INTEGRATED CROP MANAGEMENT OF RICE UNDER SYSTEM OF RICE INTENSIFICATION (SRI)

by

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(2011 - 11 - 149)

THESIS

Submitted in partial fulfillment of the
requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM – 695 522
KERALA, INDIA

2014

DECLARATION

I hereby declare that this thesis entitled **"Integrated crop management of rice under System of Rice Intensification (SRI)."** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Beloved Parents

ACKNOWLEDGEMENT

I humbly bow my head before GOD for all the blessings showered on me that alone helped me to complete this project.

Let me place on record of my profound feeling of gratitude and sincere thanks to my chairman of the advisory committee, Dr. Latif P. H., Associate Professor (Agronomy), Instructional Farm, for his valuable guidance, whole hearted help, constructive, technical and timely advice and constant encouragement rendered to me throughout the period of my M.Sc. programme. This work would not have been possible without his valuable help and support.

I wish to express my sincere gratitude to Dr. V. L. Geethakumari, Professor and Head, Department of Agronomy, for her suggestions, constructive criticisms and constant guidance at all the stage of research work.

I have great pleasure in recording my thanks to Dr. Arthur Jacob, Associate Director Research, NARP, for his motivation, support and advice rendered throughout the course of work.

I extent my heartfelt thanks to Dr. Elizabeth K. Syriac, Professor, Department of Agronomy, for her keen interest, constructive suggestions and co-operation rendered throughout the course of this research endeavor.

I express my sincere gratitude to Dr. Sajitha Rani, Dr. Sreekumar, Dr. Hajilal, Dr. Kamala Nair and Dr. Nandakumar for their well wishes and support which had been rendered whole heartedly throughout my course of study.

I take this opportunity to express my obligations to all teachers of the Agronomy Department for their sincere co-operation and assistance rendered during the course of investigation.

I accord my sincere thanks to Mr. C. E. Ajith Kumar, Junior Programmer of Department of Agricultural Extension for helping me in getting the data analysed.

I thankfully acknowledge my immense gratitude to Raju chetan and Kuchelan chetan for being with me whenever I was in trouble.

I express my immense gratitude to, Shibu chetan, Remani chechi, Viji chechi, Jabasheeba chechi and Mohanan chetan for their sincere and whole hearted co-operation and help during the entire period of my research work.

All the teaching and non-teaching staff of Instructional Farm who have helped me during the course of my study, I express my indebtedness and thanks.

Words fail to express my sincere gratitude to my classmates and my friends Cuckoo, Jo, Raj, Murgi, Nilu and Akshay who helped me willingly throughout and who were beside me during happy and hard moments.

It is a pleasure to acknowledge my friends Mekha, Abhi, Meemo, NRS, Manju, Amla and Shruthy for their love, affection, inspiration, special care and all time pragmatic help and cooperation which helped for my goal setting and spiritual upliftment during my studies and worries.

I owe a great deal of thanks to my friends Ashish, Maddy, Praveen, Datta, Boli, GB, Sudha, Vijayaraj, Gajju and Srinivas chettan for their encouragement and ever willing help.

I place on record my sincere gratitude to my seniors Subitha, Asha , Sneha and Shimi for their valuable help and encouragement. My special thanks to my juniors Reshma, Athira, Pintu and Pavan for their valuable help in my field work and also for their encouragement in my research work.

I am most indebted to my loving Sasichan, amma, ammachan, Rakhi and Kingini for their affection, prayers, constant encouragement, moral support and blessings that have enabled me to accomplish this work without which I would not have completed this research.

Finally, I wish my humble thanks to one and all who have directly or indirectly contributed to the conduct of the study.

Asha Sasi

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LIST OF ABBREVIATIONS

BCR	–	Benefit cost ratio
CD (0.05)	–	Critical difference at 5 % level
cm	–	Centimetre
cm^2	–	Square centimetre
cm^3	–	Cubic centimetre
DAS	–	Days after sowing
day^{-1}	–	Per day
DMP	–	Dry matter partitioning
et al.	–	And others
Fe	–	Iron
Fig.	–	Figure
FYM		Farm yard manure
g	–	Gram
$g\ cc^{-1}$	–	Gram per cubic centimetre
$g\ hill^{-1}$	–	Gram per hill
HI	–	Harvest index
i.e.	–	That is
K	–	Potassium
K_2O	–	Potassium
Kg	–	Kilogram
kg^{-1}	–	Per kilogram
$kg\ ha^{-1}$	–	Kilogram per hectare
LAI	–	Leaf area index
M	–	Metre
m^{-2}	–	Per square metre
Mg	–	Milligram

Mm – Millimetre
N – Nitrogen
NS – Non significant
P – Phosphorus
P_2O_5 – Phosphate
PI stage – Panicle initiation stage
Plant^{-1} – Per plant
POP of KAU – Package of Practices Recommendations of Kerala Agricultural University
RDF – Recommended dose of fertilizers
RH – Relative humidity
Rs – Rupees
SE _ Standard error of mean
t ha^{-1} – Tonnes per hectare
viz. – Namely
RGR - Relative Growth Rate

LIST OF SYMBOLS

% – Per cent
°C – Degree Celsius
@ – At the rate of
& – And

Introduction

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple food for a large part of the world's human population especially in Asia and West Indies. In Asia, more than two billion people are getting 60-70 % of their energy requirement from rice. It is the grain with the second highest worldwide production. Within Southeast Asia alone, rice consumption is projected to increase by 11 per cent by 2015 (IRRI, 2006).

Rice is one of the most important food crops of India in term of area, production and consumer preference. India is the second largest producer and consumer of rice in the world. Rice production in India crossed the mark of 100 million metric tonnes in 2011-12 accounting for 22.81 per cent of global production in that year. The productivity of rice has increased from 1984 kg ha $^{-1}$ in 2004-05 to 2372 kg ha^{-1} in 2011-12.

Area, production and productivity of rice in Kerala during 2011-2012 was 2.1 lakh ha, 4.7 lakh tonnes and 2668 kg ha $^{-1}$ respectively. The productivity of summer rice crop in general is higher due to the conducive growing environment. Paradoxically, the area under summer rice is the least due to limited irrigation sources. Phasic stress irrigation is advocated to save water and to increase the cropped area (KAU, 2011).

Increasing food demand and declining water resources are becoming big challenges for food security (Kreye *et al.*, 2009). With decreasing water availability, rice cultivation may be switched towards water saving production systems. Traditionally rice is cultivated in standing water and thus requires huge inputs of irrigation water and labour as well. System of rice intensification (SRI) is recently introduced water saving rice production system (Uphoff, 2002). Several reports indicate substantial yield increase in this system of rice production with significant decrease in water input (Uphoff, 2002, 2007).

