (40 q ha^{-1}) of finger millet. Application of FYM (10 t ha^{-1}) along with 100 per cent recommended NPK recorded significantly higher grain yield (33.56 q ha^{-1}) of finger millet compared to recommended NPK (22.55 q ha^{-1}) (Anon ., 2000).

Singh and Verma (1999) noticed that application of FYM at 10 t ha^{-1} coupled with 50 per cent recommended N recorded maximum values of yield attributes of rice, viz., number of tillers hill^{-1}, panicle length and grains panicle^{-1} and increased the grain yield to the tune of 77.6 per cent compared to 100 per cent fertilizer alone.

Anil Kumar (2000) revealed that application of 7.5 t ha^{-1} of compost with recommended dose of fertilizers (RDF) produced significantly higher dry matter hill^{-1} (1.60, 7.85, 16.24 and 30.52 g at 30, 60, 90 DAS and at harvest, respectively) as compared to recommended fertilizers (1.54, 7.42, 15.26 and 26.91 g hill^{-1} at 30, 60, 90 DAS and at harvest respectively) of finger millet.

Babu and Reddy (2000) reported that higher grain yield (38.26 q ha^{-1}) as well straw yield (6.79 t ha^{-1}) of rice was obtained by applying FYM @ 5 tonnes along with 50 kg N ha^{-1}. The yield was superior to 100 per cent NPK alone, which had less grain (35.56 q ha^{-1}) and straw (6.68 t ha^{-1}) yields. Further, observed that uptake of nutrients was higher by the combined use of 5 t FYM and 50 kg N ha^{-1} (137 kg N, 46 kg P_2O_5 and 231 kg K_2O ha^{-1}), which lead to produce higher plant height (82.9 cm), more number of tillers per plant (16.4), Leaf area index (5.4), higher dry matter (32.13 g plant^{-1}), more panicles per plant (15) and more number of spike lets (123), lowest chaffiness (9.3 per cent) coupled with higher harvest index (0.35).

Chandrashekara *et al.* (2000) noticed higher grain yield of maize (50.8 q ha^{-1}) and fodder (7.44 t ha^{-1}) with the application of poultry manure at 10 t ha^{-1} + RDF (150:75:37.5 kg NPK ha^{-1}) over vermicompost at 2.5 t ha^{-1} or FYM 10 t ha^{-1} + RDF.

Dey (2000) reported that higher grain and straw yields (36.40 and 94.88 q ha^{-1} respectively) were obtained with application of 100 per cent NPK along with 10 t of

FYM ha^{-1}, which were on par with 75 per cent (35.61 and 91.25 q ha^{-1} respectively) and 50 per cent of fertilizers rate (35.34 and 91.62 q ha^{-1}, respectively) combined with 10 t of FYM ha^{-1}.

Parasuraman *et al.* (2000) reported that application of FYM (10 t ha^{-1}) recorded significantly higher plant height of finger millet over control and found to be on par with recommended inorganic fertilizers in loamy sand soils of Paiyur.

Azad and Lehina (2001) studied the usage of organic and inorganic sources of nutrients. They observed that application of FYM at 10 t ha^{-1} in conjunction with different fertilizer levels exhibited a significant increase in effective tillers, grain and straw yields of rice as compared to 100 per cent fertilizers treatment alone.

Murali and Setty (2001) reported that application of vermicompost at 5 t ha^{-1} combined with NPK at 150:75:75 kg ha^{-1} recorded significantly higher grain yield (48.89 q ha^{-1}) of rice crop as compared to no vermicompost application (40.70 q ha^{-1}). Increased grain yield with vermicompost was because of significantly higher yield attributes like number of panicle per hill (10.91) and number of grains per panicle (186.82) due to increased availability of nutrients.

Nanjappa *et al*. (2001) reported that combined application of 50 or 75 per cent recommended dose of fertilizer with 12 t FYM ha^{-1} or 2.7 t vermicompost ha^{-1} caused higher productivity of maize compared to the application of organic manures.

Purushottam Kumar *et al.* (2001) revealed that the application of FYM at 15 t ha^{-1} + 90 kg N ha^{-1} recorded on par grain yield of maize with the application of 90 kg N ha^{-1} alone and FYM at 15 t ha^{-1} + 45 kg N ha^{-1}. These treatments were significantly superior over control (no fertilizer and manure application).

Balasubramaniyan *et al.* (2002) obtained higher grain yield of rice to the tune of 3.9 t ha^{-1} by adopting integrated nutrient management system, which had the combination of FYM, green manure and 100 per cent recommended dose of fertilizer.

Beena and Balachandran (2002) reported that the grain and straw yields of rice which received a combination of 100 per cent NPK along with FYM was significantly higher (31.19 and 39.56 q ha^{-1}, respectively) as compared to the treatment that received only NPK fertilizers (25.48 and 22.93 q ha^{-1}, respectively).

Significantly higher grain yield of maize (56.02 q ha^{-1}) was recorded with the application of poultry manure (1 t ha^{-1}) + 100 per cent RDF (150:75:37.5 kg NPK ha^{-1}) when compared to FYM (5 t ha^{-1}) + RDF or vermicompost (2 t ha^{-1}) + RDF and control (Basavaraj and Manjunath, 2003).

Jayaprakash *et al.* (2003) reported higher grain yield of maize with the application of vermicompost at 2 t ha^{-1} (67.47 q ha^{-1}) and FYM at 10 t ha^{-1} (65.22 q ha^{-1}) compared to control (52.35 q ha^{-1}). Dry matter content, length of cob, number of grains cob^{-1}, grain yield, stover yield and total N uptake were significantly higher with 150 kg. N ha^{-1} over lower levels of N and control. However, nitrogen and protein content could increase significantly up to 50 kg N ha^{-1} + *Azospirillum* (Jat and Balyan, 2004).

Higher grain yield (59.39 q ha^{-1}) of rice was recorded with the application of 25 per cent of N through FYM along with 100 per cent fertilizer through urea and was significantly superior over 100 per cent RDF (54.87 q ha^{-1}). Combined application of inorganic fertilizers with FYM increased the productive tillers per hill, panicle length and number of grains per panicle (Malla Reddy *et al*., 2003).

Manish Kumar *et al. (*2003) reported that integrated use of wheat straw (10 t ha^{-1}), 100 per cent RDF and FYM resulted in higher grain yield (4.5 t ha^{-1}) of rice crop.

Sudha and Chandini (2003) observed that application of vermicompost at 5 t ha^{-1} had positive influence on growth and yield attributes of rice and resulted in better grain (45.4 q ha^{-1}) and straw yield (5.15 t ha^{-1}) along with NPK dose of 105:52.5:52.5 kg ha^{-1} supplied through inorganic sources.

Subha and Gajendra Giri (2004) reported that application of Vermicompost alone or in combination with 50 per cent RDF recorded significantly higher dry matter in maize over 50 per cent RDF alone.

Ashok kumar *et al.* (2005) reported that the growth parameters, yield attributes and yields of maize and wheat crops were found maximum when 100 per cent NPK was applied along with FYM at 10 t ha^{-1}.

Kholy *et al.* (2005) observed a positive and significant correlation between maize yield and that of plant height, ear height, and ear length, grain weight, shelling percentage, grain index, straw yield and biological yield. But, this correlation was not significant with rows number per ear head, grain number per row, crop index and harvest index due to associative action of bio-fertilizers.

Rajashekar Reddy (2006) reported that higher yield (66.58 q ha^{-1}) was obtained by applying 75 per cent inorganic fertilizers (RDF) with 25 per cent organic nutrients (through FYM, vermicompost and poultry manure in equal proportion) over control treatment.

Prakash *et al.* (2010) conducted a field experiment at Agricultural Research station, Honnavile. Shivamogga during *kharif* 2007 to study the effect of INM approaches on productivity of rice crop *(Oryza sativa)*. The results of the experiment indicated that the treatment which received 50 per cent N through urea + 25 per cent N through GM + 25 per cent N through FYM + *Azospirillum* recorded highest value of yield attributes, grain and straw yield. The highest net return was also recorded in the same treatment as compared to fertilizer alone.

Devi *et al*. (2011) revealed that the application of 100 per cent recommended dose of fertilizers (RDF) i.e. 120:26:4:50 N:P:K kg ha^{-1}+ vermicompost @ 5 t ha^{-1} +phosphate solubilizing bacteria (PSB) and75per cent RDF + vermicompost @ 1 t ha^{-1}+ PSB produced higher yield attributes and grain yield than the other treatments.

The higher yield led to higher NPK uptake by wheat. Further, the available NPK content of soil also increased in above INM treatment over control.

Parasuraman *et al.* (2000) reported that application of FYM (10 t ha^{-1}) recorded significantly higher plant height of finger millet over control and found to be on par with recommended inorganic fertilizers in loamy sand soils of Paiyur.

From a long-term experiment in sorghum-wheat cropping system, Katkar *et al.* (2012) concluded that highest grain yield of sorghum was recorded with the application of 150 per cent NPK during initial nine years, but subsequently the treatment of 100 per cent NPK + FYM showed its superiority over 150 per cent NPK. Application of only FYM at 10 t ha^{-1} before sowing of sorghum crop reduced the yield to the tune of 60.4 per cent over 100 per cent NPK and could not sustain the crop productivity.

Paramesh *et al.* (2013) revealed that among integrated nutrient management practices 50 per cent RDN through chemical fertilizers + 50 per cent RDN through vermicompost recorded significantly higher plant height (80.54 cm), leaf area (1537.69 cm^2), number of tillers $hill^{-1}$ (30.04), total dry matter accumulation $hill^{-1}$ (84.78 g) grain yield (39.48 q ha^{-1}) and straw yield (52.9 q ha^{-1}).

Sharma *et al.* (2013) reported that application of fertilizers on the basis of soil test (100 per cent NPK) was more effective in comparison to below recommended levels (75 per cent or 50 per cent NPK), but the integrated use of organic, inorganic and biofertilizers (75 per cent NPK + 5 t ha^{-1} FYM + *Azotobactor* + PSB and Zn) was more effective in enhancing the yield and protein quality of wheat crop.

Yogesh *et al.* (2013) revealed that among the different treatments RDF + FYM 10 t ha^{-1} + ZnSO4 @ 20 kg ha^{-1} + VAM + Azospirillum + PSB recorded significantly higher grain yield (43.63 q ha^{-1}).

Manoj Dutta and Roba Sangtam, (2014) revealed that the grain yield in NPK+Poultry litter, NPK+FYM+Zn, NPK+FYM and NPK+Forest litter increased significantly (55.9, 45.7, 37.0 and 29.8per cent, respectively) as compared to addition of NPK alone.

2.7. Effect of Integrated Nutrient Management on nutrient uptake.

Application of Vermicompost increased the uptake of primary and secondary nutrients such as N, P, K, Ca and Mg by rice and maximum nitrogen uptake was recorded by the conjunctive use of 75 kg N ha^{-1} through urea along with 25 kg N ha^{-1} through vermicompost (Jadhav *et al*., 1997).

Murali and Setty (2001) observed that application of vermicompost at 5 t ha^{-1} combined with NPK at 150-75-75 kg ha^{-1} recorded maximum total nitrogen uptake (168 kg ha^{-1}) as compared to no vermicompost treatment (1152 kg ha^{-1}).

Yaduvanshi (2001) reported that application of inorganic fertilizers alone or in combination with green manure or FYM significantly enhanced the uptake of N by rice and wheat crop as compared to N alone and control treatment. The mean increase in uptake of N over control with 50 per cent recommended treatment and its combined use with green manuring and FYM and 100 per cent recommended treatments was 39.3, 78.1 and 77.3 kg ha^{-1} in rice and 36.8, 47.2, 44.8 and 76.4 kg ha^{-1} in wheat respectively.

Manoj Kumar and Singh (2003) reported that, the nitrogen and phosphorous uptake by grain and stover of maize was increased significantly up to 150 kg ha^{-1} and 80 kg ha^{-1} respectively. The highest N uptake by grain was 12.68 kg ha^{-1} and by straw 20.77 kg ha^{-1}.

Application of recommended fertility dose along with the FYM at 10 t ha^{-1} resulted significantly higher grain yield, N, P and K uptake by 9.0, 11.0 and 9.87 per cent compared with the recommended fertility alone (Ravindra Singh and Agarwal., 2004).

Rathore *et al.* (2008) observed that rice grain yield (55.7 q ha^{-1}) was significantly higher with the application of FYM at 5 t ha^{-1} along with NPK (60:37.5:22.5 kg ha^{-1}) as compared to control. Further increase in plant uptake of 9 to 12 kg N ha^{-1} and 3 kg P_20_5 ha^{-1} in FYM treated plots was observed at harvest stage.

Shashidhar *et al*. (2009) concluded that significantly higher uptake of nitrogen (185.86 kg ha^{-1}), phosphorus (64.13 kg ha^{-1}), and potassium (180.24 kg ha^{-1}) by maize plant was recorded in the treatment received 125 per cent recommended NPK coupled with poultry manure on N equivalent basis of recommended FYM as compared to rest of the treatments and lower uptake of nitrogen (102.18 kg ha^{-1}), phosphorus (17.92 kg ha^{-1}) and potassium (95.52 kg ha^{-1}) was observed with application of only recommended NPK through inorganic fertilizers. Further, continuous application of FYM 10 t ha^{-1} to finger millet mono cropping also recorded significantly higher organic carbon (0.41 per cent), available N (148.78 kg ha^{-1}), available phosphorus (20.03 kg ha^{-1}) and available potassium (136.41 kg ha^{-1}) as compared to control (0.26, 94.34, 18.25 and 113.21, respectively).

Siddaram *et al.* (2010) revealed that Significantly higher nitrogen, phosphorus and potassium uptake (124.2, 30.6 and 93.9 kg ha^{-1}, respectively) registered with recommended dose of fertilizer (100:50:50 kg N:P:K ha^{-1}) + 10 tonnes of FYM ha^{-1}.

Jayakumar *et al*. (2014), revealed that application of 100N + 50P_2O_5 + 50K_2O kg through fertilizers + 10 t FYM ha^{-1} and 50 N + 50 K_2O kg ha^{-1} through fertilizers + 50 kg 50 P_2O_5 through P enriched compost recorded a higher grain yield of 8.14 and 7.96 t ha^{-1} and a straw yield of 10.5 and 10.36 t ha^{-1} respectively. The higher grain yield is due to increased tillers (10.3 and 8.2), productive tillers (7.9 and 7.4), panicle weight (3.9 and 3.4g), gain number panicle^{-1} (135 and 121) and test weight (29.3 and 29.8 g).

Shah and Kumar (2014) revealed that the maximum grain yield (63 and 67 q per hectare during 2009 and 2010, respectively) was obtained with the integration of NPK 50 per cent RDF + Neem cake @ 2.5 tonnes ha^{-1} + FYM @5 tonnes ha^{-1} + Azotobacter + PSB @ 5 kg ha^{-1}.

2.8. Effect of Integrated Nutrient Management on economics of aerobic rice.

Mehla and Panwar (2000) obtained higher gross returns (RS. 45425 ha^{-1}) with the conjunctive use of FYM and nitrogen in aromatic rice as compared to FYM alone (Rs. 36225 ha^{-1}).

Aravind Kumar and Prasad (2002) conducted experiments dur*ing Kharif* and *rabi* season from 1997 to 2000 at Ranchi and revealed that higher rice and straw yield (21.7 and 41.4 q ha^{-1}, respectively) and higher annual net returns of Rs. 33415 ha^{-1} were obtained in rice-berseem crop sequence treated with 75 per cent NPK along with 10 tonnes of FYM ha^{-1} in both *Kharif* and *rabi* season (17.0 and 34.2 q ha^{-1} respectively) as compared to fertilizer alone with net returns of RS. 36189 ha^{-1}.

Mondal *et al.* (2003) reported that the higher grain yield (6 t ha^{-1}) and the higher benefit cost ratio (1.82) was recorded with 75 per cent of RDF along with 4 tonnes of FYM ha^{-1} as compared to 100 per cent NPK alone (1.61).

Jose Mathew *et al.* (2005) recorded higher cost of cultivation (Rs. 11026 ha^{-1}) with the conjunctive use of FYM and RDF as compared to green manure in summer and the use of 50 per cent nitrogen and full dose of phosphorous and potassium fertilizer (Rs. 9772 ha^{-1}). Net income was also higher in the former treatment (Rs. 3064 ha^{-1}) as compared to the later one.

Application of vermicompost at 5 tonnes ha^{-1} recorded lower benefit cost ratio of 1.05 whereas, the net monetary returns was Rs. 473 ha^{-1} in rice (Godhawale and Dahipale, 2007).

Prasanna Kumar *et al.* (2007) pointed out that gross returns of using vermicompost (2.5 t ha^{-1}) in maize cultivation was maximum (Rs. 29,592 ha^{-1}), but the benefit cost ratio ranked at last (1.59), because of higher cost of cultivation.

Jagathjothi *et al.* (2008) revealed that band placement of enriched FYM at 2 t ha^{-1} + 100 per cent of recommended N and K recorded higher microbial population viz., bacteria, fungi and actinomycetes with enhanced soil nutrient availability. Significantly higher grain and straw yield (32.69 q ha^{-1} and 5.90 t ha^{-1}) were obtained in the same treatment, while it was lowest in application of recommended fertilizer alone and as well as in control plot. The highest net return (Rs.13, 446 ha^{-1}) and benefit: cost ratio (2.69) was registered with band placement of enriched FYM at 2 t ha^{-1} + 100 per cent of recommended N and K in direct sown finger millet under rainfed condition.

Mathew *et al.* (2008) reported that the net income (Rs. 3064 ha^{-1}) was higher with the conjunctive use of FYM and RDF as compared to green manuring and RDF (Rs. 2465 ha^{-1}).

Yogesh *et al.* (2013), revealed that among the different treatments RDF + FYM 10 t ha^{-1} + ZnSO4 @ 20 kg ha^{-1} + VAM + Azospirillum + PSB recorded significantly higher cost of cultivation (Rs. 14165 ha^{-1}), gross returns (Rs. 44637 ha^{-1}) and net returns (Rs. 30472 ha^{-1}).

