

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

**MEGHA, B.
MA1TAF0169**

***DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE, SHIVAMOGGA***

**UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES,
SHIVAMOGGA**

July, 2018

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

**MEGHA, B.
MA1TAF0169**

Thesis submitted to the

**UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES
SHIVAMOGGA**

In partial fulfillment of the requirements
for the award of the degree of

Master of Science (Agriculture)
in

AGRONOMY

Shivamogga

July, 2018


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

CERTIFICATE

This is to certify that the thesis entitled “**INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON GROWTH AND YIELD OF AEROBIC RICE (*Oryza sativa* L.)**” submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) in AGRONOMY** to the College of Agriculture, Shivamogga, University of Agricultural and Horticultural Sciences, Shivamogga, is a bonafide record of research work carried out by **Miss. Megha B, ID. No. MA1TAF0169** (meghabuddinni@gmail.com) during the period of study in this university under my guidance and supervision and no part of this thesis has previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

Shivamogga
July, 2018




(C. J. SRIDHARA)
MAJOR ADVISOR

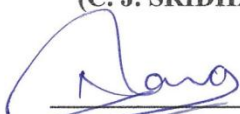
APPROVED BY:

Chairperson:



(C. J. SRIDHARA))

Members: 1.



(NARAYANA. S. MAVARKAR)

2.



(K. T. GURUMURTHY)

3.



(M. S. NANDISH)

ACKNOWLEDGEMENT

It is not sufficient for me to reasonably acknowledge the help, assistance and guidance rendered by a cluster of personalities, whatever I write here can only be deceptively placed reflection of the tumult of feelings that is in my heart at this moment as I write.

*First of all, I owe an immeasurable debt of gratitude to **Dr. C. J. Sridhara**, Professor, Department of Agronomy, VAHS, Shivamogga for acting as chairman to my advisory committee who is a person with patience, kindness, elegance and honesty. It is because of his valuable guidance helped me not only throughout this research but also in my personal life, I could reach this stage and an important step up in my career.*

*I am very much greatfull and thankfull to my advisory committee members, **Dr. N.S. Mavarkar**, Professor and Head, Department of Agronomy, VAHS, Shivamogga, **Dr. K. T. Gurumurthy**, Professor, Dept. of SS & AC, VAHS, Shivamogga, **Dr. M. S. Nandish**, Assistant professor, Dept. of microbiology, VAHS, Shivamogga acting as members of my advisory committee for their valuable suggestions, inspiring encouragement and painstaking animating and ameliorating this manuscript and blessing my dreams come true in the form of thesis.*

*At the same time, I wish to place my sincere thanks and respect to **Dr. Dinesh Kumar**, **Dr. G. K. Girijesh**, **Dr. S. Sridhara**, **Dr. H. K. Veeranna**, **Dr. Soumya** and **Dr. Basavaraj Naik** for their whole hearted encouragement, suggestions, steadfast inspiration in my successful accomplishment of the study. I never forget enormous timely help rendered by Siddappa uncle for their help throughout the course of investigation.*

*I thank **Dr. Sunil**, farm superindent, **Bhavikere**, **Ashok sir**, **Manu anna**, **Nithin anna**, field assistants, labours of Bhavikere and other staff members working at AHRS, Bhavikere for their support and guidance to complete the research work without whom my work would be impossible to complete my field research.*

*I owe my all success to my beloved parents. My ways in this world paves through the path curved by my father **Rachappa** and mother **Sumithra**, whom I wish to idolize throughout my life, without whose ambitious encouragement, constant support, affection, unbroken inspiration, sacrifice, love and blessings, I would not have grown to this level. I wish to express my heartfelt gratitude to my grandparents **Veereshappa** and **Parvathi**, they always inspired me with love, affection and positive thoughts which enable me to withstand all types of stresses and strains to reach this cherished goal. I am profoundly grateful to my family members **Amarappa**,*

Akkamma, Thippanna, Mallamma, Vikas, Manjula, Shivaraj, Gowri, Nagaraj, Soumya, Vinutha, Siddharath, Siddhanth, Sampreeth, Shashank, Chinni, Sony, Vinay and Sagar.

*I must manifest the great moral support in both personal and professional life and for being my best friend, instructor, guide and great personalities, my siblings **Vinutha** and **Siddharth**, my best friend **Sagar**, my senior **Divyashree U**.*

My diction doesn't seem too rich enough to provide suitable words to articulate my sincere and heartfelt gratitude to Shivaraj Kumar, Irfan, Umesh Mamathashree, Nandhini, Jeevana Lakshmi, Prakash, Mohan Kumar, Yusuf and Thimmaiah my senior friends who devoted all of their time and efforts to correct my manuscript and their advice and guidance helped me to carry out my research and also in every time extending their help for encouragement.

I take immense pleasure in extending my heartfelt thanks to my roommates Ashwini, Kavyashree and Maheswari for their endurance and affection whose company I enjoyed a lot during my stay in hostel.

*I may fail in my duty, if I don't express my deep sense of gratitude to my classmates, **Ashwini, Chaithra, Chandrashekar, Gajanan, Manjunath, Raagavalli, Savitha, Shruthi** and **Shwetha** and juniors **Abhishek, Bhavya, Nishchitha, Pooja, Shilpa, Yallappa, Hanumanth, Shreeshaail, Sachin K. H. and Sachin K.S.** for their unforgettable help during the PG programme. A handful of friends count much more than thousand relatives, an ear to cherish, a shoulder for support, a relation that knows no boundaries and one that supersedes all dissimilarities. So, I must remain ever grateful to such cluster of friends. To mention few **Sheelu, Pratima, Sangamesh, Sunil, Manoj, Soumya, Kavyashree, Madhu, Sasipriya, Shwetha, Saroja, Shruthi, Divya and Vinay** for their invaluable help and all the support extended in my life.*

*My Sincere thanks to **Snehamilana**, Shivamogga for their patience and kind support during the final thesis submission and special thanks to **Dinesh** uncle who made our work easy during the course of study.*

Finally, I thank all those who are involved in helping me directly or indirectly to attain this stage, any omission in this brief acknowledgement does not mean lack of gratitude.

Thanking you all once again

Shivamogga

July, 2018

Megha B
(Megha B)

**Influence of Integrated Nutrient Management Practices on Growth and Yield of
Aerobic Rice (*Oryza sativa* L.)
(Megha, B.)**

ABSTRACT


A field experiment was conducted at Agricultural and Horticultural Research Station, Bhavikere, UAHS, Shivamogga during *Kharif* 2017, to study the influence of integrated nutrient management practices on growth and yield of aerobic rice. The texture of soil was sandy loam having acidic pH with organic carbon of 0.40g kg⁻¹, available nitrogen 220.80 kg ha⁻¹, phosphorous 33.90 kg ha⁻¹ and potassium 163.60 kg ha⁻¹. The variety used was MAS 946-1 (Sharada). The experiment was laid out in a Randomized Complete Block Design with ten treatments replicated thrice. The treatments comprised of 100 per cent RDF and 75 per cent RDF with different levels of FYM and vermicompost.

Among different treatment combinations application of 100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR recorded significantly higher growth parameters like number of tillers (34.2), leaf area (1396.9 cm²), dry matter production (89.04 g), yield attributes like number of productive tillers per hill (16.32), panicle length (23.52 cm), panicle weight (2.68 g), number of filled grains (87.0), grain yield (3868.0kg ha⁻¹) straw yield (4225.72kg ha⁻¹) and total nutrient uptake of nitrogen (93.13 kg ha⁻¹), phosphorus (25.05 kg ha⁻¹), and potassium (92.63 kg ha⁻¹). The yield increment was 27 per cent over the control.

Higher gross returns and net returns were registered with 100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR (Rs. 81,228, Rs.45,175) whereas, higher benefit cost ratio (2.87) was obtained with application of 75% RDF +25% vermicompost (N Equivalent) + PGPR.

Dept. of Agronomy
UAHS, Shivamogga
July, 2018


Megha, B
(meghabuddinni@gmail.com)


C. J. Sridhara
(cjsridhara1966@gmail.com)

ಸಮಗ್ರ ಪೋಷಕಾಂಶಗಳ ನಿರ್ವಹಣೆಯಿಂದ ಎರೋಝ್ ಭತ್ತದ ಬೆಳವಣಿಗೆ ಮತ್ತು ಇಳುವರಿಯ

ಮೇಲಾಗುವ ಪರಿಣಾಮಗಳು

(ಮೇಘಾ. ಐ.)

ಸಾರಾಂಶ

ಸಮಗ್ರ ಪೋಷಕಾಂಶಗಳ ನಿರ್ವಹಣೆಯಿಂದ ಎರೋಝ್ ಭತ್ತದ ಬೆಳವಣಿಗೆ ಮತ್ತು ಇಳುವರಿಯ ಮೇಲಾಗುವ ಪರಿಣಾಮ ತಿಳಿಯಲು ಕ್ಷೇತ್ರ ಪ್ರಯೋಗವನ್ನು ೨೦೧೭ ರ ಮುಂಗಾಲಿನಲ್ಲಿ ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕೆ ವಿಶ್ವವಿದ್ಯಾಲಯದ ಭಾವಿಕರೆ ಸಂಶೋಧನ ವಲಯದಲ್ಲಿ ತೆಗೆದುಕೊಳ್ಳಲಾಯಿತು. ಕ್ಷೇತ್ರ ಪ್ರಯೋಗದ ಮಣ್ಣು ಮರಳು ಮಿಶ್ರಿತ ಕೆಂಪು ಆಗಿದ್ದು ಅಲ್ಲಿಯ ಗುಣವುಳ್ಳದ್ದಾಗಿರುತ್ತದೆ. ಮಣ್ಣಿನಲ್ಲಿ ಸಾವಯವ ಇಂಗಾಲ (೦.೪ ಗ್ರಾಂ), ಸಾರಜನಕ (೨೦ ಕೆ. ಜೆ), ರಂಜಕ (೩೩.೯೦ ಕೆ. ಜೆ), ಪೊಷ್ಠಾಸಿಯಮ್ (೧೩೩.೩೦ ಕೆ. ಜೆ) ಪೋಷಕಾಂಶಗಳು ಇರುವುದು ಕಂಡುಬಂದಿದೆ ಹಾಗೂ ಪ್ರಯೋಗಕ್ಕೆ ಮಾಸ್ ೯೪೩-೧ (ಶಾರದಾ) ತಳಿಯನ್ನು ಬಳಸಲಾಗಿತ್ತು. ಪ್ರಯೋಗವು ಹತ್ತು ಉಪಚಾರಗಳನ್ನು ತ್ರಿಪತಿಯಾಗಿ ಯಾದ್ಯತಿಕ ಸಂಸೂಚಾ ವಿಭಾಗ ವಿನ್ಯಾಸದಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು.

ವಿಭಿಧ ಉಪಚಾರ ಸಂಯೋಜನೆಗಳ ಅನ್ವಯ ಶೇ. ೧೦೦ ರಷ್ಟು ನಿಯೋಜಿತ ಗೊಬ್ಬರ ಬಳಕೆ (ಆರ್. ಡಿ. ಎಫ್) + ಶೇ. ೧೦೦ ಎರೆಹುಳು ಗೊಬ್ಬರ + ಸಸ್ಯ ಬೆಳವಣಿಗೆ ಅಭಿವರ್ಧಕ ಸೂಕ್ಷ್ಮ ಜೀವಿಗಳ ಮಿಶ್ರಣ ಹೊಂದಿದ್ದ ಉಪಚಾರದಲ್ಲಿ ಹೆಚ್ಚಿನ ಬೆಳವಣಿಗೆಯ ಅಂಶಗಳಾದ ತೆಂಡೆಗಳ ಸಂಖ್ಯೆ (೩೪.೨), ಎಲೆಗಳ ವಿಸ್ತೀರ್ಣ (೧೩೯.೬೯ ಸೆಂ. ಮೀ), ಇಳುವರಿ ನಿರ್ಧರಿತ ಅಂಶಗಳಾದ ಉತ್ಪನ್ನ ತೆಂಡೆಗಳ ಸಂಖ್ಯೆ (೧೩.೩೨), ತನೆಯ ಉದ್ದ (೨೩.೫೨ ಸೆಂ. ಮೀ), ತನೆಯ ತೂಕ (೨.೩೮ ಗ್ರಾಂ), ತುಂಚದ ಧಾನ್ಯಗಳ ಸಂಖ್ಯೆ (೮೭.೦), ಧಾನ್ಯ ಇಳುವರಿ (೩೮.೩೮.೦ ಕೆ. ಜೆ), ಹುಲ್ಲಿನ ಇಳುವರಿ (೪೨೨೫.೭೨ ಕೆ. ಜೆ), ಮತ್ತು ಒಟ್ಟು ಸಾರಜನಕ (೯೩.೧೩ ಕೆ. ಜೆ), ರಂಜಕ (೨೫.೦೫ ಕೆ. ಜೆ), ಪೊಷ್ಠಾಸಿಯಮ್ (೯೨.೩೩) ಪೋಷಕಾಂಶಗಳ ರಹಿತೆಯನ್ನು ದಾಖಲಿಸಲಾಗಿದೆ. ಹೆಚ್ಚಿನ ಒಟ್ಟು ಆದಾಯ (ರೂ. ೮೧,೨೨೮) ಮತ್ತು ನಿವ್ವಳ ಆದಾಯವನ್ನು (ರೂ. ೪೫,೧೭೫) ಶೇ. ೧೦೦ ರಷ್ಟು ನಿಯೋಜಿತ ಗೊಬ್ಬರ ಬಳಕೆ (ಆರ್. ಡಿ. ಎಫ್) + ಶೇ. ೧೦೦ ಎರೆಹುಳು ಗೊಬ್ಬರ + ಸಸ್ಯ ಬೆಳವಣಿಗೆ ಅಭಿವರ್ಧಕ ಸೂಕ್ಷ್ಮ ಜೀವಿಗಳ ಮಿಶ್ರಣ ಉಪಚಾರದಲ್ಲಿ ಕಂಡುಬಂದಿದೆ ಆದರೆ, ಹೆಚ್ಚಿನ ಲಾಭ ವೆಚ್ಚದ ಅನುಪಾತವು ಶೇ. ೭೫ ರಷ್ಟು ನಿಯೋಜಿತ ಗೊಬ್ಬರ ಬಳಕೆ ಶೇ. ೨೫ ಎರೆಹುಳು ಗೊಬ್ಬರ + ಸಸ್ಯ ಬೆಳವಣಿಗೆ ಅಭಿವರ್ಧಕ ಸೂಕ್ಷ್ಮ ಜೀವಿಗಳ ಮಿಶ್ರಣ ಉಪಚಾರದಲ್ಲಿ ಕಂಡುಬಂದಿದೆ.

ಬೇಸಾಯಶಾಸ್ತ್ರ ವಿಭಾಗ


ಕೃ.ಮ.ತೋ.ವಿ.ವಿ ಶಿವಮೊಗ್ಗ

ಜೂನ್, ೨೦೧೮



ಮೇಘಾ. ಐ.

(meghabuddin@gmail.com)



ಸಿ. ಜಿ. ಶ್ರೀಧರ

(cjsridhara1966@gmail.com)

CONTENTS

CHAPTER	TITLE	PAGE NO.
I	INTRODUCTION	1-4
II	REVIEW OF LITRATURE	5-20
	2.1 Performance of aerobic rice	5-6
	2.2 Effect of inorganic fertilizers on growth and yield of aerobic rice	6-7
	2.3 Effect of farm yard manure on growth and yield of aerobic rice	7-10
	2.4. Effect of vermicompost on growth and yield of rice	10-12
	2.5 Combined effect of FYM and vermicompost on growth and yield of aerobic rice	12
	2.6 Effect of PGPR on growth and yield of aerobic rice	12-15
	2.7 Effect of integrated nutrient management (INM) on aerobic rice	15-17
	2.8 Water requirement and water use efficiency in aerobic rice	17-20
III	MATERIAL AND METHODS	21-33
	3.1 Location of experimental site	21
	3.2 Soil properties of the experimental site	21
	3.3 Climatic conditions	21-24
	3.4 Cropping history of experimental site	24
	3.5 Experimental details	24-27
	3.6 Biometric observation	27-30
	3.7 Soil sample collection and analysis	30-31
	3.8 Chemical analysis of plant samples	31-32
	3.9 Nutrient uptake studies	32
	3.10 Enumeration of rhizosphere microorganism in soil	32
	3.11 Economic analysis	33
	3.12 Statistical analysis and interpretation of data	33

IV	EXPERIMENTAL RESULTS		34-68
	4.1	Growth parameters	34-51
	4.2	Yield and yield parameters	52-59
	4.3	Microbial population after harvest of the crop	59
	4.4	Nutrient uptake (kg ha ⁻¹)	59-64
	4.5	Soil nutrient status after the harvest of the crop	64-66
	4.6	Economics of aerobic rice as influenced by integrated nutrient management practices	66
	4.7	Coefficient of correlation between yield, growth and yield traits as influenced by integrated nutrient management practices in aerobic rice	66-68
V	DISCUSSION		69-77
	5.1	Influence of weather on performance of crop	70
	5.2	Effect of integrated nutrient management practices on yield and yield parameters of aerobic rice	70-73
	5.3	Effect of different integrated nutrient management practices on growth parameters of aerobic rice	73-75
	5.4	Effect of different integrated nutrient management practices on soil nutrient status and nutrient uptake of aerobic rice	75-76
	5.5	Effect of different integrated nutrient management practices on economics of aerobic rice cultivation	76-77
		Practical application of results	77
		Future line of work	77
VI	SUMMARY		78-79
VII	REFERENCES		80-91
VIII	APPENDICES		92-94

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
3.1	Soil physical and chemical properties of experimental site	22
3.2	Monthly meteorological data for the experimental period and normal (mean of ten years) at AHRS, Bhavikere UAHS, Shivamogga	23
3.3	Nutrient composition of different organic manures	26
4.1	Plant height (cm) as influenced by integrated nutrient management practices at different growth stages of aerobic rice.	35
4.2	No of tillers plant ⁻¹ as influenced by integrated nutrient management practices at different growth stages of aerobic rice	37
4.3	Number of leaves plant ⁻¹ as influenced by integrated nutrient management practices at different growth stages of aerobic rice.	38
4.4	Leaf area plant ⁻¹ (cm ²) as influenced by integrated nutrient management practices at different growth stages of aerobic rice.	40
4.5	Leaf area index as influenced by integrated nutrient management practices at different growth stages of aerobic rice.	42
4.6	Leaf area duration (days) as influenced by integrated nutrient management practices at different growth stages of aerobic rice.	43
4.7	Total dry matter plant ⁻¹ (g) as influenced by integrated nutrient management practices at different growth stages of aerobic rice	45
4.8	Absolute growth rate (g day ⁻¹) as influenced by integrated nutrient management practices at different growth stages of aerobic rice.	47
4.9	Crop growth rate (g m ⁻² day ⁻¹) as influenced by integrated nutrient management practices at different growth stages of aerobic rice.	48
4.10	Relative growth rate (g g ⁻¹ day ⁻¹) as influenced by integrated nutrient management practices at different growth stages of aerobic rice.	50
4.11	Net assimilation rate (g cm ⁻¹ day ⁻¹) as influenced by integrated nutrient management practices at different growth stages of aerobic rice	51
4.12	Yield parameters as influenced by integrated nutrient management practices at different growth stages of aerobic rice	53

4.13	Total number of grains, filled grains, unfilled grains per panicle and Chaffiness (%) as influenced by integrated nutrient management practices of aerobic rice	55
4.14	Days taken to 50 per cent flowering and days taken for maturity as influenced by integrated nutrient management practices of aerobic rice.	57
4.15	Grain yield, straw yield ($q\ ha^{-1}$) and harvest index (%) as influenced by integrated nutrient management practices of aerobic rice	58
4.16	Effect of integrated nutrient management practices on microbial population at harvest of aerobic rice	60
4.17	Nitrogen, Phosphorus and potassium uptake by grain and straw ($kg\ ha^{-1}$) as influenced by integrated nutrient management practices of aerobic rice.	61
4.18	Available soil nutrient statues at harvest as influenced by integrated nutrient management practices in aerobic rice	65
4.19	Economics of aerobic rice as influenced by integrated nutrient management practices in aerobic rice	67
4.20	Correlation coefficient between yield, yield parameters and growth parameters as influenced by integrated nutrient management practices of aerobic rice.	68

LIST OF FIGURES

FIGURE NO.	TITLE	BETWEEN PAGES
3.1	Mean monthly meteorological data for the experimental year 2017 and normal (mean of ten years 2006 - 2016).	24-25
3.2	Layout of the Experiment	24-25
5.1	Total leaf area duration as influenced by integrated nutrient management practices in aerobic rice.	72-73
5.2	Relationship between grain yield (a) Number of Panicles per plant, (b) Panicle length and (c) Panicle weight.	72-73
5.3	Relationship between grain yield (a) Number of tillers per plant, (b) Total dry matter and (c) Leaf area index (LAI)	76-77
5.4	Relationship between grain yield (a) Crop growth rate and (b) Net assimilation rate	76-77

LIST OF PLATES

PLATE NO.	TITLE	BETWEEN PAGES
5.1	100 per cent RDF + 100 per cent vermicompost + PGPR	70-71
5.2	100 per cent RDF + FYM (POP)	70-71
5.3	100 per cent RDF + 50 per cent vermicompost + 50 per cent FYM + PGPR	70-71

INTRODUCTION

I INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for half of the world's population, farmers need to produce more food in less area because agricultural land use is reducing day by day (Mohanty, 2009). The United Nations General Assembly, in a resolution declared the year of 2004 as the “International Year of Rice” which has tremendous significance to food security.

Worldwide, rice is grown in an area of 158.8 m ha with a production of 740.9 m t with an average productivity of 4,660kg ha⁻¹, out of which 90 per cent of world's rice is produced in Asian continent including six countries such as China, India, Indonesia, Bangladesh, Vietnam and Japan (Anon., 2016). India being the second largest producer of world (106.57 m t), covers an area of 43.97 m ha with the productivity level of 2,424 kg ha⁻¹ (Anon., 2016a). In Karnataka, rice occupy 1.33 m ha producing 3.52 m t with a productivity of 2,649 kg ha⁻¹ (Anon., 2016b). The crop is again one of the important staple food of the Southern Transitional Zone (STZ) and grown both under irrigated and rainfed upland situations to the tune of three lakh hectares with a productivity of 2,990 kg ha⁻¹.

The world population is expected to be exceeded 9 billion by 2040 with an increase of about 50 per cent in less than 40 years (U. S. census Bureau, Population Division, 2009). About 50 million tons of rough rice is to be increased per year by 2015 to face world's demand where the projected demand for Asia is an additional 38 million tons (Pandey *et al.*, 2007). This crop is different from other important crops such as soybean, maize and wheat because of its high concentration in consumption and production (Mohanty, 2009). Rice is not just like another commodity, it has social, cultural and even religious role which make it more psychological weight. Agricultural commodities of the world have been pressurized by the growing population. Since the possibility of increasing production of rice by increasing land is practically little, especially in Asia, the ways to increase yield per unit area must be explored in different angles.

Rice is cultivated in different methods, among them transplanting is the most prominent and traditional method of rice cultivation under flood irrigation, as it is a profligate user of water which consumes around 3000-5000 litres to produce one kilogram of rice. This not only consumes more water but also causes wastage of water that leads to degradation of land. The climatic changes, especially water scarcity helps researchers think to develop production technologies for cultivation of rice under less water condition.

Tuong and Bouman (2003) predicted that many Asian countries will have severe water problems by 2025. With this prediction rice is going to be worstly

affected crop. Hence, based on the climate change and water scarcity there is an essentiality to develop suitable cultivation practices, which is both economically viable and also enable effective utilization of valuable resources. Such important system of cultivation is DSR (Direct seeded rice), SRI (system of rice intensification), Aerobic rice method.

Aerobic rice is a new method of growing rice characterized by direct seeding of specific varieties in non puddled condition without standing water. The total water requirement from sowing to harvest is estimated at 650 to 830 mm under aerobic condition and about 1,350 mm under flooded condition and water productivity will be increased from 20 to 40 per cent (Castaneda *et al.*, 2005). Further, water use in aerobic rice is about 60 per cent less than that of low land rice, the total water productivity being 1.6 to 1.9 times higher and net returns to water use two times higher (Wang Huaqui *et al.*, 2007).

Use of fertilizers in conventional rice cultivation has been reported to have poor nutrient use efficiency due to excessive use of water and readily available nature of nutrients in fertilizers. But total replacement of fertilizer by manures to avoid such losses may not be an easy alternative as manures contain less nutrients. 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, biofertilizers and enriched compost deserves priority for sustained production and better resource utilization in integrated nutrient management *i.e.*, use of organic manures within organic fertilizers. INM technology is sustainable as compared to modern chemical farming as it relies more on organic inputs (Muneshwar Singh *et al.*, 2001).

Nitrogen has important role in realization of rice yield. In India about 67 per cent of soils are estimated to be deficit in adequate nitrogen and consequently rice crop has become a major consumer of nitrogen fertilizer (Hooper, 1982).

The addition of organic manures for aerobic rice crop improves the organic matter status of soil. It helps the soil to supply the nutrients and also improves the physical properties of soil. Further, organic matter acts as a food for microorganisms and boosts the multiplication of their population, which in turn improves the

mineralization of nitrogen in soil and thus, fertility and productivity of the soil is improved.

Another important source of maintaining soil fertility is use of biofertilizers. The role of biofertilizers, an alternate low cost input has a prime importance in recent decades and they play a vital role in maintaining long-term soil fertility. Biological nitrogen fixing microorganisms significantly contributed for nitrogen addition to soil while phosphate and potassium helps in solubilizing bound form of phosphorous and potassium in soil. These beneficial microorganisms are known to secrete plant growth promoting substances for improved plant growth and crop yield (Venkateshwarlu and Prasad 2012).

The role and importance of biofertilizers in sustainable crop production has been reported by several research workers (Wani and Lee, 1995; Katyalet *al.* 1994). Soil harbours a huge population of microorganisms and their abundance play a key role in making plant nutrients available to plants and keep the soil productive for crop production. Among the varied form of biological nitrogen fixing biofertilizers in rice cultivation *Azospirillum* has a prime role and has been recognized as a potential nitrogen fixing diazotroph colonizing root environment of paddy and other cereal crops. It fixes atmospheric N₂, enhances uptake of nutrients and also produces plant growth promoting substances. The N₂ fixing ability of *Azospirillum* is 25 to 30 kg N per ha per season. The first species of the genus *Azospirillum* originally named *Sprillum lipoferum* was isolated from soil in Netherlands in 1925. Then, it was rediscovered in 1970's during a search for associative nitrogen fixers in the rhizosphere of *Digitaria* and *Zea mays* in Brazil. Since then, isolation of *Azospirillum* from roots of numerous wild and cultivated plants from different soil types have been reported from all over the world.

Several researchers have examined and reported the ability of different bacterial species have been known to solubilize insoluble inorganic phosphate compounds, such as tricalcium phosphate, dicalcium phosphate, hydroxyapatite and rock phosphate. The phosphate solubilizers which belongs to bacterial genera are *Pseudomonas*, *Bacillus*, *Burkholderia*, *Achromobacter*, *Aerobacter*, *Flavobacterium* and *Erwinia*. There are considerable populations of phosphate solubilizing bacteria in the soils of plant rhizospheres. (Raghu and Macrae, 2000).

The combination of all these nutrient sources not only play a role in increasing the crop yield levels but also improves the soil physical, chemical and biological properties in order to maintain soil fertility status as well as achieving sustainable yield in aerobic rice.

On this context, the present investigation entitled “Influence of integrated nutrient management practices on growth and yield of aerobic rice (*Oryza sativa* L.)” was carried out during *kharif* 2017 in AHRS, Bhavikere with the following objectives.

1. To study the effect of integrated nutrient management practices on growth and yield of aerobic rice
2. To assess the nutrient uptake by the crop as influenced by different nutrient management practices
3. To find out the economic feasibility of the integrated nutrient management practices on aerobic rice

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

A field experiment was conducted to study the "Influence of integrated nutrient management practices on growth and yield of aerobic rice (*Oryza sativa*)" at AHRS, Bhavikere. The literature pertaining to the effect of integrated nutrient management are reviewed and presented in this chapter.