The System of Rice Intensification (SRI) is a methodology developed in Madagascar in 1983 by the Jesuit priest Fr. Henri de Laulanie. The system took shape based on his serendipitous discovery of the extra ordinary capacity of the singly planted very young rice seedling to grow and produce very high yields that too with lesser quantities of inputs especially water. Laulanie (1993) observed that the full potential of individual plants could be realized only when the growth and development conditions during the early phases have been optimal with minimal negative effect from early setbacks.

SRI is centered on making the best use of existing genetic potential of rice by breaking many of the conventional “rules” of management. It is based on the insights that rice has the potential to produce more tillers and grains than now observed and that early transplanting and optimal growth conditions (spacing, biologically active and healthy soil, and aerobic soil condition during vegetative phase) can fulfill this potential (Uphoff and Fernandes, 2002).

SRI is a water-saving technology. Irrigation water is applied to flood the field a certain number of days after the disappearance of ponded water. The field is alternately flooded and non-flooded in the alternate wetting and drying (AWD) system of irrigation. The number of days of non-flooded soil in AWD between irrigations can vary from 1 day to more than 10 days. With adequate weed and fertility management along with frequent use of a rotary weeeder for soil aeration and weed incorporation, AWD can increase yield up to 30 per cent. It reduces methane emission from rice fields (Zeigler, 2012). If SRI were to be applied with the water now being used for rice irrigation, it would be able to increase irrigated area by at least 50 per cent, leading to 50 per cent increase in rice production (Thakkar, 2005).

The success of SRI is based on the synergistic development of both the tillers and roots and basic principles of SRI are exploiting tillering potential and root growth. The full potential for tillering can be exploited by the management practices like transplantation of young seedlings, careful and quick planting, transplanting of single seedling, wide spacing etc. Each tiller can produce another tiller, two phyllochrons later (about 10 days later). Under favorable conditions rice plant can go through 12 phyllochrons or more in its vegetative growth phase. The number of tillers can increase exponentially with as many as 84 or more forming on a single plant (Anitha and Mathew, 2002). The full potential for root growth can be exploited by alternative wetting and drying method, early and frequent weeding using rotary weeder, application of compost etc.

SRI method have been adopted by more than one million farmers across Asia and the world as these practices have become a well known and accepted system for cultivating rice (Uphoff, 2010).

Priming of rice seeds induce improved efficiency in plants on production and partitioning of photosynthate to developing reproductive parts (Ashraf and Foolad, 2005). Muhammad Farooq *et al.* (2006b) stated that seed priming of field sown rice seed enhanced germination, seedling establishment, allometry, grain yield and its quality. Also it increased the number of fertile tillers, LAI and Harvest Index.

Keeping the above factors in view, the present study was undertaken to evaluate the efficacy of integrated input management for increasing the soil, crop and water productivity of transplanted rice grown under SRI in an economically viable mode.

Review of Literature

2. REVIEW OF LITERATURE

The SRI methodology was synthesized in the early 1980s by Fr. Henri de Laulanie, S.J. a Jesuit priest in Madagascar. He fortuitously spends 34 years of his life working with Malagasy farmers to improve their agricultural systems, and particularly their rice production, since rice is the staple food in Madagascar. Fr. de Laulanie established an agricultural school in Antsirabe on the high plateau in 1981, to help rural youths gain an education that was relevant to their vocations and family needs. The key element in SRI was discovered almost by accident in 1983-1984. Over the previous 20 years, Fr. Laulanie assembled or improvised a number of beneficial practices that enhanced the growth and productivity of rice plants. But the keystone in the SRI 'arch' was established serendipitously. Under the pressures from a drought and shortages of rice seeds, he started to experiment at his agricultural school near Antsirabe. The experiments initially focused on transplanting very young rice seedlings of just 10-15 days old in a fairly wide spacing 25 cm X 25 cm as single seedlings. A square planting pattern was used to facilitate mechanized weeding. The rice was not grown in flooded paddies, but in moist soil, with intermittent irrigation. Under such conditions Laulanie observed tremendous increases in tillering and rooting as well as number of panicles and panicle sizes, contributing to spectacular grain yields.

The System of Rice Intensification (SRI) is not a new technology, not a fixed package of practices. Rather it is a set of ideas and insights, some old and some new, all focused on how to get more benefit from available resources. SRI concepts and methods show how to create better growing environments for rice and other plants; thereby, raising the productivity of the resources - land, labor, water, seeds, and capital - that are already controlled by farmers. The System of Rice Intensification involves cultivating rice with as much organic manure as possible, starting with young seedlings planted singly at wider spacing in a square pattern; and with intermittent irrigation that keeps the soil moist but not inundated, and frequent inter cultivation with weeder that actively aerates the soil.

SRI agronomy at the level of practice represents an ‘integrated’ production system. Through integrated management of its various crop-soil biota water - nutrient -space - time components, SRI seeks to capitalize on a number of basic agronomic principles that should not be controversial. They are aimed at optimizing the above as well as below-ground plant growth and development, and improving the performance of the crop as a whole (Uphoff, 2008).

The key physiological principle of SRI practices is to provide optimal growing conditions to individual rice plants so that tillering is maximized and phyllochrons are shortened, which is believed to accelerate growth rates (Nemoto *et al*., 1995).

Laulanie established the following key elements of SRI (Uphoff, 2007).

- Transplanting very young seedlings of 8-12 days old, carefully and quickly to have minimum trauma to the roots
- Transplanting singly, only one seedling hill^{-1} instead of 3-4 together, this causes root competition.
- Widely spaced to encourage greater root and canopy growth
- Keeping the soil well drained than continuously flooded up to vegetative growth period
- Early and frequent weeding with rotary weeder
- Application of organic manures

2.1 GROWTH AND GROWTH ANALYSIS

2.1.1 Tillers hill^{-1} at panicle initiation (PI) stage

Grain yield of cereals is highly dependent upon the number of effective tillers produced by each plant (Power and Alessi, 1978; Nerson, 1980).

The decrease in the number of tillers plant^{-1} was attributed to the death of some of the last tillers as a result of their failure in competition for light and nutrients. Another explanation for this effect is that during the panicle initiation stage of crop growth period, competition for assimilates exists between developing panicles and young tillers. Eventually, growth of many young tillers is suppressed, and they may senesce without producing seed (Dofing and Karlsson, 1993; Fageria, *et al*., 1997b).

Tillering plays a vital role in determining rice grain yield since it is closely related to number of panicle per unit ground area. Too few tillers result in too few panicles, but excess tillers enhance high tiller mortality, small panicles, poor grain filling, and consequent reduction in grain yield (Peng *et al.,* 1994).

Saina (2001) reported that in SRI fifty tillers plant^{-1} were easily obtained, and farmers who had mastered the methods and understand the principles had been able to get over 100 tillers from single tiny seedling.

Rice grown under SRI principles was found to produce more tillers hill^{-1} than those under conventional system *i.e.,* upto 70 tillers by the 75th day after transplanting (MSSRF, 2002).

