PRODUCTIVITY AND QUALITY OF RED RICE (*Oryza sativa* L.) GENOTYPES AS INFLUENCED BY ORGANIC, INORGANIC AND INTEGRATED NUTRIENT MANAGEMENT PRACTICES

Ph.D. Thesis

by

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INDIRA GANDHI KRISHI VISHWAVIDYALAYA
RAIPUR (Chhattisgarh)
2017

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Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

Manish Kumar

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Doctor of Philosophy

In

Agriculture

(Agronomy)

Roll No. 421 **ID No. : AG\91\329**

JULY, 2017

CERTIFICATE-I

This is to certify that the thesis entitled **“Productivity and quality of red rice (*Oryza sativa* L.) genotypes as influenced by organic, inorganic and integrated nutrient management practices**” submitted in partial fulfillment of the requirement for the degree of **Doctor of Philosophy in Agriculture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of bonafide research work carried out by **MANISH KUMAR** under my guidance and supervision. The subject of the thesis has been approved by the student’s Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or has been publish / published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been duly acknowledged by him.

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This is to certify that the thesis entitled **"Productivity and quality of red rice (*Oryza sativa* L.) genotypes as influenced by organic, inorganic and integrated nutrient management practices**" submitted by **MANISH KUMAR** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Agriculture** in the **Department of Agronomy** has been approved by the external examiner and Student's Advisory Committee after oral examination.

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ACKNOWLEDGEMENT

I would like to express my sincere thanks to the many wonderful people that I have found on the path of life and education many hands pushed me forward, enlighten by their knowledge and experience, I am ever thankful to them. All my acknowledgements are many more than what I am expressing here.

I would like to thank my committee members for their continuous guidance and inspiration during the course of my doctoral studies. It is my great privilege and immense pleasure in availing this golden opportunity to express my deepest sense of gratitude and humble indebtedness towards my Hon'ble Chairman ***Dr. Narendra Pandey*** *Former Dean College of agriculture Rajnanandgaon and Head, Department of Agronomy, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur for his kind, generous and valuable guidance, intellectual inspiration, keen interest, constant encouragement, unlimited patience and parental affection with cheerful smiling gesture. His encouraging words always filled me with sense of courage in every trying situation during the course of this investigation.*

I equally and ineffably cheered to place on record my obligation and gratitude to my advisory committee members Department of Agronomy, Dr.(Major)G.K. Shrivastava, Dean stundent's walfare, IGKV, Raipur, Dr. S. C. Mukherjee, Dean ,SGCARS, Jagdalpur and Dr. Ravi R. Saxena, ADR and Professor, Agricultural statistics and social science for their everlasting , vibrant and valuable guidance.

I own my heartfelt gratitude to Dr. M. L. Lakhera, Professor (Agril. Statistics & Social Science) Dr.J. D. Sarkar, Professor (Agricultural Extension), Dr. K.K. Sahu, Professor (Soil Science & Agril. Chemistry), Dr. Alok Tiwari, Scientist (Soil Science & Agril. Chemistry), Shri R.P.Kujur, Assistant professor (English) Dr. Hulas Pathak, Assistant Professor (Agricultural Economics), Dr. Sanjay Kumar Dwivedi, Scientist (Agronomy) whose diligent support & help could lead to timely completion of this work.

I would like to express my sincere gratitude to Dr. M. Pandey (Librarian, Nehru library, Raipur) and Shri U.K. Watti (Assistant Librarian), D.K.S. College of Agriculture & Research Station, Bhatapara (C.G.), for giving me there kind help during my present study.

My respected colleagues Inservice candidates and friends Dr.J.L.Salam Dr. G.L. Sharma, Dr.Ajay Tregar, Dr. J.L. Nag, Shri N.C. Mandavi, Shri D. Khalkho and Dr O.P. Parghaniha for their enduring help Support and wholehearted co-operation during the entire course of study.

I am thankful to Dr. S. K. Patil, Hon'ble vice chancellor, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Dr. S.S Shaw, Director of Instruction ,Dr. S. S. Rao , Director Research Services and Dr.O.P. Kashyap, Dean college of Agriculture, Raipur for providing necessary facilities during the course of investigation.

I take this privilege to express my sincere thanks to the faculty members Dr. J. S. Urkurkar, Dr. N.K Choubey, late Dr.A.P.Singh Dr. M.C. Bhambri, Dr. S.N. Khajanji, Dr.S.K.Taunk , Dr.H.L.Sonboir Dr. G.K. DAS, , Dr. G.P. Pali, Dr. S.S. Tuteja, Dr. G.S. Tomar, Dr. S Chitale, Dr.(Mrs) A.Tandon, Dr. G.Banjara , Dr. D. Chandrakar, Dr. A.K. Verma, Dr. Y.K. Dewangan Dr. N. Tiwari Shri S.Agrawal for *their co-operation, valuable suggestions and encouragement during the course of study.*

I express my heartfelt thanks to my colleagues and friends, Santosh Jha, Pandu Ram Paikra, Manish Singh, Smt Neelam Tode, Chandu Lal Thakur, Lekh Ram Sahu, Diproshan and Bhujendra Kothari for their fervent help and constant encouragement during course of my studies and thesis writing.

My special thanks to Dr. Grish chandel, shri P. Pandey and all staff members of SGCARS, Jagdalpur for their support.

To express my sincere gratitude to my beloved parents in the form of word in rather restrictive both in expression and quantum, yet at his juncture it is my esteem duty to reserve my high regards to my affectionate Father Dr .R .K. Singh , Mother Shanti Singh , Elder sister in law Shri Prabash Pandey ,Sister Smt Anuradha Pandey , brother Shri Anish, babhi Chandani ,younger sister in laws Dr. Kasav and Shri Anish, sister Anupma and Tanuja whose unfailing love and affection have always been a source of inspiration to me.

The completion of this work is impossible without family support. I haven't the words which express my heartily gratitude for my wife Sweta , beloved daughter Sneha Singh and son Aditya Sai Singh for their love, patience, obstinate sacrifices, support and understand me a lot to complete this endeavor.

I am thankful to all those, whose name is not mentioned here but they are attached to me directly or indirectly and extended their cooperation and help.

And above all, my humble and devoted prostration to God Almighty with soulful respect I bow down my head to him, who enlighten and leads me in right way, with his blessing I reach at this stage.

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TABLE OF CONTENTS

Chapter No.	Title	Page No.
	3.15.1.2 Leaf area index (LAI)	43
	3.15.1.3 Dry matter accumulation (g $hill^{-1}$)	43
	3.15.1.4 Crop growth rate (CGR)	43
	3.15.1.5 Relative growth rate (RGR)	44
	3.15.2 Post- harvest studies	44
	3.15.2.1 Number of effective tillers $hill^{-1}$	44
	3.15.2.2 Panicle length (cm)	44
	3.15.2.3 Panicle weight (g)	44
	3.15.2.4 Grains $panicle^{-1}$	44
	3.15.2.5 1,000 grain weight (g)	44
	3.15.2.6 Grain yield (q ha^{-1})	44
	3.15.2.7 Straw yield (q ha^{-1})	45
	3.15.2.8 Harvest index (%)	45
	3.15.2.9 Root biomass (cm)	45
	3.16 Chemical analysis	45
	3.16.1 Iron and Zinc estimation	45
	3.17 Quality characters	46
	3.17.1 Paddy length :breadth (mm)	46
	3.17.2 Paddy length : breadth ratio	46
	3.17.3 Head rice recovery percentage	46
	3.18 Production efficiency	47
	3.19 Energetic	47
	3.20 Economic analysis	47
	3.21 Statistical analysis	48
IV	**RESULTS AND DISCUSSION**	**49-189**
	4.0 Weather effect	49
	4.1 Red rice Expt. No. -1	51
	4.1.1 Pre-harvest studies	51
	4.1.1.1 Plant height (cm)	51
	4.1.1.2 Dry matter accumulation (g $hill^{-1}$)	51
	4.1.1.3 Leaf area index	58
	4.1.1.4 Crop growth rate (g $hill^{-1}$ day^{-1})	66
	4.1.1.5 Relative growth rate (g g^{-1} $hill^{-1}$ day^{-1})	76
	4.1.2. Root volume, yield attributes and yield	76
	4.1.2.1 Root volume(cc)	76
	4.1.2.2 Effective tillers (No .$hill^{-1}$)	76
	4.1.2.3Panicle length (cm)	92
	4.1.2.4 Panicle weight (g)	93
	4.1.2.5 Grains $panicle^{-1}$ (No)	93
	4.1.2.6 Test weight (g)	93

Chapter No.	Title	Page No.
	4.1.2.7 Grain yield (q ha^{-1})	94
	4.1.2.8 Straw yield (q ha^{-1})	94
	4.1.2. 9 Harvest index (%)	95
	4.1.3 Nutrient content in red rice	95
	4.1.3.1 N content in grain and straw (%)	95
	4.1.3.2 P content in grain and straw (%)	96
	4.1.3.3 P content in grain and straw (%)	105
	4.1.3.4 Zinc content in grain (ppm)	105
	4.1.3.5 Iron content in grain (ppm)	106
	4.1.4 Economics	106
	4.1.4.1 Gross return ('000 Rs/ ha)	106
	4.1.4.2 Net return ('000 Rs/ ha)	107
	4.1.4.3 B:C ratio ('000 Rs/ ha)	107
	4.1.5 Energetics	108
	4.1.5 .1 Energy use efficiency ($MJ^{-1}x10^{-3}$)	108
	4.1.5 .2 Energy output input ratio	108
	4.1.5 .3Energy productivity (g MJ ha^{-1})	109
	4.1.5 .4 Energy intensiveness (MJ Re^{-1})	109
	4.1.5 .5 Production efficiency (kg ha^{-1} day^{-1})	110
	Discussion on effect of genotype	110
	Discussion on effect of plant spacing	112
	Discussion on effect of fertitity levels	112
	Discussion on interaction effect between genotype and plant spacing	113
	Discussion on interaction effect between genotype and fertility levels	114
	Discussion on interaction effect between plant spacing and fertility levels	114
	Discussion on micro-nutrient content	115
	Discussion on economics	118
	4.2 Red rice Expt. No. –II	118
	4.2.1 Pre harvest observation	118
	4.2.1.1 Plant height (cm)	118
	4.2.1.2 Dry matter accumulation (g $hill^{-1}$)	121
	4.2.1.3 Leaf area index	121
	4.2.1.4 Crop growth rate (g $hill^{-1}$ day^{-1})	121
	4.2.1.5 Relative growth rate (g g^{-1} $hill^{-1}$ day^{-1})	124
	4.2.2. Root volume, yield attributes and yield	124
	4.2.2.1 Root volume(cc)	124
	4.2.2.2 Effective tillers (No .hill $^{-1}$)	124

LIST OF TABLE

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

Abbreviations	Description	Abbreviations	Description
+	Plus	m^{-2}	Square metre
%	Per cent	max.	Maximum
@	At the rate	mg	milligram
a.i.	Active ingredient	MJ	Mega joule
B: C ratio	Benefit cost ratio	mm	Millimeter
^{o}C	Degree Celsius	min.	Minimum
CG	Chhattisgarh	M t	Millon ton
CGR	Crop growth rate	N	Nitrogen
cm	Centimetre	Na	Sodium
DAT	Days after transplanted	No.	Number
EC	Emulsifiable concentrates	NS	Non- significant
et al.	And others/ co-workers	P= 0.05	Probability of (95)
Fig	Figure	P	Phosphorus
g	Gram	q	Quintal
ha	Hectare	RGR	Relative growth rate
a^{-1}	Per hectare	Rs.	Rupees
Hrs	Hour	SC	Soluble concentrates
Hr^{-1}	Per hour	SL	Soluble liquid
i.e.	That is	S. No.	Serial number
K	Potassium	T	Tonnes
Kg	Kilogram	*viz.*	For example
km^{-1}	Per kilometre	WP	Wettable powder
km	Kilometre	W/V	Weight/volume
Kmph	Kilometre per hour	WDG	Weight/dissolved grains
m	Metre	PPM	Part per million

THESIS ABSTRACT

a) Title of the Thesis	:	Productivity and Quality of Red Rice (*Oryza sativa* L.) Genotypes as Influenced by Organic, Inorganic and Integrated Nutrient Management Practices
b) Full name of the student	:	Manish Kumar
c) Major Subject	:	Agronomy
d) Name and Address of the Major Advisor	:	Dr. N Pandey, Professor & Head, Department of Agronomy, College of Agriculture, IGKV, Raipur (C.G.)
e) Degree to be Awarded	:	Doctor of Philosophy in Agriculture (Agronomy)

Signature of the Student

Signature of the Major Advisor

Date: **Signature of Head of the Department**

ABSTRACT

In order to the increase the productivity of red rice, three separate field experiments, first on performance of different red rice genotypes under varied spacing and fertility level, second on grain yield and nutrient uptake of red rice as influenced by integrated use of inorganic, organic and micro nutrients ,while third on enhancement of productivity and quality of red rice through organic and inorganic application of nutrients were conducted during *kharif* season of 2013 and 2014 at Instructional cum Research Farm of Shaheed Gundadhoor College and Agricultural Research Station, Jagdalpur, Chhattisgarh. The soil of the experimental site is characterized as silty loam (fairly leveled). The soil was locally known as Mal (*Alfisols*). It is well fertile soil belongs to mid land situation of landscape in Jagdalpur .The soil was slightly acidic in reaction and medium to low in fertility levels having low in nitrogen and phosphorus and high in potash contents . Rainfall received during cropped period was 695.9 mm and 792 mm in 50 and 49 rainy days in the year of 2013 and 2014, respectively.

In first experiment, treatments comprised of 3 red rice genotypes (RR 14 EN-7, RR 14 EN-8 and RR 12 EN-11) in main-plot, 2 spacing (15 cm x 10 cm and 20 cm x 10 cm) in sub-plot and 3 fertility levels (60:40:30 $N:P_2O_5:K_2O$ kg ha^{-1}, 90:60:40 $N:P_2O_5:K_2O$ kg ha^{-1}) and 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1}) in sub-sub plot were tested in split-split design with three replications. In second experiment, treatments was composed of 12 integrated use of inorganic, organic and micro-nutrient Viz. $N_{80}P_{60}K_{40}$ (T_1),$N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40+}FYM_{5t}$ (T_3), $N_{120}P_{80}K_{60+}$ FYM_{5t} (T_4), $N_{80}P_{60}K_{40}$+Zn (T_5), $N_{80}P_{60}K_{40}+S_I$ (T_6), $N_{80}P_{60}K_{40}$+B (T_7), $N_{80}P_{60}K_{40}$+Zn $_+S_I$ (T_8), $N_{80}P_{60}K_{40}$+Zn $_+$B (T_9), $N_{80}P_{60}K_{40}+B_+$ S_I (T_{10}), $N_{80}P_{60}K_{40}$+Zn+ S_I $_+$B (T_{11})and Control (T_{12}). These treatments were laidout in randomized block design with three replications. Red rice genotype RR12EN-11 was taken as a test crop. In third experiment, 9 treatments comprised of organic and inorganic application of nutrients *i.e.* $N_{60}P_{40}K_{30}$ (I) (T_1), N $_{120}P_{60}K_{40}$ (I) (T_2), N $_{60}$ $P_{40}K$ $_{30}$ (25% O +75% I) (T_3), $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4), N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5), $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6), N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7), N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) and Control (T_9) were laid out in randomized block design with three replications. Red rice genotype RR12EN-1 was grown as test crop.

The findings on performance of different red rice genotypes grown at varied spacing and fertility levels revealed that genotype RR 12 EN-11 produced significantly highest number of grain $panicle^{-1}$, longest panicle, test weight, grain and straw yield. The gross return, net return, B:C ratio , energy use efficiency, energy output input ratio, energy productivity, and production efficiency were also registered in genotype RR12EN-11. The planting of these genotype at spacing 20cm x10cm registered higher number of effective tillers $hill^{-1}$, longer panicle, panicle weight, grain panicle-1, test weight, root volume and straw yield. While the higher grain yield, net return and B:C ratio were registered under spacing 15cm x10cm during both the years. The increase in above parameter was supported with the observation of growth and yield components. The concentration of zinc and uptake nitrogen and phosphorus followed similar pattern to that of grain yield. The application of 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} increased growth, yield components, grain yield, gross and net return and B:C ratio. The highest energy use efficiency, energy output input ratio, energy productivity and energy of intensiveness was also observed under fertility levels 60:40:30 $N:P_2O_5:K_2O$ kg ha^{-1} during both the years.

The interaction of genotypes and spacing revealed that red rice genotype RR 12 EN-11 planted at spacing of 20cm x 10cm gave the highest grain yield, net return and B: C ratio and energy use efficiency during both the years. While interaction of genotype and fertility levels revealed that red rice genotype RR 12 EN-11fertilized with 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} gave the highest grain yield, net return and B:C ratio and it was followed by genotype RR 14 EN-8 with spacing 15 cm x10cm and fertility level of 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1}.

The findings of inorganic, organic and micronutrients application of nutrients indicated that application of $N_{80}P_{60}K_{40}$+Zn_{25} +S_4+B_{10} ha^{-1} (T_{11}) increased grain yield, net return and B:C ratio, which was comparable to that of $N_{120}P_{80}K_{60}$ ha^{-1} (T_2), $N_{120}P_{80}K_{60}$ FYM5t h^{-1} (T_4) and $N_{80}P_{60}K_{40}$ + S4 ha^{-1} (T_6). The increase was mainly due to enhancement in growth and yield attributes. The concentration and uptake of nutrient also increased in these treatments.

The results obtained from organic and inorganic application of nutrients revealed that effective tillers $hill^{-1}$, panicle length and weight, grains $panicle^{-1}$, grain and straw yield, harvest index, root volume, zinc and iron content in grain, nitrogen, phosphorus and potash content in grain and straw, gross and net returns and B:C ratio were significantly highest under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) but it was comparable to $N_{120}P_{60}K_{40}$ (25% Organic +75 % Inorganic (T_4) was applied to the crop during both the years.

शोधग्रथ सारांश

अ. शोधग्रंथ का शीर्षक	:	लाल धान (*ओराइजा सेटाइवा* एल.) के विभिन्न प्रमेदों की उत्पादकता एवं गुण्वक्ता को प्रभावित करने वाले जैविक रासायनिक एवं एकीकृत पोषक तत्वों के प्रबंधन का प्रभाव
ब. विद्यार्थी का नाम	:	मनीष कुमार
स. प्रमुख विषय	:	सस्य विज्ञान
द. मुख्य सलाहकार का नाम व पता	:	डॉ. एन. पाण्डे, प्राध्यापक एवं विभागाध्यक्ष सस्य विज्ञान विभाग, कृषि महाद्यिालय, इं.गां.कृ.वि. रायपुर 492012 (छत्तीसगढ़)
इ. उपाधि से सम्मानित करने के लिए	:	कृषि में डॉक्टर ऑफ फिलॉसाफी (सस्य विज्ञान)

विद्यार्थी के हस्ताक्षर

मुख्य सलाहकार के हस्ताक्षर

दिनांक :

विभागाध्यक्ष के हस्ताक्षर

सांराश

शहीद गुण्डाधूर कृषि महाविद्यालय एवं अनुसंधान प्रक्षेत्र में वर्ष 2013 और 2014 के खरीफ मौसम में लाल धान (*ओराइजा सेटाइवा* एल.) के विभिन्न प्रमेदों की उत्पादकता एवं गुण्वक्ता को प्रभावित करने वाले जैविक रासायनिक एवं एकीकृत पोषक तत्वों के प्रबंधन का अध्ध्सन अलग–अलग तीन परीक्षण किये गये। यह तीनों परीक्षण सिल्टी लोम मिटटी (समतल भूमि) में किये गये जिसे स्थानीय भाषा में माल (अल्फीसोल) कहा जाता है। यह भूमि अच्छी उर्वरक होने के साथ मध्यम स्थिति की भूमि जगदलपुर मे ंपायी जाती है। यह भूमि कम अम्लीय तथा कम उर्वरता वाली होती है जिसमें नत्रजन और स्फूर की कम मात्रा पोटाश की अधिक मात्रा पायी जाती है। धान की फसल अवधि मे ंक्रमशः वर्ष 2013 और 2014 में क्रमशः 695.9 मि.मी. और 792 मि.मी. वर्षा 50 और 49 वर्षा दिवसों में हुई है।

पहले प्रयोग में 3 जीनोटाईप क्रमशः आर.आर. 14 ई.एन.–7 (वी.$_{1}$), आर.आर. 14 ई.एन.–8 (वी.$_{2}$) और आर.आर. 12 ई.एन.–11 (वी.$_{3}$) मुख्य प्लाट, अंतरण 15से.मी. x 10से.मी. एवं 20से.मी. x 10से.मी. सब प्लाट में उर्वरक स्तर 60:40:30 (एफ.$_{1}$),

90:60:40 (एफ.$_2$) और 120:60:40 (एफ.$_3$) किलोग्राम नत्रजन, स्फुर और पोटाश प्रति हेक्टेयर, 2013 और 2014 में स्पीलिट–स्पीलिट डिजाईन में तीन पुनरावृत्ति में किये गये। दूसरे परीक्षण में 12 प्रयोग नत्रजनः स्फुरः पोटाशःएफ.वाय.एम और सूक्ष्म पोषक तत्व जस्ता, बोरान एवं सिलिकान विभिन्न संयोजन एन.80पी.60के.40 (टी$_1$), एन.120पी.80के.60 (टी$_2$), एन. 80पी.60के.40+एफ.वाय.एम.5$_{टी}$ (टी$_3$),एन.120पी.80के.60+एफ.वाय.एम.5$_{टी}$ (टी$_4$),एन.80पी.60के.40 +जेड.एन.(टी$_5$), एन.80पी.60के. 40+एस.$_{आई}$ (टी$_6$), एन.80पी.60के.40+बी (टी$_7$), एन.80पी.60के.40+जेड. एन.+एस.$_{आई}$ (टी$_8$), एन.80पी.60के.40+जेड. एन + बी (टी$_9$), एन.80पी.60के.40+बी+एस.$_{आई}$ (टी$_{10}$), एन.80पी.60के.40+जेड.एन.+एस.$_{आई}$+बी (टी$_{11}$), और नियंत्रण (टी$_{12}$) के साथ किये गये, आर. बी. डी. डिजाईन में लाल धान के प्रभेद आर.आर. 12 ई.एन.–11 में वर्ष 2013 और 2014 में तीन पुनरावृत्ति में किये गये, तीसरे परीक्षण में 9 परीक्षण 60पी40के30(आई)(टी$_1$),एन120पी60के40(आई)(टी$_2$)एन,संयोजन,एन60पी40के30 (25%ओ+75%आई),(टी$_3$),एन120पी60के40(25%ओ+75%आई),(टी$_4$),एन60पी40के30(50%ओ+50%आई),(टी$_5$),एन120पी60के40(5 0% आई), (टी$_6$),एन टी$_1$ जैविक माध्यम के द्वारा + पर्णीय छिड़काव कंसे की अवस्था तथा पेनीकल निकलते समय (टी$_7$) एन टी$_2$ जैविक माध्यम के द्वारा + पर्णीय छिड़काव कंसे की अवस्था तथा पेनीकल निकलते समय (टी$_8$), और नियंत्रण (टी$_{12}$) साथ किये गये, आर. बी. डी. डिजाईन में लाल धान के प्रभेद आर.आर. 12 ई.एन.–1 में वर्ष 2013 और 2014 में तीन पुनरावृत्ति में किये गये।

लाल धान के विभिन्न प्रभेद संबंधी परीक्षण में यह ज्ञात हुआ कि वृद्धि मापक (पौधों की ऊंचाई, कंसों की संख्या, शुष्क पदार्थो का संचय, पत्ती क्षेत्र सूचकांक) और उपज मापक (प्रभावकारी कंसे, बाली की लंबाई, बाली का वजन, 1000 दानों का वजन, बाली में कुल दानों की संख्या), दानों और पैरा की उपज, नत्रजन, स्फुर और पोटाश की ग्राहयता दानों में, पैरा में एवं इन दोनों में, कुल उत्पादन दक्षता और उत्पादकता कम सूचकांक, सकल और शुद्ध प्रतिफल और लाभ लागत अनुपात की प्राप्ति प्रभेद आर.आर. 12 ई.एन.–11 (वी.$_3$) में हुई। पौधों से पौधों की दूरी 20 से.मी X10 से.मी में वृद्धि मापक (पौधे की ऊंचाई, कसों की संख्या, शुष्क पदार्थों का संचय, बाली की संख्या, फसल वृद्धि दर और संबंधित वृद्धि दर) और उपज मापक (प्रभावकारी कंसों की संख्या, बाली की लंबाई, बाली का वजन, 1000 दानों का वजन, बाली में कुल दानों की संख्या, जड़ का आयतन भरे हुये दानों की संख्या), दाना और पैरा की उपज, नत्रजन, स्फुर और पोटाश की ग्राह्यता दानों में, पैरा में एवं इन ऊर्जा उत्पाद, ऊर्जा उत्पाद–लागत अनुपात, ऊर्जा उपयोग दक्षता एवं ऊर्जा संघनता, सकल एवं शुद्ध प्रतिफल और लाभ लागत अनुपात दोनों वर्षो एवं उनके औसत के आधार पर उपचार उपरोक्त मापक तुलनात्मक रुप से बराबर पाये गये।

उपचार उर्वरक स्तर 120:60:40 नत्रजनः स्फुरः एवं पोटाश में उत्पादन एंव उत्पादकता को प्रभावित करने वाले कारक जैसे (पौधे की ऊंचाई, कंसों की संख्या, शुष्क पदार्थ संचय, फसल वृद्धि दर) और उपज मापक (प्रभावकारी कंसे, बाली की लंबाई, बाली का वजन, 1000 दानों का वजन, बाली में कुल दाने और प्रति बाली भरे दानों की संख्या), दाना और पैरा की उपज, दाने में नत्रजन ग्राहयता, पैरा एवं दोनों (दाना एवं पैरा) में पोटाश की ग्राह्यता, उत्पादन दक्षता और उत्पादकता कम सूचकांक और सकल प्रतिफल की गणना की प्राप्ति।

आर.आर. 12 ई.एन.–11 (वी.$_3$) अंतरण 20से.मी. X 10से.मी. वृद्धि मापक (शुष्क पदार्थो का संचय, पत्ती क्षेत्र सूचकांक) और उपज मापक (प्रभावकारी कंसे, बाली की लंबाई, बाली का वजन, 1000 दानों का वजन, बाली में कुल दानों की संख्या), दानों पोटाश की ग्राहयता दानों में, पैरा में एवं इन दोनों में, कुल उत्पादन दक्षता और उत्पादकता कम सूचकांक, सकल और शुद्ध प्रतिफल और लाभ लागत अनुपात की प्राप्ति हुई।

प्रभेद आर.आर. 12 ई.एन.–11 (वी.$_3$) x उपचार उर्वरक स्तर 120:60:40 वृद्धि मापक (पौधे की ऊंचाई, कसों की संख्या, शुष्क पदार्थों का संचय, बाली की संख्या, फसल वृद्धि दर और संबंधित वृद्धि दर) और उपज मापक (प्रभावकारी कंसों की संख्या, बाली की लंबाई, बाली का वजन, 1000 दानों का वजन, बाली में कुल दानों की संख्या, जड़ का आयतन भरे हुये दानों की संख्या), दाना और पैरा की उपज, नत्रजन, स्फुर और पोटाश की ग्राह्यता दानों में, पैरा में एवं इन ऊर्जा उत्पाद, ऊर्जा उत्पाद–लागत अनुपात, ऊर्जा उपयोग दक्षता एवं ऊर्जा संघनता, सकल एवं शुद्ध प्रतिफल और लाभ लागत अनुपात दोनों वर्षों एवं उनके औसत के आधार पर उपचार उपरोक्त मापक तुलनात्मक रुप से बराबर पाये गये।

रासायनिक जैविक तथा और सूक्ष्म पोषक तत्वों के प्रयोग के अंतर्गत एन.80पी.60के.40+जेड.एन.+एस.$_{\text{आई}}$+बी (टी$_{11}$) दोनों वर्षो एवं उनके औसत के आधार पर उपचार उपरोक्त मापक एन.120पी.80के.60 (टी$_2$,एन.120पी.80के.60+एफ.वाय.एम.5$_{\text{टी}}$ (टी$_4$) एवं एन.80पी.60के.40+एस.$_{\text{आई}}$ (टी$_6$)तुलनात्मक रुप से बराबर पाये गये। वृद्धि मापक (पौधे की ऊंचाई, कसों की संख्या, शुष्क पदार्थों का संचय, बाली की संख्या, फसल वृद्धि दर और संबंधित वृद्धि दर) और उपज मापक (प्रभावकारी कंसों की संख्या, बाली की लंबाई, बाली का वजन, 1000 दानों का वजन, बाली में कुल दानों की संख्या, जड़ का आयतन भरे हुये दानों की संख्या), दाना और पैरा की उपज, नत्रजन, स्फुर और पोटाष की ग्राह्यता दानों में, पैरा में एवं इन ऊर्जा उत्पाद, ऊर्जा उत्पाद–लागत अनुपात, ऊर्जा उपयोग दक्षता एवं ऊर्जा संघनता, सकल एवं शुद्ध प्रतिफल और लाभ लागत अनुपात दोनों वर्षो एवं उनके औसत के आधार पर उपचार उपरोक्त मापक तुलनात्मक रुप से बराबर पाये गये।

रासायनिक एवं जैविक पोषक तत्वों का धान की उत्पादकता एवं गुणवत्ता बढ़ाने हेतु किये गये अनुसन्धान के आधार पर यह पाया गया कि धान के प्रभावी कंसों की संख्या प्रति हिल, बाली की लम्बाई एवं वजन, दानों की संख्या प्रति बाली, दाना एवं पैरा की उपज एन.120पी.60के.40 (50%आई), (टी$_6$) तथा एन.120पी.60के.40 (25%ओ+75%आई), (टी$_4$), वृद्धि मापक (पौधे की ऊंचाई, कसों की संख्या, शुष्क पदार्थों का संचय, बाली की संख्या, फसल वृद्धि दर और संबन्धित वृद्धि दर) और उपज मापक (प्रभावकारी कंसों की संख्या, बाली की लंबाई, बाली का वजन, 1000 दानों का वजन, बाली में कुल दानों की संख्या, जड़ का आयतन, भरे हुये दानों की संख्या), दाना और पैरा की उपज, नत्रजन, स्फुर और पोटाष की ग्राह्यता दानों में, पैरा में एवं इन ऊर्जा उत्पाद, ऊर्जा उत्पाद–लागत अनुपात, ऊर्जा उपयोग दक्षता एवं ऊर्जा संघनता, सकल एवं शुद्ध प्रतिफल और लाभ लागत अनुपात दोनों वर्षों एवं उनके औसत के आधार पर उपचार उपरोक्त मापक तुलनात्मक रुप से बराबर पाये गये।

परीक्षण में ऊर्जा उत्पाद, ऊर्जा उत्पाद–लागत अनुपात, ऊर्जा उपयोग दक्षता एवं ऊर्जा संघनता, एन60पी40के30(50% ओ+50%आई),(टी$_5$) के अंतर्गत सर्वाधिक पाये गये।

CHAPTER - I
INTRODUCTION

Rice is an important food crop for a large proportion of the world's population. It is staple food in the diet of the population of Asia, Latin America and Africa (Fageria, 2001). Rice is cultivated on all the continents except Antarctica, over an area of more than 161 million ha (production of about 680 million metric tonnes), but most rice production takes place in Asia (Fageria, 2014). It occupies about 23% of the total area under cereal production in the world (Jagadish *et al.*, 2010). The historical importance of rice in Asia is so significant that it supported many civilizations in the river deltas of India, China, and Southeast Asia and has become deeply intertwined with the cultures in these regions (Krishan *et al.*, 2011). More than 90% of rice is produced and consumed in Asia (Grewal *et al.,* 2011). During the thousands of years since its domestication, Asia rice has been cultivated under significantly diverse agro-ecosystems to meet different human demands (Xiong *et al.,* 2011). This has resulted in tremendous genetic diversity in rice around the world, as shown by different molecular tools such as the analysis of restriction fragment length polymorphism and simple sequence repeats (Zhang *et al.,* 1992). As a consequence, many rice varieties with different characteristics have arisen under natural and human selection (Vaughan *et al.,* 2007). Yan *et al.* (2010) studied genetics diversity in the USDA rice world collection and concluded that germplasm accessions obtained from the Southern Asia, Southeast Asia, and Africa were highly diversified, while those from North America and Western and Eastern Europe had the lowest diversity.

Rice is the major food of more than 3 billion people representing the major carbohydrate and even protein source not only in South East Asia but also in some part of Africa. Deficiencies of from (Fe) and Zinc (Zn) results in impaired mental development, anaemia, reduced immunity, poor appetite and stunting. Micronutrient malnutrition is caused by poor quality diets. Increasing the Fe and Zn concentration of staple foods, such as rice could solve Fe and Zn deficiencies.

Enhancement of cereals grains with micronutrients is a high priority area of research and will contribute to minimising micronutrients deficiency related health problems in humans (Prasad *et al.,* 2013). Foliar feeding is a relatively new and controversial technique by applying liquid fertilizer directly to their leaves (Mahdi *et al.,* 2011). Ferti-fortification, which involves fertilizing crops with micro nutrients, gives immediate results by increasing the concentration of micronutrients in plant with an increase in yield. Foliar feeding results in rapid absorption and is less costly (Elfouly and El-Saxed, 1997). Iron (Fe) and zinc (Zn) can play an important role in increasing yield of cereals including rice.

The rice is stable food crop of nearly 60% population of the country and in Chhattisgarh too rice is a staple food for majority of the population. In Chhattisgarh, rice is grown in nearly 74% of total cultivated area during rainy season having the productivity level of 1.6 t ha^{-1} with total production of 9.23 millions tonnes. The Chhattisgarh is mainly having three defined agro climate zones i.e. Chhattisgarh plain, Bastar plateau and Northern hilly region. Among these Northern Hills of Surguja and Baster plateau is dominated by tribal population. The malnutrition is serious problem in these agro climate zones. The red rice is popularly grown in Baster plateau of the state with low productivity and so far, no attention have been given to enhance the productivity of red rice.

Health conscious individuals or those with special nutritional needs are often recommended to consume colour rice in place of the more popular type of rice i.e. white rice. It is said that of the three colours, brown and red bring more nutritional benefits to the consumer than white rice. Red rice can refer to many forms of rice of which one common description is that red rice is partially hulled or unhulled rice that have red husks. They are similar to brown rice in terms of the milling process and have a nutty taste and provide high nutrition. Red rice can also mean ‘red yeast rice’ which is a product offered by Japan and China. Red yeast rice may be eaten as regular rice or a medical ingredient as part of dietary treatment for a variety of health conditions such as indigestion, harmful cholesterol, and blood circulation concerns. Lastly, red rice can also mean a wild rice variety that is regarded as a weed because it produces very few grains and can cross-breed with regular rice, resulting in low-quality rice crops. Anthocyanins are the pigments that give the rice its red colour. Anthocyanin is a known antioxidant that is linked to lowering the risk of developing several chronic health conditions. Similar to brown rice, red rice is found to be rich in fiber, iron, zinc, B vitamins and even calcium. Unfortunately, the potential and it use have been by in large neglected by the research community and the farmers. With the awareness about health, red rice has gained the importance and demanded for research needs in view to increase the productivity and quality of the produce. In general, low yield of red rice has been reported due to less panicle bearing tillers and panicle density

The nitrogen, phosphorus and potassium are the major nutrient required by rice crop. Besides many micro nutrients one also needed for growth development and yield of rice. Rice plant requires an adequate supply of nutrients from various sources for optimal growth. These nutrients are supplied by indigenous sources such as soil minerals, soil organic matter, rice straw, manure, and water (rain, irrigation), but the amount supplied is usually insufficient to achieve high and sustainable yields. Fertilizers need to be applied to overcome the deficit between crop requirement and nutrient supply from the above-mentioned sources. The crop requirement of nutrients depends on variety and season. However, the full potential of improved nutrient management can only be reached with good crop management and selection suitable varieties. Searching rice cultivars or variety with high yield potential quality under different levels of nutrient supplied and plant population are prime important in the present context of rice research.

An effective agronomic management is therefore necessary to exploit the yield potential of red rice. Integrated nutrient management (INM) involving organic and inorganic sources of nutrient are very important in rice production. Many of our problems on declining productivity (increasing cost, declining yield) can be traced to improper and inefficient use of nutrients. Improper nutrient management has resulted in the nutrient imbalances in the soil with nutrients in excess while other nutrients depleted. Through this, farmers can increase agricultural productivity and safeguard the environment as they efficiently use fertilizer.

Bastar Plateau Zone joins boundaries with Orissa state in the East, Andhra Pradesh in the south and Maharashtra state in the west. It comprises of large plateau having elevation ranging from 550 m to 760 m from mean sea level in between 17°46' N and 20°34' N latitudes and 80°15' and 82°15' E longitudes. The Bastar plateau region of India which is a mega biodiversity hot spot of the world has numerous cultivars of rice with tremendous potential of high quality rice. Bastar is rich in indigenous germplasm which have been conserved since time immemorial by the traditional culture of the aboriginal people. So far 16 genotypes of red rice have been collected from this region.

Bastar Plateau is tribal predominantly zone having 6 districts viz. Jagdalpur, Narayanpur, Kondagaon, Bijapur, Dantewara and Sukma. Bastar is primarly mono cropped area of rice. Rice is grown during *kharif* season. Most of the field left fallow after its harvest. Besides , many land races commonly grown in the region, the zone is also rich in other wild species of rice like. *O. rufephogon, O. nivara, O. minuta* and weedy form *i.e. O. spontanum*. Red rices are grown in every niche of the niche of the region with poor yield. The nutritional qualities of such genotypes are still not studied. Thus the present work aim to enhance the productivity through selection of suitable genotypes, manipulation of planting geometry for yield and nutrient schedule nutritional quality of some indigenous rice genotypes from Bastar in order to identify the better genotypes for processing and nutritional fulfilment of worldwide consumers.

In view of the above points, the present investigation ***entitled*** **"Productivity and quality of Red rice (*Oriya sativa* L.) genotypes as influenced by organic, inorganic and integrated nutrient management practices"** was conducted during *kharif* season of 2013 and 2014 at the Research cum Instructional Farm, SGCARS, Kumhrawand, Jagdalpur, with the following objectives:

1. To identify suitable genotype, spacing and fertility levels for red rice in Bastar plateau.
2. To study the effect of macro and micronutrient management on productivity and quality of red rice.
3. To examine the effect of organic and inorganic application of nutrients on productivity and quality of red rice.
4. To study the influence of organic, inorganic and INM on nutrient uptake by red rice and nutrient balance in soil.
5. To assess the economics and energy of red rice as influenced by different agronomic management.

CHAPTER - II
REVIEW OF LITERATURE

Food crops grown using organic inputs having less or no chemicals are being preferred over conventionally over conventionally produced food by the end users. Food materials produced organically has got its place in food market is developed and developing countries (Urkurkar *et al*., 2010). Scientists and policy planner are therefore, reassessing agricultural practices, which relied more on biological input rather than heavy usage of chemical fertilizers and pesticides

There is a wide gap between production and consumption of nitrogen fertilizers and considerable interest has been aroused on supplementing the use of chemical fertilizers with renewable and low priced organic sources of nutrients. Fertilizer N applied in conjunction with organic manure produced equivalent or even higher dry matter and N uptake than inorganic source alone.

The pertinent literature is cited here in the following sections as per the objectives of the experiment

2.1 Effect of genotype

2.2 Effect of spacing

2.3 Effect of inorganic nutrient

2.4 Effect of organic nutrient

2.5 Effect of integrated nutrient management

2.6 Effect of micronutrient

2.6.1 Effect of zinc

2.6.2 Effect of boron

2.6.3 Effect of silicon

2.7 Interaction effect

2.1 Effect of genotype

The review on the breeding progress for high yields indicates that the improvement of the harvest index has made substantial contributions to achieve high yields of rice (Chandler, 1969).

The main environmental conditions considered in classifying rice ecosystems are soil moisture regime, soil drainage, land topography and temperature (IRRI, 1984).

Fageria (1984) reported that upland rice genotypes grain yield increased with the application of calcium carbonate but increase varied with genotype to genotype.

Taniyama *et al*. (1988) reported that the difference in the crop growth rate and CO_2 uptake in different rice genotypes was due to the variation in the amount of chlorophyll in the leaves and that CO_2 uptake and yield are positively correlated with each other. The genotype with higher DM accumulation and partitioning greater amounts into reproductive parts (panicles) at PDM had significantly higher productivity and profitability (Pukhraj > F-Malakand > Bamati-385).

Song *et al*. (1990) and Yamauchi (1994) stated that hybrid rice had a 15% greater yield than inbred rice, mainly because of an increase in biological yield rather than HI.

Amano *et al*. (1993) noted that the HI of 67% for japonica F1 hybrid rice in South China.

Ishii (1995) mentioned that grain harvest index is an important parameter in determining distribution of photosynthetic product between shoot and grain and consequently grain yield

Qui *et al*. (1995) reported a higher variability in mineral contents in some rice cultivars and the 6 level of iron content varied from 15.41 mg kg^{-1} to 162.37 mg kg^{-1} and zinc content ranged from 23.92 mg kg^{-1} to 145.78 mg kg^{-1}.

Rice hybrids have a mean yield advantage of 10-15% over varieties since they possess a more vigorous and extensive root system and increased growth rate during vegetative period when grown under normal transplanting condition (Yamauchi, 1994 and Yang *et al.*, 1999).

Wang *et al*. (1997) reported that zinc content in grains of rice ranged from 0.79 - 5.89 mg 100^{-1} g with an average of 3.34 mg 100^{-1} g in a study done among 57 rice varieties. The largest zinc value was found in Ganjay Roozy, a variety grown at IRRI while the lowest zinc value recorded was in long grain fragrant rice.

Mae (1997) described that the HI of old rice genotypes is about 30% and 50% for improved and semi-dwarf ones. The genotypes with higher HI produced higher grain yield. The increase in HI of coarse genotypes was attributed to higher DM accumulation and partitioning greater amounts into panicles.

Fageria (1998) reported adequate N concentrations for maximum yield about 8.7 g kg^{1} in the shoot of upland rice under field condition at harvest.

Peng *et al*. (2000) determined the trend in the yield of rice cultivars/lines developed since 1966 at the International Rice Research Institute (IRRI), Philippines. These authors concluded that the increasing trend in yield of cultivars released before 1980 was mainly due to the improvement in grain harvest index (GHI), while an increase in total biomass was associated with yield trends for cultivars/lines developed after 1980. They also suggested that further increases in rice yield potential will likely occur through increasing biomass production rather than increasing GHI. Peng *et al*. (2000) reported that high yielding rice cultivars/lines developed at the IRRI from 1985 to 1995 were intermediate in canopy height, tillering capacity, and leaf area index. Cultivars in this group were able to maintain relatively high grain harvest index.

Kiniry *et al*. (2001) reported that the GHI varied greatly among cultivars, locations, seasons, and ecosystems, ranging from 0.35 to 0.62, indicating the importance of this variable for yield stimulation. Nitrogen concentration was higher in grain compared to shoot. Nitrogen concentration in the grain of rice is always higher than the Stover. The yield variability among rice cultivars is highly dependent on grain harvest index.

Uphoff (2002) reported that drought resistance genotypes have thick voluminous and deep root system compared to other genotypes. Cassman *et al*. (2002) reported that N concentration of 12 g kg^{-1} is desired in the grain of rice for optimal cooking and eating quality. Besides, rice hybrids exhibited highest yield potential even under SRI method, due to profuse tillering capacity, lodging tolerance, greater stress resistance and wide ecological adaptability (Yan, 2002).

The largest germplasm collections of rice is available in the world. This accessible collection of diverse varieties, landraces and related wild species has made great contributions to rice breeding. Landraces harbor a great deal of useful traits with genetic potential for rice improvement and they played a very important role in the local food security and sustainable development of agriculture, in addition to their significance as genetic resource for rice genetic improvement (Tang *et al.,* 2002).

Welch and Graham (2004) found 4-fold differences in mineral levels of iron and zinc concentration among rice genotypes, which suggests that there is a potential to increase the concentration of these micronutrients in rice grain with genetic technology.

Bhattacharjee (2006) observed 0.136 to 11.4 per cent of amylose content in glutinous rice cultivars of Assam. Nine genotypes of rice were evaluated for iron and zinc content in rice grain at IRRI by found a range of 8.8 to 21.0 ppm, 14.0 to 40.0 ppm for iron, and zinc, respectively (Martinez *et al.*, 2006). Zozali *et al.* (2006) reported grain of Zn concentration is substantially higher in certain landraces of Southeast Asia than in commonly grown high yielding rice varieties.

Thorat (2007) and Fageria (2007) revealed that different spacing had no significant influence on N and P content in grain and straw of rice. Rice genotypes differ significantly in N uptake and utilization efficiency.

Uphoff and Randriamiharisoa (2007) observed in different root character's in different genotypes .

Devi *et al.* (2008) reported significant variation among cultivars for total starch content from 73.77% to 85.33% of carbohydrate content while studying fifteen indigenous rice and 100 upland rice cultivars respectively.

Ahmed *et al.* (2008) studied that the yield potential of wild relatives of rice, which involves the improvement of seed protein content. A significant increase in seed protein content was observed in an interspecific hybrid between *Oryza sativa ssp. indica* and the wild species *Oryza nivara.* The hybrid showed a protein content of 12.4%, which was 28 and 18.2% higher than those of the parents *O. nivara* and IR 64, respectively.

Lafarge and Bueno (2009) reported that the yield advantage of hybrid rice over old rice cultivars in tropical environments is up to 15%. This increase in grain yield is because of higher dry matter production due to higher seedling vigor leading to quicker growth rate and higher HI. Chakraborty *et al.* (2009) noticed bold grained rice genotypes had starch content varied from 65.60 to 79.88 per cent.

Islam *et al.* (2010) noticed that hybrid rice give higher yield over conventional rice.

Mallikarjuna *et al.* (2011) studied 126 accessions/varieties of rice germplasm including wild relatives *O. rufipogon* and *O. nivara*. The Fe concentration in brown rice ranged from 6 ppm (Athira) to 72 ppm (O. *nivara*). Zn concentration ranged from 27 ppm (Jyothi) to 67 ppm (O.*rufipogon*). Iron and zinc concentration varies between brown rice and polished rice. Also, when whole rice grains and broken rice grains were compared, there was variation in iron concentration but not in zinc concentration.

Anuradha *et al.* (2012) analyzed 126 accessions of brown rice genotype including 7 accessions of two wild species for Fe and Zn concentration and reported that iron concentration ranged from 6.2 ppm to 71.6 ppm and zinc from 26.2 ppm to 67.3 ppm. Zn concentration and grain elongation (-0.25) were significantly correlated. The wild accessions had the highest Fe and Zn.

Yadi *et al*. (2012) described significant effect of Zn fertilizer on HI of rice. More over, the coarse rice genotypes (Pukhraj and F-Malakand) had higher HI than fine genotype (Bamati-385). Differences in the HI of rice genotypes have been reported by many researchers.

Devi *et al.* (2012) observed a range of 70% to 89.25% of total carbohydrate content studying eighteen indigenous cultivars of North-Eastern hill regions of India. 79% carbohydrate content is recommended by USDA Nutritional database, U.S.

Wiangsamut *et al*. (2013) reported that hybrid rice has higher DM partitioning efficiency and consequently has higher grain yield than inbred.

2.2 Effect of spacing

Bridgit and Potty (2002) and Nayak *et al*. (2003) reported that higher yield in 30 cm x 30 cm spacing was due to less competition among the plants for nutrients and moisture better aeration which encourages better root development. Productive tillers hill^{-1} was not affected significantly by seedling density.

Obulamma *et al*. (2004) mentioned that spikelet's panicle^{-1} was significantly higher at wider spacing. Sterility percentage was observed to be significantly higher at closer spacing (20 cm x 10 cm). Grain yield was not significantly affected by spacing. However, wider spacing of 20 cm x 15 cm produced more grain yield compared to narrow spacing (20 cm x 10 cm).The number of filled grains panicle^{-1} was significantly higher with one seedling hill^{-1}. This can be attributed to the significantly higher sterility percentage recorded at two seedlings hill^{-1}.

Frizzell *et al*. (2006) while comparing row widths for conventional varieties suggested that narrows rows may be preferable over wider rows.

Islam *et al*. (2009) reported that thousand grain weight failed to show any significant variation with seedling density as it may be an attribute controlled by the genetic make up of the variety.

2.3 Effect of inorganic nutrient

Barker *et al.* **(**1985) observed that the impact of increased fertilizer use on crop production has been large, but ever increasing cost of energy is an important constraint for increased use of inorganic fertilizer.

Kumar and Prasad (2003) reported that application of 10 t ha^{-1} FYM in rice-wheat system significantly increased N, P and K content by 4.0, 7.8 and 7.6 percent as compared with no FYM. In rice straw N and P content remained unaffected with increase in fertilizer levels but K content was increased significantly with increased fertilizer dose from 0 to 100 % RDF. Highest level of fertilizer (100 % RDF) produced highest K content in straw and was followed by 50 % RDF. Significantly minimum K content in Straw was observed with no fertilization.

Ahmad *et al*. (2005) reported that the increase in straw yield and harvest index at higher nutrient levels.

Tripathi *et al*. (2013) mentioned that the better yield attributes and yield with the application of highest level of nutrients might be due to its key role in root development, energy translocation and metabolic process through which increased translocation of photosynthates towards sink development might have occurred.

Hairmansis *et al*. (2010) reported that grain yield and straw yield were maximum at 150:75:75 kg NPK ha^{-1}. This could be attributed to the positive and moderate direct effect of number of productive tillers and the strong direct effect of filled grains $panicle^{-1}$ on grain yield. Significant improvement in dry matter accumulation of rice with increasing nutrition on account of better growth and development of the plant.

2.4 Effect of organic nutrients

Mathew *et al*. (1993) also recorded increment in grain yield by application of FYM. Manjappa *et al.* (1994) found sustaining soil productivity, organic manures also improved nutrient use efficiency of the crop . Sharma(1994) noted that the grain and straw increased with the increased rate of FYM. Gill *et al*. (1994) reported that rice yields increased significantly with the increase in nitrogen levels up to 100 kg ha^{-1}. Rice yields still higher in 100 per cent application of N, P and K and in treatments with part of N supplied through various organic sources. Among all the treatments, application of 25 per cent and 50 per cent N through paddy straw gave significantly higher grain and straw yields, respectively.

Ladha *et al*. (1996) noticed that application of organic sources of nutrients in rice crop showed beneficial effect on succeeding crop *i.e.* maize in the summer season. Though the green manures are good source nutrients, they can not meet the total crop nutrient requirement in the present day agriculture water management alternatives and plant spacing optimum plant density per unit area is an important factor needed for realizing higher yields.

Mhaske *et al.* (1997) noted higher plant height and number of tillers $plant^{-1}$ with the application of FYM @ 12 t ha^{-1} compared to no FYM application.

Pandey *et al.* (1999) observed that the head rice recovery was higher with the application of 10 t ha^{-1} of FYM. They also reported that the application of 10 t FYM ha^{-1} as well as 5 t FYM ha^{-1} were equally effective as 120 kg N ha^{-1} for grain yield of scented rice cv. Madhuri and Pusa Basmati-1. Similarly at CRRI, Cuttack, application of 10 t FYM ha^{-1} increased the grain yield compared with no FYM, and the yield was similar to that obtained with 20 or 40 kg N ha^{-1} while ,Ghosh and Sharma, (1999) noticed there was no significant difference in grain yield due to the application of N-fertilizer in plots treated with FYM. Ayoub (1999) reported that use of organic matter to meet the nutrient requirement of crops would be an inevitable practice in years to come, particularly for resource poor farmers. Further, more ecological and environment concerns over the increased and indiscriminate use of inorganic fertilizers have made research on use of organic materials as a source of nutrients very necessary.

Hossain and Singh (2002) revealed that the organic materials particularly farmyard manure and green manure have traditionally been used by rice farmers in pre industrial age. But the present day high yielding cultivars, which have higher nutrient requirements, the use of inorganic fertilizers has increased considerably leading to decline in the use of organic materials.

Sharma and Sharma (2002) observed that the increase in organic carbon content in treatments with combination of both organic and in organic sources may be attributed to higher biomass addition to soil through crop residues.

Tolanur and Badanur (2003) reported that FYM and green manure addition with inorganic fertilizers had the beneficial effect on increasing the available P status of soil.

Mirza *et al.* (2005) reported that productive tillers were increased by the application of FYM but differences were not significant between 10 and 20 t ha^{-1} of FYM application. The increase in paddy yield due to application of 5, 10 and 20 t ha^{-1} of FYM were 6.8%, 24.4% and 37.6%, respectively over control.

Laxminarayana (2006) reported that the declining trend of available potassium among all the treatments may be attributed to crop removal due to continuous cropping.

Singh *et al*. (2008) mentioned that lowering of organic carbon content of soil was common in control and in treatments with only inorganic fertilizers .This type of lowering of organic carbon content of soil may be due to its rapid mineralization resulting from intensive cropping and also as a result of attaining stable equilibrium with the changing soil crop environment.

Singh *et al*. (2008) noted that organic sources have maintained relatively higher available potassium content.

Yogananda *et al*. (2012) reported that transplanted rice responded positively with increasing level of FYM. The maximum average grain yield (4166 kg ha^{-1}) and straw yield (5212 kg ha^{-1}) was observed with application of

12.5 t FYM followed by 10 t FYM equivalent (3918 and 4769 kg ha^{-1} , respectively) and found superior over all other treatments.

Pandey (2012) and Rathod *et al. (*2012) the improvement in organic carbon, microbial population and physical properties of the soil may be the reason of the more crop productivity .

2.5 Effect of integrated nutrient management

Diverse studies across different agro-ecosystems have shown importance of organic nutrient sources in improving crop yield and improving soil quality. Reference reported that response of rice to nutrient supply by organic and inorganic fertilizer is universal but may vary with locations, soil and fertilizer types. Similarly, crops have been reported to respond differently to different composts under similar soil fertility condition.

Santhy *et al.* (1998) observed that total uptake of N, P and K increased progressively in the supply of NPK to the crops, because of higher availability of these nutrients. Application of NPK at 100 % of optimum level along with FYM @ 10 t ha^{-1} increased nutrient uptake over the application of 100 % optimum level of NPK alone.

Pandey *et al.* (1999) reported that application of 10 t FYM ha^{-1}, 80 kg N ha^{-1} along with 5 t FYM ha^{-1} and 40 kg N ha^{-1} were as effective as 120 kg N ha^{-1} for grain yield of scented rice cv. Madhuri and Pusa Basmati-1.