Material and methods

III MATERIAL AND METHODS

A field experiment was conducted to study the "Effect of integrated nutrient management on growth and yield of aerobic rice (*Oryza sativa* L.)" at Agriculture and Horticulture Research Station (AHRS), Bavikere, University of Agricultural and Horticultural Sciences, Navile, Shivamogga, Karnataka under rainfed condition with protective irrigation during *Kharif* 2014. The details of material used and techniques adopted during the course of investigation are presented in this chapter.

3.1 Location of the Experimental site

Agricultural and Horticulture Research Station, Bavikere is located in north western side of Tarikere, midway between Tarikere and Lakkavalli towns at a distance of 9 kms from Tarikere. The research station comes under Southern Transition Zone (Zone No- 7). It is situated between 75^0 51' E longitudes and 13^0 42' N latitude. The farm is having good transportation network in the form of both roads as well as railway network nearby Tarikere.

3.2 Physico-chemical properties of experimental soil

A composite soil sample was collected from the experimental site before start of the experiment and analyzed for its physical and chemical properties. Data pertaining to physical and chemical properties of experimental site was presented in Table 3.2

3.3 Climatic conditions

The normal weather data and the actual climatic condition that prevailed during crop growth period and the deviations from the normal with respect to rainfall, maximum and minimum temperature and mean relative humidity are presented in Table 3.1

3.3.1 Normal climatic conditions

The Normal annual rainfall of the station is 1037.61 mm. The major portion of it is received during August to September with two peaks in the months of October (113.9mm) and November (154.4 mm). The mean maximum air temperature ranges from 30.3^0C to 27.7^0C. The higher mean maximum temperature is recorded during

October (30.3^0C) is followed by November (30.2^0C). The Mean monthly relative humidity ranges from 80.3 percent in august to 60.3 per cent in December. The mean daily maximum sunshine hours are maximum during September (7.2 hours) followed by (4.9 hours) in August.

3.3.2 Actual climatic conditions during 2014

During the crop growth period the highest monthly rainfall was recorded in September 2014 (164.6 mm) and the lowest was in December 2014 (28.0 mm). During the cropping season a total rainfall of 549.38 mm was received. The average maximum air temperature of 32.8°C was recorded in the month of September and minimum temperature of 30.6°C was recorded during the month of December. The mean monthly relative humidity ranged from 86.2 per cent in August to 62.6 per cent in December during the crop period. The mean bright sunshine hour was higher during the month of September (8.1 hours) and higher of 4.7 hours during the month of December. The overall weather conditions prevailed during the cropping period was nearly normal.

Table 3.1 Meteorological data indicating monthly normal, actual and deviation of rainfall, relative humidity, temperature and sunshine hours during the experimental period at AHRS, Bavikere, for the year 2014

Month	**Rainfall (mm)**			**Temperature °C**			**Sunshine Hours**			**Relative Humidity (%)**		
	N	A	D	N	A	D	N	A	D	N	A	D
August	277.1	303.6	26.5	38.8	37.7	1.1	4.9	5.8	0.8	80.3	86.2	6.9
September	185.2	164.6	-20.6	31.8	32.8	0.4	7.2	8.1	0.9	77.5	85.8	8.3
October	118.9	142.8	25.9	30.7	31.3	0.6	5.5	7.3	1.7	75.1	74.3	0.7
November	154.4	32.3	122.1	30.6	31.2	1.1	6.0	5.6	0.4	69.6	71.6	2.0
December	-	28.0	28.0	30.1	30.6	0.5	7.0	4.7	2.3	65.3	62.6	3.76

A: Actual N: Normal Max: Maximum Min: Minimum

Note:

Annual Normal rain fall (average of 7 years) – 1037.61 mm

Annual Actual rainfall (January to December, 2014)-1288.7 mm

Normal rainfall received during cropping period (average 7 years) – 729.6 mm

Actual rainfall received during cropping period (August to December, 2014) 549.38 mm

Normal and Actual relative humidity, temperature and sunshine hours during the crop growth period

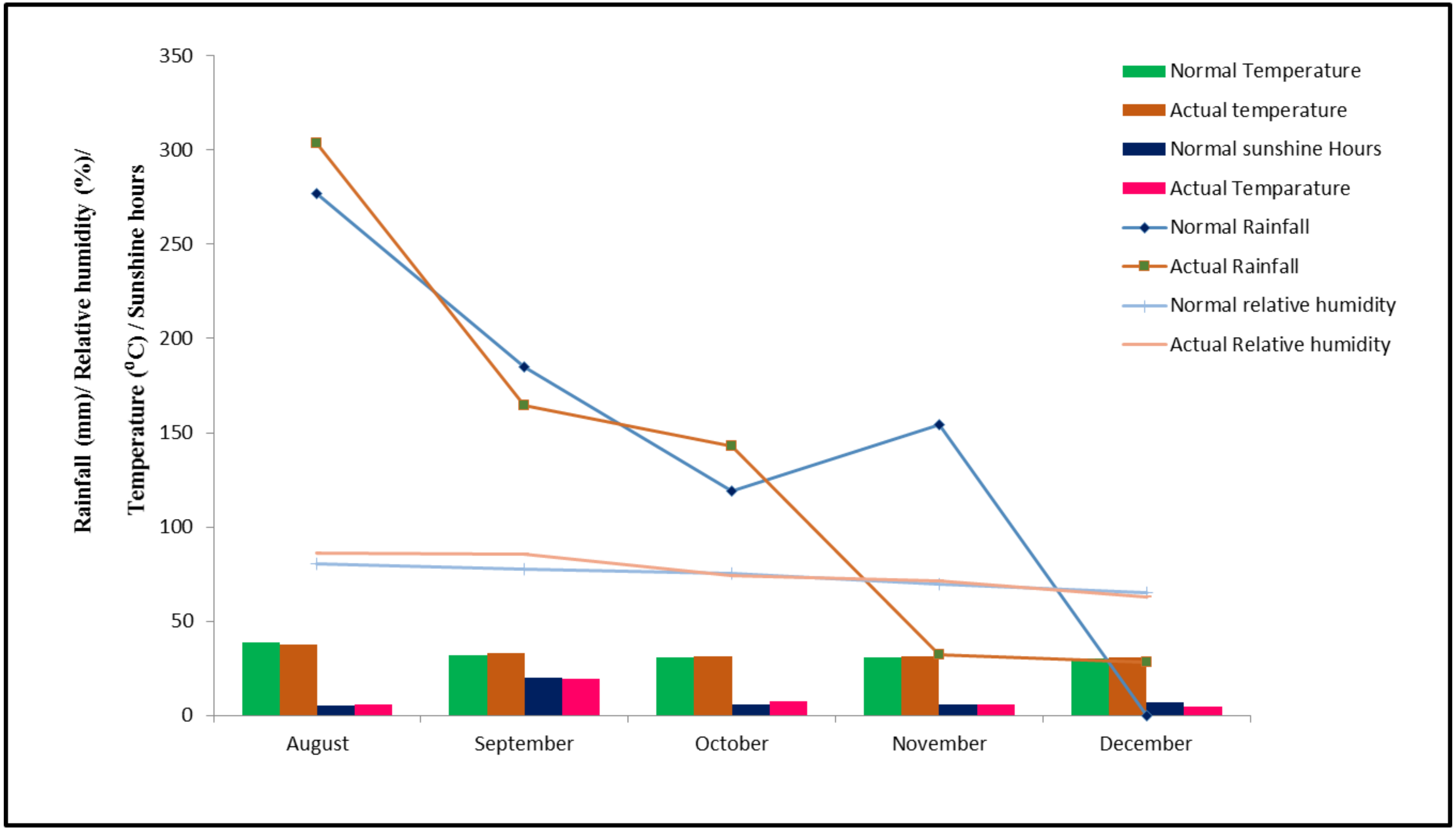

Figure 3.1 Meteorological data indicating monthly normal , actual and deviation of rainfall , relative humidity , temperature and sunshine hours during the experimental period at AHRS, Bavikere, for the year 2014

Table 3.2 Physico-chemical properties of soil in the experimental site

Particulars	Values	Status	Method followed
I. Physical properties			
1. Coarse sand (per cent)	65.55	-	International pipette method (Piper, 1966)
3. Silt (per cent)	16.60	-	
4. Clay (per cent)	17.80	-	
5. Soil type	Red clay loam		
II. Chemical properties			
1. pH	5.50	Acidic	Buckman's Zero metric pH meter (Piper, 1966)
2. EC (d Sm^{-1})	0.20	Low	Conductometry (Jackson, 1973)
3. Organic carbon (g kg^{-1})	5.6	Mediun	Wet digestion method (Walkley and Black, 1934)
4. Available N (kg ha^{-1})	265.16	Low	Alkaline permanganate method (Subbiah and Asija, 1956)
5. Available P_2O_5 (kg ha^{-1})	77.92	High	Bray's method (Jackson, 1973)
6. Available K_2O (kg ha^{-1})	153.73	Medium	Neutral Normal Ammonium acetate method (Jackson, 1973)

3.4 Cropping history of the experimental site

Cowpea crop was grown in the plot during July to December 2013. Latter on it was kept fallow during summer season of 2014 before taking up the present investigation.

3.5 Application of organic manures and treatment imposition.

Well decomposed farm yard manure, vemicompost and green manuring crop Glyricidia are collected from the Agriculture and Horticulture Research Station (AHRS), Bavikere. Nutrient content of the different organic manures was analyzed and the results are presented in Table. 3.3 The required quantity of organic manures were applied as per treatment to the different plots 15 days before sowing.

Table 3.3 Nutrient composition of different organic manures used in the experiment

Organic manures	Nutrient composition (per cent)		
	N	**P_2O_5**	**K_2O**
Farm Yard Manure	0.62	0.13	0.71
Vermicompost	1.18	0.82	0.68
Glyricidia	2.4	0.1	1.8

3.6 Salient features of the cultivar

Variety MAS 946-1 was developed by the University of Agriculture Sciences, Bengaluru at the Marker assisted selection laboratory, Department of genetics and plant breeding, GKVK, Bengaluru in 2007. It matures in 120-125 days. This is a semi-tall plant of 100-105 cm height and tolerant to blast disease. It reduces methane emission up to 70 per cent. It is having profuse rooting and high tillering capacity. The cultivar has medium slender grain type and yields 6 t ha^{-1}.

3.7 Experimental details.

1.	**Crop**	:	Rice
2.	**Variety**	:	MAS 946-1
3.	**Location**	:	AHRS Bavikere
4.	**Design**	:	RCBD
5.	**Treatment**	:	11
6.	**Replication**	:	3
7.	**Spacing**	:	25 cm × 25 cm
8.	**Gross plot**	:	5.0 m × 4.0 m
9.	**Net plot**	:	4.20 m × 3.20 m
10.	**Date of sowing**	:	4-09-2014

3.7.1 Treatment details

T_1. RDF

T_2. RDF + FYM (POP)

T_3. RDF + Vermicompost (FYM equivalent)

T_4. RDF + FYM +25 per cent Nitrogen through FYM

T_5. RDF + FYM + 25 per cent Nitrogen through Vermicompost

T_6. RDF + FYM + 25 per cent Nitrogen through Glyricidia

T_7. RDF + Vermicompost + 25 per cent Nitrogen through Glyricidia

T_8. RDF + FYM + PSB + 25 per cent Nitrogen through Glyricidia

T_9. RDF + Vermicompost + PSB + 25 per cent Nitrogen through Glyricidia

T_{10}. RDF + FYM + PSB

T_{11}. RDF + Vermicompost + PSB

Note: RDF: Recommended Dose of Fertilizer (100 : 50 : 50 kg N, P_2O_5 & K_2O ha^{-1})

FYM : Farm yard manure : 7.5 t ha^{-1}

POP: Package of Practice.

Table 3.4 Quantity of nutrients supplied through different approaches

Treatments	N	P_2O_5	K_2O	Total
T_1. RDF	100.00	50.00	50.00	200.00
T_2. . RDF + FYM (POP)	104.50	50.98	53.33	210.81
T_3. RDF + Vermicompost (FYM equivalent)	104.50	50.98	50.33	210.81
T_4. RDF + FYM +25 per cent Nitrogen through FYM	129.50	56.18	83.95	269.63
T_5. RDF + FYM + 25 per cent Nitrogen through Vermicompost	129.50	68.35	69.74	267.59
T_6. RDF + FYM + 25 per cent Nitrogen through Glyricidia	129.50	55.10	74.07	258.67
T_7. RDF + Vermicompost + 25 per cent Nitrogen through Glyricidia	131.00	52.00	72.14	255.14
T_8. RDF + FYM + PSB + 25 per cent Nitrogen through Glyricidia	129.50	52.00	74.07	255.57
T_9. RDF + Vermicompost + 25 per cent Nitrogen through Glyricidia	131.00	55.10	72.14	258.24
T_{10}. RDF + FYM + PSB	104.50	50.98	55.33	210.81
T_{11}. RDF + Vermicompost + PSB	106.00	54.10	53.40	213.50

Fig 3.2 Plan of layout of the experiment

3.8 Crop husbandry

3.8.1 Land preparation

The land was ploughed once mechanically with mould board plough and later harrowed twice to bring the soil to fine tilth. Experiment was laid out as per plan. The plots were prepared and levelled within the plots. Each plot was made by 20 cm width and 15 cm height bunds and given a gap of half meter between replications. The buffer channels of 50 cm width were opened in between the treatment plots for irrigation purpose.

3.8.2 Fertilizer management

Recommended dose of fertilizer for rice (100: 50: 50 kg N, P_2O_5 & K_2O ha^{-1}) was applied through chemical fertilizer and organic manures. Nitrogen was applied in three split doses *viz.* 50 per cent as basal, 25 per cent at 30 days after sowing and remaining 25 per cent at 60 days after sowing. Deficit amount of phosphorus and potassium in organic manures was balanced through chemical fertilizer.

3.8.3 Sowing

Before sowing furrows were opened at 25 cm intervals with the help of hand hoe as per treatment and two seeds were dibbled in each hill at 25 cm spacing. Basal dose of fertilizers were applied at the base of seed row and covered with soil. Sowing was done on 04-09-2014. The general view of experimental site is shown in plate 3.1

3.8.4 Irrigation

All plots were irrigated immediately after sowing as like irrigated upland crops. Further, irrigation was given once in seven to eight days during vegetative stage and once in five days during reproductive stage of crop depending upon the rain fall. Irrigation was skipped when rainfall received. Irrigation was stopped 10 days prior to the harvest of the crop.

3.8.5 Thinning and gap filling

Thinning was done ten days after the emergence of seedling by pulling out excess seedling in each hill and retaining only one seedling plant^{-1}. Gap filing was done to maintain optimum plant population.

Plate 3.1 General view of the experimental plot

3.8.6 Weed management

Weeds are the major problems in aerobic rice. Weed control was done by hand weeding at 25 and 45 days after sowing and two times inter cultivation by wheel hoe at 15 and 45 days after sowing to keep all the plots weed free throughout the crop growth period.

3.8.7 Intercultivation

The soil was loosened with the help of hand hoe at 30, 45 and 60 DAS. This enables easy penetration of roots and to develop good root system and inducing more number of tillers.

3.8.8 Plant protection measures

During the experimental period, the crop was affected by stem borer at 60 days after sowing, but it was timely controlled by the application of Monocrotophos at the rate of 2 ml l^{-1} water.

3.8.9 Harvesting and threshing

The crop was harvested at its physiological maturity stage in different plots. Two rows on all sides of each plot were harvested as border rows and the remaining area as net plot. The crop in each net plot was harvested and threshed separately. The grains were cleaned and weight was recorded at less than 10 per cent moisture content. The straw from the individual plot was sun dried and weighed and finally converted in to quintals per hectare.

3.9 Collection of experimental data

Five plants were randomly selected in each net plot and labeled them for recording observations. Growth and yield observations were recorded at 30, 60, 90 days after sowing (DAS) and at harvest.

3.9.1 Growth parameters

3.9.1.1 Plant height (cm)

Five plants were randomly selected to record plant height at 30, 60, 90 DAS and at harvest. The plant height was measured from the base of plant to the base of fully opened leaf and the mean was worked out in centimeter.

3.9.1.2 Total number of leaves plant^{-1}

Total number of leaves plant^{-1} was counted from five labeled plants. It was recorded at 30, 60, 90 DAS and at harvest and mean was worked out.

3.9.1.3 Total number of tillers plant^{-1}

Total number of tillers plant^{-1} was counted at 30, 60, 90 DAS and at harvest from the five labeled plants in each treatment and the mean was computed.

3.9.1.4 Leaf area (cm^{2} plant^{-1})

The green leaves per plant^{-1} from randomly selected five plants were fed into the leaf area meter at 30, 60, 90 DAS and at harvest. The leaf area plant^{-1} was worked out and expressed as cm^{2} plant^{-1}.

3.9.1.5 Leaf area index (LAI)

It was calculated at 30, 60, 90 DAS and at harvest as per the formula given by Watson (1952).

$$LAI = \frac{\text{Leaf area plant}^{-1}\ (\text{cm}^2)}{\text{Spacing}\ (\text{cm}^2)}$$

3.9.1.7 Dry matter accumulation in leaves (g plant^{-1})

Two plants were uprooted at random from the border of gross plot rows at 30, 60, 90 DAS and at harvest. Leaf portion of the plant samples was washed in water, dried under the shade and in hot air oven at 65^{0} C. The mean dry weight per plant was taken and expressed as grams per plant.

3.9.1.8 Dry matter accumulation in stem (g plant^{-1})

Two plants were uprooted at random from the border rows at 30, 60, 90 DAS and at harvest. Stem portion of the plant samples was washed in water, dried under the shade and in hot air oven at 65^0 C. The mean dry weight plant^{-1} was taken and expressed in grams plant^{-1}.

3.9.1.9 Total dry matter accumulation (g plant^{-1})

Two plants were uprooted at random from the border of gross plot rows at 30, 60, 90 DAS and at harvest. The above total ground portion (leaf and stem) of the plant samples was washed in water and dried under the shade and kept in hot air oven at 65^0 C for further drying. The mean dry weight plnat^{-1} was calculated and expressed in grams plant^{-1}.

3.9.2. Growth indices

Different growth indices like leaf area duration, relative growth rate, net assimilation rate and crop growth rate were worked out at regular intervals using different formulae.