Sengthong (2002) from Laos observed that 9 day old seedlings produced 43 tillers hill^{-1} compared to 28 and 23 tillers hill^{-1} produced by 12 and 18 day old seedlings, respectively. Similarly, Yamah (2002) reported 20-69 tillers hill^{-1} by planting 10 day old seedlings compared to 8-9 tillers hill^{-1} by planting 30 day old seedlings.

Udaykumar (2005) observed profuse tillering under SRI method. The number of tillers plant^{-1}and per unit area were more under SRI method compared to normal method.

According to Vijayakumar *et al.* (2006), mechanical weeding not only helped in reducing the weed competition, but also improved root growth by increasing soil aeration and root pruning which ultimately resulted in increased number of tillers plant^{-1}.

Thakur *et al*. (2011) reported that there was no significant difference in tillers per unit area in SRI compared to traditional practice.

2.1.2 Leaf Area Index at flowering stage

The leaf area index (LAI) is a determinant of dry matter production, and hence higher LAI increased total dry matter production and grain yield for a given rice variety (Yoshida, 1972).

The variations in LAI are an important physiological parameter that determines crop yield (Evans and Wardlaw, 1976).

Yoshida (1983) reported that LAI of rice increased as crop growth advanced and reached a maximum at heading or flowering stage.

Singh and Ghosh (1990) in their study observed that number of tillers m^{-2} and leaf area index were reduced with application of 50 per cent recommended dose of fertilizer (100:22:25 NPK kg ha^{-1}) compared to the full dose of recommended fertilizers.

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

Fageria *et al*. (1997a) reported that optimum LAI for upland rice is about 2–3 at 85–100 days after transplanting.

Thakur *et al*. (1998) observed that LAI was significantly higher with application of 60kg N + 5t FYM ha^{-1} compared to control +FYM alone.

The younger seedlings under wider spacing recorded better root growth which facilitated increased cell division and cell enlargement due to increased photosynthetic rate subsequently increasing LAI (Shrirame *et al*., 2000).

The water saving irrigation with mechanical weeding favourably, influenced the soil aeration which facilitated more number of tillers and subsequently higher photosynthetic rate for increased LAI (Thiyagarajan *et al*., 2002; Zheng *et al*., 2004).

Somasundaram *et al.* (2002) observed significant increase in leaf area index with each successive increase in N level from 0 to 150 kg ha^{-1}. Addition of

N from 100 to 150 kg ha^{-1} did not significantly improve the above parameters. However, maximum values for LAI was recorded by N application at 125 kg ha^{-1}.

Farooq *et al.* (2006) stated that seed priming of field sown rice seed enhanced germination, seedling establishment and increased the LAI.

Abou-khalifa (2007) found that Leaf area index was increase by increased nitrogen levels of up to 165 kg N ha^{-1}.

Thakur *et al.* (2009) established that alternate wetting and drying (AWD) water regimes significantly affect the plant architecture and canopy structure with improved leaf area index (LAI), leaf area duration (LAD) that allowed greater sun light interception and efficient utilization of photosynthesis from source to sink.

2.1.3 Relative Growth Rate (Panicle initiation to 50 per cent flowering)

Thakur *et al.* (1998) observed that RGR was significantly higher with the application of 60 kg N ha^{-1} + FYM @ 5 t ha^{-1} compared to control and FYM alone.

Kim *et al*. (1999) found that RGR was the highest in 10 day old seedlings up to 40 DAT, while after 50 DAT, RGR was higher for seedlings transplanted after 35 or 40 days.

The wider spacing recorded more RGR due to lesser competition among the plants that will boost more carbohydrate assimilation leading to more total dry matter production (Obulamma and Reddy, 2002).

RGR values were more at early stage in the season and showed a decreasing trend with the advancement of plant age irrespective of treatments (Alam *et al.,* 2009).

2.1.4 SPAD Reading at 50 per cent flowering

A chlorophyll measurement (SPAD meter) technology offers a new strategy for measuring the relative chlorophyll content of the plant or to indirectly identify the N status of the plant (Kariya *et al*., 1982; Inada, 1985; Peng *et al*., 1994; Balasubramanian *et al*., 1999).

At present, SPAD meter is widely used in several countries to determine the right time and right amount of N fertilizer application to rice crops (Balasubramanian *et al*., 1999) but it is rarely used to screen varieties for nitrogen.

Chlorophyll content recorded by chlorophyll meter (SPAD 502) indicated that significantly higher SPAD values at flowering were noticed with SRI (42.74 and 39.48 respectively during summer and kharif season), wet seeded rice and transplanted rice as compared to aerobic rice and alternate wetting and drying method (Geethalakshmi *et al*., 2009).

2.1.5 Root length (maximum)

Rice seedling starts with a radicle (seminal root), mesocotyl root, and nodal roots. However, the rice root system is basically composed of nodal or adventitious roots. The capacity of the plant to absorb water and nutrients is closely related to the total length of the root system which subsequently leads to higher assimilation which will favor higher yield attributes and yield (Yoshida, 1981).

Klepper (1992) reported that the general pattern of root development over the life of the crop shows a shift from a heavy investment in roots during seedling establishment and early vegetative growth in the first part of crop growth period to a heavy investment in reproductive organs during the latter part of crop growth period. This may explain roots reaching a plateau during grain filling stage.

Partial excision of roots of cereal seedlings resulted in an increase in the growth rate of the remaining root system (Hunt, 1975; Vysotskaya *et al*., 2001).

Incorporation of weed with mechanical weeder increased the root activity which stimulated the new cell division in roots by pruning of some upper roots encouraged deeper root growth thereby increased the shoot: root ratio (Uphoff, 2001).

Barison (2002) observed that root growth was restricted to top 20 cm soil, when 25 and 45 day old seedlings were transplanted compared to root growth beyond 30 cm soil depth when 8 day old seedlings were transplanted.

Nutrient uptake by plants depends either on the increment of the nutrient ion to the absorbing root surface or on the roots' ability to reach the zone of nutrient availability (Reddy and Reddi, 2002).

Rice root systems play an important role in uptake of water and nutrients from soil (Yang *et al.,* 2004). Roots of SRI plants extended 10-15 cm deeper than plants under conventional system.

2.1.6 Root volume

The architecture of the root system is also well known to be a major determinant of root functions in the acquisition of soil resources such as nutrients and water (Yamauchi *et al*., 1996; Fitter, 2002; Wang *et al*., 2006).

Root volume in rice increased from planting to the flowering stage. The increase in root volume from active tillering to panicle initiation stage is 110 per cent in young seedlings and 73 per cent in conventional seedling (Thyagarajan *et al*., 2002).

Rice plants in the SRI plots had 10 times more root mass, about 5 per cent more root length density, and about 7 per cent more root volume in the top 30 cm of soil profile, compared with roots in the plots of flooded rice (Rupela *et al*., 2006).

Thakur *et al*. (2011) reported that SRI crop had 40 per cent more root volume m^{-2} and 125 per cent more root length density than the crop under standard management practice.