Sarawgi and Sarawgi (2004) found that higher level of nutrients (*i.e.* 50:50:40 kg NPK ha^{-1} + nitrogen blended with FYM) recorded significantly higher number of tillers plant^{-1}, plant height, panicles plant^{-1}, length of panicle, number of filled grains panicle^{-1}, filled grain weight, test weight and grain yield of tall and short slender scented rice varieties compared to lower level of nutrients (*i.e.* 25:40:30 kg NPK ha^{-1}) with or without blending with FYM. At both level of nutrients, blending with FYM proved better in all growth, yield and yield attributing characters. It was also found that application of 10 t FYM ha^{-1} (*i.e.* 45:20:40 kg NPK ha^{-1}) did not show any positive effect on yield and yield attributes of short to medium slender rice varieties.

Sarawgi and Sarawgi (2004) revealed that higher level of nutrients (*i.e.* 60:50:40 kg NPK ha^{-1} + N blended with FYM) recorded significantly higher number of tillers plant^{-1} at maximum tillering stage, plant height, panicles plant^{-1}, panicle length, panicle weight, test weight, filled grains as well as total number of grains panicle^{-1}, grain and straw yield of semi tall and short to medium slender scented rice varieties followed by same level of nutrients blending and lower level of nutrients (40:40:30 kg NPK ha^{-1}) with or without blending. Further, it was observed that there was no significant differences in between lower level of nutrient blended with FYM (40:40:30 kg NPK ha^{-1} + N blended with FYM) and higher level of nutrient without blending (60:50:40 kg NPK ha^{-1}) for plant height, panicle length, test weight, number of filled grains as well as total number of grains panicle^{-1} and straw yield. It was also found that application of 10 t FYM ha^{-1} (45:20:40 kg NPK ha^{-1}) proved as good as higher level of nutrient (60:50:40 kg NPK ha^{-1}) without blending.

Pandey and Nandeha (2004) reported that application of chemical fertilizers @ 120:60:30 kg NPK ha^{-1} produced significantly higher grain yield of scented rice during both the years. However, the response of FYM alone was at par with all the chemical fertilizers.

Singh *et al.* (2005) reported that soil OC and available P content increased significantly due to organic farming practice compared the control as well as chemical fertilizer application.

Khadayate *et al*. (2005) reported that the different organic and inorganic sources of nutrients, alone and in combinations, significantly influenced the rice yield, yield attributing parameters, content and uptake of nutrients (N P and K) by rice. Among the different organic sources, FYM was recorded the highest yield.

Sarawgi *et al*. (2006) revealed that the grain yield of scented rice varied significantly due to nutrient management. Higher level of nutrients (*i.e.* 60:50:40 kg N: P_2O_5: K2O ha^{-1} + Nitrogen blended with FYM) recorded significantly higher grain yield of scented rice than rest of the nutrient management practices.

Urkurkar *et al.* (2006) found highest yield sustainability and net return of rice and available N in soil under 50% of N substituted through green manure in conjunction with 50% of recommended NPK through inorganic fertilizers than 100% recommended dose of fertilizer and other combination of organic and inorganic sources over 16 years of study at Raipur.

Roul *et al*. (2007) reported that the growth parameters like plant height, dry matter accumulation, root mass density as well as the physiological parameters like leaf area index, leaf area duration, light interception etc were significantly higher under 100% recommended dose of nitrogen blended with FYM at 3 t ha^{-1} . Similar trend was also recorded with different yield attributes, grain and straw yield of rice.

Salahuddin *et al*. (2010) studied that five levels of nitrogen (0, 50, 100, 150, 200 kg N ha^{-1}) and three spacing's (25 cm x 20 cm, 25 cm x 15 cm, 25 cm x 10 cm) and noted gradual increase in panicle length (24.50 cm), grains $panicle^{-1}$ (110) and grain yield (4.91 t ha^{-1}) were with the increase in nitrogen levels upto 150 kg ha^{-1} and declined thereafter. Thousand-grain weight was not significantly influenced by application of different levels of nitrogen. The maximum grain yield (4.22 t ha^{-1}) was observed at the spacing 25 cm x 10 cm closely followed by 25 cm x 15 cm (4.21 t ha^{-1}). Wider spacing (25 cm x 10 cm) produced the tallest plant (108.38 cm), but significantly highest tllers hill (8.06) and grains $panicle^{-1}$ was recorded from (25 cm x 20 cm). Plant spacing had also no significant effect on 1000 grain weight. The interaction effects of nitrogen and plant spacing was significant in panicle length, grains $panicle^{-1}$, and grain yield. The higher grain yield (5.00 t ha^{-1}) was recorded from the treatment combination of 150 kg N ha^{-1} with 25 cm x 15 cm spacing, but statistically identical to same N dose with other two spacing. Response of grain yield to added N was quadratic. The optimum doses were found to be 132 kg N ha^{-1} for 25 cm x 20 cm, 119 kg N ha^{-1} for 25 cm, and 177 kg N ha^{-1} for 25 cm x 10 cm spacing, yielding 4.38, 4.63 and 4.75 t ha^{-1} respectively.

Satish *et al.* (2011) noticed significant increase in rice yield in treatments with paddy straw as source of nitrogen (25 to 50%). Higher maize yield was observed in treatments with both organic and inorganic fertilizers in *kharif* followed by 100 per cent NPK in summer season, thus showing the beneficial effect of organic sources of nutrients on the succeeding crop and also improving the soil fertility levels.

Gogoi (2011) reported that the application of 50% recommended dose of fertilizers (RDF) + 50% N (FYM) showed the lowest bulk density and the highest water holding capacity of soil. The above treatment was at par with 50% N (inorganic) + 50% N (FYM) + PK. However, effect of integrated nutrient management had a non significant effect on pH of soil. At the end of the cropping sequence, significant soil organic carbon increased and higher available N, P_2O_5 and K_2O of soil were observed when 50% recommended dose of fertilizers (inorganic) substituted through 50% N FYM (organic) over RDF and control.

Ghosh *et al.* (2011) informed that on adoption of INM technology, the soil quality index (SQI) improved from 11.9 to 18.8% exhibiting highest in maize-potato-onion and lowest in paddy-wheat system. It is inferred that maize-potato-onion under limited irrigation treatment and maize-wheat + mustard under rainfed conditions are the best management options for maximizing water productivity, net return and soil quality.

Upadhyay *et al.* (2011) noted that at the end of 5 cropping cycles, application of organic manures resulted in higher soil organic carbon, available N, P and K than the chemical fertilizers. Maximum beneficial micro-organisms were recorded under organic nutrient management (ONM) after completion of 5 crop cycles and the bulk density of soil was also lowered significantly in ONM. The B:C ratio was higher for chemical fertilizers in case of rice-durum wheat-green manuring (3.6) and rice-potato-okra (3.1) due to lesser cost of cultivation.

Jahiruddin *et al.* (2012) stated that the integrated use of poultry manure or compost with fertilizers demonstrated about 25% yield increase over 100% fertilizer treatment. Positive residual effect of manure was observed in the following two rice crops. A separate field trial was made to evaluate the effect of INM with cow dung or poultry bio-slurry on potato crop. It revealed that bio-slurry had better effect on tuber yield compared to cow dung or poultry manure. This study indicates that integrated use of manure and fertilizers is a better practice for obtaining higher crop yield.

Hussain *et al.* (2012) noted that the values of yield attributes *viz.*, panicle length and number of spikelets panicle^{-1} were significantly higher with application of RFD + poultry manure @ 20 t ha^{-1}, whereas grains panicle^{-1} and panicles m^{-1} were significantly higher with application of FYM @ 20 t ha^{-1} + 75% recommended fertilizer dose.

Nath *et al.* (2012) investigated the multifaceted effects of INM treatments that facilitated beneficial soil conditions were reflected in terms of significant increase in the grain yield of both rice (3.87 t ha^{-1}) and *toria* (1.04 t ha^{-1}) even over the 100% NPK.

Dheri *et al.* (2013) studied five treatments (100%N, 100%NP, 100%NPK, 100% NPK + FYM and the control). In the surface soil layer (0–15 cm), soil organic carbon (SOC) increased from the initial status of 2.42 to 3.26 g kg^{-1} in the control, which significantly increased with the application of 100% NPK (4.11 g kg^{-1}) and 100% NPK + FYM (4.55 g kg^{-1}). The rice–wheat cropping even without any fertilization (control) contributed toward carbon sequestration (1.94 Mg C ha^{-1}) with soil organic carbon pools and carbon sequestration rate of 7.84 Mg C ha^{-1} and 0.22 Mg C ha^{-1} yr^{-1}, respectively.

Cao *et al.* (2013) reported that the integrated high-efficiency practice is effective in reducing NH_3 loss and increasing rice yield and nitrogen use efficiency (NUE), and can be used for the sustainable development of rice production systems in the Taihu Lake region.

Patel *et al.* (2013) from Varanasi reported that for securing higher yield and remuneration in rice - sugarcane (plant)– sugarcane (ratoon) cropping sequence, application of 25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer to the rice–sugarcane (plant)–sugarcane (ratoon) cropping sequence not only gave net return and B:C ratio close to that obtained with application of 100% recommended dose of fertilizer as per soil test value or as per general state recommendation but also improved the soil health in terms of positive nutrient balance.

Mohanty *et al.* (2013) reported from Odisha that application of 1/3 rd recommended dose (RD) of N each through chemical fertilizer; FYM and Azolla registered the highest plant height and leaf area index in rice (*Oryza sativa* L.) as compared to other treatment combinations. Higher yield components (viz. number of panicles m^{-2}, number of filled grains $panicle^{-1}$) and grain and straw yield of rice were also achieved from the same treatment as compared to 100% recommended dose of fertilizer and control.

Singh *et al.* (2013) observed that application of 75% of recommended NPK through inorganic + FYM @ 10 t ha^{-1}+ BGA @ 15 kg ha^{-1} recorded significantly higher plant height, more no. of tillers/hill and yield.

Tripathi *et al.* (2013) noted that the residual soil fertility improved considerably with the combined application of inorganic fertilizer and organics. It was concluded that integration of organics (Rhizobium, PSB & FYM) with in organics led to 50% saving of inorganic fertilizer without scarifying the yield of sun hemp-rice cropping sequence and improved soil fertility status.

Singh *et al.* (2013) noticed that INM resulted in higher plant height with longer leaves than chemical fertilizer alone. The seed quality parameters like germination rate and vigor index as well as N uptake and soil organic carbon content were higher in INM than those in chemical fertilizer alone.

2.6 Effect of Micronutrient

Micronutrient deficiencies are becoming serious because of escalated nutrient demand from more intensive and exploitative agriculture coupled with use of single nutrient fertilizers and low amount of organic manures (Savithri, 2008). Cultivation shift for fine genotypes from flooded to aerobic condition have raised another question for rice growers on micronutrient deficient soil. Although significant amount of water may save in this shift but it may not suitable for already existing genotypes which can lead toward poor crop performance.

2.6.1 Effect of Zinc

Rashid.(2001) reported that diffusion is belived to be the dominant mechanism for Zn^{2+} transport to plant roots.Dubey and Chauhan (2002) reported that the minimum Zn uptake was recorded at no crop residue (control) and maximum at 100% crop residue. Tripathi and Rawat (2002) reported that the increase in Zn content may be attributed to increased availability of Zn due to addition of crop residue. Singh and Tripathi (2005) reported that solubilisation of native as well as applied zinc at higher levels by crop residues which produces complexion agents.

Meena *et al.* (2008) noticed that the minimum Zn uptake was recorded at no crop residue (control) and maximum at 100% crop residue.

Ehsanullah *et al*. (2011) evaluated the effect of different methods and timing of zinc application on growth and yield of rice at Faisalabad. Zinc application methods and timing had significantly pronounced effect on paddy yield. Maximum paddy yield (5.21 t ha^{-1}) was achieved in treatment Zn (Basal application at the rate of 25 kg ha^{-1} 21 % $ZnSO_4$) and minimum paddy yield (4.17 t ha^{-1}) was noted in Zn7 (foliar application at 75 DAT @ 0.5% Zn solution). Zinc application increases the crop growth rate of rice.

Jha *et al.* (2013) noted that green manure had the greatest contribution to total N, total P, zinc, iron, and manganese (Mn). Yadav *et al.* (2013) observed that Zn uptake obviously increased with the application of Zn. Zn and crop residue treatment exerted a favourable influence on zinc uptake by rice crop. Tripathi and Kumar (2013) noticed that minimum Zn uptake was recorded at no crop residue (control) and maximum at 100% crop residue. Chandel *et al.* (2013) showed that crop residue increased the grain and straw yield of rice and iron content and ultimately iron uptake by the crop. Yadav *et al.* (2013) studied the response of rice to zinc and organic matter application and noted that rice grown in flooded conditions has higher requirement of zinc because the availability of other nutients in submerged condion increases which decrease zinc availibily to crop.

2.6.2 Effect of Boron

Boron is second emerging deficient nutrient in rice tract which is affecting crop impassively.

Garge *et al*. (1979) found that Boron may stimulate the enzymatic activity, availability of sugar and respiration which leads toward improved pollen growth.

Hossain *et al*. (2001) reported that in case of severe boron deficiency, root growth of plant ceases which leads toward the death of root tips. Paddy yield was significantly higher with the application of micronutrients (Zn, B and Mo) alone or in combination with each other.

Rashid *et al.* (2009) perceived the effect of boron on rice cultivars Super Basmati, Basmati 85 and KS- 282 and reported 14-25% increase in paddy yield as compared with control. Rice crop behaved positively with optimum boron dose at 0.75 kg ha^{-1}.

Rafique *et al*. (2006) reported that crop production and quality is desperately affecting with emerging deficient micronutrients (B and Zn) all over the world.

Jin *et al*. (2008) found that concentration of Fe, B and Zinc contents increased significantly in rice grain with combined foliar application of these nutrients. PARC (2002) Studied on boron fertilization and explained that paddy yield consistently increased with boron application.

Boron application improved all the agronomic growth parameters and increased the yield. Both B fertilizers significantly increased the plant height, panicles $plant^{-1}$, number of grains $panicle^{-1}$ and weight of 1000 grains. Both B sources were found equally effective in supplying B to rice crop. Borax gave significantly high yield at 2 kg B ha^{-1} and powder colemanite at 3 kg B ha^{-1}. Yield difference between borax and powder colemanite was not significant at all three levels .Powder colemanite applied plots had significantly high residual B in compare to borax at 0-15 and 15-30 cm and at 30-45 cm depth borax applied plots had high B content. Granular colemanite application did not significantly increase the crop growth and yield due to the large particle size B so that release was very slow.

2.6.3 Effect of Silicon

Although silicon has not been recognized as an essential element for higher plants, its beneficial effects have been observed in many plants. Rice plant has been considered to be a typical siliciphilous plant. It is recognized that silicon promotes photosynthesis prevents fungal and insect injuries and alleviates lodging. In Japan, silicon materials are widely applied to paddy fields to enhanced rice production.

Okuda and Takahashi (1961) studied the effect of silicon application on the growth of rice plant at different growth stages, and observed that the plant height, grain weight, and uptake of silicon were larger when silicon was added at later growth stages (after panicle initiation stage) than at earlier growth stages. They therefore suggested that silicon application is more important in the later growth stages.

Takahashi *et al*. (1966) found that silicon promotes CO_2 assimilation in the leaf blades and translocation of assimilated products to the panicle.

The first reports of such a response appears to be those of Yamauchi and Winslow (1989), and Winslow (1992) in West Africa. Si sharply reduced all fungal diseases, particularly neck blast and grain discoloration which are the most serious problems in the humid forest zone; and clear differences in Si response among rice varieties were observed.

The role of Si in plants has been reviewed by Lewin and Reimann (1969) and Werner and Roth (1983). Commercial Si fertilizer use in irrigated rice is well established in Japan. Nearly one third of Japan's rice hectare age falls into this category. Si fertilizers are also used in Korea. In the Asian humid tropics, responses to Si in irrigated rice were observed in Sri Lanka where leaf Si fell below 5%, and straw Si was below 2% for indica varieties (Taakijima and Gunawardena, 1969) or 2.5% for japonicas (Yoshida *et al*., 1969). Irrigated rice yield responses have also been observed in Taiwan and India, according to Silva (1973). In comparison to lowland culture, little is known about the Si responses of upland rice.

Transport of Si up the shoot appears to be passive, *via* the transpiration stream (Yoshida *et al*., 1962) upon reaching the end of the transpiration stream, most (90-95%) of the silicic acid condenses to form insoluble, hydrated, amorphous silica, cIten called "silica gel" ($SiO_2.nH_2O$). When dehydrated, this is called biogenetic opal, which Lanning (1963) argued is the real form present (not gel) within rice tissues. Monomeric silicic acid constitutes just 0.5 to 8% of plant silica, and colloidal silicic acid forms the remaining O to 3.3% (Yoshida el al., 1962b). No enzyme appears to participate in the condensation that converts soluble Si to the insoluble form in rice (Yoshida *et al*., 1962).

Winslow (1992) found varietal differences in Si content which were associated with differences in resistance to neck blast and grain discoloration diseases in West Atrica. Furthermore, the varietal differences were greatest between the two major genetic sub-groups of cultivated rice, the indica and japonica types. Japonica types, which are the traditional upland rices of the tropics.had substantially higher levels of Si in plant tissues, and were more resistant to these ímportant upland díseases. While this is circumstantial 37 evidence, it is significant in light of the known effect of applied Si in reducing hose same diseases. When Si was applied in that same study, the indica types showed a greater response in terms of increased Si content, yield and disease control, than did japonicas, as might be expected given the greater "inherent deficiency" characteristic of indicas.

Kaufman (1979) suggested that silica cells might serve as a "window" in the epidermal system of sugarcane, and they may allow light to be transmitted to photosynthetic mesophyll tissue below the epidermis better. Therefore the silicon absorbed during the reproductive stage plays an important role in promoting the photosynthesis of leaves, especially the flag leaf.

Mizuno (1987) reported that the hull size and 1000 grain weight increased with the increase in the silicon content of the hull. The leaf blades are the main organ of photosynthesis and the flag leaf contributes significantly to the yield.

2.7 Interaction effect

Akita (1989) and Amano *et al*. (1993) also reported that higher grain yield from rice was achieved by increasing biomass production.
According to Peng *et al*. (1999), grain yield improvement of lowland rice cultivars released by the International Rice Research Institute in the Philippines after 1980 is due to increases in biomass production.

Fertilizers are a costly input, such that their use limits the profitability of rice farming for high- or low-input systems, and the use of fertilizers for these two rice nutrients is extremely inefficient .About the interaction of Zn and P, numerous studies have been done and all confirms that Zn and P imbalance in the plant, as a result of excessive accumulation of P, causing Zn imposed, deficiency (Cakmak, 2000; Das *et al*., 2005 and Alloway, 2009).

Marschner, (2002) stated that phosphorus (P) and zinc (Zn) deficiencies are two of the most important nutritional constraints to rice growth. Zn is absorbed by plants as cations (Zn^{2+}) and P is taken up by plants as phosphate anions (H_2PO_4 or HPO_4^{2-}). These cations and anions attract each other which facilitates the formation of chemical bonds that can form within the soil or the plant. If excess P binds a large quantity of Zn normally available to the plant, the result can be a P-induced Zn deficiency. This generally results in reduced shoot Zn concentration and reduced growth

Mafi *et al*. (2013) reported that increasing P and Zn levels increase yield and HI in rice. Fageria *et al*. (2011) stated that HI increased with Zn fertilization, and the increase in HI was 32% while using 5 mg kg^{-1} Zn of soil as compared to the Zn-control plots.

HI in rice increased with application of higher P (80 and 120 kg ha^{-1}) and Zn rates (10 and 15 kg ha^{-1}) and the increase was more when both nutrients were applied in combination than sole application. The increase in yield components and grain yield as well as higher dry matter accumulation and partitioning greater amount of dry matter into panicles was attributed to the higher P and Zn levels that resulted in higher HI of rice and vice versa (Rose *et al*., 2013).

High soil pH appears to be the main factor associated with the widespread Zn deficiency in the calcareous soils of the Indo-Gangetic plains of India and Pakistan (Tahir *et al*., 1991).

The yield of rice is an integrated result of various processes, including canopy photosynthesis, conversion of assimilates to biomass and partitioning of assimilates to grains (Weng and Chen, 1984; Wu *et al*., 1998; Ying *et al*., 1998).

Next to nitrogen (N) and P deficiency, Zn deficiency is now considered as the most widespread nutrient disorder in lowland rice (Quijano *et al*., 2002 and Singh *et al*., 2005).

Studies on Zn and P interaction and their impact on dry matter (DM) accumulation and partitioning into leaf, culm and panicle at different growth stages and harvest index (HI) of lowland rice are scanty. The hypothesis was tested that there is no difference in the DM accumulation and partitioning into various plant parts at different growth stages (Tillering, heading and physiological maturity), and the HI of lowland rice genotypes when applied with variable rates of P and Zn.

CHAPTER - III
MATERIALS AND METHODS

The present investigation on **"Productivity and Quality of Red Rice (*Oryza sativa* L.) Genotypes as Influenced by Organic, Inorganic and Integrated Nutrient Management Practices**" was carried out during *kharif* season of 2013 and 2014. The details of the materials used, experimental procedures followed and techniques adopted during the course of investigation are described in this chapter.

3.1 Experimental Site

The location of the experimental site was Instructional cum Research Farm of Shaheed Gundadhoor College and Agricultural Research Station, Jagdalpur, Chhattisgarh. It comes under baster plateau of Chhattisgarh which comprises of large plateau having elevation of 553 m above mean sea level and lies between 17°46' N and 20°34' N latitudes and 80°15' and 82°15' E longitudes.

3.2 Climate

Climatologically, Jagdalpur comes under the seventh agro-climatic region of India *i.e.* Eastern plateau and hills which is classified as sub tropical humid with hot summer and cold winter. The source of rainfall is south-western monsoon. It receives an average annual rainfall of 1326 mm, mostly (85%) precipitated during the period of June to September. A few showers are expected during winter and occasionally during summer months.

3.3 Weather condition during the crop growth period (*kharif* 2013 and 2014)

Weekly pattern of different meteorological parameters during the crop period of *kharif* 2013 and 2014 are depicted in Fig 3.1 and 3.2 (Appendix-I & II). During *kharif* 2013, a total of 1180.9 mm rainfall was recorded against the normal rainfall of 1195 mm. With the onset of monsoon, 102.2 mm of rainfall was received during 23rd SMW. Total rainfall received during the June month was 477.1 mm. In the months of July, August and September rainfall of 189.2, 204.9 and 133.8 mm was received, respectively. Thereafter rainfall continues till the end of the season and a total of 76.3 mm of rainfall was recorded in 43rd SMW in the month of October before the withdrawal of monsoon. The evapo-transpiration, maximum and minimum temperature and wind velocity ranged between 0.6 to 6.7 mm, 27^0 to 34^0 C, 19.2^0 to 22.8^0C and 1.0 to 8.6 km ph respectively (Fig 3.1).

During *kharif* 2014, a total of 1250.8 mm rainfall was recorded against the normal rainfall of 1195 mm. With the onset of monsoon, 94 mm of rainfall was received during 26^{th} SMW. Total rainfall received during June, July, August and September was 152, 336, 327.9 and 351.3 mm, respectively. Thereafter rainfall continues till the end of the season and a total of 106.6 mm of rainfall were recorded in 41^{st} SMW in the October before the withdrawal of monsoon. The evapo-transpiration, maximum and minimum temperature and wind velocity ranged between 1.7 to 3.9 mm, 27.7^0 to 33.6^0 C, 14.6^0 to 24.4^0C and 1.4 to 6.6 km ph, respectively (Fig 3.2).

3.4 Physico-Chemical Characteristics of Soil

Soil samples from 0-20 cm depth were collected from 15 randomly selected spots in the experimental area priar to start of the field experiment with the help of soil auger and the composite sample was prepared for mechanical and chemical analysis during both the years. The soil of the experimental site is characterized as silty loam (fairly levelled). The soil was locally known as Mal **(***Alfisols*). It is well fertile soil belongs to mid land situation of landscape in Jagdalpur. The textural composition and other soil physical and chemical properties of experimental field are given in Table 3.1.

3.5 Cropping history of the field

The experimental field was under cultivation since many years during *kharif* and *rabi* season. The rice - maize/wheat system was adopted since last five years with recommended package and practices.

3.6 Test crop

In Experiment No-I, genotypes *viz* V_1- RR 14 EN-7, V_2- RR 14 EN-8 and V_3-RR 12 EN-11; in Experiment No-II, genotype RR 12 EN-11 and in Experiment No-III, genotype RR 12 EN-1 were grown as local ideotype of red rice.

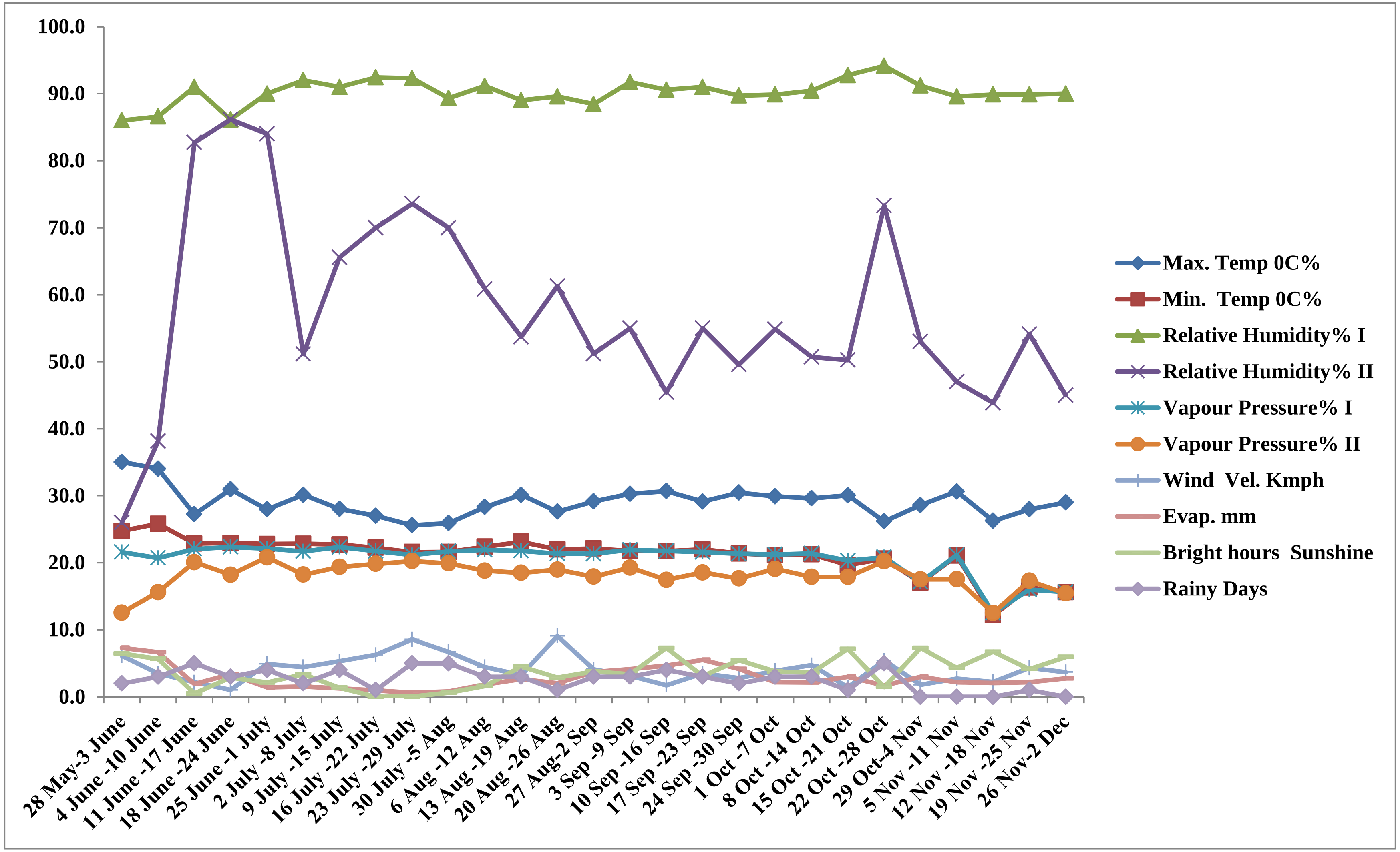


Fig 3.1: Weekly meteorological data during the crop growth period (22 to 48 SMW) of *kharif* 2013

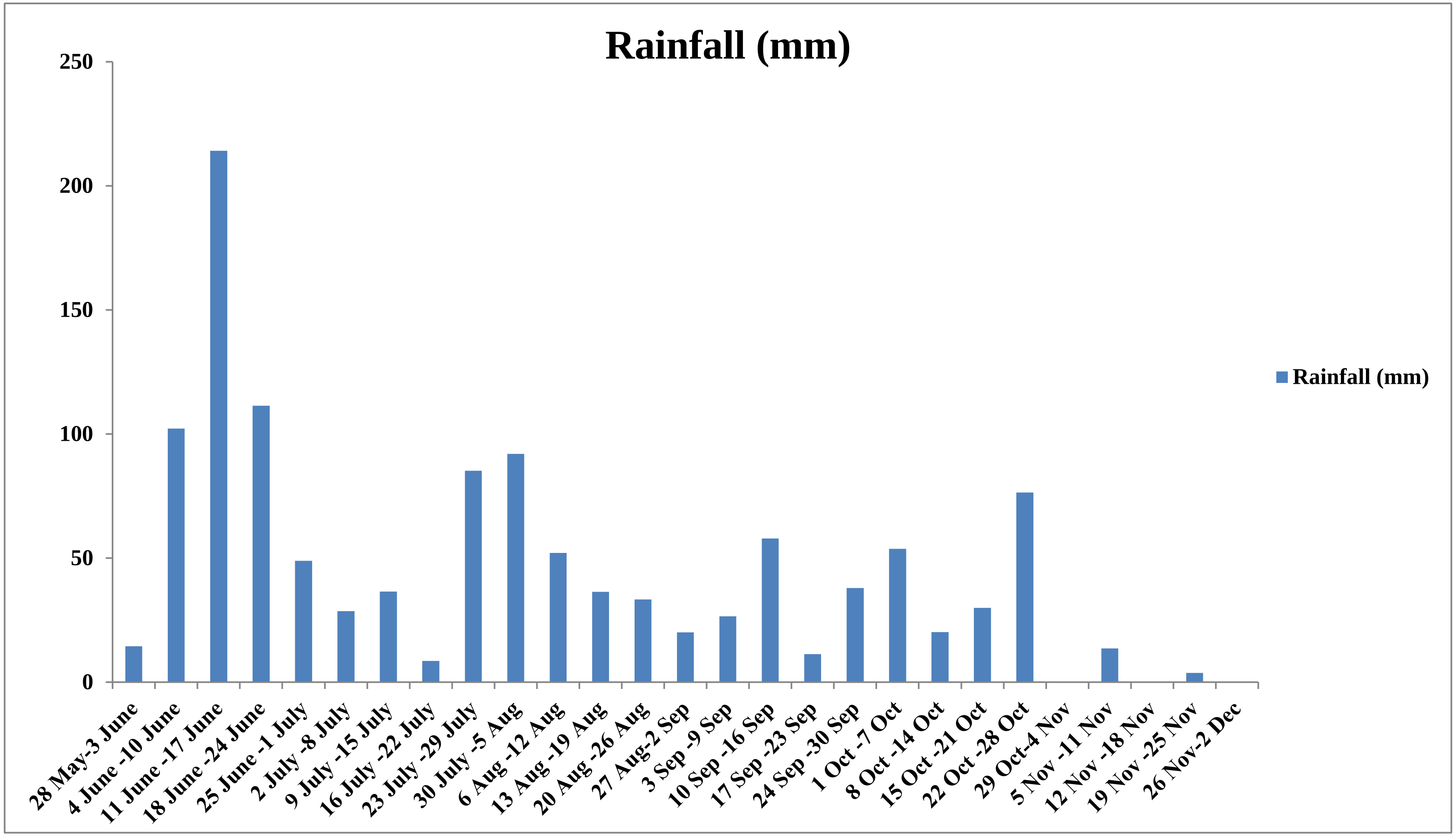


Fig 3.2: Weekly rainfall data during the crop growth period (22 to 48 SMW) of *kharif* 2013

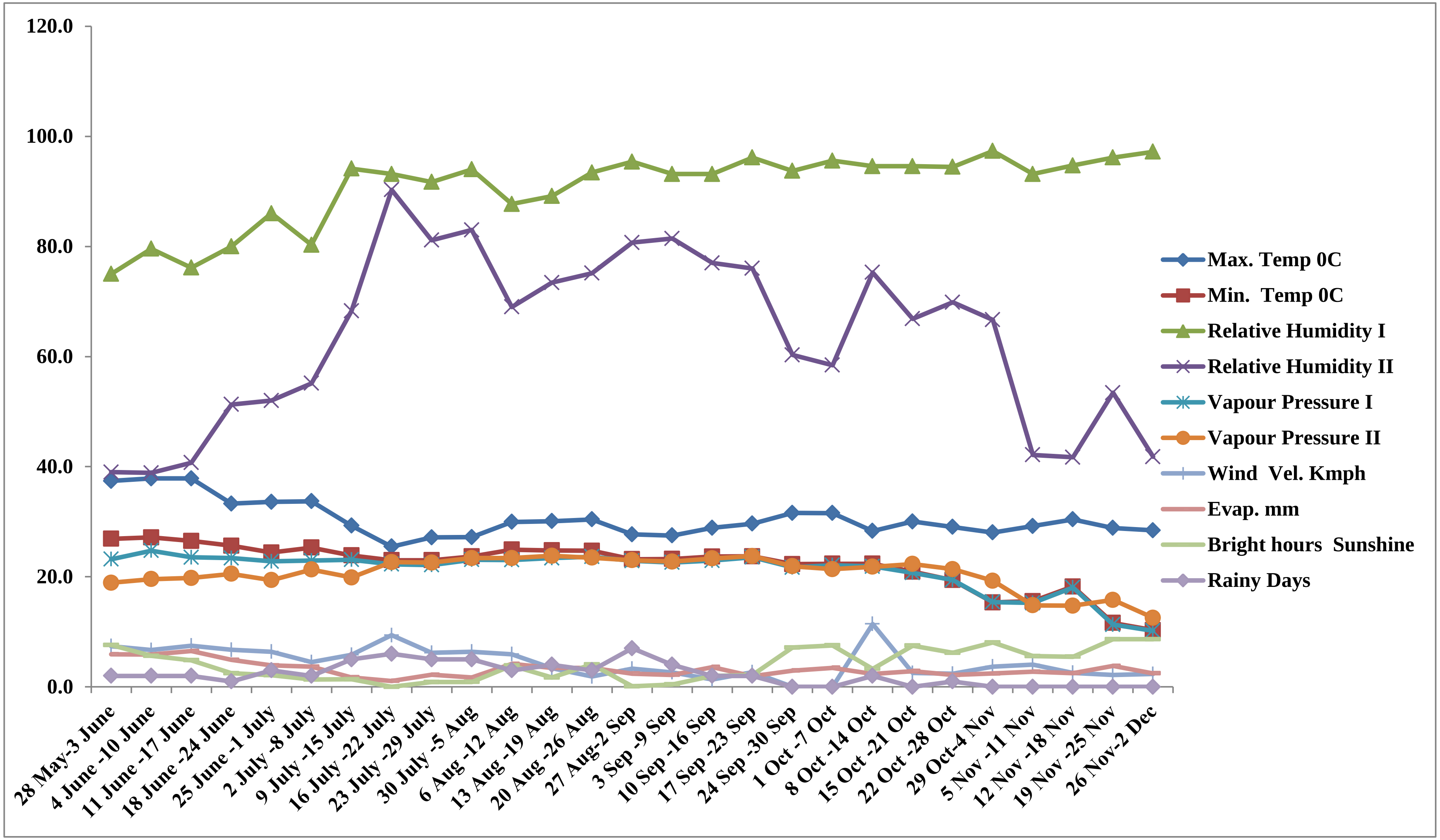


Fig 3.3: Weekly meteorological data during the crop growth period (22 to 48 SMW) of *kharif* 2014

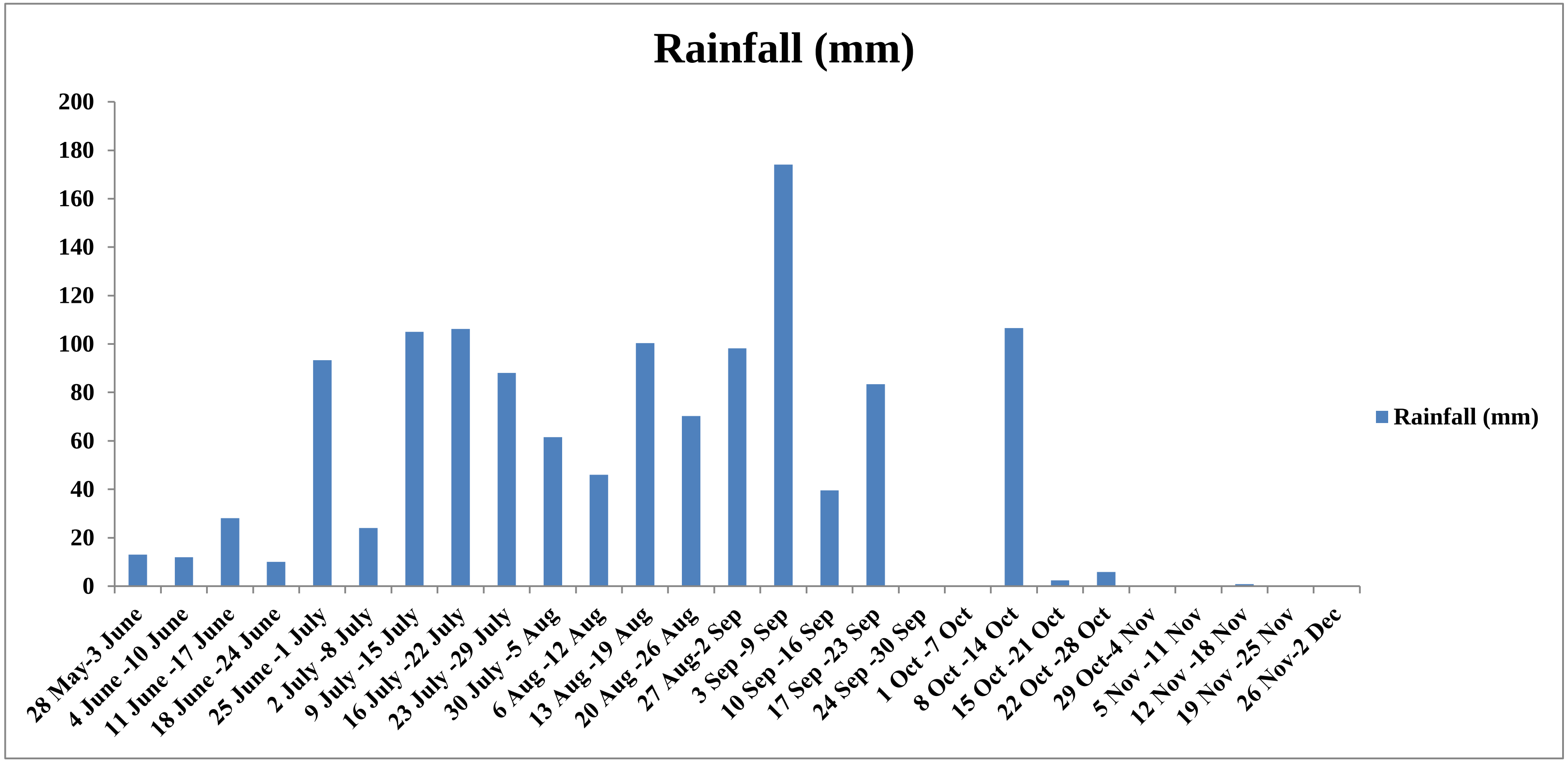


Fig 3.4: Weekly rainfall data during the crop growth period (22 to 48 SMW) of *kharif* 2014

Table 3.1: Initial physico-chemical properties of the soil (0-20 cm) of the experimental soil

Properties	Values				Method of estimation
	Experiment No-I		Experiment No-II and III		
A. Physical	**Values**	**Rating**	**Values**	**Rating**	
Fine Sand (%)	23.42		21.22		International pipette method (Black, 1965)
Silt (%)	44.72		43.22		
Clay (%)	31.86		35.56		
Soil class		*Alfisols* (Mal)		*Alfisols* (Mal)	
Bulk density (Mg m^{-3})	1.52		1.41		Soil core method (Black, 1965)
B. Chemical					
pH (soil: water 1:2.5)	6.1	Acidic	6.4	Acidic	Glass electrode pH meter (Piper, 1967)
EC (dS m^{-1} at 25^oC)	0.21	Normal	0.28	Normal	Solubridge conductivity method (Black,1965)
Organic carbon (%)	0.39	Low	0.42	Low	Walkley and Black's rapid titration method (Black, 1965)
Available N (kg ha^{-1})	218	Low	238	Low	Alkaline permanganate method (Subbiah and Asija,1956)
Available P_2O_5 (kg ha^{-1})	13.45	Low	15.13	Low	Olsen's $NaHCO_3$ (Olsen,1959)
Available K_2O (kg ha^{-1})	296	High	308	High	Flame photometer method (Jackson,1973)

3.7 Experimental details

In Experiment No-I, the treatments comprised of 3 genotype in main-plot, 2 spacing in sub-plot and 3 fertility levels in sub-sub plot. The Experiment No-II was composed of 12 integrated use of inorganic, organic and micro-nutrient, whereas in Experiment No-III, the treatment consisted of 9 organic and inorganic application of nutrients. The treatment details of Experiment No-I, Experiment No-II and III are given in Table 3.2, 3.3 and 3.4, respectively. The layout plan of Experiment No-I, II and III is depicted in Fig 3.3, 3.4 and 3.5, respectively.

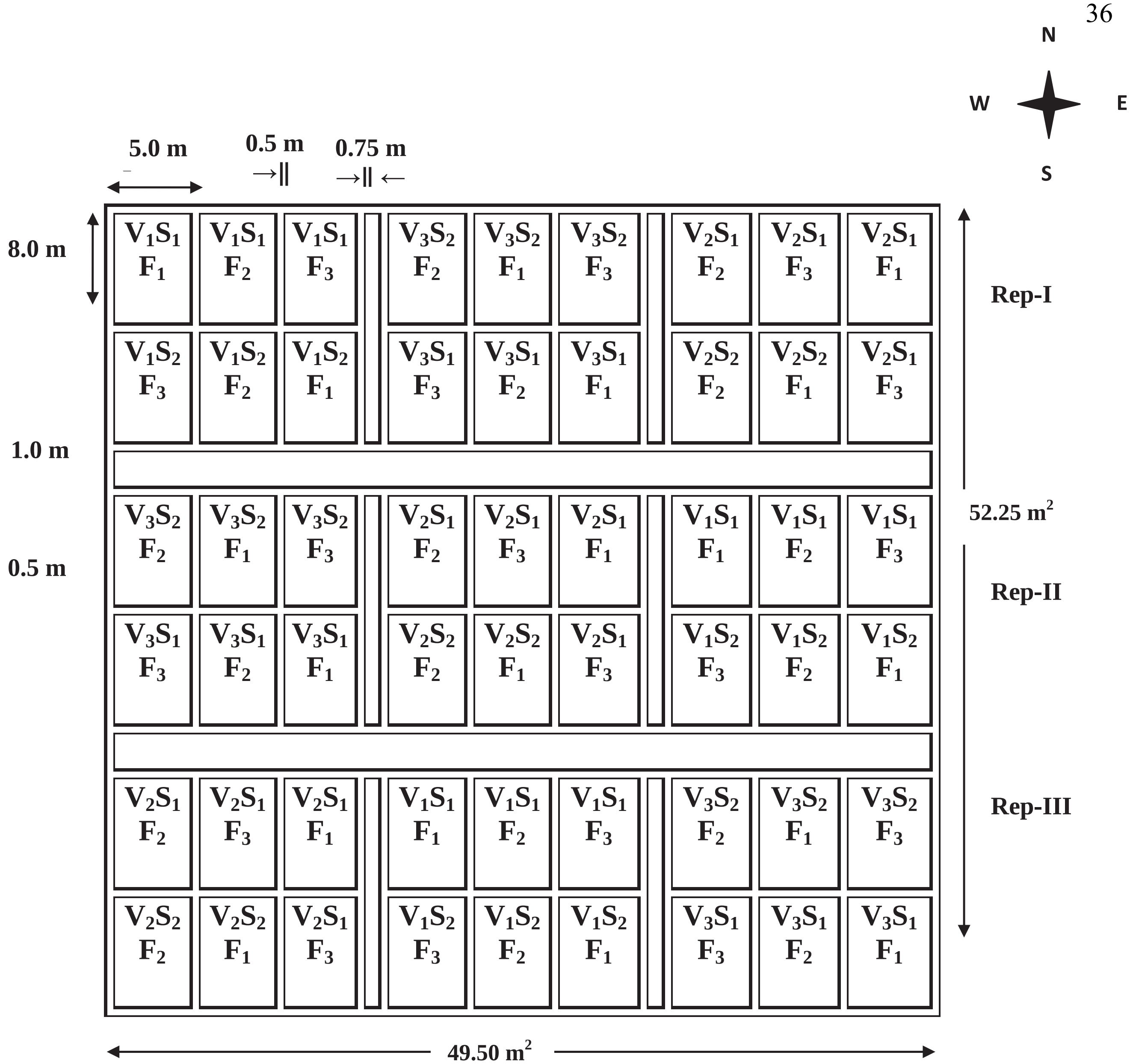
Experiment No-I

Title: Performance of different red rice genotypes under varied spacing and fertility levels

Table 3.2: Treatment details of Experiment No-I

Notation	Treatment details	Abbreviation	Treatment details
(A)	**Main-plot : Genotype (3)**	**(B)**	**Sub-plot:Spacing (2)**
V_1	RR 14 EN-7	S_1	15 cm x 10 cm
V_2	RR 14 EN-8	S_2	20 cm x10 cm
V_3	RR 12 EN-11		
(C)	**Sub-Sub Plot : Fertility levels (3)**		
F_1	60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1})		
F_2	90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1})		
F_3	120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1})		

Design of experiment	:	Split-Split plot design
Number of replications	:	03
Crop	:	Red Rice
Sub-sub plot size		
Gross	:	8.0 m x 5.0 m = 40 m^{-2}
Net		
S_1		7.4 m x 4.6 m = 34.04 m^{-2}
S_2		7.2 m x 4.6 m = 33.12 m^{-2}
Seed rate	:	40 kg ha^{-1}
Spacing between		
Replication	:	1.0 m
Main- plot	:	0.75 m
Sub-plot	:	0.50 m
Sub-sub plot	:	0.50 m
Date of transplanting	:	8.8.2013 and 15.7.2014
Date of harvesting	:	27.11.2013 and 2.11.2014



Treatment details

(A): Main plot : Genotype (3)
V1: RR 14 EN-7
V2: RR 14 EN-8
V3: RR 12 EN-11
(B): Sub plot : Spacing (2)
S1: 15 cm x 10 cm
S2: 20 cm x10 cm
(C): Sub-Sub Plot : Fertility levels (3)
F1: 60:40:30 (N:P_2O_5:K_2O kg ha^{-1})
F2: 90:60:40 (N:P_2O_5:K_2O kg ha^{-1})
F3: 120:60:40 (N:P_2O_5:K_2O kg ha^{-1})

Design : Split-split
Replication : 03
Sub-sub plot size:
Gross : 8.0 m x 5.0 m = 40 m^{-2}
Net
S1 : 7.4 m x 4.6 m = 34.04 m^{-2}
S2 : 7.2 m x 4.6 m = 33.12 m^{-2}
Spacing between
Replication : 1.0 m
Main-plot : 0.75 m
Sub-plot : 0.50 m
Sub-sub-plot: 0.50 m
D/T : 8.8.2013 and 15.07.2014
D/H : 27.11.2013 and 02.11.2014

Fig.3.2: Layout of Experiment no. I (*Kharif* season of 2013 and 2014)

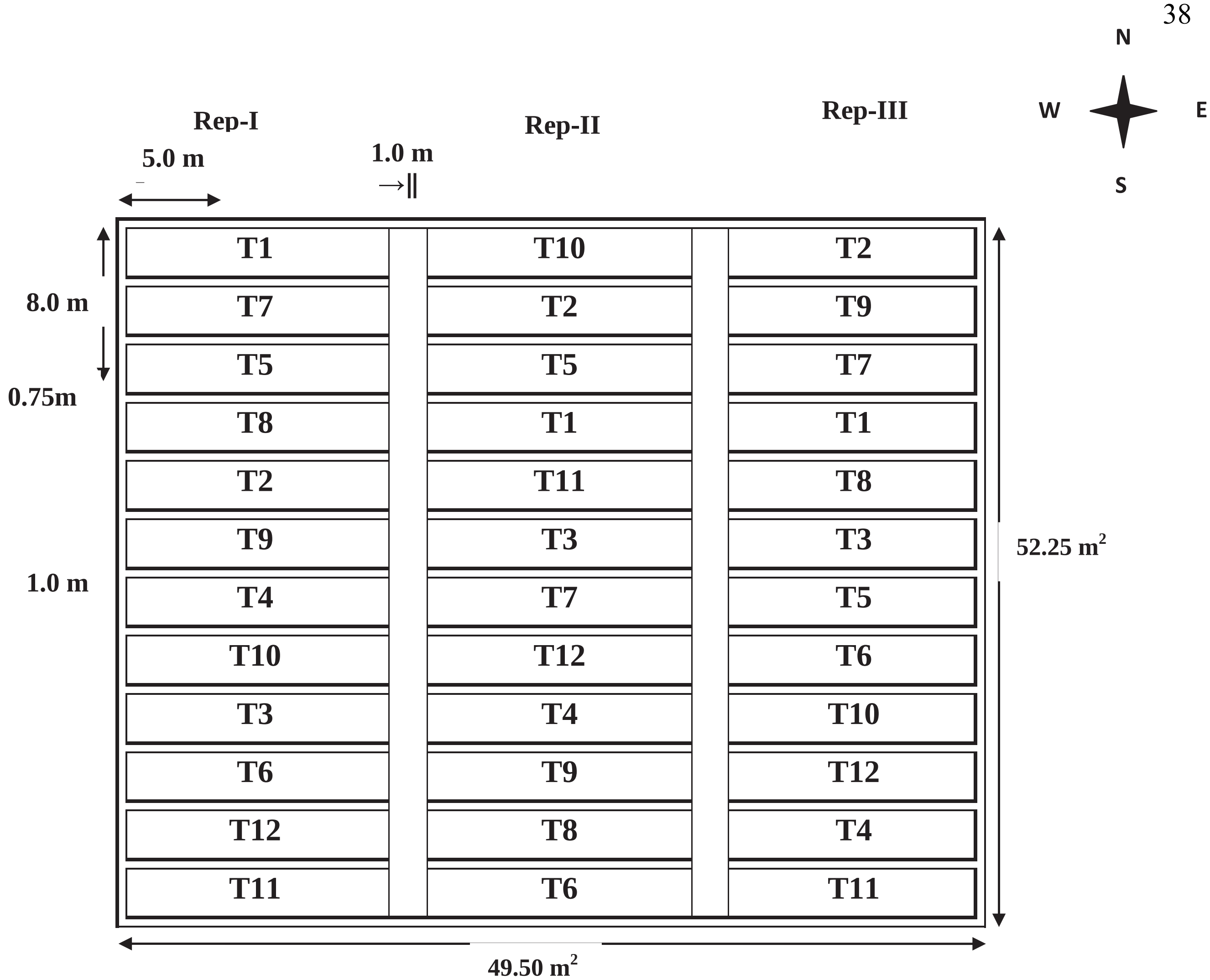
Experiment No-II

Title: Grain yield and nutrient uptake of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Table 3.3: Treatment details of Experiment No-II

Notation	Treatment details	Abbreviation
T_1	80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1})	T_1: $N_{80}P_{60}K_{40}$
T2	120:80:60 ($N:P_2O_5:K_2O$ kg ha^{-1})	T_2: $N_{120}P_{80}K_{60}$
T3	80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + 5t FYM ha^{-1}	T_3:$N_{80}P_{60}K_{40+}FYM_{5t}$
T4	120:80:60 ($N:P_2O_5:K_2O$ kg ha^{-1}) + 5t FYM^{-1}	T_4 :$N_{120}P_{80}K_{60+}$ FYM_{5t}
T5	80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + Zinc (Zn)	T_5 :$N_{80}P_{60}K_{40}$+Zn
T6	80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + Silicon (Si)	T_6 :$N_{80}P_{60}K_{40}$+S_I
T7	80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + Boron (B)	T_7 :$N_{80}P_{60}K_{40}$+B
T8	80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + Zn + Si	T_8 :$N_{80}P_{60}K_{40}$+Zn $_+S_I$
T9	80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + Zn + B	T_9:$N_{80}P_{60}K_{40}$+Zn $_+$B
T10	80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + B + Si	T_{10}: $N_{80}P_{60}K_{40}$+B_+ S_I
T11	80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + Zn + Si + B	T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I+}B
T12	Control (No fertilizer)	T_{12} :Control

Design of experiment	:	Randomized Block Design
Number of replications	:	03
Variety	:	RR 12 EN-11
Plot size		
Gross	:	8.0 m x 5.0 m = 40 m^{-2}
Net	:	7.2 m x 4.6 m = 33.12 m^{-2}
Seed rate	:	40 kg ha^{-1}
Spacing between		
Row x plant	:	20 cm x 10 cm
Replication	:	1.0 m
Plot	:	0.75 m
Date of transplanting	:	11.08.2013 and 16.07. 2014
Date of harvesting	:	20.11.2013 and 23.10.2014



Treatment details
Integrated use of inorganic, organic and micronutrients

T_1: 80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1})

T_2: 120:80:60 ($N:P_2O_5:K_2O$ kg ha^{-1})

T_3: 80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1})+ 5t FYM ha^{-1}

T_4: 120:80:60 ($N:P_2O_5:K_2O$ kg ha^{-1})+ 5t FYM^{-1}

T_5: 80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + Zn

T_6: 80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + S

T_7: 80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + B

T_8: 80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + Zn + S

T_9: 80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + Zn + B

T_{10}: 80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + B + S

T_{11}: 80:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) + Zn + S + B

T_{12}: Control (No fertilizer)

Design : Randomized Block Design
Replication : 03
Gross plot size : 8.0 m x 5.0 m = 40 m^{-2}
Net plot size : 7.2 m x 4.6 m = 33.12 m^{-2}

Spacing between

Replication : 1.0 m
Plot to plot : 0.50
D/T : 11.8.2013 and 16.07.2014
D/H : 20.11.2013 and 23.10.2014

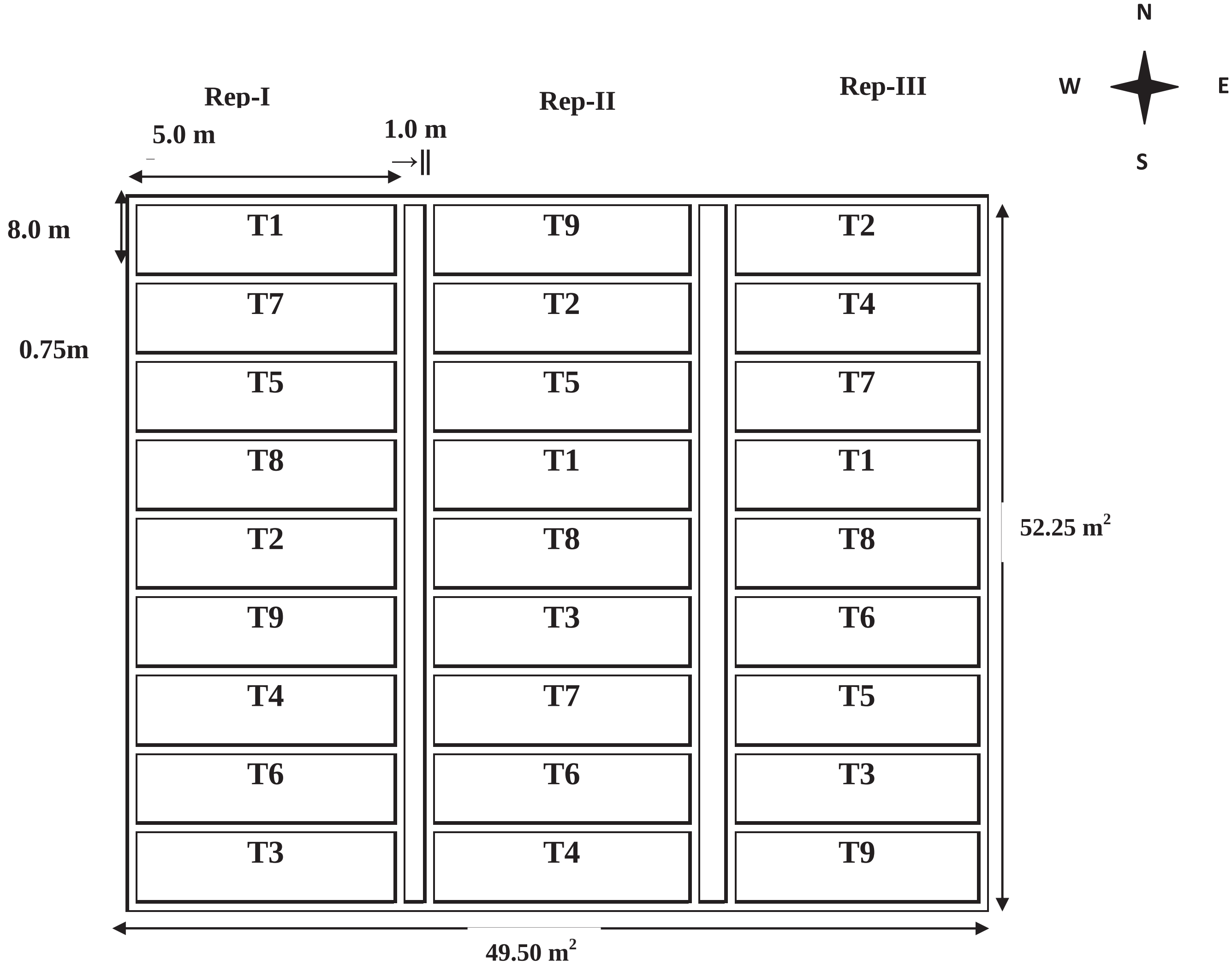
Fig.3.3 Layout of Experiment no. II (*Kharif* season of 2013 and 2014)

Experiment No-III

Title: Enhancement of productivity and quality of red rice through organic and inorganic application of nutrients

Table 3.4: Treatment details of Experiment No-III

Notation	Treatment details	Abbreviation
T_1	60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) through Inorganic	T_1: $N_{60}P_{40}K_{30}$ (I)
T_2	120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) through Inorganic	T_2: $N_{120}P_{60}K_{40}$ (I)
T_3	60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) through 25% organic(O) + 75 % through Inorganic	T_3: N_{60} $P_{40}K_{30}$ (25% O +75% I)
T_4	120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) through 25% organic + 75 % through Inorganic	T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)
T_5	60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) through 50% organic + 50 %through Inorganic	T_5: N_{60} $P_{40}K_{30}$ (50% O +50 % I)
T_6	120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) through 50% organic + 50 % through Inorganic	T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)
T_7	N of T_1 through organic + 2 Foliar spray of N at active tillering and panicle initiation stages	T_7:N of T_1 applied through organics (O) + FS of N at T and PI stages
T_8	N of T_2 through organic + 2 Foliar spray of N at active tillering and panicle initiation stages	T_8:N of T_2 applied through organics (O) + FS of N at T and PI stages
T_9	Control (No fertilizer)	T_9: Control



Treatment details

Integrated use of inorganic, organic and micronutrients

T_1: 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) through inorganic

T_2: 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) through inorganic

T_3: 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) through 25% organic + 75% through inorganic

T_4: 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) through 25% organic + 75% through inorganic

T_5: 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) through 50% organic + 50% through inorganic

T_6: 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) through 50% organic + 50% through inorganic

T_7: N of T_1 through organic + 2 foliar spray of N at active tillering and panicle initiation stages

T_8: N of T_2 through organic + 2 foliar spray of N at active tillering and panicle initiation stages

T_9: Control (No fertilizer)

Design : Randomized Block Design **Replication** : 03 **Gross plot size** : 8.0 m x 5.0 m = 40 m^{-2} **Net plot size** : 7.2 m x 4.6 m = 33.12 m^{-2}	**Spacing between** **Replication** : 1.0 m **Plot to plot** : 0.50 **D/T** : 13.8.2013 and 16.07.2014 **D/H** : 18.10.2013 and 02.10.2014

Fig.3.4 Layout of Experiment no. III (*Kharif* season of 2013 and 2014)

Design of experiment	:	Randomized Block Design
Number of replications	:	03
Variety	:	RR 12 EN-1
Plot size		
Gross	:	8.0 m x 5.0 m = 40 m^{-2}
Net	:	7.2 m x 4.6 m = 33.12 m^{-2}
Seed rate	:	40 kg ha^{-1}
Spacing between		
Row x Plant	:	20 cm x 10 cm
Replication	:	1.0 m
Plot	:	0.75 m
Date of sowing	:	13.08.2013 and 16.07.2014
Date of harvesting	:	18.10.2013 and 02.10.2014

3.8 Nursery management and transplanting

Red rice seedlings were grown on raised bed nursery having of 3.0 m length x 1.5 m width. Bed was raised up to height of 15 cm. To achieve good germination and healthy seedlings, seeds were sown in line with 5 cm apart. Seed rate @ 40 kg ha^{-1} was taken and treated with bavistin @ 2.5 g kg^{-1} seed. Nursery was kept insect pest, diseases and weed free. Twenty to twenty five days seedlings were transplanted at shallow depth. Two to three seedlings $hill^{-1}$ of each genotype was used as required in different experiments.