3.9.2.1. Leaf area duration (days)

Leaf area duration measures the ability to produce leaf area on unit land throughout its life**.** It was calculated at 30, 60, 90 DAS and at harvest as per the formula given by Powar *et al*. (1967).

$$LAD = \frac{LAI_1 + LAI_2}{2} \times (t_2 - t_1) \text{ days}$$

Where, LAI = Leaf area index;   t = time

3.9.2.2 Absolute growth rate (g p^{-1} day^{-1})

Absolute growth rate indicates rate of growth per unit dry matter per unit time. It was calculated by using the standard formula by Radford. (1967) and expressed as g p^{-1}day^{-1}.

$$AGR = \frac{W_2 - W_1}{t_2 - t_1} \quad (g\ p^{-1} day^{-1})$$

Where, W_1 and W_2 are dry weights of plant at time t_1 and t_2, respectively

3.9.2.3. Crop growth rate (g m^{-2} day^{-1})

Crop growth rate indicates the absolute growth rate per unit area of land it was worked out by using the formula suggested by Watson (1952) and expressed in g m^{-2} day^{-1}.

$$CGR = \frac{W_2 - W_1}{(t_2 - t_1) \times A} \quad (g\ m^{-2}\ day^{-1})$$

Where, W_1 and W_2 are dry weights of plant at time t_1 and t_2, respectively and A is area of the plant.

3.9.3 Yield Parameters

3.9.3.1 Number of panicles per plant

Five plants were randomly selected in each plot to record the number of panicles $plant^{-1}$ and mean was worked out.

3.9.3.2 Panicle Length (cm)

Five plants were randomly selected in each plot and panicle length was measured from base to tip of the panicle and the mean was computed and expressed in centimeter.

3.9.3.3 Panicle weight (g)

Five plants were randomly selected in each plot and panicle weight was measured by weighing panicles from each net plot and expressed as grams $panicle^{-1}$.

3.9.3.4 Number of filled grains panicle^{-1}

Total numbers of filled grains from five plants were counted and the mean was worked out.

3.9.3.5 Number of unfilled grains panicle^{-1}

Total numbers of unfilled grains from five plants were counted and the mean was computed.

3.9.3.6 Thousand grain weight (g)

The weight of thousand seeds drawn at random from the seeds of five labeled plants was recorded and expressed in g.

3.9.3.7 Chaffiness (per cent)

Percentage of chaffy grains was calculated by using the formula.

$$\text{Chaffiness (per cent)} = \frac{\text{Number of unfilled grains panicle}^{-1}}{\text{Total number of grains panicle}^{-1}} \times 100$$

3.9.3.8 Grain yield (q ha^{-1})

Grains from corresponding net plots were sun dried for 4 to 6 days and then the weight of grains per net plot was recorded and converted to quintals per hectare (q ha^{-1})

3.9.3.9 Straw yield (q ha^{-1})

Straw yield from each net plot was sun dried for 4 to 6 days and weighed and then converted to quintals per hectare (q ha^{-1}).

3.9.3.10 Harvest Index

The ratio of economic yield (grain yield) to the biological yield (grain and straw yield) was worked out as harvest index (Donald, 1962).

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

3.9.4 Chemical Analysis

3.9.4.1 Plant analysis

Five randomly selected plants from each net plot were oven dried and used for chemical analysis after grinding.

Nitrogen content was determined by digesting the plant samples with concentrated sulphuric acid and digestion mixture. The digested samples were distilled by micro kjeldhal method in an alkaline condition and titrated against standard acid (Piper, 1966).

Phosphorus and potassium contents were determined after the samples were digested with diacid mixture (Nitric acid + Perchloric acid). Phosphorus content was determined by Vanadomolybdo phosphoric yellow colour method and observation was recorded at 430 nm using Spectrophotometer instrument (Piper, 1966).

Potassium content was determined from the same diacid digested extract with the Digital Flame Photometer (Piper, 1966).

The uptake of nitrogen, phosphorus and potassium by rice crop at harvest was computed by using the following formula.

$$\text{Nutrient uptake } (\text{Kg ha}^{-1}) = \frac{\text{Nutrient content (\%)}}{100} \times \text{Dry weight (kg ha}^{-1})$$

3.9.4.2 Soil analysis

Soil samples were collected from 0-30 cm depth, dried under shade. The samples were analyzed for available nitrogen, available phosphorus and available potassium by using alkaline potassium permanganate method, Bray’s method and Neutral normal ammonium acetate method, respectively.

3.10 Economic analysis

3.10.1 Cost of cultivation

In computing the economics, different variable cost items were considered. The cost includes expenditure on seed, organic manures, chemical fertilizers, plant protection chemicals and labour charges at prevailing market prices during 2014. Labour requirement was worked out on the basis of labours engaged for performing different field operations.

3.10.2 Returns

The utility of adopting different practices was computed by using the following formulae.

Gross returns = Market price x Total yield (Grain yield + Straw yield)

Net returns = Gross returns - Cost of cultivation.

$$\text{B:C Ratio} = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

3.11 Statistical analysis

The experimental data obtained were subjected to statistical analysis by adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984). The level of significance used in 'F' test was at 5 per cent. Critical difference (CD) values are given in the Table at 5 per cent level of significance, wherever the 'F' test was significant.

3.12. Correlation studies

Correlation studies were made between grain yield and yield parameters. The values of correlation coefficient (r) was calculated and tested for their significance at five per cent as per the procedure outlined by Snedekar and Cocoharan (1967).

Experimental results

IV EXPERIMENTAL RESULTS

The results of the field experiment conducted to study the "Effect of integrated nutrient management on growth and yield of aerobic rice (*Oryza sativa* L.)" at AHRS, Bavikere, UAHS, Shivamogga, during *Kharif* 2014 are presented in this chapter.

4.1 Growth parameters

4.1.1 Plant height (cm)

Plant height recorded at 30, 60, 90 days after sowing (DAS) and at harvest as influenced by different integrated nutrient management practices are presented in Table 4.1

At 30 days after sowing, plant height differed significantly due to different integrated nutrient management practices. Significantly taller plants (10.63 cm) were recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and lower plant height (6.43 cm) was noticed with application of only recommended dose of fertilizer (RDF).

At 60 days after sowing, significantly higher plant height (22.63 cm) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and lower plant height (14.65 cm) was recorded with application of recommended dose of fertilizer(RDF).

At 90 days after sowing, significantly higher plant height (59.63 cm) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (58.23 cm). However, significantly lower plant height (48.10 cm) was observed with application of RDF alone.

At harvest, plant height differed significantly due to application of different nutrient management practices. Significantly higher plant height (65.10 cm) was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (63.80 cm). Whereas, lower plant height at harvest (51.91 cm) was recorded with application of RDF alone.

Table 4.1 Plant height (cm) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1: RDF	6.43	14.65	48.10	51.91
T_2: RDF + FYM (POP)	6.80	16.73	50.86	54.60
T_3: RDF + Vermicompost (FYM equivalent)	7.07	16.77	51.13	55.20
T_4: RDF + FYM +25% Nitrogen through FYM	8.37	17.87	54.87	57.47
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	8.63	18.24	55.03	58.03
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	7.43	17.06	51.40	56.47
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	7.80	17.14	52.89	56.87
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	10.10	20.63	58.23	63.80
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	10.63	22.63	59.63	65.10
T_{10}: RDF + FYM + PSB	8.90	19.13	55.63	58.93
T_{11}: RDF + Vermicompost + PSB	9.30	19.83	56.25	61.73
S.Em ±	0.12	0.25	0.67	0.76
C.D. at 5%	0.34	0.75	1.98	2.25

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

4.1.2 Number of leaves per plant

Data on number of leaves per plant recorded at 30, 60 and 90 DAS and at harvest as influenced by different nutrient management practices are presented in Table 4.2

Number of leaves differed significantly at 30 days after sowing. Significantly higher number of leaves per plant (13.13) was observed with application of in RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and lower number of leaves per plant (8.83) was recorded with application of recommended dose of fertilizer(RDF).

At 60 days after sowing, similar trend was observed with respect to number of leaves per plant. Significantly higher number of leaves per plant (65.35) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (64.17). Whereas, lower number of leaves per plant (42.63) was observed with application of recommended dose of fertilizer (RDF).

At 90 days after sowing, number of leaves per plant differed significantly due to integrated nutrient management practices. Significantly higher number of leaves per plant (103.32) observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (101.33) and application of RDF + Vermicompost + PSB (98.57). Significantly lower number of leaves per plant (74.77) was noticed with application of RDF.

At harvest, number of leaves per plant differed significantly. Significantly higher number of leaves per plant (98.53) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (96.93). However, lower number of leaves per plant (72.43) was observed with application of only recommended dose of fertilizer (RDF).

Table 4.2 Number of leaves as influenced by integrated nutrient management practices in aerobic rice.

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1: RDF	8.83	42.63	74.77	72.43
T_2: RDF + FYM (POP)	8.90	44.77	76.73	73.20
T_3: RDF + Vermicompost (FYM equivalent)	9.60	45.13	78.70	74.37
T_4: RDF + FYM +25% Nitrogen through FYM	10.43	56.50	78.70	89.40
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	11.43	57.40	92.37	90.53
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	10.57	49.66	82.93	76.92
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	11.40	50.60	86.80	84.60
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	12.57	64.17	101.33	96.93
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	13.13	65.35	103.32	98.53
T_{10}: RDF + FYM + PSB	11.90	59.00	96.03	93.16
T_{11}: RDF + Vermicompost + PSB	12.40	59.47	98.57	94.59
S.Em ±	0.19	1.71	1.84	1.38
C.D. at 5%	0.55	5.05	5.43	4.07

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

4.1.3 Number of tillers per plant

Data on number of tillers per plant recorded at 30, 60, 90 DAS and at harvest as influenced by different nutrient management practices are presented in Table 4.3

Number of tillers per plant differed significantly at 30 DAS. Significant higher number of tillers per plant (4.27) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (4.20) and lower number of tillers per plant was observed with application of recommended dose of fertilizer (RDF) (3.53) followed by application of RDF + FYM (3.80).

At 60 DAS, number of tillers per plant differed significantly due to integrated nutrient management practices. Significantly higher number of tillers per plant (14.70) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (14.40). However, lower number of tillers per plant was observer with application of recommended dose of fertilizer (11.57).

At 90 DAS, number of tillers differed significantly due to different nutrient management practices. Significantly higher number of tillers per plant (31.63) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (30.47). However, lower number of tillers per plant (21.36) was recorded with application of RDF alone.

Further, at harvest significance difference were noticed among different treatments. Significantly higher number of tillers per plant (30.10) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia however which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (29.60). Whereas, lower number of tillers per plant (18.87) was recorded with application of recommended dose of fertilizer (RDF).

4.1.4 Leaf area (cm^2 $plant^{-1}$)

The data on leaf area per plant recorded at 30, 60 and 90 DAS and at harvest as influenced by different nutrient management practices are presented in Table 4.4

Table 4.3 Number of tillers as influenced by integrated nutrient management practices in aerobic rice.

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1: RDF	3.53	11.57	21.36	18.87
T_2: RDF + FYM (POP)	3.80	12.20	24.02	19.70
T_3: RDF + Vermicompost (FYM equivalent)	3.83	12.57	25.60	23.07
T_4: RDF + FYM +25% Nitrogen through FYM	3.87	13.47	29.17	25.97
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	3.93	13.63	29.40	26.90
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	3.73	12.77	27.43	24.10
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	3.77	13.33	28.27	25.60
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	4.20	14.40	30.47	29.60
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	4.27	14.70	31.63	30.10
T_{10}: RDF + FYM + PSB	3.97	13.63	29.87	27.77
T_{11}: RDF + Vermicompost + PSB	4.07	14.02	29.90	28.17
S.Em ±	0.13	0.17	0.53	0.39
C.D. at 5%	0.38	0.49	1.56	1.16

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

At 30 DAS, leaf area per plant differed significantly due to different nutrient management practices. Significantly higher leaf area per plant (68.29 cm^2) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia. Whereas, lower leaf area per plant (45.93 cm^2) was observed with application of recommended dose of fertilizer (RDF).

At 60 DAS, leaf area per plant differed significantly due to integrated nutrient management practices. Significantly higher leaf area per plant (806.42 cm^2) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (782.83 cm^2). Whereas, lower leaf area per plant (520.13 cm^2) was recorded with application of only recommended dose of fertilizer (RDF).

At 90 DAS, significantly higher leaf area per plant (2323.60 cm^{-2}) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (2248.60 cm^{-2}). Lower leaf area per plant (1690.16 cm^{-2}) was noticed with application of RDF alone.

Further, at harvest leaf area differed significantly. Significantly higher leaf area (1753.89 cm^2) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was followed by application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (1725.41 cm^2). However, lower leaf area per plant (1302.96 cm^2) was recorded with application of only recommended dose of fertilizer (RDF) followed by application of RDF + FYM (1314.23 cm^2).

4.1.5 Leaf area index (LAI)

Data on Leaf area index recorded at 30, 60 and 90 DAS and at harvest as influenced by different nutrient management practices are presented in Table 4.5

At 30 DAS, leaf area index differed significantly by different nutrient management practices. Significantly higher leaf area index (0.11) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was as well as application of RDF + FYM + 25% Nitrogen through Glyricidia (0.11). Lower leaf area index (0.07) was observed with application of recommended dose of fertilizer (RDF) as well as application of RDF + FYM (0.07).

Table 4.4 Leaf area (cm^2 $plant^{-1}$) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1: RDF	45.93	520.13	1690.16	1302.96
T_2: RDF + FYM (POP)	46.28	550.43	1702.74	1314.23
T_3: RDF + Vermicompost (FYM equivalent)	49.92	561.61	1749.36	1323.73
T_4: RDF + FYM +25% Nitrogen through FYM	54.25	689.30	1983.94	1591.32
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	56.12	700.28	2050.54	1611.49
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	53.39	587.23	1841.12	1351.61
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	53.80	617.32	1926.96	1429.93
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	65.35	782.83	2248.60	1725.41
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	68.29	806.42	2323.60	1753.89
T_{10}: RDF + FYM + PSB	61.71	719.80	2109.74	1652.43
T_{11}: RDF + Vermicompost + PSB	64.13	725.56	2188.18	1660.15
S.Em ±	0.68	18.57	34.10	16.27
C.D. at 5%	2.02	54.79	100.61	48.00

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

At 60 DAS, leaf area index was significantly higher (1.29) with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was followed by application of RDF + FYM + 25% Nitrogen through Glyricidia (1.25). Whereas, lower leaf area index (0.83) was observed in application of recommended dose of fertilizer (RDF) followed by application of RDF +FYM (0.88).

At 90 DAS, leaf area index differed significantly due to integrated nutrient management practices. Significantly higher leaf area index (3.72) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (3.60). However, lower leaf area index (2.56) was noticed with application of RDF alone.

At harvest leaf area index significantly differed due to different nutrient management practices. Significantly higher leaf area index (2.81) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was followed by the application of RDF + FYM + 25% Nitrogen through Glyricidia (2.76). However lower leaf area index (1.98) was observed with application of recommended dose of fertilizer followed by application of RDF + FYM (2.08).

4.1.6 Leaf area duration (LAD) (days)

Data on Leaf area duration recorded at 30, 60 and 90 DAS and at harvest as influenced by different nutrient management practices are presented in Table 4.6

At 30-60 DAS, leaf area duration was significantly influenced due to integrated nutrient management practices. Significantly higher leaf area duration (20.95 days) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with the application of RDF + FYM + 25% Nitrogen through Glyricidia (20.30 days). However, lowesr leaf area duration (13.55 days) was recorded with application of recommended dose of fertilizer alone (RDF).

At 60-90 days there was significant difference due to integrated nutrient management practices with respect to leaf area duration. Significantly higher leaf area duration (75.05 days) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was followed by application of RDF +

Table 4.5 Leaf area index (LAI) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1: RDF	0.07	0.83	2.56	1.98
T_2: RDF + FYM (POP)	0.07	0.88	2.70	2.08
T_3: RDF + Vermicompost (FYM equivalent)	0.08	0.90	2.80	2.12
T_4: RDF + FYM +25% Nitrogen through FYM	0.09	1.10	3.17	2.48
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	0.10	1.12	3.28	2.56
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	0.09	0.94	2.95	2.16
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	0.09	0.99	3.08	2.29
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	0.11	1.25	3.60	2.76
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	0.11	1.29	3.72	2.81
T_{10}: RDF + FYM + PSB	0.10	1.15	3.38	2.58
T_{11}: RDF + Vermicompost + PSB	0.10	1.16	3.50	2.64
S.Em ±	0.0011	0.03	0.06	0.03
C.D. at 5%	0.0032	0.09	0.17	0.10

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

Table 4.6 Leaf area duration (LAD) (DAS) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	30-60 DAS	60-90 DAS	90-harvest
T_1: RDF	13.55	50.90	68.20
T_2: RDF + FYM (POP)	14.30	53.80	71.90
T_3: RDF + Vermicompost (FYM equivalent)	14.70	55.50	73.80
T_4: RDF + FYM +25% Nitrogen through FYM	17.90	64.20	84.80
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	18.25	66.00	87.90
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	15.45	58.25	76.55
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	16.10	61.05	80.55
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	20.30	72.70	95.35
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	20.95	75.05	97.75
T_{10}: RDF + FYM + PSB	18.80	67.95	89.00
T_{11}: RDF + Vermicompost + PSB	18.85	69.85	92.15
S.Em ±	0.44	0.86	1.14
C.D. at 5%	1.29	2.55	3.37

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

FYM + 25% Nitrogen through Glyricidia (72.70 days). However, lower leaf area duration (50.90 days) was observed with application of recommended dose of fertilizer (RDF).

At 90 days and harvest, leaf area duration differed significantly due to different nutrient management practices. Significantly higher leaf area duration (97.75 days) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was followed by application of RDF + FYM + 25% Nitrogen through Glyricidia (95.35 days). Significantly lower leaf area duration was recorded with application of recommended dose alone (68.20 days) followed by RDF + FYM (71.90 days).

4.1.7 Leaf dry mater accumulation (g plant^{-1})

Data pertaining to leaf dry matter accumulation recorded at 30, 60 and 90 DAS and at harvest as influenced by different nutrient management practices are presented in Table 4.7

At 30 DAS significantly higher leaf dry matter accumulation (2.24 g plant^{-1}) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was followed by application of RDF + FYM + 25% Nitrogen through Glyricidia (2.10 g plant^{-1}). However, lowest leaf dry matter T_1 (1.34) was observed with application of RDF.