2.1.7 Root dry matter production (RDMP)

Richmond and Lang (1957) reported that the main compound which influences plant growth and development through root activity is cytokinine.

78 per cent of the roots of rice plants grown in soil that was kept in saturated conditions had degenerated by the reproductive phase (panicle initiation stage), where as those grown on well drained soil had virtually no root degeneration (Kar *et al.,* 1974).

In general, root activity and root quantity are responsible for increasing the physiological efficiency of rice plants (Lee, 1980; Jiang *et al.*, 1985).

The phytohormone that is mainly synthesized in the roots is cytokinin which has a significant effect on tiller bud formation and plant nutrient mineralization. It delays leaf senescence, regulates chloroplast development, and determines sink-source relationships (Li *et al.*, 1992: John *et al.*, 1993; Bangerth *et al.*, 2000).

Baba (1997) reported that intermittent irrigation may increase root mass during vegetative stages and stimulates more root activity, and production of more cytokinin. This favorable condition can be achieved by maintaining higher rates of cytokinin production at a later growth stage, first by following intermittent irrigation during the vegetative stage and then by maintaining shallow flooding during the reproductive phase.

Traditional transplanting methods destroy many seminal roots and set back young plants growth by 1-2 weeks (Kirk and Solivas 1997).

With more root growth, the plant can access a much larger volume of soil, absorbing required amount of Cu, Zn, Mn and other essential trace elements. Having a “more balanced diet” of nutrients, not just N, P and K, presumably adds to the growth and vigor of SRI plants (Drew, 1997).

When continuously flooded, 75 per cent of rice plant roots remain in the top soil (6 cm) at 28 days after transplanting (Kirk and Solivas, 1997), while with SRI, the roots go deeper (10-15 cm) with a 45 per cent increase in dry weight (Tao *et al.*, 2002).

Root dry weight plant^{-1} is also higher with SRI. Root activity in SRI during each developmental stage is significantly higher than that of conventional method. Plants had enhanced root activity during the entire growth period especially during late growth stage which is an important physiological characteristic in SRI plants (Wang *et al.*, 2002).

SRI produces vigorous plants with larger root systems. High efficient photosynthetic performance of super high-yielding rice cultivars is largely due to the increased cytokinin content in their roots contributing to higher grain yield (Doberman, 2004; Shu-Qing *et al*., 2004; Stoop, 2005).

Root quantity and cytokinin content are enhanced in the rice plant in SRI even at later growth stages. This results in increased grain yield per plant due to enhanced physiological efficiency of the plant (San-oh *et al*., 2006).

Reduced intra-hill competition of SRI plants favoured the development of more lateral roots and root mass (Mishra and Salokhe, 2010).

2.1.8 Total dry matter production (TDMP)

The total yield of dry matter accumulation is the total amount of dry matter produced, less the photosynthates used for respiration. Finally, the amount of economic yield depends on the manner in which the net dry matter produced is distributed among the different parts of the plants which will determine the magnitude of economic yield (Arnon, 1972).

Reddy *et al.* (1984) and Alam and Azmi (1984) reported that dry matter, plant height and number of tillers increased significantly with increasing nutrient level.

The most important process for rice yield determination is post flowering biomass production (Akita, 1989).

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

Thakur *et al.* (1998) observed that dry matter production was significantly higher with the application of 60kg N ha^{-1} + FYM @ 5 t ha^{-1} compared to control and FYM alone.

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

Kumari *et al.* (2000) conducted a field experiment to study the effect of different levels of nitrogen on growth of rice. They observed dry matter production increased with increased level of nitrogen up to 120 kg ha $^{-1}$.

The wider spacing recorded lesser competition among the plants that will boost more carbohydrate assimilation leading to more total dry matter production (Obulamma and Reddy, 2002).

The production of total dry matter per unit area is the prerequisites for higher production. The amount of dry matter production depends on the effectiveness of photosynthesis of the crop which in turn depends on large and efficient assimilating area for adequate absorption of solar radiation and carbon dioxide and favorable environmental condition (Reddy and Reddi, 2002).

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

Increased shoot: root ratio and production of more number of tillers recorded under wider spacing were the reason for increased TDMP (Rajesh and Thanunathan, 2003).

2.2 YIELD ATTRIBUTES AND YIELD

2.2.1 Productive tillers hill^{-1}

Wang *et al.* (2002) reported higher number productive tillers hill^{-1} from planting of 12-13 days old seedlings than from planting of 28-30 days old seedlings

Yamah (2002) reported 3 fold increase in panicles hill^{-1} and significant increase in spikelets panicle^{-1} from planting of 10 day old seedlings over those from planting of 30 day old seedlings.

In, Chris *et al.* (2002) more effective tillers m^{-2} and yield in 30 cm x 30 cm planting than in 40 cm x 40 cm planting.

Healthy and more vigorous nursery seedlings, which gave a vigorous start, resulted in higher number of tillers m^{-2} and number of fertile tillers m^{-2} (Reddy 2004).

At Maruteru in Andhra Pradesh, Paladugu *et al.* (2004) observed increase in number of ear-bearing tillers (167.5%) under the SRI over those under traditional method of cultivation.

Uphoff (2005) observed more number of productive tillers hill^{-1} (23.4), higher percentage of filled grains (30%) and yield (6.6 t/ha) by planting seedlings at 20 cm x 15 cm spacing compared to 40 cm x 40 cm spacing. But, higher number of filled grains was observed in the widest spacing *i.e.,* 40 cm x 40 cm.

Farooq *et al*. (2006a, b) reported seedlings from primed seeds produced more panicle bearing tillers.

Yield attributes like number of productive tillers hill^{-1}, productive tillers m^{-2} and panicle length were superior with 75 per cent RDF (RDF - 150:75:75 N: P_2O_5: K_2O kg ha^{-1}) than rest of the treatments (Wijebandara *et al*., 2009).

2.2.2 Thousand grain weight

Barthakur and Gogoi (1974) observed non-significant influence of age of seedlings (30, 35, 40 and 45 days) on 1000 grain weight in rice varieties IR-8, Jaya and Co-63.

Rao and Raju (1987) reported that thousand grain weight increased by transplanting younger seedlings (25 days) as compared to older seedlings (45 days).

In contrast, Gill and Sahi (1987) stated that transplanting of 60 days old seedlings yielded heavier thousand grains.

Latchanna *et al.* (1989) reported that application of phosphorus resulted in increased thousand grain weight however the increase was marked up to 40 kg P_2O_5 ha^{-1} only.

Panda *et al*. (1991) also observed an increasing trend in grain weight by transplanting seedlings grown with sufficient fertilizer application.

Ravi and Rao (1992) reported that maximum test weight was obtained due to application of potassium in two equal splits as basal and at PI stage.

Thousand grain weights is an important yield contributor that depends on genetic makeup and is the least affected by growing conditions (Ashraf *et al*., 1999).

At Maruteru in Andhra Pradesh, Paladugu *et al.* (2004) observed an increase in thousand grain weight (1.7%) under the SRI over those under traditional method of cultivation.