2.1 Performance of aerobic rice

2.2 Effect of inorganic fertilizers on growth and yield of aerobic rice

2.3 Effect of Farm Yard Manure (FYM) on growth and yield of aerobic rice

2.4 Effect of vermicompost on growth and yield of rice

2.5 Combined effect of FYM and vermicompost on growth and yield of aerobic rice

2.6 Effect of PGPR on growth and yield of aerobic rice

2.7 Effect of integrated nutrient management (INM) on aerobic rice

2.8 Water requirement and water use efficiency in aerobic rice

2.1 Performance of aerobic rice

Bouman (2001) reported several water saving technologies for aerobic rice and noticed that alternate wetting and drying during critical stages resulted in more number of productive tillers (35 tillers plant⁻¹) as compared to conventional planting (18 tillers plant⁻¹). He also noticed that potential water savings were large when rice was grown under upland condition, as compared to that of transplanted or lowland conditions.

George and Virmani (2001) working at IRRI, Philippines, reported that higher yield of 8 t ha⁻¹ was obtained under aerobic condition, due to high tillering capacity, reduced plant height and higher efficiency in soil nitrogen uptake by the aerobic genotypes.

Bouman *et al.* (2002) revealed that water input in aerobic rice was more than 50 per cent lower (only 470-650 mm) as compared to lowland rice. Further water productivity was 64 to 88 per cent higher whereas, gross return and labour use was reduced by 28 to 44 per cent and 55 per cent over lowland rice.

Wang Huaqui *et al.* (2002) reported that yield levels varied from 4.5 to 6.5 t ha⁻¹ in aerobic condition, which was doubled to that of traditional upland varieties and about 20 to 30 per cent lower than that of lowland varieties grown under flooded condition. He also opined that in aerobic rice, water use was about 60 per cent less

than that of lowland rice and the total productivity of water was also higher (1.6-1.9 times).

Yang Xiangwang *et al.* (2005) showed that water use of aerobic rice culture was about 60 per cent less than that of lowland rice at Philippines.

Ambracio *et al.* (2004) reported that aerobic rice saved 73 per cent of irrigation water for land preparation and 56 per cent during the crop growth stage. Moreover, it could effectively use rainfall during the dry season.

Atlin *et al.* (2004) revealed that aerobic rice cultivars yielded better (3.89 t ha⁻¹) in favourable upland environment compared to improved upland and irrigated varieties by 100 and 30 per cent, respectively. Aerobic cultivars maintain harvest index of nearly 0.4 or about one third higher than other cultivars, at IRRI, Philippines.

Magat and Apo (2004) recorded highest yield potential between 5 to 6 t ha⁻¹ in a tropical low land rice hybrid and a traditional upland inbred under aerobic condition at IRRI, Philippines.

Wang Huaqui *et al.* (2007) worked on aerobic rice genotypes in China and reported that aerobic genotypes such as Han Dao 277, Han Dao 297, Han Dao 502, Han 58, Dhanjing 5 and Dhanjing 8 have better adaptability to aerobic situations. These genotypes with wider spacing resulted in more number of productive tillers (38 – 45 tillers plant⁻¹).

2.2 Effect of inorganic fertilizers on growth and yield of aerobic rice

Samrath Lal Meena (2003) recorded significantly higher plant height (126.8 and 127.9 cm), productive tillers (16.2 and 16.3), dry matter accumulation (15.6 and 16.3 tonnes ha⁻¹), grain and straw yields (6.5 and 9.5 tonnes ha⁻¹ based on pooled data) of hybrid rice with application of 200 kg N ha⁻¹, while 100 kg N ha⁻¹ resulted in highest B: C of the crop over other treatments. Similar trend was observed with application of 62.5 kg ha⁻¹ when applied in 2 splits (half at transplanting + half at maximum tillering).

Maheshwari *et al.* (2007) conducted an experiment and reported that N levels followed a quadratic response ($R^2 > 0.973$) with 150 and 175 kg N ha⁻¹ and found on par with growth and yield. Irrigation scheduled by IW/CPE approach recorded significantly higher crop growth rate and yield with no moisture stress. Hence, irrigation at 1.2 IW/CPE ratio with 150 kg N ha⁻¹ was optimum to realise the maximum productivity under aerobic rice cultivation.

Shekara *et al.* (2010) revealed that application of 125 kg N ha⁻¹ recorded significantly higher values of plant height (92.21 cm), number of tillers hill⁻¹ (34.97), total dry matter accumulation (161.39 g hill⁻¹), grain yield (7.25 t ha⁻¹) and net returns but these parameters were on par with 100 kg N ha⁻¹ at harvest. Among phosphorus levels 62.5 kg P₂O₅ ha⁻¹ recorded significantly higher plant height (90.44 cm), number of tillers hill⁻¹ (33.11), total dry matter accumulation (150.51 g hill⁻¹), grain yield (7.21 t ha⁻¹) and net returns (Rs. 25836 ha⁻¹) but these parameters were on par with 50 kg P₂O₅ ha⁻¹ at harvest. Application of potassium 62.5 kg K₂O ha⁻¹ recorded significantly higher plant height (89.51 cm), more number of tillers hill⁻¹ (33.01), total dry matter accumulation (151.08 g hill⁻¹), grain yield (7.241 ha⁻¹) and net returns (Rs. 26553 ha⁻¹) but these parameters were on par with 50 kg K₂O at harvest.

Ganga Devi *et al.* (2012) concluded that yield attributes of scented rice under aerobic culture responded up to 150 kg ha⁻¹ nitrogen with four equal splits of nitrogen at ¼ basal + ¼ at active tillering + ¼ at panicle initiation and ¼ at heading. Higher grain and straw yields were obtained with higher N level *i.e.* 175 kg ha⁻¹ and was comparable with 150 kg ha⁻¹. Grain quality parameters like milling percent, head rice recovery, kernel length, breadth, amylose content and protein content of rice registered significantly highest values with 150 kg N ha.

Jing Xiang *et al.* (2013) showed that deep placement of urea and urea super granules (USG) increased grain yield of aerobic rice by 1.66 t ha⁻¹.

2.3 Effect of Farm Yard Manure (FYM) on growth and yield of aerobic rice

2.3.1 Composition of FYM.

Muneshwar Singh *et al.* (2001) reported that the nutrient content of farm yard manure was 0.62 per cent nitrogen (N), 0.13 per cent phosphorus (P) and 0.71 per cent potassium (K).

Singh and Chauhan (2002) stated that farm yard manure possessed 1.73 per cent, 0.28 per cent and 1.02 per cent nitrogen, phosphorus and potassium, respectively. In addition to these three nutrients, it also contained Sulphur (S) (0.34 %) and Calcium (Ca) (0.79 %).

2.3.2 Effect of FYM on growth and yield of rice

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

Subhendu Mandal and Adhikary (2005) reported that grain yield was significantly higher with the treatment that received 50 per cent N through chemical fertilizer and 50 per cent N through FYM followed by the treatment that received 75 per cent N through chemical fertilizer and 25 per cent N through FYM.

Singh and Sharma (2005) reported that application of 10 tonnes of FYM ha⁻¹ to rice crop increased the plant height, LAI, crop growth rate (CGR) and dry matter accumulation resulting in higher grain yield (43.51 q ha⁻¹) and straw yield (60.48 q ha⁻¹) over control under rice-wheat cropping sequence.

Godhawale and Dahipale (2007) reported that among different organic treatments, green leaf manure (5t ha⁻¹) along with FYM (10 t ha⁻¹) recorded significantly higher grain yield (2771kg ha⁻¹) and production efficiency (22.17 kgha⁻¹day⁻¹).

Prabhakar Reddy *et al.* (2007a) reported that dry matter production of rice was significantly increased with the addition of fly ash, FYM and their interactions. The higher dry matter production was recorded by combined application of 10 tonnes of fly ash along with 10 tonnes of FYM ha⁻¹ at 60 DAS (3.31 t ha⁻¹) and at harvest (12.63 t ha⁻¹).

Prabhakar Reddy *et al.* (2007b) reported that higher grain yield (5.84 t ha⁻¹) and straw yield (7.87 t ha⁻¹) was obtained by combined application of 10 tonnes of fly ash and 10 tonnes of FYM ha⁻¹, which was on par with 15 tonnes of fly ash along with 10 tonnes of FYM ha⁻¹

Mankotia *et al.* (2008) recorded statistically equal rice and wheat yields with the application of 5 tonnes of FYM ha⁻¹ (5.03 t ha⁻¹ rice and 2.48 t ha⁻¹ wheat) and 2.5 tonnes of FYM along with mushroom spent compost at 1.25 tonnes ha⁻¹ (4.94 t ha⁻¹ rice and 2.33 t ha⁻¹ wheat), whereas application of gobhi sarson (mustard) straw at 5 tonnes ha⁻¹ recorded lower yields (4.24 t ha⁻¹ rice and 1.99 t ha⁻¹ wheat)

2.3.3 Effect of FYM on yield

Babu and Reddy (2000) reported that grain yield and nutrient uptake were higher with application of 5t FYM + 50 kg N. Among the genotypes KRH-2 gave significantly higher grain yield, leaf area index, crop growth rate and number of spikelets than Rasi.

Nguyen Van Quyen *et al.* (2002) showed that grain yield of rice increased significantly with increasing rate of fertilizer application from 0 to 60 kg N + 30 kg P₂O₅ + 20 kg K₂O ha⁻¹ (50% recommended fertilizer dose). Effect of 10 t ha⁻¹ FYM and Sesbania green manuring (SGM) before crop transplanting was found to be

similar to 50 per cent RFD, whereas combined effect of FYM + SGM was similar to 120 kg N + 60 kg P₂O₅ + 40 kg K₂O ha⁻¹ (100% RFD).

Vasanth Rao *et al.* (2004) revealed that N supplementation through the combination of fertilizers and organic sources produced significantly higher growth and yield parameters as compared to other combination treatments.

Krishna Kumar *et al.* (2005) reported that application of FYM + Neem cake at the rate of 90 kg N ha⁻¹ significantly increased the higher grain yield (5675 kg ha⁻¹) during *kharif* and *rabi* (5175 kg ha⁻¹). The same treatment recorded higher straw yield in both the seasons (6520 kg ha⁻¹, 6020 kg ha⁻¹, respectively).

Gopakkali Pradeep *et al.* (2012) conducted an experiment and noticed that significantly higher grain yield (45.4 q ha⁻¹), straw yield (57.8 q ha⁻¹), net returns (Rs. 34732 ha⁻¹) and B:C (2.57) were recorded with the application of FYM at 2.5 t ha⁻¹ + cattle urine equivalent to 125 kg N ha⁻¹ as compared to other treatments. Whereas significantly lower grain yield, straw yield, net returns and B:C were recorded with application of FYM at 7.5 t ha⁻¹ + cattle urine equivalent to 75 kg N ha⁻¹.

Sujatha *et al.* (2014) revealed that among different organic manure treatments, application of 100 per cent RDN through FYM recorded higher amount of NPK in soil at harvest, followed by basal application of 50 per cent RDN + 50 per cent at 10 days before PI stage through FYM which were however on a par with each other. The lower amount of NPK in soil at harvest was recorded with the application of recommended dose of fertilizers followed by 100 per cent RDN through poultry manure.

Ashwini *et al.* (2015) reported that application of 125:62.5:62.5 kg NPK ha⁻¹ recorded higher plant height (66.07 cm), number of tillers plant⁻¹ (37.94), total dry matter accumulation (103.27 g plant⁻¹) and grain yield (53.54 q ha⁻¹). Among the different methods of application, spot application of enriched manure recorded significantly higher plant height (66.12 cm), total dry matter accumulation (97.10 g plant⁻¹), number of tillers (37.06), 1000 grain weight (24.24 g) and grain yield (54.03 q ha⁻¹) due to timely availability of nutrients. Interaction of spot application of enriched manure with 125:62.5:62.5 NPK kg ha⁻¹ has registered higher 1000 grain weight (25.80 g) which led to higher grain yield (60.58 q ha⁻¹) in aerobic rice

Malik and Chaman Singh (2016) conducted a study and showed that highest rice and wheat, yield (8060 and 5770 kg ha⁻¹, respectively) was obtained when 60 per cent NPKZn with 10 t FYM ha⁻¹ and blue green algae @ 5 kg ha⁻¹ were applied. This increase in yield was more than the treatment, where 100 per cent NPKZn with 10 t FYM ha⁻¹ and 5 kg ha⁻¹ blue green algae were applied

2.4 Effect of vermicompost on growth and yield of rice

Murali and Setty (2001) revealed that the treatment with application of vermicompost at 5 tonnes ha⁻¹ combined with NPK at 150-75-75 kg ha⁻¹ recorded significantly higher grain yield (4889 kg ha⁻¹) as compared to the treatment devoid of vermicompost application (4070 kg ha⁻¹). Increased grain yield with vermicompost was because of significantly higher yield attributes like number of panicles per hill (10.91) and number of grains per panicle (186.82) due to increased availability of nutrients in vermicompost treatment.

Sudha and Chandini (2003) observed that application of vermicompost at 5 t ha⁻¹ when applied in combination with fertilizers (105:52.5:52.5 kg NPK ha⁻¹) had positive influence on growth and yield attributes of rice which resulted in higher grain yield (4.54 tonnes ha⁻¹) and straw yield (5.15 tonnes ha⁻¹).

Adhikari and Mishra (2004) indicated that rice varieties like Basmati 370 and Pusa Sugandh 3 gave higher yields with combined application of 60 kg N ha⁻¹ through prilled urea, 60 kg N through vermicompost and 40 kg N through farmyard manure.

Pandu *et al.* (2005) reported that N management using leaf colour chart at critical value 3 with vermicompost seemed to be promising in respect of nitrogen use efficiency (NUE) and significantly increased rice grain yield, with the saving of 20 per cent chemical.

Singh *et al.* (2005) proved that effective substitution of recommended dose of N in rice with vermicompost could be possible to the extent of 33 per cent.

Haq *et al.* (2005) revealed that the treatment 90 kg N + *Azospirillum* showed significantly higher values of plant height (109.16 cm) and dry matter production (89.75 g), followed by vermicompost + *Azospirillum* + 60 kg N ha⁻¹ and also number of panicles m⁻² (335.66), grain yield (49.66 q ha⁻¹) and straw yield (91.40 q ha⁻¹) were significantly higher as compared to other treatments.

Higher grain and straw yields were obtained from the use of 50 per cent recommended N, P, K fertilizers with vermicompost 10 t ha⁻¹ when compared with 100 per cent N, P, K through fertilizers and also produced significantly higher number of effective tillers m⁻² and number of filled grains per panicle (Barik *et al.*, 2006).

Godhawale and Dahipale (2007) reported that application of vermicompost at 2.5 tonnes ha⁻¹ recorded higher grain yield of rice (1348 kg ha⁻¹) as compared to control (925 kg ha⁻¹).

Sanjay Koushal *et al.* (2011) reported that application of 50 per cent commended dose of nitrogen through vermicompost and rest through chemical fertilizer (urea) produced significantly higher grain and straw yield of rice. However, gross return, net return and B:C values were significantly higher in the plot which received 25 per cent N through vermicompost and 75 per cent through chemical fertilizers.

Thirunavukkarasu and Vinoth (2013) revealed that growth parameters, yield attributes, NPK uptake and B:C were higher under the treatment that received vermicompost at the rate of 2.5 t ha⁻¹ and nitrogen application based on leaf colour chart critical value less than 4.

Singh *et al.* (2013) reported that yield attributes such as number of effective tillers per hill, panicle length and panicle weight of rice in both the varieties were significantly higher in INM treatments as compared to chemical fertilizer alone.

Bharat Lal *et al.* (2014) revealed that application of 75 per cent GRD (general recommended dose) +60t FA (fly ash) ha⁻¹+5 t FYMha⁻¹ gave higher paddy yield (42.6 q ha⁻¹) as compared to rest of the treatments. The straw yield was not significantly influenced by FA treatments, but the beneficial effect of enriched fly ash was observed on straw yield. Application of 75 per cent GRD + fly ash@ 60 t ha⁻¹ +FYM @ 5 t ha⁻¹ recorded the highest soil available phosphorus, potassium and zinc as compared to other treatments and soil available N was higher in application of 75 per cent GRD + fly ash@ 40 t ha⁻¹ + FYM @ 5 t ha⁻¹.

Cielito Beltran (2015) reported that application of 100 per cent vermicompost + 100 per cent beneficial microorganisms derived compost and 50 per cent VC + 50 per cent BMC (beneficial microorganisms compost) produced higher grain yield over control plants. The response was in the same trend in computed weight of grains per ha⁻¹ which ranges from 3,841.66 kg ha⁻¹ to 4,591.66 kg ha⁻¹.

Jana *et al.* (2015) revealed that grain yield of rice in aerobic situation was not significantly influenced by the irrigation schedules during pre *Kharif* season. Among different levels of nutrient applications, highest grain yield (4.42 t ha⁻¹) of aerobic rice [variety: Puspa (IET 17509)] was obtained from the treatment that received 80, 40, 40 kg N, P₂O₅, K₂O ha⁻¹ along with Vermicompost @ 2.5 t ha⁻¹.

Taheri Rahimabadi *et al.* (2017) revealed that application of 30 t ha⁻¹ cow manure + 10 t ha⁻¹vermicompost recorded higher grain yield of 3,537 kg ha⁻¹and 3,958 kg ha⁻¹. In addition, the application of cow manure and vermicompost increased the grain N, P and K content by 8 to 20 per cent, 22 to 23 per cent and 20 to 33 per cent, respectively but the starch content was decreased by 3 to 7 Per cent.

2.4.1. Economics of vermicompost

Barik *et al.* (2004) revealed that combined application of 40 per cent recommended dose of N as vermicompost and 60 per cent recommended dose of N as urea produced higher values of growth parameters, yield attributes and significantly higher grain yield of rice (52.7 q ha^{-1}) compared to 100 per cent recommended dose of N in the form of urea. Hence, instead of using 100 per cent recommended dose of nitrogen solely from inorganic source (urea), integrated supply of N through vermicompost and urea not only produced higher yield attributes and grain yield of rice but also ensured an eco-friendly approach towards sustainable crop production. The highest gross returns were recorded with the application of 50 per cent RDF in combination with $10 \text{ t vermicompost ha}^{-1}$. Net returns and benefit cost ratio were at par with the application of 50 per cent RDF + $10 \text{ t vermicompost ha}^{-1}$ and 50 and 75 per cent RDF + $10 \text{ t farmyard manure ha}^{-1}$. Such comparable economic benefits of integrated nutrient management of *Kharif* rice with vermicompost and farmyard manure in spite of considerable higher yields with vermicompost, were attributed to the higher cost of vermicompost application compared to farmyard manure.

2.5 Combined effect of FYM and vermicompost on growth and yield of rice

Sunil Kumar *et al.* (2017) reported that grain, straw and total nitrogen, phosphorus and potassium uptake by scented rice were significantly highest noted under treatment 100 per cent N through $1/3 \text{ Vermicompost} + 1/3 \text{ FYM} + 1/3 \text{ poultry manure}$ at basal (N_1), which was at par to treatment 100 per cent N through $1/2 \text{ poultry manure}$ as basal + $1/2 \text{ vermicompost}$ at 30 DAT.

Shaikh *et al.* (2017) showed that growth parameters of paddy *i.e.* plant height and number of tillers plant^{-1} were maximum and statistically higher with the application of $2.5 \text{ t FYM ha}^{-1} + 0.750 \text{ t vermicompost ha}^{-1} + 0.375 \text{ t green leaves of glyricidia ha}^{-1} + 0.250 \text{ t neem cake ha}^{-1}$. The next best treatment was application of $5 \text{ t FYM ha}^{-1} + 1.5 \text{ t vermicompost ha}^{-1}$. The corresponding values were 93.7 cm and 11.3, respectively at harvest.

2.6. Effect of PGPR on growth and yield

Dhanya *et al.* (2006) conducted an experiment and showed that application of 150 per cent RDF, bio fertilizers and $\text{ZnSO}_4 @ 25 \text{ kg ha}^{-1}$ recorded higher uptake of N, P, K and Zn at all the stages of the crop growth. Residual N, P and K was also higher in this particular treatment. Whereas residual Zn was higher in the treatment receiving RDF, bio fertilizers and $\text{ZnSO}_4 @ 25 \text{ kg ha}^{-1}$.

Mhalevilie Thorie *et al.* (2013) revealed that great or plant dry weight was recorded in the treatment that received FYM @ 12 t ha⁻¹+ Azotobacter @ 20 g kg⁻¹ seed followed by Poultry manure @ 4 t ha⁻¹ + Azotobacter @ 20 g kg⁻¹ seed. FYM @ 12 t ha⁻¹+Azotobacter @ 20 g kg⁻¹ seed treated plot also produced higher yield parameters like number of panicles m⁻², grain yield, straw yield, grains panicle⁻¹, fertility percentage and test weight. The increase in the available NPK status of soil was observed in organic manure treated plot.

Choudhary *et al.* (2013) revealed that inoculation of rice seedlings with plant growth promoting *Rhizobacteria* had a favourable effect on root growth, yield and quality of rice hybrids. Inoculation of rice with *Azospirillum brasilense* and *Bacillus subtilis* significantly improved quality parameters, *viz.*, hulling, milling, head rice recovery and protein content significantly over the control.

SaravanKumar and Panneerselvam (2015) conducted an experiment to study effect of nitrogen on yield parameters and yield of rice and found that the yield attributes *viz.*, productive tillers, number of grains per panicle, number of filled grains per panicle and thousand grain weight were favourably increased by the application of 125per cent RDF + biofertilizer which was on par with 100 per cent N through organic sources.

Basha *et al.* (2016) reported that integrated application of recommended dose of fertilizer (RDF) (100:50:50 kg N, P₂O₅ and K₂O ha⁻¹) + farmyard manure @5 t ha⁻¹ + microbial consortium (*Azospirillum*+ phosphate solubilizing bacteria) and soil application of bio digester @ 2500 l ha⁻¹ at 30,60 and 90 DAS recorded significantly higher productive tillers m⁻² (466.62), filled grains panicle⁻¹ (92.97), grain yield (4262 kg ha⁻¹), straw yield (6033 kg ha⁻¹), protein content (8.75%) and starch (22.70%). Among the treatment combinations, integrated application of RDF+ FYM + microbial consortium and soil application of cow urine @ 500 l ha⁻¹ at 30,60 and 90 DAS recorded significantly higher net returns (Rs. 34,595 ha⁻¹) and B:C ratio of 2.17 over other treatments.

Siddaram *et al.* (2017) conducted an experiment and reported that significantly higher population of bacteria (24.2 cfu × 10⁵ g⁻¹ of soil), fungi (16.4 cfu × 10³ g⁻¹ s of soil) and actinomycetes (11.2 cfu × 10⁴ g⁻¹ of soil) was found after harvest of aerobic rice with FYM 12.5 t + BDLME to 150 kg N ha⁻¹ as compared to the recommended practice but was on par with FYM 12.5 t + BDLME (Bio-Digester Liquid Manure Equivalent) to 125 kg N ha⁻¹.

2.6.1. Combined effect of *Azospirillum* and phosphate solubilizing

Kennedy *et al.* (2004) reported that a range of diazotrophic plant growth promoting *Rhizobacteria* participated in interactions of C₃ and C₄ crop plants

(e.g. rice, wheat, maize, sugarcane and cotton), resulting in significant increase of vegetative growth and grain yield.

Gholami *et al.* (2009) reported that use of six bacterial strains including *P. putida* strain R-168, *P. fluorescens* strain R-93, *P. fluorescens* DSM 50090, *P. putida* DSM291, *A. lipoferum* DSM 1691, *A. brasilense* DSM 1690 improve the maize seeds with all bacterial strains significantly increased plant height, leaf area, number of seed per cob and 100 seed weight. The results also showed significant increase in cob and shoot dry weight of maize.

Iranie *et al.* (2009) reported that the effect of nutrient levels was significant on plant height at all the growth stages. Among the nutrient levels tried, the treatment receiving 75 per cent RDF + bio fertilizers with 25 kg ZnSO₄ per ha recorded highest growth parameters, yield attributes and grain and straw yield than the rest of the treatments and the lower was recorded in the treatment receiving 50 per cent RDF with 10 kg ZnSO₄ per ha.

Bhabesh Gogoi *et al.* (2010) revealed that application of biofertilizer in rice improved the plant height (94.3cm) and effective tillers (287.0) as compared to control.

2.6.2 Effect of nitrogen fixers and PSB on crop yield

Patidar and Mali (2002) reported that *Azospirillum* alone as well as and its combination with phosphate solubilizing bacteria increased sorghum yield by 6 to 7 per cent over control.

Chinnusamy *et al.* (2006) reported that, the microbial inoculants namely BGA, PSB, VAMF, and *Azospirillum* positively interacted with one another resulting in significant improvement of yield and nutritional parameters. Application of biofertilizers also substantially improved the soil (peat) fertility status (nitrogen (N), phosphorous (P), and organic carbon content). The Microbial consortia of BGA + PSB + VAMF + *Azospirillum* was found to be the best treatment for improved growth and yield traits.

Majumdar *et al.* (2007) reported that the inoculation of *Azotobacter* and *Azospirillum* increased the grain yield by 15.9 and 9.1 per cent, respectively over non-inoculated treatments.

Pattanayak *et al.* (2007) revealed that 40 kg N through inorganics (50% N dose) integrated with biofertilizers (*Azotobacter*, *Azospirillum* and *Azolla*), 17.5 kg of P and 32 kg of K ha⁻¹ resulted in the higher grain (3.57 t ha⁻¹) and straw yields (4.32 t ha⁻¹) of rice.

Choudhary *et al.* (2010) revealed that using of *Azospirillum brasilense* and *Bacillus subtilis*, increased the grain yield of 5.09 and 4.39 tha^{-1} , respectively over control.

Bhabesh Gogoi *et al.* (2010) reported that application of biofertilizer rice improved the grain yield (2.9 tonnes ha^{-1}) as compared to control.

Yogananda *et al.* (2010) reported that the application of 4.25 t urban compost+ 50:50:50 kg NPK ha^{-1} + *Azotobacter*+ phosphate solubilizing bacteria resulted in higher grain yield (61.41 q ha^{-1}) and was on par with 8.5 t urban compost +50:50 kg PK ha^{-1} +*Azotobacter*+ phosphate solubilizing bacteria and 4.25 t urban compost +50:50 kg PK ha^{-1} + *Azotobacter*+ phosphate solubilizing bacteria.

2.7 Effect of integrated nutrient management (INM) on aerobic rice

Anny Mrudhula *et al.* (2005) revealed that the growth parameters, yield attributes and yield increased significantly by the combined use of nitrogen fertilizer and FYM *i.e.*, 100 per cent RDN through urea and 25 per cent RDN through FYM.

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.

Yadav and Christopher lourduraj (2006) reported that application of 50 per cent N through composted poultry manure and 50 per cent N through green leaf manure recorded significantly higher physical characteristics of rice when compared to recommended dose of NPK through fertilizers.

Application of 75 per cent RDN + 25 per cent kg GM – N + 25 kg PM-N recorded the highest NPK uptake by rice at the all stages of crop growth which was significantly superior to application of 100 per cent RDN through different sources. This is due to higher availability of N, P_2O_5 and K_2O in the soil (Upendra Rao, 2007).

Siddaram *et al.* (2010) showed that application of recommended dose of fertilizer (100:50:50 kg NPK 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}). However, it was at par with 200 per cent recommended dose of nitrogen (RDN) equivalent through vermicompost ha^{-1} , 200 per cent RDN equivalent through FYM ha^{-1} , 150 per cent RDN equivalent through vermicompost ha^{-1} and 100 per cent RDN equivalent through poultry manure ha^{-1} .

Asim Biswas and Pallanagari Reddy (2010) reported highest yield and net return in the treatment which received 75 per cent RDF of N through fertilizer and rest 25 per cent of N through combination of FYM, vermicompost and poultry manure. The treatment with 75 per cent RDF of nitrogen and the combination or individual use of organic source produced better grain and straw yield with higher harvest index indicating better nutrient management technique for aerobic rice.