Similar, trend was followed at 60 and DAS, higher leaf dry matter (5.80 and 23.41g plant^{-1}) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was followed by the application of RDF + FYM + 25% Nitrogen through Glyricidia (5.67 and 22.66 g plant^{-1}), Whereas lower leaf area per plant (3.83 and 13.99 g plant^{-1}) was recorded with application of only recommended dose of fertilizer.

At harvest, leaf dry matter accumulation differed significantly due application different nutrient management practices. Significantly higher leaf dry matter accumulation (25.29 g plant^{-1}) was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and lower leaf dry matter (14.72 g plant^{-1}) was recorded with application of only recommended dose of fertilizer (RDF).

Table 4.7 Leaf dry matter accumulation (g plant^{-1}) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1: RDF	1.34	3.83	13.99	14.72
T_2: RDF + FYM (POP)	1.36	3.92	14.63	15.23
T_3: RDF + Vermicompost (FYM equivalent)	1.55	4.02	14.87	15.51
T_4: RDF + FYM +25% Nitrogen through FYM	1.72	4.25	16.15	17.66
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	1.86	4.73	16.55	17.72
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	1.63	4.07	15.09	16.35
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	1.69	4.18	15.54	17.00
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	2.10	5.67	22.66	24.20
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	2.24	5.80	23.41	25.29
T_{10}: RDF + FYM + PSB	1.93	4.80	18.33	20.39
T_{11}: RDF + Vermicompost + PSB	2.05	4.99	21.68	23.58
S.Em ±	0.05	0.17	0.46	0.30
C.D. at 5%	0.15	0.50	1.36	0.90

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

4.1.8 Stem dry mater accumulation (g plant^{-1})

Data on stem dry matter accumulation recorded at 30, 60 and 90 DAS and at harvest as influenced by different nutrient management practices are presented in Table 4.8

At 30 DAS, stem dry matter accumulation varied significantly due to the effect of integrated nutrient management practices, significantly higher stem dry matter accumulation (2.15 g plant^{-1}) was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia followed by application of RDF + FYM + 25% Nitrogen through Glyricidia. However, lowest stem dry matter accumulation (0.92 g plant^{-1}) was observed with application of recommended dose of fertilizer alone (RDF).

At 60 DAS, significant variation was observed with respect to stem dry matter accumulation due to integrated nutrient management practices. Significantly higher stem dry matter (8.10 g plant^{-1}) was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia. However, it was on par with application of RDF + FYM + 25% Nitrogen through Glyricidia (7.99 g plant^{-1}) and application of RDF + Vermicompost + PSB (7.91 g plant^{-1}). However, lower stem dry matter (4.63 g plant^{-1}) was recorded wit application of recommended dose of fertilizer (RDF).

At 90 DAS, stem dry matter accumulation differed significantly due to different integrated nutrient management practices. Significantly higher stem dry matter accumulation (48.16 g plant^{-1}) was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia, followed by application of RDF + FYM + 25% Nitrogen through Glyricidia (48.10 g plant^{-1}). However, lowest stem dry matter (35.49 g plant^{-1}) was observed with application of RDF alone.

At harvest, integrated nutrient management practices had significant effect on stem dry matter accumulation. Significantly higher stem dry matter accumulation (71.17 g plant^{-1}) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was followed by application of RDF + FYM + 25% Nitrogen through Glyricidia (70.32 g plant^{-1}). Whereas, lower stem dry matter (55.67 g plant^{-1}) was observed with application of recommended dose of fertilizer alone.

Table 4.8 Stem dry matter accumulation (g plant^{-1}) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1: RDF	0.92	4.63	35.49	55.67
T_2: RDF + FYM (POP)	1.02	4.80	36.71	57.39
T_3: RDF + Vermicompost (FYM equivalent)	1.10	5.46	37.98	62.55
T_4: RDF + FYM +25% Nitrogen through FYM	1.26	7.38	44.05	65.16
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	1.45	7.79	45.63	66.15
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	1.12	5.86	42.12	64.56
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	1.16	6.92	43.58	65.10
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	2.04	7.99	48.10	70.32
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	2.15	8.10	48.16	71.17
T_{10}: RDF + FYM + PSB	1.59	7.82	46.07	68.34
T_{11}: RDF + Vermicompost + PSB	1.80	7.91	46.61	69.74
S.Em ±	0.05	0.14	0.44	0.95
C.D. at 5%	0.13	0.43	1.30	2.79

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

4.1.9 Total dry mater accumulation (g plant^{-1})

Data pertaining to total dry matter accumulation recorded at 30, 60 and 90 DAT and at harvest as influenced by different nutrient management practices are presented in Table 4.9

Total dry matter accumulation differed significantly at 30 DAS, significantly higher total dry matter accumulation (4.38 g plant^{-1}) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia followed by application of RDF + FYM + 25% Nitrogen through Glyricidia (4.14 g plant^{-1}) and application of RDF + Vermicompost + PSB (3.84 g plant^{-1}). Lower total dry matter was recorded with application of RDF alone (2.26 g plant^{-1}).

At 60 DAS, significant variation was observed with respect to stem dry matter accumulation due to integrated nutrient management practices. Significantly higher stem dry matter (13.90 g plant^{-1}) was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia. However, lower total dry matter accumulation was recorded with application of RDF alone (8.46 g plant^{-1}).

Similar, trend was followed at 90 days and harvest with respect to total dry matter accumulation. Significantly higher total dry matter accumulation (71.58 and 96.46 plant^{-1}) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which is followed by application of of RDF + FYM + 25% Nitrogen through Glyricidia (70.76 and 94.52 g plant^{-1}). Whereas, lower total dry matter (49.48 and 70.39 g plant^{-1}) was recorded with application of recommended dose of fertilizer alone.

4.1.10 Absolute growth rate (AGR) (g p^{-1} day^{-1})

The data on AGR as influenced by different nutrient management practices are presented in Table 4.10

AGR differed significantly between 30 to 60 DAS. Significantly higher AGR (0.317 g p^{-1} day^{-1}) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia. However, it was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (0.317 g p^{-1} day^{-1}) followed by application of RDF + FYM + 25% Nitrogen through Vermicompost (0.307 g p^{-1}

Table 4.9 Total dry matter accumulation (g plant^{-1}) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T_1: RDF	2.26	8.46	49.48	70.39
T_2: RDF + FYM (POP)	2.38	8.72	51.34	72.63
T_3: RDF + Vermicompost (FYM equivalent)	2.66	9.48	52.85	78.06
T_4: RDF + FYM +25% Nitrogen through FYM	2.98	11.63	60.20	82.83
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	3.31	12.52	62.18	83.86
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	2.76	9.93	57.21	80.91
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	2.86	11.10	59.12	82.10
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	4.14	13.19	70.76	94.52
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	4.38	13.90	71.58	96.46
T_{10}: RDF + FYM + PSB	3.52	12.62	64.41	88.73
T_{11}: RDF + Vermicompost + PSB	3.84	12.90	68.29	93.32
S.Em ±	0.06	0.22	0.61	0.95
C.D. at 5%	0.18	0.65	1.80	2.80

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

Table 4.10 Absolute Growth Rate (g p^{-1} day^{-1}) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	30-60 DAS	60-90 DAS	90-harvest
T_1: RDF	0.207	1.367	0.747
T_2: RDF + FYM (POP)	0.211	1.421	0.759
T_3: RDF + Vermicompost (FYM equivalent)	0.227	1.446	0.840
T_4: RDF + FYM +25% Nitrogen through FYM	0.288	1.619	0.754
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	0.307	1.655	0.753
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	0.239	1.576	0.790
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	0.275	1.600	0.766
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	0.317	1.903	0.792
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	0.317	1.923	0.829
T_{10}: RDF + FYM + PSB	0.303	1.726	0.811
T_{11}: RDF + Vermicompost + PSB	0.302	1.846	0.834
S.Em ±	0.010	0.023	0.034
C.D. at 5%	0.030	0.068	NS

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

day^{-1}), RDF + FYM + PSB (0.303 g p^{-1} day^{-1}), RDF + Vermicompost + PSB (0.302 g p^{-1} day^{-1}) and RDF + FYM +25% Nitrogen through FYM (0.288 g p^{-1} day^{-1}), significantly less AGR (0.207 g p^{-1} da^{-1}) recorded with application of RDF alone.

Application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia recorded significantly higher AGR (1.923 g p^{-1} da^{-1}) at 60 to 90 DAS which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (1.903 g p^{-1} da^{-1}). Significantly lower AGR per plant (1.367 g p^{-1} day^{-1}) was recorded with application of recommended dose of fertilizer alone.

AGR did not differed significantly between 90 to harvest, but higher AGR was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (0.840 g p^{-1} da^{-1}) followed by application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (0.834). However, lowest AGR (0.747 g p^{-1} da^{-1}) was recorded with application of RDF alone.

4.1.11 Crop growth rate (g m^{-2} day^{-1})

The data pertaining to crop growth rate (g m^{-2} day^{-1}) at different days after sowing as influenced by various nutrient management practices are presented in Table 4.11

At 30-60 DAS, crop growth rate differed significantly due to nutrient management practices. Significantly higher crop growth rate was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (5.08 g m^{-2} day^{-1}). However, it was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (5.07 g m^{-2} day^{-1}) followed by RDF + FYM + 25% Nitrogen through Vermicompost (4.91 g m^{-2} day^{-1}), RDF + FYM + PSB (4.85 g m^{-2} day^{-1}) and RDF + Vermicompost + PSB (4.83 g m^{-2} day^{-1}). Significantly lowest crop growth rate (3.31 g m^{-2} day^{-1}) was recorded with application of recommended dose of fertilizer alone.

At 60-90 DAS, Crop growth rate differed significantly due to various nutrient management practices. Significantly higher crop growth rate was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (0.0033 g cm^{-2} day^{-1}) (30.76 g m^{-2} day^{-1}), which was on par with the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (30.45 g m^{-2} day^{-1}). Whereas,

Table 4.11 Crop Growth Rate (g m^{-2} day^{-1}) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	30-60 DAS	60-90 DAS	90-harvest
T_1: RDF	3.31	21.88	11.15
T_2: RDF + FYM (POP)	3.38	22.73	11.35
T_3: RDF + Vermicompost (FYM equivalent)	3.64	23.13	13.45
T_4: RDF + FYM +25% Nitrogen through FYM	4.61	25.91	12.07
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	4.91	26.48	11.57
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	3.83	25.22	12.64
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	4.40	25.61	12.26
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	5.07	30.45	12.67
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	5.08	30.76	13.27
T_{10}: RDF + FYM + PSB	4.85	27.62	12.97
T_{11}: RDF + Vermicompost + PSB	4.83	29.54	13.35
S.Em ±	0.11	0.37	0.55
C.D. at 5%	0.32	1.10	NS

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

lowest crop growth rate (21.88 g m^{-2} day^{-1}) was recorded with application of recommended dose of fertilizer (RDF) alone.

At 90 DAS-harvest, crop growth rate did not differed significantly due to nutrient management practices. Application of RDF + Vermicompost (FYM equivalent) (13.45 g m^{-2} day^{-1}) has recorded higher crop growth rate followed by application of RDF + Vermicompost + PSB (13.35 g m^{-2} day^{-1}), RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (13.27 g m^{-2} day^{-1}), RDF + FYM + PSB (12.97 g m^{-2} day^{-1}). However, the lowest crop growth rate (11.15 g m^{-2} day^{-1}) was recorded with application of recommended dose of fertilizer (RDF) alone.

4.1.12 Days to 50% flowering

The data on days to 50% flowering and days taken to maturity as influenced by different nutrient management practices are presented in Table 4.12

Days to 50% flowering differed significantly due to different nutrient management practices. Significantly more days to 50% flowering (96.71 days) was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (96.20 days), RDF + FYM + PSB (94.81days), RDF + Vermicompost + PSB (94.47 days), RDF + FYM + 25% Nitrogen through Vermicompost (92.77 days). However, lowest number of days taken to 50% flowering was (80.41 days) recorded with application of recommended dose of fertilizer (RDF) alone.

Different nutrient management practices did not differed significantly with respect to days to maturity of the crop. However, application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (137.7 days) taken higher days to maturity followed by application of RDF + Vermicompost + PSB (136.3 days) and application of only recommended dose of fertilizer (RDF) recorded lesser days to maturity (129.0 days).

Table 4.12 Days taken for 50% flowering and days taken for maturity as influenced by integrated nutrient management practices in aerobic rice.

Treatments	Days taken for 50% flowering	Days taken for maturity
T_1: RDF	80.41	129.0
T_2: RDF + FYM (POP)	83.73	132.3
T_3: RDF + Vermicompost (FYM equivalent)	84.62	131.0
T_4: RDF + FYM +25% Nitrogen through FYM	89.49	133.3
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	92.77	134.0
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	86.55	134.0
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	87.77	134.0
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	96.20	133.3
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	96.71	135.7
T_{10}: RDF + FYM + PSB	94.81	137.7
T_{11}: RDF + Vermicompost + PSB	94.47	136.3
S.Em ±	1.40	3.60
C.D. at 5%	4.13	NS

4

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

5

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

6

POP: Package of Practice.

6.2 Yield and Yield components

6.2.1 Number of panicles per plant

The data pertaining to number of panicles per plant as influenced by different integrated nutrient management practices are presented in Table 4.13

Among different nutrient management practices, significantly higher number of panicles per plant (23.40) was noticed with the application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia, which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (22.69). Whereas significantly lower number of panicles per plant was (11.53) observed with application of recommended dose of fertilizer (RDF).

4.2.2 Panicle length (cm)

The data pertaining to panicle length as influenced by different integrated nutrient management practices are presented in Table 4.13

Panicle length differed significantly by different nutrient management practices. Significantly higher panicle length (20.45 cm) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia, which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (20.40 cm). However, significantly lower panicle length (16.32 cm) was recorded with application of recommended dose of fertilizer (RDF).

4.2.3 Panicle weight (g)

The data pertaining to panicle weight as influenced by integrated nutrient management practices are presented in Table 4.13

Different nutrient management practices had significant influence on the panicle weight. Significantly higher panicle weight (3.19 g) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia, followed by application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (3.14 g) and application of RDF + Vermicompost + PSB (3.01 g). However, significantly lowest panicle weight was observed (2.08 g) was observed with

Table 4.13 Yield parameters as influenced by integrated nutrient management practices in aerobic rice.

Treatments	Number of panicles $plant^{-1}$	Panicle length (cm)	Panicle weight (g)	Test weight (g)
T_1: RDF	11.53	16.32	2.08	17.64
T_2: RDF + FYM (POP)	12.65	16.67	2.09	18.22
T_3: RDF + Vermicompost (FYM equivalent)	14.10	17.59	2.18	18.59
T_4: RDF + FYM +25% Nitrogen through FYM	18.17	18.76	2.65	21.37
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	19.50	19.13	2.82	21.79
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	15.14	18.00	2.38	19.45
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	16.00	18.07	2.60	20.11
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	22.69	20.40	3.14	23.55
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	23.40	20.45	3.19	24.22
T_{10}: RDF + FYM + PSB	21.50	19.33	2.89	22.49
T_{11}: RDF + Vermicompost + PSB	22.00	19.87	3.01	23.20
S.Em ±	0.51	0.27	0.07	0.24
C.D. at 5%	1.51	0.79	0.19	0.70

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})
FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}
POP: Package of Practice.

application of recommended dose of fertilizer (RDF) which was followed by application of RDF + FYM (2.18 g).

4.2.4 Test weight (g)

The data on thousand seeds weight (g) as influenced by different nutrient management practices are presented in Table 4.13

Test weight varied significantly due to application of different nutrient management practices. Significantly higher test weight (24.22 g) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia, which was on par with the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (23.55 g). Whereas, lowest test weight (17.64 g) was observed with application of RDF.

4.2.5 Total number of grains per panicle

The data pertaining to number of panicles per plant as influenced by different integrated nutrient management practices are presented in Table 4.14

Number of grains per panicle differed significantly due to different integrated nutrient management practices. Significantly higher number of grains per panicle (127.67) was registered with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia, which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (122.49). Among all the treatments significantly lower number of grains per panicle (97.62) was noticed with application of RDF.

4.2.6 Filled grains per panicle

The data pertaining to number of filled grains per panicle as influenced by different nutrient management practices are presented in Table 4.14

Among the different nutrient management practices, significantly more number of filled grains per panicle (114.48) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia, compared to all the treatments which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (108.32). However, lower number of filled grains per panicle

Table 4.14 Total number of grains panicle^{-1}, filled grain panicle^{-1}, unfilled grains panicle^{-1} and chaffiness (%) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	Total number of grains panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	Chaffiness (%)
T_1: RDF	97.62	72.75	24.88	25.48
T_2: RDF + FYM (POP)	102.13	78.25	23.87	23.39
T_3: RDF + Vermicompost (FYM equivalent)	106.56	84.11	22.44	21.07
T_4: RDF + FYM +25% Nitrogen through FYM	117.74	96.05	21.69	18.43
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	118.73	99.19	19.54	16.46
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	113.55	92.85	20.70	18.28
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	116.85	95.78	18.79	16.09
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	122.49	108.32	14.17	11.57
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	127.67	114.48	13.19	10.35
T_{10}: RDF + FYM + PSB	119.77	102.09	17.67	14.78
T_{11}: RDF + Vermicompost + PSB	120.14	103.44	16.70	13.93
S.Em ±	2.20	2.25	0.62	0.54
C.D. at 5%	6.50	6.65	1.82	1.60

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})
FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}
POP: Package of Practice.

(72.75) was recorded with application of RDF alone which was followed by application of RDF + FYM (78.11).

4.2.7 Unfilled grains per panicle

The data pertaining to number of unfilled grains per panicle as influenced by different nutrient management practices are presented in Table 4.14

Number of unfilled grains per panicle differed significantly due to application of different nutrient management practices. Significantly lower number of unfilled grains per panicle (13.19) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia, which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (14.17). Whereas, significantly higher number of unfilled grains per panicle were observed with application of RDF (24.88) followed application of RDF + FYM (23.87).

4.2.8 Chaffiness (%)

The data pertaining to chaffiness percentage due to application of different nutrient management practices are presented in Table 4.14

Among different nutrient management practices lower chaffiness percentage (10.35) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia. However, lower chafiness percentage (25.48) was noticed with application of recommended dose of fertilizer only (RDF), which was followed by application of RDF + FYM (23.39).