Farooq *et al*. (2007) reported that there was no significant difference in 1000-grain weight by planting healthy seedlings grown with seed priming.

The test weight was superior with 75 per cent RDF (RDF - 150:75:75 N: P_2O_5: K_2O kg ha^{-1}) than rest of the treatments (Wijebandara *et al*., 2009).

Thakur *et al*. (2011) reported 2.9% higher grain weight in the SRI crop compared to the crop of same variety grown with best recommended practices from the Central Rice Research Institute of India. Variations in the effect of SRI practices on yield attributes are also reported.

Zhao *et al*. (2011) reported that grain weight were more in SRI than in the conventional flood-irrigated crop.

2.2.3 Mean no. of spikelets panicle^{-1}

Sridevi (1997) observed higher number of spikelet panicle^{-1} and filled spikelets panicle^{-1} with transplanting of 30 days old seedlings compared to 25 and 35 days old seedlings hybrid rice.

Wang *et al.* (2002) reported higher spikelet number panicle^{-1} and productive tillers hill^{-1} from planting of 12-13 days old seedlings than from planting of 28-30 days old seedlings.

Yamah (2002) reported significant increase in spikelets panicle^{-1} from planting of 10 day old seedlings over those from planting of 30 day old seedlings.

2.2.4 Mean no. of grains panicle^{-1}

Singh and Verma (1999) reported that application of FYM @ 10 t ha^{-1} coupled with 50per cent recommended N recorded higher number of grains panicle $^{-1}$.

Sebastien (2002) from Madagascar reported increase in grains panicle^{-1} with increasing plant spacing from 25 cm x 25 cm to 50 cm x 50 cm.

At Maruteru in Andhra Pradesh, Paladugu *et al.* (2004) observed a 29 per cent increase in fertile grains panicle^{-1} under the SRI over those under traditional method of cultivation.

Vijayakumar *et al.* (2006) reported that mechanical weeding resulted in higher number of grains panicle^{-1}.

The mean number of grains panicle $^{-1}$ was superior with 75 per cent RDF (RDF - 150:75:75 N: P_2O_5 : K_2O kg ha^{-1}) than rest of the treatments (Wijebandara *et al*., 2009).

Thakur, *et al*. (2011) concluded that number of filled grains at SRI with compost application was greater than standard management practice with chemical alone.

Thakur *et al*. (2011) reported 40.5 per cent more grains panicle^{-1} in the SRI crop compared to the crop of same variety grown with best recommended practices from the Central Rice Research Institute of India. Variations in the effect of SRI practices on yield attributes are also reported.

2.2.5 Grain yield

2.2.5.1 *Yield increase in SRI*

Cultivation of rice under the principles of SRI *i.e.,* transplantation of 8-day old seedlings at 25 cm x 25 cm spacing resulted in 2-4 times more yield than under conventional practices . Combination of plant, soil, water and nutrient management practices followed in SRI increased the root growth, along with increase in productive tillers, grain filling and higher grain weight that ultimately resulted in maximum grain yield (Uphoff, 2001).

Transplanting of 8 day old seedlings @ one per hill at a spacing of 25 cm x 25 cm followed by two to three weedings at 10 day interval starting from the 10th day, the farmers in Madagascar got yield upto 10-15 t ha^{-1} and even more than that under wider spacing of 50 cm x 50 cm in fertile soils (Berkelaar, 2001).

Studies confirmed that the yield increment in SRI is mainly attributed to greater tiller number (over 30 tillers $hill^{-1}$), number of grains $panicle^{-1}$ (>200) and resulting healthier plants with low pest and diseases problems that enhance efficient resource capture and portioning of dry matter for grain production (Longxing *et al.*, 2002) .

Increased grain yield under SRI is mainly due to the synergistic effects of modification in the cultivation practices such as use of young and single seedlings $hill^{-1}$, limited irrigation, and frequent loosening of the top soil to stimulate aerobic soil conditions (Stoop *et al.*, 2002).

Randriamiharisoa and Uphoff (2002) reported the results of factorial trials. In Madagascar, three ages of seedlings (8, 16 and 20 days old) were evaluated under different combinations of water management (aerated and saturated soil), plant density (one and three seedlings per hill) and fertilization (compost vs NPK 16-11-12). Among all the practices studied by them, planting of younger seedlings (8 day old) @ one per hill and maintained in aerated soil with the use of compost had resulted in 140 per cent to 245 per cent increase in grain yield.

Robert (2002) reported maximum yield of 5.1 t ha^{-1} with 25 cm x 25 cm spacing compared to the yields of 4.7, 3.5 and 2.7 t ha^{-1} with 15 cm x 15 cm, 33 cm x 33 cm and 40 cm x 40 cm spacing, respectively.

Yuan (2002) reported 21.3 per cent yield increase with 33 cm x 33 cm spacing over that of 16 cm x 26 cm planting. However, no difference between yields of 25 cm x 25 cm and 30 cm x 30 cm planting was found (Randriamiharisoa and Uphoff, 2002).

Barison (2002) obtained higher grain yield (6.26 t ha^{-1}) from the plots of

SRI method where compost was applied, than conventional system wherein compost was not applied. Similarly, Hua *et al.* *(*2002) also noticed that, application of 10 t ha^{-1} cow dung resulted in higher number of tillers, leaves and seeds $panicle^{1}$ under SRI method of cultivation.

There are evidences that cultivation of rice through system of rice intensification (SRI) can increase rice yields by two to three fold compared to current yield levels (Abu, 2002; Uphoff, 2005). However Namara *et al*. (2003) recorded only a moderate increase of 44 per cent in Sri Lanka. Husain *et al.* (2004) recorded even lesser yield increase of 30 per cent in Bangladesh.

Under SRI about 28 per cent to 49.8 per cent increase in grain yield was reported from India and other countries (Thakkar, 2005).

Uphoff (2005) also reported the highest yield (6437 kg ha^{-1}) with the use of younger seedlings (14 day old) compared to that (5212 kg ha^{-1}) with the use of older seedlings (33 day old).

Thakkar (2005) reported 28 per cent higher grain yield with planting of 14 day old seedlings at a spacing of 20 cm x 20 cm than planting of 21 day old seedlings at 15 cm x 15 cm spacing.

Vijayakumar *et al*. (2006) also reported that incorporation of weeds mechanical weeder recorded the highest grain yield.

Mishra and Uphoff (2010) reported increase in grain yield by 20- 50% or even more with SRI using less inputs of water and other resources.

Mahender Kumar (2012) opined 7-20% more yields in SRI over normal method, irrespective of soils and locations across the years in the country.

Bhowmick *et al*. (2013) reported 15-20% higher grain and straw yields with SRI than normal transplanting in different parts of West Bengal.

2.2.5.2 *Yield increase with seed priming*

Primed seeds, when planted, usually emerge faster with better, uniform, and vigorous crop stand persistent under less than optimum field conditions. Crop stands from primed seeds lead to earlier flowering and higher grain yield than non-primed seeds (Harris *et al*., 2001).