Rajanna *et al.* (2011) reported that significantly higher values of productive tillers hill⁻¹ (28.02), number of filled grains panicle⁻¹ (140.2) and thousand grain weight (22.78 g), grain yield (40.49 q ha⁻¹) and straw yield (46.35 q ha⁻¹) were obtained with the application of recommended dose of fertilizer (100:50:50 kg NPK ha⁻¹) + 10 tonnes of FYM ha⁻¹. Significantly higher net return (Rs.28267) as well as higher benefit cost ratio (3.68) was recorded with the application of poultry manure equivalent to 10 t of FYM + biodigester liquid at 100 per cent N equivalent basis.

Sunil and Shankaralingappa (2013) revealed that application of RDF + FYM + Biofertilizers + FeSO₄ + IWM (integrated weed management) practices recorded significantly higher growth, yield parameters and yield as compared to RDF + FYM + IWM practices and was on par with RDF + FYM + Biofertilizers + IWM practices.

Pradhan and Moharana (2015) revealed that DM, CGR and RGR were highest in treatment receiving Dhanicha + FYM + Vermicompost in *Kharif* and FYM + Vermicompost in summer (75.99 and 75.80 g hill⁻¹ DM). Maximum average grain yield of 4.47 and 4.26 t ha⁻¹ were also witnessed during *kharif* and summer seasons respectively.

Sunil *et al.* (2015) reported that application of RDF + FYM + biofertilizers + FeSO₄ along with integrated weed management practices resulted in significantly higher grain and straw yields, water productivity and nutrient uptake (N, P, K, Zn and Fe) in rice over RDF + FYM + pyrazosulfuron ethyl at 25 g a.i. ha⁻¹. Similar trend was also observed for net returns as well as benefit cost ratio.

Venkatesha *et al.* (2015) confined that application of 50 per cent N through inorganic fertilizers + 50 per cent N through vermicompost recorded significantly higher number of productive tillers (40.24 hill⁻¹), test weight (25.87 g), absolute growth rate (g day⁻¹ at 60- 90 DAS) and grain yield (63.1q ha⁻¹) as compared to other integrated nutrient practices. Maximum net return (Rs. 20,401 ha⁻¹) and B:C (1:2.57) were found in 100 per cent RDF + Biofertilizer application whereas, lowest net return (Rs. 16,512 ha⁻¹) and B:C (1.81) were recorded in 50 per cent recommended dose of nitrogen + 50 per cent N through enriched compost (N₅).

DivyaSahare and Babalad (2016) conducted an experiment and revealed that integrated application of M₂- EC (1/3) + VC (1/3) + GLM (1/3) equivalent to RDF + FYM with soil application of jeevamrut @ 500 l ha⁻¹ at planting, 30 and 60 DAS + Panchagavya foliar application @ 5 per cent at panicle emergence and flowering stages recorded significantly higher grain yield (3,837 kg ha⁻¹) and straw yield (5,855 kg ha⁻¹) along with higher nutrients uptake.

Arpita Sharma *et al.* (2017) revealed that application of vermicompost + FYM + neem oil cake recorded significantly higher grain yield (30.21 q ha⁻¹) which was statistically at par with 100 per cent recommended dose of fertilizer (RDF) + green manuring + vermicompost.

Rakesh Kumar Verma *et al.* (2017) conducted an experiment and revealed that application of 50 per cent recommended dose of fertilizers (RDF) + 25 per cent recommended dose of nitrogen (RDN) through vermicompost (VC) + biofertilizer was found to be the best treatment for most of the yield attributes, grain yield (3.72 tha⁻¹) straw yield (7.14 tha⁻¹) and gross returns followed by 50 per cent RDF + 25 per cent RDN through leaf compost (LC) + biofertilizer.

Balamurugan *et al.* (2018) conducted an experiment and concluded that ANNA 4 rice cultivation with application of pressmud compost @ 6.0 t ha⁻¹ along with foliar application of seaweed extract @ 500 ml ha⁻¹ was found to be a promising combination for higher physiological characters *viz.*, LAI, CGR and grain yield.

SupreetSaajan *et al.* (2018) reported that application of *Azotobacter* + 25 per cent vermicompost + 50 per cent RDN gave significant results with respect to growth and yield attributes over control treatment (inorganic sources only).

2.8 Water requirement and water use efficiency in aerobic rice

Balasubramanian and Krishnarajan (2000) studied water use efficiency in direct seeded rice and revealed that continuous submergence of 2.5 cm throughout crop period resulted in enhanced growth characters and saved 25 per cent irrigation water as compared to application of 5 cm depth by recording higher water use efficiency.

Ganesh (2000) reported that irrigating rice once in every seven days to maintain field saturation saved 41 per cent irrigation water needs by less consumption 80.3 cm without any significant reduction in grain yield over 2.5 to 5.0 cm submergence till 15 days before harvest.

Ganesh and Jayadeva Hakkali (2000) revealed that irrigating the field once in five days consumed least amount of water (89.5 cm) and saved 39 per cent irrigation water compared to farmer's practice (continuous irrigation 230.8 cm).

Patel (2000) indicated that the water management practice of saturation till ripening recorded significantly higher grain yield as well as water use efficiency compared to other treatments except continuous system.

Bouman (2001) reported that for crop growth duration of 100 days, water required is about 1500 to 2000 mm as a typical value in many low land areas depending on the season and soil characteristics.

Cabangon *et al.* (2001) reported that dry seeded rice significantly increased the water productivity with respect to irrigation water over wet seeded and transplanted rice. Further, early establishment of the direct seeded rice reduced the water uptake, thereby saving in irrigation water up to 40 per cent.

Adak and Gupta (2002) observed that rice cultivation showed significant reduction in yield under submergence over normal saturated conditions.

Castaneda *et al.* (2002) reported that direct seeded aerobic management eliminate water loss due to puddling and percolation, thereby reducing losses due to evaporation and percolation and saved total irrigation requirement by 30-50 per cent.

Gani *et al.* (2002) reported that plants under intermittent irrigation produced more tillers hill⁻¹ (40.6), longer root length (32.5 cm), higher root and dry matter hill⁻¹ (9.2 g and 35.5 g, respectively) as compared to flooded treatment.

Mc Hugh *et al.* (2002) found that under SRI method, alternate wetting and drying irrigation used 19 to 55 per cent less water than conventional lowland rice, depending on the permeability of the soil.

Palanisami (2002) reported that about 70-80 per cent of water was used for rice cultivation and its use efficiency was as low as 30-35 per cent, whereas average water use efficiency ranged from 45 to 50 per cent in aerobic condition.

Qinghao *et al.* (2002) concluded that intermittent irrigation treatment with variety Youch 647 received 48 mm (27 %) irrigation water less than flooded treatment, while its yield was 6 per cent higher and WUE of intermittent irrigation treatment was an average 61 per cent higher than that of flooded treatment.

Sinha (2002) studied the tillering phenology and grain yield of rice under different situations and reported that submergence resulted in fewer grains per plant and lower grain weight in IR-42 variety.

Tabbal *et al.* (2002) reported reduced water input and increased water productivity of rice grown under just saturated soil condition as compared to that of traditional flooded rice.

Wang Huaqui *et al.* (2002) found that the water use was about 60 per cent less than that of lowland rice. Total water productivity was 1.6 to 1.9 times higher and the net return to water use was two times higher.

Atlin *et al.* (2004) at IRRI reported that aerobic rice genotypes yielded 3.89 t ha⁻¹ in favourable upland environments and these genotypes resulted in higher water use efficiency compared to other genotypes.

Belder *et al.* (2004) studied the effect of water saving irrigation on rice yield. The result revealed that alternate wetting and drying of rice resulted in significantly higher grain yield (5.5 t ha⁻¹) with more number of productive tillers (40 tillers plant⁻¹).

Cabangon *et al.* (2004) reported that aerobic variety yielded less than lowland variety probably caused by reduced tillering and shorter growth duration. They also reported that water productivity ranged from 0.87 to 1.45 kg m⁻² for inbred rice and 0.54 to 0.95 g m⁻² for aerobic rice.

Abdul Aziz *et al.* (2005) reported that deep water inflicted higher tiller mortality, minimal increase in weight of aerial parts and leaf area, decrease in root length and root weight.

Bouman *et al.* (2005) studied the yield and water use of aerobic rice genotypes at IRRI and reported that aerobic rice genotype APO yielded 5.7 t ha⁻¹ compared to Magat (5.0 t ha⁻¹) and aerobic rice utilizes only 450-500 mm water and resulted in increased water productivity of 32 to 88 per cent higher than flooded conditions.

Yang Xiangwang *et al.* (2005) conducted an experiment at IRRI, Philippines and reported that aerobic rice variety HD 502, produced 3 to 3.5 t ha⁻¹ with 450 to 500 mm water input and 5.3-5.7 t ha⁻¹ with 650 mm water.

Bouman *et al.* (2006) conducted an experiment at IRRI, Philippines and reported that aerobic rice yield ranged from 4.7 to 6.6 t ha⁻¹ as compared to 8.8 t ha⁻¹ under lowland rice. They also reported that HD 502 is the most promising variety because of its high yield potential and reduced water input by 50 per cent (470 to 650 mm). It recorded increased water productivity by 64 to 88 per cent and reduced gross returns by 28 to 40 per cent.

Rajput Pankaj Kumar *et al.* (2006) showed that yield attributes such as number of panicles, length of panicles, number of grains per panicle was highest under 7cm irrigation one day after disappearance of ponded water followed by continuous submergence.

All the reviews revealed that the application of organic source of nutrients on aerobic rice shown positive response. Recommended fertilizers in combination with different organic manures met out the nutrient demand of the crop with sustainable crop production. Integrated nutrient management with inorganic, organic and biofertilizer not only increases the yield but also maintains healthy soil with less pollution hazard.

MATERIAL AND METHODS

III MATERIAL AND METHODS

A field experiment was conducted to study the “Influence of integrated nutrient management practices on growth and yield of aerobic rice (*Oryza sativa* L.)” at Agricultural and Horticultural Research Station (AHRS), Bhavikere under rainfed condition with protective irrigation during *Kharif* 2017. The details of the materials used and methods adopted during the course of study are elaborated in this chapter.

3.1 Location of the experimental site

The study was conducted at Agriculture and Horticultural Research Station, Bhavikere, which is located at 75°51` E longitude and 13°42` N altitude of 695 meters above the mean sea level. It lies in the Southern Transitional Zone (STZ-VII) of Karnataka.

3.2 Soil properties of the experimental site

To study the soil characters, a composite soil sample was drawn randomly from the experimental site before start of the experiment from all replication. The soil was air dried, powdered and passed through 2mm sieve and was analysed for physical and chemical properties. The results of the analysis are given in Table 3.1

3.3 Climatic conditions

The normal weather data for ten years and the actual climatic conditions that prevailed during the crop growth period (July to December 2017) and the deviations from the normal with respect to rainfall, maximum and minimum temperature and mean relative humidity are presented in Table 3.2

3.3.1 Normal climatic conditions of the research station

The normal annual rainfall of Bhavikere station was 1037.30 mm. The major portion of rainfall was received during May to November with highest rainfall in the months of July (277.9 mm) followed by August (257.1 mm). The mean monthly maximum temperature was highest during July (39.2°C), while it was lowest in the month of December (20.1°C). The mean minimum temperature was highest in the month of September (21.4 °C) and lowest in the month of December (17.9 °C). The maximum relative humidity was observed in the months of August (80 %) and minimum during December (65 %).

Table 3.1: Soil physical and chemical properties of the experimental site

Physical composition			
Particulars	Values	Method adopted	
Sand (%)	62.55	Boyucos hydrometer method (Piper, 1966)	
Silt (%)	16.78		
Clay (%)	18.89		
Texture	Sandy loam		
Chemical composition			
Particulars	Values	Status	Method adopted
PH (1:2.5)	5.25	Acidic	Potential metric method (Piper, 1966)
Electrical conductivity (dSm ⁻¹)	0.067	Normal	Conductivity bridge method (Jackson, 1973)
OC (g kg ⁻¹)	0.40	Low	Wet oxidation method (Walkly and Black, 1934)
Avail N (kg ha ⁻¹)	220.80	Low	Alkaline permanganate method (Subbaiah and Asija, 1956)
Avail P ₂ O ₅ (kg ha ⁻¹)	33.90	Medium	Bray's method (Jackson, 1973)
Avail K ₂ O (kg ha ⁻¹)	163.60	Medium	Neutral normal ammonium acetate method (Jackson, 1973)

Table 3.2: Monthly meteorological data for the experimental period and normal (mean of 10 years) at AHRS, Bhavikere, UAHS, Shivamogga

Month	Rainfall			Monthly Maximum Temperature (°C)			Monthly Minimum Temperature (°C)			Relative humidity (%)			Sunshine hours (hr day ⁻¹)		
	A	N	D	A	N	D	A	N	D	A	N	D	A	N	D
July	151.7	277.9	-126	26.4	39.2	-12.8	22.4	21.1	1.3	89.8	77.2	12.6	4.0	4.6	-0.6
August	126.2	257.1	-130.9	26.2	38.8	-12.6	22.1	21.0	1.1	91.0	80.0	11.0	7.0	4.9	-2.1
September	157.4	175.2	-157.4	27.1	31.7	-4.6	22.0	21.4	0.6	89.2	77.0	12.2	5.2	4.8	-0.4
October	0	102.1	-102.1	26.9	30.7	-3.8	21.3	20.2	1.1	86.9	75.0	11.9	7.2	6.4	0.8
November	0	50.6	-50.6	27.4	29.8	-2.4	19.6	19.5	0.1	81.5	69.0	12.5	4.6	7.3	-2.7
December	0	14.4	-14.4	26.7	20.1	6.6	17.9	17.9	-0.1	76.3	65.0	11.3	8.6	7.0	1.6

N – Normal, A- Actual, D- Deviation

3.3.2 Actual climatic condition during the crop growth period

During 2017, the rainfall received was maximum in the month of September (157.4 mm) during crop growth period. The monthly maximum temperature was recorded highest in the month of November (27.4°C) and lowest in the month of August (26.2°C). Monthly minimum temperature was recorded highest in the month of July (22.4°C) and less during December (17.9°C). Relative humidity was maximum in the month of August (91.0%) and minimum in December (76.3 %). The sunshine hours are higher in the month of October (7.2 hrs). The overall weather conditions prevailed during cropping season was normal.

3.4 Cropping history of experimental site

The previous crop grown at the experimental site was chilli which sown during summer 2017 and received uniform dose of 25:50:25 kg N, P and K per hectare, respectively, and which was harvested in the month of May. The plot was kept fallow thereafter until sowing of experimental crop in July 2017.

3.5 Experimental details

3.5.1 Design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with ten treatments and three replications. The plan of lay out of the experiment has been presented in Fig 2.

3.5.1.1 Treatment details

T₁=100 % RDF +FYM (POP)

T₂= 100 % RDF + PGPR

T₃= 100 % RDF + 100 % FYM + PGPR

T₄= 100 % RDF + 100 % Vermicompost (FYM N Equivalent) + PGPR

T₅= 100 % RDF + 50 % FYM+ 50 % Vermicompost (FYM N Equivalent) + PGPR

T₆= 75 % RDF + FYM

T₇= 75 % RDF + PGPR

T₈= 75 % RDF + 25 % FYM + PGPR

T₉= 75 % RDF + 25 % Vermicompost (FYM N Equivalent) + PGPR

T₁₀= 75 % RDF + 25 % FYM + 25 % Vermicompost (FYM N Equivalent) + PGPR

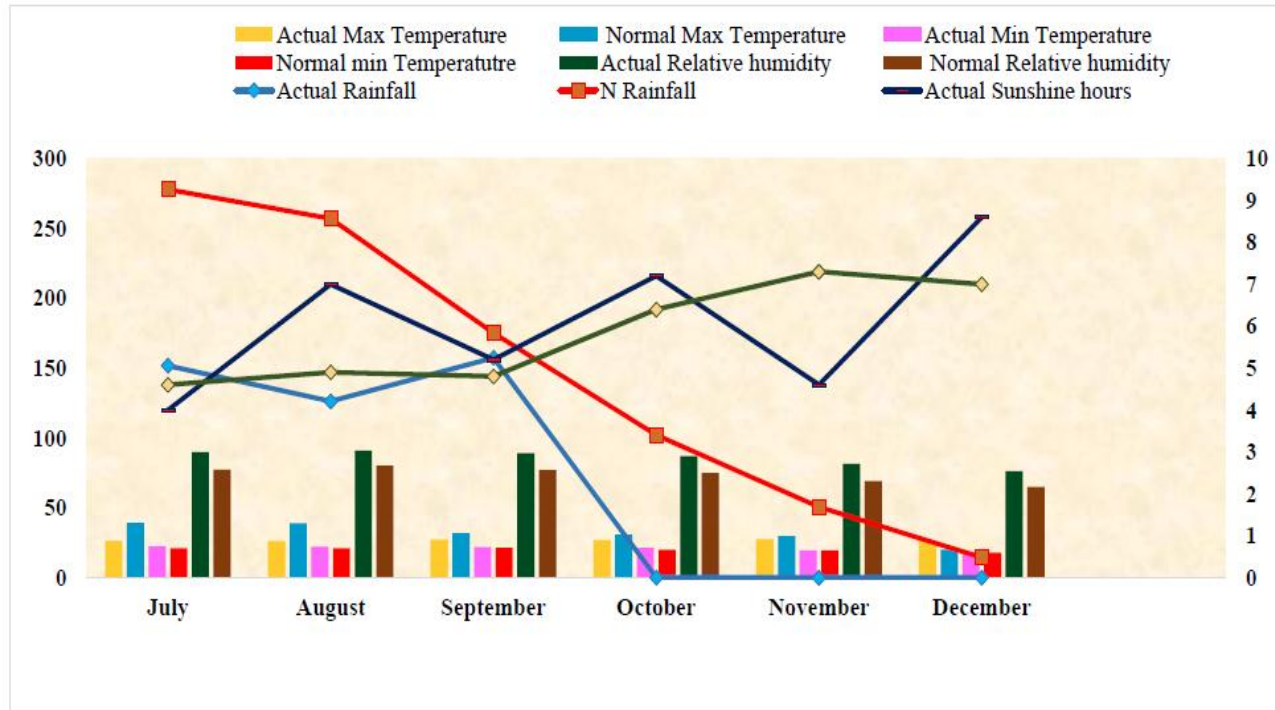


Fig. 3.1 Mean monthly meteorological data for the experimental year 2017 and normal (mean of 10 years 2006 -2016)

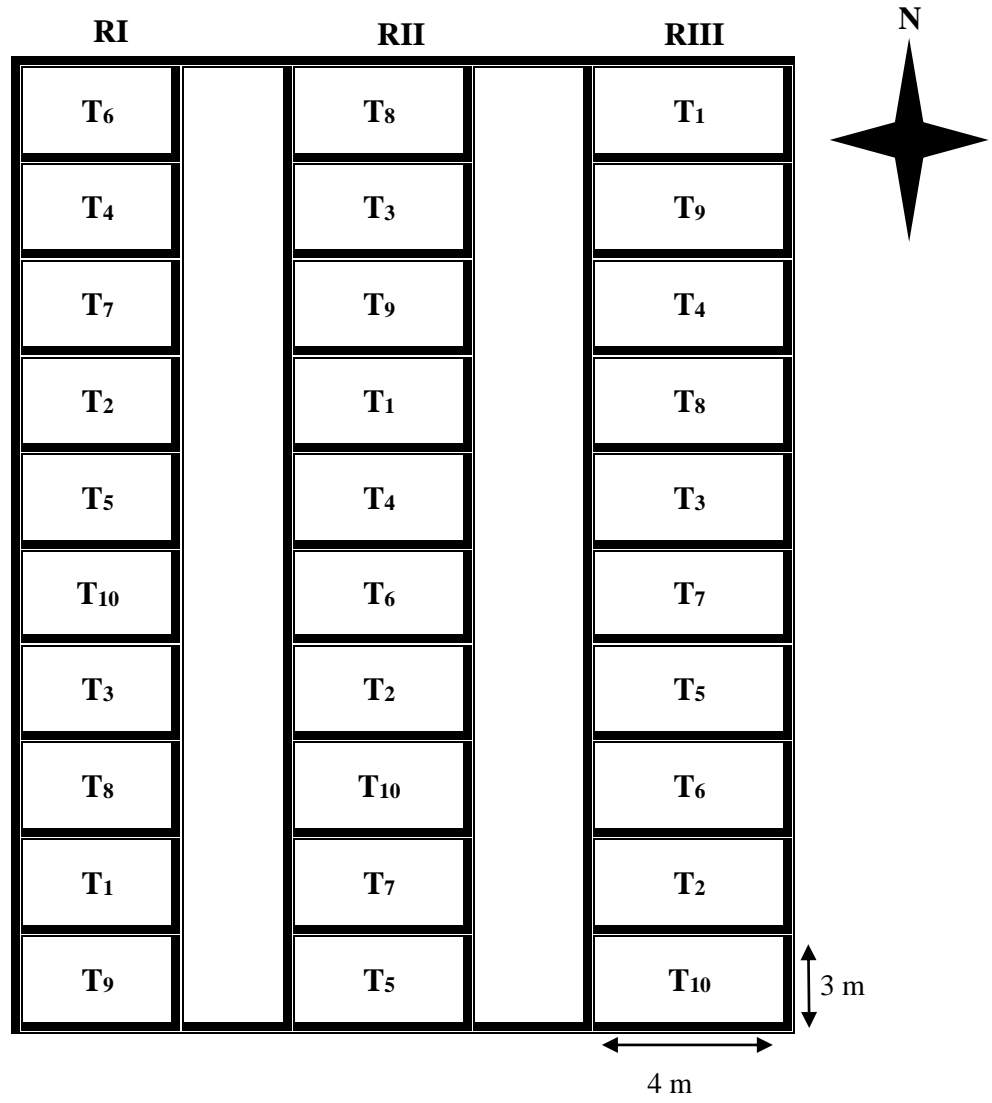


Fig. 2: Layout of the experiment

Note: RDF- 100:50:50, FYM-10 t ha⁻¹, Vermicompost- 7.5 t ha⁻¹, PGPR- 250 ml acre⁻¹.

PGPR- Liquid consortia of *Azospirillum brasilense*, *Bacillus megaterium*(PSB) and *Bacillus mucilaginosus* (KSB)

3.5.1.2 Plot size

Gross plot: 3.0m × 4.0 m = 12 m²

Net plot: 2.5 m × 3.5 m = 8.5 m²

3.5.1.3 Test variety

The rice variety used was MAS946-1 (Sharada) and it was developed by University of Agricultural Sciences, Bengaluru. It is a medium duration variety, medium fine grain, and comes to maturity in 100 to 120 days. The variety is capable of producing higher grain yield (40-50 q ha⁻¹) and straw yield (50-75 q ha⁻¹) and has capacity to tolerate drought and blast disease.

3.5.1.4 Cultural practices

3.5.1.4.1 Land preparation

The land was ploughed once with mould broad plough followed by passing cultivator twice and entire plot was levelled with leveller and individual plot was levelled manually. The experimental area was laid out as per the plan.

3.5.1.4.2 Manures and Fertilizer application and treatment imposition

Farm yard manure (FYM) and vermicompost was applied to the plot three weeks prior to sowing as per the treatments. At the time of sowing 50 per cent of recommended nitrogen, entire quantity of phosphorus and 50 per cent of recommended potassium were applied as per treatment plan using urea, single super phosphate and muriate of potash as source, respectively. The remaining 50 per cent nitrogen was top dressed at the rate of 25 per cent each at 30 and 60 days after sowing. The remaining 50 per cent of potassium was top dressed at panicle initiation stage. The microbial inoculants of *Azospirillum brasilense* and *Bacillus megaterium* (PSB) and KSB (PGPR) at the rate of 250 ml acre⁻¹ was applied at the time of sowing as per the treatments.

Table 3.3 Nutrient composition of different organic manures

Organic manures	Nutrient composition (%)		
	Nitrogen	P ₂ O ₅	K ₂ O
Farm yard manure	0.51	0.31	0.46
Vermicompost	1.34	0.79	0.62

3.5.1.4.3 Sowing

Before sowing of crop furrows were opened at 25 cm interval with the help of hand hoe. Two to three pre soaked seeds were dibbled in each hill at 25 cm spacing on 9th July 2017. Recommended nutrients and microbial inoculants were applied separately at the base of row and covered with soil.

3.5.1.4.4 Thinning

Thinning was attended ten days after the sowing of crop by pulling out the excess seedlings manually in each hill leaving only one seedling per hill.

3.5.1.5 After care

3.5.1.5.1 Weeding

Hand weeding was done twice at 20 and 45 days after sowing and 3 times inter – cultivation by wheel hoe was carried out at 15, 30 and 55 days after sowing to keep all the plots uniformly weed free throughout the crop growth period.

3.5.1.5.2 Irrigation

Proper care was taken to avoid movement of fertilizer from one plot to another during irrigation. All plots were irrigated immediately after sowing like irrigated upland crops for uniform germination. Further, irrigation was given at 5 days interval during vegetative growth stage and 3 days interval during reproductive growth stage of crop with 5 cm depending upon rainfall. Irrigation was stopped a week prior to harvest of crop.

3.5.1.5.3 Pest and Disease Management

During the experimental period, the crop was meagrely affected by leaf blast and stem borer but was controlled by spraying Carbendazime (1g l⁻¹ of water) and Monocrotophos (2 ml l⁻¹ of water) respectively with spray solution of 750 liters ha⁻¹.

3.5.1.5.4 Harvesting and threshing

The crop was harvested on 16th December 2017. Five plants were randomly selected in each net plot area for making observation on yield attributing parameters. The crop in the net plot was harvested and threshed separately. Grain and straw were sun dried and weight was recorded as per treatment and converted to per hectare.

3.6 Biometric observations

3.6.1 Pre-harvest observation

All observations were recorded treatment wise in the net plot area at monthly interval, starting from 30 days after sowing to till harvest. Five plants were randomly selected and labelled them for recording various observations.

3.6.1.1 Plant height

Plant height was measured from the ground level to the tip of the plant. It was recorded at 30, 60, 90 days after sowing and at harvest from five randomly selected plants. The mean was worked out and expressed in centimetre.

3.6.1.2 Number of tillers per plant

Number of tillers were recorded at 30, 60, 90 days after sowing and at harvest from five plants selected randomly in each net plot and expressed as mean number of tillers per plant.

3.6.1.3 Total dry matter production

The total dry matter production includes both root and shoot weight per plant recorded at 30, 60, 90 days after sowing and at harvest by uprooting three plants, which were selected from each plot. Roots were cleaned with running water, air dried and both shoot and root were dried at 60 °C to get constant weight and average total dry matter production was recorded and expressed in grams per plant.

3.6.1.4 Days to 50 per cent flowering

The number of days taken for emergence of 50 per cent of flowering (emergence of 50 per cent flowering in 100 per cent population) in individual plot was recorded based on visual assessment and expressed in days.

3.6.1.5 Days to maturity

The number of days taken complete maturity of the crop (number of matured plants in 100 per cent population) in individual plot was recorded based on visual assessment and expressed in days.

3.6.2 Growth indices

3.6.2.1 Leaf Area

Leaf area was worked out by length \times breadth method (Montgomery, 1911) at 30, 60, 90 days after sowing and at harvest. The length of fully opened leaf lamina was measured from the base to tip. Leaf breadth was taken at the widest point of the leaf lamina. The product of leaf length and breadth of each leaf was multiplied by factor 0.75 to get leaf area. For the purpose five plants from the destructive sampling was used and their mean as calculated and expressed as $\text{cm}^2 \text{ plant}^{-1}$.

3.6.2.2 Leaf area index (LAI)

Leaf area index was worked out using the following formulae (Sestak *et al.*, 1971).