3.9 Fertilizer application

In Experiment No-I, the nitrogen, phosphorous and potash were applied as per treatments. The 50 % dose of nitrogen and 100 % recommended dose of phosphorus and potassium were applied as basal and remaining nitrogen was applied in two equal split during tillering and panicle initiation stages of the crop. In Experiment No-II, N, P and K were applied as indicated in Experiment No-I. Further, the organic source FYM (N and K 0.5 % and P 0.2 %) and K and micro nutrients like Zinc sulphate @ 25 kg ha^{-1}, borax @ 10 kg ha^{-1} and silicon @ 4 kg ha^{-1} were applied as basal dose. In Experiment No-III, the N, P and K were applied as indicated in above experiments. Further, the organic manure was applied as basal and foliar application of nitrogen was done as per treatments.

3.10 Weed management

One manual weeding was done at 30 DAT in all three experiments.

3.11 Water management

The experiments were raised totally based on natural rainfall maintaining water depth of 5 ± 2 cm with provision of drainage to remove excess of rainfall.

3.12 Plant protection

In both years, fungicide tricyclazole was sprayed at the rate of 0.3 % as per need.

3.13 Harvesting and threshing

Harvesting and threshing of all red rice ideotypes was done manually to minimize yield losses and reducing experimental error by using sickle.

3.14 Cultural operations and application of treatments

Table 3.5: Calendar of cultural operations in red rice

SN.	Operation	Experiment No-I		Experiment No-II		Experiment No-III	
		2013	2014	2013	2014	2013	2014
1.	Ploughing	13.07.2013	19.06.2014	13.07.2013	19.06.2014	13.07.2013	19.06.2014
2.	Nursery	15.07.2013	20.06.2014	15.07.2013	20.06.2014	15.07.2013	20.06.2014
3.	Transplanting	08.08.2013	15.07.2014	11.08.2013	16.07.2014	13.08.2013	16.07.2014
4.	Hand weeding	05.09.2013	08.08.2014	07.09.2013	09.08.2014	15.09.2013	13.08.2014
5.	Top dressing						
	I-At Tillering	04.09.2013	12.08.2014	06.09.2013	14.08.2014	11.09.2013	13.08.2014
	II-At PI stage	29.09.2013	09.09.2014	30.09.2013	10.09.2014	26.09.2013	06.09.2014
6.	Fungicide	02.09.2013	28.08.2014	13.09.2013	02.09.2014	22.09.2013	26.08.2014
7.	Rouging	1.10.2013	19.09.2014	3.10.2013	21.09.2014	25.09.2013	09.09.2014
8.	Harvesting	27.11.2013	2.11.2014	20.1120.13	23.10.2014	18.10.2013	02.10.2014

3.15 Observations recorded

3.15.1 Pre-harvest studies

In order to record pre - harvest observations of red rice, five randomly selected hills in each treatment were marked in all the three experiments. The observation on different parameters was taken at 30, 60 and 90 DAT.

3.15.1.1 Plant height

Five randomly selected hills were marked and the plant height was measured with the help of meter scale from the base of the plant to the tip of the top most leaf and then average was worked out.

3.15.1.2 Leaf area index (LAI)

Leaf area index is defined as leaf area per unit land area. It was calculated by dividing the leaf area per plant by the land area occupied by single plant (Sestak *et al*., 1971).

$$LAI = \frac{Total\ leaf area\ of the\ hill}{Total\ ground\ area\ of\ the\ hill}$$

3.15.1.3 Dry matter accumulation (g hill^{-1})

Plants from five hills in each plot from the second were selected randomly and uprooted carefully then thoroughly washed and after complete drying, the sample was oven dried at 60°C to get constant weight. The oven dry weight was recorded and expressed in g hill^{-1}.

3.15 .1.4 Crop growth rate (CGR)

The crop growth rate was calculated for period 0-30, 30-60 and 60-90 DAT with the help of following formula:

$$\text{Crop growth rate (g hill}^{-1}\text{day}^{-1}) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

W_2 and W_1 are the total dry weight of plant at the time t_2 and t_1, respectively.

3.15.1.5 Relative growth rate (RGR)

The RGR was worked out with the help of following formula:

$$\text{Relative growth rate (g g}^{-1}\text{ hill}^{-1}\text{ day}^{-1}) = \frac{LnW_2 - LnW_1}{t_2 - t_1}$$

Where,

LnW_1 and LnW_2 are the natural logarithm of total dry weight of plant at the time interval t_2 and t_1, respectively.

3.15.2 Post-harvest studies

3.15.2.1 Number of effective tillers hill^{-1}

Numbers of effective tillers were counted from five randomly selected hills and then mean was worked out for expressed as effective tillers hill^{-1}.

3.15.2.2 Panicle length (cm)

The length of five randomly selected panicles was measured and then mean was worked out.

3.15.2.3 Panicle weight (g)

The weight of five randomly selected panicles was measured and then mean was worked out.

3.15.2.4 Grains panicle^{-1}

Total grains were counted from five panicles which were already collected for measurement of length and then mean was worked out.

3.15.2.5 1,000 grain weight (g)

The weight of thousand grains were recorded from the samples drawn from the produce obtained in each of the net plot and is expressed in gram per thousand grains.

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

The harvested crop was threshed manually and the grain weight was recorded. Average grain yield for each plot was worked out separately and converted into q ha^{-1}.

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

It was calculated by subtracting the grain yield from the total biomass production.

3.15.2.8 Harvest index (%)

It was calculated by using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Total biomass yield (kg ha}^{-1}\text{)}} \times 100$$

3.15.2.9 Root biomass (cc)

Five hills were uprooted carefully from the second row of each plant with the help of root sampler, washed it and measured with help of measuring known volume of water filled cylinder and dipping the root and increased in volume of water was measured.

3.16 Chemical analysis

Soil samples were collected from each plot following standard soil sampling technique at initially and at harvest of rice. Analysis of organic carbon (Walkely and Black's rapid titration method; Black, 1965), available N (Alkaline permanganate method; Subbiah and Asija, 1956), P (Olsen's $NaHCO_3$; Olsen *et al.,* 1959) and K (Flame photometer method; Jackson, 1973) were carried out.

N, P and K content were determined in grain and straw of red rice .The analysis was done by micro kjeldhal, vanadomolybdate yellow colour and flame photometer for nitrogen, phosphorus and potassium, respectively. The N, P and K uptake was also worked out by multiplying concentration with respective dry weight of rice grain on oven dry basis.

3.16.1 Iron and Zinc estimation

Whole rice grains were subjected to di-acid mixture based digestion as described below in triplicate with rice flour as a standard in each batch of digestion to establish accuracy of digestion. Iron and zinc content was estimated by using standard method described under *Harvest Plus*, (2006) guidelines using Atomic Absorption Spectrophotometer (AAS 200, Perkin Elmer make). Rice flour standards (SRM 1568a; National Institute of Standards and Technology, Gaithersburg, MD) were digested and analyzed along with the tissue samples to ensure accuracy of the instrument calibration. The protocol for step-wise procedure is as follows.

1. 0.5 g of rice sample of each rice genotype under study was placed in a vessels and 11ml of di-acid mixture (9 ml HNO_3, 2 ml HCl) was added and kept overnight at room temperature for pre-digestion.
2. Digestion was carried out at temperature 180^0C in a microwave digestion chamber (CEM-MARS equipment) for 45 minutes.
3. Completion of digestion was confirmed when the liquid turns colorless.
4. After cooling, the solution was filtered through a whatman’s No. 40 filter paper and volume of the filtrate was made up to 50 ml using double distilled water. Aliquots of this solution were used for determination of Fe and Zn using atomic absorption spectrophotometer.

Reagents and solutions used for Iron and Zinc estimation

1. Acid mixture

- 9 ml Nitric acid (HNO_3),
- 2 ml Hydrochloric acid (HCL) (All glass distilled or A.R. grade)

1. Zero TDS water (Total Dissolved Solutes) for volume make up to 50 ml.

3.17Quality characters

3.17.1 Paddy length and breadth (mm)

Ten paddy were taken randomly and average length and breadth were recorded in mm.

3.17.2 Paddy length: breadth ratio

It was calculated by the formula:

$$\text{Paddy length: breadth ratio} = \frac{\text{Length of paddy grain}}{\text{Breadth of paddy grain}}$$

3.17.3 Head rice recovery percentage

Head rice recovery percentage was recorded on 100 g composite seed sample collected from each plot in each replication separately .Seed samples were hulled and milled by Satake huller and miller and the percentage of head rice recovery was calculated as procedure given by Govindasawamy and Ghosh, (1969).

3.18 Production efficiency

Production efficiency was calculated using formula given by Tomar and Tiwari (1990) as fallows:

$$\text{Production efficiency (kg ha}^{-1}\text{ day}^{-1}\text{)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Duration of the crop (Days)}}$$

3.19 Energetic

Energy inputs were calculated and estimated in Mega Joule (MJ) ha^{-1} with reference to the standard values prescribed by Mittal *et al*. (1985). These inputs were taken to each treatment of rice. The standard energy coefficient for seed and straw of rice was multiplied with their respective yields and summed up to obtain the total energy output. The energy input for rice was calculated by adding the respective values. Energy use efficiency, energy output-input ratio, energy productivity and energy intensiveness were calculated as per the following formulas:

$$\text{Energy use efficiency (MJ}^{-1}\text{x}10^{-3}\text{)} = \frac{\text{Total produce}}{\text{Energy input (MJx}10^{-3}\text{)}}$$

$$\text{Energy output input ratio} = \frac{\text{Energy output}}{\text{Energy input}}$$

$$\text{Energy productivity (g MJ ha}^{-1}\text{)} = \frac{\text{Mean grain yield (g)}}{\text{Total energy input (MJ)}}$$

$$\text{Energy of intensiveness (MJ Re}^{-1}\text{)} = \frac{\text{Total energy output (MJ)}}{\text{Total cost incurred (Rs)}}$$

3.20 Economic analysis

The cost of cultivation of individual crop was calculated on the basis of prevailing market prices for different inputs. Net return was calculated by deducting the cost of cultivation from the gross return. Benefit- cost ratio was compared by dividing net return with cost of cultivation. The values for calculation of cost of cultivation were presented in Appendix III and IV.

3.21 Statistical analysis

The data obtained on various parameters were tabulated and subjected to statistical analysis. The difference of treatment was tested with ‘F’ test, where ‘F’ test shown their significance, the level of treatment were compared by critical difference at 5% level of probability. The skeleton of analysis of variance and formula used for various estimations are given by Gomez and Gomez, (1984).

CHAPTER-IV
RESULTS AND DISCUSSION

Research trials on **"Productivity and Quality of Red Rice (*Oriza sativa* L.) Genotypes as Influenced by Organic, Inorganic and Integrated Nutrient Management Practices**" were conducted at Instructional cum Research Farm of Shaheed Gundadhoor College and Agricultural Research Station, Jagdalpur, Chhattisgarh during *kharif* season of 2013 and 2014. In both *kharif* season three experiments were conducted .In first experiment entitled "**Performance of different red rice genotypes under varied spacing and fertility level**", the treatments comprised of 3 genotype in main-plot, 2 spacing in sub-plot and 3 fertility levels in sub-sub plot. Whereas, in second experiment entitled "**Grain yield and nutrient uptake of red rice as influenced by integrated use of inorganic, organic and micro nutrients**", the treatments was composed of 12 integrated use of inorganic, organic and micro-nutrient. Further, in third experiment entitled "**Enhancement of productivity and quality of red rice through organic and inorganic application of nutrients**", the treatment consisted of 9 organic and inorganic application of nutrients.

In this chapter experiment wise findings are presented with help of table and graphics related to the mandate of experiments .The interpretation in terms of cause and effect relationship highlighted in this chapter along with earlier established scientific views of national and international research works.

4.0 Weather effect

Rice is one of the most important agricultural products and it is cultivated in almost all countries in the world. Climate chooses the right crop for a particular environment, while the prevailing weather condition of that environment decides the potentiality of that crop. The most important weather parameters are rainfall, temperature and solar radiation. Rainfall (spatial and temporal variation) is the direct critical weather parameter in rainfed ecologies. When considering the growth stages of rice, reproductive and ripening stages are the most sensitive stages to weather.

Spikelet fertility is the most sensitive yield component when rice is subjected to stress *viz*., low or high temperature, low solar radiation or water deficit (drought).

The rice plant usually takes 3-6 months from germination to maturity, depending on the variety and the environment. Agronomically the growth cycle can be divided into 3 growth stages: vegetative, reproductive, and ripening. Vegetative stage: tillering, gradual increase in plant height and leaf emergence. Start of tillering when the 5th or 6th leaf develops. Differences in growth duration are primarily due to differences in the length of the vegetative growth stage. (*e.g.* early maturing varieties have short vegetative stages). Heading synonym for anthesis usually defined as the time when 50% of the panicles have exerted. It takes 10-14 days for a crop to complete heading because there is a variation in panicle excretion within tillers of the same plant and between plants in the same field.

The weather data during the experimentation periods indicated that the weekly average sunshine hour varied from 0-7.3 hrs day^{-1} and 0.1-7.5 hrs day^{-1} during *kharif* period 2013 and 2014, respectively. Even due to cloudy weather diffused sun light favored the red rice crop during both years. So far rainfall is concerned during cropped period 695.9 mm and 792 mm with 50 and 49 rainy day were noted in 2013 and 2014 rainfall, respectively. The rainy days indicate that on an average after three days rain was received during both cropping season. The maximum temperature varied from 25.6^{0} C in fourth week of July to 30.7^{0}C in third week of September 2013, further in year 2014, its varied from 26^{0} C in fourth week of November to 31.6^{0}C in fourth week of September month. The minimum temperature experienced by rice crop varied from 17^{0} C in fourth week of October to 23.1^{0}C in third week of August during 2013, further in year 2014, it varied from 6.3^{0}C in fourth week of November to 29.80C in third week of July. The relative humidity ranged between 45.4–89.9 and 33.4- 96.6, during 2013 and 2014, respectively. The evapo-transpiration ranged between 0.6-5.5 mm and 1.7-4.7 mm during 2013 and 2014 respectively. Further, the wind velocity ranged between 1.4-9.1 km hr^{-1} and 1.7-11.4 km hr^{-1} during 2013 and 2014, respectively.

4.1 Experiment No. I : Performance of different red rice genotypes under varied spacing and fertility level

4.1.1 Pre-harvest studies

4.1.1.1 Plant height (cm)

The data on plant height of different red rice genotypes under varied spacing and fertility level recorded at 30, 60 and 90 DAT are presented in Table 4.1.1. Among the genotypes, taller plant of red rice was recorded for red rice genotype VRR12EN-11which was significantly superior over RR14EN-7 and RR14EN-8 at all the crop grwoth stages during both the years and on mean basis.

As regard to spacing rice planted at 20 cm x 10 cm was found to be better for producing taller plant as compared to other planting geometry during both the years and on mean basis.

The fertility levels found non-significant for plant height at all the crop growth stages during both the years and on mean basis.

The significant interaction effect for plant height was noted under genotype x spacing, and it was noted that in interaction RR12EN-11 x 20cm x 10cm produced taller plants at all the growth stages during both the years and on mean basis, however, it was at par to interaction between RR12EN-11 x 15 cm x10 cm at 30 and 60 DAT during 2014, as well as interaction between RR12EN-11 x 15cm x10cm at 30 DAT during (Table 4.1.2).

Interaction between genotype x fertility levels for plant height was significant during both the years and on mean basis at all growth stages. Significantly taller plant was noted under interaction between RR 12 EN-11 x 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1}, but it was at par with interaction between RR 12 EN-11 x 90:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} at 30 DAT (Table 4.1.3).

4.1.1.2 Dry matter accumulation (g $hill^{-1}$)

Dry matter accumulation recorded at 30, 60 and 90 DAT was influenced significantly due to genotypes planted under varied spacing and fertility levels (Table 4.1.1.4). At all the stages significantly highest dry matter accumulation was noticed under

Table 4.1.1: Plant height at different stages of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	Plant height (cm)								
	30 DAT			60 DAT			90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Genotypes									
V1	15.48	15.93	15.71	54.16	56.06	55.11	73.32	74.87	74.09
V2	17.62	18.89	18.26	56.53	58.36	57.44	77.64	80.14	78.89
V3	21.29	22.96	22.13	65.11	66.36	65.73	133.82	136.00	134.91
SEm±	0.30	0.40	0.33	1.13	1.18	1.11	0.39	0.69	0.41
CD (P=0.05)	0.91	1.19	1.00	3.38	3.53	3.34	1.16	1.80	1.23
Spacing									
S1	17.65	18.77	18.21	56.99	58.77	57.89	93.84	95.85	94.84
S2	18.61	19.76	19.19	60.20	61.74	60.97	96.02	98.16	97.09
SEm±	0.31	0.23	0.26	0.30	0.92	0.59	0.37	0.50	0.42
CD (P=0.05)	0.92	0.69	0.78	0.89	2.81	1.77	1.10	1.51	1.27
Fertility levels									
F1	15.29	16.51	15.90	55.62	57.43	56.53	74.83	92.14	91.12
F2	18.16	18.94	18.55	59.40	61.01	60.20	78.07	97.28	96.36
F3	20.95	22.33	21.64	60.78	62.34	61.56	77.50	101.58	100.41
SEm±	2.68	3.12	2.96	13.78	11.14	10.78	3.56	4.13	3.16
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
VXS	S	S	S	S	S	S	S	S	S
VXF	S	S	S	S	S	S	S	S	S
SXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3), **Sub-plot : Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2),**Sub-Sub Plot : Fertility levels (3);** 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.2: Plant height (cm) at different duration of red rice as influenced by interaction between genotypes and spacing

Treatment	Spacing (cm)											
	30 DAT		60 DAT		90 DAT		30 DAT		60 DAT		90 DAT	
	2013						2014					
Genotype	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
VI	14.89	16.09	51.61	56.70	73.11	73.53	15.28	16.59	53.88	58.24	74.31	75.42
V2	16.78	18.48	55.69	57.37	76.80	78.48	18.27	19.51	57.58	59.14	79.10	81.19
V3	22.31	21.27	63.68	66.54	131.60	136.03	22.76	23.17	64.88	67.83	134.14	137.86
	2013						2014					
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
Comparison of three genotype at the same level of spacing	0.53	1.58	0.51	1.53	0.63	1.90	0.40	1.19	1.60	4.86	0.87	2.61
Comparison of two spacing at the same level of genotype	0.47	1.42	0.55	1.64	0.61	1.88	0.48	1.44	0.95	2.84	0.68	2.06

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3),
Sub-plot : Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2)

Table 4.1.3: Plant height (cm) at different duration of red rice as influenced by interaction between genotype and fertility levels

Treatment	30 DAT 2013			60 DAT 2013			90 DAT 2013			30 DAT 2014			60 DAT 2014			90 DAT 2014		
Genotype	**F1**	**F2**	**F3**	**F1**	**F2**	**F3**	**F1**	**F2**	**F3**	**F1**	**F2**	**F3**	**F1**	**F2**	**F3**	**F1**	**F2**	**F3**
VI	12.40	15.20	18.87	53.08	57.87	51.52	68.45	73.97	77.55	13.17	15.57	19.07	55.55	60.08	52.55	69.88	75.13	79.58
V2	14.63	17.13	21.12	53.02	55.60	60.97	75.95	78.75	78.22	15.80	17.82	23.05	54.00	57.40	63.68	78.30	80.93	81.20
V3	18.85	22.15	22.88	60.75	64.73	69.85	125.8	133.6	141.9	20.57	23.45	24.87	62.75	65.53	70.78	128.2	135.7	143.9

	2013						2014					
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three genotype at the same fertility levels	0.47	1.42	0.55	1.64	0.61	1.88	0.48	1.44	0.95	2.84	0.68	2.06
Comparison of fertility levels at the same level of genotype	0.53	1.58	0.51	1.53	0.63	1.90	0.40	1.19	1.60	4.86	0.87	2.61

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3), **Sub-Sub Plot : Fertility levels (3);** 60:40:30 (N:P_2O_5:K_2O kg ha^{-1}) (F1), 90:60:40 (N:P_2O_5:K_2O kg ha^{-1}) (F2), 120:60:40 (N:P_2O_5:K_2O kg ha^{-1}) (F3)

Table 4.1.4: Dry Weight at different stages of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	Dry matter accumulation (g $hill^{-1}$)								
	30 DAT			60 DAT			90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Genotypes									
V1	9.09	13.27	11.22	18.57	20.31	19.46	30.49	32.61	31.64
V2	8.36	14.02	11.21	20.21	21.33	20.81	30.96	32.58	32.56
V3	9.29	14.42	11.89	23.94	24.15	24.07	39.32	40.63	40.86
SEm±	0.29	0.27	0.26	0.15	0.88	0.50	0.34	0.22	0.50
CD (P=0.05)	NS	0.80	NS	0.45	2.66	1.50	1.02	0.65	1.51
Spacing									
S1	8.80	13.56	11.21	20.14	21.50	20.85	32.87	34.51	34.28
S2	9.03	14.24	11.67	21.67	22.37	22.04	34.31	36.03	35.76
SEm±	0.33	0.09	0.14	0.10	0.98	0.17	026.	0.16	0.16
CD (P=0.05)	NS	0.26	0.43	0.32	N.S	0.50	0.77	0.48	0.49
Fertility levels									
F1	8.87	12.62	10.77	19.19	20.23	19.73	31.49	33.03	33.19
F2	9.24	14.07	11.69	20.66	22.11	21.41	33.94	35.54	35.34
F3	8.63	15.03	11.86	22.88	23.46	23.19	35.33	37.24	36.53
SEm±	0.22	0.16	0.21	0.16	0.95	0.26	0.36	0.45	0.46
CD (P=0.05)	NS	0.47	0.62	0.50	NS	0.79	NS	1.36	NS
Interaction									
VXS	NS	S	S	S	S	S	S	S	S
VXF	NS	S	NS	S		S	S	S	S
SXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), , RR 12 EN-11 (V3), **Sub-plot : Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2),
Sub-Sub Plot : Fertility levels (3): 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.5: Dry weight (g hill^{-1}) at different stages of red rice as influenced by interaction between genotypes and varied spacing

	Spacing (cm)											
	30 DAT		60 DAT		90 DAT		30 DAT		60 DAT		90 DAT	
	2013						2014					
Genotype	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
VI	8.50	9.69	17.41	19.73	29.71	31.27	12.49	14.06	19.19	21.43	31.54	33.67
V2	8.46	8.27	19.96	20.47	30.76	31.17	14.43	13.60	21.04	21.62	32.28	32.88
V3	9.43	9.14	23.07	24.82	38.14	40.49	13.77	15.08	24.26	24.04	39.71	41.54
	2013						2014					
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
Comparison of three rice genotype at the same level of spacing	0.15	NS	0.19	0.55	0.45	1.32	0.16	0.44	0.68	1.98	0.29	0.82
Comparison of two spacing at the same level of genotype	0.14	NS	0.33	0.88	0.41	1.20	0.27	0.81	0.72	NS	0.83	2.36

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2)

Table 4.1.6: Dry weight (g hill^{-1}) at different stages of red rice as influenced by infraction between genotypes and fertility levels

Treatment	Fertility levels																	
	30 DAT			60 DAT			90 DAT			30 DAT			60 DAT			90 DAT		
	2013									2014								
Genotype	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**
VI	9.35	8.65	9.28	16.83	18.05	20.83	28.87	30.38	32.22	11.78	12.83	15.20	18.42	19.72	22.80	31.22	32.43	34.17
V2	7.87	8.65	8.57	17.55	20.50	22.58	29.48	30.68	32.72	13.10	14.72	14.23	18.92	21.95	23.13	31.38	32.02	34.33
V3	9.40	10.43	8.03	23.20	23.42	25.22	36.13	40.77	41.05	12.97	14.65	15.65	23.37	24.65	24.43	36.50	42.17	43.22

	2013						2014					
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.14	N.S	0.33	0.88	0.41	1.20	0.27	0.81	0.72	NS	0.83	2.36
Comparison of two spacing at the same level of genotype	0.15	NS	0.19	0.55	0.45	1.32	0.16	0.44	0.68	1.98	0.29	0.82

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3),**Sub-Sub Plot : Fertility levels (3);** 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3) genotype RR 12 EN-11 during both the years and on mean basis, however it was at par to genotype RR14EN-8 at 30 DAT during 2014.

As regards to spacing, significantly highest dry matter accumulation was noted under 20cm x 10cm (S_2) as compared to 15cm x 10cm (S_1) at all the growth stages during both the years and on mean basis.

Regarding fertility levels, application of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) produced significantly highest dry matter accumulation at all the growth stages during both the years and on mean basis.

The interaction effect of genotype x spacing revealed that interacton between RR12EN-11 x 20cm x 10 cm produced significantly highest dry matter accumulation at all the stages during both the years and on mean basis, however, it was at par to interaction between RR12EN-11 x 15cm x 10cm at 60 DAT during 2014 and interaction between RR 14 EN-7 x 20cm x 10cm, RR14 EN-8 x 15cm x 10cm and RR12EN-11 x 15cm x 10cm at 30 DAT on mean basis (Table 4.1.5). As regards to interaction effect of genotype x fertility levels at most of the crop stages interaction between RR12EN-11 x 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} recorded significantly highest dry matter accumulation during both the years and on mean basis, however it was at par to interaction between RR 12 EN-11 x 90:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} at 90 DAT during 2014 (Table 4.1.6). Further, other interactions were found non significant.

4.1.1.3 Leaf area index

The data on leaf area index was recorded at 30, 60 and 90 DAT and presented in Table 4.1.7**.** The leaf area index increased from 30 DAT to 90 DAT, but the trend of increase was more from 30 DAT to 60 DAT, but after wards it decreased from 60 DAT to 90 DAT.

The genotype RR 12 EN-11 registered significantly highest leaf area index as compared to RR 14 EN-7 and RR 14 EN-8 at all the stages of observation during both the years and on mean basis.

The red rice planted at spacing of 15 cm x10cm registered significantly highest leaf area index at all the stages of observation during both the years and on mean basis,

Table 4.1.7: Leaf area index at different stages of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	Leaf area index								
	30 DAT			60 DAT			90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Genotypes									
V1	1.94	1.86	1.92	2.82	2.72	2.79	3.93	4.08	4.03
V2	2.10	2.09	2.12	2.94	2.89	2.94	4.24	4.31	4.29
V3	2.22	2.29	2.28	3.12	3.25	3.20	5.17	5.27	5.24
SEm±	0.03	0.03	0.03	0.05	0.07	0.06	0.04	0.03	0.03
CD (P=0.05)	0.11	0.14	0.11	0.15	0.20	0.17	0.13	0.08	0.09
Spacing									
S1	2.02	2.17	2.12	3.04	3.06	3.07	4.64	4.74	4.72
S2	2.15	1.99	2.10	2.88	2.86	2.89	4.25	4.36	4.33
SEm±	0.01	0.01	0.01	0.03	0.02	0.02	0.02	0.05	0.02
CD (P=0.05)	0.04	0.04	NS	0.10	0.07	0.06	0.06	0.14	0.10
Fertility levels									
F1	1.91	1.94	1.95	2.79	2.79	2.81	4.17	4.26	4.24
F2	2.13	2.09	2.13	3.00	2.93	2.99	4.48	4.62	4.57
F3	2.23	2.21	2.24	3.08	3.14	3.14	4.70	4.78	4.76
SEm±	0.12	0.02	0.02	0.05	0.07	0.06	0.08	0.11	0.13
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
VXS	S	S	S	S	S	S	S	S	S
VXF	S	NS	S	S	NS	S	NS	NS	NS
SXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3), **Sub-plot: Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.8: Leaf area index at different stages of red rice as influenced by interaction between genotypes and varied spacing

Treatment	Spacing (cm)											
	30 DAT		60 DAT		90 DAT		30 DAT		60 DAT		90 DAT	
	2013						2014					
Genotype	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
VI	1.84	2.04	2.89	2.74	4.09	3.77	1.93	1.78	2.86	2.59	4.20	3.96
V2	2.08	2.12	3.03	2.84	4.39	4.10	2.19	2.00	3.02	2.77	4.49	4.13
V3	2.14	2.29	3.19	3.06	5.46	4.89	2.38	2.20	3.29	3.21	5.53	5.00
	2013						**2014**					
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.02	0.07	0.06	0.17	0.03	0.10	0.02	0.07	0.04	0.12	0.08	0.23
Comparison of two spacing at the same level of genotype	0.03	0.10	0.06	0.16	0.05	NS	0.03	NS	0.03	NS	0.07	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3),
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2),

Table 4.1.9: Leaf area index at different stages of red rice as influenced by interaction between genotypes and fertility levels

Treatment	Fertility levels								
	30 DAT			60 DAT			90 DAT		
	2013								
Genotype	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**
VI	1.73	2.08	2.02	2.57	2.85	3.03	3.63	3.90	4.25
V2	1.88	2.13	2.28	2.95	3.03	2.83	3.93	4.28	4.52
V3	2.10	2.17	2.38	2.87	3.12	3.38	4.93	5.25	5.33

	2013					
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of two spacing at the same level of genotype	0.02	0.07	0.06	0.17	0.03	0.10

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), , RR 12 EN-11 (V3), **Sub-Sub Plot : Fertility levels (3);** 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.10: Crop growth rate at different stages of red rice as influenced by interaction between genotypes and varied spacing and fertility levels

Treatment	Crop growth rate (g $hill^{-1}$ day^{-1})								
	30 DAT			60 DAT			90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Genotypes									
V1	0.30	0.44	0.38	0.32	0.23	0.28	0.40	0.41	0.41
V2	0.28	0.47	0.37	0.40	0.24	0.32	0.36	0.38	0.37
V3	0.31	0.48	0.40	0.49	0.35	0.42	0.51	0.55	0.53
SEm±	0.02	0.01	0.04	0.03	0.02	0.02	0.02	0.03	0.02
CD (P=0.05)	NS	0.03	NS	0.09	0.05	0.05	0.05	0.08	0.06
Spacing									
S1	0.29	0.45	0.37	0.38	0.26	0.32	0.42	0.43	0.43
S2	0.30	0.48	0.39	0.42	0.29	0.36	0.42	0.46	0.44
SEm±	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.01
CD (P=0.05)	NS	0.01	0.02	0.03	0.01	0.02	NS	NS	NS
Fertility levels									
F1	0.30	0.42	0.36	0.34	0.25	0.30	0.41	0.43	0.42
F2	0.31	0.47	0.39	0.38	0.27	0.33	0.44	0.45	0.45
F3	0.29	0.50	0.40	0.48	0.31	0.39	0.41	0.46	0.44
SEm±	0.02	0.01	0.01	0.02	0.01	0.02	0.03	0.03	0.02
CD (P=0.05)	NS	0.02	0.02	NS	0.02	NS	NS	NS	NS
Interaction VXS	NS	S	S	S	S	S	NS	NS	NS
VXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
SXF	S	S	S	S	S	S	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot : Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm(V2),

Table 4.1.11: Crop growth rate (g hill^{-1} day^{-1}) at different stages of red rice as influenced by interaction between genotypes and varied spacing

Treatment	Spacing (cm)											
	30 DAT		60 DAT		90 DAT		30 DAT		60 DAT		90 DAT	
	2013						2014					
Genotype	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
VI	0.28	0.32	0.30	0.33	0.41	0.38	0.42	0.47	0.22	0.25	0.41	0.41
V2	0.28	0.28	0.30	0.33	0.36	0.36	0.48	0.45	0.22	0.27	0.37	0.38
V3	0.31	0.31	0.45	0.52	0.50	0.52	0.46	0.50	0.35	0.35	0.52	0.58
	2013						2014					
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
Comparison of three rice genotype at the same level of spacing	0.14	NS	0.17	0.52	0.12	NS	0.01	0.01	0.01	0.2	0.14	NS
Comparison of two spacing at the same level of genotype	0.02	0.05	0.02	0,06	0.02	NS	0.01	0.02	0.01	0.03	0.04	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2),

Table 4.1.12: Crop growth rate (g $hill^{-1}$ day^{-1}) at different stages of red rice as influenced by interaction between varied spacing and fertility levels

Treatment	Spacing (cm)											
	30 DAT		60 DAT		90 DAT		30 DAT		60 DAT		90 DAT	
	2013						2014					
Fertility levels	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
FI	0.28	0.34	0.35	0.31	0.41	0.45	0.40	0.45	0.26	0.25	0.45	0.45
F2	0.26	0.31	0.48	0.35	0.41	0.41	0.50	0.45	0.29	0.25	0.41	0.40
F3	0.28	0.31	0.31	0.48	0.43	0.42	0.48	0.50	0.29	0.33	0.45	0.51
	2013						2014					
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
Comparison of three rice genotype at the same level of spacing	0.02	0.05	0.02	0,06	0.02	NS	0.01	0.02	0.01	0.03	0.04	NS
Comparison of two spacing at the same level of genotype	0.14	NS	0.17	0.52	0.12	NS	0.01	0.01	0.01	0.2	0.14	NS

Table 4.1.13: Relative crop growth rate at different stages of red rice as influenced by interaction between genotypes under varied spacing and fertility levels

Treatment	Relative growth rate (g g^{-1} $hill^{-1}$ day^{-1})								
	30 DAT			60 DAT			90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Genotypes									
V1	0.08	0.09	0.09	0.02	0.01	0.02	0.02	0.02	0.02
V2	0.08	0.10	0.09	0.03	0.01	0.02	0.01	0.01	0.02
V3	0.08	0.10	0.09	0.03	0.02	0.02	0.02	0.02	0.02
SEm±	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
CD (P =0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Spacing									
S1	0.08	0.09	0.09	0.03	0.02	0.02	0.02	0.02	0.02
S2	0.08	0.10	0.09	0.03	0.02	0.02	0.02	0.02	0.02
SEm±	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
CD (P =0.05)	NS	NS	NS	0.01	NS.	0.00	0.00	NS.	0.00
Fertility levels									
F1	0.08	0.09	0.09	0.03	0.02	0.02	0.02	0.02	0.02
F2	0.08	0.10	0.09	0.03	0.02	0.02	0.02	0.02	0.02
F3	0.08	0.10	0.09	0.03	0.01	0.02	0.02	0.02	0.02
SEm±	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
CD (P =0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction VXS	NS	NS	NS	NS	NS	NS	NS	NS	NS
VXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
SXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3), **Sub-plot: Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

however, at 30 DAT during 2013 at spacing of 20cm x 10cm, gave significantly highest leaf area index.

The effect of fertility levels on leaf area index was noted to be non significant at all the stages of observations during both the years and on mean basis.

The interaction effect of genotype x spacing data revealed that significantly highest leaf area index was recorded under interaction between during both the years and on mean basis, however, RR12EN-11 x 15cm x 10cm during 2013 at 30 DAT, interaction RR12EN-11 x 20cm x 10cm had significantly higher leaf area index over rest of the interaction (Table 4.1.8). The interaction effect of genotype x fertility levels showed that interaction between RR12EN-11 x 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) gave the maximum leaf area index at 30 and 60 DAT during 2013 (Table 4.1.9). The interaction effect of spacing x fertility levels and genotype x spacing x fertility levels were found non significant for leaf area index.

4.1.1.4 Crop growth rate (g $hill^{-1}$ day^{-1})

The crop growth rate computed at 0-30, 30-60 and 60-90 DAT are presented in (Table 4.1.10)**.** In general, crop growth rate increased from 0-30 to 60-90 DAT. The genotype RR12EN-11 and spacing 15cm x 10cm registered significantly highest crop growth rate, but the effect of genotypes at 30 DAT and spacing at 30 and 90 DAT were found non-significant during 2013. During 2014 at 30 DAT and on mean basis and at 60 DAT the fertility level of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) recorded significantly higher crop growth rate.

The interaction effect of genotype x spacing data indicate that significantly highest crop growth rate at 30 and 60 DAT during 2014 and on mean basis and at 60 DAT during 2013 was recorded under interaction between genotype RR12EN-11 x 20cm x 10cm which was at par to interaction between RR12EN-11 x 20cm x 10cm at 30 DAT on mean basis. Further, during 2013 at 30 DAT interaction between RR12EN-11 x 20cm x 10cm recorded significantly highest crop growth rate over rest of the interaction (Table 4.1.11).

Table 4.1.14: Root volume, effective tillers and length of panicle of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	Root volume (cm)			Effective tillers (No. $hill^{-1}$)			Panicle length (cm)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Genotypes									
V1	22.16	22.59	22.37	14.16	15.29	14.74	19.13	20.68	19.93
V2	23.09	23.47	23.28	16.39	17.37	16.91	20.41	22.63	21.55
V3	24.31	22.49	23.76	16.87	18.19	17.56	24.74	26.56	25.67
SEm±	0.22	0.24	0.22	0.19	0.27	0.23	0.33	0.50	0.38
CD (P=0.05)	NS	NS	0.64	0.57	0.83	0.68	1.00	1.51	1.13
Spacing									
S1	22.39	21.98	22.55	14.78	16.14	15.48	20.91	22.67	21.82
S2	21.98	23.72	23.72	16.83	17.76	17.33	21.94	23.90	22.95
SEm±	0.21	0.23	0.07	0.14	0.18	0.12	0.25	0.27	0.09
CD (P=0.05)	NS	NS	0.20	0.42	0.55	0.35	0.75	0.82	0.27
Fertility levels									
F1	21.13	22.38	22.24	14.20	15.46	14.86	20.26	22.03	21.17
F2	23.09	23.44	23.32	15.84	17.06	16.47	21.05	22.86	21.97
F3	22.33	22.72	23.84	17.38	18.33	17.88	22.97	24.98	24.00
SEm±	0.22	0.23	0.24	0.17	0.19	0.10	0.22	0.23	0.14
CD (P=0.05)	NS.	NS.	0.29	0.51	NS	0.31	NS	NS	0.41
Interaction									
VXS	NS.	NS.	S	S	S	S	S	S	S
VXF	NS.	NS.	S	NS	S	S	S	S	S
SXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3), **Sub-plot: Spacing (2):** 15 cm x 10 cm, (S1), 20 cm x10 cm (V2)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.15: Root volume, effective tillers and length of panicle of panicle of red rice as influenced by interaction between genotypes and varied spacing

Treatment	Root volume (cc)				Effective tillers (No. $hill^{-1}$)				Panicle length (cm)			
	Spacing (cm)											
	2013		2014		2013		2014		2013		2014	
Genotype	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
VI	21.61	22.70	22.22	22.96	12.73	15.58	14.00	16.59	18.59	19.67	19.66	21.70
V2	22.77	23.41	23.32	23.61	15.70	17.09	16.68	18.06	19.86	20.97	22.03	23.23
V3	22.79	19.82	20.39	24.59	15.91	17.83	17.73	18.64	24.29	25.19	26.33	26.78
	2013				2014				Mean			
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
Comparison of three rice genotype at the same level of spacing	0.03	N.S	0.02	NS	0.24	0.72	0.32	0.95	0.44	1.29	0.45	1.42
Comparison of two spacing at the same level of genotype	0.02	NS	0.01	NS	0.13	NS	0.26	0.77	0.18	0.54	0.23	0.72

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), , RR 12 EN-11 (V3), **Sub-plot : Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.16: Effective tillers and length of panicle of red rice as influenced by interaction between genotypes and fertility levels

Treatment	Fertility levels											
	2013			2014			2013			2014		
	Effective tillers (No. $hill^{-1}$)						Panicle length (cm)					
Genotype	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
VI	13.03	14.23	15.20	14.23	15.48	16.17	17.80	18.60	20.98	18.83	19.72	23.48
V2	14.50	16.40	18.28	15.68	17.68	18.73	18.62	20.05	22.57	21.27	22.30	24.33
V3	15.07	16.88	18.67	16.47	18.02	20.08	24.37	24.50	25.35	26.00	26.55	27.12

	2013		2014		2013		2014	
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
Comparison of three rice genotype at the same level of spacing	0.13	NS	0.26	0.77	0.23	0.72	0.46	1.39
Comparison of two spacing at the same level of genotype	0.24	0.72	0.32	0.95	0.44	1.29	0.45	1.42

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.17: Panicle weight, grains panicle^{-1} and test weight of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	Panicle weight (g)			Grains panicle^{-1} (No.)			Test weight (g)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Genotypes									
V1	3.13	3.37	3.28	130.87	132.33	131.62	22.40	22.60	22.50
V2	3.37	3.58	3.50	127.05	135.77	131.44	22.84	22.98	22.91
V3	3.58	4.01	3.82	136.88	139.38	138.16	24.62	24.75	24.69
SEm±	0.07	0.04	0.04	0.98	0.48	0.88	0.03	0.02	0.02
CD (P =0.05)	0.22	0.11	0.13	NS	1.43	NS	0.09	0.07	0.08
Spacing									
S1	3.27	3.55	3.44	131.82	134.39	133.13	23.27	23.41	23.34
S2	3.45	3.75	3.63	131.39	137.26	134.35	23.31	23.47	23.39
SEm±	0.02	0.02	0.02	0.96	0.32	0.85	0.01	0.01	0.01
CD (P =0.05)	0.07	0.07	0.06	NS	0.95	NS	0.02	0.04	0.03
Fertility levels									
F1	3.07	3.30	3.22	128.79	132.63	130.73	23.14	23.33	23.23
F2	3.34	3.64	3.52	133.62	134.68	134.18	23.27	23.44	23.36
F3	3.67	4.01	3.86	132.39	140.16	136.31	23.45	23.56	23.51
SEm±	0.11	0.12	0.11	0.92	0.98	0.95	0.02	0.03	0.02
CD (P =0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
VXS	S	S	S	NS	NS	NS	S	S	S
VXF	NS	NS	NS	NS	NS	NS	S	S	S
SXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3), **Sub-plot: Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm (V2)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.18: Panicle weight and test weight of red rice as influenced by interaction between genotypes and varied spacing

Treatment	Spacing (cm)							
	2013		2014		2013		2014	
	Panicle weight (g)				Test weight (g)			
Genotype	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
VI	3.04	3.21	3.30	3.43	22.40	22.41	22.60	22.60
V2	3.28	3.46	3.44	3.71	22.82	22.85	22.93	23.02
V3	3.48	3.69	3.91	4.11	24.59	24.66	24.71	24.78
	2013				**2014**			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.04	0.11	0.03	0.11	0.01	0.03	0.21	0.06
Comparison of two spacing at the same level of genotype	0.02	NS	0.02	NS	0.01	0.04	0.02	0.05

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot : Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm(V2)

Table 4.1.19: Test weight and root volume of red rice as influenced by interaction between genotypes and fertility levels

Treatment	Fertility levels											
	2013			2014			2013			2014		
	Test weight (g)						Root volume (cc)					
Genotype	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
VI	22.31	22.39	22.52	22.50	22.59	22.72	21.28	22.42	22.77	21.68	23.07	23.02
V2	22.72	22.85	22.95	22.91	22.95	23.07	22.58	23.32	23.37	23.10	23.60	23.70
V3	24.38	24.59	24.90	24.57	24.77	24.90	19.53	23.53	22.58	22.37	23.65	21.45

	2013		2014		2013		2014		
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±
Comparison of three rice genotype at the same level of spacing	0.01	0.04	0.02	0.05	0.02	NS		0.01	NS
Comparison of two spacing at the same level of genotype	0.01	0.03	0.21	0.06	0.03	NS		0.02	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.20: Root volume of red rice as influenced by interaction between varied spacing and fertility levels

Treatment	Spacing (cm)			
	2013		2014	
	Root volume (cc)			
Fertility levels	**S_1**	**S_2**	**S_1**	**S_2**
F1	21.37	22.58	21.40	23.20
F2	23.20	20.90	21.33	23.37
F3	23.60	21.43	23.68	24.11
	2013			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.14	NS	0.18	NS
Comparison of two spacing at the same level of genotype	0.12	NS	0.16	NS

Main plot: Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.21: Yield and harvest index of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	Grains yield(q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Genotypes									
V1	37.46	39.22	38.37	43.15	46.24	44.72	46	46	46
V2	39.28	39.57	39.45	46.96	49.37	48.20	45	44	45
V3	42.48	42.86	42.69	50.24	52.55	51.42	46	45	45
SEm±	0.50	0.59	0.52	0.77	0.76	0.68	10	11	11
CD (P=0.05)	1.50	1.86	1.57	2.24	2.22	2.03	NS	NS	NS
Spacing									
S1	39.96	41.74	40.87	45.18	47.73	46.48	47	47	47
S2	39.52	39.36	39.47	48.39	51.04	49.74	45	44	44
SEm±	0.11	0.50	0.39	0.45	0.53	0.48	01	01	01
CD (P=0.05)	0.34	1.49	1.17	1.35	1.60	1.42	02	01	01
Fertility levels									
F1	34.93	36.57	35.78	43.37	46.14	44.79	45	44	45
F2	40.45	40.43	40.47	47.11	49.56	48.36	46	45	46
F3	43.84	44.64	44.27	49.87	52.46	51.19	47	46	46
SEm±	0.34	0.34	0.20	0.43	0.31	0.34	12	11	11
CD (P=0.05)	1.04	0.97	0.59	1.26	0.93	1.03	NS	NS	NS
Interaction VXS	S	S	S	S	S	S	S	S	S
VXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
SXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), , RR 12 EN-11 (V3), **Sub-plot : Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2), **Sub-Sub Plot : Fertility levels (3);** 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.22: Yield and harvest index of red rice as influenced by interaction between genotypes and varied spacing

Treatment	Grains yield (q ha^{-1})				Straw yield (q ha^{-1})				Harvest index (%)			
	2013		2014		2013		2014		2013		2014	
	Spacing (cm)											
Genotype	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
VI	37.98	36.94	41.29	37.16	43.52	42.78	46.49	45.99	46	46	47	45
V2	40.62	37.93	41.36	37.78	45.29	48.63	47.31	51.42	47	44	47	42
V3	41.28	43.69	42.58	43.13	46.72	53.76	49.39	55.71	47	45	46	44
	2013				**2014**				**Mean**			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.94	2.79	0.85	2.58	0.78	2.34	0.92	2.76	0.01	02	01	01
Comparison of two spacing at the same level of genotype	0.72	NS	0.66	NS	0.62	NS	0.78	NS	0.01	NS	0.01	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2)

As regards to interaction effect of genotype x fertility levels, the interaction between RR12EN-11 x 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) noticed maximum crop growth rate at 30 and 60 DAT (Table 4.1.12).

4.1.1.5 Relative growth rate (g g^{-1} $hill^{-1}$ day^{-1})

The data relative growth rate at 0-30, 30-60 and 60-90 DAT are presented in 4.1.13.The finding revealed that the relative growth rate was found statistically non significant at all the stages of observation during both the years and on mean basis.

4.1.2. Root volume, yield attributes and yield

4.1.2.1Root volume (cc)

The data on root volume of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1. 14. Significantly highest root volume was registered under genotype RR12 EN-11as compared to RR 14 EN-7 and RR 14 EN-8 during both the years and on mean basis.

The spacing at 20cm x 10cm recorded significantly higher volume of root as compared to spacing of 15cm x 10cm only on mean basis.

The fertility levels of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) gave significnaly higher root volume as compared to fertility levels of 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) and 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) only on mean basis.

The interactions between RR 12 EN-11 x 20cm x 10cm (Table 4.1.15). RR12EN-11 x 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (Table 4.1.16) and 20cm x10cm x 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} (Table 4.1.20) recorded significantly highest root volume only on mean basis.

4.1.2.2 Effective tillers (No. hill $^{-1}$)

The data on effective tillers of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.14 .Significantly highest number of effective tillers hill $^{-1}$ was registered under genotype RR 12 EN-11 but it was at par with genotype RR 14 EN-8 during both the years and on mean basis.