Harris *et al*. (2002) reported that on-farm priming in direct seeded rice resulted in a faster rate of germination and emergence, more uniform and vigorous seedling growth, and a wide range of phenological and yield associated benefits.

Harris *et al*. (2002) indicated that hydro-priming is the best option for smallholder farmers in developing countries since it is a low cost and low risk intervention. Success of seed priming is influenced by the duration of priming until the optimum hours. For every crop species, there is a `safe limit', the maximum length of time, if exceeded, could lead to seed damage.

Harris *et al*. (2002) recommended a 24-hr safe limit for rice with only minor varietal differences.

According to Ceesay (2004) and Hassanein *et al*. (2012) seed priming and pre-germination are agronomic techniques that could enable the crop to give higher yields under terminal moisture stress conditions.

Thakur *et al*. (2005) recommended 15 to 18 hours hydro-priming duration for rice.

Farooq *et al.* (2006b) stated that seed priming of field sown rice seed enhanced germination, seedling establishment and increased the grain yield.

Rehman (2006) reported increased rice grain yields and harvest index in response to planting hydro-primed seeds.

Farooq *et al*. (2009) reported 11–24% yield advantage over non-primed seeds by planting rice seeds soaked in water for 24 hrs and then air-drying them. They attributed the increase in yield to the increased number of productive tillers and 1000-kernel weight.

2.2.5.3 *Yield increase with inorganic fertilizer*

Singh *et al.* (1976) working with traditional varieties reported that application of K_2O at 120 kg ha^{-1} at transplanting gave the highest straw yield, but split application *viz*., at transplanting, tillering and panicle initiation gave the highest grain yield.

Murthy and Murthy (1978) observed significant increase in the yield when nitrogen rate increased from 60 to 120 kg ha^{-1}. Increase in the grain yield was due to increase in total dry matter hill^{-1}, panicle m^{-2}, spikelets m^{-2} and high leaf area index.

Grain production, which is the final product of growth and development, is controlled by dry matter accumulation during the ripening phase (De Datta, 1982).

Bhargava *et al.* (1985) reported a progressive increase in response to K_2O. At 60 kg K_2O ha^{-1}, the increase in yield was about 6-8 kg grain kg^{-1} in rice. The yield response in most soils was significant at 40 to 60 kg K_2O ha^{-1}.

Shad (1986) also reported that the combination of limited irrigation and mechanical weeding increased the yield.

Anil *et al.* (1989) reported that grain yield significantly increased with increasing nitrogen levels up to 120 kg N ha^{-1}. Whereas, Singundhupe and Rajput (1989) indicated that application of nitrogen significantly increased both grain and straw yields up to 150 kg N ha^{-1} compared with unfertilized treatment.

Pandey and Tripathi (1994) reported that the grain yield was significantly higher at 120 kg N ha^{-1} than at lower levels owing to significant increase in panicles m^{-2} and panicle weight.

Krishnan *et al.* (1998) revealed a linear rice response with increasing N levels though the grain yield continued to increase up to 240 kg N ha^{-1}. The yield increase per kg of N was the highest from 0-60 kg N ha^{-1} (31.3 kg N ha^{-1}) followed by 60-120 kg N ha^{-1} (21.51 kg N ha^{-1}). Beyond 180 kg N ha^{-1}, the yield increase was not significant and registered only 0.5 kg increase for each kg of N applied.

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

Abou-khalifa (2007) found that grain yield was increase by increased nitrogen levels of up to 165 kg N ha $^{-1}$.

Experiments conducted at the China National Rice Research Institute, Hangzhou, showed that the highest yield in SRI was obtained with equal proportions of organic and inorganic nutrient applications rather than a 25:75 ratio or 100 per cent organic (Lin *et al.* 2011).

2.2.5.4 *Yield increase with combination of organic and inorganic fertilizers*

Vasanthi and Kumaraswamy (1996) reported that the seed yield of 4.34 t ha^{-1} was significantly higher in treatments that received vermicompost @ 5 t ha^{-1} along with recommended NPK compared to that in treatment with only recommended NPK application (3.45 t ha^{-1}) alone.

Ravi and Srivastva (1997) reported that combined application of vermicompost and inorganic fertilizers recorded significantly effective tillers $hill^{-1}$, grain and straw yield of rice compared to application of organic fertilizers alone. This resulted in saving of inorganic fertilizers to the extent of 30 per cent.

Thakur *et al.* (1998) observed that grain yield was significantly higher with the application of 60kg N ha^{-1} + FYM @ 5 t ha^{-1} compared to control and FYM alone.

Sujathamma *et al.* (2001) reported significantly higher yield (3546 kg ha^{-1}) with the application of 50 per cent N through vermicompost plus 50 per cent N through chemical fertilizer compared to control (2978 kg ha^{-1}) in rice.

Pandu (2002) reported that application of vermicompost @ 2.5 t ha^{-1} recorded significantly higher seed yield of 3.54 t ha^{-1} than no vermicompost (3.07 t ha^{-1}) but it was on par with FYM application of 10 t ha^{-1} (3.30 t ha^{-1}).

Hossain *et al.* (2003) reported higher grain and straw yields in SRI method (5.98 t ha^{-1}) with 50 per cent chemical fertilizers + 50 per cent organic manures compared to the use of chemical fertilizers alone.

Experiments conducted at the China National Rice Research Institute, Hangzhou, showed that the highest yield in SRI was obtained with equal proportions of organic and inorganic nutrient applications rather than a 25:75 ratio or 100% organic (Lin *et al.* 2011).

2.2.6 Straw yield

Latchanna *et al.* (1989) reported that straw yield increased by 9.5, 15, 18 and 20 per cent with 20, 40, 60 and 80 kg P_2O_5 ha^{-1} application over control.

Ravindra and Bhagya Laxmi (2011) also reported a 19% reduction in straw yield of the SRI crop from a survey with SRI farmers in Andhra Pradesh.

On farm priming was also found successful in enhancing the kernel and straw yield of direct-seeded rice (Rehman *et al*. 2011).

2.2.7 Harvest index

Grain yield in cereals is related to biological yield and grain harvest index (Donald and Hamblin, 1976).

Snyder and Carlson (1984) reviewed harvest index for selected annual crops and noted variations 23 to 50% for rice.

Raju *et al.* (1999) reported that rice yield and its attributing characters responded favourably to higher dose (60 kg K_2O ha^{-1}) of K, but not at lower doses (40 kg ha^{-1}) except when the entire dose was applied at panicle initiation stage. In general, K fertilization showed beneficial effect on harvest index and reduced the duration of crop.

The values of rice harvest index varied greatly among cultivars, locations, seasons, and ecosystems, and ranged from 0.35 to 0.62, indicating the importance of this variable for yield simulation (Kiniry *et al*., 2001).