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Land area (cm}^2\text{)}}$$

3.6.2.3 Leaf Area Duration (LAD)

Leaf area duration is the integration of leaf area index over a growth period (Watson, 1952). LAD for various growth periods was worked out as outlined by Power *et al.* (1967) and expressed in days.

$$\text{LAD} = \frac{\text{LAI}_i + \text{LAI}_{i+1}}{2} \times (t_2 - t_1)$$

Where,

LAI_i = Leaf area index at i^{th} stage

$\text{LAI}_{(i+1)}$ = Leaf area index at $(i+1)^{\text{th}}$ stage

$(t_2 - t_1)$ = Time interval in days

3.6.2.4 Absolute growth rate (AGR)

AGR is defined as growth rate of plant at any given point of time. It indicates dry weight increase per unit time. It was calculated at different intervals as per the formula given by Radford (1967) and expressed in $\text{g plant}^{-1} \text{ day}^{-1}$.

$$\text{AGR} = \frac{W_2 - W_1}{2} \times (t_2 - t_1)$$

Where,

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

3.6.2.5 Relative growth rate (RGR)

It is the rate of increase in dry weight per unit dry weight already present and is expressed in $g\ g^{-1}\ day^{-1}$. Relative growth rate was calculated as suggested by Radford (1967).

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

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

3.6.2.6 Crop growth rate (CGR)

Crop growth rate is defined as rate of dry matter production per unit ground area per unit time (Watson, 1952). It is expressed in $g\ m^2\ day^{-1}$ and calculated by using formula.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

Where,

W_1 and W_2 are dry matter production per plant in g at time t_1 and t_2 , respectively. P = Spacing (m^2)

3.6.2.7 Net assimilation rate (NAR)

It is the rate of increase in dry weight per unit leaf area per unit time. The net assimilation rate was estimated by using formula given by Gregory (1926) and expressed as $g\ dm^{-2}\ day^{-1}$.

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

Where,

W_1 and W_2 – Dry matter production per plant in g at time t_1 and t_2 , respectively.

L_1 and L_2 – Leaf area per plant in dm^2 at time t_1 and t_2 , respectively.

\log_e = Logarithm to the base e

3.6.3 Post harvest observations

3.6.3.1 Grain yield

At maturity, two rows all around the plot were harvested separately as border rows. The crop from the net plot area was harvested and threshed plot wise. Grains

were sun dried for 3-4 days and cleaned. The grain weight from each net plot was recorded separately at 10 per cent grain moisture and expressed in kg per hectare.

3.6.3.2 Straw yield

The straw obtained after threshing of grains from the net plot area was sun dried and the dry weight was recorded and expressed in kg per hectare.

3.6.3.3 Yield components

Five hills were randomly selected from each net plot for the purpose of recording observations of yield attributes.

3.6.3.3.1 Panicle length

Ten panicles were selected randomly from the samples from each net plot. Length of each panicle was measured in centimetre from the base of the panicle to the tip. Mean length of ten panicles was calculated and expressed in centimetre.

3.6.3.3.2 Panicle weight

Mean panicle weight was obtained by weighing randomly selected ten panicles from each net plot and expressed as grams panicle⁻¹.

3.6.3.3.3 Total number of grains per panicle

Number of total grains panicle⁻¹ were counted separately from randomly selected ten panicles from each net plot and expressed as mean number of total grains panicle⁻¹.

3.6.3.3.4 Thousand grain weight (g)

Thousand filled grains were collected from ten panicle of each net plot and weight was expressed in gram.

3.7 Soil sample collection and analysis

Before starting of the experiments and after harvest of individual plots of the experiments, soil samples were collected separately from each experimental plot. Soil samples were air dried under shade, ground using wooden pestle and mortar, passed through 2 mm sieve for analysis and stored in polythene bags for further analysis (Jackson, 1973).

3.7.1 Available Nitrogen

Available nitrogen in the soil was determined by alkaline potassium permanganate method as described by Subbaiah and Asija (1956) and expressed as kg ha^{-1} .

3.7.2 Available Phosphorus

Available phosphorus was extracted from soil using Bray's NO.1 extractant ($0.03 \text{ N NH}_4\text{F} + 0.025 \text{ N HCl}$) and concentration in the extract was determined by chlorostannous reduced molybdophosphoric acid blue colour in HCl system using spectrophotometer (Jackson, 1973) and results were expressed as kg ha^{-1} .

3.7.3 Available Potassium

Available potassium was extracted from the soils using neutral *N* ammonium acetate in 1:5 soil to extract ratio and the concentration of potassium present in the extract was determined by flame photometer (Jackson, 1973) and results were expressed as kg ha^{-1} .

3.8 Chemical analysis of plant samples

Rice grains and straw samples from experiments collected at harvest. The samples were air dried, and then oven dried at 65°C . The dried leaves were powdered and used for further chemical analysis.

3.8.1 Nutrient contents in plant

3.8.1.1 Nitrogen content (%)

The nitrogen content in the grain and straw samples was estimated by Micro Kjeldhal method (Jackson, 1973) and expressed in percentage on dry weight basis. The powdered sample of 0.5 g was digested with concentrated H_2SO_4 in presence of digestion mixture ($\text{K}_2\text{SO}_4:\text{CuSO}_4.5\text{H}_2\text{O}:\text{Se}$ in the proportion of 100:20:1) and distilled under alkaline medium. The liberated NH_3 was trapped in 4 per cent boric acid containing mixed indicator and titrated against standard H_2SO_4 .

3.8.1.2 Digestion of plant sample for phosphorus and potassium analysis

The phosphorus and potassium in the plant sample were analysed using 0.5 g of powdered sample which was digested in tri-acid mixture ($\text{HNO}_3:\text{HClO}_4:\text{H}_2\text{SO}_4$ at 9:4:1), until colourless and clear residue was developed. After cooling residue was dissolved in distilled water and then volume was made up to 50 ml. Then sample were used for P and K estimation

3.8.1.3 Phosphorus content (%)

The phosphorus content of the tri-acid digested grain and straw samples were determined by Vanadomolybdo phosphoric yellow colour method in HNO₃ acid system (Jackson, 1973) and expressed in percentage on dry weight basis.

3.8.1.4 Potassium content (%)

The potassium content in grain and straw samples were determined by flame photometry method as described by Jackson (1973) and expressed in Percentage on dry weight basis.

3.9 Nutrient uptake studies

Uptake of nitrogen, phosphorus and potassium were calculated using the following formula and expressed in kg ha⁻¹.

$$\text{Nutrient uptake by grain (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Grain yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Nutrient uptake by straw (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Straw yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Total nutrient uptake} = \text{Nutrient uptake by grain} + \text{Nutrient uptake by Straw}$$

3.10 Enumeration of rhizosphere microorganism in soil

The microbial population in the soil before sowing of crop and after harvest was determined by standard dilution plate count method. Soil samples from different treatments were collected separately replication wise and then they were pooled. 10 grams of pooled soil (treatment wise) weighed and mixed in 90 ml sterilized water blank to give 10⁻¹ dilutions. Subsequent dilutions up to 10⁻⁶ were made by transferring serially 1 ml of each dilution to 9ml sterilized water blanks. The population of bacteria, fungi, actinomycetes, phosphate solubilizing microorganisms (PSB) and potassium solubilizing bacteria were estimated by serial dilution plate count technique and by taking 1 ml from selected dilution of 10⁻³, 10⁻⁴, 10⁻⁵, 10⁻⁶ were transferred aseptically to petridishes and the desired melted agar media were added to their respective dilutions. Plating on appropriate media *viz.*, soil extract agar, Martin's Rose Bengal agar, Kuster's agar and Pikovskaya's media, respectively. The inoculated plates were kept for incubation at 30°C ± 10°C for a week time and emerged colonies were counted. To enumerate *Azospirillum* sp. in soil, the most probable number (MPN) method was followed with semi solid Dobreiner *et al* medium and calculation done by referring to statistical tables of Cochran (1950) and expressed as MPN per gram of soil.

3.11 Economic analysis

3.11.1 Cost of Cultivation (Rs. ha⁻¹)

The total cost of cultivation for different treatments was worked out by taking into account the expenditure incurred to meet the requirements of various inputs, labour and bullock power required to carry out various cultural operations from pre sowing stage to harvest (Appendix-II). The value of the main and by-products was calculated using the market prices which existed at the time of cropping period. Treatment wise cost of cultivation was worked out and expressed in Rupees per hectare.

3.11.2 Gross return (Rs. ha⁻¹)

Gross returns were calculated by taking price into consideration of the product that was prevailing in market after harvest as per treatment.

3.11.3 Net return (Rs. ha⁻¹)

The net returns per hectare was calculated treatment wise by subtracting the total cost of cultivation from gross returns.

Net returns (Rs. ha⁻¹) = Gross returns (Rs. ha⁻¹) – Cost of cultivation (Rs. ha⁻¹)

3.11.4 Benefit cost ratio

Benefit cost ratio was worked out treatment wise by using the following formula.

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Total cost of cultivator (Rs. ha}^{-1}\text{)}}$$

3.12 Statistical analysis and interpretation of data

The experimental data collected on various growth and yield components of plant was subjected to Fisher's method of "Analysis of variance" (ANOVA) as outlined by (Gomez and Gomez, 1984). Whenever F test was found significant critical differences values were worked out for the comparison of treatment means. All the data were analysed and the results are presented and discussed at a probability level of 5 per cent.

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

The results of the field experiment entitled “Influence of integrated nutrient management practices on growth and yield of aerobic rice (*Oryza sativa* L.)” conducted at Agricultural Research Station, Bhavikere during *Kharif*, 2017 are presented in this chapter.

4.1 Growth parameters

4.1.1 Plant height (cm)

The data pertaining to plant height at 30, 60, 90 and at harvest are presented in Table 4.1

Plant height differed significantly due to treatments. At 30 DAS, significantly higher plant height (23.03 cm) was recorded with application of 100 per cent recommended dose of fertilizer (RDF) + 100 per cent vermicompost + plant growth promoting rhizobacteria (PGPR). The lower plant height (10.55 cm) was recorded with application of 75 per cent RDF + PGPR.

At 60 DAS, significantly higher plant height (60.49 cm) was recorded with application of 100 per cent RDF + 100 per cent vermicompost + PGPR which was on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (59.78 cm) and 100 per cent RDF + 100 per cent FYM + PGPR (57.62 cm). Significantly lower plant height (32.05 cm) was recorded with application of 75 per cent RDF + PGPR.

Significantly taller plant (68.94 cm) was recorded at 90 DAS with application of 100 per cent RDF + 100 per cent vermicompost and found to be on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (68.05) and 100 per cent RDF + 100 per cent FYM + PGPR (65.26 cm). Application of 75 per cent RDF + PGPR recorded shorter plant (49.74 cm).

Plant height differed significantly at harvest. Higher plant height (73.31 cm) was recorded with application of 100 per cent RDF + 100 per cent vermicompost + PGPR which was on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (71.31 cm) and 100 per cent RDF + 100 per cent FYM + PGPR (68.05 cm). Significantly lower plant height at harvest was recorded with 75 per cent RDF + PGPR (53.48 cm).

Table 4.1: Plant height (cm) as influenced by integrated nutrient management practices at different growth stages of aerobic rice

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T ₁ -100 % RDF + FYM (POP)	13.61	43.54	58.15	61.70
T ₂ -100 % RDF + PGPR	14.53	47.97	60.49	63.57
T ₃ -100 % RDF + 100 % FYM + PGPR	18.74	57.62	65.26	68.05
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	23.03	60.49	68.94	73.31
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	20.97	59.78	68.05	71.31
T ₆ - 75 % RDF + FYM	11.77	39.84	55.81	60.50
T ₇ -75 % RDF + PGPR	10.55	32.05	49.74	53.48
T ₈ -75 % RDF + 25 % FYM + PGPR	13.73	49.72	60.56	62.02
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	14.73	50.72	61.56	64.02
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	16.13	54.55	61.42	65.50
S.E_m ±	0.34	1.82	2.10	2.43
C.D (P= 0.05)	1.02	5.41	6.24	7.23

4.1.2 Number of tillers per plant.

The number of tillers per plant as influenced by integrated nutrient management practices at different growth stages are presented in Table 4.2

Number of tillers differed significantly due to treatments. At 30 DAS, number of tillers per plant differed significantly due to integrated nutrient management practices. Significantly more number of tillers per plant was noticed with application of 100 per cent RDF + 100 per cent vermicompost +PGPR (6.7) which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (6.2) and application of 100 per cent RDF + 100 per cent FYM + PGPR (5.4). Significantly lesser number of tillers per plant (3.9) was observed with application of 75 per cent RDF + PGPR.

At 60 DAS, significantly more number of tillers per plant (36.3) was noticed with application of 100 per cent RDF + 100 per cent vermicompost +PGPR which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (35.2) and 100 per cent RDF + 100 per cent FYM + PGPR (34.4). Significantly lower number of tillers per plant was recorded with application of 75 per cent RDF and PGPR (23.7).

Number of tillers differed significantly at 90 DAS. Higher number of tillers (39.2) was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR and was on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (38.8) and 100 per cent RDF + 100 per cent FYM + PGPR (36.3). Significantly lower number of tillers was recorded with application of 75 per cent RDF and PGPR (28.1).

At harvest, significantly higher number of tillers (34.2) was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR and was on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (33.6) and 100 per cent RDF + 100 per cent FYM + PGPR (31.8). Significantly least number of tillers at harvest was observed with application of 75 per cent RDF and PGPR (23.1).

4.1.3 Number of leaves

The number of leaves per plant as influenced by integrated nutrient management practices at different growth stages are presented in Table 4.3

Number of leaves differed significantly due to treatments. At 30 DAS, significantly more number of leaves (20.70) were recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR which is on par with

Table 4.2: Number of tillers plant⁻¹ as influenced by integrated nutrient management practices at different growth stages of aerobic rice

Treatment	30 DAS	60 DAS	90 DAS	At harvest
T ₁ -100 % RDF + FYM (POP)	4.10	27.80	31.90	25.40
T ₂ -100 % RDF + PGPR	4.20	29.90	33.60	29.10
T ₃ -100 % RDF + 100 % FYM + PGPR	5.40	34.40	36.30	31.80
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	6.70	36.30	39.20	34.20
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	6.20	35.20	38.80	33.60
T ₆ - 75 % RDF + FYM	4.00	24.60	29.60	25.90
T ₇ -75 % RDF + PGPR	3.90	23.70	28.10	23.10
T ₈ -75 % RDF + 25 % FYM + PGPR	4.20	28.90	31.80	27.20
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	4.30	29.80	32.80	28.10
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	4.80	31.40	33.90	28.50
S.Em ±	0.6	1.08	1.45	1.29
C.D (P= 0.05)	1.9	3.21	4.31	3.83

Table 4.3: Number of leaves plant⁻¹ as influenced by integrated nutrient management practices at different growth stages of aerobic rice.

Treatments	30 DAS	60 DAS	90 DAS	At harvest
T ₁ -100 % RDF + FYM (POP)	18.91	76.76	106.85	99.80
T ₂ -100 % RDF + PGPR	19.18	78.34	107.82	102.75
T ₃ -100 % RDF + 100 % FYM + PGPR	19.75	79.93	108.79	104.70
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	20.70	85.90	116.30	108.00
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	20.40	82.30	112.90	105.70
T ₆ - 75 % RDF + FYM	16.39	68.55	77.84	73.84
T ₇ -75 % RDF + PGPR	15.52	63.88	71.92	68.51
T ₈ -75 % RDF + 25 % FYM + PGPR	19.17	79.55	110.39	104.25
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	18.46	78.90	109.94	103.50
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	19.75	80.24	111.89	105.75
S.Em ±	0.39	1.61	2.14	2.48
C.D (P= 0.05)	1.17	4.83	6.42	7.37

application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (20.40) and application of 75 per cent RDF + 25 per cent FYM + 25 per cent vermicompost+ PGPR (19.75). Significantly less number of leaves was recorded with application of 75 per cent RDF and PGPR (15.52).

At 60 DAS, significantly more number of leaves (85.90) were recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR which is on par with application of 100 per cent RDF +50 per cent FYM + 50 per cent vermicompost + PGPR (82.30). Significantly lower number of leaves was recorded with application of 75 per cent RDF and PGPR (63.88).

Similar trend was noticed at 90 DAS and at harvest. Significantly more number of leaves were recorded with the application of 100 per cent RDF + 100 per cent vermicompost +PGPR (116.30, 108.0, respectively) which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (112.90, 105.70, respectively), 75 per cent RDF +25 per cent FYM+PGPR (110.39, 104.25, respectively), 75 per cent RDF +25 per cent vermicompost + PGPR (109.94, 103.50, respectively) and 75 per cent RDF +25 per cent FYM +25 per cent vermicompost+ PGPR (111.89,105.75, respectively). Significantly lower number of leaves were recorded with application of 75 per cent RDF and PGPR (71.92, 68.51, respectively).

4.1.4 Leaf area

The data pertaining to leaf area at 30, 60, 90and at harvest are presented in Table 4.4

Leaf area varied significantly due to treatments. Leaf area differed significantly at 30 DAS and 60 DAS. Significantly higher leaf area (154.8 cm², 893.2 cm², respectively)was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR which was on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (145.8cm², 840.0cm², respectively) and application of 100 per cent RDF + 100 per cent FYM +PGPR (143.5 cm², 823.5cm², respectively). Significantly least leaf area was noticed in treatment applied with 75 per cent RDF + PGPR (126.7, 651.3 cm², respectively).

Similar trend was noticed at 90 DAS and at harvest. Significantly higher leaf area (2108.4 cm², 1396.9 cm², respectively) was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (2036.0cm², 1356.2 cm², respectively). Significantly lower leaf area was recorded with 75 per cent RDF + PGPR (1217.7, 812.5 cm², respectively).

Table 4.4: Leaf area plant⁻¹ (cm²) as influenced by integrated nutrient management practices at different growth stages of aerobic rice.

Treatments	30DAS	60 DAS	90 DAS	At harvest
T ₁ -100 % RDF + FYM (POP)	130.30	787.60	1343.20	903.20
T ₂ -100 % RDF + PGPR	134.60	778.70	1370.70	972.60
T ₃ -100 % RDF + 100 % FYM + PGPR	143.50	823.50	1478.90	1055.40
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	154.80	893.20	2108.40	1396.90
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	145.80	840.00	2036.00	1356.20
T ₆ - 75 % RDF + FYM	128.50	719.40	1280.40	857.80
T ₇ -75 % RDF + PGPR	126.70	651.30	1217.70	812.50
T ₈ -75 % RDF + 25 % FYM + PGPR	128.40	693.70	1342.30	901.80
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	130.40	758.50	1400.40	943.80
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	132.40	793.30	1461.80	985.80
S.Em ±	5.06	33.09	66.45	36.63
C.D (P= 0.05)	15.03	98.32	197.44	108.82

4.1.5 Leaf area index

Leaf area index as influenced by different integrated nutrient management practices in aerobic rice recorded at 30, 60, 90 DAS and at harvest is presented in Table 4.5

Leaf area index differed significantly at all stages. At 30 DAS application of 100 per cent RDF + 100 per cent vermicompost +PGPR recorded significantly higher LAI (0.25) which was on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (0.23) and 100 per cent RDF + 100 per cent FYM +PGPR (0.23). Significantly lower LAI was recorded with application of 75 per cent RDF and PGPR (0.20).

At 60 DAS, significantly higher LAI (1.43) was observed with application of 100 per cent RDF + 100 per cent vermicompost +PGPR which is on par with 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (1.34), 100 per cent RDF + 100 per cent FYM +PGPR (1.32) and 75 per cent RDF + 25 per cent FYM + 25 per cent vermicompost + PGPR (1.32). Significantly lower LAI was obtained with application of 75 per cent RDF and PGPR (1.04).

Similar trend was observed at 90 and at harvest. Significantly higher LAI (3.47, 2.24 respectively) was observed with application of 100 per cent RDF + 100 per cent vermicompost +PGPR at 90 and at harvest which was on par with 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (3.22, 2.17) at 90 and at harvest respectively. Significantly lower LAI (1.95, 1.30respectively).

4.1.6 Leaf area duration

The data pertaining to leaf area duration at various intervals as influenced by integrated nutrient management are presented in Table 4.6.

Leaf area duration differed significantly at all intervals of crop growth stage due to treatments. At 30 and 60 DAS significantly higher LAD (3.72, 25.15 days, respectively) was observed with application of 100 per cent RDF + 100 per cent vermicompost +PGPR which was on par with application of with 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (3.50, 23.66 days, respectively) and 100 per cent RDF + 100 per cent FYM +PGPR (3.43, 23.21 days, respectively). Significantly lower LAD (3.04, 18.67 days, respectively) was observed with application of 75 per cent RDF and PGPR.

Table 4.5: Leaf area index as influenced by integrated nutrient management practices at different growth stages of aerobic rice

Treatment	30 DAS	60 DAS	90 DAS	At harvest
T ₁ -100 % RDF + FYM (POP)	0.22	1.26	2.15	1.45
T ₂ -100 % RDF + PGPR	0.22	1.25	2.19	1.56
T ₃ -100 % RDF + 100 % FYM + PGPR	0.23	1.32	2.37	1.69
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	0.25	1.43	3.47	2.24
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	0.23	1.34	3.22	2.17
T ₆ - 75 % RDF + FYM	0.21	1.15	2.05	1.37
T ₇ -75 % RDF + PGPR	0.20	1.04	1.95	1.30
T ₈ -75 % RDF + 25 % FYM + PGPR	0.21	1.11	2.15	1.44
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	0.21	1.21	2.24	1.51
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	0.22	1.32	2.34	1.58
S.E.m ±	0.01	0.06	0.09	0.07
C.D (P= 0.05)	0.03	0.17	0.26	0.20

Table 4.6: Leaf area duration (days) as influenced by integrated nutrient management practices at different growth stages of aerobic rice

Treatment	0-30 DAS	30-60 DAS	60-90 DAS	At harvest
T ₁ -100 % RDF + FYM (POP)	3.13	22.03	51.14	53.91
T ₂ -100 % RDF + PGPR	3.24	21.92	51.59	56.24
T ₃ -100 % RDF + 100 % FYM + PGPR	3.43	23.21	55.26	60.82
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	3.72	25.15	72.04	84.13
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	3.50	23.66	69.02	81.41
T ₆ - 75 % RDF + FYM	3.08	20.35	48.00	51.32
T ₇ -75 % RDF + PGPR	3.04	18.67	44.86	48.72
T ₈ -75 % RDF + 25 % FYM + PGPR	3.08	19.73	48.86	53.86
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	3.13	21.33	51.81	56.26
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	3.18	22.94	54.84	58.74
S.Em ±	0.11	0.70	1.17	1.31
C.D (P= 0.05)	0.32	2.09	3.47	3.88

Similar trend was observed at 90 and at harvest. Significantly higher LAD was observed with application of 100 per cent RDF + 100 per cent vermicompost +PGPR (72.04, 84.13 days) respectively and was on par with 100 per cent RDF +50 per cent FYM + 50 per cent vermicompost + PGPR (69.02, 81.41 days respectively). Significantly lower LAD 44.86 and 48.72 days with 75 per cent RDF and PGPR.

4.1.7 Total dry matter accumulation

The data pertaining to dry matter accumulation at 30, 60, 90, and at harvest is presented in Table 4.7

Total dry matter accumulation differed significantly due to treatments. At 30 DAS, significantly higher dry matter accumulation ($4.86 \text{ g plant}^{-1}$) was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR ($4.41 \text{ g plant}^{-1}$). Significantly least dry matter accumulation was recorded with application of 75 per cent RDF and PGPR ($2.71 \text{ g plant}^{-1}$).

At 60 DAS, significantly higher total dry matter ($20.92 \text{ g plant}^{-1}$) was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR ($19.63 \text{ g plant}^{-1}$). Significantly lower dry matter accumulation was recorded with application of 75 per cent RDF and PGPR ($11.44 \text{ g plant}^{-1}$).

At 90 DAS significantly higher total dry matter accumulation ($59.89 \text{ g plant}^{-1}$) was recorded with the application of 100 per cent RDF + 100 per cent vermicompost +PGPR which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR ($58.03 \text{ g plant}^{-1}$) and 100 per cent RDF + 100 per cent FYM + PGPR ($55.88 \text{ g plant}^{-1}$). Significantly lower dry matter accumulation was recorded with application of 75 per cent RDF and PGPR ($42.61 \text{ g plant}^{-1}$).

At harvest, significantly higher total dry matter accumulation was recorded with the application of 100 per cent RDF + 100 per cent vermicompost +PGPR ($89.04 \text{ g plant}^{-1}$) which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR ($87.99 \text{ g plant}^{-1}$) and 100 per cent RDF + 100 per cent FYM + PGPR ($84.99 \text{ g plant}^{-1}$). Significantly lower dry matter accumulation was recorded with application of 75 per cent RDF and PGPR ($71.35 \text{ g plant}^{-1}$).

Table 4.7: Total dry matter plant¹ (g) as influenced by integrated nutrient management practices at different growth stages of aerobic rice

Treatment	30 DAS	60 DAS	90 DAS	At harvest
T ₁ -100 % RDF + FYM (POP)	3.38	14.06	46.95	78.33
T ₂ -100 % RDF + PGPR	3.57	15.92	52.31	78.60
T ₃ -100 % RDF + 100 % FYM + PGPR	4.07	17.94	55.88	84.99
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	4.86	20.92	59.89	89.04
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	4.41	19.63	58.03	87.99
T ₆ - 75 % RDF + FYM	3.19	13.19	45.26	75.93
T ₇ -75 % RDF + PGPR	2.77	11.44	42.61	71.35
T ₈ -75 % RDF + 25 % FYM + PGPR	2.71	15.62	51.55	78.66
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	3.81	16.58	52.68	79.63
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	3.73	17.35	54.10	80.10
S.E_m ±	0.15	0.79	1.87	2.59
C.D (P= 0.05)	0.45	2.37	5.55	7.71

4.1.8 Absolute growth rate (AGR)

AGR calculated at intervals of 0-30, 30-60, 60-90 and 90-harvest as influenced by different integrated nutrient management practices in aerobic rice is presented in Table 4.8

AGR differed significantly at 0 to 30 and 30 to 60 DAS. At 0 to 30 DAS higher AGR (0.163 g day^{-1}) was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR. Lower AGR was recorded with application of 75 per cent RDF + 25 per cent FYM (0.090 g day^{-1}). Between 30 to 60 DAS higher AGR was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR (0.535 g day^{-1}) which is found to be on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (0.507 g day^{-1}). Significantly lower AGR was observed in treatment receiving 75 per cent RDF and PGPR (0.289 g day^{-1}).

At 60 to 90 interval, significantly higher AGR was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR (1.299 g day^{-1}) which is on par with rest other treatments except 100 per cent RDF + PGPR (1.096 g day^{-1}) and 75 per cent RDF + FYM (1.069 g day^{-1}). Significantly lower AGR was recorded with application of 75 per cent RDF and PGPR (1.039 g day^{-1}).

At 90-harvest, significantly higher AGR (1.056 g day^{-1}) was recorded with application of 100 per cent RDF + FYM and on par with 100 per cent RDF + 100 per cent FYM +PGPR (0.951 g day^{-1}), 75 per cent RDF + 25per cent vermicompost +PGPR (0.934 g day^{-1}). Significantly lower AGR was recorded with 75 per cent RDF + 25per cent FYM +25per cent vermicompost +PGPR (0.901 g day^{-1}).

4.1.9 Crop growth rate (CGR)

CGR computed at intervals of 0-30, 30 to 60, 60 to 90, 90 to harvest as influenced by different organics sources in aerobic rice is presented in Table 4.9.

CGR differed significantly between 0 to 30 DAS, significantly higher CGR ($2.59 \text{ g m}^2 \text{ day}^{-1}$) recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR. Significantly lower CGR was recorded with application of 75 per cent RDF + 25 per cent FYM ($1.45 \text{ g m}^2 \text{ day}^{-1}$). Between 30 to 60 DAS, significantly higher CGR was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR ($8.57 \text{ g m}^2 \text{ day}^{-1}$) which was on par with application 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR ($8.12 \text{ g m}^2 \text{ day}^{-1}$). Significantly lower CGR was recorded with application of 75 per cent RDF and PGPR ($4.62 \text{ g m}^2 \text{ day}^{-1}$).