4.2.9 Grain yield (q ha^{-1})

The data pertaining to grain yield as influenced by different nutrient management practices are presented in Table 4.15

Grain yield differed significantly due to application of different nutrient management practices. Significantly higher grain yield (42.41 q ha^{-1}) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia, which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (41.11 q ha^{-1}). However, lower grain yield was recorded with application of RDF.

Table 4.15 Grain yield (q ha^{-1}), straw yield (q ha^{-1}) and harvest index as influenced by integrated nutrient management practices in aerobic rice.

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index
T_1: RDF	35.30	41.33	0.46
T_2: RDF + FYM (POP)	35.96	42.02	0.46
T_3: RDF + Vermicompost (FYM equivalent)	36.54	44.65	0.45
T_4: RDF + FYM +25% Nitrogen through FYM	38.23	46.20	0.45
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	38.57	47.05	0.45
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	37.32	44.67	0.45
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	37.74	46.97	0.45
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	41.11	52.48	0.44
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	42.41	54.87	0.44
T_{10}: RDF + FYM + PSB	39.54	48.82	0.45
T_{11}: RDF + Vermicompost + PSB	40.44	51.78	0.44
S.Em ±	0.63	1.02	0.01
C.D. at 5%	1.85	3.01	0.02

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

4.2.10 Straw yield (q ha^{-1})

The data pertaining to straw yield as influenced by different nutrient management practices are presented in Table 4.15

Application of different nutrient management practices responded significantly with respect to straw yield. Significantly higher straw yield was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (54.87 q ha^{-1}), which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (52.48 q ha^{-1}). However, lower straw yield (41.33 q ha^{-1}) was recorded with application recommended dose of fertilizer (RDF).

4.2.11 Harvest index (HI)

The data on harvest index as influenced by different nutrient management practices are presented in Table 4.15

Harvest index did not differ significantly due to different nutrient management practices.

4.3 Nutrient uptake

4.3.1 Nitrogen uptake (kg ha^{-1})

The data pertaining to nitrogen uptake by grain, straw and total as influenced by different integrated nutrient management practices are presented in Table 4.16

4.3.1.1 Nitrogen uptake by grain (kg ha^{-1})

Nitrogen uptake by grain was significantly influenced by different integrated nutrient management practices. Significantly higher nitrogen uptake by grain was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (80.65 kg ha^{-1}) which was on par with the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (76.89 kg ha^{-1}). However, the lowest nitrogen uptake by grains (49.87 kg ha^{-1}) was observed with application of recommended dose of fertilizer (RDF) alone.

Table 4.16 Nitrogen uptake (kg ha^{-1}) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	Grain (kg ha^{-1})	Straw (kg ha^{-1})	Total uptake (kg ha^{-1})
T_1: RDF	49.87	37.06	86.93
T_2: RDF + FYM (POP)	53.81	37.91	91.71
T_3: RDF + Vermicompost (FYM equivalent)	54.38	38.58	92.96
T_4: RDF + FYM +25% Nitrogen through FYM	62.99	46.22	109.21
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	63.36	47.16	110.52
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	56.41	45.13	101.54
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	59.92	45.69	105.61
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	76.89	48.65	125.54
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	80.65	50.67	131.32
T_{10}: RDF + FYM + PSB	65.32	47.54	112.86
T_{11}: RDF + Vermicompost + PSB	71.60	47.99	119.59
S.Em ±	1.97	1.92	2.77
C.D. at 5%	5.82	5.65	8.18

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

4.3.1.2 Nitrogen uptake by straw (kg ha^{-1})

Nutrient management practices had significant influence on nitrogen uptake by straw. Significantly higher nitrogen uptake by straw (50.67 kg ha^{-1}) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (48.65 kg ha^{-1}), RDF + Vermicompost + PSB (47.99 kg ha^{-1}), RDF + FYM + PSB (47.54 kg ha^{-1}), RDF + FYM + 25% Nitrogen through Vermicompost (47.16 kg ha^{-1}), RDF + FYM +25% Nitrogen through FYM (46.22 kg ha^{-1}), RDF + Vermicompost + 25% Nitrogen through Glyricidia (45.69 kg ha^{-1}) and RDF + FYM + 25% Nitrogen through Glyricidia (45.13 kg ha^{-1}). Whereas, lowest nitrogen uptake by straw (37.06 kg ha^{-1}) was observed with application of recommended dose of fertilizer (RDF) alone.

4.3.1.3 Total nitrogen uptake (kg ha^{-1})

Application of different nutrient management practices had siginificant influence on total nitrogen uptake by crop. Significantly higher total nitrogen uptake by crop (131.32 kg ha^{-1}) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and which was on pr with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (125.54 kg ha^{-1}). However, lowest total nitrogen uptake (86.93 kg ha^{-1}) was noticed with application of recommended dose of fertilizer (RDF) alone.

4.3.2 Phosphorus uptake (kg ha^{-1})

The data on phosphorus uptake by grain, straw and total as influenced by integrated nutrient management practices are presented in Table 4.17

4.3.2.1 Phosphorus uptake by grain (kg ha^{-1})

Different nutrient management practices had significant influence on phosphorus uptake by grain. Significantly higher phosphorus uptake by grain was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (18.62 kg ha^{-1}) and which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (16.68 kg ha^{-1}). However, lowest phosphorus uptake by grain (7.81 kg ha^{-1}) was observed with application of recommended dose of fertilizer (RDF) alone.

4.3.2.2 Phosphorus uptake by straw (kg ha^{-1})

Different integrated nutrient management practices did not differed significant with respect to phosphorus uptake by straw. Higher phosphorous uptake (8.61 kg ha^{-1}) was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia followed by application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (8.34 kg ha^{-1}) and lowest phosphorus uptake by straw (5.45 kg ha^{-1}) was noticed with application of recommended dose of fertilizer (RDF) alone.

4.3.2.3 Total phosphorus uptake (kg ha^{-1})

Application of different nutrient management practices had siginificant influence on total phosphorus uptake by crop. Significantly higher total phosphorus uptake by crop (26.95 kg ha^{-1}) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (25.28 kg ha^{-1}). However, lowest total phosphorus uptake (13.26 kg ha^{-1}) was observed with application recommended dose of fertilizer (RDF) alone.

4.3.3 Potassium uptake (kg ha^{-1})

The data on potassium uptake by grain, straw and total as influenced due to integrated nutrient management are presented in Table 4.18

4.3.3.1. Potassium uptake by grain (kg ha^{-1})

Different nutrient management practices had significance influence on potassium uptake by grain. Significantly higher potassium uptake by grain (27.95 kg ha^{-1}) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application RDF + FYM + PSB + 25% Nitrogen through Glyricidia (27.24 kg ha^{-1}) and RDF + Vermicompost + PSB (26.73 kg ha^{-1}). However, lowest potassium uptake by grain (21.74 kg ha^{-1}) was observed with application of recommended dose of fertilizer (RDF) alone.

Table 4.17 Phosphorus uptake (kg ha^{-1}) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	Grain (kg ha^{-1})	Straw (kg ha^{-1})	Total uptake (kg ha^{-1})
T_1: RDF	7.81	5.45	13.26
T_2: RDF + FYM (POP)	8.38	6.72	15.10
T_3: RDF + Vermicompost (FYM equivalent)	9.40	7.01	16.41
T_4: RDF + FYM +25% Nitrogen through FYM	13.25	7.66	20.91
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	12.58	7.58	20.16
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	11.47	7.57	19.04
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	11.71	7.71	19.42
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	16.68	8.34	25.28
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	18.62	8.61	26.95
T_{10}: RDF + FYM + PSB	15.11	7.41	22.52
T_{11}: RDF + Vermicompost + PSB	14.82	7.70	22.53
S.Em ±	0.88	0.66	1.04
C.D. at 5%	2.59	NS	3.07

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

4.3.3.2 Potassium uptake by straw (kg ha^{-1})

Nutrient management practices had significant influence on potassium uptake by straw. Significantly higher potassium uptake by straw (85.12 kg ha^{-1}) was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (84.73 kg ha^{-1}) followed by RDF + Vermicompost + PSB (84.70 kg ha^{-1}) and RDF + FYM + PSB (83.74 kg ha^{-1}). However, lowest potassium uptake by straw (63.72 kg ha^{-1}) was observed with application of recommended dose of fertilizer (RDF) alone.

4.3.3.3 Total potassium uptake (kg ha^{-1})

Application of diffrent nutrient management practices had significant influence on total potassium uptake by crop. Siginificantly higher total potassium uptake by cop was (113.07 kg ha^{-1}) noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (111.97 kg ha^{-1}) followed by application of RDF + Vermicompost + PSB (111.43 kg ha^{-1}) and RDF + FYM + PSB (109.27 kg ha^{-1}). However, lowest total potassium uptake by crop (85.46 kg ha^{-1}) was recorded with application of recommended dose of fertilizer (RDF) alone.

4.4 Available nutrient status (kg ha^{-1})

The data regarding available nutrients at harvest as influenced by various nutrient management practices are furnished in the Table 4.19

4.4.1 Available nitrogen (kg ha^{-1})

Nutrient management practices did not differed significantly with respect to available nitrogen status in soil. Higher available nitrogen in soil at harvest (269.40 kg ha^{-1}) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (262.62 kg ha^{-1}). Whereas, lower available nitrogen in soil at harvest (255.14 kg ha^{-1}) was noticed with application of recommended dose of fertilizer (RDF) alone.

Table 4.18 Potassium uptake (kg ha^{-1}) as influenced by integrated nutrient management practices in aerobic rice.

Treatments	Grain (kg ha^{-1})	Straw (kg ha^{-1})	Total uptake (kg ha^{-1})
T_1: RDF	21.74	63.72	85.46
T_2: RDF + FYM (POP)	23.78	67.39	91.16
T_3: RDF + Vermicompost (FYM equivalent)	24.14	69.69	93.83
T_4: RDF + FYM +25% Nitrogen through FYM	25.57	75.56	101.13
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	25.74	76.62	102.36
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	24.09	73.93	98.02
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	24.62	74.69	99.32
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	27.24	84.73	111.97
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	27.95	85.12	113.07
T_{10}: RDF + FYM + PSB	25.53	83.74	109.27
T_{11}: RDF + Vermicompost + PSB	26.73	84.70	111.43
S.Em ±	0.70	1.37	1.50
C.D. at 5%	2.06	4.05	4.42

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

Table 4.19 Available soil nutrient status (kg ha^{-1}) of soil after harvest of the crop as influenced by integrated nutrient management practices in aerobic rice.

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1: RDF	255.14	76.81	94.46
T_2: RDF + FYM (POP)	256.62	77.62	98.23
T_3: RDF + Vermicompost (FYM equivalent)	257.18	78.02	103.15
T_4: RDF + FYM +25% Nitrogen through FYM	258.67	81.66	117.46
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	259.42	83.76	118.64
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	256.15	82.92	106.98
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	258.16	83.35	107.93
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	262.62	85.69	141.46
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	269.40	86.95	145.70
T_{10}: RDF + FYM + PSB	260.55	84.47	122.13
T_{11}: RDF + Vermicompost + PSB	261.30	85.76	129.70
S.Em ±	4.65	1.89	2.15
C.D. at 5%	NS	5.57	6.57

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

4.4.2 Available phosphorus (kg ha^{-1})

Application of different nutrient management practice had significance influence on available phosphorus in soil at harvest. Significantly higher available phosphorus was (86.95 kg ha^{-1}) recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + Vermicompost + PSB (85.76 kg ha^{-1}) followed by application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (85.69 kg ha^{-1}), RDF + FYM + PSB (84.47 kg ha^{-1}), RDF + FYM + 25% Nitrogen through Vermicompost (83.76 kg ha^{-1}), RDF + Vermicompost + 25% Nitrogen through Glyricidia (83.35 kg ha^{-1}), RDF + FYM + 25% Nitrogen through Glyricidia (82.92 kg ha^{-1}) and RDF + FYM +25% Nitrogen through FYM (81.66 kg ha^{-1}). However, lowest available phosphorus (76.81 kg ha^{-1}) was recorded with application of recommended dose of fertilizer (RDF) alone.

4.4.3 Available potassium (kg ha^{-1})

Nutrient management practices had significant influence on available potassium in soil. Significantly higher available potassium (145.70 kg ha^{-1}) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (141.46 kg ha^{-1}). Whereas, lowest available potassium (94.46 kg ha^{-1}) was recorded with application recommended dose of fertilizer (RDF) alone.

4.5 Economic analysis

The data related to cost of cultivation, gross returns, net returns and benefit cost ratio as influenced by various nutrient management practices are furnished in Table 4.20

Among different treatments higher cost of cultivation (Rs. 22,107), gross returns (Rs. 70485), net returns (Rs. 48378) and B: C ratio (2.19) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia. Lower cost of cultivation (Rs. 16961), gross returns (Rs. 49224), net returns (Rs. 32264) and lower B: C ratio (1.90) was observed with application of recommended dose of fertilizer (RDF) alone.

Table 4.20 Economics of integrated nutrient management practices in aerobic rice.

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T_1: RDF	16961	49224	32264	1.90
T_2: RDF + FYM (POP)	17861	55233	37372	2.09
T_3: RDF + Vermicompost (FYM equivalent)	18261	55251	36990	2.03
T_4: RDF + FYM +25% Nitrogen through FYM	19013	57819	38807	2.04
T_5: RDF + FYM + 25% Nitrogen through Vermicompost	19261	58371	39109	2.03
T_6: RDF + FYM + 25% Nitrogen through Glyricidia	18313	56391	38078	2.08
T_7: RDF + Vermicompost + 25% Nitrogen through Glyricidia	18861	58153	39292	2.08
T_8: RDF + FYM + PSB + 25% Nitrogen through Glyricidia	20907	63432	42528	2.03
T_9: RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia	22107	70485	48378	2.19
T_{10}: RDF + FYM + PSB	20907	60902	39995	1.91
T_{11}: RDF + Vermicompost + PSB	22107	62408	40301	1.82

RDF: Recommended Dose of Fertilizer (100 : 50 : 50 NPK kg ha^{-1})

FYM: Farm yard manure: 7.5 t ha^{-1} , Vermicompost : 5 t ha^{-1}

POP: Package of Practice.

4.6. Coefficient of correlation between yield, growth and yield traits as influenced integrated nutrient management practices in aerobic rice

The data on co-efficient of correlation between yield, growth and yield components are presented in Table 4.21

Significantly positive correlation was noticed between grain yield and leaf area (cm^2 $plant^{-1}$) from 90 days after sowing ($r=0.946^{**}$), total leaf area duration (days) from 90 days after sowing to harvest (0.980^{**}), number tiller at 90 day after sowing ($r=0.950^{**}$), total dry matter at harvest ($r=0.989^{**}$), number of panicles $plant^{-1}$ ($r=0.972^{**}$), panicle length ($r=0.975^{**}$), panicle weight ($r=0.972^{**}$) and number of grains $panicle^{-1}$ ($r=0.930^{**}$) at both 1 and 5 per cent level of significance.

Table 4.21 Correlation for grain yield with growth and yield parameters as influenced by integrated nutrient management practices in aerobic rice.

S.No.	Y (Yield)	X (Parameter)	Correlation (r)
1.	Grain yield	Leaf area (cm^2 $plant^{-1}$) from 90 days after sowing to harvest	0.946^{**}
2.	Grain yield	Total leaf area duration (days) from 90 days after sowing to harvest	0.980^{**}
3.	Grain yield	Number of tiller at 90 days after sowing	0.950^{**}
4.	Grain yield	Total dry matter at harvest (g $plant^{-1}$)	0.989^{**}
5.	Grain yield	Number of panicles $plant^{-1}$	0.972^{**}
6.	Grain yield	Panicle length (cm)	0.975^{**}
7.	Grain yield	Panicle weight (g)	0.972^{**}
8.	Grain yield	Number of grains $panicle^{-1}$	0.930^{**}
9.	Grain yield	Test weight (g)	0.980^{**}

**- significant at both 0.01 & 0.05 %

Discussion

V DISCUSSION

A field experiment was conducted during *Kharif* 2014 at Agriculture and Horticulture Research Station (AHRS), Bavikere, University of Agriculture and Horticulture Sciences Shivamogga to study the "Effect of integrated nutrient management on growth and yield of aerobic rice (*Oryza sativa* L.)" The experimental area was located in southern transitional zone of Karnataka. The results obtained are discussed critically in this chapter.

5.1 Crop and weather

The normal and actual weather data that prevailed during *Kharif* 2014 and deviation from the normal with respect to rainfall, temperature and mean relative humidity are presented in the (Table. 3.1)

The total rainfall during crop growth (1288.7 mm) was slightly higher as compared to normal rainfall (1037.61 mm). During the crop growth period, the higher monthly rainfall was recorded in September (164.6 mm) and the lower in October (28.0 mm) months. The mean maximum air temperature during the period of experimentation was 31.8 ^{0}C in September and mean minimum air temperature was 30.1 ^{0}C in December. The mean monthly relative humidity ranged from 85.8 per cent in September to 62.6 per cent in December. The crop did not suffer from any of the prevailing weather conditions during cropping period.

5.2 Effect of integrated nutrient management practices on yield and yield components of aerobic rice

Many factors, both external and internal influence the crop growth and productivity. Nutrient management is one such important factor which largely decides the yield of the crop produced. The grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The synthesis, accumulation and translocation of photosynthates depend upon efficient photosynthetic structure as well as the extent of translocation into sink and also on plant growth and development during early stages of crop growth.

In agricultural practices the factor mineral nutrition is routinely manipulated to increase the yield. Adequate supply of essential nutrients in balanced way is one of the factor to get high yield. This is particularly true for high yielding varieties and hybrids. The use of inorganic fertilizers is essential to meet the nutrients demand of crop to get maximum yield (Tiwari, 2002). Now a day's more emphasis is given on environmental quality due to continuous use of chemical fertilizers. So, integrated nutrient management system is an alternative and is characterized by reduced input of chemical fertilizers and combined use of chemical fertilizers along with organic materials such as animal manures, crop residues, green manure and composts (Dutta *et al*., 2003). For sustainable crop production, integrated use of chemical and organic fertilizer has proved to be highly beneficial for rice crop.

The pre-requisite for getting higher yields in any crop is higher total dry matter production (TDM) and it's partitioning into various plant parts coupled with maximum translocation of photosynthates to the sink. Total dry matter accumulation (TDMA) is the sum of dry matter accumulation in individual plant parts which depends on the moisture, nutrients and availability of light.