Farooq *et al.* (2006b) stated that seed priming of field sown rice seed enhanced germination, seedling establishment and increased the harvest index.

Thakur *et al*. (2011) reported there was a 20.6% reduction in straw yield of SRI when compared with standard management practice, although the SRI grain yield was 47.7% higher, showing considerably higher harvest index.

2.3 WATER PRODUCTIVITY

It was reported that 25-50% water could be saved by intermitted irrigation without any adverse effect on rice yield (Ramamoorhy *et al*., 1993; Tajima, 1995).

In SRI plots alternative wetting and drying method of water management was practiced. SRI treatment plots registered higher water productivity than the control treatment. Rice plants grown conventionally but under well-drained soil conditions can give a yield 5-10 per cent higher than if flooded, and sometimes more (Ramasamy *et al*., 1997; Lin *et al*., 2005). Benjamin *et al.* (2001) proved that the process of drying and rapid rewetting of soil increases the amount of available water soluble phosphorus.

McHugh *et al.* (2002) observed that primary drawbacks reported by farmers with implementing alternate wetting and drying and non-flooding irrigation were the lack of reliable water source, little water control and water use conflicts. SRI was associated with a significantly higher grain yield of 6.4 t ha^{-1} compared with 3.4 t ha^{-1} from conventional practices.

Ceesay and Uphoff (2003) reported that among water management practices proposed for the system of rice intensification (SRI), cycles of repeated wetting and drying were found beneficial to rice plant growth through increased nutrient availability leading ultimately to higher grain yields.

Already the AWD method of irrigation is an accepted and well documented practice leading to an increase in water productivity and yield (Belder *et al* 2004).

If SRI were to be applied with the water now being used for rice irrigation, it would be able to increase irrigated area by atleast 50 per cent, leading to 50 per cent increase in rice production (Thakkar, 2005).

Despite the various dispute among the rice researchers, SRI has been disseminated to the farmers in and around 45 countries mostly in South and Southeast Asia. A compilation of results from 11 surveys in 8 countries including 16000 SRI farmers has shown on average 40% water saving compared to conventional rice cultivation (Sato and Uphoff 2007 Africare *et al.* 2010).

Thakur *et al.,* 2009 established that AWD water regimes significantly affect the plant architecture and canopy structure with improved Leaf Area Index

(LAI), Leaf Area Duration (LAD) which allowed greater sun light interception and efficient utilization of photosynthesis from source to sink.

Studies conducted in Tamil nadu in four locations to compare the efficiency of SRI irrigation with the conventional irrigation under IAMWARM (Irrigated Agriculture Modernization and Water Bodies Restoration and Management) a World Bank assisted project during 2007-2010, confirm that for SRI, water requirement is low and crop productivity is high (VibhuNayar and Ravichandran, 2012).

2.4 PEST INCIDENCE

Batuvitage (2002) reported that SRI method of rice cultivation does not require the application of agrochemicals or pesticides, the plants raised under SRI method are able to resist damage from pests and diseases, making agrochemicals usually unnecessary.

Stem borers and leaf folders were the two kinds of pests that increased their population in SRI plots much more than in plots with conventional management (David *et al*. 2005).

Field experiments conducted in Kerala have showed that the incidences of stem borer and leaf folder were significantly higher in SRI than normal method of cultivation (Karthikeyan *et al*. 2008).

The studies conducted by Sumathi *et al.* (2008) on the effect of manures on SRI crops showed that application of chemical fertilizers with and without organic manures increased the leaf folder damage. Leaf folder damage was minimum when FYM only was applied.

2.5 SOIL CHEMICAL CHARACTERS

2.5.1 Soil reaction

Pattanayak *et al.* (2001) observed a decrease in soil pH after the use of organic materials. The production of organic acids (amino acid, glycine, cystein and humic acid) during mineralization (amminization and ammonification) of organic materials by heterotrophs and nitrification by autotrophs would have caused this decrease in soil pH.

During microbial decomposition of incorporated organic manures, organic acid might have been released, which neutralized the alkalinity of the organic manures thereby leaving the pH of the soil almost what it was initially, that might be favourable for a good crop production (Okwuagwu *et al.,* 2003)**.**

2.5.2 Soil organic carbon

Yadvinder Singh *et al*. (1995) reported that FYM improved the availability of organic carbon, P and K contents of the soil

Titilola (2006) reported that the level of OC decreased by 59% under inorganic fertilizer due to stimulated decomposition of soil OM by the applied fertilizer which led to higher N mineralization.

Oo *et al* (2010) reported application of FYM with inorganic fertilizer significantly increased soil organic matter.

2.5.3 Available Iron in soil

Prabha *et al.,* (2007) have reported that the increase on manganese, iron, zinc and copper nutrient status of soil was greatly enhanced by the application of vermicompost and other organic sources

Large amounts of organic materials repeatedly applied on a soil with lower buffering capacity and high reducible Fe content may also accelerate soil reduction and thereby the potential for Fe toxicity in rice (Ponnamperuma, 1972).

2.5.4 Available nitrogen in soil

Soil N content was highest in treatment receiving 100% N from FYM or 75% from FYM and 25% from urea (Regmi *et al.,* 2002)

Reduction in soil N content was less under inorganic + organic fertilizers than inorganic fertilizer alone indicating N was conserved under combined application of fertilizers (Chettri *et al.* 2003; Myint *et al*., 2009; Oo *et al.*, 2010).

2.5. 5 Available phosphorus in soil

Benjamin *et al* (2001) proved that the process of drying and rapid rewetting of soil increases the amount of available water soluble phosphorus.

Chettri *et al*. (2003) stated that from the third year, green manuring was able to replace the effect of the recommended P fertilizer application in increasing rice yield.

Singh *et al*. (2007) observed that available P value was significantly increased due to organic farming practice over control as well as chemical fertilizer application.

Hasan *et al*. (2009) reported that soils treated with P fertilizers contained higher amount of available P compared to other treatments.

Oo *et al.* (2010) reported the applications of FYM together with inorganic fertilizers significantly increased soil OM and CEC, then availability of P.

2.5.6 Available potassium in soil

According to Main and Moslehuddin (1999), a nutrient balance study indicated a severe loss of K each year due to weathering of soil material.

Singh *et al.* (2001) also reported that use of FYM with fertilizer N increased the available K status of the soil.

According to Linquist *et al.* (2007), K balance was maintained for a long time under FYM among all other organic treatments.

Hasan *et al.* (2009) found that integrated use of inorganic and organic fertilizers significantly decreased the soil exchangeable K value by 50% over the initial level during the last 29 years.

Oo *et al.* (2010) reported that the highest value of exchangeable K in soil was recorded in the plots with the combination of FYM and inorganic fertilizers.

2.6 PLANT ANALYSIS

2.6.1. Nutrient uptake

Sriramachandrasekharan *et al.* (1996) found thatapplication of FYM@ 10tha^{-1} increased the uptake of N, P and K content in straw and grain significantly compared to control.