Table 4.8. Absolute growth rate (g day⁻¹) as influenced by integrated nutrient management practices at different growth stages of aerobic rice

Treatment	0-30 DAS	30-60 DAS	60-90 DAS	90- Harvest
T ₁ -100 % RDF + FYM (POP)	0.113	0.356	1.096	1.056
T ₂ -100 % RDF + PGPR	0.119	0.412	1.213	0.911
T ₃ -100 % RDF + 100 % FYM + PGPR	0.136	0.462	1.265	0.951
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	0.163	0.535	1.299	0.923
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	0.147	0.507	1.280	1.019
T ₆ - 75 % RDF + FYM	0.106	0.333	1.069	1.033
T ₇ -75 % RDF + PGPR	0.092	0.289	1.039	0.920
T ₈ -75 % RDF + 25 % FYM + PGPR	0.090	0.430	1.198	0.922
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	0.127	0.426	1.203	0.934
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	0.124	0.454	1.225	0.901
S.Em ±	0.004	0.016	0.049	0.042
C.D (P= 0.05)	0.013	0.049	0.146	0.125

Table 4.9: Crop growth rate ($\text{g m}^{-2} \text{ day}^{-1}$) as influenced by integrated nutrient management practices at different growth stages of aerobic rice

Treatment	0-30 DAS	30-60 DAS	60-90 DAS	90-Harvest
T ₁ -100 % RDF + FYM (POP)	1.80	5.70	17.54	16.74
T ₂ -100 % RDF + PGPR	1.90	6.59	19.41	14.02
T ₃ -100 % RDF + 100 % FYM + PGPR	2.17	7.40	20.24	15.52
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	2.59	8.57	20.78	15.55
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	2.35	8.12	20.48	15.98
T ₆ - 75 % RDF + FYM	1.70	5.33	17.10	16.36
T ₇ -75 % RDF + PGPR	1.54	4.62	16.62	15.33
T ₈ -75 % RDF + 25 % FYM + PGPR	1.45	6.89	19.16	14.46
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	2.03	6.81	19.25	14.37
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	1.99	7.26	19.60	13.87
S.Em \pm	0.08	0.20	0.96	0.63
C.D (P= 0.05)	0.22	0.60	2.84	1.86

CGR was superior over other treatments between 60 to 90 DAS, significantly higher CGR was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR ($20.78 \text{ g m}^2 \text{ day}^{-1}$) which was on par with all other treatments except 100 per cent RDF +FYM ($17.54 \text{ g m}^2 \text{ day}^{-1}$) and 75 per cent RDF + FYM ($17.10 \text{ g m}^2 \text{ day}^{-1}$). Significantly lower CGR was recorded with application of 75 per cent RDF and PGPR ($16.62 \text{ g m}^2 \text{ day}^{-1}$).

CGR was found to be highest in treatment applied with 100 per cent RDF + FYM ($16.74 \text{ g m}^2 \text{ day}$) and on par with 100 per cent RDF + 100 per cent FYM +PGPR ($15.52 \text{ g m}^2 \text{ day}$), 100 per cent RDF + 100per cent vermicompost +PGPR ($15.55 \text{ g m}^2 \text{ day}$), 100 per cent RDF + 50per cent FYM + 50per cent vermicompost + PGPR ($15.98 \text{ g m}^2 \text{ day}$), 75 per cent RDF + FYM ($16.36 \text{ g m}^2 \text{ day}^{-1}$). 75 per cent RDF + PGPR ($15.33 \text{ g m}^2 \text{ day}$). Significantly lower CGR was recorded with 75 per cent RDF + 25per cent FYM +25per cent vermicompost +PGPR ($13.87 \text{ g m}^2 \text{ day}$).

4.1.10 Relative growth rate (RGR)

The data pertaining to relative growth rate at different intervals 0-30, 30-60, 60-90, and 90-harvest is presented in Table 4.10

At 0 to 30 DAS, higher RGR was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR ($0.053 \text{ g g}^{-1} \text{ day}^{-1}$). Significantly lower RGR ($0.033 \text{ g g}^{-1} \text{ day}^{-1}$) was observed in treatment applied with 75 per cent RDF + PGPR.

At different growth stages *viz.*, 30 to 60, 60 to 90 and 90 to harvest RGR was not differed significantly by different integrated nutrient management practices.

4.1.11 Net assimilation rate (NAR)

NAR computed at intervals of 0 to 30, 30 to 60, 60 to 90 DAS to at harvest as influenced by different organic sources in aerobic rice is presented in Table 4.11

Significantly higher NAR was recorded with application of 100 per cent RDF + 100 per cent vermicompost +PGPR ($0.0024, 0.0036 \text{ g dm}^{-2} \text{ day}^{-1}$, respectively) at 0 to 30 and 30 to 60 DAS, respectively. Significantly lower NAR was recorded with application of with 75 per cent RDF + PGPR ($0.0007, 0.016 \text{ g dm}^{-2} \text{ day}^{-1}$ respectively).

At 60 to 90 days interval, significantly higher NAR was observed with application of 100 per cent RDF + 100 per cent vermicompost +PGPR($0.108 \text{ g dm}^{-2} \text{ day}^{-1}$) and on par with 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR ($0.106 \text{ g dm}^{-2} \text{ day}^{-1}$). Significantly lower NAR was observed in treatment receiving 75 per cent RDF + PGPR ($0.060 \text{ g dm}^{-2} \text{ day}^{-1}$).

Table 4.10: Relative growth rate ($\text{g g}^{-1} \text{day}^{-1}$) as influenced by integrated nutrient management practices at different growth stages of aerobic rice.

Treatment	0-30 DAS	30-60 DAS	60-90 DAS	90-Harvest
T ₁ -100 % RDF + FYM (POP)	0.041	0.048	0.040	0.017
T ₂ -100 % RDF + PGPR	0.042	0.050	0.040	0.014
T ₃ -100 % RDF + 100 % FYM + PGPR	0.047	0.049	0.038	0.014
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	0.053	0.049	0.035	0.013
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	0.049	0.050	0.036	0.014
T ₆ - 75 % RDF + FYM	0.039	0.047	0.041	0.017
T ₇ -75 % RDF + PGPR	0.033	0.047	0.044	0.017
T ₈ -75 % RDF + 25 % FYM + PGPR	0.034	0.058	0.040	0.014
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	0.045	0.049	0.039	0.014
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	0.044	0.051	0.038	0.013
S.Em ±	0.002	0.002	0.001	0.001
C.D (P= 0.05)	0.005	NS	NS	NS

Table 4.11: Net assimilation rate ($\text{g dm}^{-2} \text{ day}^{-1}$) as influenced by integrated nutrient management practices at different growth stages of aerobic rice

Treatment	0-30DAS	30-60 DAS	60- 90 DAS
T ₁ -100 % RDF + FYM (POP)	0.0010	0.022	0.063
T ₂ -100 % RDF + PGPR	0.0012	0.026	0.072
T ₃ -100 % RDF + 100 % FYM + PGPR	0.0016	0.030	0.079
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	0.0024	0.036	0.108
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	0.0018	0.033	0.106
T ₆ - 75 % RDF + FYM	0.0009	0.020	0.061
T ₇ -75 % RDF + PGPR	0.0007	0.016	0.060
T ₈ -75 % RDF + 25 % FYM + PGPR	0.0008	0.025	0.075
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	0.0011	0.026	0.075
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	0.0012	0.029	0.076
S.Em \pm	0.0000	0.001	0.002
C.D (P= 0.05)	0.0001	0.003	0.007

4.2 Yield and Yield parameters

4.2.1 Number of panicles plant⁻¹

The data on number of panicles plant⁻¹ of aerobic rice as influenced by integrated nutrient management practices at harvest is presented in Table 4.12

Application of 100 per cent RDF + 100 per cent vermicompost +PGPR recorded significantly higher number panicles per hill (16.32) and was on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (15.50). Significantly lower number of panicles per hill was recorded with application of 75 per cent RDF + PGPR (12.34).

4.2.2 Panicle length

The data on panicle length of aerobic rice as influenced by integrated nutrient management practices at harvest are presented in Table 4.12

Application of 100 per cent RDF + 100 per cent vermicompost +PGPR recorded significantly higher panicle length (23.52 cm) which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (22.89 cm). Significantly lower panicle length was recorded with application of 75 per cent RDF and PGPR (18.43 cm).

4.2.3 Panicle weight

The data on panicle weight of aerobic rice as influenced by integrated nutrient management practices at harvest are presented in table 4.12

Application of 100 per cent RDF + 100 per cent vermicompost +PGPR recorded significantly higher panicle weight (2.68 g) which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (2.59 g).

Whereas, significantly lower panicle weight was recorded with application of 75 per cent RDF + PGPR (1.90 g).

4.2.4 Test weight

The data on thousand grain weight of aerobic rice as influenced by integrated nutrient management practices at harvest are presented in Table 4.12.

Application of 100 per cent RDF + 100 per cent vermicompost +PGPR recorded significantly higher thousand grain weight (22.65 g) which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost +

Table 4.12: Yield parameters as influenced by integrated nutrient management practices at different growth stages of aerobic rice

Treatment	Number of Panicles per plant	Panicle length (cm)	Panicle weight (g)	Test weight (g)
T ₁ -100 % RDF + FYM (POP)	13.55	20.44	2.08	20.63
T ₂ -100 % RDF + PGPR	14.00	21.51	2.43	21.59
T ₃ -100 % RDF + 100 % FYM + PGPR	14.03	21.45	2.44	22.35
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	16.32	23.52	2.68	22.65
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	15.50	22.89	2.59	22.53
T ₆ - 75 % RDF + FYM	13.45	19.35	1.96	20.62
T ₇ -75 % RDF + PGPR	12.34	18.43	1.90	19.05
T ₈ -75 % RDF + 25 % FYM + PGPR	13.78	19.25	2.09	20.72
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	13.89	20.10	2.14	20.82
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	14.00	21.66	2.25	21.16
S.Em ±	0.30	0.44	0.05	0.44
C.D (P= 0.05)	0.89	1.31	0.14	1.32

PGPR (22.53 g), 100 per cent RDF + 100 per cent FYM + PGPR (22.35 g). Significantly lower test weight was recorded with application of 75 per cent RDF + PGPR (19.05 g).

4.2.5 Total number of grains

The data on total number of grains per panicle of aerobic rice as influenced by integrated nutrient management practices at harvest are presented in Table 4.13.

Application of 100 per cent RDF + 100 per cent vermicompost + PGPR recorded significantly higher number of grains per panicle (126.80) which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (124.10). Significantly less number of grains was recorded with application of 75 per cent RDF + PGPR (108.9).

4.2.6 Number of filled grains panicle⁻¹

The data on filled grains per panicle of aerobic rice as influenced by integrated nutrient management practices at harvest are presented in table 4.13.

Significantly more number of filled grains per panicle of aerobic rice at harvest was recorded with application of 100 per cent RDF + 100 per cent vermicompost + PGPR (98.60) and was on par with 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (95.20) and 100 per cent RDF + PGPR (93.0). Significantly less number of filled grains were recorded with application of 75 per cent RDF and PGPR (87.0).

4.2.7 Number of unfilled grains per panicle⁻¹

The data pertaining to unfilled grains per panicle of aerobic rice as influenced by integrated nutrient management practices at harvest are presented in table 4.13.

Significantly higher number of unfilled grains was recorded with application of 75 per cent RDF and PGPR (22.0) which was on par with rest other treatments except 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (18.90). Significantly lower number of unfilled grains per panicle (16.10) was observed with application of 100 per cent RDF + 100 per cent vermicompost + PGPR.

4.2.8 Chaffiness (%)

The data pertaining to chaffiness (%) of aerobic rice as influenced by integrated nutrient management practices at harvest are presented in Table 4.13.

Table 4.13: Total number of grains, filled grains, unfilled grains per panicle and Chaffiness (%) as influenced by integrated nutrient management practices of aerobic rice

Treatments	Total no of grains	Filled grains	Unfilled grains	Chaffiness (%)
T ₁ -100 % RDF + FYM (POP)	112.50	91.20	21.30	18.93
T ₂ -100 % RDF + PGPR	113.80	93.00	21.40	18.81
T ₃ -100 % RDF + 100 % FYM + PGPR	111.80	90.50	21.90	19.59
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	126.80	98.60	16.10	12.70
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	124.10	95.20	18.90	15.23
T ₆ - 75 % RDF + FYM	111.70	90.30	21.40	19.16
T ₇ -75 % RDF + PGPR	108.90	87.00	22.00	20.20
T ₈ -75 % RDF + 25 % FYM + PGPR	109.70	87.80	21.90	19.96
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	110.90	89.50	21.40	19.30
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	111.40	88.60	21.80	19.57
S.Em ±	2.40	1.91	0.43	0.38
C.D (P= 0.05)	7.19	5.73	1.28	1.13

Significantly higher chaffiness was recorded with application of 75 per cent RDF and PGPR (20.20 %). However, the lowest chaffiness (12.70 %) was observed in treatment receiving 100 per cent RDF + 100 per cent vermicompost +PGPR.

4.2.9 Days to 50 per cent flowering

The data pertaining to days to 50 per cent flowering in aerobic rice as influenced by integrated nutrient management practices is presented in Table 4.14.

Among different treatments application of 100 per cent RDF + 100 per cent vermicompost +PGPR has resulted in early days to 50 per cent flowering (81.64 days) over rest of the treatments.

4.2.10 Days to maturity

The data pertaining to days to maturity in aerobic rice as influenced by integrated nutrient management practices is presented in Table 4.14.

Application of 100 per cent RDF + 100 per cent vermicompost +PGPR has resulted in early days to maturity (129.42 days) over rest of the treatments. Whereas, delay in maturity was observed in treatment receiving 75 per cent RDF + FYM (138.85 days)

4.2.11 Grain yield (kg ha⁻¹)

The data on grain yield of aerobic rice as influenced by integrated nutrient management practices is presented in Table4.15.

Grain yield varied significantly due to treatments. Application of 100 per cent RDF + 100 per cent vermicompost + PGPR recorded significantly higher grain yield(3868.0 kg ha⁻¹) and it was on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (3,680.33 kg ha⁻¹) over other treatments. However, significantly lower grain yield was observed with 75 per cent RDF + PGPR (2,737.65 kg ha⁻¹)

4.2.12 Straw yield (kg ha⁻¹)

The data on straw yield of aerobic rice as influenced by integrated nutrient management practices is presented in Table4.15.

The straw yield of aerobic rice was significantly varied. Application of 100 per cent RDF + 100 per cent vermicompost + PGPR recorded significantly higher straw yield (4225.72 kg ha⁻¹) and it was on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (3733.16 kg ha⁻¹). Significantly lower straw yield was recorded with application of 75 per cent RDF + PGPR (3283.38 kg ha⁻¹) over other treatments.

Table 4.14: Days taken to 50 per cent flowering and days taken for maturity as influenced by integrated nutrient management practices of aerobic rice

Treatments	Days to 50 % flowering	Days to maturity
T ₁ -100 % RDF + FYM (POP)	83.66	132.46
T ₂ -100 % RDF + PGPR	85.38	134.89
T ₃ -100 % RDF + 100 % FYM + PGPR	82.00	130.25
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	81.64	129.42
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	82.54	130.78
T ₆ - 75 % RDF + FYM	87.63	138.85
T ₇ -75 % RDF + PGPR	85.24	135.62
T ₈ -75 % RDF + 25 % FYM + PGPR	86.75	136.74
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	86.98	137.46
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	85.04	135.49
S.Em ±	1.49	3.54
C.D (P= 0.05)	4.44	10.53

Table 4.15. Grain yield, straw yield, harvest index and water use efficiency as influenced by integrated nutrient management practices of aerobic rice

Treatment	Grain Yield (kg ha ⁻¹)	Straw Yield (kg ha ⁻¹)	HI	Total WUE (kg ha-cm ⁻¹)
T ₁ -100 % RDF + FYM (POP)	3035.67	3582.05	0.47	32.01
T ₂ -100 % RDF + PGPR	3048.33	3617.43	0.46	32.15
T ₃ -100 % RDF + 100 % FYM + PGPR	3304.34	3667.84	0.47	34.85
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	3868.00	4225.72	0.48	40.79
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	3680.33	3733.16	0.51	38.81
T ₆ - 75 % RDF + FYM	2911.67	3333.74	0.47	30.71
T ₇ -75 % RDF + PGPR	2737.65	3283.38	0.45	28.87
T ₈ -75 % RDF + 25 % FYM + PGPR	3045.01	3592.49	0.46	32.11
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	3190.67	3585.17	0.46	33.65
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	3161.32	3633.95	0.47	33.34
S.Em ±	118.20	174.18	0.01	0.71
C.D (P= 0.05)	351.18	517.51	NS	NS

Effective rainfall – 348.24 mm

Water used through irrigation – 600 mm

Total water used- 948.24

4.2.13 Harvest Index

Harvest index did not differ significantly due to different integrated nutrient management practices and data are presented in Table 4.15.

However, highest harvest index was recorded with application of 100 per cent RDF + 50 per cent vermicompost + 50 per cent FYM + PGPR (0.51) and lowest harvest index was recorded with application of 75 per cent RDF + PGPR (0.45).

4.2.14 Total water use efficiency

Higher water use efficiency (40.79 kg ha cm⁻¹) was recorded with treatment applied with 100 per cent RDF + 100 per cent vermicompost + PGPR followed by 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost (N Equivalent) + PGPR (38.81 kg ha cm⁻¹). Lower water use efficiency was noticed with application of 75 per cent RDF + PGPR (28.87 kg ha cm⁻¹).

4.3 Microbial population after harvest of the crop

The data pertaining to microbial population after the harvest of the crop are presented in the table 4.16.

At harvest, significantly higher bacteria (47.83 cfu per g soil), fungi (15.50 cfu per g soil), actinomycetes (10.96 cfu per g soil), PSB (24.0 cfu per g soil), and KSB (8.9 cfu per g soil) was recorded with application of 100 per cent RDF + 100 per cent vermicompost + PGPR. Significantly lower population of bacteria (33.40 cfu per g soil), fungi (12.66 cfu per g soil), actinomycetes (7.83 cfu per g soil), PSB (9.66 cfu per g soil), KSB (4.6 cfu per g soil) with application of 75 per cent RDF + FYM.

4.4 Nutrient uptake

The data on uptake of nutrients *viz.*, nitrogen, phosphorus and potassium by straw and grains of aerobic rice as influenced by integrated nutrient management practices are presented in table 4.17

4.4.1 Nitrogen uptake

The nitrogen uptake by aerobic rice varied significantly due to different integrated nutrient management practices at harvest.

Table 4.16: Effect of integrated nutrient management practices on microbial population at harvest of aerobic rice

Treatments	Bacterial population	Fungi population	Actinomycetes population	PSB population	KSB population
	cfu x 10 ⁶ g soil ⁻¹	cfu x 10 ⁴ g soil ⁻¹	cfu x 10 ³ g soil ⁻¹	cfu x 10 ⁵ g soil ⁻¹	cfu x 10 ⁵ g soil ⁻¹
T ₁ -100 % RDF + FYM (POP)	37.83	14.00	8.5	10.33	5.2
T ₂ -100 % RDF + PGPR	38.16	14.50	8.66	21.66	6.8
T ₃ -100 % RDF + 100 % FYM + PGPR	41.00	13.16	9.16	10.66	5.9
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	47.83	15.50	10.96	24.00	8.9
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	34.50	14.50	8.00	21.33	7.1
T ₆ - 75 % RDF + FYM	33.40	12.66	7.83	9.66	4.6
T ₇ -75 % RDF + PGPR	38.00	14.66	9.00	22.50	5.1
T ₈ -75 % RDF + 25 % FYM + PGPR	35.16	13.83	8.66	23.66	7.3
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	40.16	12.50	7.16	23.66	8.6
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	33.50	14.16	8.24	10.33	7.6
S.Em ±	0.80	0.30	0.18	0.58	0.24
C.D (P= 0.05)	2.37	0.88	0.54	1.71	0.72

Table 4.17: Nitrogen, Phosphorus and potassium uptake by grain and straw (kg ha⁻¹) as influenced by integrated nutrient management practices of aerobic rice

Treatment	N uptake (kg ha ⁻¹)			P uptake (kg ha ⁻¹)			K uptake (kg ha ⁻¹)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
	T ₁ -100 % RDF + FYM (POP)	41.59	36.18	72.40	12.45	5.37	17.82	19.13	50.86
T ₂ -100 % RDF + PGPR	43.28	37.62	81.98	13.41	6.51	19.92	19.51	51.72	71.23
T ₃ -100 % RDF + 100 % FYM + PGPR	46.25	44.74	77.06	13.21	6.23	19.44	21.48	52.81	74.29
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	57.63	53.23	93.13	17.02	8.03	25.05	26.30	66.33	92.63
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	54.46	47.04	90.68	16.20	7.09	23.29	25.03	58.61	83.64
T ₆ -75 % RDF + FYM	38.44	31.00	68.77	11.94	5.34	17.28	17.18	46.00	63.18
T ₇ -75 % RDF + PGPR	35.59	29.87	65.47	9.58	4.92	14.50	15.60	44.98	60.58
T ₈ -75 % RDF + 25 % FYM + PGPR	41.72	35.20	72.25	12.48	5.39	17.87	19.49	51.01	70.50
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	43.59	36.21	81.22	13.29	6.45	19.74	19.78	50.91	70.69
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	45.20	39.60	84.07	13.59	6.54	20.13	19.92	51.22	71.14
S.Em ±	0.95	0.83	1.65	0.28	0.13	0.41	0.43	1.11	1.55
C.D (P= 0.05)	2.84	2.50	4.94	0.84	0.39	1.24	1.29	3.34	4.63

4.4.1.1 Nitrogen uptake by grains

Nitrogen uptake by aerobic rice varied significantly due to different integrated nutrient management practices at harvest of the crop. Higher nitrogen uptake in grain was noticed in the treatment receiving 100 per cent RDF + 100 per cent vermicompost + PGPR (57.63 kg ha⁻¹) followed by 100 per cent RDF + 50 per cent FYM +50 per cent vermicompost+ PGPR (54.46 kg ha⁻¹). Whereas, the lowest uptake of nitrogen was recorded in 75 per cent RDF + PGPR (35.59kg ha⁻¹).

4.4.1.2 Nitrogen uptake by straw

Significantly higher nitrogen uptake in straw was noticed in a treatment applied with 100 per cent RDF + 100 per cent vermicompost+ PGPR (53.23 kg ha⁻¹) followed by 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (47.04 kg ha⁻¹). Whereas, the lowest uptake of nitrogen was recorded in 75 per cent RDF + PGPR (29.87kg ha⁻¹).

4.4.1.3 Total nitrogen uptake by the crop

Significantly higher total nitrogen was recorded in treatment receiving 100 per cent RDF + 100 per cent vermicompost + PGPR (93.13 kg ha⁻¹) followed by 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (90.68 kg ha⁻¹). On the other hand, lower uptake of total nitrogen was observed in 75 per cent RDF + PGPR (65.47 kg ha⁻¹).

4.4.2 Phosphorus uptake

The phosphorus uptake by aerobic rice varied significantly due to different integrated nutrient management practices at harvest of the crop

4.4.2.1 Phosphorus uptake by grains

Phosphorus uptake by aerobic rice varied significantly due to different integrated nutrient management practices at harvest of the crop. Higher phosphorus uptake in grain was noticed in the treatment receiving 100 per cent RDF + 100 per cent vermicompost + PGPR (17.02 kg ha⁻¹) which is on par with application of 100 per cent RDF +50 per cent FYM + 50 per cent vermicompost + PGPR (16.20kg ha⁻¹). Whereas, the lowest uptake of phosphorus by grain was recorded in 75 per cent RDF + PGPR (9.58kg ha⁻¹).

4.4.2.2 Phosphorus uptake by straw

Significantly higher phosphorus uptake in straw was noticed in a treatment applied with 100 per cent RDF + 100 per cent vermicompost + PGPR (8.03 kg ha⁻¹) followed by 100 per cent RDF + 50 per cent FYM +50 per cent vermicompost + PGPR (7.09 kg ha⁻¹) and these treatments were on par with each other. Whereas, the lowest uptake of phosphorus was recorded in 75 per cent RDF + PGPR (4.92kg ha⁻¹).

4.4.2.3 Total phosphorus uptake by the crop

Total phosphorus uptake by the crop was significantly influenced by integrated nutrient management practices. Significantly higher total phosphorus uptake was recorded in treatment receiving 100 per cent RDF + 100 per cent vermicompost + PGPR (25.05 kg ha⁻¹) followed by 100 per cent RDF +50 per cent FYM +50 per cent vermicompost + PGPR (23.29 kg ha⁻¹). On the other hand, lower uptake of phosphorus by grain and straw was observed in 75 per cent RDF + PGPR (14.50 kg ha⁻¹).

4.4.3 Potassium uptake

The potassium uptake by aerobic rice varied significantly due to different integrated nutrient management practices at harvest of the crop

4.4.3.1 Potassium uptake by grains

Potassium uptake by aerobic rice varied significantly due to different integrated nutrient management practices at harvest of the crop. Higher potassium uptake in grain was noticed in the treatment receiving 100 per cent RDF + 100 per cent vermicompost + PGPR (26.30 kg ha⁻¹) which is on par with application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (25.03 kg ha⁻¹). Whereas, the lowest uptake of potassium by grain was recorded in 75 per cent RDF + PGPR (15.60 kg ha⁻¹).

4.4.3.2 Potassium uptake by straw

Significantly higher potassium uptake in straw was noticed in a treatment applied with 100 per cent RDF + 100 per cent vermicompost + PGPR (66.33 kg ha⁻¹) followed by 100 per cent RDF + 50 per cent FYM +50 per cent vermicompost + PGPR (58.61 kg ha⁻¹) and these treatments were on par with each other. Whereas, the lowest uptake of potassium was recorded in 75 per cent RDF + PGPR (44.98kg ha⁻¹)

4.4.3.3 Total Potassium uptake by the crop

Total potassium uptake by the crop was significantly influenced by integrated nutrient management practices. Significantly higher total potassium was recorded in treatment receiving 100 per cent RDF + 100 per cent vermicompost + PGPR (92.63kg ha⁻¹) followed by 100 per cent RDF +50 per cent FYM + 50 per cent vermicompost + PGPR (83.64kg ha⁻¹). On the other hand, lower uptake of potassium by grain and straw was observed in 75 per cent RDF + PGPR (60.58 kg ha⁻¹).

4.5. Soil nutrient status after harvest of crop

4.5.1 Available soil Nitrogen (kg ha⁻¹)

The data on soil nitrogen as influenced by integrated nutrient management practices after harvest is presented in Table 4.18

Application of 100 per cent RDF + FYM recorded significantly higher soil nitrogen (253.40 kg ha⁻¹) followed by of 100 per cent RDF + 100 per cent FYM + PGPR (251.74 kg ha⁻¹), 100 per cent RDF + PGPR (245.82 kg ha⁻¹) and 75per cent RDF + PGPR (241.33 kg ha⁻¹). Whereas, lower available soil nitrogen was found with application of 100 per cent RDF + 25 per cent FYM + 25 per cent vermicompost + PGPR (223.73kg ha⁻¹)

4.5.2 Available soil phosphorus (kg ha⁻¹)

Significantly higher available phosphorus in soil was recorded with application of 100 per cent RDF + FYM (51.08 kg ha⁻¹) followed by 100 per cent RDF + 100 per cent FYM + PGPR (49.46 kg ha⁻¹), 100 per cent RDF + PGPR (48.98 kg ha⁻¹) and application of 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (45.61 kg ha⁻¹). Whereas, lower available phosphorus was recorded with application of 100 per cent RDF + 25 per cent FYM + 25 per cent vermicompost + PGPR (36.27kg ha⁻¹)

4.5.3 Available soil potassium (kg ha⁻¹)

The data on available soil nitrogen was significantly influenced by influenced by integrated nutrient management practices. Application of 100 per cent RDF + FYM recorded significantly higher available soil potassium (146.61 kg ha⁻¹) followed by 100 per cent RDF + PGPR (144.37 kg ha⁻¹), 100 per cent RDF + 100 per cent FYM + PGPR (144.31kg ha⁻¹) and 75 per cent RDF + FYM (145. 92 kg ha⁻¹) and 75 per cent RDF + PGPR (147.52 kg ha⁻¹).