Table 4.1.23: Iron and Zinc content in grain index of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	Iron conten (ppm)			Zinc conten (ppm)		
	2013	2014	Mean	2013	2014	Mean
Genotypes						
V1	5.89	5.70	5.80	23.17	23.00	23.09
V2	6.26	6.37	6.32	23.99	24.15	24.07
V3	5.51	5.35	5.43	22.36	22.29	22.33
SEm±	0.24	0.23	0.20	0.35	0.20	0.25
CD (P=0.05)	NS	0.70	0.60	1.06	0.60	0.74
Spacing						
S1	5.52	5.34	5.43	21.44	21.53	21.49
S2	6.25	6.27	6.26	24.91	24.76	24.839S
SEm±	0.14	0.11	0.11	0.14	0.18	0.16
CD (P=0.05)	0.43	0.36	0.34	0.48	0.55	0.50
Fertility levels						
F1	5.61	5.51	5.56	22.31	22.09	22.21
F2	5.93	5.98	5.96	23.33	23.33	23.33
F3	6.11	5.93	6.03	23.88	24.01	23.95
SEm±	0.11	0.12	0.14	0.16	0.13	0.14
CD (P=0.05)	NS	NS	NS	0.50	0.40	0.42
Interaction						
VXS	NS	NS	NS	S	S	S
VXF	S	S	S	S	S	S
SXF	NS	NS	NS	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), , RR 12 EN-11 (V3), **Sub-plot : Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2), **Sub-Sub Plot : Fertility levels (3);** 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.24: Zinc (ppm) content in grain of red rice as influenced by genotypes and varied spacing

Treatment	Spacing(cm)			
	2013		2014	
	Zn			
Genotype	**S_1**	**S_2**	**S_1**	**S_2**
VI	21.88	24.47	21.87	24.13
V2	22.13	25.84	22.44	25.85
V3	20.30	24.42	20.27	24.31
	2013			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.28	0.82	0.32	0.94
Comparison of two spacing at the same level of genotype	0.29	0.86	0.26	0.69

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3),
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2)

Table 4.1.25: Iron and Zinc conten (ppm) in grain of red rice as influenced by interaction between genotypes and fertility levels

	Iron conten (ppm)						Zinc conten (ppm) in grain					
	2013			2014			2013			2014		
	Fertility levels											
Genotype	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**
VI	6.22	5.66	5.79	6.20	5.57	5.34	22.75	23.36	23.41	22.42	23.22	23.37
V2	5.01	6.60	7.17	4.77	6.75	7.59	22.81	24.49	24.66	22.74	24.68	25.02
V3	5.60	5.54	4.59	5.55	5.63	4.87	21.38	22.13	23.57	21.12	22.11	23.64

	2013				2014			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.30	0.90	0.42	1.23	0.29	0.86	0.24	0.69
Comparison of two spacing at the same level of genotype	0.22	NS	0.31	NS	0.28	0.82	0.32	0.94

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.26: N content in grain and straw of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	N content in grain and straw (%)					
	N content in grain			N content in straw		
	2013	2014	Mean	2013	2014	Mean
Genotypes						
V1	1.41	1.41	1.41	0.50	0.51	0.51
V2	1.37	1.38	1.37	0.47	0.47	0.47
V3	1.45	1.45	1.45	0.49	0.50	0.49
SEm±	0.01	0.01	0.01	0.01	0.01	0.01
CD (P =0.05)	0.02	0.04	0.02	0.02	0.02	0.02
Spacing						
S1	1.29	1.29	1.29	0.44	0.45	0.44
S2	1.53	1.53	1.53	0.54	0.54	0.54
SEm±	0.01	0.01	0.01	0.01	0.01	0.01
SEm±	0.02	0.02	0.02	0.02	0.02	0.02
CD (P =0.05)						
F1	1.35	1.35	1.35	0.47	0.48	0.47
F2	1.37	1.37	1.37	0.49	0.50	0.49
F3	1.51	1.51	1.51	0.50	0.51	0.51
SEm±	0.01	0.01	0.01	0.01	0.01	0.01
CD (P =0.05)	0.03	0.02	0.02	0.02	N.S	0.02
Interaction VXS	S	S	S	S	S	S
VXF	S	S	S	S	S	S
SXF	S	S	S	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), , RR 12 EN-11 (V3), **Sub-plot : Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2), **Sub-Sub Plot : Fertility levels (3);** 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.27: N content in grain and straw (%) of red rice as influenced by interaction between genotypes and varied spacing

Treatment	Spacing(cm)							
	2013		2014		2013		2014	
	N content in grain				N content in straw			
Genotype	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
VI	1.28	1.55	1.28	1.54	0.45	0.55	0.46	0.56
V2	1.26	1.49	1.25	1.50	0.42	0.52	0.43	0.52
V3	1.34	1.55	1.34	1.55	0.44	0.54	0.45	0.54
	2013				**2014**			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.006	0.017	0.005	0.014	0.001	0.002	0.003	0.009
Comparison of two spacing at the same level of genotype	0.004	0.013	0.004	0.012	0.002	0.007	0.003	0.008

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2)

Table 4.1.28: N content in grain and straw (%) of red rice as influenced by interaction between genotypes and fertility levels

Treatment	Fertility levels											
	2013			2014			2013			2014		
	N content in grain						N content in straw					
Genotype	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**
VI	1.35	1.36	1.52	1.35	1.36	1.52	0.48	0.50	0.53	0.49	0.51	0.53
V2	1.32	1.33	1.48	1.32	1.33	1.48	0.46	0.47	0.48	0.46	0.48	0.49
V3	1.37	1.43	1.54	1.38	1.41	1.54	0.48	0.49	0.50	0.48	0.50	0.51

	2013				2014			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.004	0.013	0.004	0.012	0.002	0.007	0.003	0.008
Comparison of two spacing at the same level of genotype	0.006	0.017	0.005	0.014	0.001	0.002	0.003	0.009

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3),
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.29: N content in grain (%) of red rice as influenced by interaction between varied spacing and fertility levels

Treatment	Spacing (cm)			
	2013		2014	
Fertility levels	**S_1**	**S_2**	**S_1**	**S_2**
FI	1.13	1.28	1.14	1.27
F2	1.45	1.56	1.46	1.56
F3	1.46	1.57	1.46	1.57
			2013	
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.004	0.011	0.004	0.010
Comparison of two spacing at the same level of genotype	0.004	0.013	0.004	0.012

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V

Table 4.1.30: P content in grain and straw of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	P content in grain and straw (%)					
	2013	2014	Mean	2013	2014	Mean
	P content in grain (%)			P content in straw (%)		
Genotypes						
V1	0.243	0.251	0.247	0.119	0.121	0.120
V2	0.249	0.253	0.250	0.116	0.118	0.117
V3	0.259	0.260	0.260	0.124	0.125	0.125
SEm±	0.007	0.019	0.008	0.007	0.009	0.008
CD (P=0.05)	0.002	0.006	0.003	0.002	0.003	0.003
Spacing						
S1	0.230	0.233	0.232	0.116	0.119	0.118
S2	0.271	0.275	0.273	0.124	0.124	0.124
SEm±	0.016	0.012	0.004	0.007	0.006	0.007
CD (P=0.05)	0.005	0.004	0.001	0.002	0.002	0.002
Fertility levels						
F1	0.234	0.235	0.235	0.115	0.116	0.116
F2	0.252	0.257	0.255	0.121	0.122	0.122
F3	0.266	0.271	0.269	0.124	0.126	0.125
SEm±	0.009	0.006	0.007	0.008	0.006	0.007
CD (P=0.05)	0.003	NS	0.002	NS	NS	NS
Interaction VXS	S	S	S	S	S	S
VXF	S	S	S	NS	NS	NS
SXF	NS	S	S	NS	S	S
VXSXF	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), , RR 12 EN-11 (V3), **Sub-plot : Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2), **Sub-Sub Plot : Fertility levels (3);** 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.31: P content in grain and straw (%) of red rice as influenced by interaction between genotypes and varied spacing

Treatment	Spacing (cm)							
	2013		2014		2013		2014	
	P content in grain				P content in straw			
Genotype	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
VI	0.22	0.27	0.23	0.28	0.12	0.12	0.12	0.12
V2	0.23	0.27	0.23	0.27	0.11	0.12	0.12	0.12
V3	0.24	0.28	0.24	0.28	0.12	0.13	0.12	0.13
	2013				2014			
	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
Comparison of three rice genotype at the same level of spacing	0.003	0.008	0.002	0.007	0.001	0.004	0.001	0.003
Comparison of two spacing at the same level of genotype	0.002	0.006	0.001	0.004	0.001	NS	0.002	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2)

Table 4.1.32: P content in grain (%) of red rice as influenced by interaction between genotypes and fertility levels

Treatment	Fertility levels					
	2013			2014		
Genotype	F_1	F_2	F_3	F_1	F_2	F_3
VI	0.22	0.24	0.26	0.23	0.26	0.27
V2	0.24	0.25	0.26	0.23	0.25	0.27
V3	0.25	0.26	0.27	0.24	0.26	0.28

	2013		2014	
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.002	0.006	0.001	0.004
Comparison of two spacing at the same level of genotype	0.003	0.008	0.002	0.003

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)

Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.33: P content in grain and straw of red rice as influenced by interaction between varied spacing and fertility levels

Treatment	Spacing (cm)							
	2013		2014		2013		2014	
	P content in grain (%)				P content in straw (%)			
Fertility levels	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
FI	0.21	0.23	0.21	0.24	0.11	0.12	0.11	0.12
F2	0.25	0.26	0.25	0.26	0.12	0.12	0.12	0.12
F3	0.27	0.29	0.28	0.29	0.13	0.13	0.12	0.13
	2013				**2014**			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.01	NS	0.001	0.003	0.001	NS	0.001	0.002
Comparison of two spacing at the same level of genotype	0.002	NS	0.001	0.003	0.001	NS	0.001	0.002

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2)

Table 4.1.34: K content in grain and straw of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	K content in grain and straw (%)					
	2013	2014	Mean	2013	2014	Mean
	K content in grain			K content in straw		
Genotypes						
V1	0.295	0.302	0.297	1.375	1.378	1.376
V2	0.285	0.293	0.289	1.490	1.499	1.495
V3	0.297	0.300	0.299	1.471	1.479	1.475
SEm±	0.016	0.010	0.005	0.009	0.012	0.004
CD (P=0.05)	0.005	0.003	0.002	0.003	0.004	0.001
Spacing						
S1	0.272	0.277	0.275	1.383	1.390	1.387
S2	0.313	0.320	0.317	1.507	1.514	1.510
SEm±	0.014	0.008	0.009	0.008	0.007	0.005
CD (P=0.05)	0.005	0.003	0.003	0.003	0.002	0.002
Fertility levels						
F1	0.279	0.284	0.282	1.389	1.395	1.392
F2	0.291	0.297	0.294	1.440	1.449	1.445
F3	0.307	0.314	0.311	1.507	1.512	1.510
SEm±	0.012	0.009	0.008	0.009	0.008	0.009
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction VXS	S	S	S	S	S	S
VXF	S	S	S	S	N.S	S
SXF	S	S	S	S	S	S
VXSXF	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), , RR 12 EN-11 (V3), **Sub-plot : Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2), **Sub-Sub Plot : Fertility levels (3);** 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.35: K content in grain and straw of red rice as influenced by interaction between genotypes and varied spacing

Treatment	Spacing (cm)							
	2013		2014		2013		2014	
	K content in grain (%)				K content in straw (%)			
Genotype	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
VI	0.27	0.32	0.28	0.32	1.31	1.44	1.31	1.44
V2	0.27	0.31	0.27	0.31	1.43	1.55	1.44	1.56
V3	0.28	0.32	0.28	0.32	1.41	1.53	1.42	1.54
	2013				**2014**			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.003	0.009	0.002	0.006	0.001	0.004	0.001	0.004
Comparison of two spacing at the same level of genotype	0.001	0.003	0.001	0.004	0.002	0.005	0.002	N.S

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2)

Table 4.1.36: K content in grain and straw of red rice as influenced by interaction between genotypes and fertility levels

Treatment	Fertility levels											
	2013			2014			2013			2014		
	K content in grain (%)						K content in straw (%)					
Genotype	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
VI	0.28	0.30	0.31	0.29	0.30	0.32	1.32	1.37	1.43	1.32	1.38	1.44
V2	0.27	0.29	0.30	0.28	0.29	0.31	1.44	1.49	1.55	1.44	1.50	1.56
V3	0.29	0.29	0.31	0.29	0.30	0.31	1.41	1.46	1.54	1.42	1.47	1.54

	2013				2014			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.001	0.003	0.001	0.004	0.002	0.005	0.002	N.S
Comparison of two spacing at the same level of genotype	0.003	0.009	0.002	0.006	0.001	0.004	0.001	0.004

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.37: K content in grain and straw of red rice as influenced by interaction between varied spacing and fertility levels

Treatment	Spacing (cm)							
	2013		2014		2013		2014	
	K content in grain				K content in straw			
Fertility levels	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
FI	0.27	0.27	0.27	0.28	1.29	1.38	1.29	1.39
F2	0.28	0.29	0.28	0.30	1.48	1.49	1.49	1.50
F3	0.31	0.34	0.32	0.35	1.50	1.53	1.51	1.53
	2013				**2014**			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.001	0.004	0.001	0.003	0.002	0.004	0.002	0.005
Comparison of two spacing at the same level of genotype	0.001	0.003	0.001	0.004	0.002	0.005	0.002	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm(V2)

Significantly higher number of effective tillers hill $^{-1}$ was observed under spacing 20cm x 10cm as compared to spacing of 15cm x 10cm.

The fertility level of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) gave significantly higher number of effective tillers hill^{-1} as compared to fertility levels of 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) and 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) during both the years and on mean basis.

The interaction between genotype x spacing registered significantly highest effective tillers during both the years and on mean basis under treatment RR12EN-11 x 20cm x10 cm, but it was at par with RR12EN-11 x 20 cm x 10cm and RR 12EN-11 x 15cm x10cm during 2014 (Table 4.1.15). While, genotype x fertility levels interaction revealed that during 2014 and on mean basis RR12EN-11 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) was significantly superior over rest of the treatments (Table 4.1.16).

4.1.2.3 Panicle length (cm)

The data on panicle length of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.14. Significantly longest panicle was registered with genotype RR12EN-11 as compared to RR14EN-7 and RR14EN-8 during both the years and on mean basis.

The spacing of 20cm x 10cm recorded during both the years and on mean noticed significantly higher panicle length as compared to spacing of 15cm x 10cm during both the years and on mean basis.

The fertility level on mean basis registared significanlty higher panicle length under treatment 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} as compared to fertility levels at 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) and 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}).

Interaction between RR12EN-11x 20cm x 10cm gave significantly longest panicle during both the years and on mean basis, but it was at par with RR12EN-11 x15cm x 10cm during 2013 (Table 4.1.15). Interaction between RR12EN-11 x 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) gave significantly longest panicle during both the years and on mean basis, but it was at par with RR 12 EN-11 x 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) during 2014 and on mean basis (Table 4.1.16).

4.1.2.4 Panicle weight (g)

The data on panicle weight of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.14. Significantly highest panicle weight was registered under genotype RR12EN-11, but it was at par with RR14EN-8 during both the years and on mean basis.

The spacing of 20cm x 10cm registered significantly heavier panicle weight as compared to geometry of 15cm x 10cm during both the years and on mean basis. The effect of fertility levels was found non-significant for panicle weight.

The interaction between RR12EN-11x 20cm x 10cm gave significantly highest panicle weight during both the years and on mean basis (Table 4.1.15).

4.1.2.5 Grains panicle^{-1} (No)

The data on grains panicle^{-1} of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.17. Rice grains panicle^{-1} was significantly higher under genotype RR12EN-11 as compared to RR14EN-7 and RR14EN-8 during 2014.

The spacing of 20cm x 10cm registered significantly higher grains panicle^{-1} during 2014 over the treatment 15cm x 10cm.

The fertility level at 120:60:40 (N:P_2O_5:K_2O kg ha^{-1}) during 2014 gave significanlty higher grains panicle^{-1} as compared to fertility levels at 60:40:30 (N:P_2O_5:K_2O kg ha^{-1}) and 90:60:40 (N:P_2O_5:K_2O kg ha^{-1}).

4.1.2.6 Test weight (g)

The data on test weight of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.17. The test weight was registered significantly higher under genotype RR12EN-11 as compared to RR14EN-7 and RR14EN-8 during both the years and on mean basis.

The geometery of 20cm x 10 cm registered significantly higher test weight as compared to spacing of 15cm x 10cm during both the years and on mean basis.

The effect of fertility levels was found non significant during both the years and on mean basis.

Interaction effect of genotype x spacing revealed that during both the years and on mean basis significantly highest test weight was recorded under RR12EN-11 x 20cm x10 cm (Table 4.1.18). As regard to interaction effect of genotype x fertility levels significantly highest test weight was recorded under RR12 EN-11 x 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) during both the years and on mean basis (Table 4.1.19).

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

The data on grain yield of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.21.The grain yield was significantly highest under genotype RR12EN-11 as compared to RR14 EN-7 and RR14EN-8 during both years and on mean basis.

Under geometery of 15cm x10 cm significantly higher grain yield during both the years and on mean basis was noted as compared to spacing 20cm x 10cm .

The grain yield was significnaly higher under fertility level at 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) during both the years and on mean basis as compared to fertility level at 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) and 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) .

The interaction between RR12EN-11 x 20cm x10cm gave significantly higher grain yield, but it was at par with treatment RR12EN-11 x 15cm x10cm during both the years and on mean basis as well as RR12EN-7 x 15cm x 10cm and RR12EN-8 x 15cm x 10cm during 2014 (Table 4.1.22).

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

The data on straw yield of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.21. Significantly higher straw yield was registered under genotype RR12EN-11 as compared to RR14EN-7 and RR14EN-8 during both the years and on mean basis.

The straw yield was significantly higher under spacing of 20cm x 10cm as compared to geometery of 15cm x 10cm.

The fertitity level at 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) produced significantly higher straw yield as compared to fertility levels of 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F_1) and 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) during both the years and on mean basis.

The interaction effect of genotype and spacing was significantly for straw yield where interaction between RR12EN-11 x 20cm x 10 cm recorded significantly highest straw yield during both the years and on mean basis (Table 4.1.22).

4.1.2.6 Harvest index (%)

The data on harvest index of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.21. Significantly higher harvest index was registered under spacing 15cmx10 cm as compared to geometry 20cm x 10cm (S2) during both the years and on mean basis. However, effect of genotype and fertility levels was found non significant for harvest index during both the year and on mean basis.

The interaction between RR 12 EN-8 x 15cm x10cm during 2013 and on mean basis recorded significantly highest straw yield, but it was at par with RR 12 EN-7 x 15cm x 10cm, RR12EN-7 x 20cm x 10cm and RR12EN-11x 15cm x10 cm. further it was at par to RR12 EN-7 x 15cm x10 cm, RR12EN-7 x 20cmx10 cm and RR 12 EN-11 x 15cm x 10cm on mean basis where as, during 2014 interaction between RR12EN-7 x 15cm x10cm recorded significantly highest harvest index, but it was at par to RR12EN-8 x 15cm x10cm and RR 12 EN-11x 15cm x 10cm (Table 4.1.22)·

4.1.3 Nutrient content in red rice

4.1.3.1 N content in grain and straw (%)

The data on N content of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.26. Significantly highest N content in grain was registered under genotype RR12EN-11, which N content in straw was noted significantly higher during both the years and on mean basis.

As regarding to spacing significantly highest N content in grain and straw was registered under 20cm x10cm as compared to geometry 15cm x10cm during both the year and on mean basis.

The fertility level at 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) reduced significantly highest nitrogen content in grain and straw during both the years and on mean basis except nitrogen content in straw which was found non significant during 2014.

The interaction between RR12EN-11 x 20 cm x 10 cm gave significantly highest N content in grain during both the years and on mean basis, but it was at par with RR14EN-7 x 20cm x 10cm recorded (Table 4.1.27). While, interaction between RR12EN-11x 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) recorded significantly highest N content in grain during both the year and on mean basis (Table 4.1.28). Similarly interaction between 20cm x 10cm x 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) gave significantly highest N content in grain, but it was at par with 15 cm X 10cm X 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (Table 4.1.29). Further, the interaction between RR 14 EN-7 (V1) X 20cm X 10cm (S2) and RR 14 EN-7(V1) X 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) noted significantly highest N content in straw.

4.1.3.2 P content in grain and straw (%)

The data on P content of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.30. Significantly higher P content in grain and straw was registered under genotype RR12EN-11 in comprison of RR14EN-7 and RR14EN-8 during both the years and on mean basis.

Spacing of 20cm x10cm registered significantly higher P content in grain and straw as compared to narrow spacing during both the years and on mean basis.

The fertility level of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) recorded significantly highest P content in grain during 2014 and on mean basis except during 2013 which was found non significant. As regards to effect of fertility level, it was found non significant for P content straw during both the years and on mean basis.

The interaction between RR12EN-11 x 20cm x10cm recorded significantly highest P content in grain and straw during both the years and on mean basis but, it was at par with RR14EN-7 x 20cm x10cm during both the years for P content in grain and during 2013 for P content in straw (Table 4.1.31). The interaction between RR12EN-11x

Table 4.1.38: Economics of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	Gross realization (000 Rs ha^{-1})			Net realization (000 Rs ha^{-1})			B:C ratio		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Genotypes									
V1	62213	65562	63888	26067	27210	26638	1.38	1.37	1.37
V2	65918	67227	66572	28247	27623	27935	1.49	1.39	1.44
V3	71076	72447	71761	32093	31570	31832	1.70	1.59	1.64
SEm±	858	819	814	599	745	625	0.03	0.04	0.03
CD (P=0.05)	2571	2450	2436	1793	2227	1871	0.09	0.11	0.10
Spacing									
S1	66022	69181	67601	29124	30292	29708	1.54	1.53	1.54
S2	66782	67643	67213	28480	27310	27895	1.50	1.37	1.43
SEm±	823	867	822	612	598	466	0.04	0.03	0.02
CD (P=0.05)	NS	NS	NS	NS	1793	1396	NS	0.09	0.07
Fertility levels									
F1	59260	62344	60802	23753	24757	24255	1.31	1.29	1.30
F2	67384	68342	67863	29470	28480	28975	1.55	1.42	1.48
F3	72562	74549	73556	33183	33167	33175	1.71	1.63	1.67
SEm±	447	395	276	417	391	237	0.05	0.02	0.01
CD (P=0.05)	1335	1181	818	1246	1168	707	NS	0.06	0.04
Interaction									
VXS	S	S	S	S	S	S	S	S	S
VXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
SXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), , RR 12 EN-11 (V3), **Sub-plot : Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm (V2)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.39: Economics of red rice as influenced by interaction between genotypes and varied spacing

Treatment	Spacing (cm)											
	2013		2014		2013		2014		2013		2014	
	Gross realization (000 Rs ha^{-1})				Net realization (000 Rs ha^{-1})				B:C Ratio (Rs $^{-1}$)			
Genotype	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
VI	62982	61444	68142	62982	26747	25387	29750	24670	1.41	1.34	1.50	1.23
V2	66862	64973	68551	65902	29920	26573	29830	25417	1.59	1.40	1.50	1.28
V3	68222	73929	70849	74044	30707	33480	31297	31843	1.63	1.76	1.58	1.59
	2013				**2014**				**Mean**			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	1018	3054	1020	3057	1119	3353	1037	3105	0.06	0.17	0.05	0.15
Comparison of two spacing at the same level of genotype	918	2766	924	2787	1087	3178	927	2705	0.04	0.14	0.03	0.10

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot : Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm(V2)

Table 4.1.40: Energetics of red rice as influenced by genotypes under varied spacing and fertility levels

Treatment	Energy use efficiency ($qMJ^{-1}x10^{-3}$)			Energy output input ratio			Energy productivity ($g\ MJ\ ha^{-1}$)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Genotypes									
V1	0.82	0.87	0.84	4.77	5.11	4.94	378.31	397.35	387.83
V2	0.88	0.91	0.89	5.18	5.43	5.31	398.28	402.06	400.17
V3	0.94	0.97	0.96	5.56	5.81	5.68	430.87	434.92	432.90
SEm±	0.01	0.01	0.01	0.09	0.08	0.08	5.15	6.43	5.49
CD (P=0.05)	0.04	0.03	0.03	0.26	0.23	0.23	15.42	19.25	16.43
Spacing									
S1	0.86	0.90	0.88	4.97	5.25	5.11	401.19	420.48	410.83
S2	0.90	0.93	0.91	5.37	5.65	5.51	403.79	402.41	403.10
SEm±	0.01	0.01	0.01	0.04	0.05	0.04	6.45	6.38	5.67
CD (P=0.05)	0.02	0.02	0.02	0.12	0.16	0.13	NS	NS	NS
Fertility levels									
F1	0.98	1.04	1.01	5.88	6.25	6.06	437.95	458.41	448.18
F2	0.87	0.89	0.88	5.07	5.32	5.19	401.11	400.91	401.01
F3	0.79	0.82	0.80	4.56	4.78	4.67	368.39	375.02	371.71
SEm±	0.01	0.01	0.01	0.04	0.03	0.04	6.12	3.45	1.98
CD (P=0.05)	0.02	0.02	0.02	0.13	0.10	0.11	NS	10.33	5.93
Interaction									
VXS	S	S	S	S	S	S	S	S	S
VXF	S	S	S	S	S	S	S	NS	S
SXF	NS	NS	NS	NS	NS	NS	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS	NS	NS	NS

Main plot : Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3), **Sub-plot : Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2), **Sub-Sub Plot : Fertility levels (3);** 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 41.41: Energy of red rice as influenced by interaction between genotypes and varied spacing

Treatment	Spacing(cm)											
	2013		2014		2013		2014		2013		2014	
	Energy use efficiency ($qMJ^{-1}x10^{-3}$)						Energy output input ratio				Energy productivity ($g MJ ha^{-1}$)	
Genotype	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
VI	0.82	0.82	0.88	0.85	4.76	4.78	5.10	5.11	379.58	377.04	415.98	378.72
V2	0.87	0.89	0.90	0.91	5.01	5.36	5.22	5.64	408.70	387.86	416.79	387.33
V3	0.89	1.00	0.93	1.02	5.13	5.99	5.42	6.20	415.28	446.46	428.68	441.17
	2013						**2014**				**Mean**	
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.01	0.02	0.01	0.03	0.01	0.02	0.01	0.01	10.02	29.20	9.12	26.34
Comparison of two spacing at the same level of genotype	0.01	0.02	0.01	0.02	0.03	N.S	0.05	0.16	7.32	18.20	6.22	N.S

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), , RR 12 EN-11 (V3)

Sub-plot : Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2)

Table 4.1.42: Energy of red rice as influenced by interaction between genotypes and fertility levels

	Fertility levels																	
	2013			2014			2013			2014			2013			2014		
	Energy use efficiency (qMJ^{-1}x10^{-3})						Energy output input ratio						Energy productivity (g MJ ha^{-1})					
Genotype	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
VI	0.90	0.82	0.74	0.97	0.86	0.78	5.38	4.71	4.23	5.78	5.05	4.50	399.39	386.04	349.50	436.47	391.42	364.17
V2	0.98	0.87	0.78	1.03	0.88	0.81	5.86	5.12	4.57	6.17	5.32	4.80	438.49	395.12	361.23	454.13	388.48	363.58
V3	1.07	0.92	0.84	1.12	0.94	0.86	6.40	5.40	4.88	6.79	5.58	5.05	475.98	422.18	394.46	484.63	422.83	397.32

	2013				2014				Mean			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.01	0.02	0.01	0.02	0.03	NS	0.05	0.16	7.32	18.20	6.22	NS
Comparison of two spacing at the same level of genotype	0.01	0.02	0.01	0.03	0.01	0.02	0.01	0.01	10.02	29.20	9.12	26.34

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3), **Sub-plot: Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2)
Sub-Sub Plot : Fertility levels (3); 60:40:30 (N:P_2O_5:K_2O kg ha^{-1}) (F1), 90:60:40 (N:P_2O_5:K_2O kg ha^{-1}) (F2), 120:60:40 (N:P_2O_5:K_2O kg ha^{-1}) (F3)

Table 4. 1.43: Production efficiency and energy intensiveness of red ice as influenced by genotypes under varied spacing and fertility levels

Treatment	Production efficiency and energy intensiveness of red Rice					
	2013	2014	Mean	2013	2014	Mean
	Production efficiency (kg ha^{-1} day^{-1})			Energy intensiveness (MJ Re^{-1})		
Genotypes						
V1	28.38	29.71	29.05	6.05	6.47	6.26
V2	28.88	29.09	28.99	6.57	6.88	6.72
V3	33.19	33.48	33.34	7.04	7.36	7.20
SEm±	0.38	0.48	0.41	0.11	0.10	0.10
CD (=0.05)	1.15	1.43	1.20	0.32	0.29	0.29
Spacing						
S1	30.30	31.65	30.97	6.30	6.65	6.48
S2	30.00	29.88	29.94	6.81	7.15	6.98
SEm±	0.42	0.38	0.30	0.05	0.07	0.06
CD (=0.05)	NS	1.14	0.88	0.15	0.20	0.17
Fertility levels						
F1	26.50	27.74	27.12	7.44	7.91	7.68
F2	30.68	30.68	30.68	6.43	6.73	6.58
F3	33.27	33.87	33.57	5.78	6.06	5.92
SEm±	0.27	0.25	0.15	0.15	0.04	0.04
CD (*P*=0.05)	0.80	0.74	0.45	0.16	0.12	0.13
Interaction VXS	S	S	S	S	S	S
VXF	NS	NS	NS	NS	S	S
SXF	NS	NS	NS	NS	NS	NS
VXSXF	NS	NS	NS	NS	NS	NS

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), , RR 12 EN-11 (V3), **Sub-plot : Spacing (2):** 15 cm x 10 cm (S1), 20 cm x10 cm(V2), **Sub-Sub Plot : Fertility levels (3);** 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

Table 4.1.44: Production efficiency and energy intensiveness of red rice as influenced by interaction between genotypes and varied spacing

Treatment	Spacing(cm)							
	2013		2014		2013		2014	
	Production efficiency (kg ha^{-1} day^{-1})				Energy of intensiveness (MJ Re^{-1})			
Genotype	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
VI	28.77	27.99	31.28	28.15	6.04	6.05	6.47	6.47
V2	29.87	27.89	30.41	27.78	6.35	6.78	6.62	7.14
V3	32.25	34.13	33.27	33.70	6.50	7.58	6.87	7.84
	2013				**2014**			
	SEm±	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**	**SEm±**	**CD (P=0.05)**
Comparison of three rice genotype at the same level of spacing	0.71	2.10	0.67	1.98	0.08	0.25	0.11	0.34
Comparison of two spacing at the same level of genotype	0.14	NS	0.18	NS	0.06	NS	0.07	0.20

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-plot: Spacing (2): 15 cm x 10 cm (S1), 20 cm x10 cm (V2)

Table 4.1.45: Energy intensiveness of red rice as influenced by interaction between genotypes and fertility levels

Treatment	Fertility levels					
	2013			2014		
	Energy intensiveness (MJ $Re^{-1)}$					
Genotype	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**
VI	6.81	5.97	5.37	7.31	6.39	5.69
V2	7.42	6.49	5.79	7.80	6.73	6.08
V3	8.10	6.84	6.19	8.59	7.06	6.40
		2013			**2014**	
	SEm±	**CD (P=0.05)**		**SEm±**	**CD (P=0.05)**	
Comparison of three rice genotype at the same level of spacing	0.06	NS		0.07	0.20	
Comparison of two spacing at the same level of genotype	0.08	0.02		0.07	0.22	

Main plot: Genotype (3): RR 14 EN-7 (V1), RR 14 EN-8 (V2), RR 12 EN-11 (V3)
Sub-Sub Plot : Fertility levels (3); 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2), 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F3)

120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) gave significantly highest P content in grain during both the years and on mean basis (Table 4.1.32). The interaction between 20cm x10cm x 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) gave significantly highest P content in grain and straw during 2014 and on mean basis (Table 4.1.33).

4.1.3.3 K content in grain and straw (%)

The data on K content of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.34. Significantly highest K content in grain and straw was registered under genotype RR12 EN-11, but it was at par with RR14 EN-7during 2013 and on mean and genotype RR 14 EN-7 during 2014.

The spacing of 20cm x10 cm during both the years as well as on mean basis registered significantly higher K content in grain and straw as compared to narrow spacing. The effect of fertility level was found non-significant for K content in grain and straw during both years and on mean basis.

The interaction between RR12EN-11 xc20cm x10cm recorded significantly highest K content in grain, but it was at par with RR14EN-7 x 20cm x 10cm during both the years. While, K content in straw was significantly highest under RR12EN-8 x 20cm x10 (Table 4.1.35). Moreover, interaction between RR12EN-7x 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} registerd significantly highest K content in grain but, it was at par with RR12EN-11 x 120:60:40 $N:P_2O_5:K_2O$ kg ha $^{-1}$ during 2013 and on mean basis. Interaction between RR12EN-11 x 120:60:40 $N:P_2O_5:K_2O$kg ha^{-1} registered significantly highest K content in straw (Table 4.1.36). More over the interaction between 20cm x 10cm x 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} recorded significantly highest K content in grain and straw during both the years and on mean basis (Table 4.1.37).

4.1.3.4 Zinc content in grain (ppm)

The data on zinc content in grain of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.23. Significantly highest zinc content in grain during both the years and on mean basis was registered under genotype RR14EN-8, but it was at par with RR14EN-7 during 2013.

Under spacing of 20cm x10cm noticed significantly higher zinc content in grain as compared to narrow spacing of 15cm x 10cm during both the years and on mean basis.

The fertility level of 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} recorded significantly higher zinc content in grain as compared to fertility levels of 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) and 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}).

The interaction between RR14EN-8 x 20cm X 10cm (Table 4.1.24) and RR14 EN-8 x 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} (Table 4.1.25) registered recorded significantly highest zinc content in grain during both the years and on mean basis.

4.1.3.5 Iron content in grain (ppm)

The data on iron content in grain of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.23.

Significantly highest iron content in grain was registered under genotype RR14 EN-8, but it was at par with RR14EN-7 during 2014 and on mean basis.

The spacing of 20cm x10 cm recorded significantly higher iron content in grain as compared to narrow spacing 15cmx 10 cm during both the years and on mean basis.

The effect of fertility levels for iron content in grain was found non significant during both the years and on mean basis.

The interaction between RR14EN-8 x 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} gave significantly highest iron content in grain during both the years and on mean basis (Table 4.1.25)·

4.1.4 Economics

4.1.4.1 Gross return (000 Rs ha^{-1})

The data on gross return of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.38. Significantly higher gross return was registered under genotype RR12EN-11 as compared to RR14EN-7 and RR14EN-8 during both the years and on mean basis.

The fertility level of 120:60:40 N:P_2O_5:K_2O kg ha^{-1} recorded significantly higher gross return as compared to fertility levels of 60:40:30 (N:P_2O_5:K_2O kg ha^{-1}) and 90:60:40 (N:P_2O_5:K_2O kg ha^{-1}). The effect of spacing for gross return was found non significant.

The interaction between RR12EN-11x 20cm x10cm gave significantly highest gross return during both the years and on mean basis (Table 4.1.39).

4.1.4.2 Net return (000 Rs ha^{-1})

The data on net return of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.38. Significantly higher net return was noted under genotype RR 12 EN-11 as compared to RR14EN-7 and RR14EN-8 during both the years and on mean basis.

Spacing of 15cm x 10cm recorded significant higher net return as compared to spacing of 20cmx10cm during both the years and on mean basis.

The fertility level of 120:60:40 N:P_2O_5:K_2O kg ha^{-1} gave significantly higher net return as compared to fertility levels of 60:40:30 (N:P_2O_5:K_2O kg ha^{-1}) and 90:60:40 (N:P_2O_5:K_2O kg ha^{-1}) during both the years and on mean basis. The interaction between RR 12 EN-11 X 20cm x10cm gave significantly highest net return during both the years and on mean basis (Table 4.1.39).

4.1.4.3 B: C ratio

The data on B: C ratio of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.38. Significantly highest B: C ratio was registered under genotype RR12EN-11 during both the years and on mean basis.

The spacing of 15cm x 10cm recorded significantly highest B: C ratio during both the years and on mean basis·

Similarly fertility level of 120:60:40N:P_2O_5:K_2O kg ha^{-1} gave significantly highest B: C ratio during 2014 and on mean basis.

The interaction between RR12EN-11x 20cm x 10cm recorded significantly highest B: C ratio during both the years and on mean basis (Table 4.1.39).

4.1.5 Energetics

4.1.5 .1 Energy use efficiency (qMJ^{-1}x10^{-3})

The data on energy use efficiency of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.40.

Significantly higher energy use efficiency was registered under genotype RR12EN-11 as compared to RR14EN-7 and RR14EN-8 during both the years and on mean basis.

The Significantly higher energy use efficiency was recorded under spacing of 20 cm x 10cm as compared to spacing of 15cm x10cm during both the years and on mean basis.

The significantly higher energy use efficiency was obtained under fertility level of 60:40:30 (N:P_2O_5:K_2O kg ha^{-1}) as compared to 90:60:40 (N:P_2O_5:K_2O kg ha^{-1}) and 120:60:40 (N:P_2O_5:K_2O kg ha^{-1}) during both the years and on mean basis.

The interaction between RR12EN-11 x 20cm x10cm (Table 4.1.41) and RR12EN-11 x 60:40:30 (N:P_2O_5:K_2O kg ha^{-1}) recorded significantly highest energy use efficiency during both the years and on mean basis (Table 4.1.42).

4.1.5 .2 Energy output input ratio

The data on energy output input ratio of red rice as influenced by genotypes under varied spacing's and fertility levels are presented in Table 4.1.40. Significantly higher energy output input ratio was registered under genotype RR12EN-11as compared to RR14 EN-7 and RR14EN-8 during both the years and on mean basis.

Significantly higher energy output input ratio was obtained under fertility level of 60:40:30 (N:P_2O_5:K_2O kg ha^{-1}) as compared to 90:60:40 (N:P_2O_5:K_2O kg ha^{-1}) and 120:60:40 (N:P_2O_5:K_2O kg ha^{-1}) during both the years and on mean basis.

The significantly higher energy output input ratio was noted under spacing of 20cm x10cm as compared 15cm x10cm during both the years and on mean basis.

The interaction between RR12EN-11 x 20cm x10cm (Table 4.1.41) and RR12EN-11 x 60:40:30 $N:P_2O_5:K_2O$ kg ha^{-1} (Table 4.1.42) gave significantly highest energy output input ratio during both the years and on mean basis.

4.1.5 .3Energy productivity (g MJ ha^{-1})

The data on energy productivity of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.40. Significantly higher energy productivity was registered under genotype RR12 EN-11 as compared to RR14EN-7 and RR14EN-8 during both the years and on mean basis.

The energy productivity was significantly highest under fertility level of 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) during 2014 and on mean basis, but effect of spacing was found non-significant.

The interaction between RR12EN-11 x 20cm x10cm (Table 4.1.41) and RR12EN-11 x 60:40:30$N:P_2O_5:K_2O$kgha^{-1}) gave significantly highest energy productivity except during 2014 (Table 4.1.42).

4.1.5 .4 Energy intensiveness (MJ Re^{-1})

The data on energy intensiveness of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.43. Significantly highest energy intensiveness during both the years and on mean basis was registered under genotype RR12EN-11 as compared to RR14 EN-7 and RR14EN-8.

The spacing of 20cm x 10cm recorded significantly higher energy intensiveness as compared to closer spacing during both the years and on mean basis.

Fertility level of 60:40:30 ($N:P_2O:K_2O$ kg ha^{-1}) recorded significantly highest energy intensiveness as compared to higher fertility level during both the years and on mean basis.

The interaction between RR12EN-11 x 20cm x 10cm (Table 4.1.44) and RR12EN-11 x 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) gave significantly highest energy intensiveness during 2014 and on mean basis (Table 4.1.45)·

4.1.5 .5 Production efficiency (kg ha^{-1} day^{-1})

The data on production efficiency of red rice as influenced by genotypes under varied spacing and fertility levels are presented in Table 4.1.43. Significantly highest production efficiency during both the years and on mean basis was registered under genotype RR12EN-11, spacing of 20cm x 10cm and fertility level of 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1})·

The interaction between RR12EN-11 x 20cm x10cm gave significantly highest production efficiency (Table 4.1.44).

Discussion on effect of genotype

Growth and yield characters, grain and straw yields, economic returns energy parameters and production efficiency were registered significantly highest under genotype RR12EN-11during both the years and on mean basis. The effective translocation of assimilates to the sink, which might have resulted in sound filling of grains as revealed by Bouman *et al.* (2006) in their findings. Underlying physiological features of plants growing in diverse environments and the linkage between structures and functions as components of progressive evolution the spirit continues unabated in modern plant biology. Searching rice cultivars or variety with good processing and high in important essential nutrients are prime important in the present context of rice research. The southern plateau region of Chhattisgarh which is a mega biodiversity hot spot of the world has numerous cultivars of rice with tremendous potential of high quality rice. Rice has tremendous genetic and phenotypic variability among cultivars in competitive ability is more commonly the rule rather than the exception across rice cropping systems. Rice is unique among in the variety of environments in which it can be grown. The remarked increase in the grain yield of rice plants, especially after the 'Green Revolution, was due mainly to the release of improved high-yielding varieties with the characteristics of high response to nitrogen fertilizer and high tillering ability. However, canopy structure of modern varieties with luxuriant vegetative growth and dense foliar canopy has also created lodging and disease problems that cause crop yield fluctuation and reduced benefit because of high inputs to prevent pest. The modern rice varieties suffer from many diseases caused by fungi, bacteria, virus etc. Estimation of losses due to different diseases under various farming systems has not been fully evaluated but in general, it has been estimated to be 10 to 15 percent annually. In certain cases, individual diseases have been reported to cause tremendous losses, even up to 100 percent (Singh, 1999).Lodging is also another constraint to achieving higher yields for current varieties when N supply is high. The local land races are well adopted for their microclimatic condition and they are quite resistant against plant protection and lodging resistant even we observed during the two successive severe cyclone during cropping seasons. Thus, crop and nutrient management for better canopy should link tidily together for minimizing the input and maximizing profit for farmers. Although plant height of rice cultivar is a varietal character, it is also affected by environmental conditions (Yoshida, 1981). Tillering plays an important role in determining rice grain yield since it is closely related to panicle number per unit ground area. Too few tillers result in too few panicles, but excess tillers cause high tiller mortality, small panicles, poor grain filling and consequent reduction in grain yield (Peng *et al*., 1994). Modern rice varieties tiller profusely under favorable conditions, but only about 50 percents of those produce panicles. Unproductive tillers compete for resources with tillers those later produce panicles. Reduced tillering is not only thought to facilitate synchronous flowering and maturity, more uniform panicle size, and efficient use of horizontal space (Janoria, 1989). Leaf area index (LAI) is an important parameter of rice canopy because it is directly and positively related to crop photosynthesis. However, increasing LAI cause increased shading and tiller mortality and is associated with reduced tillering rate in rice crops (Yoshida and Hayakawa, 1970). Additional tillers become unproductive and led to excessive LAI and vegetative growth, and a favorable environment for resulting in a higher percentage of unfilled grains. In the other hand, Zhong *et al.* (2002) revealed that LAI and plant N status are two major factors that influence tiller production in rice crops. The low temperature along with short periods of sunshine in late August particularly under late transplanting were responsible for the lower percentage of grain filling (Singh *et* *al*.,2006b). Plant height is an important morphological attribute. It is a function of combined effects of genetic make up of a plant, soil nutrient status, seedling vigor and the environmental conditions in which it is grown.

Discussion on effect of plant spacing

Plant spacing influenced the plant height, dry matter accumulation, number of effective tillers hill^{-1}, panicle length, grains panicle^{-1} and grain yield ha^{-1}. Plant height, dry matter accumulation, CGR, number of effective tillers hill^{-1}, panicle length and weight, test weight were significantly highest at the spacing of 20cm x 10cm. Plant spacing had significant effect on grain yield ha^{-1}. Yield increased from 3.90 t ha^{-1} to 4.22 t ha^{-1} with the decrease in plant spacing. Higher grain yield (4.22 t ha^{-1}) was obtained at closer spacing (15cm x10cm) followed by 20cm x 10cm (4.21 t ha^{-1}) .The contribution of closer spacing for higher yield was strongly supported by Padmajarao (1995) and Islam *et al.* (1994). The increase in grain yield with decreasing plant spacing up to 15cm x 10 cm might be attributed to higher number effective tillers hill^{-1} and grains panicle^{-1}. Number of panicles per unit area is the most important component of yield. Similar results were reported by Kenneth *et al.* (1996). Rajesh and Thanunathan (2003) and Uphoff (2001) observed that the roots of rice plants have more competition under narrow spacing so that growth is stimulated by sunlight and space for the canopy expansion there by increasing the yield attributes and yield.

Discussion on effect of fertitity levels

Significantly highest dry matter accumulation , number of effective tillers hill^{-1}, panicle length, grains panicle^{-1}, test weight and grain yield were observed under fertility level of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}). Plant height, RGR, panicle weight, test weight and HI remain unaltered due to fertility levels, while highest energy use efficiency, energy output input ratio, energy productivity and energy intensiveness during both the years and on mean basis were registered under fertility level of 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) Similar results were also reported by Navin *et al.* (1996). Number of effective tillers hill^{-1} followed a pattern similar to that obtained for panicle length which increased with the increase of fertility level up to 120 kg N ha^{-1}. The longest panicle (24.00 cm) was observed with fertility level of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) and the shortest panicle (21.17 cm) was noted from lower level. Nitrogen nutrient takes part in panicle formation as well as panicle elongation and for this reason, panicle length increased with the increase of N fertilization under fertility level of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}). The highest number of grains $panicle^{-1}$ was obtained under fertility level of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}), which was significantly different from other N levels. Nitrogen helped in proper filling of seeds which resulted higher produced plump seeds and thus the number of grains $panicle^{-1}$. Grain yield of rice increased gradually with the increasing fertility level of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}). Similar trend was also observed by Haider *et al.* (1988). The yield difference between the highest and the lowest yielding treatments was 25 %. The yield advantage of N application up to fertility level of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) was mainly due to improvement of yield components viz., panicle length and number of grains $panicle^{-1}$. Rice requires high quantity of N particularly up to panicle initiation stage for high production as most of the rice growing soils are poor in N Status. The recovery of fertilizer N in rice under lowland system does not exceed 50% (Blaise and Prasad, 1996) and in many cases even less due to various losses.Optimization of split application of N at critical stage of plant growth by synchronizing with the controlled release N fertilizers are the approaches being suggested for improving the nitrogen use efficiency (Reddy *et al.*, 1986).

Discussion on interaction effect between genotype and plant spacing

Interaction effect between genotype and plant spacing showed significant influence on plant height ,dry matter accumulation, leaf area index ,crop growth rate ,panicle length and weight, test weight, gross return, net return and B:C ratio, energy use efficiency, energy output input ratio, energy productivity, energy intensiveness and production efficiency and these parameters were significantly highest under interaction between RR12EN-11 x 20cm x10cm. The interaction between RR12EN-11 x 20cm x 10cm gave significantly highest K content in grain, but it was at par to RR14EN-7 x 20cm x 10cm during both the years, while K content in straw was recorded significantly highest under interaction between RR12 EN-8 x 20cm x 10. The interaction between

RR12EN-11 x 20cmx10cm gave significantly higher grain yield, but it was at par to interaction between RR12EN-11 x 15cmx10cm during both the years and on mean basis as well as interaction between RR12EN-7 x 15cmx10cm and RR12EN-8 x 15cm x10cm during 2014.

Discussion on interaction effect between genotype and fertility levels

Interaction effect between genotype X fertility levels were found non-significant for panicle weight ,grain panicle^{-1} grain and straw yield, harvest index, root volume, grain and straw nitrogen content ,gross returns, net return and B:C ratio. However, the interaction effect between genotype X fertility levels for N content was found signitant for N grain and straw, where it was noted that interaction between RR12EN-11X 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) in case of N content in grain, while interaction between RR 14 EN-7 X 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}). In case of N content in straw recorded the highest values. Many researches on nutrient and crop management are taking separately that the interacting effects and the combination of nutrient and crop management for healthy canopy are not always achieved. Proper selection of a variety and appropriate nutrient management are important in organic rice production (Manjunath *et al*., 2009). A number of organic waste materials are available, which can supply a good amount of plant nutrients, NPK to produce comparable yield (Ghosh, 2005). Maximum uptake of nitrogen, phosphorus and potassium were noticed by the rice and it was significantly superior to rest of the treatments. Nutrient uptake by red rice is the function of crop yield and nutrient content. The results are in conformity with the findings of Debjani *et al.* (2009).

Discussion on interaction effect between plant spacing and fertility levels

Interaction effect of plant spacing and fertility levels showed significant influence on panicle length, number of grains panicle^{-1} and grain yield. Plant height, number of effective tillers hill^{-1} and 1000 grain weight were not found significant due to interaction between plant spacing and nitrogen fertilizer. It was evident that significantly the longest panicle (25.39cm) was obtained from interaction between 20 cm x 10 cm with 120 kg N ha^{-1}. The maximum number of grains panicle^{-1} (112.50) was obtained by interaction between 20cm x 10cm spacing with 120 kg N ha^{-1}, which was significantly higher than other treatment combinations. Grain yield increased with increasing level of nitrogen up to 120 kg N ha^{-1} irrespective of plant spacing. The spacing 20cm x 10cm accompanied with 120 kg N ha^{-1} gave the highest yield (4.3 t ha^{-1}).The remarked increase in the grain yield of rice a higher plant density as well as higher nitrogen application normally led to a higher plant height because of competition for light. In the high density rice field, individual plant trends to prolong their culm to get light. As a result, plant height of the rice crops is more. Short stature reduces the susceptibility to lodging and increases the harvest index.

Discussion on micronutrient content

Significantly highest zinc content during both the years and on mean basis was registered under genotype RR14EN-8, but it was at par with RR14EN-7 during 2013. Further, spacing of 20cm x10cm and fertility level of 20:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) recorded significantly highest zinc content during both the years and on mean basis. The interaction between genotypes x spacing under RR14EN-8 x 20cm x 10 cm and interaction between genotype x fertility levels under RR14EN-8 x 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) gave significantly highest value of zinc content during both the years and on mean basis. More over, highest iron content was registered under genotype RR14EN-8, which was at par to RR14EN-7 during 2014 and on mean basis. The spacing of 20cm x10cm recorded significantly highest iron content while, fertility levels was found non significant during both the years and on mean basis. The interaction effect of genotypes x fertility levels recorded that interaction between RR14EN-8 x 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) recorded significantly highest iron content during both the years and on mean basis. Iron and zinc are very important limiting trace minerals in rice grains. Enhancing or finding out rice genotypes having higher content of these two minerals are thrust areas of many rice research workers. Rice usually has up to 10 ppm iron and 15 pmm zinc in its kernel. The International Rice Research, Philippines, developed the rice variety, IR68144 which has 20 ppm iron and 34 ppm zinc. Their human trial should increased level of ferrtin in the blood of the anemic subjects (Annual report, IRRI).Ahmed *et al*. (1998) reported the crude protein content of nine aromatic rice cultivars ranged from 9.17 to 11.77% and iron content from 1.5 to 5.0 mg/1000g.

Plate No.1: Photo graphs of red rice during *kharif* 2013

Plate No.2: Photo graphs of red rice during *kharif* 2014

Discussion on economics

Significantly highest gross return was registered under treatment genotype RR12EN-11 and fertility level of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}). The interaction between RR12EN-11 x 20cm x10 cm had significantly highest gross return during both the years and on mean basis. Significantly highest net return was registered under genotype RR12EN-11, fertility levels of 120:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) and spacing of 15cm x 10cm during both the years and on mean basis. The interaction between RR12EN-11x 20cm x10cm gave significantly highest net return during both the years and on mean basis. Further, the interaction effect of genotype x fertility levels, spacing x fertility levels and genotype x spacing x fertility levels were found non significant B: C ratio was registered significantly highest under genotype RR12EN-11 and fertility level of 120:60:40 ($N:P_2O_5:K_2O$kgh^{-1}) during both the years and on mean basis while, spacing 15cm x10cm recorded significantly highest B: C ratio during 2014 and on mean basis. The interaction between RR12 EN-11x 20 cmx 10cm recorded significantly highest B: C ratio during both the years and on mean basis. This was the confirmation of economics in closer spacing as reported by Azad *et al.* (1995).

Experiment No. II : Grain yield and nutrient uptake of red rice as influenced by integrated use of inorganic, organic and micro nutrients

4.2.1 Growth Parameters

4.2.1.1 Plant height (cm)

The red rice variety RR 12 EN-11 was tested under integrated use of inorganic, organic and micro nutrients. The plant height at different intervals significantly affected due to various treatments Table 4.2.1. At 30 DAT, significantly taller plant of red rice was observed under the treatment $N_{120}P_{80}K_{60}$ (T_2) as compared to others during both the years as well as on mean basis, excepting the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during 2014. At 60 and 90 DAT, treatment of $N_{120}P_{80}K_{60}$ (T_4) FYM_{5t} produced significantly taller plant as compared to others, however it was at par to the treatment of $N_{80}P_{60}K_{40}$+Zn + S_I +B (T_{11}) at 90 DAT during both the years as well as on mean basis .