The dry matter accumulation influences the economic yield on one hand, while production of dry matter dependent upon supply of adequate quantity of plant nutrients. The amount of nutrients present in soil and their availability in tune with the synchrony of crop demand is essential to decide the plant growth and yield. The economic yield is a fraction of the total biological yield of the crop and dry matter production, is an important determinant of the grain yield (Donald, 1962).

The grain yield of a crop is the integrated results of a number of physiological processes. In this present study result showed that integrated nutrient management practices significantly influenced the yield and yield attributes in aerobic rice. Application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia recorded significantly higher grain yield (42.41 q ha^{-1}) which is 22.01 % higher than the recommended dose of fertilizer (RDF) alone and was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (41.11 q ha^{-1}). Higher grain yield may be attributed to the high yielding parameters like number of panicles per plant, number of filled grains per panicle, test weight and significant reduction in chaffiness (Table 4.15 and Fig 5.1). The results of this present investigation are in confirmation with the findings of Khan *et al*. (2007) and Rajashekhara Reddy (2006). Significantly lower grain yield (35.30 q ha^{-1}) was observed with application of

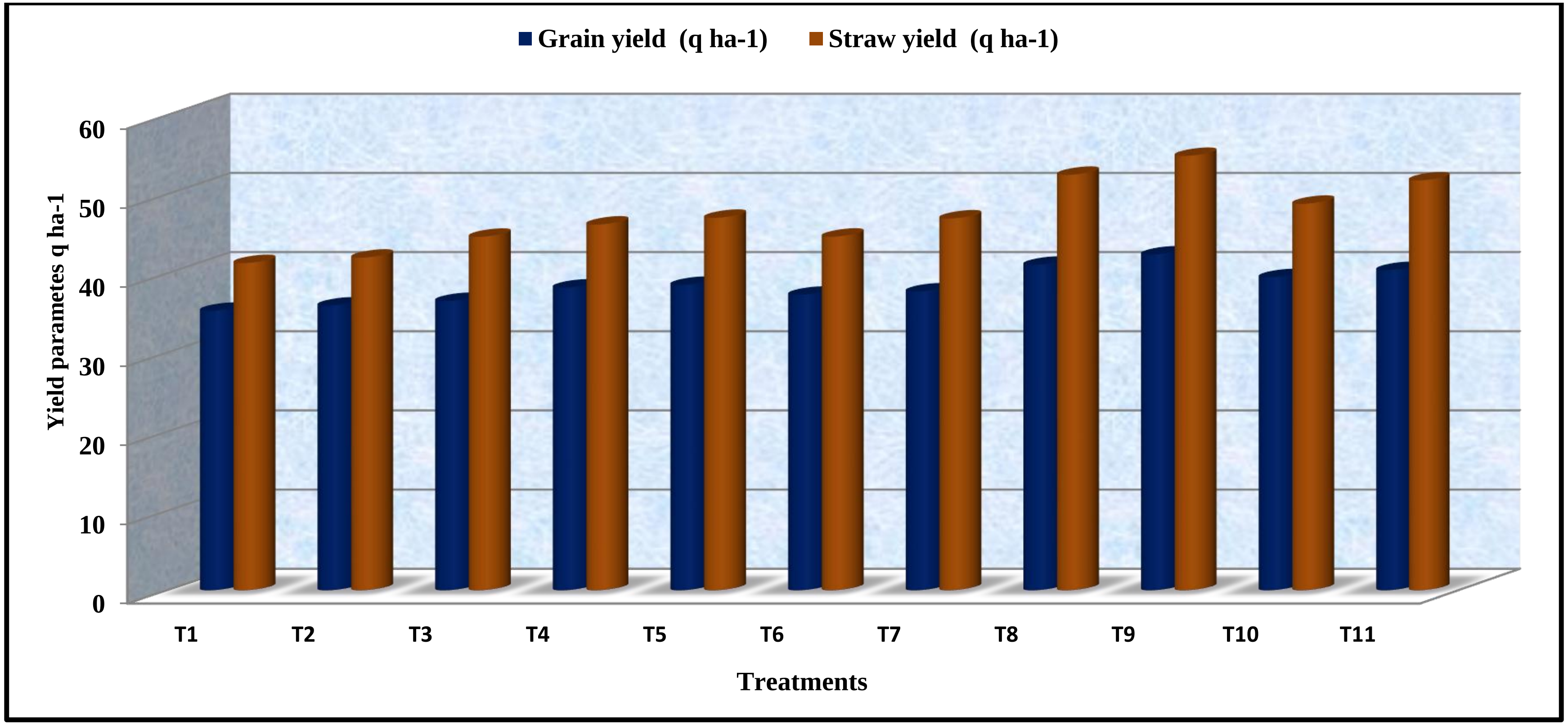

Fig 5.1 Influence of integrated nutrient management practice on grain and straw yield of aerobic rice

T_1. RDF
T_2. RDF + FYM (POP)
T_3. RDF + Vermicompost (FYM equivalent)
T_4. RDF + FYM +25% Nitrogen through FYM
T_5. RDF + FYM + 25% Nitrogen through Vermicompost
T_6. RDF + FYM + 25% Nitrogen through Glyricidia
T_7. RDF + Vermicompost + 25% Nitrogen through Glyricidia
T_8. RDF + FYM + PSB + 25% Nitrogen through Glyricidia
T_9. RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia
T_{10}.RDF + FYM + PSB
T_{11}.RDF + Vermicompost + PSB

recommended dose of fertilizer (RDF) only, this result was in confirmation with the findings of Beena and Balachandran (2002) and Dutta & Sangtam (2014).

The significant increase in yield was due to adequate quantities and balanced proportions of plant nutrients supplied to the crop as per need during the growth period resulting in favourable increase in yield attributing characters which ultimately led towards an increase in economic yield. Rao *et al.* (1996) also reported that the combination of organic and inorganic sources resulted in comparable rice yield to the application of inorganic alone. Improved physico-chernical properties of the soil through the application of organic manure might be the other possible reason for higher productivity.

The variation in yield could also be explained in terms of other yield attributes like, number of panicles per plant. The total number of panicles in a given area is a product of the number of established seedlings and the number of effective tillers produced by each seedling. Of all the yield components, the number of panicles per unit area is most easily influenced by management practices. Significantly higher panicles per plant (23.40) was recorded by application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia followed by application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (22.69). More panicles per plant might be due to better availability of nutrients and reduced mortality of tillers which in turn resulted in higher uptake of nutrients. Adequate quantity of macro nutrients and moisture during panicle differentiation stage might have helped to obtain higher number of grains per panicle and better availability of moisture and aeration of roots, which might have helped to retain more number of panicles per plant at harvest (Table 4.13 and Fig. 5.2). These results are in conformity with the findings of Ravi and Srivasthava (1997) and Barik *et al*. (2006), Alagesan (1997) also proved the positive correlation between N application and formation of higher panicles per plant. Use of higher dose of nitrogen, phosphorus and potassium through organic sources might have helped in inducing good vegetative growth (Dhurandher and Tripathi, 1999) and this produced higher number of panicles leading to higher yield. The increased number of grain per panicle (127.67) was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (122.49) (Fig 5.2). It might be due to higher nutrient uptake, higher leaf area and dry matter

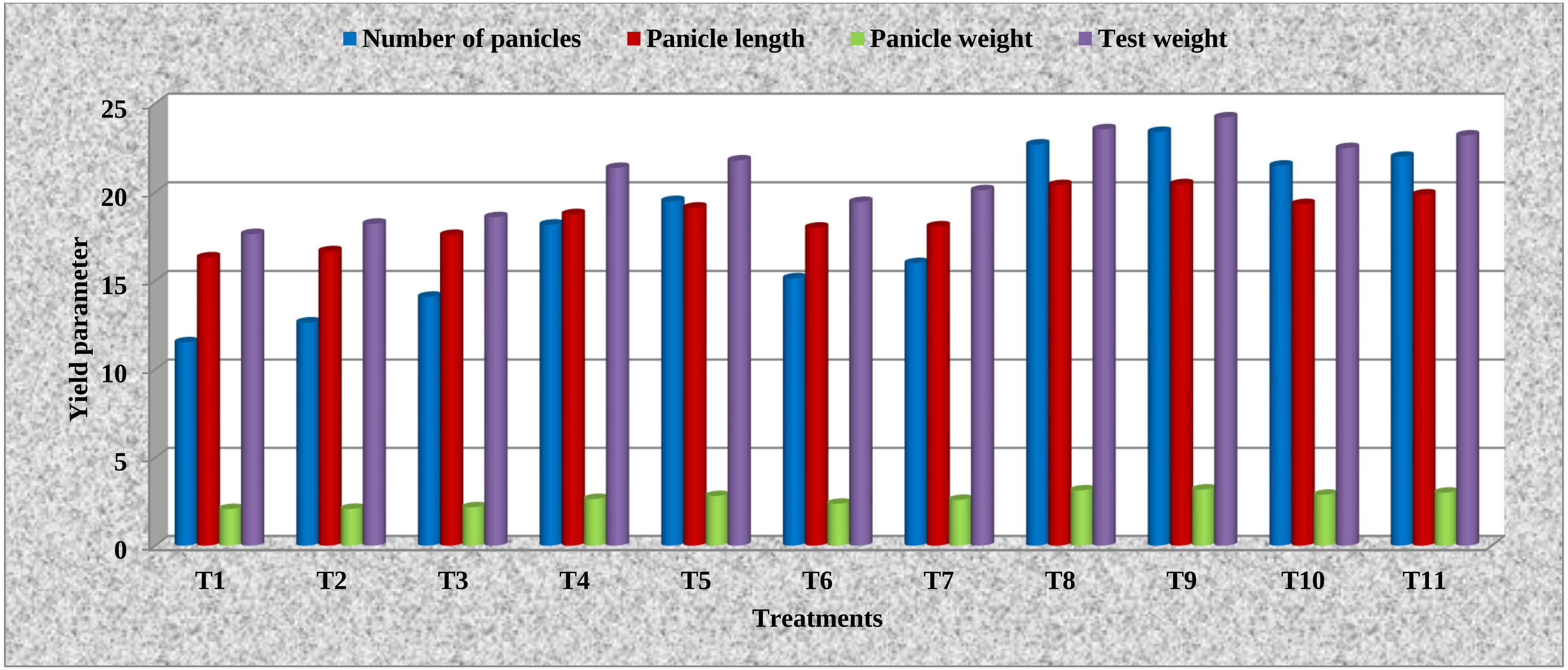

Fig 5.2 Influence of integrated nutrient management practice on yield parameters of aerobic rice

T_1. RDF
T_2. RDF + FYM (POP)
T_3. RDF + Vermicompost (FYM equivalent)
T_4. RDF + FYM +25% Nitrogen through FYM
T_5. RDF + FYM + 25% Nitrogen through Vermicompost
T_6. RDF + FYM + 25% Nitrogen through Glyricidia
T_7. RDF + Vermicompost + 25% Nitrogen through Glyricidia
T_8. RDF + FYM + PSB + 25% Nitrogen through Glyricidia
T_9. RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia
T_{10}.RDF + FYM + PSB
T_{11}.RDF + Vermicompost + PSB

production, which in turn favoured the development of large sink. The results of the present investigation are in conformation with the findings of Ahmed *et al.* (1990), Dahatonde (1992) & Jaiswal and Singh (2001).

The number of filled grains has the greatest influence among the yield components in constituting yield so that the success of rice cultivation is largely decided by the number of filled grains per panicle. Number of filled grains mainly depends on amount of starch transported during the grain filling stage. Mathsushima (1966) concluded that the ratio of the amount of starch translocated to the total yield would be approximately only one third. Murayama *et al.* (1955) also reported that the percentage of the weight of starch translocated from straw to panicles is directly proportional to harvested grain yield. Significantly higher number of filled grains per panicle (114.48) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (108.32), it may be due to higher starch stored in the straw better translocation of accumulated dry matter to the sink (grain) and also higher nitrogen supplied by vermicompost and glyricidia which resulted in increased amount of interception of photosynthetically active radiation and greater photosynthesis. Supply of adequate micronutrients through vermicompost improved the chlorophyll content and enzymatic activity caused reduction of chaffy percentage. Similar results were also reported by Murali and Setty (2001), Das *et al*. (2002) and Barik *et al*. (2006).

The decreased number of chaffy grains (13.19) was noticed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with the application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (14.19). This may be due to less leaching loss of nutrients and more availability of photosynthates for better grain filling as a consequence of increased green leaves plant^{-1}, higher leaf area and higher dry matter. Increase in filled grain and thousand-grain weight under increased nitrogen levels might be due to N induced enhancement in photosynthetic activity and these resulted in the translocation of photosynthates and amino acids from the leaves and culms to the grain. This work is in accordance with findings of Belder *et al.* (2005), and Dhyani and Mishra (1994).

Plate 5.1 RDF+Vermicompost+PSB+25% Nitrogen through Glyricidia

Significantly higher panicle length (20.45 cm) and higher panicle weight (3.19 g) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia However, panicle length was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (20.40 cm) and RDF + Vermicompost + PSB (19.87 cm) and panicle weight was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (3.14 g). This increased panicle length and panicle weight, might be attributed to higher concentration of nutrients, applied through soil application. Hence, more availability for uptake and steady supply of nutrients which enhanced the dry matter production due to more availability of photosynthates. These results are corroborate with the findings of Jena *et al.* (2006).

The test weight was significantly higher (24.22 g) with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (23.55 g) (Fig 5.2) due to higher the level of fertilizer leads to more chaffiness grains and decreases the grain filling, distribution of starch to more number of panicles leads to decreases the grain size similar observation was made by Maragatham *et al.* (2010). Venkateshwaralu and Mahatim Singh (1980) reported that yield attributes increased with increase in the fertilizer levels.

5.3 Effect of integrated nutrient management practices on growth parameters of aerobic rice

The grain yield in any crop is dependent upon the photosynthetic source, in terms of plant height, number of tillers to support and hold the leaves are logically able to increase the total dry matter production and later lead to higher grain yield. The grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts which in turn depends on total photosynthetic area and rate of photosynthesis. The dry matter accumulation influences the economic yield on one hand, while production of dry matter dependent upon supply of adequate quantity of plant nutrients. The amount of nutrients present in soil and their availability in tune with the synchrony of crop demand is essential to decide the plant growth and yield. The economic yield is a fraction of the total biological yield of the crop and dry matter production is an important determinant of the grain yield (Donald, 1962).

In the present investigation, integrated nutrient management practices exhibited significance difference with respect to total dry matter production from 30 DAS to harvest. Significantly higher total dry matter production (96.46 g plant^{-1}) (Table 4.9 and fig. 5.3) at harvest was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and was on par with the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (94.52 g plant^{-1}). Application of vermicompost helped in balanced availability of nutrients at all stages. Improved soil aggregation, higher quantity of nutrient availability and enhanced soil microbial activity, resulting in congenial soil condition which improved uptake of nutrients resulted in higher dry matter. Total dry matter accumulation is an index to growth, it was significantly influenced by organic and inorganic sources of nutrients along with bio fertilizers under Integrated Nutrient Management approach this might have been attributed to increased photo-synthetically active leaf area with higher efficiency of CO_2 assimilating under increased supply of NPK (Rayees and Sandeep, 2014). The dry matter accumulation increased with increase in nitrogen application rates was reported by Limeng *et al.* (2009). The increased dry matter production in higher fertilizer was due to better uptake of nutrients and moisture from soil. Similar results were reported by Stalin *et al.* (2008) and Shekara *et al*. (2010).

Dry matter has influence on grain yield. Higher dry mater per plant might be due to more number of tillers per plant (Table 4.9 Fig 5.3). These results are in conformity with the findings of Vasanthi and Kumaraswamy (2008) who reported that higher dry matter accumulation through increased shoots, bear physiologically active green leaves, provided room for increased photosynthetic activity. The improvement in yield components with application of RDF + Vermicompost + PSB + Glyricidia might be due to good root development which favoured good vegetative growth, higher leaf area and DMP. These in turn might have favoured the development of large sink (Mahajan *et al.*, 1997). Increase in filled grain and thousand-grain weight under integrated nutrient management practices might be due to availability of nutrients to crop throughout crop growth period, N induced enhancement in photosynthetic activity and these resulted in the translocation of photosynthesis and

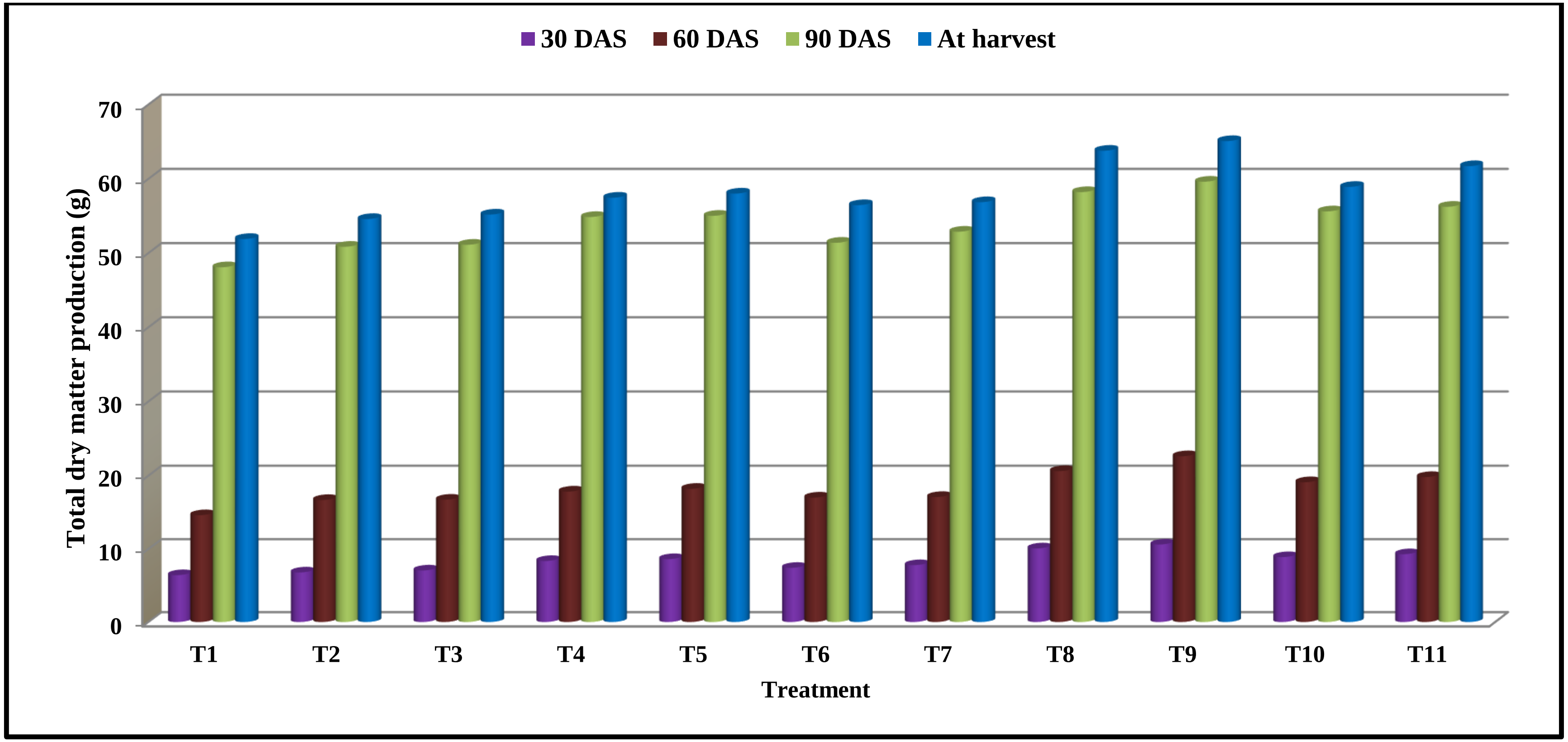

Fig 5.3 Influence of integrated nutrient management practice on total dry matter production of aerobic rice

T_1. RDF
T_2. RDF + FYM (POP)
T_3. RDF + Vermicompost (FYM equivalent)
T_4. RDF + FYM +25% Nitrogen through FYM
T_5. RDF + FYM + 25% Nitrogen through Vermicompost
T_6. RDF + FYM + 25% Nitrogen through Glyricidia
T_7. RDF + Vermicompost + 25% Nitrogen through Glyricidia
T_8. RDF + FYM + PSB + 25% Nitrogen through Glyricidia
T_9. RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia
T_{10}.RDF + FYM + PSB
T_{11}.RDF + Vermicompost + PSB

amino acids from the leaves and culms to the grain. It is in accordance with findings of Belder *et al.* (2005) and Dhyani and Mishra (1994).