Table 4.18: Available soil nutrient statuses at harvest as influenced by integrated nutrient management practices in aerobic rice

Treatment	N (kg ha ⁻¹)	P (kg ha ⁻¹)	K (kg ha ⁻¹)
T ₁ -100 % RDF + FYM (POP)	253.40	51.08	146.61
T ₂ -100 % RDF + PGPR	245.82	48.98	144.37
T ₃ -100 % RDF + 100 % FYM + PGPR	251.74	49.46	144.31
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	235.67	43.85	125.97
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	239.12	45.61	135.96
T ₆ - 75 % RDF + FYM	237.03	39.12	145.92
T ₇ -75 % RDF + PGPR	241.33	41.90	147.52
T ₈ -75 % RDF + 25 % FYM + PGPR	236.55	38.53	139.6
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	227.58	36.66	139.41
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	223.73	36.27	137.96
S.Em ±	4.47	0.90	2.54
C.D (P= 0.05)	13.37	2.71	7.62

INITIAL: N- 220.80 kg ha⁻¹, P₂O₅- 33.9 kg ha⁻¹, K₂O-163.6 kg ha⁻¹

Whereas, lower soil potassium was found with application of 100 per cent RDF + 100 per cent vermicompost + PGPR (125.97 kg ha⁻¹).

4.6 Economics of aerobic rice as influenced by integrated nutrient management practices

The data on gross returns, cost of cultivation, net returns and benefit cost ratio are presented in table 4.19.

Among the different integrated nutrient management practices, highest gross returns was recorded with application of 100 per cent RDF + 100 per cent vermicompost + PGPR (Rs. 81,228) followed with 100 per cent RDF + 50 per cent FYM + 50 per cent vermicompost + PGPR (Rs. 77,301). Application of 75 per cent RDF + PGPR (Rs. 57,498).

The maximum cost of cultivation was incurred due to application 100 per cent RDF + 100 per cent FYM + PGPR (Rs. 37,733) followed by 100 per cent RDF + FYM (Rs. 36,899). Whereas, lowest cost of cultivation was recorded with application of 75 per cent RDF + PGPR (Rs. 21,743).

The maximum net returns was realized with application of 100 per cent RDF + 100 per cent vermicompost + PGPR (Rs. 45,175) followed by 75 per cent RDF + 25 per cent FYM + 25 per cent vermicompost + PGPR (Rs. 42,328). Whereas, lowest net returns was recorded with application of 75 per cent RDF + FYM (Rs. 25,243).

The highest benefit cost ratio was obtained with application of 75 per cent RDF + 25 per cent vermicompost + PGPR (2.87) followed by 100 per cent RDF + PGPR (2.82). Whereas, least benefit cost ratio was recorded with 75 per cent RDF + FYM (1.70).

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

The data on co-efficient of correlation was noticed between yield, growth and yield components are presented in table 4.20.

Significantly positive correlation was noticed between grain yield and leaf area (0.978**), panicles per plant (0.973**), total dry matter accumulation at harvest (0.961**), plant height (0.954**), panicle length (0.918**), panicle weight (0.916**), number of tillers per plant (0.915**), filled grains per panicle (0.877**), and test weight (0.873**) at 1 per cent level of significance.

Table 4.19: Economics of aerobic rice as influenced by integrated nutrient management practices

Treatments	Gross returns (Rs.)	COC (Rs.)	Net returns (Rs.)	B:C
T ₁ -100 % RDF + FYM (POP)	63756	36899	26857	1.73
T ₂ -100 % RDF + PGPR	64008	22733	41275	2.82
T ₃ -100 % RDF + 100 % FYM + PGPR	69405	37733	31672	1.84
T ₄ -100 % RDF + 100 % Vermicompost (N Equivalent) + PGPR	81228	36053	45175	2.25
T ₅ -100 % RDF + 50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR	77301	36893	40408	2.10
T ₆ - 75 % RDF + FYM	61152	35909	25243	1.70
T ₇ -75 % RDF + PGPR	57498	21743	35755	2.64
T ₈ -75 % RDF + 25 % FYM + PGPR	63945	22956	40989	2.79
T ₉ -75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR	64911	22583	42328	2.87
T ₁₀ -75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR	66381	23796	42585	2.79

Table 4.20: Correlation coefficient between yield, yield parameters and growth parameters as influenced by integrated nutrient management practices of aerobic rice

Parameters	Grain yield
Grain yield (kg ha ⁻¹)	1
Filled grains per panicle	0.877**
Panicle length (cm)	0.918**
Panicle weight (g)	0.916**
Test weight (g)	0.873**
Panicles per plant	0.973**
Total dry matter at harvest (g)	0.961**
Plant Height at harvest (cm)	0.954**
Number of tillers per plant at 90 DAS	0.915**
Leaf area index at 90 DAS (cm ²)	0.978**

** Correlation is significant at the 0.01 level (2-tailed)

DISCUSSION

V DISCUSSION

Field experiment entitled “Influence of integrated nutrient management practices on growth and yield of aerobic rice (*Oryza sativa* L.)” was carried out at Agricultural and Horticultural Research Station (AHRs), Bhavikere, Tarikere taluk, University of Agricultural and Horticultural Sciences, Navile, Shivamogga during *Kharif* 2017. The results obtained during different growth stages of crop are discussed in this chapter.

Cultivating rice in rainfed ecosystem, by adopting aerobic rice culture technique provide abundant scope to increase production of rice on one hand and also increases production of cereals on the other.

The productivity of rice is mainly affected by soil and climatic conditions, keeping these two aside, nutrient management plays vital role in increasing the crop productivity. It is desired that the soil should have the required nutrient in sufficient quantities and in optimum proportion to meet out the nutrient requirement of the crop. Presently, the chemical fertilizers are used as a major source of nutrients. But, the escalating price coupled with increasing demand for chemical fertilizers and depleting soil health, necessitates the safe and efficient use of organics in rice production. Further, in aerobic rice production, organic matter management is crucial as it helps to improve water holding capacity of the soil. These practices gaining much popularity to enhance and maintain soil fertility status for obtaining sustainable crop yields.

Concept of integrated nutrient management (INM) or applying organic manures is to feed the soil rather than the crops. It is a means of giving back the nutrients which has been taken by the crop and to maintain soil health. As INM combines the use of chemical fertilizers and organic sources from the perspective of eco-service management, it shows superiority over conventional agriculture. Hence, an integrated organic nutrient supply system provides an ideal nutrition for a crop through proper combination of various sources of nutrients.

On this context, the present investigation was undertaken with an objective to find out the integrated nutrient management practice in aerobic rice cultivation which is sustainable and ecologically sound. This study has brought out some useful results and they have been critically analysed and discussed with cause and effect in this chapter under the following subheads.

- 5.1 Influence of weather on the crop performance
- 5.2 Effect of integrated nutrient management practices on yield and yield parameters of aerobic rice
- 5.3 Effect of different integrated nutrient management on growth parameters of aerobic rice
- 5.4 Effect of different integrated nutrient management on soil nutrient status and nutrient uptake of aerobic rice
- 5.5 Influence of different integrated nutrient management on economics of aerobic rice cultivation

5.1 Influence of weather on the performance of crop

Crop growth and development is influenced by environmental factors and fluctuations in weather condition and thereby shows large impact on yield potential. The field experiment was conducted at Bhavikere under Southern Transitional Zone of Karnataka. The total rainfall received during the crop growth period was 435.3mm as against normal rainfall (877.3mm) which was distributed from July to December 2017. The highest monthly rainfall was recorded in the month of September (157.4 mm) which favoured crop growth and development.

The monthly mean maximum air temperature was lesser than the normal during crop growth period and maximum during November (27.4°C). The minimum air temperature was highest in July (22.4°C) and actual mean sunshine hours were considerably higher during October. Mean monthly relative humidity varied from 76.3 per cent in December to 91.0 per cent in August (Table 3.2 and Fig 3.1). The weather was warm and humid during growth period, which was congenial for better growth and development of the crop. Incidence of pest and disease was least during crop period therefore, the crop produced normal yield under aerobic condition.

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

The economic yield is a part of total biological yield of the crop and crop yield is a function of various independent factors. Among several factors responsible for sustained aerobic rice production, adequate supply of essential nutrients in balanced way is one of the important factors for realizing the potential yield. Application of organic sources has been a traditional way of maintaining soil fertility along with supplying nutrients throughout the growing period and minimize the nutrient losses due to increased absorption of nutrients.

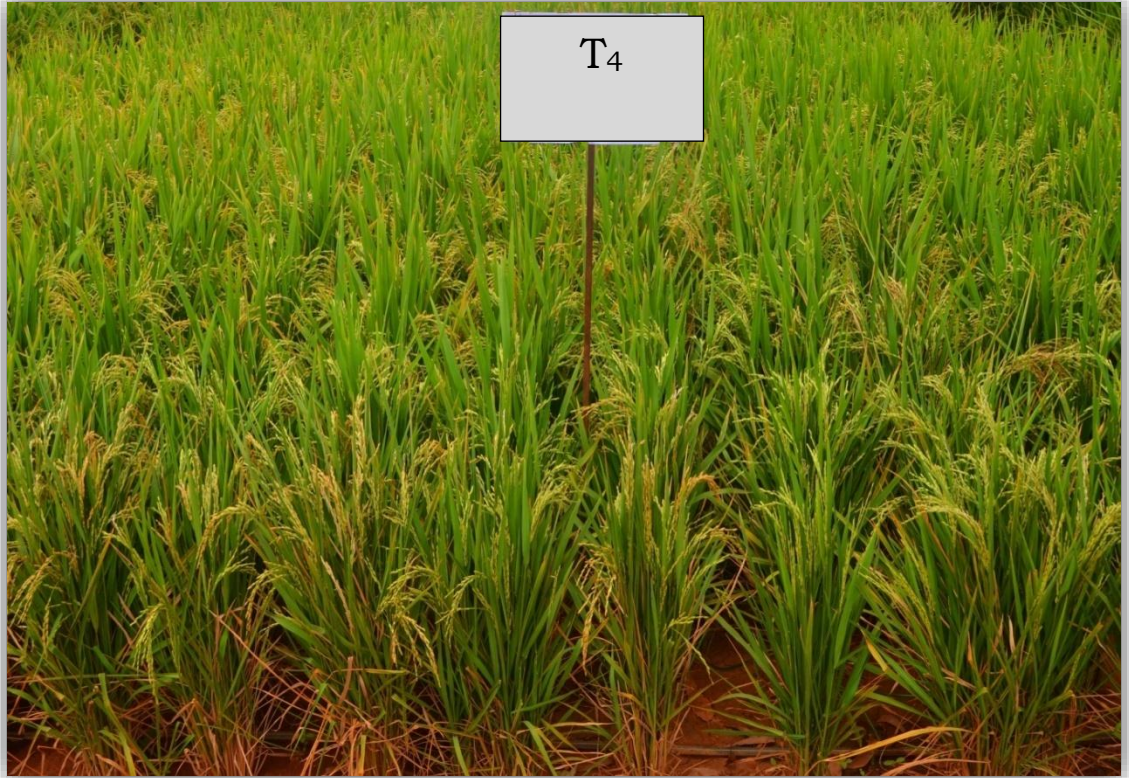


Plate 1: 100 per cent RDF + 100 per cent vermicompost + PGPR

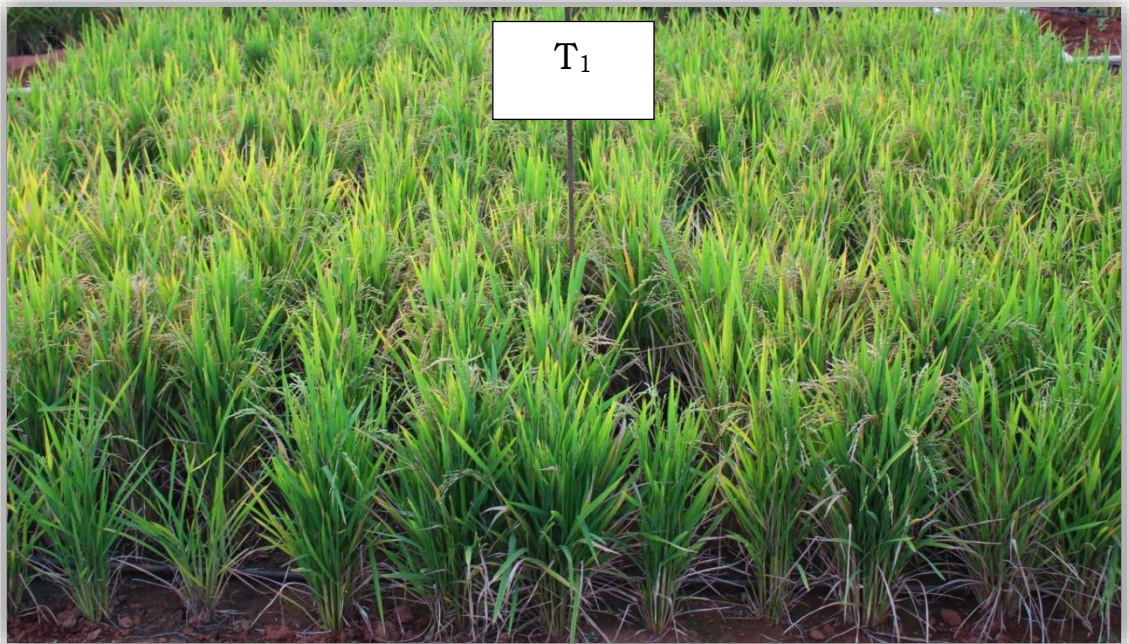


Plate 2: 100 per cent RDF + FYM (POP)

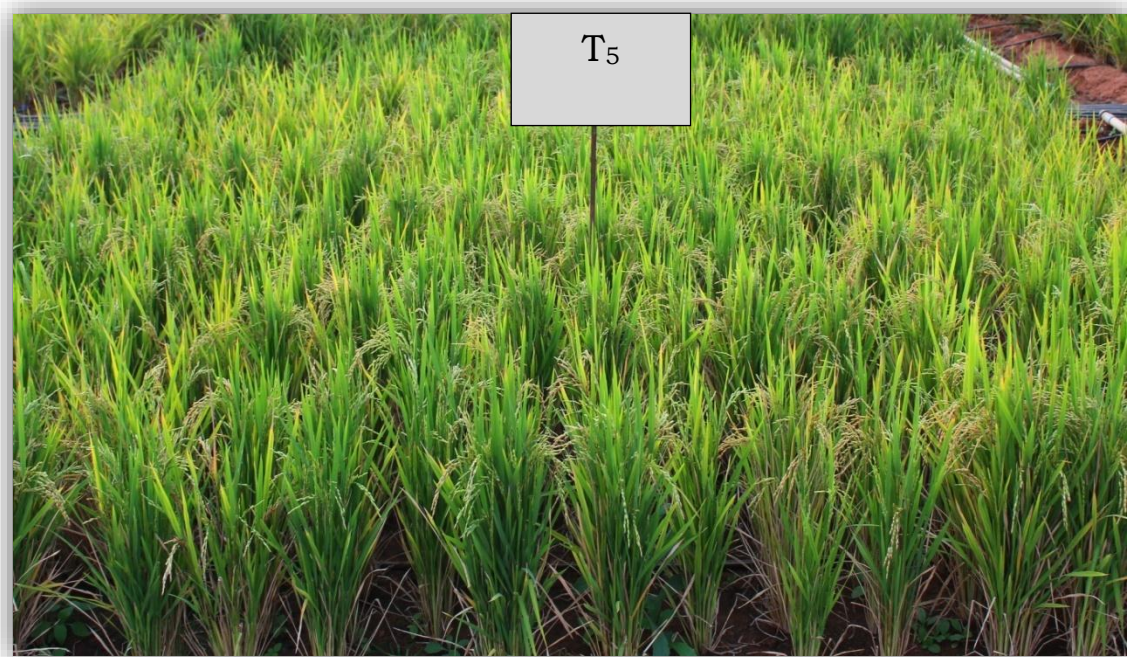


Plate 3: 100 per cent RDF + 50 per cent vermicompost + 50 per cent FYM + PGPR

Application of 100 per cent RDF + 100 per cent vermicompost + PGPR increased grain and straw yield up to 27.4 per cent and 17.9 per cent, respectively over the control. The significant increase in grain yield is due to better nutrient mobilization by *Azospirillum* and PSB and their synergistic positive interaction in soil reflected through more number of panicles per plant, total number of grains per panicle, individual panicle weight and test weight. These results are in conformity with the findings of Bhabeshgogoi *et al.* (2010), Rajashekhara Reddy *et al.* (2006), Roul and Sarawgi *et al.* (2005) and Sudha and Chandini (2003).

Higher grain yield is due to significantly positive relationship of grain yield with yield attributes and growth indices like number of panicles per plant (0.973**), panicle length (0.918**), panicle weight (0.916**), total dry matter (0.961**), number of tillers (0.915**) and LAI (0.978**) indicated in Table 4.20.

Significant increase in grain and straw yield was mainly due to increased dry matter production which was indicated by higher growth attributing characters like plant height, productive tillers, leaf area, leaf area index, leaf area duration and dry matter production. Because of more leaf area and more light interception, dry matter production was increased significantly resulting in higher grain and straw yield.

Application of equal ratio of chemical fertilizer and organic manure increased the nutrient concentration and nutrient availability to the crop. As the nitrogen supply increased, the protein content was increased by amino acid synthesis and this might have induced the plant leaves to grow larger and made more surface area for photosynthesis. These results confirm with the findings of Rajanna *et al.* (2011).

The lower grain yield and straw yield (2,738 and 3,283 kg ha⁻¹) were recorded with 75 per cent RDF + PGPR. This might be due to lower growth parameters like plant height, number of leaves, number of tillers, leaf area, leaf area index, leaf area duration, total dry matter accumulation, absolute growth rate (AGR), relative growth rate (RGR) and yield parameters. The lower growth parameters might be due to non availability of nutrients at early stage of the crop growth. These findings are in accordance with Divyasahare and Babalad (2016). Less number of panicle m⁻² and less filled grains panicle⁻¹ coupled with high chaffiness in this treatment which did not translate them in to yield as compared with other treatments (Basha *et al.*, 2016).

Application of 100 per cent RDF + 100 per cent vermicompost + PGPR produced significantly higher number of productive tillers per plant (16.32), higher panicle length (23.52 cm), higher panicle weight (2.68g) and higher test weight (22.65 g). Higher yield parameters is reflected back in terms of higher yield. More

grain formation can be attributed to higher photosynthates production and dry matter production and its distribution in crop. Similar results were obtained by Murali and Setty (2001).

The increased panicle length can be attributed to higher dry matter production and its distribution in crop. These are in line with the findings of Babu and Reddy (2000) and Chinnusamy *et al.* (2006). Panicle weight was mainly attributed due to better partitioning and assimilation of photosynthates as indicated by higher dry matter production and its translocation to the crop. The present results are in conformity with the results obtained by Singh *et al.* (2013)

Thousand grain weight was significantly higher due to the production of more dry matter *i.e.* photosynthates by plants and higher translocation efficiency. These results uphold the findings of Ashwini *et al.* (2015).

The treatment applied with 100 per cent RDF + 100 per cent vermicompost + PGPR taken less number of days to fifty per cent flowering, this is mainly attributed to better nutrient availability by the application of microbial inoculants and vermicompost which served as quick source of nutrient leading to better growth and partitioning of assimilates. These results are in conformity with Prabhakar Reddy *et al.* 2007a and Rajashekhara Reddy 2006.

Significantly higher number of filled grains per panicle (98.60) was observed with 100 per cent RDF + 100 per cent vermicompost + PGPR (Table 4.13). This might be due to better translocation of accumulated dry matter to the sink (grain).

Total leaf area duration (LAD) (Fig 1) indicating more number of active green leaves up to maturity might have helped for contribution of current photosynthesis for filling up of grains. The decreased number of chaffy grains (Table 4.13) was noticed with combined use of organic and inorganic form of nutrient sources. This may be due to less leaching loss of nutrients and more availability of photosynthates for better grain filling. These results are in line with findings of Rajashekhara Reddy *et al.*, 2006 and Siddaram, 2010. Increase in filled grains per panicle might be due to N induced enhancement in photosynthetic activity and greater translocation of photosynthates and amino acids from the leaves and culms to the grain. The present findings are in accordance with the findings of Belder *et al.* (2004). The characters discussed above clearly indicates the positive relationship of yield with all the yield contributing characters in aerobic rice (Fig 5.2)

The increase in the yield and yield parameters is mainly attributed to combined application of organic manures along with the microbial inoculants which encourages the growth of microbial population in soil and resulted in better root

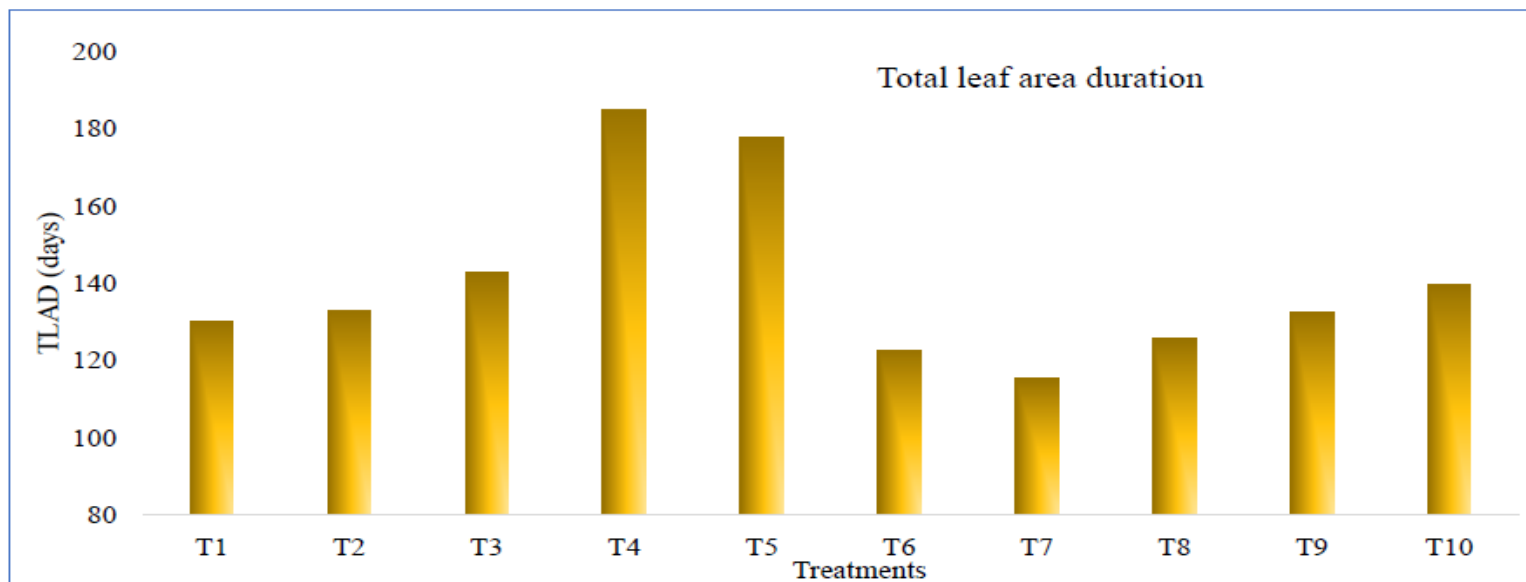


Fig 5.1: Total leaf area duration (TLAD) as influenced by integrated nutrient management practices in aerobic rice.

T₁-100 % RDF + FYM (POP)

T₂-100 % RDF + PGPR -

T₃-100 % RDF + 100 % FYM + PGPR

T₄-100 % RDF +100 % Vermicompost (N Equivalent) + PGPR

T₅-100 % RDF +50 % FYM + 50 % Vermicompost (N Equivalent) + PGPR

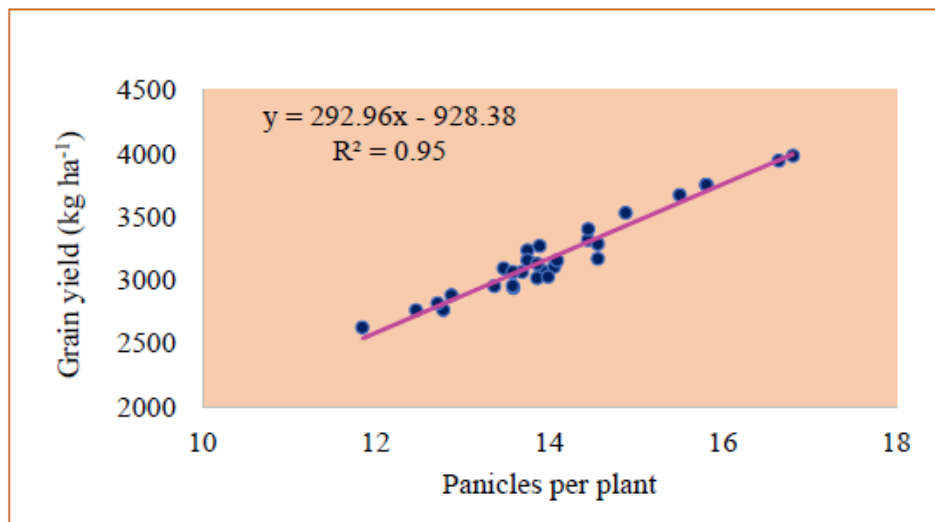
T₆-75 % RDF + FYM

T₇-75 % RDF + PGPR

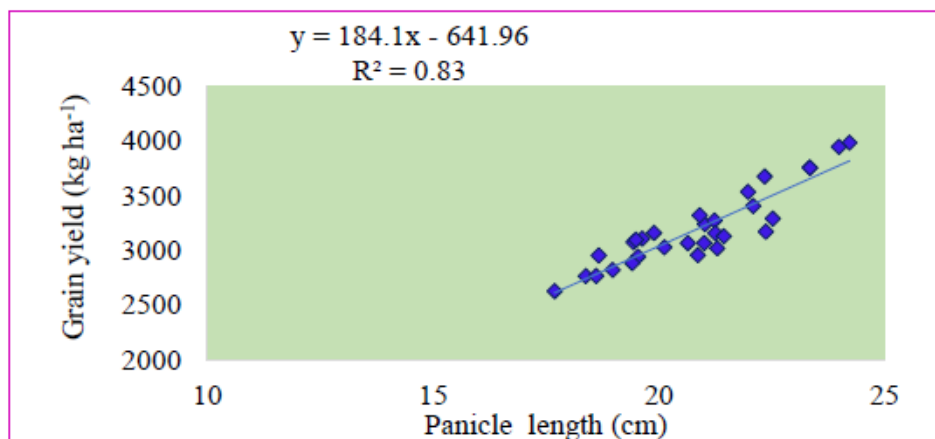
T₈-75 % RDF + 25 % FYM + PGPR

T₉-75 % RDF + 25 % Vermicompost (N Equivalent) + PGPR

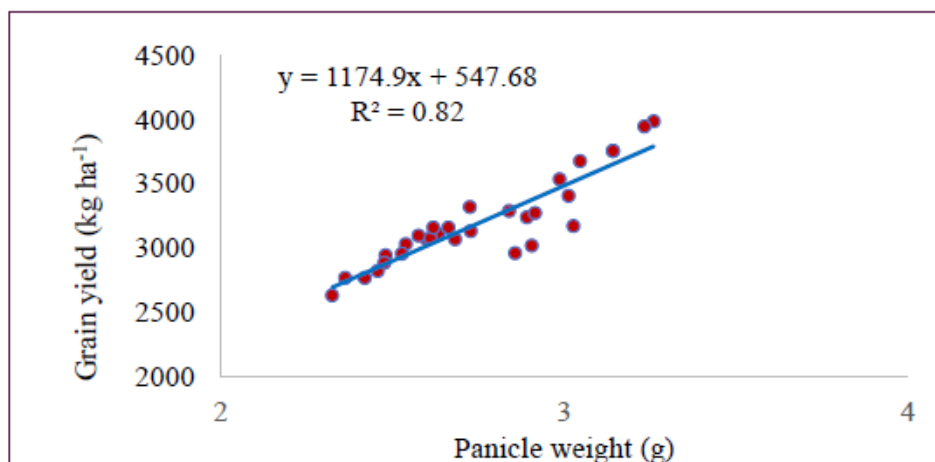
T₁₀-75 % RDF + 25 % FYM + 25 % Vermicompost (N Equivalent) + PGPR



(a)



(b)



(c)

Fig 5.2: Relationship between grain yield (a) Number of Panicles per plant, (b) Panicle length and (c) Panicle weight.

proliferation, nutrient mobility as well as availability and nutrients uptake which led to the better dry matter production and its partitioning in the crop.