Table 4.2.1: Plant height at different durations of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Plant height (cm)								
	30 DAT			60 DAT			90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
T_{1}: $N_{80}P_{60}K_{40}$	15.8	17.3	16.5	67.7	70.0	68.8	124.2	126.6	125.4
T_{2}: $N_{120}P_{80}K_{60}$	17.8	20.5	19.1	73.4	75.7	74.6	132.2	136.0	134.1
T_{3}:$N_{80}P_{60}K_{40}$+FYM_{5t}	14.2	15.2	14.7	69.4	71.8	70.6	125.6	129.5	127.5
T_{4} :$N_{120}P_{80}K_{60}$+ FYM_{5t}	16.2	18.2	17.2	75.2	80.2	77.7	140.0	143.6	141.8
T_{5} :$N_{80}P_{60}K_{40}$+Zn	14.5	16.7	15.6	68.6	71.3	70.0	114.6	115.5	115.1
T_{6} :$N_{80}P_{60}K_{40}$+S_{I}	14.3	16.1	15.2	68.0	69.7	68.9	112.4	114.7	113.6
T_{7} :$N_{80}P_{60}K_{40}$+B	14.5	15.0	14.8	67.7	67.9	67.8	114.0	116.6	115.3
T_{8} :$N_{80}P_{60}K_{40}$+Zn +S_{I}	14.9	16.8	15.8	70.6	70.9	70.8	117.0	119.9	118.5
T_{9}:$N_{80}P_{60}K_{40}$+Zn +B	14.6	16.1	15.4	69.8	73.2	71.5	116.4	119.0	117.7
T_{10}: $N_{80}P_{60}K_{40}$+B+ S_{I}	14.4	15.9	15.2	68.7	69.1	68.9	120.6	124.8	122.7
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I} +B	16.4	20.0	18.2	73.2	74.7	74.0	138.4	142.9	140.7
T_{12} :Control	12.8	14.2	13.5	55.1	57.7	56.4	103.6	107.3	105.4
SEm±	**0.24**	**0.46**	**0.25**	**0.50**	**0.42**	**0.39**	**0.93**	**0.69**	**0.52**
CD (P=0.05)	**0.71**	**1.35**	**0.74**	**1.48**	**1.26**	**1.16**	**2.76**	**2.04**	**1.55**

Table 4.2.2: Dry matter accumulation at different durations of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Dry matter accumulation (g $hill^{-1}$)								
	30 DAT			60 DAT			90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
$T_{1:}$ $N_{80}P_{60}K_{40}$	12.4	13.5	12.9	22.4	24.1	23.2	30.8	32.1	31.5
$T_{2:}$ $N_{120}P_{80}K_{60}$	13.9	16.6	15.3	26.6	28.0	27.3	36.5	38.8	37.7
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	12.8	14.3	13.6	24.4	26.3	25.3	34.9	36.1	35.5
T_4 :$N_{120}P_{80}K_{60+}$ FYM_{5t}	14.4	15.6	15.0	27.8	29.4	28.6	40.9	42.9	41.9
T_5 :$N_{80}P_{60}K_{40}$+Zn	12.8	14.5	13.7	23.5	25.8	24.6	33.3	36.5	34.9
T_6 :$N_{80}P_{60}K_{40}+S_I$	11.9	13.5	12.7	23.9	25.4	24.7	32.1	33.2	32.7
T_7 :$N_{80}P_{60}K_{40}$+B	12.1	13.7	12.9	23.8	25.2	24.5	32.4	33.8	33.1
T_8 :$N_{80}P_{60}K_{40}$+Zn $_+S_I$	12.8	14.8	13.8	24.6	26.2	25.4	33.2	34.5	33.9
$T_{9:}N_{80}P_{60}K_{40}$+Zn $_+$B	12.7	14.6	13.6	24.2	25.9	25.1	34.1	36.2	35.2
$T_{10:}$ $N_{80}P_{60}K_{40}$+B_+ S_I	12.0	13.5	12.7	23.8	25.5	24.7	34.2	36.1	35.2
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I+}B	12.5	13.8	13.1	25.4	27.7	26.5	35.4	37.9	36.6
T_{12} :Control	8.8	12.0	10.4	18.6	20.2	19.4	23.8	26.7	25.2
SEm±	**0.25**	**0.43**	**0.29**	**0.52**	**0.70**	**0.56**	**0.72**	**0.83**	**0.73**
CD (P=0.05)	**0.73**	**1.28**	**0.86**	**1.54**	**2.07**	**1.65**	**2.14**	**2.45**	**2.15**

4.2.1.2 Dry matter accumulation (g hill^{-1})

The data on dry matter accumulation recorded at 30, 60 and 90 DAT as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.2. At 30 DAT, in year 2013, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) produced the highest dry matter accumulation, which was at par with the treatment $N_{120}P_{80}K_{60}$ (T_2), while in year 2014 and on mean basis, treatment $N_{120}P_{80}K_{60}$ (T_2) gave significantly higher dry matter accumulation than others, treatments except $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4). At 60 and 90 DAT, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) produced significantly higher dry matter accumulation than that of others treatment, with the treatment of which was at par $N_{120}P_{80}K_{60}$ (T_2) at 60 DAT during both the years and on mean basis.

4.2.1.3 Leaf area index (LAI)

The data on leaf area index recorded at 30,60 and 90 DAT are presented in Table 4.2.3. In general, the leaf area index showed increasing trend from 30 DAT to 90 DAT in all the treatments. At 30 and 60 DAT, significantly higher leaf area index was registered under the treatment of $N_{80}P_{60}K_{40}$+Zn +S_{I+}B (T_{11}) as compared to others during both the years as well as on mean basis, but it was at par with the treatments of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), $N_{80}P_{60}K_{40}$+Zn (T_5), $N_{80}P_{60}K_{40}$ +S_I (T_6) and $N_{80}P_{60}K_{40}$) +B (T_7) at 30 DAT in year 2013 and treatment $N_{120}P_{80}K_{60}FYM_{5t}$ (T_4) during 2014 and on mean basis. At 90 DAT, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T4) gave significantly higher LAI than others excepting the treatment of $N_{80}P_{60}K_{40}$+Zn+S_I+B (T_{11}) during both the years and on mean basis and treatment $N_{120}P_{80}K_{60}$ (T_2) during 2013.

4.2.1.4 Crop growth rate (g hill^{-1} day^{-1})

The crop growth rate computed at 0- 30, 30-60 and 60-90 DAT are presented Table 4.2.4. In general, the crop growth rate increased from 0- 30 to 30-60 and thereafter, it declined at 60-90 DAT. At 0-30 DAT, in year 2013, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) gave the highest CGR followed by treatments of $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$+S_I (T_6), $N_{80}P_{60}K_{40}$+B (T_7), $N_{80}P_{60}K_{40}$+Zn+S_I (T_8),$N_{80}P_{60}K_{40}$+B1_0+S_I (T_{10}) and $N_{80}P_{60}K_{40}$+Zn +S_I+B(T_{11}), while in year 2014 treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) gave significantly the highest CGR followed by $N_{80}P_{60}K_{40}$ FYM_{5t} (T_3), $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) , $N_{80}P_{60}K_{40}$+S_I (T_6) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}). On mean basis, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) gave

Table 4.2.3: Leaf area index of red rice at different interval as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Leaf area index								
	30 DAT			60 DAT			90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
T_1: $N_{80}P_{60}K_{40}$	1.97	2.13	2.05	2.73	2.77	2.75	4.07	4.23	4.15
T_2: $N_{120}P_{80}K_{60}$	2.47	2.57	2.52	3.33	3.37	3.35	4.70	4.67	4.69
T_3:$N_{80}P_{60}K_{40}$+FYM_{5t}	2.30	2.43	2.37	3.20	3.23	3.22	4.37	4.43	4.40
T_4 :$N_{120}P_{80}K_{60}$+ FYM_{5t}	2.70	2.67	2.69	3.53	3.63	3.58	4.97	5.07	5.02
T_5 :$N_{80}P_{60}K_{40}$+Zn	2.63	2.53	2.58	3.47	3.37	3.42	4.40	4.43	4.42
T_6 :$N_{80}P_{60}K_{40}$+S_I	2.60	2.63	2.62	3.33	3.30	3.32	4.27	4.33	4.30
T_7 :$N_{80}P_{60}K_{40}$+B	2.60	2.67	2.64	3.50	3.50	3.50	4.17	4.20	4.19
T_8 :$N_{80}P_{60}K_{40}$+Zn +S_I	2.17	2.30	2.24	3.27	3.60	3.44	3.70	3.97	3.84
T_9:$N_{80}P_{60}K_{40}$+Zn +B	2.37	2.43	2.40	3.03	3.17	3.10	4.33	4.40	4.37
T_{10}: $N_{80}P_{60}K_{40}$+B+ S_I	2.20	2.23	2.22	2.93	3.07	3.00	3.93	4.10	4.02
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_I +B	2.73	2.77	2.75	3.97	4.03	4.00	4.60	4.83	4.72
T_{12} :Control	1.80	2.03	1.92	2.50	2.47	2.49	3.37	3.20	3.29
SEm±	**0.07**	**0.07**	**0.06**	**0.10**	**0.12**	**0.10**	**0.13**	**0.14**	**0.13**
CD (P=0.05)	**0.22**	**0.21**	**0.20**	**0.30**	**0.37**	**0.30**	**0.38**	**0.42**	**0.38**

Table 4.2.4: Crop growth rate at different periods of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Crop growth rate (g $day^{-1}hill^{-1}$)								
	0-30 DAT			30- 60 DAT			60- 90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
$T_{1:}$ $N_{80}P_{60}K_{40}$	0.330	0.350	0.343	0.412	0.450	0.431	0.283	0.270	0.280
$T_{2:}$ $N_{120}P_{80}K_{60}$	0.423	0.380	0.403	0.463	0.553	0.508	0.333	0.357	0.347
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	0.387	0.400	0.393	0.427	0.476	0.452	0.350	0.327	0.340
T_4 :$N_{120}P_{80}K_{60+}$ FYM_{5t}	0.450	0.460	0.457	0.479	0.519	0.499	0.437	0.447	0.443
T_5 :$N_{80}P_{60}K_{40}$+Zn	0.357	0.377	0.370	0.427	0.484	0.456	0.327	0.360	0.347
T_6 :$N_{80}P_{60}K_{40}+S_I$	0.400	0.400	0.400	0.397	0.449	0.423	0.273	0.260	0.270
T_7 :$N_{80}P_{60}K_{40}$+B	0.390	0.380	0.390	0.403	0.457	0.430	0.283	0.287	0.290
T_8 :$N_{80}P_{60}K_{40}$+Zn $_+S_I$	0.390	0.383	0.387	0.428	0.492	0.460	0.287	0.277	0.283
$T_{9:}N_{80}P_{60}K_{40}$+Zn $_+$B	0.383	0.377	0.383	0.424	0.486	0.455	0.327	0.343	0.337
$T_{10:}$ $N_{80}P_{60}K_{40}+B_+$ S_I	0.393	0.400	0.400	0.400	0.449	0.424	0.347	0.350	0.353
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I+}B	0.430	0.463	0.450	0.416	0.460	0.438	0.333	0.337	0.337
T_{12} :Control	0.327	0.270	0.300	0.293	0.401	0.347	0.173	0.220	0.200
SEm±	**0.021**	**0.026**	**0.022**	**0.008**	**0.015**	**0.010**	**0.032**	**0.034**	**0.031**
CD (P=0.05)	**0.061**	**0.076**	**0.064**	**0.024**	**0.043**	**0.029**	**0.094**	**0.100**	**0.091**

significantly highest CGR which was at par with treatments $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$ FYM_{5t} (T_3), $N_{80}P_{60}K_{40}$+S_I (T_6), $N_{80}P_{60}K_{40}$+B_{10}+S_I (T_{10})and $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}). At 30-60DAT , the CGR was registered significantly highest with treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during 2013, but during 2014 and on mean basis, treatment $N_{120}P_{80}K_{60}$ (T_2) gave significantly higher CGR than others which was at par to treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4). At 60-90 DAT, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) gave the highest CGR followed by $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during both the years as well as on mean basis.

4.2.1.5 Relative growth rate (g g^{-1} $hill^{-1}$ day^{-1})

The data on relative growth rate (RGR) computed at 0- 30,30-60 and 60-90 DAT are presented Table 4.2.5. It was observed that relative crop growth rate declined with advancement of crop age. The data revealed that at early (0- 30 DAT) and later stages(60-90DAT) the relative growth rate were found non- significant due to different treatments of integrated use of inorganic, organic and micro nutrients, but at mid stage (30-60 DAT), during 2013 treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T4) gave significantly the highest RGR, which was at par with treatment $N_{120}P_{80}K_{60}$ (T2) during 2013 where as during 2014 and on mean basis treatment $N_{120}P_{80}K_{60}$ (T_2) gave significantly the highest RGR, which was at par with the treatment of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4).

4.2.2 Root Volume, Yield Attributes and Yield

4.2.2.1 Root volume (cc)

The data on root volume (cc) of red rice as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.6. Significantly highest root volume was registered during both the years and on mean basis under treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) excepting with treatment of $N_{80}P_{60}K_{40}$+Zn + B (T_9) during year 2014.

4.2.2.2 Effective tillers (No. hill $^{-1}$)

The on effective tillers hill $^{-1}$ significantly affected by integrated use of inorganic, organic and micro nutrients (Table 4.2.6). Significantly highest number of effective tillers hill $^{-1}$ in year 2013 and on mean basis was obtained with treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) which was at par with the treatment of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4). In the year 2014 noticed significantly highest number of effective tillers $hill^{-1}$ was noticed under the

Table 4.2.5: Relative growth rate at different durations of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Relative growth rate (g g^{-1} day^{-1} $hill^{-1}$)								
	0-30 DAT			30- 60 DAT			60- 90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
$T_{1:}$ $N_{80}P_{60}K_{40}$	0 .020	0.020	0.020	0.091	0.094	0.093	0.011	0.009	0.010
$T_{2:}$ $N_{120}P_{80}K_{60}$	0.022	0.017	0.019	0.095	0.101	0.098	0.011	0.011	0.011
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	0.021	0.020	0.021	0.092	0.096	0.094	0.012	0.011	0.011
T_{4} :$N_{120}P_{80}K_{60+}$ FYM_{5t}	0.022	0.021	0.022	0.096	0.099	0.097	0.013	0.013	0.013
T_{5} :$N_{80}P_{60}K_{40}$+Zn	0.020	0.021	0.020	0.092	0.097	0.095	0.012	0.012	0.012
T_{6} :$N_{80}P_{60}K_{40}+S_{I}$	0.023	0.021	0.022	0.090	0.094	0.092	0.010	0.08	0.009
T_{7} :$N_{80}P_{60}K_{40}$+B	0.023	0.020	0.021	0.091	0.095	0.093	0.010	0.010	0.010
T_{8} :$N_{80}P_{60}K_{40}$+Zn $_{+}S_{I}$	0.022	0.019	0.020	0.092	0.097	0.095	0.010	0.010	0.010
$T_{9:}N_{80}P_{60}K_{40}$+Zn $_{+}$B	0.022	0.019	0.020	0.092	0.097	0.095	0.011	0.011	0.011
$T_{10:}$ $N_{80}P_{60}K_{40}+B_{+}$ S_{I}	0.023	0.021	0.022	0.090	0.094	0.092	0.012	0.012	0.012
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I} $_{+}$B	0.024	0.023	0.023	0.091	0.095	0.093	0.011	0.011	0.011
T_{12} :Control	0.025	0.017	0.021	0.080	0.090	0.085	0.008	0.010	0.009
SEm±	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**
CD (P=0.05)	**N S**	**N S**	**N S**	**0.002**	**0.003**	**0.002**	**N S**	**N S**	**N S**

Table 4.2.6: Root volume, effective tillers and length of panicle of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Root volume (cc)			Effective tillers (No. hill^{-1})			Panicle length (cm)		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_{1}: $N_{80}P_{60}K_{40}$	19.6	21.2	20.4	13.3	14.9	14.1	18.8	20.7	19.8
T_{2}: $N_{120}P_{80}K_{60}$	22.2	23.3	22.8	14.5	15.3	14.9	20.8	22.8	21.8
T_{3}:$N_{80}P_{60}K_{40+}FYM_{5t}$	22.3	23.3	22.8	14.7	14.3	14.5	18.9	20.2	19.6
T_{4} :$N_{120}P_{80}K_{60+}$ FYM_{5t}	23.0	23.8	23.4	17.6	19.5	18.6	22.7	23.8	23.3
T_{5} :$N_{80}P_{60}K_{40}$+Zn	22.8	23.2	23.0	13.6	14.6	14.1	19.0	19.9	19.4
T_{6} :$N_{80}P_{60}K_{40}+S_{I}$	22.4	22.9	22.7	12.6	14.7	13.7	18.6	20.2	19.4
T_{7} :$N_{80}P_{60}K_{40}$+B	22.3	23.4	22.9	14.2	14.9	14.6	18.7	19.9	19.3
T_{8} :$N_{80}P_{60}K_{40}$+Zn $_{+}S_{I}$	22.7	23.5	23.1	14.6	16.4	15.5	20.3	21.4	20.8
T_{9}:$N_{80}P_{60}K_{40}$+Zn $_{+}$B	22.9	24.4	23.7	15.6	16.3	16.0	19.3	21.9	20.6
T_{10}: $N_{80}P_{60}K_{40}+B_{+}$ S_{I}	22.3	23.3	22.8	13.6	15.3	14.4	18.9	19.5	19.2
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ $S_{I\,+}$B	24.8	25.2	25.0	18.3	19.0	18.7	21.1	23.6	22.4
T_{12} :Control	12.1	14.2	13.2	7.3	9.3	8.3	16.3	17.6	16.9
SEm±	**0.4**	**0.3**	**0.2**	**0.41**	**0.56**	**0.38**	**0.31**	**0.44**	**0.32**
CD (P=0.05)	**1.3**	**1.1**	**0.7**	**1.22**	**1.66**	**1.13**	**0.92**	**1.30**	**0.96**

treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), which was at par with the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}).

4.2.2.3 Panicle length (cm)

The data on panicle length of red rice as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.6. Significantly longest panicle was registered with treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during both the years and on mean basis which was at par with the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B(T_{11}) and $N_{120}P_{80}K_{60}$ (T_2) during 2014.

4.2.2.4 Panicle weight (g)

The data on panicle weight of red rice was significantly influenced by integrated use of inorganic, organic and micro nutrients (Table 4.2.7). The significantly highest panicle weight was registered with the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) as compared to others treatments during both the years and on mean basis. The treatments of $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$ FYM_{5t} (T_3), $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), $N_{80}P_{60}K_{40}$+Zn +S_I (T_8) and $N_{80}P_{60}K_{40}$+Zn +B (T_9) 2013, treatments $N_{120}P_{80}K_{60}$ (T_2) and $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during 2014 and on mean values were statistically similar to that of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}).

4.2.2.5 Grains panicle^{-1} (No)

The data on number of grains panicle^{-1} of red rice significantly affected by integrated use of inorganic, organic and micro nutrients (Table 4.2.7). The significantly highest number of grains panicle^{-1} was registered under the treatment of $N_{80}P_{60}K_{40}$+Zn_{25} +SI+B_{10} ha^{-1}(T_{11}) during both the years and on mean basis which was on par with the treatment of $N_{120}P_{80}K_{60}$ FYM5t ha^{-1} (T_4) in year 2013 and on mean basis.

4.2.2.6 Test weight (g)

The test weight of red rice was significantly influenced by integrated use of inorganic, organic and micro nutrients (Table 4.2.7). The highest test weight was registered under the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) as compared to others treatments, which was at par with the treatments $N_{120}P_{80}K_{60}$ (T_2) and $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during both the years and on mean basis. The treatment of $N_{80}P_{60}K_{40}$+S_I (T_6) also produced similar test weight to that of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during 2014.

Table 4.2.7: Panicle weight, grains panicle^{-1} and test weight of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Panicle weight (g)			Grains panicle^{-1} (No.)			Test weight (g)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
$T_{1:}$ $N_{80}P_{60}K_{40}$	3.83	3.87	3.85	102.6	105.3	104.0	25.2	25.5	25.4
$T_{2:}$ $N_{120}P_{80}K_{60}$	4.13	4.50	4.32	140.8	142.4	141.6	25.8	25.8	25.8
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	3.90	3.97	3.93	115.0	115.7	115.3	25.3	25.4	25.4
T_4 :$N_{120}P_{80}K_{60+}$ FYM_{5t}	4.07	4.60	4.33	144.5	146.4	145.5	25.7	25.8	25.8
T_5 :$N_{80}P_{60}K_{40}$+Zn	3.80	3.97	3.88	109.2	110.7	110.0	25.3	25.4	25.4
T_6 :$N_{80}P_{60}K_{40}+S_I$	3.70	3.83	3.77	114.9	118.6	116.8	25.3	25.8	25.6
T_7 :$N_{80}P_{60}K_{40}$+B	3.83	3.80	3.82	108.8	112.8	110.8	25.3	25.3	25.3
T_8 :$N_{80}P_{60}K_{40}$+Zn $_+S_I$	3.93	3.93	3.93	116.7	119.0	117.8	25.6	25.3	25.4
$T_{9:}N_{80}P_{60}K_{40}$+Zn $_+$B	3.90	4.03	3.97	117.8	120.0	118.9	25.5	25.5	25.5
$T_{10:}$ $N_{80}P_{60}K_{40}+B_+$ S_I	3.80	3.97	3.88	109.8	114.2	112.0	25.4	25.4	25.4
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I+}B	4.20	4.63	4.42	145.7	152.0	148.9	25.9	25.9	25.9
T_{12} :Control	2.77	3.07	2.92	76.5	78.7	77.6	24.1	24.3	24.2
SEm±	**0.11**	**0.08**	**0.08**	**1.36**	**1.72**	**1.17**	**0.04**	**0.04**	**0.03**
CD (P=0.05)	**0.34**	**0.25**	**0.24**	**4.03**	**5.08**	**3.46**	**0.12**	**0.12**	**0.09**

Table 4.2.8: Yield and harvest index of red rice as influenced by integrated use of inorganic, organic and micro nutrients.

Treatment	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
$T_{1:}$ $N_{80}P_{60}K_{40}$	42.2	40.8	41.5	53.9	44.9	49.4	44.0	47.8	45.6
$T_{2:}$ $N_{120}P_{80}K_{60}$	49.1	48.4	48.8	58.8	54.8	58.5	45.5	47.1	45.5
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	50.3	50.7	50.5	57.5	47.4	54.1	46.7	52.0	48.3
T_{4} :$N_{120}P_{80}K_{60+}$ FYM_{5t}	53.7	53.3	53.5	62.8	58.2	62.2	46.1	47.9	46.2
T_{5} :$N_{80}P_{60}K_{40}$+Zn	49.9	50.2	50.1	58.2	53.5	57.5	46.2	48.5	46.5
T_{6} :$N_{80}P_{60}K_{40}+S_{I}$	46.9	47.9	47.4	55.0	51.7	55.0	46.0	48.2	46.3
T_{7} :$N_{80}P_{60}K_{40}$+B	47.6	48.7	48.2	55.8	51.5	55.3	46.1	48.8	46.6
T_{8} :$N_{80}P_{60}K_{40}$+Zn $_{+}S_{I}$	51.5	50.2	50.9	57.7	53.3	57.2	47.1	48.6	47.1
$T_{9:}N_{80}P_{60}K_{40}$+Zn $_{+}$B	50.8	51.8	51.3	61.3	56.4	60.5	45.4	48.0	45.9
$T_{10:}$ $N_{80}P_{60}K_{40}+B_{+}$ S_{I}	49.5	50.3	49.9	57.6	53.8	57.4	46.2	48.4	46.5
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I} $_{+}$B	54.1	55.8	54.9	61.9	57.5	61.3	46.6	49.3	47.2
T_{12} :Control	13.8	14.03	13.93	13.03	15.55	14.29	51.3	47.5	49.2
SEm±	**0.77**	**0.79**	**0.59**	**1.19**	**1.49**	**0.81**	**0.6**	**1.1**	**0.7**
CD (P=0.05)	**2.29**	**2.35**	**1.76**	**3.51**	**4.40**	**2.41**	**NS**	**NS**	**NS**

Discussion on growth and yield attributes and root volume

The data on growth and yield attributes revealed that integrated use of inorganic, organic and micronutrients significantly affected plant height, dry matter accumulation, leaf area index, number effective tillers hill^{-1}, panicle length, panicle weight, test weight and total grain panicle^{-1}. At most of stages application of $N_{120}P_{80}K_{60}$ +FYM_{5t} (T_4) produced taller plant as compared to others treatments, however it was at par to the treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during both the years as well as on mean basis. The soil was in general low in available, N, P and K and the availability of these nutrients through inorganic and organic sources enhanced the Culm length and finally plant height. Application of $N_{120}P_{80}K_{60}$+ FYM_{5t} (T_4) produced the highest dry matter accumulation which was at par with the treatment of $N_{120}P_{80}K_{60}$ (T_2) during both the years and on mean basis. The dry matter accumulation is the function of number of tillers and leaves, plant height and tillers panicle weight. The release of nutrients while application of said sources and levels and its observation, translocation and conversion of energy for growing parts helped to increase the dry matter accumulation. The crop growth rate followed all most similar trend to that of dry matter accumulation, while its reverse trend was notices for relative crop growth rate. Further, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) gave significantly highest CGR but it was at par with treatments $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$+S_I (T_6), $N_{80}P_{60}K_{40}$+B (T_7), $N_{80}P_{60}K_{40}$+Zn +S_I (T_8), $N_{80}P_{60}K_{40}$+B+ S_I (T_{10})and $N_{80}P_{60}K_{40}$+Zn + S_I +B (T_{11}) .Significantly longest panicle was registered with treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during both the years and on mean basis , while treatment $N_{80}P_{60}K_{40}$+Zn + S_I +B (T_{11}) was at par during the year 2014 and mean basis. These result corroborate with those reported by Belder *et al.* (2005) and Sathiya and Ramesh (2009). Awan *et al.* (2000) and Shanmugam and Veeraputhran (2001) they also reported beneficial effects of FYM application on growth, yield parameters and yield of rice. Either, use of macro and micro nutrients or FYM the release of organic acids and other microbial products through the mineralization of organic matter might have influence the availability of all these essential nutrient and resulted on better growth and yield attributing characters (Katyal *et al.*, 2003) .

Leaf area index, root volume (cc), highest number of effective tillers hill $^{-1}$ panicle weight, highest number of grains panicle^{-1} and test weight was registered under

Table 4.2.9: N content in red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	N content (%)					
	Grain			Straw		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_{1}: $N_{80}P_{60}K_{40}$	1.212	1.213	1.212	0.409	0.429	0.419
T_{2}: $N_{120}P_{80}K_{60}$	1.341	1.351	1.346	0.424	0.440	0.432
T_{3}:$N_{80}P_{60}K_{40}$+FYM_{5t}	1.449	1.419	1.434	0.432	0.453	0.443
T_{4} :$N_{120}P_{80}K_{60}$+ FYM_{5t}	1.555	1.554	1.555	0.528	0.537	0.533
T_{5} :$N_{80}P_{60}K_{40}$+Zn	1.370	1.370	1.370	0.444	0.461	0.453
T_{6} :$N_{80}P_{60}K_{40}$+S_{I}	1.364	1.364	1.364	0.452	0.468	0.460
T_{7} :$N_{80}P_{60}K_{40}$+B	1.363	1.368	1.365	0.458	0.462	0.460
T_{8} :$N_{80}P_{60}K_{40}$+Zn +S_{I}	1.361	1.363	1.362	0.461	0.464	0.463
T_{9}:$N_{80}P_{60}K_{40}$+Zn +B	1.373	1.367	1.370	0.461	0.475	0.468
T_{10}: $N_{80}P_{60}K_{40}$+B+ S_{I}	1.389	1.412	1.401	0.463	0.462	0.463
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I} +B	1.411	1.434	1.423	0.464	0.473	0.469
T_{12} :Control	1.104	1.112	1.108	0.013	0.017	0.015
SEm±	**0.015**	**0.017**	**0.015**	**0.002**	**0.002**	**0.002**
CD (*P*=0.05)	**0.045**	**0.051**	**0.045**	**0.007**	**0.006**	**0.006**

Table 4.2.10: P content in red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	P content (%)					
	Grain			Straw		
	2013	2014	Mean	2013	2014	Mean
$T_{1:}$ $N_{80}P_{60}K_{40}$	0.237	0.237	0.237	0.105	0.108	0.106
$T_{2:}$ $N_{120}P_{80}K_{60}$	0.243	0.253	0.248	0.112	0.113	0.113
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	0.277	0.282	0.279	0.115	0.116	0.116
T_{4} :$N_{120}P_{80}K_{60+}$ FYM_{5t}	0.289	0.291	0.290	0.131	0.133	0.132
T_{5} :$N_{80}P_{60}K_{40}$+Zn	0.251	0.261	0.256	0.112	0.114	0.113
T_{6} :$N_{80}P_{60}K_{40}+S_{I}$	0.251	0.263	0.257	0.116	0.121	0.119
T_{7} :$N_{80}P_{60}K_{40}$+B	0.269	0.279	0.274	0.114	0.123	0.119
T_{8} :$N_{80}P_{60}K_{40}+Zn_{+}S_{I}$	0.263	0.265	0.264	0.125	0.124	0.125
$T_{9:}N_{80}P_{60}K_{40}+Zn_{+}B$	0.254	0.259	0.257	0.128	0.127	0.128
$T_{10:}$ $N_{80}P_{60}K_{40}+B_{+}$ S_{I}	0.252	0.267	0.260	0.121	0.127	0.124
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ $S_{I\,+}B$	0.260	0.270	0.265	0.124	0.132	0.128
T_{12} :Control	0.181	0.182	0.182	0.021	0.023	0.022
SEm±	**0.003**	**0.003**	**0.002**	**0.001**	**0.001**	**0.001**
CD (*P*=0.05)	**0.008**	**0.008**	**0.007**	**0.003**	**0.004**	**0.002**

treatment $N_{80}P_{60}K_{40}$+Zn + S_I +B (T_{11}) during both the years and on mean basis but, it was at par with treatment $N_{120}P_{80}K_{60}$ FYM$_{5t}$ (T_4) $_I$. The higher growth, yield attributes and yield under NPK+Zn+S_i treatment may be due to the combined effect of both Zn and S_i which might have triggered the overall growth of the crop. Similar increase in growth and yield of rice to zinc application were also observed by Chapale and Badole (1999) and availability of other essential nutrients, which resulted in improvement of plant metabolic process and finally increased the crop growth These results are in accordance with Naik and Das (2007) who reported that adequate supply of zinc produced more number of productive tillers per m^{-2}.These findings are in line with the results of Maqsood *et al.* 1999 and Naik and Das (2007), who reported that the application of zinc, kernels per panicle was increased. These results are in line with the findings of Jin *et al.* (2008) who reported that soil application of zinc increased paddy yield.

Boron is a micronutrient essential for normal healthy plant growth and development of reproductive tissues. The sodium salts of B are reasonably soluble and hence are used widely. Boron application significantly increased the growth and yield of rice by crushing the number of tillers, panicles, grains and its weight. Fertilizer application also increased in the content of plant tissue. Application of Zn, S amd B improved crop growth and yield of rice reported by Singh *et al*. (2008), Khurana *et a*l., (2008) and Singh and Bansal (2010). Batter performance under higher level of N in respect of yield attributes of rice under aerobic culture confirms the findings of Maheswari *et al.* (2007). Bouman *et al*., (2006) using different N levels, which was due to enhanced of yield attributes, forming larger sink size coupled with efficient translocation of photosynthates to the sink. There is evidence from field research that high and sustainable yields are possible integrated with fertilizers and manure. Farmyard manure is a heterogeneous composted organic material comprising of dung, crop residue, and or sweeping in the various stages of decomposition on growth, yield and yield of red rice.

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

The data on rice grain yield of red rice as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.8. The significantly highest rice grain yield was registered under treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during both the years

Table 4.2.11: K content in red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	K content (%)					
	Grain			Straw		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**
$T_{1:}$ $N_{80}P_{60}K_{40}$	0.278	0.291	0.285	1.331	1.343	1.337
$T_{2:}$ $N_{120}P_{80}K_{60}$	0.308	0.312	0.310	1.415	1.451	1.433
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	0.340	0.346	0.343	1.604	1.617	1.611
T_4 :$N_{120}P_{80}K_{60+}$ FYM_{5t}	0.264	0.269	0.267	1.521	1.530	1.526
T_5 :$N_{80}P_{60}K_{40}$+Zn	0.268	0.273	0.270	1.511	1.522	1.517
T_6 :$N_{80}P_{60}K_{40}+S_I$	0.266	0.268	0.267	1.563	1.572	1.568
T_7 :$N_{80}P_{60}K_{40}$+B	0.272	0.275	0.274	1.565	1.572	1.569
T_8 :$N_{80}P_{60}K_{40}$+Zn $_+S_I$	0.273	0.268	0.271	1.552	1.558	1.555
$T_{9:}N_{80}P_{60}K_{40}$+Zn $_+$B	0.282	0.288	0.285	1.546	1.541	1.544
$T_{10:}$ $N_{80}P_{60}K_{40}+B_+$ S_I	0.314	0.319	0.317	1.544	1.572	1.558
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ $S_{I\,+}$B	0.306	0.305	0.305	1.566	1.561	1.564
T_{12} :Control	0.191	0.194	0.193	1.292	1.302	1.297
SEm±	**0.003**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**
CD (*P*=0.05)	**0.009**	**0.005**	**0.005**	**0.006**	**0.006**	**0.005**

Table 4.2.12: Zinc and Iron content in grain of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Zinc and iron content in grain (%)					
	Zn			Fe		
	2013	2014	Mean	2013	2014	Mean
$T_{1:}$ $N_{80}P_{60}K_{40}$	16.5	17.5	17.0	3.9	4.5	4.2
$T_{2:}$ $N_{120}P_{80}K_{60}$	23.2	22.7	23.0	5.5	5.5	5.5
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	15.4	16.6	16.0	4.4	4.4	4.4
T_{4} :$N_{120}P_{80}K_{60+}$ FYM_{5t}	20.1	21.1	20.6	4.0	4.2	4.1
T_{5} :$N_{80}P_{60}K_{40}$+Zn	17.9	20.9	19.4	5.7	6.0	5.8
T_{6} :$N_{80}P_{60}K_{40}+S_{I}$	19.6	20.6	20.1	5.0	5.0	5.0
T_{7} :$N_{80}P_{60}K_{40}$+B	21.7	21.4	21.6	4.4	5.1	4.7
T_{8} :$N_{80}P_{60}K_{40}+Zn_{+}S_{I}$	19.5	19.7	19.6	3.5	3.7	3.6
$T_{9:}N_{80}P_{60}K_{40}+Zn_{+}B$	16.2	17.3	16.7	4.7	5.5	5.1
$T_{10:}$ $N_{80}P_{60}K_{40}+B_{+}$ S_{I}	15.2	16.1	15.7	3.2	3.6	3.4
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ $S_{I+}B$	15.8	16.3	16.0	4.5	4.9	4.7
T_{12} :Control	14.3	14.7	14.5	4.6	5.3	5.0
SEm±	**0.31**	**0.89**	**0.44**	**0.23**	**0.54**	**0.33**
CD (*P*=0.05)	**0.92**	**2.64**	**1.32**	**0.68**	**N.S**	**0.99**

and on mean basis but, it was at par with treatment $N_{120}P_{80}K_{60}$ FYM5t ha^{-1} (T_4) during year 2013 and mean basis.

4.2.2.8 Straw yield (q ha^{-1}) and harvest index

The straw yield of red rice was significantly affected by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.8. Significantly highest rice straw yield during both the years and on mean basis was registered under the treatment of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) over rest of treatments, but it was at par with treatments of $N_{80}P_{60}K_{40}$+Zn+B (T_9) and $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during 2013 and on mean basis and treatments $N_{80}P_{60}K_{40}$ (T_2) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during 2014. On the other hand harvest index of red rice found to be Non significant.

Discussion on yield and harvest index

Significantly highest rice grain yield (54.9 qha^{-1}) was registered under treatment $N_{80}P_{60}K_{40}$+Zn+ S_I +B (11) during both the years and on mean basis but, it was on par with the treatment of $N_{120}P_{80}K_{60}$ +FYM_{5t} (T_4) during year 2013 and mean basis. Increasing levels of nutrients probably exerted a positive effect on the development of source and sink strength of the plants, which ultimately resulted in the higher yield attributing traits. This might be due to either direct or cumulative effect of supplied macro and micro nutrients on metabolic processes of rice. Availability of nutrients, especially the micro nutrients at optimum level has direct impact on accelerated cell division and enlargement, root growth and plant vigor. Use of NPK along with application of $S_{i,}$ B, and Zn results in significantly larger and higher panicles m^{-2} having higher and heavier grains, which have positive correction with grain yield. Similar results were also reported by Shinde *et al*. (2005), Misra and Abidi (2006), Zhang *et al.* (2006), Gill (2006), Mubarak and Bhattacharya (2006) and Rui *et al*. (2007). Boron and zinc are known to influence translocation of metabolites and improving sink strength in plants. Zinc is constituent of several enzymes namely carbonic anhydrase, tryptophan synthetase, alcohol dehydrogenase etc. which are responsible for better photosynthesis and auxin metabolism directly affecting source strength leading to better tillering, growth, yield attributing characters like panicle number, grain number and weight, which ultimately increased crop growth and yield of red rice.

Table 4.2.13: N uptake by red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	N uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
T_{1}: $N_{80}P_{60}K_{40}$	51.03	49.44	50.24	20.66	22.02	20.71	71.69	71.46	70.94
T_{2}: $N_{120}P_{80}K_{60}$	65.86	65.44	65.65	24.94	22.02	25.28	90.79	91.02	90.92
T_{3}:$N_{80}P_{60}K_{40}$+FYM_{5t}	72.88	71.99	72.45	24.86	22.96	23.96	97.73	94.95	96.40
T_{4} :$N_{120}P_{80}K_{60}$+ FYM_{5t}	83.50	82.82	83.19	33.17	33.04	33.12	116.67	115.86	116.31
T_{5} :$N_{80}P_{60}K_{40}$+Zn	68.37	68.75	68.57	25.86	26.20	26.05	94.22	94.95	94.61
T_{6} :$N_{80}P_{60}K_{40}$+S_{I}	63.96	65.29	64.63	24.87	25.78	25.34	88.83	91.07	89.96
T_{7} :$N_{80}P_{60}K_{40}$+B	64.88	66.55	65.72	25.54	25.33	25.45	90.42	91.88	91.16
T_{8} :$N_{80}P_{60}K_{40}$+Zn +S_{I}	70.06	68.48	69.28	26.63	26.31	26.48	96.68	94.78	95.75
T_{9}:$N_{80}P_{60}K_{40}$+Zn +B	69.77	70.79	70.30	28.27	28.37	28.33	98.04	99.15	98.62
T_{10}: $N_{80}P_{60}K_{40}$+B+ S_{I}	68.78	70.99	69.89	26.66	26.41	26.56	95.44	97.39	96.44
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I} +B	76.30	79.95	78.14	28.71	28.77	28.78	105.00	108.72	106.91
T_{12} :Control	15.22	15.61	15.42	0.17	0.27	0.22	15.38	15.87	15.64
SEm±	**1.04**	**1.42**	**0.94**	**0.45**	**0.61**	**0.42**	**1.22**	**1.51**	**1.09**
CD (*P*=0.05)	**3.07**	**4.19**	**2.79**	**1.33**	**1.82**	**1.25**	**3.60**	**4.46**	**3.23**

Table 4.2.14: P uptake by red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	P uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
$T_{1:}$ $N_{80}P_{60}K_{40}$	10.00	9.67	9.84	5.30	5.81	5.25	15.31	15.48	15.10
$T_{2:}$ $N_{120}P_{80}K_{60}$	11.94	12.24	12.11	6.61	6.57	6.59	18.55	18.18	18.70
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	13.92	14.30	14.11	6.61	5.89	6.27	20.53	20.20	20.39
T_{4} :$N_{120}P_{80}K_{60+}$ FYM_{5t}	15.50	15.95	15.71	8.22	8.16	8.21	23.72	23.67	23.72
T_{5} :$N_{80}P_{60}K_{40}$+Zn	12.52	13.11	12.83	6.49	6.46	6.48	19.02	19.58	19.31
T_{6} :$N_{80}P_{60}K_{40}+S_{I}$	11.78	12.60	12.19	6.39	6.66	6.55	18.18	19.26	18.74
T_{7} :$N_{80}P_{60}K_{40}$+B	12.82	12.60	13.20	6.37	6.74	6.58	19.19	20.30	19.79
T_{8} :$N_{80}P_{60}K_{40}$+Zn $_{+}S_{I}$	13.53	13.31	13.44	7.21	7.04	7.14	20.74	20.35	20.58
$T_{9:}N_{80}P_{60}K_{40}$+Zn $_{+}$B	12.93	13.39	13.17	7.81	7.58	7.72	20.74	20.97	20.89
$T_{10:}$ $N_{80}P_{60}K_{40}+B_{+}$ S_{I}	12.47	13.41	12.95	6.96	7.26	7.13	19.43	20.68	20.08
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ $S_{I\,+}$B	14.07	15.03	14.57	7.67	8.05	7.87	21.74	23.08	22.44
T_{12} :Control	2.49	2.55	2.52	0.27	0.35	0.31	2.76	2.90	2.84
SEm±	0.21	0.23	0.14	0.11	0.22	0.10	0.26	0.22	0.35
CD (*P*=0.05)	0.63	0.68	0.43	0.34	0.66	0.31	0.78	0.66	1.04

Similar finding was also reported by Singh *et al*. (2008), Khurana *et al.* (2008) and Singh and Bansal (2010).

Total biomass production of rice is determined mainly by crop photosynthesis and respiration losses, both of which are sensitive to temperature (Horie *et al*., 1994).Gill (2006) also advocated the use of balanced site specific nutrient management in combination with micronutrients, which may break the cereal yield barrier with an advantage of 3-4 t ha^{-1} $annum^{-1}$ more yields of rice and wheat. While highest rice straw yield during both the years and on mean basis was registered under treatment $N_{120}P_{80}K_{60}$ FYM_{5t} over rest of treatments, but it was at par with treatments$N_{80}P_{60}K_{40}$+Zn+B (T_9)and $N_{80}P_{60}K_{40}$+Zn + S_I +B (T_{11}) during 2013 and on mean basis and treatments $N_{80}P_{60}K_{40}$ (T_2) and $N_{80}P_{60}K_{40}$+B+ S_I (T_{10}) during 2014. The data on harvest index was found non-significant differences were noticed in both years as well as on mean basis. Organic manures regulated supply of N by releasing it slowly resulting in increased yield of rice Similar results were obtained by Sharma (2002).The high rice yield due to zinc is attributed to its involvement in many metallic enzymes system, regulatory function and auxin production Hacisalihoglu *et al.*, (2002), enhanced synthesis of carbohydrates and their transport to the site of grain production. Slaton *et al.* (2005) observed 12 to 18% increase in rice yield due to zinc fertilization application and could be ascribed to variation in the root zone in applied zinc and their role in the growth and development of plant .

Slaton *et al.* (2005)reported that application of zinc significantlyaffected total number of tillers Number of panicle bearing tillers m^{-2} contributes towards theproduction potential of rice crop. Increase in productive tillers m^{-2} could be ascribed to adequateupply of zinc that had increased the uptake. The integrated nutrient supply system is the most logical concept for managing long-term soil fertility and productivity Ramesh *et al*., (2009), Use of chemical fertilizers and organic manures has been found promising in arresting the decline trend in soil-health and productivity through the correction of marginal deficiencies of some secondary and micro-nutrient, micro and fauna and their beneficial influence on physical and biological properties of soil. Integrated nutrient management system can bring about equilibrium between degenerative and restorative activities in the soil eco-system (Upadhyay *et al.*, 2011). The manurial treatment might have improved soil

Table 4.2.15: K uptake by red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	K uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
T_{1}: $N_{80}P_{60}K_{40}$	11.73	11.86	11.81	67.29	72.47	66.08	79.02	84.33	77.89
T_{2}: $N_{120}P_{80}K_{60}$	15.11	15.11	15.12	83.23	84.40	83.85	98.34	99.51	98.98
T_{3}:$N_{80}P_{60}K_{40}$+FYM_{5t}	17.10	17.57	17.34	92.29	81.96	87.15	109.40	99.53	104.49
T_{4} :$N_{120}P_{80}K_{60}$+ FYM_{5t}	14.17	14.33	14.26	95.57	94.12	94.90	109.75	108.45	109.16
T_{5} :$N_{80}P_{60}K_{40}$+Zn	13.37	13.68	13.52	87.95	86.45	87.22	101.33	100.13	100.74
T_{6} :$N_{80}P_{60}K_{40}$+S_{I}	12.49	12.84	12.66	86.01	86.51	86.27	98.50	99.35	98.93
T_{7} :$N_{80}P_{60}K_{40}$+B	12.96	13.38	13.19	87.30	86.11	86.74	100.27	99.49	99.93
T_{8} :$N_{80}P_{60}K_{40}$+Zn +S_{I}	14.05	13.47	13.76	89.59	88.32	88.97	103.6	101.79	102.73
T_{9}:$N_{80}P_{60}K_{40}$+Zn +B	14.35	14.89	14.62	94.69	92.04	93.37	109.04	106.93	107.99
T_{10}: $N_{80}P_{60}K_{40}$+B+ S_{I}	15.54	16.02	15.79	88.88	89.85	89.38	104.43	105.87	105.18
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I} +B	16.52	17.01	16.76	96.87	94.96	95.94	113.40	111.97	112.70
T_{12} :Control	2.64	2.72	2.68	16.83	20.25	18.54	19.48	22.97	21.23
SEm±	**0.26**	**0.23**	**0.17**	**1.47**	**2.52**	**1.24**	**1.54**	**2.56**	**1.27**
CD (*P*=0.05)	**0.79**	**0.70**	**0.50**	**4.33**	**7.45**	**3.67**	**4.55**	**7.58**	**3.76**

Table 4.2.16: Length, breadth and L/B ratio of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatments	Length of paddy (mm)			Breadth of paddy(mm)			Length breadth ratio		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_{1}: $N_{80}P_{60}K_{40}$	7.413	7.56	7.487	2.647	2.733	2.690	2.802	2.767	2.783
T_{2}: $N_{120}P_{80}K_{60}$	8.120	8.27	8.197	2.750	2.803	2.777	2.953	2.952	2.952
T_{3}:$N_{80}P_{60}K_{40+}FYM_{5t}$	7.863	7.93	7.897	2.843	2.840	2.842	2.766	2.792	2.779
T_{4} :$N_{120}P_{80}K_{60+}$ FYM_{5t}	8.763	8.91	8.837	2.837	2.920	2.878	3.090	3.051	3.070
T_{5} :$N_{80}P_{60}K_{40}$+Zn	7.720	7.80	7.762	2.947	2.963	2.955	2.620	2.633	2.627
T_{6} :$N_{80}P_{60}K_{40}$+S_{I}	7.850	8.01	7.932	2.970	2.990	2.980	2.643	2.680	2.662
T_{7} :$N_{80}P_{60}K_{40}$+B	7.973	8.08	8.025	2.977	2.993	2.985	2.681	2.698	2.689
T_{8} :$N_{80}P_{60}K_{40}$+Zn $_{+}S_{I}$	8.080	8.17	8.127	2.987	3.017	3.002	2.706	2.713	2.708
T_{9}:$N_{80}P_{60}K_{40}$+Zn $_{+}$B	8.177	8.33	8.252	2.977	3.040	3.008	2.747	2.742	2.743
T_{10}: $N_{80}P_{60}K_{40}$+B_{+} S_{I}	8.253	8.37	8.312	3.057	3.073	3.065	2.701	2.727	2.712
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I} $_{+}$B	8.397	8.54	8.470	3.020	3.107	3.063	2.781	2.753	2.766
T_{12} :Control	6.693	6.81	6.753	2.407	2.560	2.483	2.782	2.662	2.720
SEm±	**0.036**	**0.042**	**0.031**	**0.030**	**0.016**	**0.024**	**0.027**	**0.031**	**0.021**
CD (*P*=0.05)	**0.107**	**0.124**	**0.093**	**0.089**	**0.047**	**0.070**	**0.080**	**0.092**	**0.062**

environment, encouraged root proliferation and root surface absorption zone, which in turn, drew more water and nutrients, In addition to the major nutrients from organic sources, the contribution of other macro and micro nutrients for enhancing the crop yield cannot be ruled out. The Increase in organic carbon content due to use of chemical fertilizer, direct incorporation of organic matter through FYM can be attributed to higher contribution of biomass to the soil in the form of better root growth, crop residues and biomass (Katyal *et al.*, 2003 and Ghathala *et al.*, 2007). Yaduvanshi (2003) also reported that 100% NPK + FYM (10 t/ha) significantly increased the grain yield in comparison to 150% NPK. However, due to said reason yield has been increased under the treatments where inorganic and FYM was applied.

4.2.3 Nutrient Content

4.2.3.1 N content in grain and straw (%)

The data on N content in grain and straw of red rice as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.9. Significantly highest N content in grain and straw was registered under the treatment of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) which was superior over rest of the treatments during both the years and on mean basis.

4.2. 3.2 P content in grain and straw (%)

The data on P content in grain and straw of red rice significantly affected by by integrated use of inorganic, organic and micro nutrients (Table 4.2.10). The highest P content in grain and straw during both the years and on mean basis was noted under treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4),which was significanlty superior than other treatment except $N_{80}P_{60}K_{40}$+ Zn +B (T_9) during 2013 in case of p content in straw .

4.2. 3.3 K content in grain and straw (%)

The data on K content in grain and straw of red rice as influenced by integrated use of inorganic, organic and micro nutrients (Table 4.2.11). The highest K content in grain and straw during both the years and on mean basis was registered under the treatment of $N_{80}P_{60}K_{40}$+FYM_{5t} (T_3) which was significantly superior over rest of the treatments.

Table 4.2.17: Head rice recovery of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Head rice recovery ,%		
	2013	**2014**	**Mean**
$T_{1:}$ $N_{80}P_{60}K_{40}$	48.64	49.37	49.01
$T_{2:}$ $N_{120}P_{80}K_{60}$	50.63	53.52	52.08
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	49.82	49.73	49.77
T_{4} :$N_{120}P_{80}K_{60+}$ FYM_{5t}	51.48	52.00	51.74
T_{5} :$N_{80}P_{60}K_{40}$+Zn	50.45	50.79	50.62
T_{6} :$N_{80}P_{60}K_{40}+S_{I}$	50.64	50.85	50.75
T_{7} :$N_{80}P_{60}K_{40}$+B	51.00	51.77	51.39
T_{8} :$N_{80}P_{60}K_{40}$+Zn $_{+}S_{I}$	51.01	52.09	51.55
$T_{9:}N_{80}P_{60}K_{40}$+Zn $_{+}$B	51.23	51.78	51.51
$T_{10:}$ $N_{80}P_{60}K_{40}+B_{+}$ S_{I}	51.00	51.77	51.39
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ $S_{I\,+}$B	53.78	53.59	53.68
T_{12} :Control	46.30	47.34	46.82
SEm±	**0.29**	**0.82**	**14.14**
CD (*P*=0.05)	**0.87**	**2.42**	**1.22**

Table 4.2.18: Economics of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Gross return (000 Rs ha^{-1})			Net return (000 Rs ha^{-1})			B:C ratio		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
T_{1}: $N_{80}P_{60}K_{40}$	55989	53455	54742	37089	33755	35422	1.96	1.71	1.84
T_{2}: $N_{120}P_{80}K_{60}$	64844	63603	64410	44914	42873	43894	2.25	2.07	2.16
T_{3}:$N_{80}P_{60}K_{40+}FYM_{5t}$	66113	65617	66051	43713	42417	43065	1.95	1.83	1.89
T_{4} :$N_{120}P_{80}K_{60+}$ FYM_{5t}	70723	69740	70419	47073	45290	46182	1.99	1.85	1.92
T_{5} :$N_{80}P_{60}K_{40}$+Zn	65700	65588	65831	45190	44278	44734	2.20	2.08	2.14
T_{6} :$N_{80}P_{60}K_{40}$+S_{I}	61782	62611	62383	39772	39801	39787	1.80	1.74	1.78
T_{7} :$N_{80}P_{60}K_{40}$+B	62697	63545	63328	42787	42835	42812	2.15	2.07	2.11
T_{8} :$N_{80}P_{60}K_{40}$+Zn $_{+}S_{I}$	67533	65614	66760	44023	41304	42664	1.87	1.70	1.79
T_{9}:$N_{80}P_{60}K_{40}$+Zn $_{+}$B	67126	67758	67649	45716	45548	45632	2.13	2.05	2.09
T_{10}: $N_{80}P_{60}K_{40}$+B_{+} S_{I}	65155	65703	65616	42245	41993	42120	1.84	1.77	1.81
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ S_{I} $_{+}$B	71067	72669	72055	46657	47459	47058	1.91	1.88	1.90
T_{12} :Control	17863	18395	18149	1573	1305	1439	0.10	0.08	0.09
SEm±	**965**	**978**	**740**	**965**	**978**	**734**	**0.05**	**0.04**	**0.03**
CD (*P*=0.05)	**2848**	**2887**	**2185**	**2848**	**2887**	**2167**	**0.14**	**0.13**	**0.11**

4.2. 3.4 Zinc content in grain (ppm)

The data on zinc content (ppm) in grain of red rice was significantly affected by integrated use of inorganic, organic and micro nutrients (Table 4.2.12). The significantly highest zinc content (ppm) was registered under the treatment of N_{120}:P_{80}:K_{60} (T_2) during both the years and on mean basis, but it was at par with the treatments of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), $N_{80}P_{60}K_{40}$+Zn (T_5), $N_{80}P_{60}K_{40}$+S (T_6) and $N_{80}P_{60}K_{40}$ +B (T_7) during 2014 and treatment of $N_{80}P_{60}K_{40}$) + B (T_7) on mean basis.

4.2. 3.5 Iron content in grain (ppm)

The data on iron content (ppm) in grain of red rice as influenced by as influenced by integrated use of inorganic, organic and micro nutrients (Table 4.2.12). The significantly highest iron content was registered under the treatment of $N_{80}P_{60}K_{40}$+Zn (T_5) during 2013 and on mean basis, but it was at par with the treatment of N_{120}:P_{80}:K_{60} (T_2). During 2014 significant different among the treatment was not observed for iron content in grain.

4.2. 4 N, P and K uptake by red rice

4.2.4.1 N uptake (kg ha^{-1})

The data on N uptake in grain, straw and in their total as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.13. Significantly highest N uptake in grain, straw and also in total N uptake was noticed under the treatment of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) which was significantly superior over rest of treatments during both the years and on mean basis.

4.2.4.2 P uptake (kg ha^{-1})

The P uptake in grain, straw and in their total was significantly influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2. 14. Significantly the highest P uptake in grain, straw and in their total was obtained under the treatment of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during both the years and mean basis, but it was at par with the treatments of $N_{80}P_{60}K_{40}$+Zn + B (T_9) and $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) in straw during 2014 as well as treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) in case of their total uptake during 2014.