The yield in any grain crop is dependent on photosynthetic source, which could build up a sound source in terms of plant height and number of tillers to support and hold the leaves to increase total dry matter and later leading to higher grain yield. The growth parameters *viz.*, plant height, number of leaves, number of tillers, leaf area, leaf area index, leaf area duration and total dry matter accumulation of aerobic rice was significantly influenced by various levels of nitrogen through organic sources.

In the present investigation, combined application of organic and inorganic sources of fertilizers exhibited significant difference with respect to plant height from 30 DAS to harvest. Significantly higher plant height of (65.10 cm) at harvest was recorded with application RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (Table 4.1and Fig 5.4). This could be due to solubility and accelerated release of nitrogen by chemical fertilizer and organic manure by providing an opportunity for aerobic rice to utilize higher quantum of nutrients. Devaraju *et al*. (1998) opined that adequate supply of plant nutrients influenced plant growth. Ravi and Srivasthava (1997) also reported release of greater percentage of nutrients at later stages by organic sources of nutrients.

The branches that arise at basal nodes of the stem or crown in cereals are called as tillers. Rice tillering is an important agronomic trait for grain yield, but the emergence and development of tillers are greatly influenced by factors such as nitrogen supply, solar radiation and temperature (Murata Yoshino 1975). Tillering capacity is one of the most important characteristics of a crop and it is dependent on the dry matter production and accumulation in the main stem during early stage of growth (Honda and Okazima, 1969). The longer tillering period in a crop is disadvantageous since late tillers are small, mature late and nonbearing one (Anon., 1988). Total number of tillers per plant was significantly differed from 30 DAS onwards. Significantly highest number of tillers (30.10) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (29.60) (Table 4.3). Higher number of tillers per plant noticed with application of RDF +

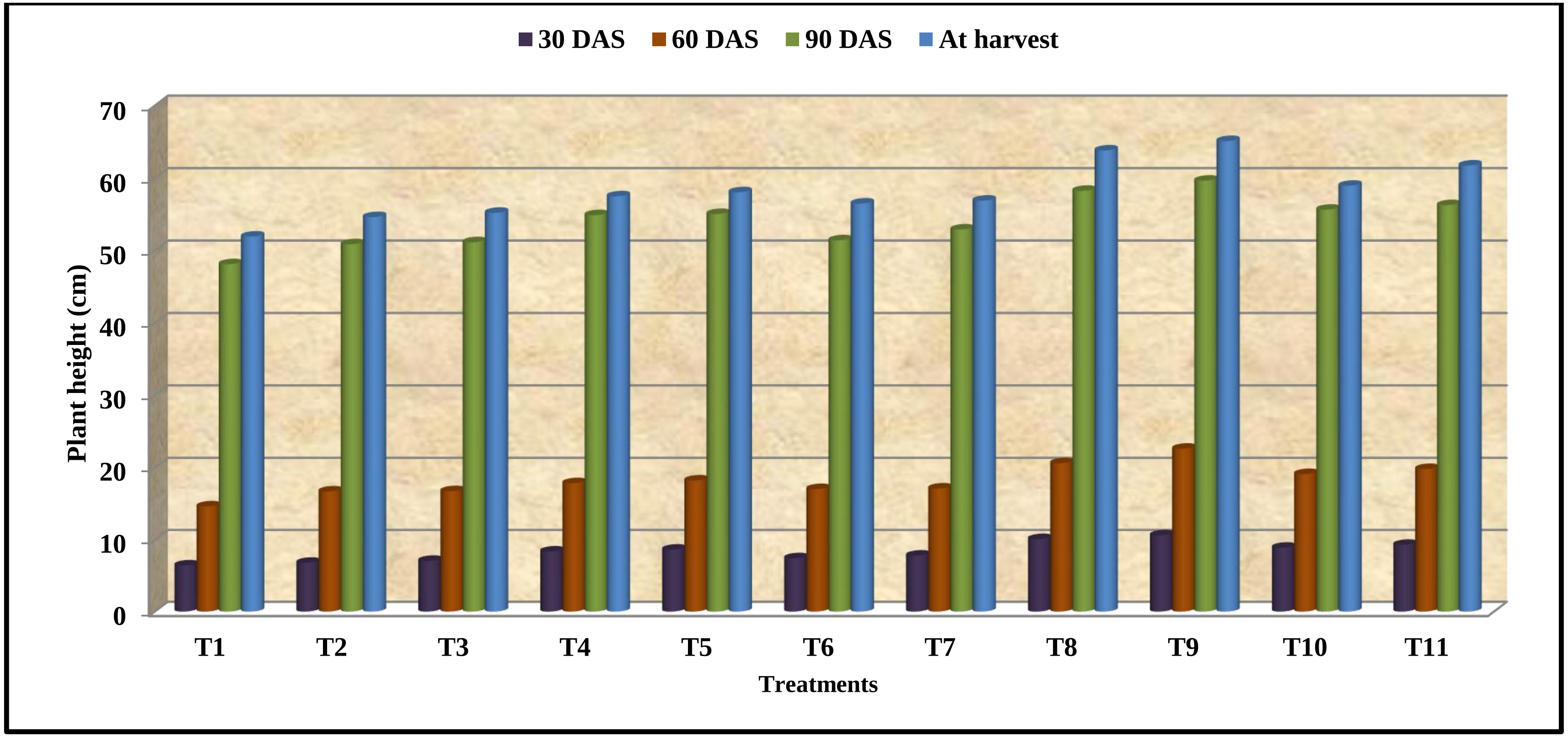

Fig 5.4 Influence of integrated nutrient management practice on plant height of aerobic rice

T_1. RDF
T_2. RDF + FYM (POP)
T_3. RDF + Vermicompost (FYM equivalent)
T_4. RDF + FYM +25% Nitrogen through FYM
T_5. RDF + FYM + 25% Nitrogen through Vermicompost
T_6. RDF + FYM + 25% Nitrogen through Glyricidia
T_7. RDF + Vermicompost + 25% Nitrogen through Glyricidia
T_8. RDF + FYM + PSB + 25% Nitrogen through Glyricidia
T_9. RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia
T_{10}.RDF + FYM + PSB
T_{11}.RDF + Vermicompost + PSB

Vermicompost + PSB + 25% Nitrogen through Glyricidia and was due to better utilization of available nutrients and slow release of nutrients from the organic sources at later stages of crop growth which might have resulted in increased number of tillers at harvest. Similar findings were documented by Babu and Reddy (2000). Tiller number increased with nitrogen supply and is in accordance with the findings of Shanmugam (1983) and Krishna Kumar (1986).

Higher the number of tillers results higher the number of leaves significantly higher number of leaves (103.32 at 90 DAS) was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (Table 4.2 and Fig 5.5) than the other treatments. Higher number of leaves and tillers lead to significantly higher leaf area per plant (2323.60 cm^2 per plant) at 90 DAS was recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia and which was on par with application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (2248.60 cm^2 per plant) (Table 4.4). The increase in leaf count as well as leaf weight due to integrated nutrient management is explainable in terms of possible increase in nutrient mining capacity of plant as a result of better root development and increased translocation of carbohydrates from source to growing points in well-fertilized plots. Similar results found by Indira Chaturvedi (2005).

Leaf area index and leaf area duration were significantly higher in combined application RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (3.72 LAI at 90 DAS and 97.75 days of LAD at harvest) which was on par with RDF + FYM + PSB + 25% Nitrogen through Glyricidia (3.60 LAI at 90 DAS and 95.35 days of LAD at harvest) (Table 4.6 & 4.6). Increased LAI and LAD mainly due to higher nutrient uptake leading to increased leaf area, LAI and LAD towards reproductive stage due to the application of organic sources of nutrients has also been documented by Kenchaiah (1997). Lower leaves are more shaded and become unproductive, so the mean photosynthetic rate of all leaves decreased and respiration would exceeded their photosynthesis (Yoshida, 1982). This might have further reduced the production and translocation of photosynthates towards sink and resulted in lower grain yield with 100 per cent RDF. These results are corroborate with the findings of Vasanthi and Kumaraswamy (2008) and Murali and Setty (2001) who reported that maximum number of functional leaves per hill, leaf area and total number of tillers per hill were

Plate 5.2 Number of tillers as influenced by INM

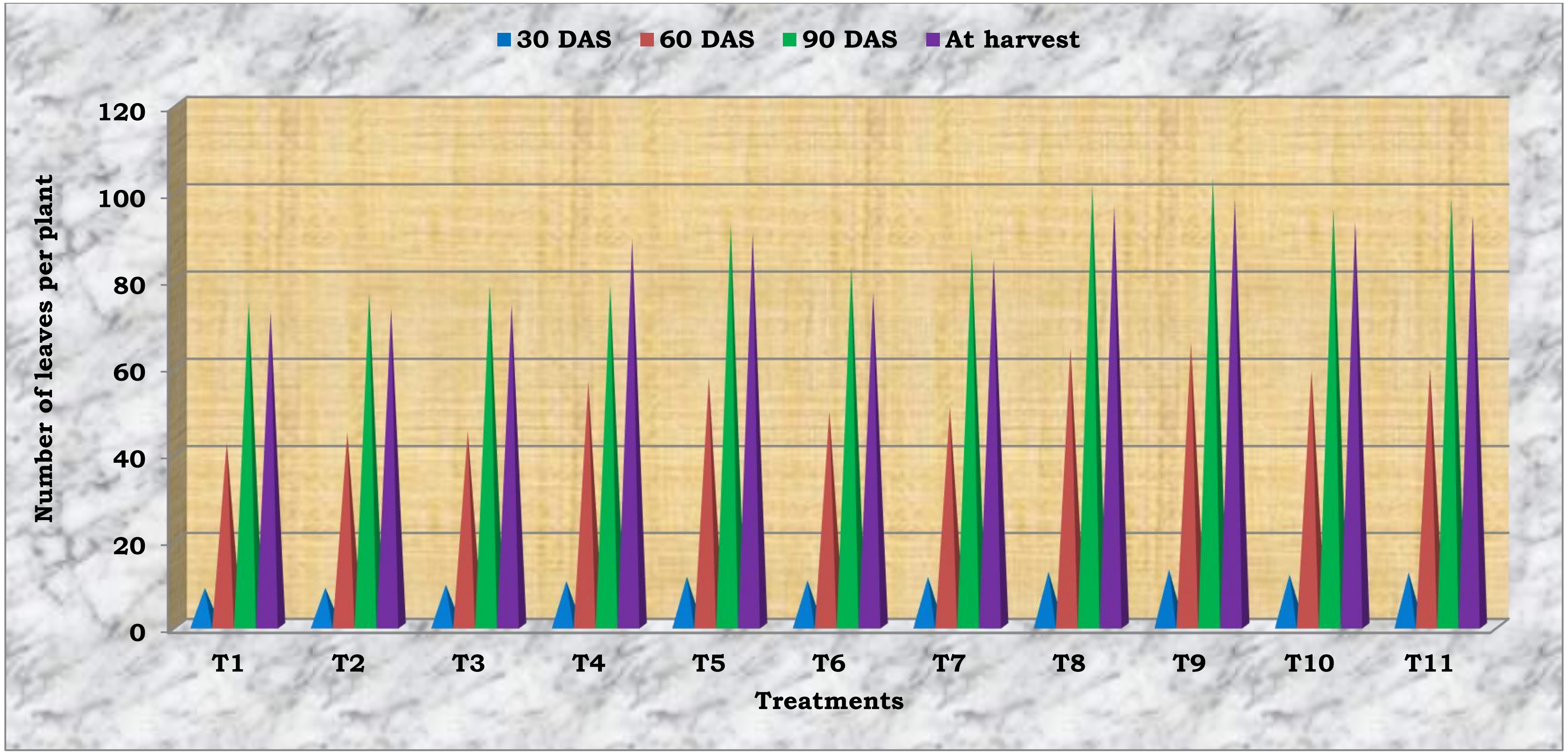

Fig 5.5 Influence of integrated nutrient management practice on number of leaves in aerobic rice

T_1. RDF
T_2. RDF + FYM (POP)
T_3. RDF + Vermicompost (FYM equivalent)
T_4. RDF + FYM +25% Nitrogen through FYM
T_5. RDF + FYM + 25% Nitrogen through Vermicompost
T_6. RDF + FYM + 25% Nitrogen through Glyricidia
T_7. RDF + Vermicompost + 25% Nitrogen through Glyricidia
T_8. RDF + FYM + PSB + 25% Nitrogen through Glyricidia
T_9. RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia
T_{10}.RDF + FYM + PSB
T_{11}.RDF + Vermicompost + PSB

higher by application of vermicompost @ 5 t ha^{-1} combined with NPK at 150-75-75 kg ha^{-1}.

The effect of various integrated nutrient management practices on straw yield was found significant. Application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia recorded significantly higher straw yield (54.87 q ha^{-1}) which was on par with the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (52.48 q ha^{-1}) (Table 4.15 and Fig 5.1). Significant increase in straw yield was mainly due to increased dry matter production which indicated by higher growth attributing characters like plant height, number of leaves, more number of tillers, leaf area, leaf area index and leaf area duration. These results are in conformity with the findings of Kenchaiah (1997) who reported that higher growth indices recorded in rice had positive association with dry matter accumulation in growth parameters. This result was also supported by Panda *et al*. (1995) who reported that grain yield and straw yield increased with increase in nutrient uptake.

5.4 Effect of integrated nutrient management practices on nutrient status in crop

Ability of a crop to yield better depends on its ability in making use of the available resources. The production and translocation of synthesized photosynthates depends upon mineral nutrition supplied either by soil or through external application. Higher nutrient uptake by plant may increase the metabolic activity of the plant leading to a greater accumulation of dry matter and subsequently increased grain yield. Nutrient uptake was varied with the application of different organic manures and inorganic fertilizrs. The higher uptake of nutrients was found with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (Table 4.17 to 4.19) (Fig. 5.6)

Significantly higher nitrogen uptake (131.32 kg ha^{-1}) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (Fig 5.6) This might be due to the improved physical conditions of the soils with better availability of N and also other essential nutrients added with these organic sources to rice crop. The combined effect of these produced higher grain and straw yield as observed in these treatments. These findings are in accordance with the findings reported by Laxminarayana and Patiram (2006). It may also due to higher mineralization of nitrogen from applied organic source of nutrients. As nitrogen is key element required at early growth stages of crop and hence nutrient uptake was greatly influenced by availability of N in soil. Vermicompost stimulates the uptake of nutrients, due to enhanced activity of nitrogenase and nitrate reducates enzyme in the soil under congenial soil physical condition. Similar results are in line with the findings of Paikaray *et al*. (2001) and Nandan (2006) who stated that use of higher dose of nitrogen through organic sources and liquid organic sources might have helped for good vegetative growth and root system, which increased the higher N uptake by plants and hence increased yield and yield components of rice.

Significantly higher phosphorus uptake (26.95 kg ha^{-1}) was taken up by crop with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia. This might be due to favourable effect of combined application of NPK with vermicompost and PSB resulting in higher availability and uptake of P to meet the need of growing plants in these treatments which produced higher grain and straw yield. Similar observations were also reported by Laxminarayana and Patiram (2006), Laxminarayana (2006) and Baskar (2003). Phosphorus increases root growth and its deficiency reduce overall plant growth. Phosphorus being a constituent of compounds *viz.,* ATP, ADP and NADP etc essential for energy changes involved in photosynthesis, the interconversion of carbohydrates and related compounds, glycolysis, amino acid metabolism, fat metabolism and biological oxidation and a host of other life processes in the plant. This is in conformity with the findings of Setty (2005) and noticed that application of goat manure was superior than application of FYM in improving nutrient uptake of P, K, Ca and Mg from soils with low organic matter status. The higher uptake of NPK might be due to the fact that Glyricidia, FYM and vermicompost act as sources of nutrients and also enhances the availability of nutrients. Further, it has a favorable effect on uptake of N, P and K by rice with goat manure, FYM and vermicompost application as reported by Dravid and Biswas (2006).