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

Dry matter accumulation is an important pre-requisite for higher yields, which indicates other bio synthetic processes, associated during the development sequences. Application of with 100 per cent RDF + 100 per cent vermicompost + PGPR recorded significantly higher total dry matter ranging from 4.86 g plant⁻¹ to 89.04 g plant⁻¹ (Table 4.9). The lower dry matter production was recorded with 75 per cent RDF + 25 per cent FYM + PGPR. The combined application of inorganic fertilizer and organic manure could have helped in balanced availability of nutrients at all crop growth stages. Further, this might have improved the soil aggregation, higher nutrient availability and enhanced soil microbial activity resulting in congenial soil condition for improved uptake of nutrients has led to more vegetative growth of the plants and also provided more photosynthetically active leaf area resulting in higher dry matter accumulation. Similar findings are represented by Siddaram *et al.* (2010). Apart from that, nitrogen might have involved in various physiological activities like increased photosynthetic activity and better light interception which in turn resulted in higher dry matter accumulation. As nitrogen could enhance tiller production and leaf area development. Similar results were reported by Haq *et al.* (2005).

Among several factors responsible for increase in rice production, adequate supply of essential nutrients in a balanced way is one factor for getting better yield. The growth parameters *viz.*, plant height, number of leaves, number of tillers, leaf area, leaf area index, leaf area duration, total dry matter accumulation, AGR and RGR of aerobic rice was significantly influenced by different inorganic and organic sources of nutrients. These are in agreement with findings of Venkatesha *et al.* (2015)

Significantly increased plant height was noticed due to different integrated nutrient management practices at all the growth stages of crop. Significantly higher plant height (73.31 cm) was recorded with 100 per cent RDF + 100 per cent vermicompost + PGPR (Table 4.1). This could be due to greater 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. Significantly increase in plant height with these treatments might be due to greater availability and steady release of nutrients from organic sources (vermicompost) will helps to increase the plant height. These findings are in line with Shaikh *et al.* (2017). Application of 100 per cent RDF + 100 per cent vermicompost + PGPR

recorded significantly higher number of leaves per plant ranging from 20.70 to 109.0 (Table 4.3).

This might be due to quick release of nutrients from the inorganic source in combination with organic source and might have resulted in better vegetative growth. The lower number of leaves per plant was observed at harvest due to senescence of leaves. Similar findings were documented by Siddaram *et al.* (2010).

Number of tillers differed significantly at all stages due to integrated nutrient management practices. Application of 100 per cent RDF + 100 per cent vermicompost+ PGPR recorded significantly higher number of tillers (6.7, 36.3, 39.2, 33.2 at 30, 60, 90 DAS and harvest, respectively). The lower number of tillers (3.9, 23.7, 38.1, 22.1 at 30, 60, 90 DAS and harvest, respectively) was recorded with 75 per cent RDF + PGPR. The higher number of tiller might be due to greater availability of nutrients that encouraged the production of more tillers. Similar findings are documented by Babu and Reddy (2000) who reported that slow release of nutrients from the organic sources at later stages of crop growth had resulted in increased number of tillers at harvest. Tiller number increased with nitrogen supply and is in accordance with the findings of Basha *et al.* (2016).

At 90DAS, leaf area, LAI and LAD differed significantly due to different combined application of organic sources and inorganic fertilizers. Application of 100 per cent RDF + 100 per cent vermicompost + PGPR recorded higher leaf area (2108.4 cm²plant⁻¹) (Table 4.4) and LAI (3.47) (Table 4.5). The development of leaf area is an important factor that could affect crop response to added nitrogen. Larger LAD and leaf area aids in the more interception of light leading to higher dry matter production. These results are in conformity with the findings of Singh and Sharma (2005).

Similarly, growth indices *viz.*, AGR and RGR differed significantly due to different combined sources. Vermicompost when applied with fertilizers showed higher AGR 0.163 to 1.299g day⁻¹ from 30-90 DAS (Table 4.8) and CGR ranging from 2.59 to 20.78 g m² day⁻¹(Table 4.9). Same treatment recorded higher RGR at 30 DAS (0.053 g g⁻¹day⁻¹) (Table 4.10). Higher growth indices recorded in paddy had a positive association with higher dry matter accumulation. The higher AGR in vermicompost combination treatment might be due to high availability of nutrients in soil which made plants vigorous enough to produce more photosynthates that had partitioned to vegetative parts as explained by Maheshwari *et al.* (2007) and Balamurugan *et al.* (2018).Among different growth parameters such as number of tillers per plant, total dry matter and growth indices LAI, CGR and NAR are the main contributing characters for yield. Hence the relationship of these parameters is studied and indicated in Fig 5.3 and Fig 5.4.

5.4 Effect of different integrated nutrient management practice on soil nutrient status and nutrient uptake of aerobic rice

Nutrient uptake by crop is directly proportional to dry matter accumulation which has resulted in higher grain yield of aerobic rice. Higher dry matter accumulation has resulted in higher nutrient uptake *i.e.* 28.6, 40.57, 32.34 per cent increase in total NPK uptake respectively. In general application of organic manures at higher dose than the recommendation improved the NPK status of soil along with improving water holding capacity of soil due to change in its physical properties. Increased nutrient availability was mainly due to mineralization of nitrogen from organic manures through increased activity of soil organisms. The results are in corroboration with the findings of Chinnusamy *et al.* (2006)

Among the major nutrients P and K are known to influence the quality aspects and N is better utilized only in the presence of P and K. When organic sources are added to the soil complex, nitrogenous compounds break down slowly and make steady N supply throughout the growth period of the crop. This might have attributed to more availability and subsequent uptake by the crop. These results are in conformity with the findings of Siddaram *et al.* (2017).

Significantly higher total nitrogen uptake (93.13 kg ha^{-1}) was observed with 100 per cent RDF + 100 per cent vermicompost + PGPR (Table 4.17). The comparative over view of grain yield and nutrient supply clearly indicates a strong positive relation established between N supplied in each treatment and the grain yield. The N mineralized during the decomposition of vermicompost would have enhanced N availability in the rhizosphere resulting in increased nutrient uptake and dry matter accumulation. The present findings are in close association with the results of Thirunavukkarasu and Vinoth (2013).

They stated that use of higher dose of nitrogen 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 total uptake of phosphorus (25.05 kg ha^{-1}) was observed with 100 per cent RDF + 100 per cent vermicompost + PGPR (Table 4.16). Higher uptake of nutrients is due to the better root proliferation which resulted in better uptake of nutrient due to the presence of PSB resulting in better P solubilization and increased availability of nitrogen by *Azospirillum* in soil which led to increased concentration of nutrients in plant which was evidenced by better growth and yield of crop and low soil nutrient status after the harvest of crop. These results are in conformity with the findings of Babu and Reddy (2000), Choudhary *et al.* (2010) Dhanya *et al.* (2006), Monkotia *et al.* (2008).

Significantly higher total potassium uptake (92.63 kg ha^{-1}) was observed with 100 per cent RDF + 100 per cent vermicompost + PGPR. Combined application of inorganics with organic manures leads to more potassium uptake. This might be due to less loss and less fixation of potassium in the soil.

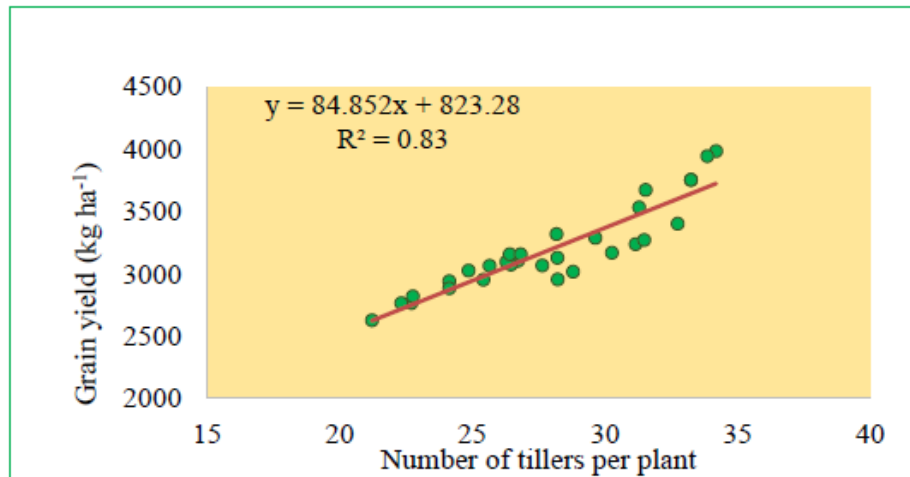
Significantly higher quantity of nitrogen ($253.40 \text{ kg ha}^{-1}$), phosphorus (51.08 kg ha^{-1}) and potassium ($146.61 \text{ kg ha}^{-1}$) were found in soil after the harvest of the crop with application of 100 per cent RDF + FYM 10 t ha^{-1} as a basal dose. Significantly lower quantity of nitrogen ($223.73 \text{ kg ha}^{-1}$), phosphorus (36.27 kg ha^{-1}) and potassium ($137.96 \text{ kg ha}^{-1}$) in soil after harvest of the crop was observed with 100 per cent RDF + 100 per cent vermicompost + PGPR (Table 4.18). This might be due to higher grain and straw yields of crop, led to more extraction of the soil nutrients resulting in low soil nutrient status of that particular treatment. Similar outcomes was reported by Bharat Lal *et al.* (2014).

5.5 Influence of different integrated nutrient management on economics of aerobic rice cultivation

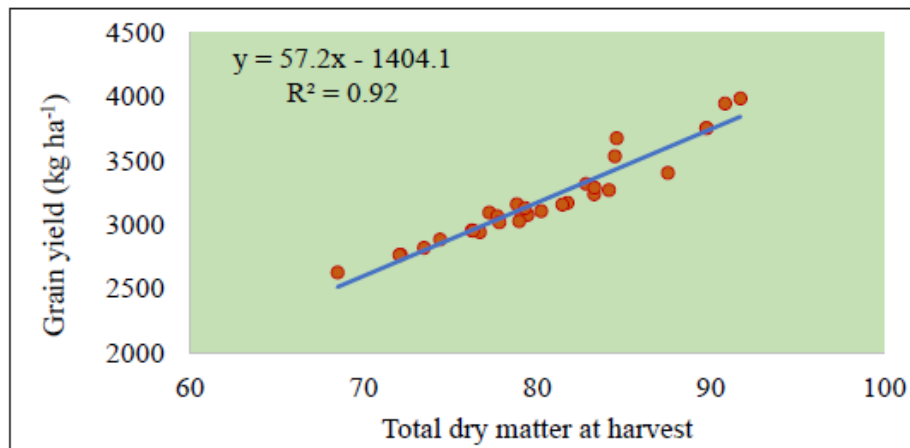
Higher gross returns of Rs. 81,228 per ha was recorded with 100 per cent RDF + 100 per cent vermicompost + PGPR over the control. Whereas, lower gross returns of Rs. 57,498 ha^{-1} was obtained with 75 per cent RDF + PGPR (Table 4.19). This was mainly due to higher grain and straw yields. Similar findings were also observed by Rakesh Kumar Verma *et al.* (2017).

Maximum net returns of Rs. 45,175 per ha was noticed with the application of 100 per cent RDF + 100 per cent vermicompost + PGPR. (Table 4.19). This is due to higher grain and straw yields. The lower net returns of Rs. 25,243 per ha was recorded with 75 per cent RDF + PGPR. This is due to lower grain and straw yields. Similar results were observed by Shekara *et al.* (2010) and Samrath Lal Meena (2003).

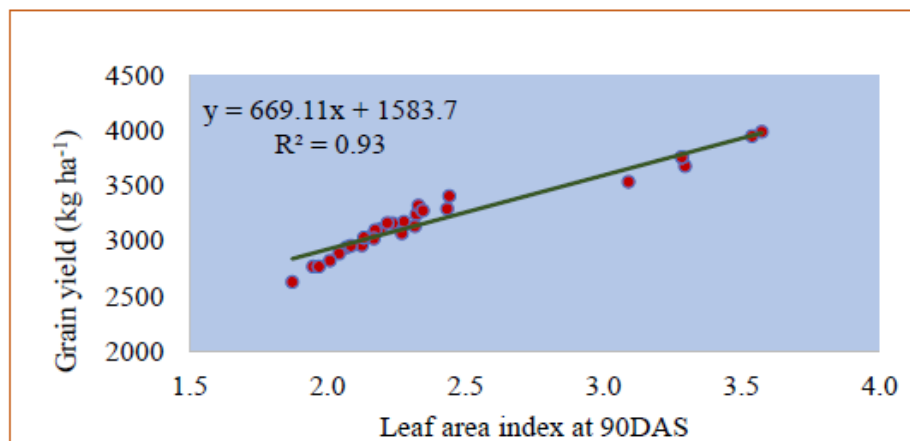
Among different treatments, 75 per cent RDF + 25 per cent FYM + 25 per cent vermicompost + PGPR significantly recorded higher benefit cost ratio 2.87 (Table 4.19). This might be due to lower cost of cultivation. Similar views were expressed by Sanjay Koushal *et al.* (2011). However, lower benefit cost ratio 1.70 was observed with 75 per cent RDF + PGPR due to high cost of cultivation and low yield levels. The study reveals that less production and high cost of cultivation in aerobic rice could be obtained by combining organic sources with inorganic sources in best combination without extra input to get higher yield along with net returns and B:C.



(a)

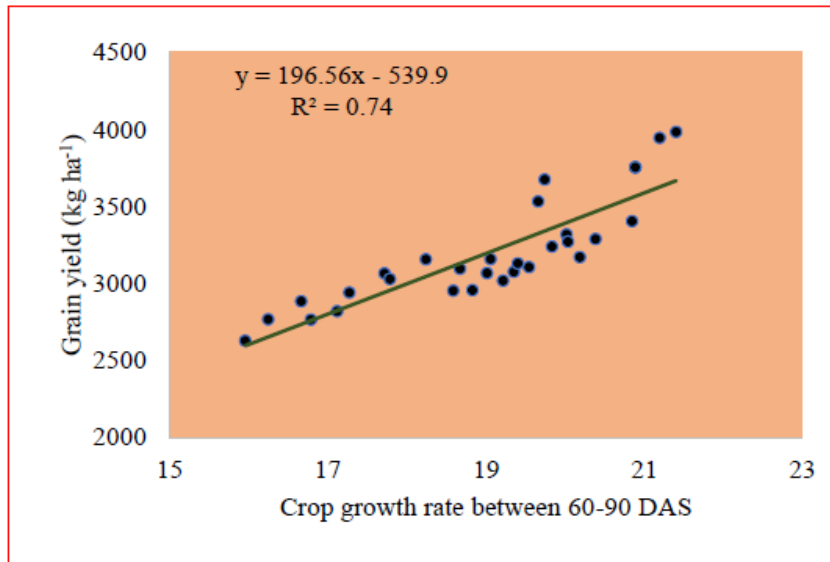


(b)

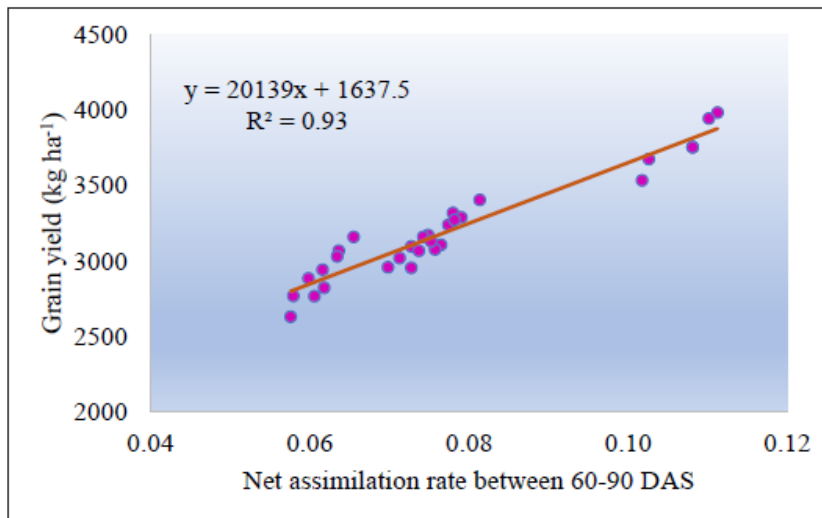


(c)

Fig 5.3: Relationship between grain yield (a) Number of tillers per plant, (b) Total dry matter and (c) Leaf area index (LAI)



(a)



(b)

Fig 5.4: Relationship between grain yield (a) Crop growth rate and (b) Net assimilation rate

Conclusion

- From the present study it can be concluded that application of 100 per cent RDF + 100 per cent vermicompost + PGPR to aerobic rice has resulted in higher growth and increase in yield (27 %) with better net returns over rest of the treatments.
- Higher B:C ratio was found with application of 75 per cent RDF +25 per cent vermicompost (N Equivalent) + PGPR.

Practical utility of the results

- Application of 100 per cent RDF + 100 per cent vermicompost (N Equivalent) + PGPR resulted in higher grain yield (3,868 kg ha⁻¹) and straw yield (4,225 kg ha⁻¹) of aerobic rice with higher net returns.
- Application of 100 per cent RDF + 100 per cent vermicompost (N Equivalent) + PGPR has recorded more nutrient uptake by crop.
- Higher B:C was obtained with application of 75 per cent RDF +25 per cent Vermicompost (N Equivalent) + PGPR.

Future line of work

- Nutrient release pattern of different source of organic manures need to be studied.
- There is a need to study the efficacy of PGPR.
- Need to study different intercropping system under integrated nutrient management practices in aerobic rice.

SUMMARY

VISUMMARY

A field experiment was conducted at Agricultural and Horticultural Research Station, Bhavikere, Tarikere, University of Agricultural and Horticultural Sciences, Shivamogga, under irrigated condition during *Kharif* 2017 to study influence of integrated nutrient management practices on growth and yield of aerobic rice.

The soils are low in nitrogen, medium in phosphorus and potassium. The test variety was MAS 946-1 (Sharada). The experiment was laid out in Randomized Block Design with three replications and ten treatment combinations with inorganic and organic sources. Observations on growth, yield and yield attributing parameters were recorded at 30, 60, 90 days after sowing and at harvest of the crop. The salient features of the experimental results are summarized in this chapter.

The growth parameter like plant height (73.31 cm), number of tillers (34.2), number of leaves (108.0), leaf area (1396.9 cm²), total dry matter accumulation (89.04 g), days to 50 per cent flowering (81.64), days to maturity (129.42) recorded significant difference with application of 100 per cent RDF + 100 per cent vermicompost + PGPR. The lowest plant height (53.48 cm), number of tillers (22.1) and total dry matter accumulation (71.35 g) at harvest was recorded in the treatment applied with 75 per cent recommended NPK + FYM.

The leaf area index (2.24), leaf area duration (84.13 days) and net assimilation rate (0.108 g dm² day⁻¹) was significantly higher with application of 100 per cent RDF + 100 per cent vermicompost + PGPR. The significantly lower LAI (1.30), LAD (48.72 days) and NAR (0.060 g dm² day⁻¹) was recorded with application of 75 per cent recommended NPK + FYM.

Significantly higher AGR (1.299 g day⁻¹), CGR (20.78 g m² day) was highest at 90 DAS in treatment receiving 100 per cent RDF + 100 per cent vermicompost + PGPR. Significantly lower AGR (1.039g day⁻¹), CGR (16.62 g m² day).

The grain yield (3,868.0 kg ha⁻¹), straw yield (4,225.72 kg ha⁻¹) were significantly highest with 100 per cent RDF + 100 per cent vermicompost + PGPR. The lower grain yield (2,737.65 kg ha⁻¹) and straw yield (3,283.38 kg ha⁻¹) were noticed in the treatment applied with 75 per cent RDF + PGPR.

The yield attributing parameters such as number of panicles per plant (16.32), panicle length (23.52 cm), panicle weight (2.68 g), and 1000 grain weight (22.65 g) number of grains per panicle (126.80) and filled grains (98.60) were significantly highest with the treatment receiving 100 per cent RDF + 100 per cent vermicompost + PGPR. All the yield parameters like number of panicles per plant (12.34), panicle length (18.43 cm), panicle weight (1.90 g), and 1000 grain weight

(19.05 g) number of grains per panicle (108.90) and filled grains (87.0) were lower in the treatment with 75 per cent RDF+ FYM.

The observation on microbial population recorded at harvest has revealed that the population of bacteria (47.83 cfu per g soil), fungi (15.50 cfu per g soil), and actinomycetes (10.96 cfu per g soil) PSB (24.0 cfu per g soil) and KSB (8.9 cfu per g soil) was found more advantageous and higher with treatment applied with 100 per cent RDF + 100 per cent vermicompost + PGPR.

The nitrogen uptake by grain (57.63 kg ha⁻¹), straw (53.23 kg ha⁻¹) and total uptake (93.13 kg ha⁻¹) in plant was significantly higher with application of 100 per cent RDF + 100 per cent vermicompost + PGPR. Significantly lower uptake of nitrogen by grain (35.59 kg ha⁻¹), straw (29.87 kg ha⁻¹) and total uptake (65.47 kg ha⁻¹) with application of 75 per cent RDF + FYM.

The phosphorus uptake by grain (17.02 kg ha⁻¹), straw (8.03 kg ha⁻¹) and total uptake (25.05 kg ha⁻¹) in plant was significantly higher with application of 100 per cent RDF + 100 per cent vermicompost + PGPR. Significantly lower uptake of phosphorus by grain (9.58 kg ha⁻¹), straw (4.92 kg ha⁻¹) and total uptake (14.50 kg ha⁻¹) with application of 75 per cent RDF + FYM.

The potassium uptake by grain (26.30 kg ha⁻¹), straw (66.33 kg ha⁻¹) and total uptake (92.63 kg ha⁻¹) in plant was significantly higher with application of 100 per cent RDF + 100 per cent vermicompost + PGPR. Significantly lower uptake of potassium by grain (15.60 kg ha⁻¹), straw (44.98 kg ha⁻¹) and total uptake (60.58 kg ha⁻¹) with application of 75 per cent RDF+ FYM.

The available soil nutrient status after the harvest *i.e.*, nitrogen (253.40 kg ha⁻¹), phosphorus (51.08 kg ha⁻¹) and potassium (146 kg ha⁻¹) of the crop was found to be higher in treatment applied with 100 per cent RDF + FYM.

Lower soil nitrogen (223.73 kg ha⁻¹) phosphorus (36.27 kg ha⁻¹) and potassium (137.96 kg ha⁻¹) was observed with 75 per cent RDF + 25 per cent vermicompost + 25 per cent FYM + PGPR.

The higher gross returns (Rs. 81,228) and net returns (Rs. 45,175) was obtained with application 100 per cent RDF + 100 per cent vermicompost + PGPR. Lower gross returns (Rs. 57,498) and net returns (Rs. 25,243) was obtained with 75 per cent RDF+ FYM.

Higher benefit cost ratio (2.87) was recorded with application of 75 per cent RDF + 25 per cent vermicompost + PGPR. Lower benefit cost ratio (1.70) was obtained in treatment applied with 75 per cent RDF+ FYM.

REFERENCES

VI REFERENCES

- ABDUL AZIZ, MOHAMMAD SAFDAR, KHALID NAVEED AND AWAM, 2005, Effect of seedling age and water depth on morphological aspects of rice. *J. Zhejiang University Sci.*, **6**(5):389-395.
- ADAK, M. K. AND GUPTA, 2002, Metabolic changes in rice varieties under stress condition. *Indian J. Plant Phy.*, **6**(3):312-316.
- ADHIKARI, N. P. AND MISHRA, B. N., 2004, Effect of integrated sources of nitrogen on yield of aromatic rice and their residual effect on succeeding wheat crop. *Ann. Agric. Res.*, **25**(2):327-328.
- AMBRACIO, R., CASTAFIEDA, BAS, A. M., BOUMAN, SHAOBING PENG AND ROMEO M., VISPERAS, 2004, Mitigating water scarcity through an aerobic system of rice production, internet file://a:\mitigating water scarcity through on aerobic system of rice production. htm.
- ANNY MRUDHULA, K., RAVIKUMAR, A., PULLA RAO, C.H. AND CHANDRASHEKAR, K., 2005, Productivity and uptake of rice as affected by integrated use of nitrogen. *The Andhra Agric. J.*, **52**(1&2):1-4.
- ANONYMOUS, 2016, Rice- Statistics and facts.[http:// www.Statista.Com/tropics/1443/rice/](http://www.Statista.Com/tropics/1443/rice/).
- ANONYMOUS, 2016a, Agricultural statistics at a glance. [http:// eands.dacnet.nic.in /PDF/Agricultural-Statistics-At-Glance2014.pdf](http://eands.dacnet.nic.in/PDF/Agricultural-Statistics-At-Glance2014.pdf).
- ANONYMOUS, 2016b, Karnataka agricultural statistics at a glance. <http://raitamitra.kar.nic.in/ENG/statistics.asp>.
- ARPITA SHARMA, KACHROO, D., PUNIYA, R., HARDEV RAM, DEEPA JOSHI, POOJA GUPTA SONI, TARAMANI YADAV AND MALU RAM YADAV, 2017, Impact of different transplanting dates and nutrient sources on soil microbial population and grain yield of basmati rice (*Oryza sativa* L.) grown under SRI. *Int. J. Curr. Microbiol. App. Sci.*, **6**(3):778-782.
- ASHWINI, M., SRIDHAR, C. J., SARASWATHI, MAMATHASHREE, C. M. NETHRAVATHI, B., 2015, Effect of enriched FYM and fertilizer levels on growth and yield components of aerobic rice (*Oryza sativa* L.). *Ecoscan*, **8**:153-159.

- ASIM BISWAS AND PALLANAGARI REDDY, R., 2010, Effect of integrated nutrient management on soil available nutrient, plant nutrient uptake, and yield of aerobic paddy (*Oryza sativa* L.). *J. Interacadamia*, **14**(4): 463-469.
- ATLIN, G. N., LAZA, M., AMANTE, M. AND LAFITTE, H.R., 2004, Agronomic performance of tropical aerobic irrigated and traditional upland rice varieties in three hydrological environments at IRRI, Phillipines. Internet file://a:\mitigating water scarcity through on aerobic system of rice production. htm.
- BABU, B. AND REDDY, V. C., 2000, Effect of nutrient sources on growth of direct seeded rice (*Oryza sativa*L.). *Crop Res.*, **19**(2):189-193.
- BALAMURUGAN, R., BABU, R., SWAMINATHAN, C., BASKAR, K. AND GOPAL, N. O., 2018, Performance of organic nutrition on physiological characters and yield of aerobic rice. *Int. J. Curr. Microbiol. App. Sci.*, **6**:2936-2947.
- BALASUBRAMANIAN, R. AND KRISHNARAJAN, J., 2000, Influence of irrigation regimes on growth and water use efficiency in direct seeded rice. *Res. on Crops*. **1**(1):1-4.
- BARIK, A. K., AMRIT RAJ, ARINDAM DAS, ROY, D. AND MANDAL, P., 2004, Integrated nitrogen management through vermicompost and urea on growth and productivity of transplanted *kharif* rice. *Indian Agriculturist*. **48**(3/4):175-179.
- BARIK, A. K., ARINDAM DAS., GIRI, A. K. AND CHATTOPADHYAY, G. N., 2006, Effect of integrated plant nutrient management on growth, yield and production economics of wet season rice (*Oryza sativa* L.). *Indian J. Agric. Sci.*, **76**(11):657-660.
- BASHA, JAFFER, S., BASAVARAJAPPA, R., BABALAD, H. B., 2016, Influence of organic and inorganic nutrient management practices on yield, economics and quality parameters of aerobic rice. *Crop Res.*, **17**(2):178-187.
- BELDER, P., BOUMAN, B. A. M., QUILAND E. J. P. AND TUONG, T. P., 2004, Effect of water saving irrigation on rice yield. *Agric. Water Mng.*, **73**:193-210.
- BHABESH GOGOI, BARUA, N. G. AND BARUAH, T. C., 2010, Effect of integrated nutrient management on growth, yield of crops and availability of nutrients in inceptisol under rainfed rice (*Oryza sativa*)–niger (*Guizotia abyssinica*) sequence of Asom. *Indian J. Agric. Sci.*, **80**(9):824–828.