Table 4.2.19: Energetic of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Energy use efficiency ($qMJ^{-1}x10^{-3}$)			Energy output input ratio			Energy productivity ($g MJ ha^{-1}$)		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
$T_{1:}$ $N_{80}P_{60}K_{40}$	1.01	0.90	0.95	13.11	12.77	12.85	441.33	427.00	434.00
$T_{2:}$ $N_{120}P_{80}K_{60}$	0.88	0.84	0.87	11.82	11.67	11.75	398.33	392.67	395.33
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	0.98	0.89	0.95	13.20	12.48	12.84	455.33	459.00	457.00
T_4 :$N_{120}P_{80}K_{60+}$ FYM_{5t}	0.84	0.81	0.84	11.39	11.22	11.31	388.33	385.00	387.00
T_5 :$N_{80}P_{60}K_{40}$+Zn	1.07	1.03	1.07	14.50	14.37	14.44	495.00	498.33	496.67
T_6 :$N_{80}P_{60}K_{40}+S_I$	1.06	1.03	1.06	14.29	14.44	14.37	487.00	496.67	492.00
T_7 :$N_{80}P_{60}K_{40}$+B	1.06	1.03	1.06	14.31	14.35	14.33	488.00	498.67	493.00
T_8 :$N_{80}P_{60}K_{40}+Zn_{+}S_I$	1.08	1.02	1.06	14.55	14.25	14.40	506.67	494.67	500.67
$T_{9:}N_{80}P_{60}K_{40}+Zn_{+}B$	1.09	1.05	1.09	14.71	14.66	14.69	494.33	503.33	498.67
$T_{10:}$ $N_{80}P_{60}K_{40}+B_{+}$ S_I	1.09	1.06	1.09	14.70	14.76	14.73	503.00	510.67	507.00
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ $S_{I+}B$	1.12	1.09	1.12	15.13	15.24	15.19	521.67	538.00	530.00
T_{12} :Control	0.71	0.78	0.75	9.71	10.63	10.17	366.33	372.33	369.00
SEm±	**0.02**	**0.01**	**0.01**	**0.31**	**0.17**	**0.19**	**13.54**	**9.64**	**10.52**
CD (*P*=0.05)	**o.07**	**0.04**	**0.04**	**0.94**	**0.51**	**0.57**	**39.98**	**28.48**	**31.06**

Table 4.2.20: Energy intensiveness and production efficiency of red rice as influenced by integrated use of inorganic, organic and micro nutrients

Treatment	Energy intensiveness (MJ Re^{-1})			Production efficiency (kg ha^{-1} day^{-1})		
	2013	2014	Mean	2013	2014	Mean
$T_{1:}$ $N_{80}P_{60}K_{40}$	6.623	6.192	6.408	36.99	35.17	36.08
$T_{2:}$ $N_{120}P_{80}K_{60}$	7.314	6.942	7.128	43.10	41.75	42.43
$T_{3:}N_{80}P_{60}K_{40+}FYM_{5t}$	6.511	5.946	6.229	44.12	43.73	43.93
T_4 :$N_{120}P_{80}K_{60+}$ FYM_{5t}	6.658	6.348	6.504	47.11	45.92	46.51
T_5 :$N_{80}P_{60}K_{40}$+Zn	7.123	6.795	6.959	43.77	43.28	43.53
T_6 :$N_{80}P_{60}K_{40}+S_I$	6.257	6.101	6.179	41.14	41.26	41.20
T_7 :$N_{80}P_{60}K_{40}$+B	7.016	6.761	6.889	41.75	41.95	41.86
T_8 :$N_{80}P_{60}K_{40}+Zn_{+}S_I$	6.287	5.952	6.120	45.15	43.30	44.23
$T_{9:}N_{80}P_{60}K_{40}+Zn_{+}B$	7.067	6.787	6.927	44.59	44.63	44.61
$T_{10:}$ $N_{80}P_{60}K_{40}+B_{+}$ S_I	6.316	6.130	6.224	43.42	43.34	43.38
T_{11} :$N_{80}P_{60}K_{40}$+Zn+ $S_{I+}B$	6.424	6.268	6.346	47.43	48.07	47.75
T_{12} :Control	2.246	2.345	2.295	12.10	12.10	12.10
SEm±	**0.099**	**0.083**	**0.070**	**0 .68**	**0.68**	**0.51**
CD (*P*=0.05)	**0.292**	**0.246**	**0.207**	**2.01**	**2.02**	**1.53**

4.2.4.3 K uptake (kg ha^{-1})

The data on K uptake in grain, straw and in their total was significantly affected by integrated use of inorganic, organic and micro nutrients (Table 4.2.15). Significantly the highest K uptake in grain was observed under the treatment of $N_{80}P_{60}K_{40}$ FYM_{5t} (T_3) during both the years and on mean basis, but it was at par with the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during 2013 and 2014 .While, K uptake in straw was significantly the highest with treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during both the years and on mean basis, but it was at par with the treatments $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) and $N_{80}P_{60}K_{40}$+Zn + B (T_9) during 2013 and 2014 as well as treatment $N_{80}P_{60}K_{40}$+Zn +S_I (T_8) during 2014.The total K uptake was significantly superior under the treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during both the years and on mean basis, but it was at par with treatments $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during both the years as well as mean basis , treatment $N_{80}P_{60}K_{40}$ FYM_{5t} (T_3) during 2013, treatment $N_{80}P_{60}K_{40}$+Zn +B (T_9) during 2013 and 2014 treatment $N_{80}P_{60}K_{40}$+S_I+B(T_{10}) during 2014.

Discussion on nutrient concentration and uptake

Significantly highest N and P content during both the years and on mean basis in grain and straw was registered under treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4). Significantly highest K content in grain and straw during both the years and on mean basis was registered under treatment $N_{80}P_{60}K_{40}$+FYM_{5t} (T_3) over rest of the treatments. Significantly highest zinc content (ppm) was registered with treatment N $_{120}P_8$:K $_{60}$ (T_2) during both the years and on mean basis, but it was at par with treatments $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), $N_{80}P_{60}K_{40}$+Zn (T_5), $N_{80}P_{60}K_{40}$+S_I (T_6) and $N_{80}P_{60}K_{40}$) + B (T_7) during 2014 and treatment $N_{80}P_{60}K_{40}$) + B (T_7) on mean basis. Significantly highest iron content (ppm) was registered under treatment $N_{80}P_{60}K_{40}$+Zn (T_5) during 2013 and on mean basis ,but it was at par with treatment N $_{120}$:P_{80}:K $_{60}$ (T_2). The application of nutrients under said treatments, enable the plant for better absorption due to readily available form and their translocation and mobilization in productive parts enhanced the concentration of above nutrients in grain and straw. The highest N uptake in grain, straw and in their total was noticed under treatment $N_{120}P_{80}K_{60}$ +FYM_{5t} (T_4) over rest of treatments during both the years and on mean basis.

The P uptake in grain, straw and in their total was under treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during both the years and mean basis. Significantly highest K uptake in grain was observed with treatment $N_{80}P_{60}K_{40}$ FYM_{5t} (T_3) during both the years and on mean basis. However, K uptake in straw was significantly highest with treatment $N_{80}P_{60}K_{40}$+Zn +S_I + B (T_{11}) during both the years and on mean basis .The total K uptake was significantly highest under treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during both the years and on mean basis .The uptake is the function of dry matter production and concentration of nutrients in plants. However, treatments received inorganic source of nutrients in addition to FYM are micro nutrients enhanced the uptake of N, P and K and grain and straw offer more balanced nutrition to be plants especially secondary and micro nutrients (Rakshit *et al.*, 2008). The yield attributing characters viz. plant height, number of panicles^{-1}, panicle length, grains panicle^{-1} and test weight increased with higher doses of NPK along with use of S, B and Zn as compared to control. The application of Zn, B and S also influenced yield attributes of rice positively during both the years and if omitted, a notable reduction was observed in yield. Farmyard manure helps in improving soil organic matter content, water-holding capacity, nutrient exchange and maintains soil health (Khan *et al,* 2010; Tadesse *et al.,* 2013). Nutrient uptake values in rice indicates that addition of FYM to inorganic fertilizer enhances the treatments Sharma and Bali (2001) confirmed that nutrient uptake (N, P and K) values were of higher order in FYM treated plots and these further improves with graded levels of nutrient application. Yadav *et al.* (2002) corroborate the similar finding, under rice-wheat cropping sequence. Judicious use of chemical fertilizers in combination with organic manures is required to improve the soil health as well as to achieve sustainable production. This might be attributed to improved soil physical condition and higher availability of macro- and micro-nutrients with the addition of FYM. There was improvement in organic carbon reserve, soil N, P and K in all the combination of organic manure from their initial values except control. The increase in organic carbon content of the soil with the application of organic manure has also reported by Banwasi and Bajpai (2006). The higher biomass and yields has enhanced nutrient uptake.

4.2.5 Quality Parameters

4.2.5.1 Head rice recovery of paddy

The data on head rice recovery of red rice as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.17. Significantly highest head rice recovery was registered with treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) which was significantly superior over other treatments during both the years and on mean basis, but it was at par with treatments $N_{120}P_{80}K_{60}$ (T_2), $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), $N_{80}P_{60}K_{40}$+B (T_7), $N_{80}P_{60}K_{40}$+Zn +S_I (T_8), $N_{80}P_{60}K_{40}$ + Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B_{10}+S_I (T_{10}) during 2014.

4.2.5.2 Length, breadth and L/B ratio of paddy

Data pertaining length, breadth and L/B ratio of red rice as influenced by integrated use of inorganic, organic and micro nutrients during both the years and on mean basis are presented in Table 4.3.16. The application of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) registered significantly longer paddy length and L/B ratio over other treatments during both the years and on mean basis. Whereas breadth of paddy was significantly highest under treatment $N_{80}P_{60}K_{40}$+B_{10}+S_I (T_{10}) which was at par with treatments $N_{80}P_{60}K_{40}$+Zn+ S_I (T_8) and $N_{80}P_{60}K_{40}$+ Zn +B(T_9) during 2013 and on mean basis as well as $N_{80}P_{60}K_{40}$+S_I (T_6)and $N_{80}P_{60}K_{40}$+B (T_7) during 2013 and treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) on mean basis. But during 2014, breadth of paddy significantly highest under treatment $N_{80}P_{60}K_{40}$+Zn + S_I + B (T_{11}).

Discussion on quality Parameters

Significantly longer paddy length and L/B ratio was registered under treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) over other treatments during both the years and on mean basis. Whereas breadth of paddy was significantly highest under treatment $N_{80}P_{60}K_{40}$+B_{10}+S_I (T_{10}) which was at par with treatments $N_{80}P_{60}K_{40}$+Zn+S_I (T_8) and $N_{80}P_{60}K_{40}$+ Zn +B (T_9) at most of recorded period. This might be due to either direct or cumulative effect of supplied macro and micro nutrients on metabolic processes of rice. Application of zinc is significantly affected total number of tillers, number ofpanicle bearing tillers, panicle length, number of branches per panicle and number of kernels panicle^{-1} and other qualiy parameters. Food crops grown using organic inputs having less or no chemicals are being preferred over conventionally produced food by the end users. Food market in developed and developing countries Urkurkar *et al.*,(2010). Scientists and policy-planners are, therefore, reassessing agricultural practices, which relied more on biological inputs rather than heavy usage of chemical fertilizers and pesticides. Yadav *et al.* (2013) reported that the organic production systems maintain and improve the soil health through stimulating the activity of soil organisms.

4.2.6 Economics

4.2.6.1 Gross return (000 Rs ha^{-1})

The data on gross return of red rice are presented in (Table 4.2.18). The highest gross return during both the years and on mean basis was registered under the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I +B (T_{11}), which was at par with treatments $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during 2013 and on mean basis.

4.2.6.2 Net return (000 Rs ha^{-1})

The data on net return of red rice as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.18. Significantly highest net return was registered during 2013 under treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), but it was at par with treatments $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$+ Zn (T_5), $N_{80}P_{60}K_{40}$+ Zn +B (T_9) and $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}). Whereas during 2014 whereas, on mean basis significantly highest net return was observed under treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) ,but it was at par with treatments $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) and $N_{80}P_{60}K_{40}$+ Zn +B (T_9).

4.2.6.3 B: C ratio (000 Rs ha^{-1})

The data on B: C ratio of red rice significantly affected by integrated use of inorganic, organic and micro nutrients (Table 4.2.17). The highest B:C ratio in year 2013 and on mean basis was registered with treatment of $N_{120}P_{80}K_{60}$ (T_2) which was significantly superior over rest of treatments expect the treatments of $N_{80}P_{60}K_{40}$+Zn (T5), $N_{80}P_{60}K_{40}$+B (T_7) and $N_{80}P_{60}K_{40}$+ Zn +B (T_9). During 2014, treatment of $N_{80}P_{60}K_{40}$+Zn (T_5) gave the maximum B: C ratio followed by $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$+B (T_7) and $N_{80}P_{60}K_{40}$+ Zn +B (T_9).

4.2.7 Energetics

4.2.7 .1 Energy use efficiency (qMJ^{-1}x10^{-3})

The data on energy use efficiency of red rice as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.19. The highest energy use efficiency during both the years and on mean basis was registered with treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B_{10} (T_{11}) but at par with treatments$N_{80}P_{60}K_{40}$+Zn (T_5), $N_{80}P_{60}K_{40}$+S_I (T_6),$N_{80}P_{60}K_{40}$+ B (T_7), $N_{80}P_{60}K_{40}$+Zn +S (T_8), $N_{80}P_{60}K_{40}$ + Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during 2013, while treatments $N_{80}P_{60}K_{40}$+ Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during 2014 and on mean basis .

4.2.7 .2 Energy output input ratio

The data on energy output input ratio of red rice as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.19. The highest energy output input ratio was registered with treatment $N_{80}P_{60}K_{40}$+Zn +SI+B (T_{11}) during both the years and on mean basis, but it was at par with treatments $N_{80}P_{60}K_{40}$+Zn (T_5),$N_{80}P_{60}K_{40}$+S_I (T_6),$N_{80}P_{60}K_{40}$+B $_{10}$ (T_7), $N_{80}P_{60}K_{40}$+Zn +S_I (T_8), $N_{80}P_{60}K_{40}$+ Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during year 2013, while treatment $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) in year 2014 and treatments $N_{80}P_{60}K_{40}$+ Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) on mean basis.

4.2.7.3 Energy productivity (g MJ ha^{-1})

The data on energy productivity of red rice as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.19. Significantly highest energy productivity during both the years and on mean basis was registered under the treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) but it was at par with treatments $N_{80}P_{60}K_{40}$+Zn (T_5),$N_{80}P_{60}K_{40}$+S_I (T_6),$N_{80}P_{60}K_{40}$+B (T_7), $N_{80}P_{60}K_{40}$+Zn+S_I (T_8), $N_{80}P_{60}K_{40}$+ Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B+S_I during 2013, and treatment $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during 2014 and on mean basis as well as treatments $N_{80}P_{60}K_{40}$+Zn +S_I (T_8) on mean basis.

4.2.7.4 Energy intensiveness (MJ Re^{-1})

The data on energy of intensiveness of red rice as influenced by integrated use of inorganic, organic and micro nutrients are presented in Table 4.2.20. Significantly highest energy of intensiveness during both the years and on mean basis was registered under treatment $N_{120}P_{80}K_{60}$ (T_2) but it was at par with treatments $N_{80}P_{60}K_{40}$+Zn (T_5) and $N_{80}P_{60}K_{40}$+ Zn +B (T_9) during both the years and on mean basis as well as treatment $N_{80}P_{60}K_{40}$+B (T_7) during 2014.

4.2.7.2. Production efficiency (kg ha^{-1} day^{-1})

The data on production efficiency of red rice are presented (Table 4.2 20). Significantly highest production efficiency was registered during both the years and on mean basis under treatment $N_{80}P_{60}K_{40}$+Zn +SI+B (T_{11}) but it was at par with treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during 2013 and on mean basis.

Discussion on economics, energetics and production efficiency

At most of data on production efficiency, energy use efficiency, energy output input ratio and energy productivity revealed that red rice were highest during both the years and on mean basis was registered with treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) which was at par with treatments $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) and $N_{80}P_{60}K_{40}$+S_I (T_6). While, energy intensiveness in during both the years and on mean basis was registered with treatment $N_{120}P_{80}K_{60}$ (T_2) which was at par with treatments $N_{80}P_{60}K_{40}$+Zn (T_5) and $N_{80}P_{60}K_{40}$+ Zn +B (T_9) with additional treatment $N_{80}P_{60}K_{40}$+B (T_7) during the year 2014. Combination of macro and micronutrients accelerate or in combination with organic source the growth and yield attributes resulted in better efficiency. This confirms the finding of Kumar and Prasad (2003).Maximum gross return during both the years and on mean basis was registered with treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) but at par with treatments $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during 2013 and on mean basis. Net return was registered during year2013 with treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) but at par with treatments $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$+ Zn (T_5), $N_{80}P_{60}K_{40}$+ Zn +B (T_9) and $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}). Further, in year 2014 and on mean basis highest net return observed with treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) but at par with treatments $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) and $N_{80}P_{60}K_{40}$+ Zn +B (T_9). Highest B:C ratio in year 2013 and on mean basis was registered with treatment $N_{120}P_{80}K_{60}$ (T_2) but at par with treatments $N_{80}P_{60}K_{40}$+Zn ha^{-1} (T_5), $N_{80}P_{60}K_{40}$+B (T_7) and $N_{80}P_{60}K_{40}$+ Zn $_{25}$ +B10 ha^{-1} (T_9). Moreover in year 2014 treatment $N_{80}P_{60}K_{40}$+Zn (T_5) noticed maximum B:C ratio but at par with treatments $N_{120}P_{80}K_{60}$ ha^{-1} (T_2), $N_{80}P_{60}K_{40}$+B_{10} ha^{-1}

(T_7) and $N_{80}P_{60}K_{40}$+ Zn $_{25}$ +B_{10} ha^{-1} (T_9). The effect of increased fertilizer use on crop production has increased, but ever increasing cost of energy is a significant constraint for increased use of inorganic fertilizers. Use of organic matter to meet the nutrient requirement of crops will be an inevitable practice in years, especially for resource poor farmers. Furthermore, ecological and environmental concerns over the increased and indiscriminate use of organic fertilizers have made research of use of organic materials as a source of nutrients very necessary. Satyanarayana *et al*., (2002) reported that recommended dose of NPK along with 10 t FYM/ha produced an optimum grain yield and economic of rice.

4.3 Experiment No. III: Enhancement of productivity and quality of red rice through organic and inorganic application of nutrients

4.3.1 Growth Parameters

4.3.1.1 Plant height (cm)

The data on plant height recorded at 30, 60 and 90 DAT are presented in Table 4.3.1. The application of N $_{120}P_{60}K_{40}$ I (T_2) found significantly superior for producing tallest plant of red rice at all the periods of observations during both the years as well as on mean basis. Further, more on par plant height was recorded under the treatments of $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during 2013 at 30 DAT, on mean basis at 60 DAT and during both the years and on mean basis at 90 DAT, treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during 2013 at 30 DAT and treatments N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) on mean basis at 60 DAT. The shortest plant height was recorded under control at all the stages during the both years and on mean basis.

4.3.1.2 Dry matter accumulation (g hill^{-1})

The dry matter accumulation of red rice was determined at 30,60 and 90 DAT and data are presented in Table 4.3.2. The dry matter accumulation was significantly influenced by organic and inorganic application of nutrients .At all the growth periods of observations, treatment N $_{120}P_{60}K_{40}$ (I) (T_2) registered significantly highest dry matter accumulation during both the years and mean basis. However, it was at par to treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during the both years and on mean basis at 60 DAT as well as treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4), N of T_1 applied through organics (O) + FS of N at T and

Table 4.3.1: Plant height at different durations of red rice as influenced by organic and inorganic application of nutrients

Treatment	Plant height (cm)								
	30 DAT			60 DAT			90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
T_1: $N_{60}P_{40}K_{30}$ (I)	12.8	13.1	12.9	60.9	63.9	62.4	108.6	112.8	110.7
T_2: $N_{120}P_{60}K_{40}$ (I)	15.7	16.6	16.2	70.4	72.6	71.5	123.5	127.2	125.3
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	13.2	13.3	13.3	56.3	61.3	58.8	105.1	108.0	106.6
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	14.4	14.8	14.6	60.2	63.9	62.0	122.1	125.8	124.0
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	12.5	13.5	13.0	63.7	64.1	63.9	108.1	111.9	110.0
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	14.4	15.5	14.9	64.7	46.5	55.6	118.1	120.9	119.5
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	12.4	13.0	12.7	58.3	59.4	58.8	103.5	107.2	105.4
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	11.8	12.8	12.3	61.2	63.2	62.2	112.7	116.5	114.6
T_9: Control	9.7	11.2	10.4	51.1	53.4	52.3	96.5	99.2	97.8
SEm±	0.49	0.27	0.35	0.90	6.53	3.18	1,55	1.36	1.44
CD (P=0.05)	1.49	0.84	1.07	2.72	NS	9.61	4.71	4.13	4.37

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

Table 4.3.2: Dry matter accumulation at different durations of red rice as influenced by organic and inorganic application of nutrients

Treatment	Dry matter accumulation (g $hill^{-1}$)								
	30 DAT			60 DAT			90 DAT		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_1: $N_{60}P_{40}K_{30}$ (I)	9.2	11.0	10.1	18.2	20.4	19.3	30.8	32.8	31.8
T_2: $N_{120}P_{60}K_{40}$ (I)	12.7	14.8	13.8	22.5	24.2	23.4	38.1	40.4	39.2
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	9.0	10.3	9.6	18.0	20.0	19.0	31.8	33.5	32.6
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	10.8	13.0	11.9	19.2	21.1	20.1	36.4	38.9	37.7
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	9.1	10.9	10.0	18.3	19.9	19.1	31.4	33.4	32.4
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	10.7	12.8	11.8	21.6	23.8	22.7	32.7	34.8	33.8
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	8.8	9.4	9.1	17.9	20.0	18.9	36.7	39.0	37.9
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	10.1	11.2	10.7	19.2	21.1	20.2	35.6	38.9	37.3
T_9: Control	7.5	9.4	8.4	14.8	17.4	16.1	22.5	25.5	24.0
SEm±	0.29	0.32	0.22	0.52	0.45	0.47	0.83	0.72	0.75
CD (P=0.05)	0.89	0.97	0.69	1.57	1.37	1.42	2.53	2.20	2.28

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

PI stages (T_7) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during the both years and on mean basis at 90 DAT.

4.3.1.3 Leaf area index

The data on leaf area index was recorded at 30, 60 and 90 DAT and presented in Table 4.3.3. The leaf area index increased from 30 DAT to 90 DAT. The rate of increase (LAI) was more pronounce from 30 DAT to 60 DAT and declined thereafter from 60 DAT to 90 DAT.

At 30 DAT, significantly the highest leaf area index was registered under treatment of $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during the both years and on mean basis , but it was at par with $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in year 2014. Further, at 60 DAT in year 2014, significantly highest leaf area index was registered with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) which was at par with treatment N_{60} $P_{40}K_{30}$ (25% O +75% I) (T_3), $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) and N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5).Whereas on mean basis significantly highest leaf area index was recorded under $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) which was at par with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8). Moreover, at 90 DAT during both years and on mean basis, significantly highest leaf area index was recorded under $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) which was at par with treatments $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) and N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) and N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) during 2013 and treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during 2014 and on mean basis.

4.3.1.4 Crop growth rate (g hill^{-1} day^{-1})

The crop growth rate computed at 0- 30, 30-60 and 60-90 DAT and presented in Table 4.3.4. In general, crop growth rate increased from 0- 30 to 60-90 DAT. At early crop growth rate (0- 30 DAT),it was highest with the treatment of $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) which was significantly superior over rest of the treatments in both the years and on mean basis. Moreover, at 30- 60 DAT in year 2014 and on mean basis the highest crop growth rate was observed under the treatment of $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) but it was at par with treatment N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) during 2014 and on mean basis and also where treatment N of T_2 applied

Table 4.3.3: Leaf area index at different durations of red rice as influenced by organic and inorganic application of nutrients

Treatment	Leaf area index								
	30 DAT			60 DAT			90 DAT		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_1: $N_{60}P_{40}K_{30}$ (I)	1.81	2.13	1.97	2.62	2.91	2.77	3.83	3.92	3.88
T_2: $N_{120}P_{60}K_{40}$ (I)	2.31	2.42	2.37	2.83	2.94	2.89	4.53	4.45	4.49
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	2.13	2.21	2.17	3.13	3.25	3.19	4.27	4.45	4.36
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	2.81	2.74	2.76	3.73	3.48	3.61	4.49	4.72	4.61
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	2.11	2.33	2.22	3.13	3.41	3.27	4.65	4.12	4.39
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	2.21	2.52	2.36	2.82	3.11	2.97	4.68	4.88	4.78
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	1.93	2.45	2.19	2.93	3.22	3.08	4.67	4.13	4.40
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	2.11	2.32	2.22	3.43	3.54	3.49	4.21	4.11	4.16
T_9: Control	1.61	1.93	1.77	2.23	2.36	2.30	3.13	3.21	3.17
SEm±	0.07	0.08	0.07	0.48	0.09	.08	0.10	0.10	0.09
CD (P=0.05)	0.22	0.26	0.22	NS	0.29	0.26	0.31	0.30	0.27

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

Table 4.3.4: Crop growth rate at different periods of red rice as influenced by organic and inorganic application of nutrients

Treatment	Crop growth rate (g $hill^{-1}$ day^{-1})								
	0 -30 DAT			30-60 DAT			60-90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
T_1: $N_{60}P_{40}K_{30}$ (I)	0.16	0.18	0.17	0.30	0.31	0.31	0.42	0.41	0.42
T_2: $N_{120}P_{60}K_{40}$ (I)	0.20	0.19	0.20	0.31	0.31	0.31	0.52	0.54	0.53
T_3: N_{60} $P_{40}K_{30}$ (25% O +75% I)	0.17	0.18	0.18	0.30	0.32	0.32	0.46	0.45	0.46
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	0.17	0.20	0.19	0.28	0.27	0.28	0.57	0.59	0.59
T_5: N_{60} $P_{40}K_{30}$ (50% O +50 % I)	0.18	0.20	0.20	0.31	0.30	0.30	0.44	0.45	0.45
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	0.28	0.29	0.42	0.36	0.37	0.37	0.57	0.57	0.57
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	0.19	0.18	0.19	0.30	0.35	0.33	0.63	0.63	0.63
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	0.15	0.17	0.16	0.30	0.33	0.32	0.56	0.60	0.58
T_9: Control	0.12	0.10	0.13	0.24	0.27	0.25	0.26	0.27	0.27
SEm±	0.02	0.01	0.01	0.024	0.01	0.01	0.01	0.03	0.01
CD (P=0.05)	0.06	0.03	0.02	NS	0.04	0.04	0.03	0.09	0.03

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

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through organics (O) + FS of N at T and PI stages (T8) was given during 2014. During the period 60- 90 DAT, treatment N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) registered maximum crop growth rate during both the years and mean basis . However, in year 2014 treatments $N_{120}P_{60}K_{40}$ (I) (T2), $N_{120}P_{60}K_{40}$ (25% O +75% I) $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4), $N_{60}P_{40}K_{30}$ (50% O +50 % I) (T_5) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T8) also recorded comparable values .

4.3.1.5 Relative growth rate (g g^{-1} $hill^{-1}$ day^{-1})

The data on relative growth rate computed at 0- 30, 30-60 and 60-90 DAT are presented in Table 4.3.5. It was observed that relative crop growth rate declined with advancement of crop age .The early relative growth rate (0- 30 DAT) was noticed highest with treatment N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) ,however it was at par with treatments $N_{60}P_{40}K_{30}$ (I) (T_1), $N_{60}P_{40}K_{30}$ (25% O +75% I) (T_3), $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6), N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) and Control during 2014 and on mean basis. More over at 30- 60 DAT treatment $N_{120}P_{60}K_{40}$ (I) (T_2) gave significantly higher relative growth rate as compared to others during both the years and mean basis. Further, at 60- 90 DAT, treatment N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) gave maximum relative growth rate which was significantly higher than others, but it was at par to treatments $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) in both the years as well as on mean basis.

4.3.2 Root volume, yield attributes and yield

4.3.2.1 Root volume (cc)

The data on root volume (cc) of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.6. Significantly highest was registered under the treatment of $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) but it was at par with treatments $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during both the years and on mean basis as well as treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during 2013.

Table 4.3.5: Relative Crop growth rate at different periods of red rice as influenced by organic and inorganic application of nutrients

Treatment	Relative growth rate ($g\ g^{-1}\ hill^{-1}\ day^{-1}$)								
	0 -30 DAT			30-60 DAT			60-90 DAT		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
T_1: $N_{60}P_{40}K_{30}$ (I)	0.023	0.021	0.022	0.081	0.087	0.084	0.018	0.016	0.017
T_2: $N_{120}P_{60}K_{40}$ (I)	0.019	0.016	0.018	0.092	0.097	0.095	0.018	0.017	0.017
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	0.023	0.022	0.023	0.080	0.085	0.083	0.019	0.017	0.018
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	0.019	0.016	0.018	0.087	0.093	0.090	0.021	0.020	0.021
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	0.023	0.020	0.022	0.081	0.087	0.084	0.018	0.017	0.018
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	0.023	0.021	0.022	0.087	0.092	0.090	0.014	0.013	0.013
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	0.024	0.025	0.024	0.080	0.082	0.081	0.024	0.022	0.023
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	0.021	0.021	0.021	0.085	0.088	0.086	0.021	0.020	0.021
T_9: Control	0.023	0.021	0.022	0.075	0.082	0.078	0.014	0.013	0.013
SEm±	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
CD (P=0.05)	NS	0.004	0.004	0.003	0.003	0.002	0.004	0.004	0.004

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

Table 4.3.6: Root volume, effective tillers and length of panicle of red rice as influenced by organic and inorganic application of nutrients

	Root volume (cc)			Effective tillers (No. hill^{-1})			Panicle length (cm)		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_1: $N_{60}P_{40}K_{30}$ (I)	18.2	20.4	19.3	10.2	12.1	11.15	16.3	18.0	17.15
T_2: $N_{120}P_{60}K_{40}$ (I)	22.8	25.2	24.0	12.8	14.7	13.75	17.9	19.6	18.75
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	21.9	22.5	22.2	11.3	15.6	13.45	17.8	17.1	17.45
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	24.2	26.7	25.4	14.5	16.8	15.65	18.6	18.7	18.75
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	21.8	23.0	22.4	14.1	14.8	14.45	17.9	18.8	18.35
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	24.3	27.2	25.8	16.9	17.8	17.35	18.8	20.9	19.85
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	21.7	23.2	22.5	9.3	10.8	10.05	16.7	17.4	17.05
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	22.6	24.5	23.5	8.9	10.2	9.55	17.7	19.9	18.8
T_9: Control	14.1	15.7	14.9	7.1	7.2	7.15	14.4	16.3	15.35
SEm±	0.69	0.75	0.65	0.41	0.35	0.23	0.26	0.39	0.30
CD (P=0.05)	2.08	2.29	1.97	1.24	1.08	0.70	0.80	1.18	0.90

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

4.3.2.2 Effective tillers (No .hill $^{-1}$)

The data on effective tillers hill $^{-1}$ as influenced by organic and inorganic application of nutrients are presented in Table 4.3.6. Significantly highest number of effective tillers hill $^{-1}$ was obtained with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during both the years as well as on mean basis, but it was at par with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) in year 2014 **.**

4.3.2. 3 Panicle length (cm)

The data on panicle length of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.6. Significantly longest panicle was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I (T_6) during both the years as well as on mean basis, but it was at par with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) in year 2013 and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during 2014 .

4.3.2.4 Panicle weight (g)

The data on panicle weight of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.7. Significantly highest panicle weight was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during both the years as well as mean basis ,but it was at par with treatments N_{60} $P_{40}K_{30}$ (25% O +75% I) (T_3), $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) , N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5), N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) in year 2014.

4.3.2.5 Grains panicle^{-1} (No)

The data on number of grains panicle^{-1} of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.7. Significantly highest number of grains panicle^{-1} was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) but it was at par with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during 2013 and on mean basis. .Further, in year 2014 treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) gave significantly highest number of grains panicle^{-1} which was at par with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6).

Table 4.3.7: Panicle weight, grains panicle^{-1} and test weight of red rice as influenced by organic and inorganic application of nutrients

Treatment	Panicle weight (g)			Grains panicle^{-1} (No.)			Test weight (g)		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_1: $N_{60}P_{40}K_{30}$ (I)	2.91	3.22	3.07	88.1	92.4	90.3	23.2	24.4	23.8
T_2: $N_{120}P_{60}K_{40}$ (I)	3.23	3.14	3.19	112.9	117.3	115.1	23.4	24.8	24.1
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	3.13	3.41	3.27	93.2	96.8	95.0	23.2	24.2	23.7
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	3.33	3.61	3.47	124.3	128.7	126.5	23.5	24.5	24.0
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	3.23	3.51	3.37	95.0	97.1	96.1	23.3	24.3	23.8
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	3.95	3.81	3.88	125.3	127.8	126.6	23.6	24.8	24.2
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	3.23	3.35	3.29	78.1	81.0	79.6	23.4	24.3	23.8
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	3.21	3.54	3.38	72.2	74.9	73.6	23.3	24.5	23.9
T_9: Control	2.43	2.61	2.52	64.5	67.1	65.8	22.8	24.1	23.5
SEm±	0.07	0.16	0.10	1.51	1.49	1.48	0.07	0.03	0.04
CD (P=0.05)	0.22	0.49	0.32	4.56	4.51	4.48	0.21	0.10	0.12

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

Table 4.3.8: Yield and harvest index of red rice as influenced by organic and inorganic application of nutrients

Treatment	Grain yield(q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_1: $N_{60}P_{40}K_{30}$ (I)	37.8	39.5	38.7	47.1	49.3	48.2	44.6	44.5	44.5
T_2: $N_{120}P_{60}K_{40}$ (I)	49.9	51.5	50.7	63.8	65.6	64.7	43.9	44.0	43.9
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	42.1	43.4	42.7	54.1	56.1	55.1	43.8	43.6	43.7
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	53.3	52.8	53.1	67.2	68.4	67.8	44.3	43.5	43.9
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	44.2	43.0	43.6	55.8	56.6	56.2	44.2	43.2	43.7
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	53.8	55.8	54.8	65.9	68.0	66.9	45.0	45.1	45.0
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	34.0	35.3	34.7	43.8	45.9	44.8	43.7	43.5	43.6
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	38.3	39.9	39.1	45.3	46.6	45.9	45.8	46.2	46.0
T_9: Control	16.1	18.8	17.4	22.6	24.6	23.6	41.7	43.3	42.5
SEm±	0.57	0.68	0.50	1.05	1.12	1.03	0.95	0.97	0.91
CD (*P*=0.05)	1.73	2.08	1.53	3.18	3.40	3.13	NS	NS	NS

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

4.3.2.6 Test weight (g)

The data on test weight of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.7. Significantly highest test weight was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both years and on mean basis ,but it was at par with treatments $N_{120}P_{60}K_{40}$ (I) (T_2), $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4), $N_{60}P_{40}K_{30}$ (50% O +50 % I) (T_5), N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) in year 2013, while in 2014 it was at par with treatments $N_{120}P_{60}K_{40}$ (I) (T_2), however ,on mean basis comparable values were also noted in treatments $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4).

Discussion on growth and yield attributes and root volume

The finding on growth parameters revealed that plant height and dry matter accumulation at most of the duration of red rice were significantly highest under treatment $N_{120}P_{60}K_{40}$ (I) (T_2) which was at par to $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4), $N_{60}P_{40}K_{30}$ (50% O +50 % I) (T_5) and $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6). Whereas leaf area index recorded maximum under treatment $N_{120}P_{60}K:_{40\ 25\%}$ Org +75 % Ino (T_4), at 30DAT and under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) at 90 DAT. As regards to CGR and RGR , the maximum values were noted under $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) followed by N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T8). Highest root volume was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both years and mean basis which was at par with treatments N_{120}:P_{60}:K_{40} (T_2) and $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) with an additional treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) in year 2013. The results on yield attributes and root volume showed that significantly highest values of effective tillers hill $^{-1}$, panicle length, panicle weight , number of grains panicle^{-1} , test weight and root volume were noted under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) followed by $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4). Sarwar *et al.*, (2008) also observed that addition of organic materials appreciably increased the height of rice plants. Application of farmyard manure significantly improved number of tillers, test weight, grain and straw yield of red rice. Organic manure plays an important role in

Table 4.3.9: N content in red rice as influenced by organic and inorganic application of nutrients

Treatment	N content (%)					
	Grain			Straw		
	2013	2014	Mean	2013	2014	Mean
T_1: $N_{60}P_{40}K_{30}$ (I)	1.192	1.204	1.198	0.341	0.342	0.342
T_2: $N_{120}P_{60}K_{40}$ (I)	1.081	1.084	1.083	0.352	0.355	0.354
T_3: N_{60} $P_{40}K_{30}$ (25% O +75% I)	1.092	1.096	1.094	0.362	0.365	0.364
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	1.194	1.195	1.195	0.417	0.420	0.418
T_5: N_{60} $P_{40}K_{30}$ (50% O +50 % I)	1.154	1.157	1.156	0.337	0.339	0.338
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	1.230	1.233	1.232	0.452	0.454	0.453
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	1.171	1.174	1.173	0.346	0.350	0.348
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	1.169	1.171	1.170	0.387	0.388	0.388
T_9: Control	0.094	0.098	0.096	0.324	0.326	0.326
SEm±	0.017	0.019	0.018	0.002	0.002	0.002
CD (P=0.05)	0.053	0.057	0.055	0.005	0.007	0.007

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

Table 4.3.10: P content in red rice as influenced by organic and inorganic application of nutrients

Treatment	P content (%)					
	Grain			Straw		
	2013	2014	Mean	2013	2014	Mean
T_1: $N_{60}P_{40}K_{30}$ (I)	0.231	0.236	0.234	0.074	0.079	0.077
T_2: $N_{120}P_{60}K_{40}$ (I)	0.235	0.238	0.237	0.076	0.081	0.079
T_3: N_{60} $P_{40}K_{30}$ (25% O +75% I)	0.245	0.248	0.247	0.088	0.093	0.090
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	0.268	0.269	0.269	0.108	0.116	0.112
T_5: N_{60} $P_{40}K_{30}$ (50% O +50 % I)	0.234	0.236	0.235	0.096	0.104	0.100
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	0.277	0.280	0.279	0.122	0.139	0.131
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	0.224	0.028	0.225	0.062	0.069	0.066
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	0.216	0.218	0.217	0.064	0.077	0.071
T_9: Control	0.217	0.215	0.216	0.048	0.060	0.054
SEm±	0.001	0.001	0.001	0.002	0.002	0.006
CD (P=0.05)	0.003	0.003	0.003	0.006	0.005	0.018

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

improving soil permeability to air and water and water stable aggregates Application of organic materials such as farm yard manure significantly improved soil physical properties and nutrient uptake resulting in greater growth, yield and yield component (Singh *et al.*, 1994). Application of farm yard manure at 10 t^{-1} contributes 30-70 kg N beside leaving a significant residual effect on succeeding crops (Sharma, 1995).Similarly the number of tillers, number of filled grain test weight are significantly high due to application of farm yard manure .This is affirmation by the long term studies on rice has increased yield factor due to farm yard manure (Nambiar and Aborol , 1989 and Singh *et al.,* 1999) .The effects are largely due to improve soil organic matter, soil physical, chemical and microbial properties with application of farm yard manure . The use of inorganic fertilizer (50%) and farmyard manure or green manure (50%) produced better growth and yields attributes than those obtained application of 100% of recommended inorganic fertilizers(Katyal and Gangwar ,2000). This suggests that judicious use of organic material can results in growth and yield characters on par with that obtained with organic fertilizers (Raman *et al.*, 1996, Singh *et al*., 1999, Pandey *et al*.,1999) .Thus application of organic materials are not only improving crop yield, but also decreasing dependence on fossil fuel based on organic fertilizers, thereby reducing hazards caused by continuous and indiscriminate use of chemical fertilizers. Studies have also shown the beneficial effects of green manures, and blue green algae on productivity of rice (Meelu, 1992). Therefore, research efforts should continue to be done by the study various organic materials such as green manures, legumes, rice straw, compost, sewage Sludge, bio fertilizers (blue green algae and azolla) and inorganic fertilizer on the productivity of rice.

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

The data on grain yield of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.8. Significantly highest grain yield was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis but was at par with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during 2013.

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

The data on straw yield of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.8. Significantly highest straw yield was registered with

Table 4.3.11: K content in red rice as influenced by organic and inorganic application of nutrients

Treatment	K content (%)					
	Grain			Straw		
	2013	2014	Mean	2013	2014	Mean
T_1: $N_{60}P_{40}K_{30}$ (I)	0.231	0.239	0.235	1.080	1.089	1.084
T_2: $N_{120}P_{60}K_{40}$ (I)	0.241	0.251	0.246	1.104	1.104	1.104
T_3: N_{60} $P_{40}K_{30}$ (25% O +75% I)	0.252	0.254	0.254	1.109	1.112	1.111
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	0.293	0.308	0.301	1.195	1.226	1.211
T_5: N_{60} $P_{40}K_{30}$ (50% O +50 % I)	0.240	0.244	0.242	1.114	1.115	1.115
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	0.302	0.316	0.309	1.319	1.138	1.229
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	0.230	0.231	0.231	1.136	1.140	1.138
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	0.227	0.225	0.226	1.232	1.142	1.187
T_9: Control	0.192	0.196	0.194	1.106	1.109	1.108
SEm±	0.002	0.002	0.001	0.035	0.002	0.017
CD (P=0.05)	0.005	0.006	0.004	0.105	0.007	0.053

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

Table 4.3.12: Zinc and iron content in grain of red rice as influenced by organic and inorganic application of nutrients

Treatment	Zinc and iron content in grain (ppm)					
	Zn			Fe		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_1: $N_{60}P_{40}K_{30}$ (I)	18.1	18.7	18.4	5.6	5.4	5.5
T_2: $N_{120}P_{60}K_{40}$ (I)	25.2	25.8	25.5	7.4	7.6	7.5
T_3: N_{60} $P_{40}K_{30}$ (25% O +75% I)	19.8	20.2	20.0	4.1	4.0	4.1
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	18.3	18.1	18.2	4.3	4.7	4.5
T_5: N_{60} $P_{40}K_{30}$ (50% O +50 % I)	23.5	23.6	23.6	4.5	4.7	4.6
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	22.2	22.6	22.4	8.9	9.5	9.2
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	20.4	21.0	20.7	6.4	7.9	7.2
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	23.1	22.2	22.7	4.5	4.7	4.6
T_9: Control	22.3	22.7	22.5	3.8	3.8	3.8
SEm±	0.41	0.50	0.40	0.31	0.80	0.51
CD (*P*=0.05)	1.24	1.53	1.21	0.96	2.42	1.55

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) in both the years and on mean basis but it was at par with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T6) during both the years and on mean basis as well as treatment $N_{120}P_{60}K_{40}$ (I) (T_2) on mean basis.

4.3.2 .9 Harvest index (%)

The data on harvest index (%) of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.8. Non significant differences was noticed in both the years as well as on mean basis.

Discussion on yield and harvest index

Highest rice grain yield was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both years and mean basis which was at par with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4).Highest rice straw yield (q ha^{-1}) was registered with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) in both years and mean basis which was at par with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) as well as treatment $N_{120}P_{60}K_{40}$ (I) (T_2) in year 2014 and mean basis. The harvest index (%) of red rice as influenced by organic and inorganic application of nutrients are found non significant during the both years as well as mean basis. Das *et al.* (2005) reported that application of 50% compost and 50% NPK fertilizers produced the maximum grain and straw yields of rice. All combinations of organic manuring were almost equally effective in increasing productivity of rice. Yield attributing characters followed similar trends. It increased organic matter content of soil, maintained and improved soil structure, reduced loss of nutrient particularly N, provide a source of N for the succeeding crop and thereby increased the production of red rice. Chattopadhyay *et al.* (1992) noted that rice performance was greater in the compost .Many factors determine the fertilizer efficiency for rice crop during cultivation such as soil, cultivar, season, environment, planting time, water management, weed control, cropping pattern, source, form, rate, time of application and method of application (Datta, 1978). In many cases aerial spray of nutrients is preferred and gives quicker and better results than the soil application (Jamal *et al*., 2006). Recently foliar application of nutrients has become an important practice in the production of crops while application of fertilizers to the soil

Table 4.3.13: N uptake by red rice as influenced by organic and inorganic application of nutrients

Treatment	N uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_1: $N_{60}P_{40}K_{30}$ (I)	45.07	47.45	46.26	16.03	16.87	16.46	61.10	64.31	62.72
T_2: $N_{120}P_{60}K_{40}$ (I)	53.96	55.86	54.92	22.44	23.28	22.89	76.40	79.14	77.81
T_3: N_{60} $P_{40}K_{30}$ (25% O +75% I)	45.97	47.51	46.75	19.61	20.48	20.05	65.58	68.00	66.80
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	63.70	63.08	63.42	28.01	28.71	28.36	91.71	91.79	91.78
T_5: N_{60} $P_{40}K_{30}$ (50% O +50 % I)	50.99	49.71	50.36	18.80	19.19	19.00	69.80	68.89	69.36
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	66.22	68.78	67.51	29.77	30.86	30.34	95.99	99.63	97.85
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	39.84	41.46	40.65	15.17	16.04	15.62	55.01	57.50	56.27
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	44.72	46.73	45.74	17.53	18.07	17.81	62.25	64.81	63.54
T_9: Control	1.51	1.83	1.67	7.33	8.03	7.69	8.84	9.86	9.36
SEm±	0.96	0.80	0.76	0.38	0.40	0.37	0.95	0.92	0.81
CD (P=0.05)	2.90	2.43	2.29	1.15	1.23	1.12	2.89	2.80	2.46

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

Table 4.3.14: P uptake by red rice as influenced by organic and inorganic application of nutrients

Treatment	P uptake (kg ha^{-1})								
	Grain			Straw			Total uptake		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
T_1: $N_{60}P_{40}K_{30}$ (I)	8.827	9.293	9.043	16.033	16.867	16.457	24.860	26.160	25.500
T_2: $N_{120}P_{60}K_{40}$ (I)	11.810	12.197	12.003	22.440	23.280	22.890	34.250	35.477	34.893
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	10.413	10.683	10.543	19.613	20.483	20.050	30.027	31.167	30.593
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	14.240	14.203	14.260	28.010	28.710	28.360	42.250	42.913	42.620
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	10.420	10.123	10.260	18.803	19.187	18.997	29.223	29.310	29.257
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	14.980	15.520	15.287	29.773	30.857	30.340	44.753	46.377	45.627
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	7.623	8.023	7.813	15.167	16.040	15.617	22.790	24.063	23.430
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	8.330	8.670	8.480	17.527	18.073	17.807	25.857	26.743	26.287
T_9: Control	3.470	4.043	3.773	7.333	8.033	7.690	10.803	12.077	11.463
SEm±	0.149	0.173	0.141	0.383	0.407	0.372	0.339	0.405	0.366
CD (P=0.05)	0.450	0.523	0.425	1.158	1.230	1.125	1.026	1.225	1.108

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

remains the basic method of feeding the majority of the crop plants. Chopra and Chopra (2000) reported that application of either 80 or 120 kg N ha^{-1} improved the entire yield attributes compared with control. Application of organic manure not only improve the soil organic carbon for sustaining the soil physical quality but also increases the soil nitrogen, However, nitrogen use efficiency is very low particularly in rice and is difficult to be first trust in sense of organic farming (Magar, 2004). The results are in confirmation with those of Velu and Rani (1999). Higher yield of rice owing to combination of green manure and recommended dose inorganic fertilizer was also reported (Pandey and Tripathi, 1992 and Mellu *et al.*, 1992). Singh *et al.* (2008) reported that under rice-based cropping system with RDF + FYM was more efficient for enhancing soil organic carbon.

4.3.3 Nutrient content in red rice

4.3.3.1 N content in grain and straw (%)

The data on N content in grain and straw of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.9. Significantly highest N content in grain and straw was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) which remained at par with treatments $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during both the years as well as on mean basis.

4.3.3.2 P content in grain and straw (%)

The data on P content in grain and straw of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.10. Significantly highest P content in grain and straw was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis.

4.3.3.0 K content in grain and straw (%)

The data on K content in grain and straw of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.11. Significantly highest K content in grain was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and mean basis. As regards, to K content in straw , significantly highest values were recorded under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) but it was at par with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during 2013 and on

Table 4.3.15: K uptake by red rice as influenced by organic and inorganic application of nutrients

Treatment	K uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
T_1: $N_{60}P_{40}K_{30}$ (I)	8.68	9.33	9.29	50.82	53.64	52.23	59.50	62.97	61.52
T_2: $N_{120}P_{60}K_{40}$ (I)	12.15	12.55	12.60	70.43	72.48	71.47	82.58	85.03	84.06
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	10.50	10.88	11.02	60.05	62.42	61.24	70.55	73.30	72.26
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	15.43	15.81	16.31	80.26	83.84	82.07	95.69	99.64	98.38
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	10.50	10.40	10.73	62.18	63.10	62.66	72.67	73.50	73.39
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	16.31	17.03	17.32	86.90	77.37	82.24	103.21	94.40	99.57
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	7.75	8.03	8.01	49.77	52.27	51.03	57.52	60.31	59.04
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	8.45	8.76	9.12	55.74	53.16	54.49	64.19	61.92	63.61
T_9: Control	3.02	3.56	3.34	24.99	27.33	26.16	28.01	30.89	29.51
SEm±	0.15	0.24	0.18	1.99	1.25	1.35	1.98	1.35	1.35
CD (P=0.05)	0.46	0.72	0.55	6.03	3.80	4.10	5.99	4.09	4.08

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

Table 4.3.16: Length, breath and L/B ratio of paddy as influenced by organic and inorganic application of nutrients

Treatment	Paddy length (mm)			Paddy breadth (mm)			Paddy L/B ratio		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
T_1: $N_{60}P_{40}K_{30}$ (I)	7.747	7.883	7.815	2.543	2.610	2.577	3.042	3.020	3.033
T_2: $N_{120}P_{60}K_{40}$ (I)	8.240	8.443	8.342	2.650	2.597	2.623	3.092	3.252	3.180
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	7.937	8.130	8.033	2.650	2.723	2.687	2.988	2.986	2.990
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	8.370	8.537	8.453	2.707	2.767	2.737	3.081	3.086	3.089
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	8.617	8.663	8.640	2.737	2.803	2.770	3.141	3.090	3.119
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	8.750	8.793	8.772	2.770	2.843	2.807	3.193	3.093	3.126
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	8.903	9.003	8.953	2.787	2.870	2.828	3.180	3.137	3.166
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	8.993	8.983	8.988	2.853	2.923	2.888	3.144	3.073	3.112
T_9: Control	6.740	6.877	6.808	2.447	2.520	2.483	2.777	2.729	2.742
SEm±	0.071	0.034	0.036	0.019	0.016	0.010	0.031	0.027	0.017
CD(P=0.05)	0.214	0.101	0.109	0.056	0.048	0.030	0.093	0.082	0.050

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

mean basis $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) on mean basis. However, in 2014 , K content in straw was significantly highest under treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4).

4.3.3.4 Zinc content in grain (ppm)

The data on zinc content (ppm) in grain of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.12. Significantly highest zinc content (ppm) was registered with treatment $N_{120}P_{60}K_{40}$ (I) (T_2) in both the years and on mean basis.

4.3.3.5 Iron content in grain (ppm)

The data on iron content (ppm) in grain of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.12. Significantly highest iron content (ppm) was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis, but it was at par with treatments $N_{120}P_{60}K_{40}$ (I) (T_2) and N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) in year 2014.

4.3. 4 N, P and K uptake by red rice

4.3.4.1 N uptake (kg ha^{-1})

The data on N uptake in grain, straw and their total as influenced by organic and inorganic application of nutrients are presented in Table 4.3.13. Significantly highest N uptake in grain, straw and their total was noticed under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis, however in year 2013, it was at par to treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) .

4.3.4.2 P uptake (kg ha^{-1})

The data on P uptake in grain, straw and in their total as influenced by organic and inorganic application of nutrients are presented in Table 4.3.14. Significantly highest P uptake in grain, straw and in their total was noticed under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis.

4.3.4.3 K uptake (kg ha^{-1})

The data on K uptake in grain, straw and in their total as influenced by organic and inorganic application of nutrients are presented in Table 4.3.15. Significantly highest K uptake in grain, straw and in their total was noticed under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6), in both the years and on mean basis, except total K uptake which was

Table 4.3.17: Head rice recovery of red rice as influenced by organic and inorganic application of nutrients

Treatment	Head rice recovery (%)		
	2013	**2014**	**Mean**
T_1: $N_{60}P_{40}K_{30}$ (I)	51.00	51.77	51.39
T_2: $N_{120}P_{60}K_{40}$ (I)	52.11	52.28	52.19
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	51.51	51.49	51.50
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	53.21	53.12	53.17
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	53.57	53.51	53.54
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	53.78	53.59	53.68
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	53.87	53.67	53.77
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	54.64	55.33	54.99
T_9: Control	48.65	49.49	49.07
SEm±	0.18	0.19	0.16
CD(P=0.05)	0.56	0.59	0.48

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

Table 4.3.18: Economics of red rice as influenced by organic and inorganic application of nutrients

Treatment	Gross return (000 Rs ha^{-1})			Net return (000 Rs ha^{-1})			B:C ratio		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_1: $N_{60}P_{40}K_{30}$ (I)	50.10	52.28	51.19	30.41	31.62	31.02	1.65	1.65	1.65
T_2: $N_{120}P_{60}K_{40}$ (I)	66.26	68.40	67.33	44.81	44.87	44.87	1.48	1.49	1.48
T_3: N_{60} $P_{40}K_{30}$ (25% O +75% I)	55.93	57.65	56.79	34.54	35.29	34.91	1.62	1.63	1.63
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	70.71	70.20	70.45	46.35	45.98	46.16	1.53	1.57	1.54
T_5: N_{60} $P_{40}K_{30}$ (50% O +50 % I)	58.62	57.22	57.92	36.43	34.06	35.24	1.61	1.68	1.64
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	71.18	73.71	72.45	43.91	45.47	44.69	1.62	1.62	1.62
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	45.22	46.94	46.08	20.47	21.22	20.84	2.21	2.21	2.21
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	50.44	52.53	51.49	17.29	18.41	17.85	2.92	2.87	2.88
T_9: Control	21.58	24.98	23.28	5.29	7.72	6.50	1.16	1..25	1.20
SEm±	6.38	7.93	5.66	6.38	7.93	5.66	0.11	0.06	0.06
CD(P=0.05)	19.32	24.00	17.12	19.32	24.00	17.12	0.36	0.18	0.20

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

recorded significantly highest under treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) in year 2014. Further, in case of straw and it total treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) also recorded comparable values.