Significantly higher total potassium uptake (113.07 kg ha^{-1}) was taken up by the crop with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia (Table 4.18). The significant increase in K uptake in these treatments might be due to the relatively higher K availability, improvement in physical environment of the soil conducive to higher plant growth, grain and straw yield resulting higher K uptake similar results were obtained by Baskar (2003). Potassium has a role in

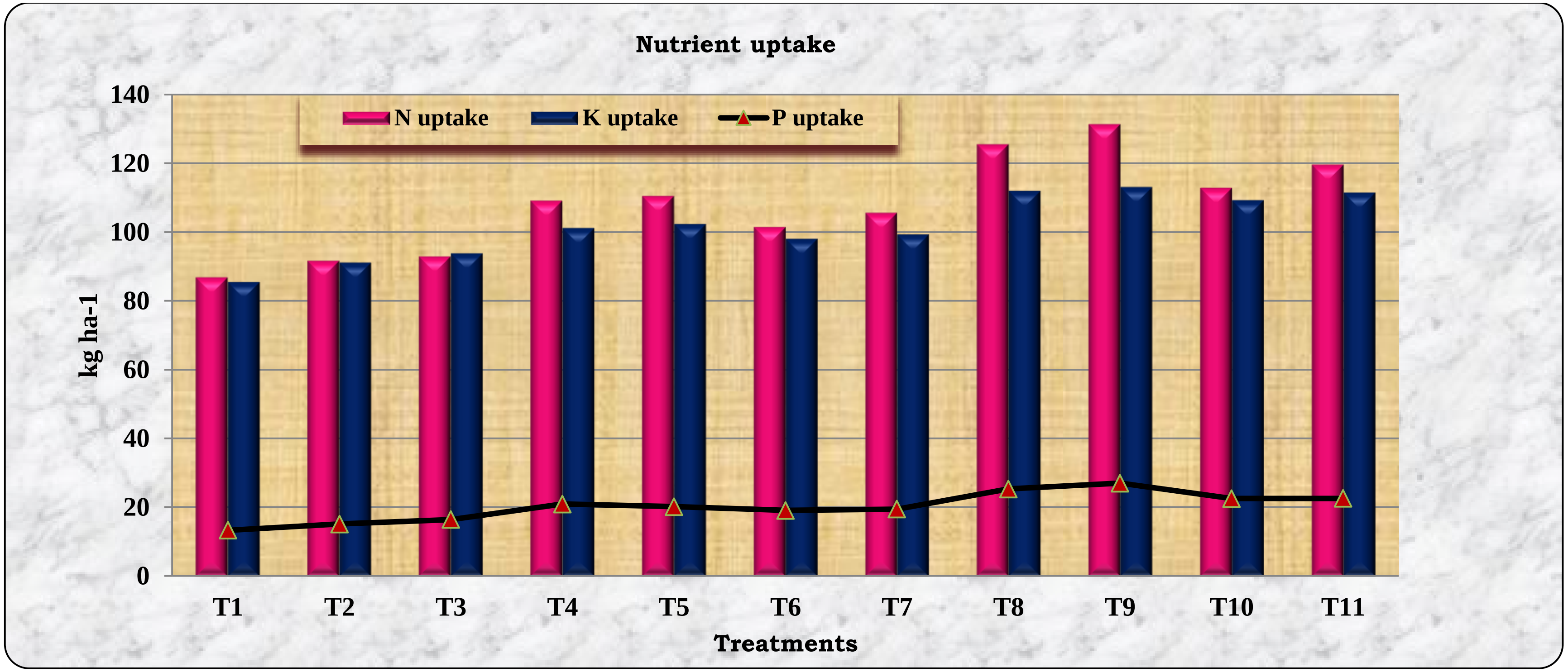

Fig 5.6 Influence of integrated nutrient management practice on nutrient uptake of aerobic rice

T_1. RDF
T_2. RDF + FYM (POP)
T_3. RDF + Vermicompost (FYM equivalent)
T_4. RDF + FYM +25% Nitrogen through FYM
T_5. RDF + FYM + 25% Nitrogen through Vermicompost
T_6. RDF + FYM + 25% Nitrogen through Glyricidia
T_7. RDF + Vermicompost + 25% Nitrogen through Glyricidia
T_8. RDF + FYM + PSB + 25% Nitrogen through Glyricidia
T_9. RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia
T_{10}.RDF + FYM + PSB
T_{11}.RDF + Vermicompost + PSB

enzyme activation, photosynthesis, protein and starch synthesis. It regulates stomatal activity, enhances the transport of sugars, water and nutrients. The beneficial effect of application of organics have resulted in increasing exchangeable K leading to increased concentration of K in available form, thereby increasing absorption of K. Further it was due to increased CEC. The results are corrugated the findings of Raju (2004), Meek *et al.* (2009) and Yamagata (2009) they observed that manures improves the uptake due to less loss and less fixation of potassium in paddy soils.

Increased uptake of NPK may be attributed to improved nutrient availability as a consequence of synergistic relationship between the organic manures and inorganic sources. Similar results were reported by Subramaniyan and Kumaraswamy (2007), Katyal and Sharma (1979) and Jadhav *et al.* (2008).

5.5 Effect of integrated nutrient management practices on soil health

Soil health in general refers to the soil productivity and sustainability on long run basis. It is measured in terms of improvement in physical, chemical and biological properties of soil.

Available N in soil differed significantly due to application of different organic and inorganic fertilizers. Significantly higher available nitrogen (269.40 kg ha^{-1}) after the crop harvest was observed with the application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia. However, it was followed by the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (262.62 kg ha^{-1}). This increase may be attributed to higher microbial activity in the integrated nutrient management practices which favoured the conversion of the organically bound nitrogen to inorganic form (Panwar and Munda, 2007). Similar increase in available N in soil due to addition of organics was observed in wheat (Singh and Verma, 2000). (Table 4.19)

Application RDF + vermicompost + PSB + 25% Nitrogen through Glyricidia increased the available phosphorus (86.95 kg ha^{-1}) (Table 4.19) This could be due to release of organic acids during the decomposition of organic matter, which helped in the solubility of native phosphates as a result of which the available phosphorus content in the soil was increased. Applied organic matter leads to the formation of a coating on sesquioxides, resulting in reduction of phosphate fixing capacity of soil

(Sheshadri Reddy *et al*., 2005). Similar, results was found by Laxminarayana,(2006) and Maitra *et al.*, (2008), who reported that Organic manures, on decomposition, solubilize insoluble organic P fractions through release of various organic acids, thus resulting into a significant improvement in available P status of the soil.

5.6 Effect of integrated nutrient management practices on economics

Economics is the ultimate criteria for acceptance or rejection and wider adoption of any technology. The aerobic rice is no exception to this. Among the different indicators of economic efficiency in any production system, net return has greater impact on the practical utility and acceptance of the technology by the farmers.

Assessment of treatments in terms of economic traits revealed that the gross return, net returns and benefit cost (B: C) ratio differed due to integrated nutrient management practices. Among the different treatment combinations the treatment with RDF + Vermicompost + PSB + 25% Nitrogen through Gyricidia has recorded higher cost (Rs. 22106.83), higher gross returns (Rs. 70485.15), higher net returns (Rs. 48378.32) and higher benefit to cost ratio (2.19) than other combination due to higher grain yield and straw yield (Table 4.20). The higher gross return and net returns was mainly due to higher grain yield and straw yields. Similar findings were also observed by Mehla and Panwar (2000), Aravind Kumar and Prasad (2002) and Godhawale and Dahipale (2007).

Practical utility of the present investigation

a) Integrated use of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia resulted in higher grain (22.01 %) and straw yield (32.70 %) as compared to recommended dose of fertilizer alone in aerobic condition.

b) Maximum gross returns (Rs. 70485), net returns (Rs. 48378) and B:C ratio (2.19) was observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia.

c) Organic manures *viz.,* FYM, Vermicompost being prepared from the locally available farm materials this can be promoted as a useful and profitable supplement for costly inorganic sources of nutrients.

d) FYM can be effectively used to minimize cost of cultivation

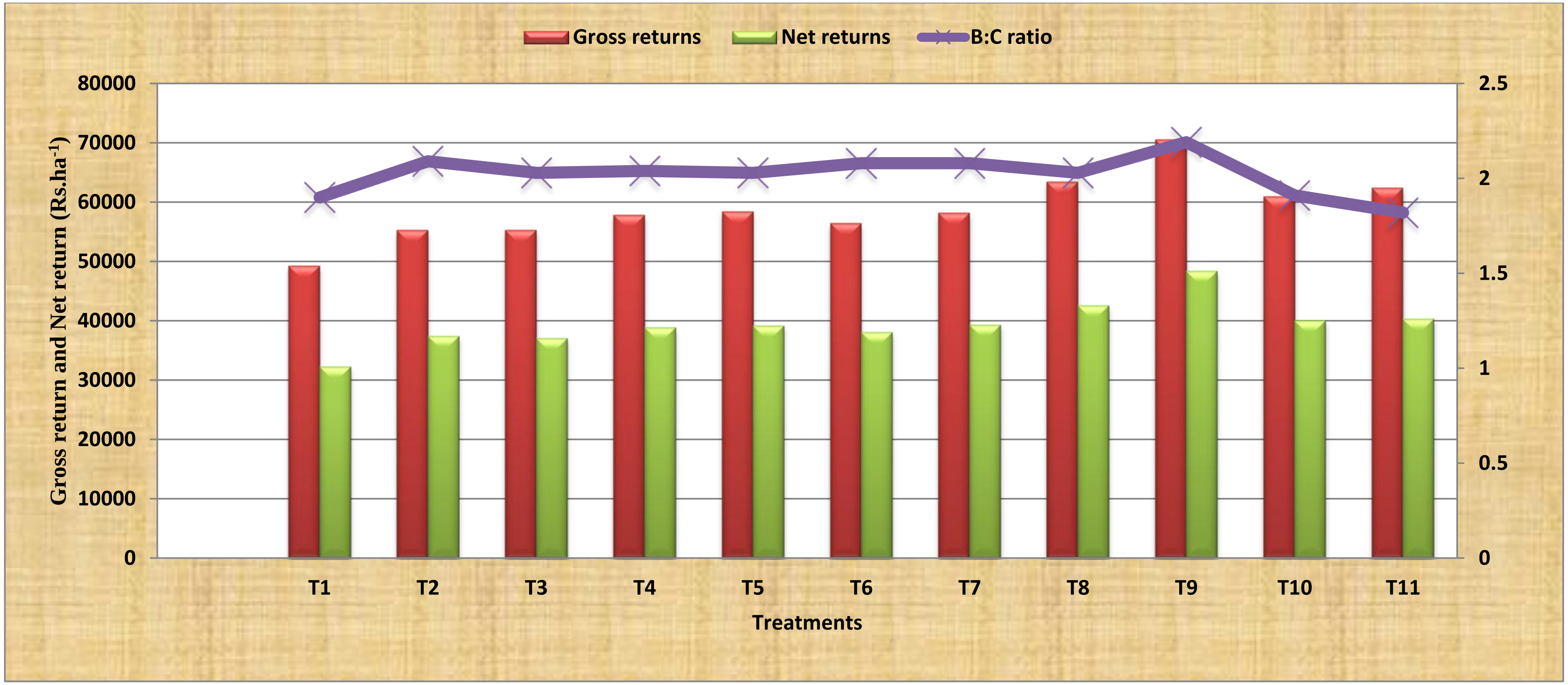

Fig 5.7 Economics of integrated nutrient management practices in aerobic rice

T_1. RDF
T_2. RDF + FYM (POP)
T_3. RDF + Vermicompost (FYM equivalent)
T_4. RDF + FYM +25% Nitrogen through FYM
T_5. RDF + FYM + 25% Nitrogen through Vermicompost
T_6. RDF + FYM + 25% Nitrogen through Glyricidia
T_7. RDF + Vermicompost + 25% Nitrogen through Glyricidia
T_8. RDF + FYM + PSB + 25% Nitrogen through Glyricidia
T_9. RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia
T_{10}.RDF + FYM + PSB
T_{11}.RDF + Vermicompost + PSB

Future line of work

1. There is a need to study the nutrient requirement at different stages of crop
2. Need to develop optimum spacing along with integrated nutrient management for yield maximization
3. Nutrient release pattern of different organic manures need to be studied.
4. Further study is required to use effective biofertilizer in aerobic rice cultivation.

Summary

VI SUMMARY

Agronomic investigation on "Effect of Integrated Nutrient Management on crop growth and yield of aerobic rice" was carried out on Red clay loam soil at Agriculture and Horticulture Research Station (AHRS) Bavikere, located in Sothern transition zone of Karnataka during *Kharif* 2014. The experiment was laid out in a Randomized Complete Block Design (RCBD) with eleven treatments replicated thrice. The treatments consist of combinations of organic manure (FYM, Vermicompost, glyricidia,) and inorganic fertilizer and these treatments were compared with RDF. Observations on growth and yield parameters were recorded at 30, 60, 90 days after sowing and at harvest. The cultivar used was MAS 946-1 designed basically for aerobic rice system. The salient features of the results are summarized in this chapter.

- Application of organic manure (FYM, Vemicompost, Glyricidia) along with inorganic fertilizer recorded superior growth and yield parameters of aerobic rice as compared to recommended dose of fertilizer (RDF) alone.

- Significantly higher grain yield (4241 kg ha^{-1}) and straw yield (5487 kg ha^{-1}) of aerobic rice observed with application of RDF + Vermicompost + PSB + 25% Nitrogen through Gyricidia followed by the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia (4111 kg ha^{-1} and 5248 kg ha^{-1}). Lower grain yield (3530 kg ha^{-1}) and straw yield (4133 kg ha^{-1}) was observed with application of recommended dose of fertilizer (RDF) alone.

- Yield parameters *viz.,* number of panicles per plant (23.40), panicle length (20.45 cm), panicle weight (3.19 g), 1000 grain weight (24.42 g) and number of filled grains per panicle (114.48) were significantly influenced by the application of RDF + Vermicompost + PSB + 25% Nitrogen through Gyricidia followed by the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia

- Application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia produced significantly higher plant height (65.10 cm) and total dry matter production per plant (96.46 g) at harvest. However, it was closely followed by the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia.

- ❖ Significantly higher number of leaves per plant (103.32), number of tillers per plant (31.63), leaf area per plant (2323.60 cm^2) and leaf area index (3.72) at 90 DAS were recorded with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia. However it was followed by the application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia.

- ❖ Application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia resulted in significantly higher total nitrogen, phosphorus and potassium uptake by aerobic rice (131.32, 26.95 and 113.07 kg ha^{-1}, respectively) followed by application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia recorded (125.54, 25.28 and 111.97 kg ha^{-1}, respectively). Lower uptake of nitrogen, phosphorus and potassium (86.93, 13.26 and 85.46 kg ha^{-1}, respectively) was observed with application recommended dose of fertilizer (RDF) alone.

- ❖ Significantly higher available nitrogen, phosphorus and potassium (272.62, 86.95 and 221.30 kg ha^{-1}, respectively) after the crop harvest were observed with the application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia followed by application of RDF + FYM + PSB + 25% Nitrogen through Glyricidia recorded (271.30, 85.69, and 201.25 kg ha^{-1}, respectively) available nitrogen, phosphorus and potassium. Lower available nitrogen, phosphorus and potassium (265.14, 76.81 and 164.82 kg ha^{-1}, respectively) were observed with application of recommended dose of fertilizer (RDF) alone.

- ❖ Higher gross returns (Rs. 70485.15), net returns (Rs. 48378.32) and B: C ratio (2.19) were realized with application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia. Lower gross returns (Rs. 49224.45), net returns (Rs. 32263.62) and B:C ratio (1.90) was observed with application of of recommended dose of fertilizer (RDF) alone.

Conclusion:

More supply of nutrients through chemical fertilizer as results reduction in total factor productivity or only supply of organic manures cannot meet the nutrient requirement and causes sudden yield loss. So, an integrated approach that recognizes soil as the storehouse of most of the plant nutrient essential for plant growth and that the way in which nutrients are managed will have a major impact on plant growth, soil fertility, and agriculture sustainability. Application of RDF + Vermicompost + PSB + 25% Nitrogen through Glyricidia produced significantly higher growth and yield in aerobic rice.

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Appendix

APPENDIX-I

Cost of inputs and outputs

Sl. No.	Particulars	Price (Rs.)
1	**Seed material**	
	MAS - 946	50 kg^{-1}
2	**Inorganic fertilizers**	
	a. Urea	Rs. 6.40 kg^{-1}
	b. DAP	Rs. 24.00 kg^{-1}
	c. Muriate of Potash	Rs. 16.40 kg^{-1}
	d. $ZnSO_4$	Rs.40.00 kg^{-1}
3	**Organic Manures**	
	a. Farm yard manure	1000 t^{-1}
	b. Vermicompost	1600 t^{-1}
	c. Glyricidia	500 t^{-1}
4	**Plant protection chemicals**	
	Monocrotophos	260 L^{-1}
5	**Labour wages**	
	a. Men labour	150.00 day^{-1}
	b. Women labour	125.00 day^{-1}
	c. Bullock pair with a man	200.00 day^{-1}
6	**Out put**	
	a. Paddy grain	1400 q^{-1}
	b. Paddy straw	70 q^{-1}

Abbreviations used in the thesis

Abbreviations	Full form
AGR	Absolute growth rate
Anon.,	Anonymous
B: C	Benefit cost ratio
C D	Critical difference
CEC	Cation exchange capacity
C D	Critical difference
CGR	Crop growth rate
cm	Centimeter
cm^{-3}	Cubic centimetre
DAS	Days after sowimg
EC	Electrical conductivity
et al.	Co workers
FYM	Farm yard manure
GLM	Green leaf manure
J.	Journal
ha^{-1}	per hectare
HI	Harvest index
IW/CPE	Pan evaporation (E pan)
K	Potassium
kg	Kilogram
LAD	Leaf area duration
LAI	Leaf area index
N	Nitrogen
OC	Organic carbon
P	Phosphorus
PM	Poultry manure
q	quintal
Rs.	Rupees
S.Em ±	Standard error mean
TDMA	Total dry matter accumulation
t	tonne