- BHARAT LAL, VINOD NAYAK, PRIYANKA SHARMA AND TEDIA, K., 2014, Effect of combined application of FYM, fly ash and fertilizers on soil properties and paddy grown on degraded land. *Curr. World Environ.*, **9**(2):531-535.
- BOUMAN, B. A. M., 2001, Water efficient management strategies in rice production, Notes 16.2 IRRI, Philippines. pp 17-22.
- BOUMAN, B. A. M., PENG, A. R. AND VISPERAS, R. M., 2005, Yield and water use of irrigated tropical aerobic system. *Agric. Water Mng.*, **74**(2):87-105.
- BOUMAN, B. A. M., YANG XIASGUANG, WANG HUAQUI AND CHENG BIN, 2006, Screening of genotypes under aerobic situation. IRRI, Phillipines. pp19-22.
- BOUMAN, B. A. M., YANG XIAO GUANG, WANG HUAQI, WANG ZHIMING, ZHAO JUN TANG, WANG CHANGGUI AND CHENG BIN, 2002, Aerobic rice (Han Dao): a new way of growing rice in water short areas. Internet file://a:\ mitigating water scarcity through on aerobic system of rice production. htm.
- CABANGON, R. G. L. V, TUONG, T. P., BOUMAN, B. A. M., FENG AND ZHANG ZHICHUAN, 2001, Irrigation management effects on yield and water productivity of inbred and aerobic rice varieties in Kaiting, IRRI, Phillipines. pp. 27
- CABANGON, T. A, HU WERHE, AND LIUJUN, A. P, 2004, Research on system of rice intensification. *J. South China Agric. Univ.*, **25**(1):5-8.
- CASTANEDA, A. R., BOUMAN, B. A. M AND VISPCRAS R. M., 2002, The potential of aerobic rice to reduce water use in water scarce irrigated lowlands in the tropics. *Water Wise Rice Production*, 8-11. IRRI, Philippines pp. 165-176.
- CASTANEDA, A. R., BOUMAN, B. A. M. AND VISPERAS, R. M., 2005, The potential of aerobic rice to reduce water use in water scarce irrigated lowlands in the tropics. *Water Wise Rice Production*, 8-11, IRRI, Philippines pp. 165-176.
- CHINNUSAMY, M., KAUSHIK, B. D AND PRASANNA, R., 2006, Growth, nutritional, and yield parameters of wetland rice as influenced by microbial consortia under controlled conditions. *J. Plant Nutri.*, **29**:857-871.

- CHOUDHARY, R. L., DINESH KUMAR, SHIVAY, Y. S., ANJALI ANAND AND LATA NAIN, 2013, Yield and quality of rice (*Oryza sativa* L.) hybrids grown by SRI method with and without plant growth promoting rhizobacteria. *Indian J. Agron.*, **58**(3):430-433.
- CHOUDHARY, R., DINESH KUMAR, SHIVAY, Y. S., LATA, GEETA SINGH AND NAIN SINGH., 2010, Performance of rice (*Oryza sativa*) hybrids grown by the system of rice intensification with plant growth promoting rhizobacteria. *Indian J. Agric. Sci.*, **80**(10):917-20.
- CIELITO A. BELTRAN, 2015, Performance of Aerobic Rice (var. NSTC RC 23) Applied with Organic Inputs under Rainfed Conditions in Tarlac, Philippines. *Int. J. Curr. Res. Biosci. Plant.Bio.* **12**(9):38-42.
- COCHRAN, W. G., 1950, Estimation of bacterial density by mean of most probable number. *Biometrics*, **6**:105-116.
- DHANYA, V., MATHEWS, PATIL, P. L. AND DASOG, G. S., 2006, Effect of nutrients and bio fertilizers on nutrient uptake by rice and residual soil fertility status in coastal alluvial soil of Karnataka. *Karnataka J. Agric. Sci.*, **19**(4):793-798.
- DIVYA SAHARE AND BABALAD H. B., 2016, Effect of organic nutrient management practices on yield and nutrient uptake of aerobic rice. *Int.J. Agril. Sci.*, **12**(1):95-100.
- GANESH, H. V. AND JAYADEVA HAKKALI, 2000, Effect of irrigation intervals on yield and water use in summer paddy at Bhadra Command. *Mysore J. Agric. Sci.*, **34**:130-137.
- GANESH, H. V., 2000, Varietal response to moisture regions in summer paddy. *Curr. Res.*, **29**:35-36.
- GANGA DEVI, M., TIRUMALA REDDY, S., SUMATI, V., PRATIMA, T. AND JOHN, K., 2012, Nitrogen management to improve the nutrient uptake, yield and quality parameters of scented rice under aerobic culture. *Int. J. App. Biol.Pharma. Technol.* **3**(1):340-344.
- GANI, A., RAHMAN, A., DAHONO, RUSTAN AND HENGSDIJK, H., 2002, In: water wise rice production, IRRI, Pub. Manila, Philippines, pp. 29-38.
- GEORGE, J. K. AND VIRMANI, L., 2001, Managing legume fixed nitrogen in lowland rice based cropping system. *Plant and Soil*, **141**:69-71.

- GHOLAMI, A., SHAHSAVANI, S. AND NEZARAT S., 2009, The Effect of Plant Growth Promoting Rhizobacteria (PGPR) on Germination, Seedling Growth and Yield of Maize. *World Aca. Sci, Engineering and Technology*, **49**:19-24.
- GODHAWALE, G. V. AND DAHIPALE, R. V., 2007, Production and economic efficiency of rice (*Oryzasativa* L.) as influenced by organic nutrition under upland drilled condition. *Int. J. Trop. Agric.*, **25**(1-2):209-212.
- GOMEZ, K. A. AND GOMEZ, A. A., 1984, *Statistical Procedures for Agricultural Research*. 2nd Ed. John Wiley & Sons, New York.
- GOPAKKALI PRADEEP, CHANNANAİK, D., RAJANNA, G. A., SANNATHIMMAPPA, H. G., RAMESHA, Y. M., VEERESHA, 2012, Economics and nutrient uptake of rice (*Oryza sativa* L.) as influenced by various levels of FYM and cattle urine application in Bhadra command area of Karnataka. *Crop Res.*, **43**(3):10-14.
- GREGORY, P. G., 1926, The effect of climatic conditions on the growth of barley, *Ann. Bot.*, **40**:1-26.
- HAQ, S. A., LONE, B. A., SMEIA WANI., KHAN, N. M. AND SOFI, N. A., 2005, Effect of integrated nutrient management on growth and yield of rice (*Oryza sativa*) cv Pusa Basmati-I. *Environment & Ecology*. **23**(3):552-554.
- HOOPEr, S. R., 1982, Cropping System Research in Asia, *Report on workshop IRRI*, Los Banos, Philippines, pp. 123-148.
- IRANIE, D. M. D., WIJEBANDARA., DASOG, G. S., PATIL, P. L. AND MANJUNATH HEBBAR., 2009, Response of rice to nutrients and biofertilizers under conventional and system of rice intensification methods of cultivation in Tungabhadra command of Karnataka. *Karnataka J. Agric. Sci.*, **22**(4):741-750.
- JACKSON, M. L., 1973, *Soil Chemical Analysis*, Prentice Hall India Pvt. Ltd., New Delhi.
- JANA, K., MALLICK, G. K., KUND, C. K., GUNRI4, S. K., AND PUSTE A. M., 2015, Effect of nutrient management on grain yield of aerobic rice under irrigated condition during pre-kharif season. *Int. J. Environ. Agric. Res.*, **1**(1):31-34.

- JING XIANG, VAN RYAN HADEN, SHAOBING PENG, BAS A. M., BOUMAN, JIANLIANG HUANG, KEHUI CUI, ROMEO M., VISPERAS, DEFENG ZHU, YUPING ZHANG, HUIZHE CHEN., 2013, Effect of deep placement of nitrogen fertilizer on growth, yield and nitrogen uptake of aerobic rice. *Australian J. crop sci.*, **7**(6):870-877.
- KATYAL, J. C., VENKATASHWARLU, B. AND DAS, S. K., 1994, Biofertilizer for Nutrient Supplementation in Dryland Agriculture. *Fertilizer News*, **39**(4):27-32.
- KENNEDY, R., CHOUDHURY, A. T. M. A. AND MIHALY KECSKES, L., 2004, Non-symbiotic bacterial diazotrophs in crop-farming systems: can their potential for plant growth promotion be better exploited. *Soil Bio. Bioch.*, **36**:1229–1244.
- KRISHNAKUMAR, S., SARAVANAN, A., RAMESH, K., NATARAJAN, K. S., VEERABADRAN, V. AND MANI, S., 2005, Organic farming: Impact on rice productivity and soil health. *Asian J. Plant Sci.*, **4**(5):510-512.
- MAGAT AND APO, 2004, Rice research, the way forward in rice production. IRRI, Phillipines. 71. pp-23.
- MAHESHWARI, J., MARAGATHAM, N. AND JAMES MARTIN, G., 2007, Relatively simple irrigation scheduling and N application enhances the productivity of aerobic rice. *American J. plant physiology*. **2**(4):261-268.
- MAJUMDAR, B., VENKATESH, M.S. AND SAHA, R., 2007, Effect of nitrogen, farmyard manure and non-symbiotic nitrogen-fixing bacteria on yield, nutrient uptake and soil fertility in upland rice (*Oryza sativa*). *Indian J. Agri. Sci.*, **77** (6):335-339.
- MALIK, R.V.S. AND CHAMAN SINGH, 2016, Effect of integrated nutrient management practices on Crop yield and change in physico-chemical properties of Soil in rice-wheat cropping system. *Agriways*, **4**(2):185-193.
- MANKOTIA, B. S., SHEKHAR, J., THAKUR, R. C. AND NEGI, S.C., 2008, Effect of organic and inorganic sources of nutrients on rice - wheat cropping system. *Indian J. Agron.*, **53**(1):32-36.
- MC HUGH, STEENHUTS, O. T. AND UPHAFF, N., 2002, Farmer implementation of alternate wet-dry and non-flooded irrigation practice in the system of rice intensification. Unpublished water paper, Carmel University.

- MHALEVILIE THORIE, SARKAR N. C. AND ATOU KHARUTSO, 2013, Effect of biofertilizer on the productivity of terraced upland rice (*Oryza sativa* L.). *International J. Bio-resource and Stress Mang.*, **4**(3):400-403.
- MOHANTY, B. B., 2009, Regional Disparity in Agricultural Development of Maharashtra. *Economic and Political Weekly*, **44**(6): pp. 63-69.
- MONTGOMERY, E. G., 1911, *Correlation studies in corn* in 24th Annu. Rep., Agricultural Experiment Station, Nebraska. Pp, 109-159.
- MUNESHWAR SINGH, SINGH, V. P. AND SAMMI REDDY, K., 2001, Effect of integrated use of fertilizer nitrogen and FYM or GM on transformation of NKS and productivity of rice-wheat system on a *Vertisol*. *J. Indian Society Soil Sci.*, **49**(3):430-435.
- MURALI, M. K. AND SETTY, R.A., 2001, Growth, yield and nutrient uptake of scented rice (*Oryza sativa* L.) as influenced by levels of NPK, vermicompost and triacontanol. *Mysore J. Agric. Sci.*, **35**(1):1-4.
- NGUYEN VAN QUYEN, SHARMA, S. N. AND GAUTAM, R. C., 2002, Comparative study of organic and traditional farming for sustainable rice production. *Omonrice*. **10**:74-78.
- PALANISAMI, K., 2002, Managing water to meet future food needs. *Tamil Nadu Agril. University, Coimbatore*. pp. 23-37.
- PANDEY, N., VERMA, A. K., ANURAG AND TRIPATHI, R. S. 2007, Integrated nutrient management in transplanted hybrid rice (*Oryza sativa*). *Indian J. Agron.*, **52**(1):40-42.
- PANDU, K. H., ANGADI, V. V., CHITTAPUR, B. M., 2005, NUE and N uptake of upland rice as influenced by integrated nitrogen management through leaf colour chart (LCC). *Karnataka J. Agric. Sci.*, **18**(1):124-126.
- PATEL, J. R., 2000, Effect of water regime and variety on rice. *Indian J. Agron.*, **45**(1):103-106.
- PATIDAR AND MALI, 2002, Residual effect of farmyard manure, fertilizer and biofertilizer on succeeding wheat (*Triticum aestivum*). *Indian J. Agron.*, **47**(1):26-32.
- PATTANAYAK, S. K., RAO, D. L. N. AND MISHRA, K. N., 2007, Effect of biofertilizers on yield, nutrient uptake and nitrogen economy of rice- peanut cropping sequence. *J. Indian Society Soil Sci.*, **55**(2):184-189.

- PIPER, C. S., 1966, *Soil and Plant Analysis, Inter. Sci. Pub., Inc.*, New York.
- POWER, J. P., WILLIS, W. O., GRUNES, D. L. AND REICHAMAN, G., 1967, Effect of soil temperature, phosphorus and plant age on growth analysis of barley. *Agron. J.*, **59**:231-234.
- PRABHAKAR REDDY, T., UMA DEVI, M. AND CHANDRASEKHAR RAO, P., 2007a, Effect of fly ash and farm yard manure on dry matter production, yield and economics of rice in Andra Pradesh. *J. Res. ANGRAU.*, **35**(4):32-38.
- PRABHAKAR REDDY, T., UMA DEVI, M., CHANDRASEKHAR RAO, P. AND BHANUMURTHY, V. B., 2007b, Effect of fly ash and farm yard manure on soil enzyme activities and yield of rice grown on an inceptisol. *Crop Res.*, **34**(1, 2&3):27-31.
- PRADHAN, S. AND MOHARANA S., 2015, Effect of organic nutrient management on growth rate and crop productivity in sustainable rice-rice system. *J. Crop and Weed*, **11**(2):28-33.
- QINGHAO, A. C., VISPERAS, R. M. AND MCCLANG, A. M., 2002, Contribution of rice tiller to dry matter accumulation and yield. *Agron. J.*, **90**: 317-323.
- RADFORD, P. J., 1967, Growth analysis formulae, their use abuse. *Crop Sci.*, **8**:171-175.
- RAGHU, K., MACRAE, I.C., 2000, Occurrence of phosphate-dissolving microorganisms in the rhizosphere of rice Plants and in submergedsoils. *J. Appl. Bacteriol.*, **29**:582–586.
- RAJANNA, G. A., MURALI, K., PRADEEP NAYAK, LAKSHMIPATHY, R. N., PRADEEP GOPAKALLI AND PARAMESH V., 2011, Effect of different sources and time of application of organic manures on yield attributes, yield and economics of aerobic rice (*Oryza sativa* L.). *Int. J. Agril. Sci.*, **7**(1):193-196.
- RAJASHEKHARA REDDY, 2006, Agronomic investigations on integrated nutrient management in aerobic paddy (*Oryza sativa* L.). *M.Sc. (Agri.) Thesis, Univ. Agric. Sci, Bangalore.*
- RAJPUT PANKAJ KUMAR, SINGH, G., R.AND ALOK KUMAR SINGH, 2006, Irrigation schedule for better growth, development and yield of hybrid rice. *Crop Res.*, **31**(1):6-10.

- RAKESH KUMAR VERMA, YASHBIR SINGH SHIVAY AND PRAKASH CHAND GHASAL, 2017, Effect of different cropping systems and nutrient sources on growth, productivity and economics of direct seeded basmati rice (*Oryza sativa*). *Indian J. Agril. Sci.*, **87**(10):1377–1383.
- ROUL, P. K. AND SARAWGI, S. K., 2005, Effect of integrated nitrogen nutrition techniques on yield, N uptake and use efficiency of rice (*Oryza sativa* L.). *Indian J. Agron.*, **50**(2):129-131.
- SAMRATH LAL MEENA, SURENDRA SINGH AND SHIVAY, Y.S., 2003, Response of hybrid rice (*Oryza sativa*) to nitrogen and potassium application in sandy clay-loam soils. *Indian J. Agril. Sci.*, **73**(1):8-11.
- SANJAY KOUSHAL, SHARMA, A. K. AND AMARJEET SINGH, 2011, Yield performance, economics and soil fertility through direct and residual effects of organic and inorganic sources of nitrogen as substitute to chemical fertilizer In rice-wheat cropping system. *Res. J. Agril. Sci.*, **43**(3):189-193
- SARAVAN KUMAR, S. AND PANNEERSELVAM, S., 2015, Effect of nitrogen management on yield attributes and yield of rice. *Haryana J. Agron.*, **31**(1&2):41-44
- SARKAR, A. K., 2000, Integrated nutrient management for better livelihood of farmer's in rainfed areas. *J. Indian Soc. Soil Sci.*, **48**(4):690-696.
- SESTEK, Z., CASTSKY, J AND JARVIS, P. G., 1971, Plant photosynthetic production. *Manual of methods*, Junky, W., M. V. Publication, The Hague, pp, 343-381.
- SHAIKH, A. A., KULKARNIK. V. AND PANDI ALEKYA, 2017, Effect of different organic manures on growth contributing characters in paddy. *Contemporary Res. in India*, **7**(3):28-32.
- SHEKARA,NAGARAJU, B. G., SHREEDHARA, D., 2010, Growth and yield of aerobic rice (*Oryza sativa* L.) as influenced by different levels of NPK in cauvery command area. *J. Maharashtra Agril Univ.*, **35**(2):195-198.
- SIDDARAM, MURALI, K., MANJUNATHA, B.N., RAMESHA, Y.M., BASAVARAJA M.K. AND POLICEPATIL, A.S., 2010, Effect of nitrogen levels through organic sources on growth, dry matter production and nutrient uptake of irrigated aerobic rice (*Oryza sativa* L.).*Int. J. Agril. Sci.*, **6**(2): 426-429.

- SIDDARAM, REDDY V. C. AND KRISHNA MURTHY N., 2017, Effect of farmyard manure and bio-digester liquid manure on soil health under aerobic rice – field bean cropping sequence. *Int. J. Curr. Microbiol. App. Sci.*, **6**(5):684-693.
- SINGH, K. M. AND SHARMA, I. P., 2005, Influence of FYM, fertilizer and spacing on growth and yield of rice. *RAU J. Res.*, **15**(1-2):5-7.
- SINGH, L. N., SINGH, R. K. K., SINGH, A. H. AND CHHANGTE, Z., 2005, Efficacy of urea in integration with Azolla and vermicompost in rain fed rice (*Oryza sativa*) production and their residual effect on soil properties. *Indian J. Agric. Sci.*, **75**(1):44-45.
- SINGH, R. D. AND CHAUHAN, V. S., 2002, Impact of inorganic fertilizer and organic manures on soil productivity under wheat - ragi system. *J. Indian Soc. Soil Sci.*, **50**(1):62-63.
- SINGH, Y. V., SINGH, K. K., SHARMA S. K., 2013, Influence of crop nutrition on grain yield, seed quality and water productivity under two rice cultivation systems. *Rice Science*, **20**(2):129–138.
- SINHA, 2002, Tiller phenology and grain yield of rice. *Indian J. Agric. Sci.*, **72**(5): 285-287.
- SUBBAIAH, B. Y. AND ASIJA, G. L., 1956, A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.*, **25**:259-260.
- SUBHENDU MANDAL AND ADHIKARY J., 2005, Effect of integrated nitrogen management on growth and yield of rice (*Oryza sativa* L.). *Agric. Sci. Digest.*, **25**(2):136-138.
- SUDHA, B. AND CHANDINI, S., 2003, Vermicompost - a potential organic manure for rice. *Int. Agric.*, **41**(1-2):18.
- SUJATHA, V., MOSHA, K., SUBBAIAH, G. AND PRASUNA RANI, P., 2014, Residual soil fertility and productivity of rice (*Oryza sativa*L.) As Influenced by different organic sources of nitrogen. *Int. J. Plant, Animal and Environ. Sci.*, **4**(1):266-269.
- SUNIL KUMAR, SHRIVASTAVA, G. K., PANDEY, N., NAVRANG, S., NAWAZ, M., ANDXALXO, A., 2017, Effect of different organic sources of nitrogen on concentration and uptake of nutrients in scented rice (*Oryza sativa* L.). *Int. J. Chemical Studies*, **5**(6):1951-1953.

- SUNIL, C. M. AND SHANKARALINGAPPA B. C., 2013, Impact of integrated package of agrotechniques on growth and yield of aerobic rice. Copyright © 2014 *Sci. Res.*, **5**(1):60-65.
- SUNIL, C. M., SHANKARALINGAPPA, B. C., SHRUTHI M. K. AND SHEKARA B. G., 2015, Effect of agronomic practices on the performance of aerobic rice (*Oryza sativa*) and associated weeds under Alfisols of eastern dry zone of Karnataka. *Indian J. Agron.*, **60**(4):541-546.
- SUPREET SAAJAN, SUMEET KOUR, NEETU, ISHITA WALIA AND ARUN KUMAR, 2018, Effect of different combination of nitrogen sources on the yield of direct seeded rice (*Oryza sativa*). *Int. J. Curr. Microbiol. App. Sci.*, **7**(3): 242-249.
- TABBAL, D. F., BOUMAN, B. A. M., BHUIYAN, S. I., SIBAYAN, E.B. AND SATTAR, M. A., 2002, On-farm strategies for reducing water input in irrigated rice; case studies in the Philippines. *Agric. Water Mng.*, **56**(2): 93-112.
- TAHERI RAHIMABADI, E., ANSARI, M. H. AND RAZAVI NEMATOLLAHI, A., 2017, Influence of cow manure and its vermicomposting on the improvement of grain yield and quality of rice (*Oryza sativa* L.) *App. Ecology Environ. Res.*, **16**(1):97-110.
- THIRUNAVUKKARASU, M. AND VINOTH, R., 2013, Influence of vermicompost application along with nitrogen on growth, nutrients uptake, yield attributes and economics of rice (*Oryza sativa* L.). *Int. J. Agric. Environ. & Biotech.*, **6**(4):599-604.
- TUONG, D. F. AND BOUMAN, B. A., 2003, On farm strategies for reducing water input in irrigated rice. *Agric. Water Mng.*, **56**(2):93-112.
- UPENDRA RAO, 2007, Integrated nutrient management in rice (*Oryza sativa* L.). *Indian J. Agron.*, **52**(1):13-18.
- VASANTHA RAO, U., REDDI RAMU, Y., RADHA KUMARI, C. AND RAGHAVA REDDY, C., 2004, Effect of organic and inorganic sources of nitrogen on growth, yield, nitrogen uptake and economics of lowland rice. *Madras Agric. J.*, **91**(7-12):389-393.

- VENKATESHA, M. M., KRISHNAMURTHY, N. G., TUPPAD, B. AND VENKATESH, K. T., 2015, Yield, economics and nutrient uptake of aerobic rice cultivars as influenced by INM practices. *Res. Environ. Life Sci.*, **8**(1): 113-118.
- VENKATESHWARALU, B. AND PRASAD, J. V. N. S., 2012, Carrying capacity of Indian agriculture: issues related to rainfed agriculture. *Curr. Sci.*, **102**(6): 882-888.
- WALKLEY, A. J. AND BLACK, T. A., 1934, Estimation of soil organic carbon by the chromic and titration method. *Soil Sci.*, **37**:29-38.
- WANG HUAQUI, BOUMAN, B. A. M. AND MOYA, P. F., 2002, Aerobic rice in northern China. In: water use rice production, IRRI, Philippines. pp. 143-154.
- WANG HUAQUI, BOUMAN, B. A. M. AND MOYA, P. F., 2007, Aerobic rice in China. IRRI report.
- WANI, S. P. AND LEE, K. K., 1995, Microorganisms as biological inputs for sustainable agriculture in Organic Agriculture. (Thampan, P.K.ed.) Peekay Tree Crops Development Foundation, Cochin, India. Pp. 39-76.
- WATSON, D. J., 1952, The physiological basis of variation in yield. *Adv. Agron.*, **4**:101-145.
- YADAV, B. K. AND CHRISTOPHER LOURDURAJ, A., 2006, Effect of organic manures and panchagavya spray on rice (*Oryza sativa* L.) quality. *Crop Res.*, **31**(1):6-10.
- YANG XIANGWANG, BOUMAN, B. A. M. AND CHEN BIN, 2005, Performance of aerobic rice under different water regimes in China. *Agric. Water Mng.*, **74**(2):107-122.
- YOGANANDA, S. B., REDDY, V. C. AND GANGADHAR ESWAR RAO., 2010, Effect of biofertilizer, inorganic fertilizer and urban compost on nutrient use efficiency, yield and economics of hybrid rice (*Oryza sativa* L.) production. *Mysore J. Agric. Sci.*, **44**(1):100-105.

APPENDICES

VIII APPENDICES

Appendix –I: Abbreviations used in the thesis

Abbreviations	Full form
STZ	Southern transitional zone
INM	Integrated nutrient management
FYM	Farm yard manure
PSB	Phosphorus solubilizing bacteria
KSB	Potassium solubilizing bacteria
PGPR	Plant Growth Promoting <i>Rhizobacteria</i>
cfu	Colony forming units
RDF	Recommended dose of fertilizer
SSP	Single super phosphate
MOP	Muriate of potash
LAI	Leaf area index
LAD	Leaf area duration
AGR	Absolute growth rate
CGR	Crop growth rate
RGR	Relative growth rate
NAR	Net assimilation rate
B:C	Benefit cost ratio
C.D	Critical difference
cm	Centimeter
DAS	Days after sowing
<i>et al</i>	Co workers
HI	Harvest index
IW/CPE	Pan evaporation (E_{pan})
N	Nitrogen
P	Phosphorus
K	Potassium
kg	Kilogram
q	Quintal
S.Em \pm	Standard error mean

Appendix –II: Cost of cultivation

Sl. No	Particulars	Price (Rs.)
Seed material		
1	Aerobic rice (MAS 946-1)	36 kg ⁻¹
Inorganic fertilizers		
1	Urea	5.6 kg ⁻¹
2	MOP	16.8 kg ⁻¹
3	SSP	4.5 kg ⁻¹
4	Plant protection	500
Organic manures		
1	Farm yard manure	1500 t ⁻¹
2	Vermicompost	4000 t ⁻¹
Labour wages (8 hrs)		
1	Man labour	250 day ⁻¹
2	Women labour	200 day ⁻¹
3	Bullock pair	650 day ⁻¹
4	Tractor rent	300 hr ⁻¹
Output (Green fodder yield)		
1	Aerobic rice	2100 q ⁻¹

Appendix – III: Per cent Nitrogen, Phosphorus and Potassium content in grain and straw of aerobic rice

Treatment	% N		% P		% K	
	Grain	Straw	Grain	Straw	Grain	Straw
1	1.37	1.01	0.41	0.15	0.63	1.42
2	1.42	1.04	0.44	0.18	0.64	1.43
3	1.40	1.22	0.40	0.17	0.65	1.44
4	1.49	1.26	0.44	0.19	0.68	1.57
5	1.48	1.23	0.43	0.18	0.67	1.55
6	1.32	0.93	0.41	0.16	0.59	1.38
7	1.30	0.91	0.35	0.15	0.57	1.37
8	1.37	0.98	0.41	0.15	0.64	1.42
9	1.41	1.01	0.43	0.18	0.64	1.42
10	1.43	1.09	0.43	0.18	0.63	1.41