Discussion on nutrient concentration and uptake

The N content in grain and straw of red rice was highest with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis and at par with treatments $N_{60}P_{40}K_{30}$ (I) (T_1) and $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) for N content in grain. The P content in grain and straw of red rice was significantly heighest with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both years and mean basis. The K content in grain and straw of red was significantly highest in grain with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during both the years and on mean basis. Highest zinc content (ppm) was registered with treatment $N_{120}P_{60}K_{40}$ (I) (T_2) in both the years and on mean basis. Maximum iron content (ppm) was noticed with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis but it was at par with treatments $N_{120}P_{60}K_{40}$ (I) (T_2) and N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) in year 2014. Selvi *et al*. (2005) reported that organic matter content of soil, maintained and improved soil structure reduced losses of nutrient particularly N and increased the yield. Organic manures provide regulated supply of N by releasing it slowly resulting in increased yields of rice and nutrient use efficiency (Sharma, 2002).Thus the balanced application of mineral fertilizers sustains soil physical environment and higher crop productivity under intensive cultivation (Hari *et al.*, 2000). The N uptake in grain , straw and in total was noted under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis but in year 2013 treatment $N_{120}P_{60}K:_{40\ 25\%}$ Org +75 % Ino (T_4) was al so at par. Highest P uptake in grain , straw and in their total was under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis. Whereas highest K uptake in grain ,straw and in their total was noted with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6), in both the years and on mean basis except total K uptake which was highest with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) in year 2014 , however, straw and total K uptake on mean basis was at par with tratment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4). The nitrogen, phosphorus and potassium efficiencies are accelerated due to addition of FYM in rice. These findings are further confirmed by Kumar

Table 4.3.19: Energetic of red rice as influenced by organic and inorganic application of nutrients

Treatment	Energy use efficiency ($qMJ^{-1}x10^{-3}$)			Energy output input ratio			Energy productivity ($g\ MJ\ ha^{-1}$)		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
T_1: $N_{60}P_{40}K_{30}$ (I)	1.06	1.10	1.08	14.42	14.63	14.54	469.98	490.27	480.13
T_2: $N_{120}P_{60}K_{40}$ (I)	0.95	0.98	0.96	12.94	13.15	12.98	416.70	430.34	423.52
T_3: N_{60} $P_{40}K_{30}$ (25% O +75% I)	1.22	1.26	1.24	16.63	16.91	16.72	534.26	550.34	542.30
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	1.03	1.03	1.03	13.82	14.05	13.88	454.91	450.36	452.63
T_5: N_{60} $P_{40}K_{30}$ (50% O +50 % I)	1.47	1.46	1.46	19.59	19.75	19.73	649.04	630.93	639.99
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	0.89	0.92	0.90	12.14	12.28	12.14	398.06	412.35	405.21
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	1.01	1.05	1.03	13.76	14.17	13.84	440.11	456.48	448.29
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	0.74	0.76	0.75	10.11	10.25	10.13	337.66	352.07	344.86
T_9: Control	1.03	1.15	1.09	14.61	15.50	14.63	427.17	497.92	462.55
SEm±	0.01	0.01	0.01	0.20	0.18	0.15	7.18	8.14	6.64
CD (P=0.05)	0.04	0.04	0.04	0.61	0.54	0.46	21.72	24.63	20.10

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

Table 4.3.20: Energy intensiveness production efficiency of red rice as influenced by organic and inorganic application of nutrients

Treatment	Energy intensiveness ($MJ\ Re^{-1}$)			Production efficiency ($kg\ ha^{-1}\ day^{-1}$)		
	2013	2014	Mean	2013	2014	Mean
T_1: $N_{60}P_{40}K_{30}$ (I)	5.90	5.70	5.80	32.34	33.73	33.03
T_2: $N_{120}P_{60}K_{40}$ (I)	7.22	7.02	7.12	42.65	44.04	43.35
T_3: $N_{60}P_{40}K_{30}$ (25% O +75% I)	6.13	5.96	6.04	35.98	37.06	36.52
T_4: $N_{120}P_{60}K_{40}$ (25% O +75% I)	6.65	6.51	6.58	45.58	45.13	45.36
T_5: $N_{60}P_{40}K_{30}$ (50% O +50 % I)	6.01	5.81	5.91	37.78	36.73	37.25
T_6: $N_{120}P_{60}K_{40}$ (50% O +50% I)	6.02	5.88	5.95	46.01	47.66	46.84
T_7: N of T_1 applied through organics (O) + FS of N at T and PI stages	4.30	4.26	4.28	29.09	30.17	29.63
T_8: N of T_2 applied through organics (O) + FS of N at T and PI stages	3.46	3.40	3.43	32.71	34.10	33.41
T_9: Control	3.38	3.38	3.39	13.76	16.04	14.90
SEm±	0.06	0.05	0.05	0.49	0.58	0.43
CD(P=0.05)	0.20	0.17	0.16	1.48	1.78	1.31

FS: Foliar spray; T: Tillering; PI: Panicle initiation; O: Organic sources; I: Inorganic fertilizer

and Prasad (2003) on clay loam soil, who recorded similar observations. Farm yard manure and inorganic ferilizer combination with produced an optimum grain yield when compared with other treatment combinations. Furthermore, the positive effects of farmyard manure were not enhanced with increased rate of inorganic fertilizers application. This is in agreement with other studies where combined application of organic and inorganic fertilizer increased productivity of rice (Ghosh and Sharma ,1999) . Few studies have even shown that organic manures with a substantial amount of Chemicals N fertilizers could produce higher dry matter yield and high N accumulation, than those of conventional inorganic N fertilizers treatments (Singh *et al*., 1994). Chung (2000) stated that combined use of organic manures and inorganic fertilizers checks nitrogen losses, conserves soil N by forming organicineral complexes and thuse nsures continuous N availability to rice plants and greater yields. The combined application of fertilizers and farmyard manure has shown long term yield benefits and these effects have been largely to be attributed to soil organic matter and microbial activity . Data on the uptake studies shows that farm yard manure on application increased N, P, and K by 20, 12 and 9%, respectively . Maximum uptake of N, P, and K were observed at a fertilizer levels of 120: 60: 40 kg N: P_2O_5: K_2O ha^{-1} in combination with application of farmyard manure The increase in N, P and K in farmyard manure application treatment can be attributed to enhanced availability of these nutrients due to improved soil structure and increased microbial activity research has shown that the combined application of farmyard manure and green manure can meet all the nitrogen requirement of high yielding varieties. Singh *et al.* (2006b) have also observed that FYM to rice were economically viable. In addition to supply of nutrients, organic source improves the physical condition and biological health of soil, which improves the availability of applied and native nutrient (Dick and Gregorich, 2004). Singh *et al.* (1999) reported similar findings who observed that application of only 100% N resulted in a decrease in the available P contents. Similar results were reported by Yaduwanshi (2003) and Singh *et al.* (2004). The higher nutrient uptake with organic manure application might be attributed to solubilization of native nutrients, chelation of complex intermediate organic manure molecules, their mobilization and accumulation of different nutrients in different plant parts. Similarly, Lui *et al.* (2010) working on long term effects of fertilizer and organic manure treatments also proved that there was greater increase in urease activity, when organic manure was applied.

4.3.5 Quality parameters

4.3.5.1 Head rice recovery of paddy

The data on head rice recovery of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.17. Significantly highest head rice recovery was registered with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) in both the years and on mean basis.

4.3.5.2 Length, breadth and L/B ratio of paddy

Data pertaining to length, breadth and L/B ratio of paddy as influenced by organic and inorganic application of nutrients are presented in Table 4.3.16. Significantly longer paddy length was registered under treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8), but it was at par with N of T_1 through organic + 2 F S N (T_7) during 2013 and on mean basis, while, in the year 2014 treatment N of T_1 through organic + 2 F S N (T_7) registered significantly highest value which was at par with treatment N of T_2 organic + 2 F S (T_8). Further, paddy breadth during both the years and on mean basis was significantly highest under treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8). The L/B ratio of paddy in year 2013 was significantly highest with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) which was at par with treatments N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5), N of T_1 through organic + 2 F S N (T_7) and N of T_2 organic + 2 F S(T_8) , while in year 2014 and on mean basis treatment $N_{120}P_{60}K_{40}$ (I) (T_2) noticed significantly highest L/B ratio which was at par with treatment N T_1 through organic + 2 F S N (T_7) .

Discussion on quality parameters

Longest paddy length was registered under treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) but at par with N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) during the year 2013 and on mean basis ,while, in the year 2014 treatment N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) proved superior which was at par with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8). Further, paddy breadth during both the years and on mean basis was highest with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8). The L/B ratio of paddy in year 2013 was highest with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) which was at par with treatments N_{60} $P_{40}K:_{30}$ org$_{50\%}$ +50 % Ino$_{50\%}$ (T_5), N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) , while in year 2014 and on mean basis treatment $N_{120}P_{60}K_{40}$ (I) (T_2) noticed highest L/B ratio and at par with treatment N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) on mean basis. Highest head rice recovery was registered with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) in both the years and on mean basis. Rice being the most important food of the world, its nutritional value and processing properties are very important for overall health of the people and commercial purposes including economy of rice growers. Quality is very important and is determinant of market price, consumer acceptance and end users. The quality of rice is not always easy to define as it depends on a combination of many subjective and objective factors, largely related to the consumer and the intended end use of the grain. The demand by the consumer for better quality has notably increased in the more economically developed countries of the world giving rice producers the opportunity to increase the total economic value of rice. Quality traits are also related to the taste of the several ethnic groups in the world. The quality parameters to be evaluated for food rice verities can be discussed in three broad categories: i. Physical, ii. Processing and iii. Nutritional qualities. Kernel length, bread/breadth ratio, grain type, chalkiness percentage, alkali spreading values could be considered under physical qualities. Milling qualities and cooking qualities are under processing quality. Milling parameters including hulling %, milling %, head rice recovery % cooking qualities including elongation ratio, water uptake, volume expansion ratio, nutritional qualities such as total crude protein, total carbohydrate, total ash, total fat, minerals, vitamins and amino acids. Enormous variations in size and shape of grain exist among the rice varieties available in the world. Rice kernel length roughly varies from 5.0 to 7.5mm and breadth from 1.9 to 3.0mm (Devi et al., 2008a). Some high yielding verities from India had 5.2 to 6.8 mm in length and 1.9 to 2.5 mm in breadth. In USA, grains are classified into long (7.0 to 7.5mm), medium (5.9 to 6.1 mm) and short (5.4 to 5.5mm). In

India grains are classified considering length, breadth and length breadth ratio into long slender (length 6.0mm and above, length. breath ratio 3.0 and above), long bold (length 6.0mm and above, L/B ratio less than 3.0mm), medium slender (length less than 6mm, L/B ratio 2.5 to 3.0mm), short slender (length less than 6mm and L/B ratio 3 and above) and short bold (length less than 6mm, L/B ratio less than 3) types Devi *et al*.,(2008) .

4.3.6 Economics

4.3.6.1 Gross return (000 Rs ha^{-1})

The data on gross return of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.18. Significantly highest gross return was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis, but it was at par with treatments N_{60} $P_{40}K_{30}$ (25% O +75% I) (T_3), $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) and N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) with additional treatments $N_{60}P_{40}K_{30}$ (I) (T_1) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) in year 2014 .

4.3.6.2 Net return (000 Rs ha^{-1})

The data on net return of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.18. Significantly highest net return was registered with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) in both the years and on mean basis , but it was at par with treatments $N_{60}P_{40}K_{30}$ (I) (T_1) , $N_{120}P_{60}K_{40}$ (I) (T_2) , N_{60} $P_{40}K_{30}$ (25% O +75% I) (T_3) , and N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) and $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) **.**

4.3.6.3 B: C ratio

The data on B: C ratio of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.18. Significantly highest B:C ratio was registered with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during both the years and on mean basis

4.3.7 Energetics

4.3.7 .1 Energy use efficiency (qMJ^{-1}x10^{-3})

The data on energy use efficiency of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.19. Significantly highest energy use efficiency was registered with treatment N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) in both the years and on mean basis.

4.3.7.2 Energy output input ratio

The data on energy output input ratio of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.18. Significantly highest energy output input ratio was registered with treatment N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) during both the years and on mean basis.

4.3.7.3 Energy productivity (g MJ ha^{-1})

The data on energy productivity of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.19. Significantly highest energy productivity was registered with treatment N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) during both the years and on mean basis.

4.3.7.4 Energy intensiveness (MJ Re^{-1})

The data on energy of intensiveness of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.20. Significantly highest energy intensiveness was registered with treatment $N_{120}P_{60}K_{40}$ (I) (T_2) during both the years and on mean basis.

4.3.8 Production efficiency (kg ha^{-1} day^{-1})

The data on production efficiency of red rice as influenced by organic and inorganic application of nutrients are presented in Table 4.3.17. Significantly highest production efficiency was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis but at par with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) in year 2013.

Discussion on economics, energetics and production efficiency

Gross return and B:C ratio were noted significantly highest in treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis but ,it was at par with treatments $N_{120}P_{60}K_{40}$ (I) (T_2), N_{60} $P_{40}K_{30}$ (25% O +75% I) (T_3) , $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) and N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) with additional treatments $N_{60}P_{40}K_{30}$ (I) (T_1) and N of T_2 organic + 2 F S (T_8) in year 2014 for gross reyurn.Net return was significantly highest with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) in both the year and on mean basis but it was at par with treatments $N_{60}P_{40}K_{30}$ (I) (T_1) , $N_{120}P_{60}K_{40}$ (I) (T_2), N_{60} $P_{40}K_{30}$ (25% O +75% I) (T_3) , and N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) and $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6). Energy use efficiency , energy output input ratio and energy productivity of red rice were significantly highest with treatment N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) in both the years and on mean basis . While,energy intensiveness was significantly highest with treatment $N_{120}P_{60}K_{40}$ (I) (T_2) during both the years and on mean basis .Highest production efficiency was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis but it was at par with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) in year 2013. The market for organic food is on the rice despite a dialogue on organic v/s modern agriculture (Prasad, 2005). Organic farming provides a way for continued rice production by resource poor farming. Further the low yields obtained in the organic farming are compensated by the higher price for organic foods. Organic farming also permits the recycling of organic wastes, the disposal of which could be difficult and expensive.

CHAPTER -V
SUMARRY, CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH WORK

Rice occupies about percent of the total area under cereal production in the world and more than percent of rice is produced and consumed in Asia. In Chhattisgarh, during *kharif* ,rice is cultivated over an area of 3.68 m ha with productivity of 20.20q/ha. Bastar Plateau is tribal predominantly zone having 6 districts viz. Jagdalpur, Narayanpur, Kondagaon, Bijapur, Dantewara and Sukma. Bastar is primarily mono cropped rice area. It comprises of large plateau having elevation ranging from 550 m to 760 m from mean sea level in between 17°46' N and 20°34' N latitudes and 80°15' and 82°15' E longitudes. Rice is grown during *kharif* season and field left fallow after its harvest. Many land races commonly grown in the region. Some of red rice is totally red of whole kernal. Red rice can also mean a wild rice genotype that is regarded as a weed because it produces very few grains and can cross-breed with regular rice, resulting in low-quality rice crops. Anthocyanins are the pigments that give the rice its red colour. Anthocyanin is a known antioxidant that is linked to lowering the risk of developing several chronic health conditions. Similar to brown rice, red rice is found to be rich in fibre, iron, zinc, B vitamins and even calcium. Unfortunately, the potential and its use have been by in large neglected by the research community and the farmers. With the awareness about health, red rice has gained the importance and demanded for research needs in view to increase the productivity and quality of the produce. Red rice have already been picked up the market with good price .Red rice will not only play vital role in nutritional security for human beings but also pay additional income for livelihood in these disadvantaged districts of Chhattisgarh. An effective agronomic management is therefore necessary to exploit the yield potential of red rice. Integrated nutrient management (INM) is very important in rice production. Many of our problems on declining productivity (increasing cost, declining yield) can be traced to improper and inefficient use of nutrients. Improper nutrient management has resulted in the nutrient imbalances in the soil with nutrients in excess while other nutrients depleted. Through this, farmers can increase agricultural productivity and safeguard the environment as they efficiently use fertilizer.

Looking to the nutritional importance of red rice in human diet, research work specially in the direction of suitable genotypes, spacing, fertility levels, integrated use of inorganic, organic and micronutrients are needed to harness higher and qualitative production under the agro climatic conditions of Baster plateau. Research trials on "**Productivity and Quality of Red Rice (*Oriza sativa* L.) Genotypes as Influenced by Organic, Inorganic and Integrated Nutrient Management Practices**" were conducted at Instructional cum Research Farm of Shaheed Gundadhoor College and Agricultural Research Station, Jagdalpur, Chhattisgarh during *kharif* season of 2013 and 2014. In both *kharif* season three experiments were conducted. The soil of the experimental site is characterized as silty loam (fairly leveled). The soil was locally known as Mal (*Alfisols*). It is well fertile soil belongs to mid land situation of landscape in Jagdalpur .The soil was slightly acidic in reaction and medium to low in fertility levels having low in nitrogen and phosphorus and high in potash contents . Rainfall received during cropped period was 695.9 mm and 792 mm with 50 and 49 rainy days during 2013 and 2014 ,respectively.

In first experiment entitled " **Performance of different red rice genotypes under varied spacing and fertility levels** " the treatments comprised of 3 genotype *viz.*, RR 14 EN-7(V1) RR 14 EN-8(V2) and RR 12 EN-11(V3) in main-plot, 2 spacing 15 cm x 10 cm (S1) and 20cm x 10cm (S1) in sub-plot and 3 fertility levels 60:40:30 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F1), 90:60:40 ($N:P_2O_5:K_2O$ kg ha^{-1}) (F2) and 120:60:40 ($N:P_2O_5:K_2O$ kg ha-^{1}) (F3) in sub-sub plot, in second experiment entitled" **Grain yield and nutrient uptake of red rice as influenced by integrated use of inorganic, organic and micro nutrients**" , the treatments was composed of 12 integrated use of inorganic, organic and micro-nutrient *viz.*, $N_{80}P_{60}K_{40}$ (T_1),

$N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$+FYM_{5t} (T_3), $N_{120}P_{80}K_{60}$+ FYM_{5t} (T_4), $N_{80}P_{60}K_{40}$+Zn (T_5), $N_{80}P_{60}K_{40}$+S_I (T_6), $N_{80}P_{60}K_{40}$+B (T_7), $N_{80}P_{60}K_{40}$+Zn +S_I (T_8), $N_{80}P_{60}K_{40}$+Zn +B (T_9), $N_{80}P_{60}K_{40}$+B+ S_I (T_{10}), $N_{80}P_{60}K_{40}$+Zn+ S_I +B (T_{11})and Control (T_{12}). Red rice genotype RR 12 EN-11 was transplanted on 11^{th} August 2013 and 16^{th} July 2014 and harvest in 3^{rd} and 1^{st} week of November and October in 2013 and 2014. Further ,in third experiment entitled "**Enhancement of productivity and quality of red rice through organic and inorganic application of nutrients**", the treatments consisted of 9 organic and inorganic application of nutrients *viz*., $N_{60}P_{40}K_{30}$ (I) (T_1), $N_{120}P_{60}K_{40}$ (I) (T_2), $N_{60}P_{40}K_{30}$ (25% O +75% I) (T_3) , $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4), $N_{60}P_{40}K_{30}$ (50% O +50 % I) (T_5), $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6), N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7), N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) and Control (T_9). Red rice genotype RR 12 EN-1 was transplanted on 13^{th} August 2013 and 16^{th} July 2014 and harvested on 3^{rd} and 1^{st} week of October in 2013 and 2014.

5.1 Red rice: Experiment No.-1

Title: Performance of different red rice genotypes under varied spacing and fertility level

5.1.1 Effect of genotype

- The genotype RR 12 EN-11 produced significantly highest number of grains panicle^{-1}, longest panicle, test weight, grain and straw yields. The gross return, net return, B: C ratio, energy use efficiency, energy output input ratio, energy productivity and production efficiency were registered highest with the above genotype.
- Significantly highest zinc and iron content was registered under treatment genotype RR 14 EN-8 during both the years and on mean basis.
- Significantly highest N content was registered under genotype RR12EN-11 and RR14EN-7 for grain and straw, respectivily during both the years and on mean basis.

- The genotype RR12 EN-11 registered significantly highest P and K content.

5.1.2 Effect of spacing

- The planting spacing of 20cm x10cm registered the highest number of effective tillers hill^{-1}, longest panicle, panicle weight, grains panicle^{-1}, test weight, root volume and straw yield.
- Spacing of 15 cmx10 cm registered highest leaf area index and crop growth rate.
- Significantly highest grain yield and harvest index was registered under spacing 15cmx10 cm.
- During both the years and on mean basis, zinc and iron contents were significantly highest under spacing 20 cm x 10 cm.
- The N, P and K contents and net return and B: C ratio was significantly highest under spacing 20 cm x 10 cm during both the years and on mean basis.
- Significantly highest energy use efficiency, energy output input ratio, energy of intensiveness and production efficiency were registered under treatment spacing 20cmx10cm during both the years and on mean basis.
- Energy productivity during both the years and on mean basis was found non significant for spacing·

5.1.3 Effect of fertility level

- The fertility level 120:60:40 N:P_2O_5:K_2O kg ha^{-1} registered highest dry matter accumulation at all growth stages.
- The relative growth rate for fertility level was found statistically non significant at all the growth duration of growth of rice.
- Significantly highest number of effective tillers hill $^{-1,}$ grains panicle^{-1}, grain yield and straw were registered under fertility level 120:60:40 N:P2O5:K2O kg h^{-1} during both the years as well as on mean basis .
- Significantly highest zinc, N and P content was registered under fertility levels 120:60:40 N:P_2O_5:K_2O kg ha^{-1} during both the years and on mean basis.
- Fertility level was found non significant for K content.

- Fertility level of 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} registered significantly highest gross and net return and B:C ratio**.**
- Significantly highest energy use efficiency, energy output input ratio and energy of intensiveness were significantly registered under fertility level of 60:40:30 $N:P_2O_5:K_2O$ kg ha^{-1} during both the years and on mean basis.
- Significantly highest production efficiency was registered under fertility level under treatment 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} during both the years and on mean basis.

5.1.4 Effect of interaction between genotype X spacing

- The interaction effect genotype X spacing was found significant for plant height interaction between RR12EN-11 and 20cm x10cm produced taller plants at all the growth stages during both the years, but it was at par with interactions of RR 12 EN-11X 15 cm x10 cm at 30 and 60 DAT, during 2014. Moreover, during 2013 at 30 DAT, interactions of RR12EN-11 X 15cmx10 cm was found comparable to RR 12EN-11 X 20 cmx10cm.
- The interaction effect of genotype x spacing revealed interaction between RR12EN-11 X 20cmx10 cm produced significantly highest dry matter accumulation at all the stages except at 60 DAT during 2014 where interaction of RR12EN-11 (V3) X 15cmX10 cm was at par to interaction of RR12EN-11 x 20cm x 10cm and on mean basis at 30 DAT interaction between RR 14 EN-7 (V3) X 20cmx10 cm , RR 14 EN-8x 15cm x10cm and RR 12 EN-11 (V3)X15cmX10 cm were found comparable
- The interaction of genotype X spacing revealed that highest leaf area index during both the years and on mean basis was recorded with interaction between genotype RR 12 EN-11 X 15 cmx10 cm, but it was at par with interaction of RR 12 EN-11 X 20cmx10 cm on mean basis at 30 DAT. Further during 2013 at 30 DAT, interaction between RR 12 EN-11 X 20cmx10 cm recorded maximum leaf area index over rest of interaction.
- The interaction of genotype X spacing revealed that highest crop growth rate at 0-60 and 30-60 DAT during 2014 and on mean basis and at 30- 60 DAT in 2013

recorded under interaction of RR 12 EN-11 X 20cmx10 cm ,but it was at par with interaction of RR 12 EN-11X 20cmx10 cm on mean at0- 30 DAT. Further during 2013 at 0-30 DAT, interaction between RR 12 EN-11 X 20cmx10 cm recorded maximum crop growth rate over rest of interactions.

- The interaction between RR 12 EN-11 X 20cmx10 cm registered significantly highest effective tillers hill^{-1} during both the years and on mean basis but, it was at par with RR 12 EN-11 X 20cmx10 cm and RR 12 EN-11 X 15cmx10 cm during 2014.
- Interaction between RR 12 EN-11 X 20cmx10 cm registered significantly highest panicle length during both the years and on mean basis but, it was at par with interaction between RR12EN-11 X15cmx10cm during 2013.
- Interaction between RR 12EN-11X20cmx10 cm recorded significantly highest panicle weight during both the years and on mean basis.
- Interaction between genotype X spacing was found non significant for number of grains panicle^{-1}.
- Significantly higher test weight was noted under interaction between RR 12 EN-11 X 20cmx10 cm during both the years and on mean basis.
- Significantly higher grain yield was noted under interaction between RR 12 EN-11 X 20cmx10cm, but it was at par to interaction between RR 12 EN-11 X 15cmx10cm during both the years and on mean basis with an additional treatment RR 12 EN-7 X 15cmx10cm and RR 12 EN-8 X 15cmx10cm during 2014.
- The interaction effect between genotype and spacing was found significant where interaction between 20cmx10 cm X120:60:40N:P2O5:K2O kg ha^{-1} significantly higher straw yield than other interaction.
- The interaction between RR14EN-8 X 20 cm X 10 cm gave significantly higher zinc content in grain.
- The interaction between RR12EN-11X 20cmx10 cm gave significantly highest N content in grain with but it was at par with RR14EN-7 X20cmX10cm while

,straw N content was highest under interaction between RR 14 EN-7 X 20 cm X 10cm.

- The interaction between RR 12 EN-11X 20cmx10 cm gave significantly highest P content in grain but, it was at par with RR 14 EN-7 X 20cmX10cm during both the years.
- The interaction between RR12EN-11X20cmx10cm gave significantly highest K content in grain during both the years, but it was at par with RR 14 EN-7 X 20cmX10cm, while in straw K it was registered highest under treatment RR 12 EN-8 X 20cmx10 registered highest potash content.
- The gross return, net return, B: C ratio, energy use efficiency, energy output input and production efficiency were found significantly highest under RR12EN-11) X 20cmx10 cm during both the years and on mean basis.

5.1.2 Effect of interaction between genotype X fertility levels

- Interaction between RR12 EN-11 X 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} gave significantly highest plant height and dry matter accumulation during both the years and on mean basis at all growth stages.
- The relative growth rate was found statistically non significant all growth duration.
- Interaction between RR 12 EN-11 x 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} gave significantly highest panicle length superior during both the years and on mean basis, but it was at par with 90:60:40 $N:P_2O_5:K_2O$ kg ha^{-1}during 2014 and on mean basis.
- Interaction between genotype X fertility levels were found non significant for panicle weight ,grains panicle^{-1} , grain and straw yield, harvest index, root volume, grain and straw nitrogen content ,gross returns, net return and B:C ratio.
- Interaction between RR 12 EN-11 X120:60:40N: $N:P_2O_5:K_2O$ kg ha^{-1} gave significantly highest test weight .

- The interaction between RR 14 EN-8X 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} gave significantly highest zinc and iron content in grain during both the years and on mean basis.
- The interaction between RR12EN-11X 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} gave significantly highest N content in grain where as , interaction between RR 14 EN-7 X 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} recorded significantly highest N content in straw .
- The interaction RR12EN-11 x 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} recorded significantly highest P content in grain while in straw it was found non significant.
- The interaction between RR12EN-7 X 120:60:40 $N:P_2O_5:K_2O$ kg $ha^{-1}$for grain but at par with RR12 EN-11 X 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} except during 2014 and for straw under treatment RR12EN-11 X 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} registered highest K content .
- The interaction between RR12EN-11X60:40:30 $N:P_2O_5:K_2O$ kg $ha^{-1}$was found significant superior for energy use efficiency during both the years and on mean basis.
- The interaction between RR12EN-11x 60:40:30 $N:P_2O_5:K_2O$ kg ha^{-1} was significantly highest energy output input, energy productivity and energy intensiveness during both the years and on mean basis.
- The interaction between genotype X fertility was found non significant for production efficiency.

5.1.3 Effect of interaction between spacing X fertility levels

- The interaction between spacing X fertility levels for plant height, dry matter accumulation, leaf area index, crop growth rate, relative growth rate, effective tillers $hill^{-1}$, panicle weight, grain $panicle^{-1}$, test weight grain and yield, harvest index, root volume, zinc and iron content gross returns, net return B:C ratio, energy use efficiency, energy use efficiency, energy productivity, energy of intensiveness and production efficiency were found non significant .

- Spacing X fertility levels for P content was highest under treatment 20cm x10 cm x 120:60:40 N:P_2O_5:K_2O kg ha^{-1} except straw P content during 2013 which, was found non significant.
- The interaction between 20cmx10 cm X 120:60:40 N:P_2O_5:K_2O kg ha^{-1} gave significantly higher K content in grain and straw as compared to others .

5.2 Red rce: Experiment No. II

Title: Grain yield and nutrient uptake of red rice as influenced by integrated use of inorganic, organic and micro nutrients

- At 30 DAT, significantly taller plant of red rice was recorded under the treatment $N_{120}P_{80}K_{60}$ (T_2) as compared to others during both the years as well as on mean basis, excepting the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during 2014. At 60 and 90 DAT, treatment of $N_{120}P_{80}K_{60}$ (T_4) gave significantly taller plant as compared to others, however it was at par to the treatment of $N_{80}P_{60}K_{40}$+Zn + S_I +B (T_{11}) at 90 DAT during both the years as well as on mean basis .
- At 30 DAT, in year 2013, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) produced the highest dry matter accumulation, which was at par with the treatment $N_{120}P_{80}K_{60}$ (T_2), while in year 2014 and on mean basis, treatment $N_{120}P_{80}K_{60}$ (T_2) gave significantly higher dry matter accumulation than others, but it was at par with the treatment of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4). At 60 and 90 DAT, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) produced significantly higher dry matter accumulation than others, but was at par with $N_{120}P_{80}K_{60}$ (T_2) at 60 DAT during both the years and on mean basis.
- In general, the leaf area index showed increasing trend from 30 DAT to 90 DAT in all the treatments. At 30 and 60 DAT, significantly higher leaf area index was registered under the treatment N80P60K40+Zn +S_{I+}B (T_{11}) as compared to others during both the years as well as on mean basis, but it was at par with the treatments of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), $N_{80}P_{60}K_{40}$+Zn (T_5), $N_{80}P_{60}K_{40}$ +S_I (T_6) and $N_{80}P_{60}K_{40}$) +B (T_7) at 30 DAT in year 2013 and treatment $N_{120}P_{80}K_{60}FYM_{5t}$ (T_4)

during 2014 and on mean basis. At 90 DAT, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T4) gave significantly higher LAI than others excepting the treatment of $N_{80}P_{60}K_{40}$+Zn+S_I+B (T_{11}) during both the years and on mean basis and treatment $N_{120}P_{80}K_{60}$ (T_2) during 2013.

- In general, the crop growth rate increased from 0- 30 to 30-60 and thereafter, it declined at 60-90 DAT. At 0-30 DAT, in year 2013, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) gave the highest CGR followed by treatments $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$+S_I (T_6), $N_{80}P_{60}K_{40}$+B (T_7), $N_{80}P_{60}K_{40}$+Zn+S_I (T_8),$N_{80}P_{60}K_{40}$+$B1_0$+S_I (T_{10}) and $N_{80}P_{60}K_{40}$+Zn +S_I+B(T_{11}), while in year 2014, treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) gave significantly highest CGR followed by $N_{80}P_{60}K_{40}$ FYM_{5t} (T_3), $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) , $N_{80}P_{60}K_{40}$+S_I (T_6) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}). On mean basis, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} ($_{T4}$) gave significantly highest CGR which was at par with treatments $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$ FYM_{5t} (T_3), $N_{80}P_{60}K_{40}$+S_I (T_6), $N_{80}P_{60}K_{40}$+B_{10}+S_I (T_{10})and $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}). At 30-60DAT, the CGR was registered significantly highest with treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during 2013, but during 2014 and on mean basis, treatment $N_{120}P_{80}K_{60}$ (T_2) gave significantly higher CGR than others which was at par to treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4). At 60-90 DAT, treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) gave the highest CGR followed by $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during both the years as well as on mean basis.
- It was observed that relative crop growth rate declined with advancement of crop age. The data reveal that at early (0-30 DAT) and later stages (60-90DAT), the relative growth rate were found non- significant due to different treatments of integrated use of inorganic, organic and micro nutrients, but at mid stage (30-60 DAT), during 2013 ,treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T4) gave significantly highest RGR, which was at par with treatment $N_{120}P_{80}K_{60}$ (T2) during 2013, whereas during 2014 and on mean basis, treatment $N_{120}P_{80}K_{60}$ (T_2) gave significantly highest RGR, which was at par with the treatment of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4).

- Significantly highest root volume was registered during both the years and on mean basis under treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) excepting with treatment of $N_{80}P_{60}K_{40}$+Zn + B (T_9) during 2014.
- Significantly highest number of effective tillers hill $^{-1}$ in year 2013 and on mean basis was obtained with treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) which was at par with the treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4). Significantly highest number of effective tillers hill^{-1} was noticed under the treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), which was at par with the treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during2014.
- Significantly longest panicle was registered with treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during both the years and on mean basis, but it was at par with the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B(T_{11}) and $N_{120}P_{80}K_{60}$ (T_2) during 2014.
- The significantly highest panicle weight was registered with the treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) as compared to others during both the years and on mean basis. The treatments $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$ FYM_{5t} (T_3), $N_{120}P_{80}K_{60}$ FYM_{5t} $^{(}T_4$), $N_{80}P_{60}K_{40}$+Zn +S_I (T_8) and $N_{80}P_{60}K_{40}$+Zn +B (T_9) during 2013 and treatments $N_{120}P_{80}K_{60}$ (T_2) and $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during 2014 and on mean basis were statistically similar to that of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}).
- The significantly highest number of grains panicle^{-1} was registered under the treatment of $N_{80}P_{60}K_{40}$+Zn_{25} +SI+B_{10} ha^{-1}(T_{11}) during both the years and on mean basis which was on par with the treatment of $N_{120}P_{80}K_{60}$ FYM5t ha^{-1} (T_4) in year 2013 and on mean basis.
- The higher test weight was registered under the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) as compared to others treatments, which was at par with the treatments $N_{120}P_{80}K_{60}$ (T_2) and $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during both the years and on mean basis. The treatment of $N_{80}P_{60}K_{40}$+S_I (T_6) also produced similar test weight to that of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during 2014.
- The significantly highest rice grain yield was registered under treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B ($_{11}$) during both the years and on mean basis but, it was at par with treatment $N_{120}P_{80}K_{60}$ FYM5t ha^{-1} (T_4) during 2013 and on mean basis.

- Significantly highest rice straw yield during both the years and on mean basis was registered under the treatment of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) , but it was at par with treatments $N_{80}P_{60}K_{40}$+Zn+B (T_9) and $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during 2013 and on mean basis and treatment $N_{80}P_{60}K_{40}$ (T_2) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during 2014. On the other hand harvest index of red rice was found to be non significant.
- Significantly highest N content in grain and straw was registered under the treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) which was superior over rest of the treatments during both the years and on mean basis.
- The highest P content in grain and straw during both the years and on mean basis was noted under treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4),which was significanlty superior than other treatment except $N_{80}P_{60}K_{40}$+ Zn +B (T_9) during 2013 in case of P content in straw.
- The highest K content in grain and straw during both the years and on mean basis was registered under the treatment of $N_{80}P_{60}K_{40}$+FYM_{5t} (T_3) which was significantly superior over rest of the treatments.
- The significantly highest zinc content (ppm) was registered under the treatment of N $_{120}$:P_{80}:K $_{60}$ (T_2) during both the years and on mean basis, but it was at par with the treatments $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), $N_{80}P_{60}K_{40}$+Zn (T_5), $N_{80}P_{60}K_{40}$+S (T_6) and $N_{80}P_{60}K_{40}$ +B (T_7) during 2014 and treatment of $N_{80}P_{60}K_{40}$) + B (T_7) on mean basis.
- The significantly highest iron content was registered under the treatment of $N_{80}P_{60}K_{40}$+Zn (T_5) during 2013 and on mean basis, but it was at par with the treatment N $_{120}$:P_{80}:K $_{60}$ (T_2). During 2014 significant difference among the treatment was not observed for iron content in grain.
- Significantly highest N uptake in grain, straw and in their total N uptake was noticed under the treatment of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) which was significantly superior over rest of treatments during both the years and on mean basis.
- Significantly the highest P uptake in grain, straw and in their total was obtained under the treatment of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during both the years and mean

basis, but it was at par with $N_{80}P_{60}K_{40}$+Zn + B (T_9) and $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) in straw during 2014 as well as treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) in case of their total uptake during 2014.

- Significantly the highest K uptake in grain was observed under the treatment of $N_{80}P_{60}K_{40}$ FYM_{5t} (T_3) during both the years and on mean basis, but it was at par with the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during 2013 and 2014 .While, K uptake in straw was significantly the highest with treatment of $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during both the years and on mean basis, but it was at par with the treatments $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) and $N_{80}P_{60}K_{40}$+Zn + B (T_9) during 2013 and 2014 as well as treatment $N_{80}P_{60}K_{40}$+Zn +S_I (T_8) during 2014.The total K uptake was significantly superior under the treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) during both the years and on mean basis, but it was at par with treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during both the years as well as on mean basis , treatment $N_{80}P_{60}K_{40}$ FYM_{5t} (T_3) during 2013, treatment $N_{80}P_{60}K_{40}$+Zn +B (T_9) during 2013 and 2014 and treatment $N_{80}P_{60}K_{40}$+S_I+B(T_{10}) during 2014.
- Significantly highest head rice recovery was registered with treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) which was significantly superior over other treatments during both the years and on mean basis, but it was at par with treatments $N_{120}P_{80}K_{60}$ (T_2), $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), $N_{80}P_{60}K_{40}$+B (T_7), $N_{80}P_{60}K_{40}$+Zn +S_I (T_8), $N_{80}P_{60}K_{40}$ + Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B_{10}+S_I (T_{10}) during 2014.
- The application of $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) registered significantly longer paddy length and L/B ratio over other treatments during both the years and on mean basis. Whereas breadth of paddy was significantly highest under treatment $N_{80}P_{60}K_{40}$+B_{10}+S_I (T_{10}) which was at par with treatments $N_{80}P_{60}K_{40}$+Zn+ S_I (T_8) and $N_{80}P_{60}K_{40}$+ Zn +B(T_9) during 2013 and on mean basis as well as $N_{80}P_{60}K_{40}$+S_I (T_6)and $N_{80}P_{60}K_{40}$+B (T_7) during 2013 and treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) on mean basis. But during 2014, breadth of paddy was significantly highest under treatment $N_{80}P_{60}K_{40}$+Zn + S_I + B (T_{11}).

- The highest gross return during both the years and on mean basis was registered under the treatment of $N_{80}P_{60}K_{40}$+Zn +S_I +B (T_{11}), which was at par with treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during 2013 and on mean basis.
- Significantly highest net return was registered during 2013 under treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4), but it was at par with treatments $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$+ Zn (T_5), $N_{80}P_{60}K_{40}$+ Zn +B (T_9) and $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}). Whereas during 2014 and on mean basis significantly highest net return was observed under treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}), but it was at par with treatments $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) and $N_{80}P_{60}K_{40}$+ Zn +B (T_9).
- The highest B:C ratio in year 2013 and on mean basis was registered with treatment of $N_{120}P_{80}K_{60}$ (T_2) which was significantly superior over rest of treatments expect the treatments of $N_{80}P_{60}K_{40}$+Zn (T5), $N_{80}P_{60}K_{40}$+B (T_7) and $N_{80}P_{60}K_{40}$+ Zn +B (T_9). During 2014, treatment of $N_{80}P_{60}K_{40}$+Zn (T_5) gave the maximum B:C ratio followed by $N_{120}P_{80}K_{60}$ (T_2), $N_{80}P_{60}K_{40}$+B (T_7) and $N_{80}P_{60}K_{40}$+ Zn +B(T_9).
- The highest energy use efficiency during both the years and on mean basis was registered with treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B_{10} (T_{11}), but it was at par with treatments$N_{80}P_{60}K_{40}$+Zn (T_5), $N_{80}P_{60}K_{40}$+S_I (T_6),$N_{80}P_{60}K_{40}$+ B (T_7), $N_{80}P_{60}K_{40}$+Zn +S (T_8), $N_{80}P_{60}K_{40}$ + Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during 2013, as well as treatments $N_{80}P_{60}K_{40}$+Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during 2014 and on mean basis.
- The highest energy output input ratio was registered with treatment $N_{80}P_{60}K_{40}$+Zn +SI+B (T_{11}) during both the years and on mean basis, but it was at par with treatments $N_{80}P_{60}K_{40}$+Zn (T_5),$N_{80}P_{60}K_{40}$+S_I (T_6),$N_{80}P_{60}K_{40}$+B $_{10}$ (T_7), $N_{80}P_{60}K_{40}$+Zn +S_I (T_8), $N_{80}P_{60}K_{40}$+ Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during year 2013, while treatment $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) in year 2014 and treatments $N_{80}P_{60}K_{40}$+ Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) on mean basis.
- Significantly highest energy productivity during both the years and on mean basis was registered under the treatment $N_{80}P_{60}K_{40}$+Zn +S_I+B (T_{11}) , but it was at par with treatments $N_{80}P_{60}K_{40}$+Zn (T_5),$N_{80}P_{60}K_{40}$+S_I (T_6),$N_{80}P_{60}K_{40}$+B (T_7),

$N_{80}P_{60}K_{40}$+Zn+S_I (T_8), $N_{80}P_{60}K_{40}$+ Zn +B (T_9) and $N_{80}P_{60}K_{40}$+B+S_I during 2013, and treatment $N_{80}P_{60}K_{40}$+B+S_I (T_{10}) during 2014 and on mean basis as well as treatment $N_{80}P_{60}K_{40}$+Zn +S_I (T_8) on mean basis.

- Significantly highest energy intensiveness during both the years and on mean basis was registered under treatment $N_{120}P_{80}K_{60}$ (T_2), but it was at par with treatments $N_{80}P_{60}K_{40}$+Zn (T_5) and $N_{80}P_{60}K_{40}$+ Zn +B (T_9) during both the years and on mean basis as well as treatment $N_{80}P_{60}K_{40}$+B (T_7) during 2014.
- Significantly highest production efficiency was registered during both the years and on mean basis under treatment $N_{80}P_{60}K_{40}$+Zn +SI+B (T_{11}), but it was at par with treatment $N_{120}P_{80}K_{60}$ FYM_{5t} (T_4) during 2013 and on mean basis.

2.3 Red rice: Experiment No.III

Title: Enhancement of productivity and quality of red rice through organic and inorganic application of nutrients

- The application of $N_{120}P_{60}K_{40}$ I (T_2) was found significantly superior for producing tallest plant of red rice at all the periods of observations during both the years as well as on mean basis. However, it was at par to of $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during 2013 at 30 DAT, on mean basis at 60 DAT and during both the years and on mean basis at 90 DAT, treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during 2013 at 30 DAT and treatments N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) on mean basis at 60 DAT. The shortest plant height was recorded under control at all the stages during both the years and on mean basis.
- At all the growth periods of observations, treatment $N_{120}P_{60}K_{40}$ (I) (T_2) registered significantly highest dry matter accumulation during both the years and on mean basis. However, it was at par to treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during both years the and on mean basis at 60 DAT as well as treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4), N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) and N of T_2 applied through organics (O) +

FS of N at T and PI stages (T_8) during both the years and on mean basis at 90 DAT.

- At 30 DAT, significantly the highest leaf area index was registered under treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during both the years and on mean basis, but it was at par with $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during 2014. Further, at 60 DAT in 2014, significantly highest leaf area index was registered with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) , which was at par with treatment N_{60} $P_{40}K_{30}$ (25% O +75% I) (T_3), $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) and N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5).Whereas, on mean basis significantly highest leaf area index was recorded under $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) which was at par with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8). Moreover, at 90 DAT during both the years and on mean basis, significantly highest leaf area index was recorded under $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) which was at par with treatments $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) and N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) and N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) during 2013 and treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during 2014 and on mean basis.
- In general, crop growth rate increased from 0- 30 to 60-90 DAT. At early stage (0-30 DAT), it was highest with the treatment of $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) which was significantly superior over rest of the treatments during both the years and on mean basis. Moreover, at 30- 60 DAT in year 2014 and on mean basis ,the highest crop growth rate was observed under the treatment of $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6), but it was at par with treatment N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) during 2014 and on mean basis and also where treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T8) was given during 2014. During the period 60- 90 DAT, treatment N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) registered maximum crop growth rate during both the years and mean basis . However, in year 2014 treatments $N_{120}P_{60}K_{40}$ (I) (T2), $N_{120}P_{60}K_{40}$

(25% O +75% I) $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4), N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T8) also recorded comparable values.

- The relative crop growth rate declined with advancement of crop age .The early relative growth rate (0- 30 DAT) was noticed highest with treatment N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7), however it was at par with treatments $N_{60}P_{40}K_{30}$ (I) (T_1), N $_{60}$ P_{40}K $_{30}$ (25% O +75% I) (T_3), $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6), N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) and Control during 2014 and on mean basis. More over at 30- 60 DAT, treatment N $_{120}P_{60}K_{40}$ (I) (T_2) gave significantly higher relative growth rate as compared to others during both the years and mean basis. Further, at 60- 90 DAT, treatment N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) gave maximum relative growth rate which was significantly higher than others, but it was at par to treatments N_{120} $P_{60}K_{40}$ (25% O +75% I) (T_4) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during both the years as well as on mean basis.
- Root volume was significantly highest under $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) ,but it was at par with treatments $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during both the years and on mean basis as well as N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during 2013.
- Significantly highest number of effective tillers hill $^{-1}$ was obtained with $N_{120}P_{60}K_{40}$ (50% O + 50% I) (T_6) during both the years as well as on mean basis, but it was at par with $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during year 2014**.**
- Significantly longest panicle was registered with $N_{120}P_{60}K_{40}$ (50% O +50% I (T_6) during both the years as well as on mean basis, but it was at par with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) in year 2013 and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during 2014 .
- Significantly highest panicle weight was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during both the years as well as on mean basis ,but it was at par with treatments N $_{60}$ P_{40}K $_{30}$ (25% O +75% I) (T_3), $N_{120}P_{60}K_{40}$ (25% O

+75% I) (T_4) , N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5), N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during 2014 .

- Number of grains panicle^{-1} was recorded significantly highest with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) but it was at par with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during 2013 and on mean basis. .Further, in year 2014 treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) gave significantly highest number of grains panicle^{-1} which was at par with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6).
- The significantly highest test weight was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during both the years and on mean basis ,but it was at par with treatments N $_{120}P_{60}K_{40}$ (I) (T_2), $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4), N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5), N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during 2013, while in 2014 it was at par with treatments N $_{120}P_{60}K_{40}$ (I) (T_2), however, on mean basis comparable values was also noted in treatments ($N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4).
- The significantly highest grain yield was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during both the years and on mean basis, but it was at par with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during 2013.
- Significantly highest straw yield was registered with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) but, it was at par with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T6) during both the years and on mean basis as well as treatment N $_{120}P_{60}K_{40}$ (I) (T_2) on mean basis.
- The significantly highest N content in grain and straw was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) which remained at par with treatments $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during both the years as well as on mean basis.
- Significantly highest P content in grain and straw was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during both the years and on mean basis.

- Highest K content in grain was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during both the years and mean basis. As regards, to K content in straw , significantly highest values were recorded under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6), but it was at par with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during 2013 and on mean basis, $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) on mean basis. However, in 2014, K content in straw was significantly highest under treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4).
- Significantly highest zinc content (ppm) was registered with treatment N $_{120}P_{60}K_{40}$ (I) (T_2) during both the years and on mean basis.
- Iron content (ppm) was significantly highest with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis, but it was at par with treatments N $_{120}P_{60}K_{40}$ (I) (T_2) and N of T_1 applied through organics (O) + FS of N at T and PI stages (T_7) during 2014.
- Significantly highest N uptake in grain, straw and in their total was noticed under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis, however in year 2013, it was at par to treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) .
- Highest P uptake in grain, straw and in their total was noticed under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) in both the years and on mean basis.
- The highest K uptake in grain, straw and in their total was noticed under treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6), during both the years and on mean basis, except total K uptake which was recorded significantly highest under treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during 2014. Further, in case of straw and it total of grain and straw treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) also recorded comparable values.
- Significantly highest head rice recovery was registered with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during both the years and on mean basis.
- Longer paddy length was registered under treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8), but it was at par with N of T_1

through organic + 2 F S N (T_7) during 2013 and on mean basis, while, in the year 2014 treatment N of T_1 through organic + 2 F S N (T_7) registered significantly highest value which was at par with treatment N of T_2 organic + 2 F S(T_8). Further, paddy breadth during both the years and on mean basis was significantly highest under treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8). The L/B ratio of paddy in 2013 was significantly highest with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) which was at par with treatments N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5), N of T_1 through organic + 2 F S N (T_7) and N of T_2 organic + 2 F S(T_8), while in year 2014 and on mean basis ,treatment $N_{120}P_{60}K_{40}$ (I) (T_2) noticed significantly highest L/B ratio which was at par with treatment N T_1 through organic + 2 F S N (T_7) .

- Significantly highest gross return was registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during both the years and on mean basis, but it was at par with treatments N_{60} $P_{40}K_{30}$ (25% O +75% I) (T_3), $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) and N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) with additional treatment $N_{60}P_{40}K_{30}$ (I) (T_1) and N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during 2014 .
- Net return was significantly highest with treatment $N_{120}P_{60}K_{40}$ (25% O +75% I) (T_4) during both the years and on mean basis , but it was at par with treatments $N_{60}P_{40}K_{30}$ (I) (T_1), $N_{120}P_{60}K_{40}$ (I) (T_2) , N_{60} $P_{40}K_{30}$ (25% O +75% I) (T_3) , and N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) and $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6)
- Highest B:C ratio was registered with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages (T_8) during both the years and on mean basis.
- Significantly highest energy use efficiency was registered with treatment N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) during both the years and on mean basis
- Energy output input ratio was significantly highest with treatment N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) during both the years and on mean basis.
- Highest energy productivity was registered with treatment N_{60} $P_{40}K_{30}$ (50% O +50 % I) (T_5) during both the years and on mean basis.

- Significantly highest energy intensiveness was registered with treatment $N_{120}P_{60}K_{40}$ (I) (T_2) during both the years and on mean basis.
- The production efficiency was significantly highest registered with treatment $N_{120}P_{60}K_{40}$ (50% O +50% I) (T_6) during both the years and on mean basis.

CONCLUSIONS

The results of present findings on red rice are concluded as under:

1. The genotype RR 12 EN-11 with spacing 20 cm x10cm and fertility level of 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} registered significantly highest grain yield, nutrient uptake, net return and B:C ratio during both the years and it was followed by genotype RR 14 EN-8 with spacing 15 cm x10cm and fertility level of 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1}.
2. Significantly highest rice grain yield, head rice recovery and paddy breadth during both the years and on mean basis was registered under treatment $N_{80}P_{60}K_{40}$+Zn +S_i +B, but it was at par with treatment $N_{120}P_{80}K_{60}$ FYM_{5t} . However, nutrient uptake, length and L/B ratio of paddy were significantly highest under later treatment.
3. Significantly highest rice grain yield was registered under treatment $N_{120}P_{60}K_{40}$ (50% O + 50% I) during both the years and on mean basis, but it was at par with treatment $N_{120}P_{60}K:_{40\ 25\%}$ Org +75 % Ino. However, significantly highest head rice recovery, length and breadth of paddy and L/B ratio was registered with treatment N of T_2 applied through organics (O) + FS of N at T and PI stages during both the years and on mean basis.

Suggestions for future research work

In the context of experience gained during the course of investigation and result obtained, it is felt that following point should be given due consideration in future studies:

1. Studies need to be conducted to evaluate the existing several others genotypes which have good field potential of red rice in Bastar plateau.
2. Studies need to be conducted to evaluate the existing several others genotypes and effect of macro and micronutrient management on productivity and quality of red rice.
3. Long term studies are required for the influence of organic, inorganic and INM on nutrient balance in soil and its uptake by red rice.
4. Studies need to be conducted to evaluate the existing several genotypes for lodging resistance.
5. There is a need to develop complete package and practices (date of sowing, methods of cultivation, fertilizer management, weed control, plant protection etc.) for red rice in Bastar plateau.
6. Studies need to be conducted to evaluate the multi location trials on red rice for its sustainable yield in Chhattisgarh.
7. Studies need to be conducted to evaluate the marketing prospects and potential of existing several genotypes of red rice in Bastar plateau.

REFERENCES

Ahmed, A.M., Sukumar, S. and Krishnan, H.B. 2008. Inter specific rice hybrid of *Oryza sativa* × *Oryza nivara* reveals a significant increase in seed protein content. Journal of Agriculture Food Chemistry, 56(2): 476–482.

Ahmed, S.A., Baraua, I. and Das, D. 1998. Chemical composition of scented rice. Oryza, 35(2):167-169.

Ahmed, S.A., Hussain, A., Ali, H. and Ahmad, A. 2005. Grain yield of transplanted rice (*Oryza sativa* L.) as influenced by plant density and nitrogen fertilization. Journal of Agriculture and Social Sciences, 1: 212–215.

Akita, S. 1989. Improving yield potential in tropical rice progress in Irrigated Rice Research. Manila, Philippines, International Rice Research Institute, 41–73.

Alloway, B.J. 2009. Soil factors associated with zinc deficiency in crops and humans. Environ Geo Chem Health, 31(5): 537–548.

Amano, T., Zhu, Q., Wang, Y., Inoue, N. and Tanaka, H. 1993. Case studies on high yields of paddy rice in Jiangsu Province China characteristics of grain production. Journal Crop Sci., 62(2): 267–274.

Anuradha, K., Agarwal , S., Batchu , K.A., Babu, P.A., Swamy, M.B.P., Longvah, T. and Sarla, N. 2012. Evaluating rice germplasm for iron and zinc concentration in brown rice and seed dimensions. Journal of Phytology, 4(1): 19-25.

Awan, Z.I., Absasia, M.K. and Hashmi, N.I. 2000. Effect of organic and inorganic manure on growth and yield of rice variety Basmati. Pakistan Journal of Agriculture Research, 16(2): 105-108.

Ayoub, A.T. 1999. Fertilizer and the Environment. Nutr. Cycl. Agroecosys, 55(2): 117–121.

Azad, A.K., Gaffer, M.A., Samanta, S.C., Kashem, M.A. and Islam, M.T. 1995. Response of BR10 rice variety to different levels of nitrogen and spacing. Bangladesh J. Sci., 30(1): 31-38.

Banwasi, R. and Bajpai, R.K. 2006. Influence of organic and inorganic fertilizer source on soil fertility,yield and nutrient uptake by wheat crop in a rice-wheat cropping system. Soil and Crops, 16(2): 303-304.

Baouman, B.A.M., Yang, X., Wang, Z., Zhao, J. and Chen, B. 2006. Performance of aerobic rice verities under irrigated conditions in North China. Journal of Field Crops Research, 97: 53-65.

Bardhan, R.S.K. and Biswas, S. 1983. Low temperature effect on rice seedlings. Oryza, 20: 204-208.

Barker, R., Herdt, R.W. and Rose, B. 1985. The Rice Economy in Asia: Resources for the Future; Government Printing Office: Washington, D C.

Belder, P., Bouman, B.A.M., Spiertz, J.H.J., Peng, S., Castaneda, A.R. and Visperas, R.M. 2005. Crop performance, nitrogen and water use in flooded and aerobic rice. Plant and Soils, 273: 167-82.

Bhattacharjee, S. 2006.Allelic and functional diversity in few glutinous rice-germplasm ofAssam. M.Sc. (Ag) Thesis. Assam Agricultural University, Jorhat, India.

Black, C.A. and Evans, D.D. 1965. Methods of soil analysis. American Society of Agronomy. Madison, Wisconsin, USA.

Blaise, D. and Prasad, R. 1996. Relative efficiency of modified urea fertilizers in wetland rice (*Oryza sativa*). Indian Journal of Agronomy, 41(3): 373-378.

Bridgit, A.J. and Potty, N.N. 2002. Influence of root characters on rice productivity in iron soils of Kerala, International. Rice Res., 27(1): 45-46.

Cakmak, I. 2000. Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. New Phytol., 146: 185–205.

Cakmak, I. 2006. Concentration and localization of zinc during seed developments and germination in wheat. Physiologia Plantarum, 128:144-52.

Cao, Y., Tian, Y., Yin, B. and Zhu, Z. 2013. Assessment of ammonia volatilization from paddy fields under crop management practices aimed to increase grain yield and N efficiency. Field Crops Research, 147: 23-31.

Cassman, K.G., Dobermann, A. and Walters, D.T. 2002. Agro ecosystems, nitrogen use efficiency, and nitrogen management. Ambio., 31: 132–140.

Chakraborty, R., Chakraborty, S., Dutta B. K. and Paul, S.B. 2009. Genetic variability and genetic correlation among nutritional and cooking quality traits in bold grain rice. *Oryza*, 46(1): 1-5

Chandel, B.S., Verma, D. and Upadhyay, A.K. 2013. Integrated effect of iron and FYM on yield and uptake of nutrients in wheat. Annals of Plant and Soil Research, 15(1): 39-42.

Chandler, R.F. 1969. Plant morphology and stand geometry in relation to nitrogen. In: Physiological Aspects of Crop Yield, eds. pp. 265–285.

Chapale, S.D. and Badole, W.P. 1999. Response of rice (*Oryza sativa* L.) to zinc application. Indian Journal of Agriculture, 44(3): 539-542.

Chattopadhyay, N., Gupta, M. D. and Gupta,S.K. 1992.Effect of city waste compost and fertilizers on the growth, nutrient uptake and yield of rice. J. Indian Sc . Soil Sci., 40: 464-468.

Chopra, N. K. and Chopra, N. 2000. Effect of row spacing and N level on growth, yield and seed quality of scented rice (*Oryza sativa* L.) under transplanted conditions. Indian J. Agron., 45(2): 304-308.

Chung, R.S., Wang, C.H., Wang, C.W .and Wang, Y.P. 2000. Influence of organic matter and inorganic fertilizer on the growth and nitrogen accumulation of corn plants. Journal Plant Nutr., 23 (3): 297-311.

Das, K., Dang, R., Shivananda, T.N. and Sur, P. 2005. Interaction between phosphorus and zinc on the biomass yield and yield attributes of the medicinal plant stevia (*Stevia rebaudiana* L.). Sci .World J., 5:390–395.

Datta, D. and Zarate, S.K. 1978. Environmental conditions affecting growth characteristics, nitrogen response and grain yield of tropical rice. Biometeorology, 4:71-89.

Debjani, S., Prakash, A. and Mahapatra, B.S. 2009. Yield and nutrient uptake of different *rabi* crops in green manure-basmati rice based cropping systems under organic mode of cultivation. Environment and Ecology, 27: 738-42.

Devi, T.P., Raychaudhury, M., Durai A., Das, S.K., Ramya, K.T., Fiyaz, R.A and Ngachan, S.V. 2012. Studies on grain and food quality traits of some indigenous rice cultivars of north-eastern hill region of India. Journal of Agriculture Science, 4(3): 259-270.

Devi, T.P., Durai, A., Singh, T.A., Gupta, S., Mitra, J., Pattanayak, A., Sharma, B.K. and Das, A. 2008. Preliminary studies on physical and nutritional qualities of some indigenous and important rice cultivars of north eastern hill region of India. Journal of Food Quality, 31(6): 686-700.

Devi,T.P. and Pattanayak, A. 2008. Medicinal rice of Manipur, their ethno pharmacological uses and preliminary biochemical studies. Asian Journal of Microbiology, Biotechnology and Environmental Sciences, 10 (1): 139-141.

Dheri, G., Kumar, B. and Singh, K. 2013. Carbon sequestration and soil carbon pools in a Rice-Wheat cropping system. Tillage Research, 128: 30-36.

Dick, W.A. and Gregorich, E.G. 2004. Developing and maintaining soil organic matter levels in managing soil quality challenging modern agriculture. CAB International, pp. 103-120. Willingford, UK.

Dubey, S.D. and Chauhan, R.P.S. 2002. Effect of Integrated use of press mud and nitrogen with and without zinc sulphate on rice in sodic soil. Annals of Plant and Soil Research, 4: 299-301.

Ehsanullah, E.G., Akbar, N., Qaisrani, A.S., Iqbal, A., Khan, Z.H., Jabran, K., Chattha, A.A., Trethowan, R., Chattha, T. and Chattha, M.B. 2011. Effect of Zinc Application on Growth and Yield of Rice (*Oryza sativa* L.). IJAVMS, **5**(6): 530-536.

Elfouly, M.M. and E1-Sayed, A.A. 1997. Foliar fertilization: An environmentally friendly application of fertilizers. Proceeding of dahlia Greidinger International Symposium on Fertilization and Environment, pp. 346-357.

Fageria, N.K. 1984. Response of rice cultivars to liming in cerrado soil. Pesquisa Agropecuaria Brasileira, 19: 883–889.

Fageria, N.K. 1998. Evaluation nutritional status of rice. In: Technology for Upland Rice, eds. F. Breseghello and L. F. Stone, pp. 59–66. Santo Antonio de Goi´as, Brazil: National Rice and Bean Research Center of EMBRAPA.

Fageria, N.K. 2001. Nutrient management for improving upland rice productivity and sustainability. Communications in Soil Science and Plant Analysis, 32: 2603–2629.

Fageria, N.K. 2007. Yield physiology of rice. Journal of Plant Nutrition, 30: 843–879.

Fageria, N.K. 2014 Mineral Nutrition of Rice. CRC Press, Boca Raton, Florida.

Fageria, N.K., Dos, A.B. and Heinemann, A.B. 2011.Low land rice genotypes evaluation for phosphorus use efficiency in tropical low land. Journal of Plant Nutr., 34(8): 1087–1095.

Fening, J.O., Ewusi, M.N. and Safo, E.Y. 2011. Short term effects of cattle manure compost and NPK application on maize grain yield and soil chemical and physical properties. Agricultural Science Research Journal, 1: 69-83.

Frizzell, D.L., Wilson, C.E., Norman, R.J., Slaton, N.A., Richards, A.L. and Runsick, S.K. 2006. Influence of row spacing and seeding rate on rice grain yield. In: R.J. Norman, J.F.

Garge, O.K., Sharma,A.N. and Konica, G.R.S.1979.Effect of boron on pollen vibal ity and yield of rice plant (*Oryza sativa*.L). Plant and Soil, 52: 591-594.

Ghathala, M.K., Kanthakia, P.C., Verma, A. and Chahar, M.S. 2007. Effect of integrated nutrient management on soil properties and humus fraction in long term fertilizer experiment, Journal of Indian Society of Soil Science, 55(3): 360-63.

Ghosh, A. and Sharma, A.R. 1999. Effect of combined used organic manure and nitrogen fertilizer on the performance of rice under flood-prone low land conditions . Journal of Agric. Sci., (Cambridge), 132(4): 461-465.

Ghosh, A., 2005. Organic rice farming technology development and its feasibility, Indian Farming, September, 4-7.

Ghosh, M. and Sharma, B.K. 1999. Performance of aromatic rice cultivars in new alluvial zone of West Bengal. Oryza, 42(2): 184-187.

Ghosh, B.N., Sharma, N.K. and Dadhwal, K.S. 2011. Integrated nutrient management a nd cropping systems impact on yield, water productivity and net return in valley soils of north-west Himalayas. Indian Journal of Soil Conservation, 39 (3):78-82.

Gill, M.S. 2006. Sustaining high yield of rice-wheat system through site-specific nutrient management in Punjab. Indian Journal of Fertilizers, 2(5): 45-50.

Gill, M.S., Singh, T. and Ran, S.D. 1994. Integrated nutrient management in rice-wheat cropping sequence in semi arid tropics. Indian J. Agron., 39(4): 606-608.

Gogoi, B. 2011. Soil properties and nutrients availability as affected by integrated nutrient management after rainfed cropping sequence. Indian Journal of Agricultural Research, 45(4): 36-39.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for Agricultural research. Second edition A Willey Inter science.

Grewal, D., Manito, C. and Bartolonme, V. 2011. Doubled haploids generated through another culture from crosses of elite indica and japonica cultivars and lines of rice: Large-scale production, agronomic performance and molecular characterization. Crop Science, 51: 544-553.

Haciasalinoglu, G. 2002. Physiological and biochemical mechanism underlying zinc efficiency in Monocot and dicot crop plants Ph.D. Thesis, Conel Uu, Ithaca, New York, USA.

Haider, M.R., Ali, M.I., Zaman, S.M. and Islam, A.F.S.M. 1988. Yield and Yield attributes of rice as affected by N, P, K, S, and Zn fertilization. Bangladesh J. Nuclear Agric., 4: 61-68.

Hairmansis, A., Bambang, K., Supartopo, M. and Suwarno, T. 2010. Correlation analysis of agronomic characters and grain yield of rice for tidal swamp areas. Indonesian Journal of Agricultural Science, 11: 11–15.

Hari, S., Katyal, K. and Dhaman, S.D. 2000. Response of two rice (*Oryza sativa* L.) hybrids to graded levels of nitrogen. Indian J. Agric. Sci., 70(3): 140-142.

Horie, T. 1994. Crop ontogeny and development. "Physiology and determination of crop yield" (K.J. Boole et al. Ed.) pp. 153-180, ASA/CSSA/SSSA, Madison (WI) USA.

Hossain, M. and Singh, V.P. 2002. Fertilizer use in Asian agriculture implications for sustaining food security and the environment. Nutr. Cycl. Agroecosy, 57(2):155–169.

Hossain, M.B., Kumar, T.N. and Ahmed, S. 2001. Effect of zinc, boron and molybdenum application on the yield and nutrient uptake by BRRI Dhan 30. Journal. Bio. Sci., 1: 698-700.

Hussain, A., Sheraz, S., Bhat, R.A., Rasool, F.A. and Raihana, H.K. 2012. Integrated nutrient management of Rice (*Oryza sativa* L.) under temperate conditions of Kashmir. Agricultural Science Digest, 32(1): 18-22.

IRRI. 1984. Terminology for Rice Growing Environments. Los Banos,Philippines: International Rice Research Institute.

Ishii, R. 1995. Roles of photosynthesis and respiration in the yield-determining process. In: Science of the Rice Plant: Physiology, 2: 691–703.

Islam, M.S., M.A.R. Sarker, M.S. Rahman, A.I.M. Musa, and S.C. Dhan. 1994. Effect of plant population density on transplant aus rice under tidally flooded conditions. Bangladesh J. Agril. Sci., 21(2): 349-353.

Islam, M.S.H., Bhuiya, M.S.U., Gomosta, A.R., Sarkar, A.R. and Hussain, M.M. 2009. Evaluation of growth and yield of selected hybrid and inbred rice varieties grown in net-house during transplanted Aman season. Bangladesh Journal of Agricultural Research, 34:67–73.

Islam, S.M., Peng, S., Visperas, R.M., Sultan, M., Bhuiya, U., Hossain, A.S.M. and Julfiquar, A.W. 2010. Comparative study on yield and yield attributes of hybrid, inbred, and npt rice genotypes in a tropical irrigated ecosystem. Bangladesh J. Agril. Res., 35(2): 343-353.

Jackson, M.L. 1973. Soil chemical analysis Prentice Hall of India Pvt. Ltd, New Delhi. pp 42-48.

Jagdish, S.V.K., Carins, J., Lafitte, R., Wheeler, T.R., Price, A.H. and Craufurd, P.Q. 2010 Genetics analysis of heat tolerance at anthesis in rice. Crop Science, 50: 187-206.

Jahiruddin, M., Rahman, M.A., Haque, M.A., Rahman, M.M. and Islam, M.R. 2012. Integrated nutrient management for sustainable crop production in Bangladesh. Acta Horticulture, 958.

Jamal, Z., Hamayun, M., Ahmad, N. and Chaudhary, M.F. 2006. Effect of soil and foliar application of different concentrations of NPK and foliar application of $(NH_4)_2SO_4$ on different parameters in wheat. J. Agron., 5(2): 251-256.

Janoria ,M . P. 1989. A basic plant ideotype for rice. Intl. Rice Res. News I, 14(3):12-13.

Jha, M.N., Chaurasia, S.K. and Bharti, R.C. 2013. Effect of integrated nutrient management on rice nutrient profile and cyano-bacteria nitrogenase activity under rice- wheat cropping system. Communication in Soil Science and Plant Analysis, 44(13): 1961-1975.

Jin, Z., Minyan, W., Lianghuan, W., Jiangguo, W. and Chunhai, S. 2008. Impact of combination of foliar iron and boron application on iron biofertification and nutritonal quality of rice grain. J. of Plant Nutr., 31:1599-1611.

Katyal, V., Gangwar, S.K. and Gangwar, B. 2003. Long term effect of fertilizer use on yield sustainability and soil fertility in rice-wheat system in sub tropical India. Fertilizer News, 48(7): 43-46.

Katyal,V. and Gangwar, B. 2000 .Effect of integrated nutrient management on crop productivity of rice (*oryza sativa* L.*)* -rice system. Indian J. Agr. Sci., 70(2): 110-113.

Kaufman, P.B., Takeoka, Y., Carlson, T.l. 1979. Studies on silica deposition in sugarcane using scanning electron microscopy, energy- dispersive X-ray analysis, neutron activation analysis and light microscopy. Phytomorpho!ogy, 29: 185-193.

Kenneth, A.G., Gravios, B. and Ronnie, S. 1996. Seeding rate effect on rough rice yield, head rice and total milled rice. Agron. J., 88: 82-84.

Khadayate, M.K., Sharma, G.K., Verma, S., Kumar, S. and Bajpayee, R.K. 2005. Effect of organic and inorganic sources of nutrients on rice yield, yield attributing parameters, content and uptake of nutrients in Alfisols of Chhattisgarh. Plant Archives, 5(2): 645-648.

Khan, N.I., Malik, A.U., Umer, F. and Bodla, M.I. 2010. Effect of tillage and farm yard manure of physical properties of soil. International Research Journal of Plant Science ,1(4): 75-82.

Khan, P., Memon, M.Y., Imtiaz, M., Depar, N., Aslam, M., Memon, M.S. and Shah, J. A. 2012. Determining the zinc requirements of rice genotype sarshar evolved at NIA Tandojam. Sarh J Agric., 28(1): 1–7.

Khurana H.S., Singh B., Bovermann A., Phillips S.B., Siddhu A.S. and Singh Y. 2008. Site specific nutrient management performance in rice-wheat cropping system. Better Crops, 92(4): 26-28.

Kiniry, J.R., Mc-Cauley, G., Xie, Y. and Arnold, J.G. 2001. Rice parameters describing crop performance of four rice cultivars. Agron. J., 93:1354–1361.

Krisnhnan, P., Ramakrishnan, B., Reddy, K.R. and Reddy, V.R. 2011 High-temperature effects on rice growth, yield and grain quality. Advances in Agronomy, 111: 87-206.

Kumar, V. and Prasad,B .2003. Integrated nutrient management for rice-wheat system. J Res Birsa Agril Uni., 15: 25-33.

Ladha, J.K., Kundu, D.K., Angelo, V., Coppenole, N.G., Peoples, M.B., Carangal, V.R. and Dart, P.J. 1996. Legume productivity and soil nitrogen dynamics in low land rice based cropping systems. Soil Science Society of American Journal, 60:183-192.

Lafarge, T. and Bueno, C.S. 2009. Higher crop performance of rice hybrids than of elite inbreds in the tropics: does sink regulation, rather than sink size, play a major role. Field Crop Res., 112:238–244.

Laxminarayana, K. 2006. Effect of integrated use of inorganic and organic manures on soil properties, yield and nutrient uptake of rice in Ultisols of Mizoram. Indian Society of Soil Science, 54(1): 120-123.

Lewin, J. and Reimann, B.E.F. 1969. Silicon and plant growth. Ann. Rev. Plt. Physiol., 20: 289-304.

Lui, E., Yan, C., Mei, X., He, W., Bing, S., Ding, L., Liu, Q., Lui, S. and Fan, T. 2010. Long term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. Geoderma, 158: 173-180.

Mae, T. 1997. Physiological nitrogen efficiency in rice: Nitrogen utilization, photosynthesis, and yield potential. Plant Soil, 196: 201–210.

Mafi, S., Sadeghi, S.M. and Doroodian, H. 2013. Effect of zinc and phosphorus fertilizers on yield and component yield of rice (Hashemi). Pers Gulf Crop Prot., 2: 30–36.

Magar, S.S. 2004. Organic farming technical feasibility, economic viability and social acceptance. Indian Society of Soil Science, 52(4): 374-78.

Maheswari, J., Maragathan, N. and James, M.G.J. 2007. Relatively simply irrigation scheduling and N application enhances the productivity of Aerobic rice. American Journal of Plant Physiology, 2(4): 216-228.

Mallikarjuna, B.P., Kaladhar, K., Anuradha, K., Batchu, A.K., Longvah, T., Viraktamath, B.C. and Sarla, N. 2011. Enhancing iron and zinc concentration in rice grains using wild species. Directorate of Rice Research, Hyderabad, National Institute of Nutrition, Hyderabad, Internal report.

Manjappa, K., Chandranath, H.T., Guggri, A.K. and Desai, B.K. 1994. Ways and means of increasing NUE in rice fields. Agricultural Reviews, 15(3-4): 195-204.

Manjunath, B.L., Prabhudesai, H.R., Wasnik, H.M., Faleiro, J.R., Ramesh, R. and Sunetra. T. 2009. Glimpses of three decades of rice research in Goa .Technical bulletin No. 19, ICAR Research Complex for Goa.

Maqsood, M., Irshad ,M., Wajid ,S.A. and Hussain, A. 1999. Growth and yield response of Basmati 385 (*Oryza sativa* L.) to zinc sulphate application .Pak J. Bio. Sci., 2: 1632-1633.

Marschner, H. 2002. Mineral Nutrition of Higher Plants. 2nd ed. San Diego, CA: Academic Press.

Martinez, C.P., Borrero, J., Carabali, S.J., Delgad, D., Correa, F. and Tohme, J. 2006. High iron and zinc rice lines for latin-america. 31st rice. Technical working group, Wood Lands, Texas, USA.

Mathew, J., Varughese, K. and Pillai, G.R. 1993. Integrated nutrient management in a sandy loam soil on productivity and economics of rice. Oryza, 30: 26-29.

Meelu, O.P., Palaniappan, S.P., Singh, Y. and Singh, B. 1992. Integrated nutrient management in crops and cropping sequences. International Symposium, held at the Punjab Agriculture University, Ludhiana, during 10-12 February .

Meena, M.C., Patel, K.P. and Rathod, D.D. 2008. Effect of Zn and Fe enriched FYM on yield and removal of nutrients under mustard-sorghum (fodder) cropping sequence in semi- arid region of Gujarat. Indian Journal of Dryland Agricultural Research and Development, 23: 28-35.

Mhaske, N.S., Borkar, S.L. and Rajgire, H.J. 1997. Effects of nitrogen levels on growth, yield and grain quality of rice. J. Soils and Crops, 7(l): 83-86.

Mirza, B.B., Zia, M.S., Szombathova, N. and Zaujec, A. 2005. Rehabilitation of Soils Through Environmental Friendly Techonologies : Role of Sesbania and Farm Yard Manure. Agricultura Tropica Et Subtropica, 38(1): 11-17.

Mishra, A. and Salokhe, V.M. 2010. The effects of planting pattern and water regime on root morphology, physiology and grain yield of rice. Journal of Agronomy and Crop Science, 196: 368–378.

Misra, J.P. and Abidi, A.B. 2006. Effect of zinc sulphate doses on yield and yield attributing characters of hybrid rice varieties. Farm Science Journal, 15(1): 13-14.

Mizno, N. 1987. Effect of silica on hull weight and ripening of rice plant. Jpn. J. Soil ScL Plant Nutr., 58: 147-151.

Mohanty, M.,Nanda, S.S. and Barik, A.K.2013. Effect of integrated nutrient management on growth, yield , nutrient uptake and economic of wet season Rice (*Oryza Sativa* L.) in Odisha. Indian Journal of Agricultural Sciences, 83(6): 22-24.

Mubarak, T. and Bhattacharya, B. 2006. Response of hybrid rice cultivars to various levels of nitrogen and potassium grown on Gangetic alluvial soil in summer season. Environment and Ecology, 245: 515-17.

Naik, S.K. and D.K. Das. 2007. Effect of split application of zinc on yield of rice (*Oryza Sativa* L.) in an inceptisol. Arch. Agron Soil Sci., 53: 305-313.

Nambiar, K.K.M. and Abrol, I.P. 1989. Long term fertilizer experiments in India: an overview. Fert News, 34: 11-20.

Nath, D.J., Ozah, B., Baruah, R., Barooah, R.C., Borah, D.K. and Gupta, M. 2012. Soil enzymes and microbial biomass carbon under Rice-Toria sequence as influenced by nutrient management. Indian Society of Soil Science, 60(1): 20-24.

Navin, K., Singh ,V.K., Thakur .R.B. and Kumar, N. 1996. Effect of level and time of N-application on the performance of winter rice. Journal of Applied Biology, Rejendra Agricultural University, Pusa, Bihar, India, 6(2): 48-53.

Nayak, B.C., Dalei, B.B. and Choudhury, B.K. 2003. Response of hybrid rice to date of planting, spacing and seedling rate during wet season. Indian Journal of Agronomy, 48: 172–174.

Obulamma, U., Reddy, M.R. and Kumari, C.R. 2004. Effect of spacing and number of seedlings per hill on yield attributes and yield of hybrid rice. Madras Agriculture Journal, 91: 344–347.

Okuda, A. and Takahashi, E. 1961. Studies on the physiological role of silicon in crop plants (Part I). Discussion on the silicon deficient culture method. J. Sci. Soil Manure, 32: 475-480.

Padmajarao, S. 1995. Yield and high density grain as influenced by crop density and level in scented rice. Madras Agriculture Journal, 82(2): 108-112.

Pandey, A. 2012. Long term effect of organic and inorganic fertilizers on the distribution and transformation of S, Zn and boron in calcareous soil. Ph.D. Thesis, Department of Soil Science, Rajendra Agriculture University, Pusa, Bihar.

Pandey, N. and Tripathi, R.S. 1992. Grain yield of lowland rice as influenced by underrated use of inorganic and organic and organic nitrogen fertilizer. Indian Journal of Agronomy, 37(3): 561-562.

Pandey, N., Sarawgi, A.K., Rastogi, N.K. and Tripathi, R.S. 1999. Effect of farm yard manure and chemical N fertilizer on grain yield and quality of scented rice (*Oryza sativa* L.) varieties. Indian Journal of Agricultural Science, 69(9): 621-623.

Pandey, T.D. and Nandeha, K.L. 2004. Response of scented rice (*Oryza sativa* L.) varieties to FYM and chemical fertilizers in Bastar Plateau. International Symposium on Rainfed Rice Ecosystems: Perspective and Potential. IGKV, Raipur, India. 11-13th Oct. pp. 105.

PARC. 2002. Annual report effect of boron on rice productivity.Pak. Agri. Res. Coun. Islamabad: 97.

Patel, K.P., Thanki, J.D., Patel, D.D., Bafna, A.M., Arvadia, M.A. and Gami, R.C. 2013. Integrated nutrient management in rice –sugarcane (plant)–sugarcane (ratoon) cropping sequence. Indian Journal of Agronomy, 58(1): 9-14.

Peng ,S., Khush, G.S. and Cassman, K.G. 1994. Evolution of the new plant ideotype for increased yield potential. Breaking the potential in favorable environments, IRRI, Page 5-20, Philippines.

Peng, S., Cassman, K.G., Virmani, S. S., Sheehy, J. and Khush, G.S. 1999. Yield potential trends of tropical rice since the release of IR8 and the challenge of increasing rice yield potential. Crop Sci., 39:1552–1559.

Peng, S., Laza, R.C., Visperas, R.C.,Sanico, A.L., Cassman, K.G. and Khush. G.S. 2000. Grain yield of rice cultivars and lines developed in the Philippines since 1966. Crop Science, 40: 307–314.

Prasad, R. 2005. Modern agriculture vis-a-vis organic farming. Current Science, 89: 252-54.

Prasad, R., Shivay, Y.S. and Kumar, D. 2013. Zinc fertilization of cereals for increased production and alleviation of zinc malnutrition in India. Agricultural Research, 2: 111-18.

Qui, L.C., Pan, J. and Dan, B.W. 1995. The mineral nutrient component and characteristic of color and white brown rice. Chinese Journal of Rice Science, 7(2): 95 -100.

Quijano, G.C., Kirk, G.J.D., Portugal, A.M., Bartolome, V.I. and Mclaren, G.C. 2002. Tolerance of rice germplasm to zinc deficiency. Field Crop Res., 76(2): 123–130.

Rafique, E., Rashid, A., Ryan, J. and Bhatti, A.U. 2006. Zinc deficiency in rainfed wheat in pakistan: Magnitude, spatial variability, management and plant anal ysis diagonistic norms.Commun.Soil Sci. and Plant Analysis, 37: 181-197.

Rajesh, V. and Thanunathan, K. 2003. Effect of seedling age, number and spacing on yield and nutrient uptake of traditional Kambanchamba rice. Madras Agriculture Journal, 90: 47-49.

Rakshit, A., Sarkar, N.C. and Debashish, S. 2008. Influence of organic manures on productivity of two varieties of rice. Journal of Central European Agriculture, 9(4): 278-79.

Raman, K.R., Singh, M.P., Singh, R.O. and Singh, U.S.P.1996. Long term effects of inorganic and organo-inorganic nutrient supply system on yield trends of rice-wheat cropping system. J. Appl. Biol., 6 (1-2): 56-58.

Ramesh, P., Panwar, N.R., Singh, A.B. and Ramanna, S. 2009. Production potential, nutrient uptake, soil fertility and economics of soybean (*Glycine max* L.) based cropping systems under organic, chemical and integrated nutrient management practices. Indian Journal of Agronomy, 54(3): 278-283.

Rashid, A. 2001. Secondary and micronutrients; Soil Science. National Book Founda tion, Islamabad, p. 372-379.

Rashid,A.,Yasin, M., Ali ,M.A., Ahmid ,Z. and Ullah, R.2009. Boron deficiency in rice in Pakistan serious constraint to productivity and grain quality, salinity and water ,.Pak .J. Agric. Res., 72 :22–26.

Rathod, D.D., Meena, N.C. and Patel, K.P. 2012. Evaluation of different zinc enriched organics as source of zinc under wheat maize (fodder) cropping sequence on zinc deficient typic Haplustepts. Journal of the Indian Society of Soil Science, 60: 50-55.

Reddy, G.R., Reddy, G.B., Ramaiah, N.V. and Reddy, G.V. 1986. Effect of different levels of nitrogen and forms of urea on growth and yield of wetland rice. Indian Journal of Agronomy, 31(4): 416-418.

Roosta, H.R. and Hamidpour, M. 2011. Effect of foliar application of some macro-and micro-nutrients on tomato plants in aquaponic and hydroponic system. Scientia Horticulturae, 129:396-02.

Rose, T. J., Impa, S.M., Rose, M.T., Pariasca.T. J., Mori, A., Heuer, S., Johnson, B. S.E. and Wissuwa, M. 2013. Enhancing phosphorus and zinc acquisition efficiency in rice: A critical review of root traits and their potential utility in rice breeding. Ann Bot., 112(2): 331–345.

Roul, P.K., Sarawgi, S.K., Kumar, D. and Rout, D.P. 2007. Response of rice (*Oryza sativa* L.) to integrated nitrogen application in Inceptisols of Chhattisgarh. Oryza, 44(1): 39-43.

Rui,Y.,Yuan, L., Bi,Y., Qiong, C. and Xiang ,Y.C. 2007. Characteristics of nutrient accumulation and partitioning in yield formation process of different rice cultivars. Zhongguo Shengtai Nongye Xuebao Chinese Journal of Economic Agriculture, 15(5): 139-146.

Salahuddin, K.M., Chowdhury, S.H., Munira, S., Islam, M.M. and Parvin, S. 2010. Response of nitrogen and plant spacing of transplanted Aman rice. Bangladesh Journal of Agricultural Research, 34:279–285.

Santhy, P., Sankar, S.J., Muthuvel, P. and Selvi, D. 1998. Long term fertilizer experiments status of N, P and K fractions in soil. J. Indian Society Soil Science, 46(3): 395-398.

Sarawgi, S.K. and Sarawgi, A.K. 2004a. Effect of blending of N with or without FYM on semi-dwarf, medium to long slender scented rice varieties in lowland alfisols of Chhattisgarh. In: International Symposium on Rainfed Rice Ecosystems: Perspective and Potential. IGKV, Raipur, India. 11-13th Oct., 2004. pp. 159-160.

Sarawgi, S.K. and Sarawgi, A.K. 2004b. Impact of integrated nutrient management on tall and short to medium slender scented rice varieties under lowland alfisols of Chhattisgarh plain. In: International Symposium on Rainfed Rice Ecosystems: Perspective and Potential. IGKV, Raipur, India. 11-13th Oct., 2004. pp.159.

Sarawgi, S.K., Purohit, K.K., Sarawgi, A.K. and Singh, A.P. 2006. Effect of nutrient management on semi dwarf, medium to long slender scented rice varieties in Alfisols of Chhattishgarh. Jounral of Agricultural Issues, 11(1): 75-78.

Sarwar, G., Hussain, N., Schmeisky, H., Suhammad, S., Ibrahim, M. and Ahmad, S. 2008. Efficiency of various organic residues for enhancing rice-wheat production under normal soil conditions. Pakistan Journal of Botany, 40(5): 107-113.

Sathiya. K. and Ramesh, T. 2009. Effect of split application of nitrogen on growth and yield of aerobic rice. Asian Journal of Experimental Sciences, 23(1): 303-306.

Satish, A., Hugar, A.Y., Kusagur, N. and Chandrappa, H. 2011. Effect of integrated nutrient management on soil fertility status and productivity of Rice-Maize sequence under permanent plot experiment. Indian Journal of Agricultural Research, 45(4): 32-34.

Satyanarayana, V., Vara, P. P.V., Murthy, V.R.K. and Boote, K.J. 2002. Influence of integrated use of farm yard manure and inorganic fertilizers on yield components of irrigated lowland rice. Journal of Plant Nutrition, 25(10): 2081-90.

Savithri, P., Perumal, R. and Nagarajan. R. 1999. Soil and crop management technol ogiesfor enhancing rice product on under micronutrient constraints. Nutr. Cycl. Agro Ecos., 53: 83-92.

Shanmugam, Y.S. and Veerputhran, R. 2001. Effect of organic and inorganic N and zinc application on soil fertility and nutrient uptake of *rabi* rice (*Oryza sativa* L.). Madras Agriculture Journal, 88(7): 514-517.

Sharma, A.R. 1995. Fertilizer use in rice and rice based cropping system. Fert News, 40 (5): 29-41.

Sharma, G.D. 1994. Utilization of weed plants as organic manure under different methods of rice establishment. Indian J. Agriculture Sciences, 64(3): 184- 186.

Sharma, M.P. and Bali, S.V. 2001. Effect of row spacing and farmyard manure with increasing levels of nitrogen, phosphorus and potassium on yield and nutrients uptake in rice-wheat cropping sequence. Indian J. Agri. Sci., 71: 661-663.

Sharma, S.K. and Sharma, S.N. 2002. Integrated nutrient management for sustainability of rice-wheat cropping system. Indian Journal of Agricultural Science, 72: 573-576.

Sharma, S.N. 2002. Nitrogen management in relation to wheat (*Triticum aestivum*) residue management in rice (*Oryza sativa* L.). Indian Journal of Agricultural Sciences, 72: 449-52.

Shinde, D.R., Dixit, A.J. and Thorat, S.T. 2005. Research of 'Sahydri' hybrid rice to different spacing, seed rates and fertilizer levels under drilled condition in

Lankan region of Maharashtra. Journal Maharashtra Agriculture University, 30(3): 357-359.

Singh, H. and S.K. Bansal. 2010. A review of crop productivity and soil fertility as related to nutrient management in the Indo-Gangetic plane of India. Better crops-South Asia: 27-29.

Singh, B., Natesan, S.K.A., Singh, B.K. and Usha, K. 2005. Improving zinc efficiency of cereals under zinc deficiency. Curr. Sci., 88(1): 36–44.

Singh, D .V. 1999. Rice diseases and their management. R. Prasad, ed. A text book of Rice Agronomy, Pages 191-210. Karol Bagh, New Delhi, India.

Singh, M., Singh, R. and Dixit, M.L. 2004. Soil test based fertilizer and FYM application for yield in paddy-wheat sequence. 69th Annual Convention: 27-30 Oct, 110-112. PAU, Ludhiana, Punjab.

Singh, N.B., Verma, K.K. and Yadav, R.S. 2006b. Nitrogen substitution in rice (*Oryza sativa* L.)- wheat (*Triticum aestivum*) cropping system through green maturing for sustainable production in eastern part of Uttar Pradesh. Extended Summaries, National Symposium on "Conservation Agriculture and Environment" 26-28 October, BHU, Varanasi, 157-158.

Singh, N.P., Sachan, R.S., Pandey, P.C. and Bisht, R.S. 1999. Effects of decade long fertilizer and manure application on soil fertility and productivity of rice-wheat system in a Mollisol. Indian Soc. Soil Sci., 47 (1): 72-80.

Singh, R.K., Kumar, A. and Kaleem, M.J.S. 2013. Yield Maximization of hybrid rice (*Oryza sativa* L.) by integrated nutrient management. Journal of Progressive Agriculture, 4(1):18-22.

Singh, R.K., Singh, S.K. and Tarafdar, J.C. 2008. Influence of cropping sequence and nutrient management on soil organic carbon and nutrient status of Typic Rhodustalfs. Indian Soc. Soil Sci., 56: 174-181.

Singh, V.N. and Tripathi, B.N. 2005. Studies on the response of rice to nitrogen and zinc application methods in partially amended sodic soils. Farm Science Journal, 14: 19-21.

Singh, Y., Singh, B., Khera, T.S. and Meelu, O.P. 1994. Integrated management of green manure, farmyard manure, and nitrogen fertilizer in a rice-wheat rotation in north-eastern. India Arid Soil Res. Rehab., 8 (2): 199-205.

Singh, Y.V., Dhar, D.W. and Agarwal, B. 2013. Influence of organic nutrient management on Basmati rice (*Oryza sativa* L.) wheat (*Triticum aestivum*) green gram (*Vigna radiata*) cropping system. Indian Journal of Agronomy, 56(3): 169-175.

Singh,V.K.,Tiwary, K.N., Gill, M.S., Sharma. S.K., Dwivedi, B. S., Shukla. A.K. and Mishra, P. 2008. Economic viability of site-specific nutrient management in rice -wheat cropping system. Better Crops, 92 (3): 28-30.

Slaton, N.A., Normon, R.J. and Wilson, J.C.E. 2005. Effect of Zn Uptake and grain yield of flood-irrigated rice. Agron. J., 92: 272- 278.

Song, X.F., Agata, W. and Kawamitsu, Y. 1990. Studies on dry matter and grain production of F_1 hybrid rice in China characteristic of dry matter production. Jpn .J .Crop Sci., 59: 19–28.

Tadesse, T., Dechassa, N., Bayu, W. and Gebeyehu, S. 2013. Effects of farmyard manure and inorganic fertilizer application on soil physico-chemical properties and nutrient balance in rainfed lowland rice ecosystem. American Journal of Plant Sciences, 4: 309-16.

Tahir, M., Kausar, M.A., Ahmad, R. and Bhatti, A.S. 1991. Micronutrient status of Faisalabad and Sheikhupura soils. Pak .J. Agric. Res., 12:134–140.

Takahashi, E., Arai, K. and Kasida, Y. 1966. Studies on the physiological role of silicon in crop plants. Effect of silicon on CO_2 assimilation and translocation of assimilate to panicle. J. Sci. Soil Manure. Jpn., 37: 594-598.

Takijima, Y. and Gunawardena, L.E. 1969. Nutrient deficiency and physiological disease of low land rice in Ceylon. Relationships between nutritional status of soil and rice growth. Soil Sci. Plant Nutr., 15: 259-266.

Tang, S.X., Jiang, Y.Z., Wei, X.H., Li, Z.C. and Yu, H.Y. 2002. Genetic diversity of isozymes of cultivated rice in china. Acta Agronomica Sinica, 28: 203-207.

Taniyama, T., Subbaiah, S.V., Rao, M.L.N. and Ikeda, K. 1988. Cultivation and eco physiology of rice plants in the tropics photosynthesis of rice cultivars in India. Jpn . J. Crop Sci., 56: 226–231.

Thorat, S.T. and Sonawane, S.V. 2007. Effect of plant density and weed control measures on phosphorus uptake and yield of rice planted by SRI technique. Second National symposium on system of rice intensification (SRI) in India progress and prospects. Oct. 3-5, Agartala, Tripura. pp 72- 73 .

Tolanur, S.I. and Badanur, V.P. 2003. Effect of integrated use of organic manure, green manure and fertilizer nitrogen on sustaining productivity of *rabi* sorghum – chickpea system and fertility of a *Vertisol*. J. Indian Soc. Soil Sci., 51: 41-45.

Tomar, S. and Tiwari, A.S. 1990. Production and economics of different crop sequences. Indian Journal of Agronomy, 35(1-2): 30-35.

Toriyama, T. and Heu, M.H. 2000. Rice research strategies for the future. IRRI, Philippines, 223-237.

Tripathi, B.N. and Rawat, S. 2002. Yield and concentration of nutrients in rice varieties under different doses of zinc. Bhartiya Krishi Anusandhan Patrika, 17: 168-174.

Tripathi, B.N., and Kumar, R. 2013. Effect of zinc and sulphur levels on rice in partially reclained typic Natrustalls sodic soil. Annals of Plant and Soil Research, 15: 27-30.

Tripathi, M.K., Majumdar, B., Bhandari, H.R., Chaudhary, B., Saha, A.R. and Mahapatra, B.S. 2013. Integrated nutrient management in sunnhemp-rice cropping sequence in Eastern Uttarpradesh, India. Indian Journal of Agricultural Research, 47(3):22-25.

Tsai, Y.Z. and Lai, K.L. 1990. The effect of temperature and light intensity on the tiller development of rice. Memoirs of the college of Agriculture, National Taiwan University, 30(2): 22-30.

UNIS, 2004. Independent expert on effects of structural adjustment, special reporter on right to food present reports. Commission continues general debate on economic, social and cultural rights .United Nation, http//www.fao.org/right to food /kc/downloads/vl/docs.

Upadhyay, V.B., Jain, V.M., Vishwakarma, S.K. and Kumar, A.K. 2011. Production potential, soil health, water productivity and economics of rice (*Oryza sativa* L.)-based cropping systems under different nutrient sources. Indian Journal of Agronomy, 56 (4): 28-32.

Uphoff, N. 2001. Opportunities for raising yields by changing management practices: The SRI in Madagascar. In. Agro-Ecological Innovations: Increasing Food Production with Participatory Development (Uphoff, N. Ed.). Earth Scan Publication Ltd. London, Sterilin, VA, pp. 145-161.

Uphoff, N. 2002. System of rice intensification for enhancing productivity of land, labour and water. J. Agric. Res. Mgmt., 1(1): 43-49.

Uphoff, N. and Randri, A. 2007. Root studies in aerobic rice genotypes. In: Water wise rice production. Int. Rice Res. Inst., Manila, Philippines, pp. 71-87.

Urkurkar, J.S., Chitale, S. and Tiwari, A. 2010. Effects of organic v/s chemical nutrient packages on productivity economics and physical status of soil in rice - potato cropping system in Chhattisgarh. Indian Journal of Agronomy, 55(1): 6-10.

Urkurkar, J.S., Tiwari, A., Chitale, S. and Bajpai, R.K. 2006. Influence of long term use of inorganic and organic manures on soil fertility and sustainable productivity of rice -wheat in *Inceptisols*. Indian J. Agricultural Sciences, 80(3): 208-212.

Vamadevan, V.K. and Murty, K.S. 1976. Influence of meteorological elements on productivity. Rice Production Manual, ICAR, New Delhi, 56-63.

Vaughan, D.A., Balazs, E. and Heslop, H.J.S. 2007.From crop domestication to super domestication, Annual of Botany, 100: 893-901.

Velu, V. and Rani P. 1999. Comparative efficiency of green leaf manure and concentrated liquid compost on the yield and nutrient availability in wetland rice. Madras Agricultural Journal, 86(7-9): 515-516.

Wang, G., Parpia, B. and Wen, Z. 1997. The composition of Chinese foods. Institute of Nutrition and Food Hygiene, Chinese Academy of Preventive Medicine. Ilsi Press, Washington D. C.

Welch, R.M. and Graham, R.D. 2004. Breeding for micronutrients in staple food crops from a human nutrient perspective. Journal of Experimental Botany, 55: 353-64.

Weng, J.H. and Chen, C.Y. 1984. Photosynthetic characteristics, dry matter production and grain yield of the first and the second rice crops in Taiwan. Wufeng, Taichung, Taiwan: Taiwan Agricultural Research Institute, 153–164.

Wiangsamut, B., Lafarge, T.A., Mendoza, T.C. and Pasuquin, E.M. 2013. Agronomic traits and yield components associated with broadcasted and transplanted high-yielding rice genotypes. Sci. J. Crop Prod., 2(1): 19–30.

Winslow, M.O. 1992. Silicon, disease resistance and yield of rice genotypes under upland cultural conditions. Crop Sci., 32: 1208-1213.

Wu, G., Wilson, L.T. and Mcclung, A.M. 1998. Contribution of rice tillers to dry matter accumulation and yield. Agron. J., 90(3): 317–323.

Xiong, Z.Y., Zhang, S.J., Ford, L., B.V., Jin, X., Wu, Y., Yan, H.X., Kui, P., Yang, X. and Lu, B.R. 2011. Latitudinal distribution and differentiation of rice germplasm its implication in breeding. Crop Science, 54:1050-1058.

Yadav, B., Khamparia, R.S. and Kumar, R. 2013. Effect of zinc and organic matter application on various zinc fractions under direct seeded rice in *Vertisols*. Indian Society of Soil Science, 61: 128-134

Yadav, R.L., Tomar, S.S. and Sharma, C. 2002. Output: input ratios and apparent balances on N, P and K input in a rice wheat system in North-west India. Exp Agri., 38: 457-468.

Yadi, R., Dastan, S. and Yasari, E. 2012. Role of zinc fertilizer on grain yield and some qualities parameters in Iranian rice genotypes. Ann Biol., 3: 4519–4527.

Yaduvanshi, N.P.S. 2003. Substitution of organic fertilizers by organic manures and the effect on soil fertility in a rice-wheat rotation on reclaimed sodic soil in India. Journal of Agriculture Science, 140(2): 161-68.

Yamauchi, M. 1994. Physiological bases of higher yield potential in F_1 hybrids. Virmani S (Ed.) Hybrid rice technology, New Development, Future sects, Mania, IRRI, 71-80.

Yamauchi, M. and Winslow, M.O. 1989. Effect of silica and magnesium on yield of upland rice in the humid tropics. Plant and Soil, 113: 265-269.

Yan, Q. 2002. The system of rice intensification and its use with hybrid rice varieties in China, In Assessments of the System of Rice Intensification (SRI): Proceedings of an International Conference held in Sanya, China, 1-4 April, 109-111.

Yang, X., Zhang, J. and Ni, W. 1999. Characteristics of nitrogen nutrition in hybrid rice. IRRN. 24(1): 5-8.

Ying, J.F., Peng, S.B., He, Q.R., Yang, H., Yang, C.D., Visperas, R.M. and Cassman, K.G. 1998. Comparison of high-yield rice in tropical and subtropical environment determinants of grain and dry matter yields. Field Crop Res., 57(1): 71–84.

Yogananda, S.B., Jagdeesh, B.R., Thimmegowda, S.K., and Vedashree, S.K. 2012. Effect of organic nutrient management practices on productivity of transplanting rice (*Oryza sativa* L.). Research J. Agriculture Sciences, 3(3): 650-653.

Yoshida, S. 1981. Fundamentals of rice crop science, IRRI, Phillippines,

Yoshida, S. and Hayakawa, Y. 1970. Effects of mineral nutrition on tillering of rice. Soil Sci. and Plant Nut., 16:186-191.

Yoshida, S., Navasero, S.A. and Ramirez, E.A. 1969. Effects of silica and nitrogen supply on some leaf characters of the rice plant. Plant Soil, 31: 48-56.

Yoshida, S., Ohnishi, Y. and Kitagishi, K. 1962b. Histo chemistry of silicon in rice plant. Localization of silicon within rice tissues. Soil Sci. Plant Nutr., 8(1):36-41.

Yoshida, S., Ohnishi, Y. and Kitagishi. K. 1962a. Histo chemistry of silicon in rice plant. A new method for detenmining the localization of silicon within plant tissues. Soil Sci. Plant Nutr., 8(1): 30-35.

Zang, Q., Wang, G.H., Feng, Y.K., Sun, Q.Z., Witt, C. and Dobermann, A. 2006. Changes in soil phosphorus fractions in a calcareous paddy soil under intensive rice cropping. Plant and Soil, 288(1): 141-54.

Zhang, Q.F., Seghai, M.A., Lu, T.Y. and Shen, B.Z., 1992. Genetic diversity and differentiation of indica and japanica rice detected by REFL analysis. Applied Genetics, 83: 495-99.

Zhong, X., Peng, S., Sheehy, J.E.,Visperas, R.M. and Liu, H. 2002. Relationship between tillering and leaf area index: quantifying critical leaf area index for tillering in rice. J. Agric. Sci., 138: 269-279.

Zozali, M.A., Shokrzadesh, M., Bazerafshan, E., Hazrati, M. and Tavakkouli, A. 2006, Investigation of zinc content in Iranian rice (*Oryza sativa* L.) and its weekly intake. American-Eurasian Journal of Agricultural and Environmental Sciences, 1(2): 156-159.

Appendix I: Weekly meteorological data during the crop growth period (22 to 48 SMW) of *kharif* 2013)

Week No.	Date	Temp. (°C)		Rain-fall (mm)	R H (%)		Wind Speed (Kmph)	Evapo-ration. (mm day^{-1})	Sun Shine (hours day^{-1})
		Max.	Min.		I	II			
22	28 May-3 June	35.0	24.7	14.5	86	26	6.1	7.3	6.5
23	4 June -10 June	34.0	25.8	102.2	87	38	3.5	6.6	5.7
24	11 June -17 June	27.2	22.9	214.2	91	83	2.2	1.9	0.5
25	18 June -24 June	30.9	22.9	111.4	86	86	1.0	3.4	2.9
26	25 June -1 July	28.0	22.8	48.9	90	84	4.9	1.4	2.1
27	2 July -8 July	30.1	22.8	28.6	92	51	4.5	1.5	3.4
28	9 July -15 July	28.0	22.7	36.5	91	66	5.3	1.3	1.4
29	16 July -22 July	27.0	22.2	8.6	92	70	6.3	1.0	0.0
30	23 July -29 July	25.6	21.6	85.2	92	74	8.6	0.6	0.0
31	30 July -5 Aug	25.9	21.6	92.0	89	70	6.7	0.8	0.6
32	6 Aug -12 Aug	28.3	22.4	52.1	91	61	4.4	1.9	1.6
33	13 Aug -19 Aug	30.1	23.1	36.4	89	54	3.3	2.6	4.5
34	20 Aug -26 Aug	27.6	22.0	33.3	90	61	9.1	2.0	2.9
35	27 Aug-2 Sep	29.2	22.1	20.1	88	51	4.1	3.7	3.8
36	3 Sep -9 Sep	30.3	21.7	26.6	92	55	3.1	4.1	3.4
37	10 Sep -16 Sep	30.7	21.7	57.9	91	45	1.7	4.7	7.3
38	17 Sep -23 Sep	29.1	22.0	11.3	91	55	3.5	5.5	3.1
39	24 Sep -30 Sep	30.5	21.4	38.0	90	50	2.8	4.2	5.5
40	1 Oct -7 Oct	29.9	21.1	53.8	90	55	3.9	2.2	3.8
41	8 Oct -14 Oct	29.6	21.2	20.2	90	51	4.7	2.1	3.6
42	15 Oct -21 Oct	30.1	19.7	30.0	93	50	1.4	3.0	7.2
43	22 Oct -28 Oct	26.2	20.6	76.5	94	73	5.4	1.7	1.5
44	29 Oct-4 Nov	28.6	17.0	0.0	91	53	1.8	3.0	7.3
45	5 Nov -11 Nov	30.6	21.0	13.6	90	47	2.7	2.2	4.3
46	12 Nov -18 Nov	26.2	12.1	0.0	90	44	2.2	2.1	6.7
47	19 Nov -25 Nov	28.0	16.3	3.8	90	54	4.3	2.2	4.1
48	26 Nov-2 Dec	29.0	15.6	0.0	90	45	3.7	2.7	5.9

Appendix II: Weekly meteorological data during the crop growth period (22 to 48 SMW) of *kharif* 2014

Week No.	Date	Temp. (°C)		Rain-fall (mm)	R H (%)		Wind Speed (Kmph)	Evapo-ration. (mm day^{-1})	Sun Shine (hours day^{-1})
		Max.	Min.		I	II			
22	28 May-3 June	37.4	26.9	13.0	75	39	7.4	5.9	7.6
23	4 June -10 June	37.9	27.1	11.9	80	39	6.7	5.9	5.6
24	11 June -17 June	37.9	26.5	28.1	76	41	7.5	6.5	4.8
25	18 June -24 June	33.3	25.6	10.0	80	51	6.7	4.9	2.5
26	25 June -1 July	33.6	24.4	93.3	86	52	6.4	3.9	2.1
27	2 July -8 July	33.7	25.3	24.0	80	55	4.5	3.7	1.3
28	9 July -15 July	29.3	23.9	105.0	94	68	5.8	1.7	1.4
29	16 July -22 July	25.5	23.0	106.2	93	90	9.4	1.1	0.0
30	23 July -29 July	27.1	23.0	88.0	92	81	6.2	2.2	0.9
31	30 July -5 Aug	27.2	23.7	61.5	94	83	6.4	1.7	0.9
32	6 Aug -12 Aug	30.0	24.9	46.0	88	69	5.9	4.2	3.9
33	13 Aug -19 Aug	30.1	24.8	100.4	89	73	3.4	3.4	1.7
34	20 Aug -26 Aug	30.4	24.7	70.2	93	75	1.9	3.4	4.1
35	27 Aug-2 Sep	27.7	23.2	98.2	95	81	3.3	2.4	0.1
36	3 Sep -9 Sep	27.5	23.2	174.1	93	81	2.6	2.2	0.4
37	10 Sep -16 Sep	28.9	23.7	39.6	93	77	1.3	3.6	2.0
38	17 Sep -23 Sep	29.6	23.7	83.4	96	76	2.7	1.9	2.2
39	24 Sep -30 Sep	31.6	22.3	0.0	94	60	-	3.0	7.1
40	1 Oct -7 Oct	31.6	22.4	0.0	96	58	-	3.5	7.5
41	8 Oct -14 Oct	28.3	22.4	106.6	95	75	11.4	2.3	3.3
42	15 Oct -21 Oct	30.0	20.9	2.4	95	67	2.5	2.9	7.5
43	22 Oct -28 Oct	29.1	19.4	5.8	94	70	2.4	2.2	6.2
44	29 Oct-4 Nov	28.0	15.3	0.0	97	67	3.7	2.4	8.1
45	5 Nov -11 Nov	29.2	15.6	0.0	93	42	4.1	2.7	5.6
46	12 Nov -18 Nov	30.4	18.2	0.8	95	42	2.5	2.5	5.5
47	19 Nov -25 Nov	28.9	11.6	0.0	96	53	2.2	3.8	8.7
48	26 Nov-2 Dec	28.4	10.3	0.0	97	42	2.3	2.5	8.7

Appendix III: Standard value for calculation of energy relationship during the course of investigatio

S. No.	Input / output form	Unit	Energy coefficient (MJ)
1.	Labour (adult man)	Man hour^{-1}	1.96
	(adult woman)	Woman hour^{-1}	1.57
2.	Diesel	Litre $^{-1}$	56.31
3.	Chemical fertilizer		
	N	kg^{-1}	60.00
	P_2O_5	kg^{-1}	11.10
	K_2O	kg^{-1}	06.70
4.	Fungicide	Litre^{-1}	120
5.	FYM	kg^{-1}	0.30
6.	Seed	Kg^{-1}	14.70
7.	Straw	Kg^{-1}	12.50

Source: research bulletin (1984): Energy audit of crop production system. School of energy studies for Agriculture, PAU, Ludhiana

Appendix IV: Values for calculation of cost of cultivation of rice

S No.	Particulars	Inputs	Rate , Rs. 2013	2014
A	**Fixed cost**			
1.	Land preparation	Tractor (5 hr)	Rs 500 hr^{-1}	Rs 500 hr^{-1}
2.	Seed	40 Kg ha^{-1}	12 Rs Kg^{-1}	12 Rs Kg^{-1}
3.	Seed treatment	120 g	5 g^{-1}	5 g^{-1}
4.	Nursery	5 man days	147 man day^{-1}	156 man day^{-1}
5.	Transplanting	60 man days	147 man day^{-1}	156 man day^{-1}
6.	Plant protection	5 man days	147 man day^{-1}	156 man day^{-1}
7.	Top dressing of urea	5 man days	147 man day^{-1}	156 man day^{-1}
8.	Harvesting	50 man days	147 man day^{-1}	156 man day^{-1}
9.	Threshing and winnowing	30 man days	147 man day^{-1}	156 man day^{-1}
B	**Variable cost**			
1.	Fertilizer N		12.21 kg^{-1}	12.21 kg^{-1}
	P		23.77 kg^{-1}	23.77 kg^{-1}
	K		10.50 kg^{-1}	10.50 kg^{-1}
2.	FYM	5 t ha^{-1}	7000 t ha^{-1}	7500 t ha^{-1}

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Signature