Maximum uptake of NPK by rice was observed when the crop received 75 per cent NPK + 10 t FYM ha^{-1} (Puste *et al*, 1996)

Nutrient uptake by plants depends either on the increment of the nutrient ion to the absorbing root surface or on the roots' ability to reach the zone of nutrient availability (Reddy and Reddi, 2002).

Barison and Uphoff (2011) found that concentrations of N and K in the grain were higher in SRI plants than conventional rice, while concentration of P was lower. In the rice straw, concentration of all the nutrients was lower in SRI plants. As SRI yields were higher than for conventional crop, the total uptake of the nutrients was thus higher in SRI plants. P was more efficiently used in grain production than N and K in SRI cultivation

2.7 ECONOMIC ANALYSIS

Minimum benefit cost ratio of 1.5 has been fixed for an enterprise in the agricultural sector to be economically viable. Therefore, any agricultural enterprise must maintain a 1.5 benefit cost ratio to be economically sustainable (Bhandari, 1993).

Benefit cost ratio is the ratio of gross return to cost of cultivation which can also be expressed as returns per rupee invested. Any value greater than 2 is considered safe as the farmer get Rs. 2.00 for every rupee invested (Reddy and Reddi, 2002).

Studies in Gambia showed that the net returns with current production techniques were \$37.30 ha^{-1} while with SRI methods, the net returns were \$852.70 ha^{-1} (Ceesay, 2011).

Materials and Methods

3. MATERIALS AND METHODS

The investigation entitled “Integrated crop management of rice under System of Rice Intensification (SRI)” was taken up at College of Agriculture, Vellayani during third crop season 2012 (December to April), to evaluate the efficacy of integrated input management for increasing soil, crop and water productivity of transplanted rice grown under SRI as compared to the conventional method in an economically viable mode. The materials used and methods adopted for the experiment is detailed below.

3.1. EXPERIMENTAL SITE

The experiment was undertaken in wet land of Block B of Instructional Farm College of Agriculture, Vellayani, Thiruvananthapuram, Kerala. The farm is located at 8^0 25’ N latitude, 76^0 59’ E longitude and at an altitude of 29 m above MSL.

3.1.1 Climate

The location experiences a humid tropical climate. The meteorological parameters recorded during the crop growing period are presented in Appendix 1 and Fig. 1.

3.1.2 Cropping Season

The experiment was conducted during Puncha season of 2012-13. Seedlings were raised in special mat nursery. Nursery was raised on 7th December 2012 following a seed rate of 7.5 kg ha^{-1}. Twelve days old seedlings were transplanted @ one seedling $hill^{-1}$ at a spacing of 25 cm X 25 cm. The nursery for conventional planting was raised on the same day using a seed rate of 75 kg ha^{-1}. In conventional system 21 days old seedlings were transplanted @ three seedlings $hill^{-1}$ at a spacing of 20 cm X 15 cm. The crop was harvested in 10th April 2013, 124 days after sowing.

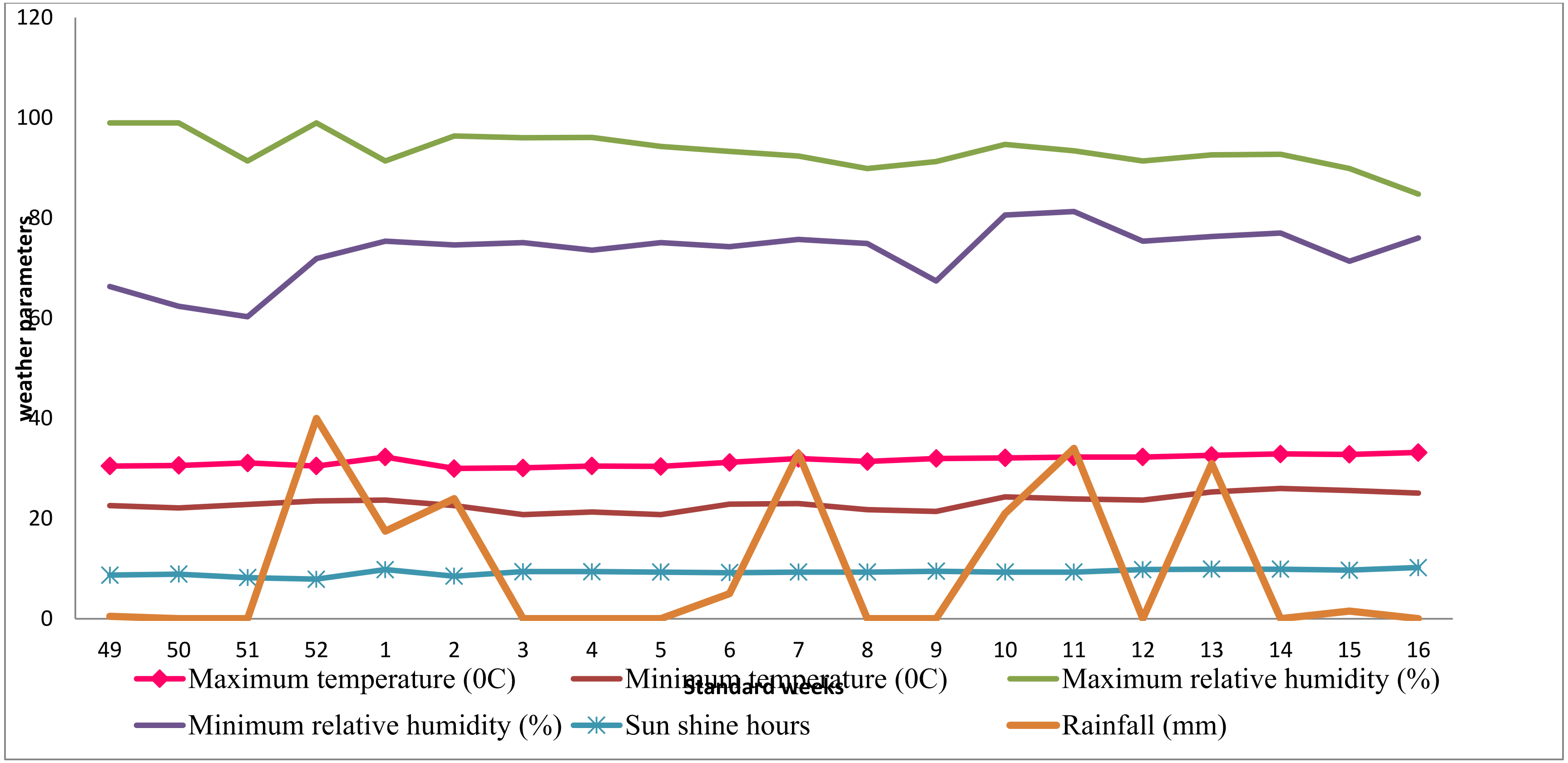

Fig. 1 Weather data (December 2012 to April 2013)

3.1.3 Soil

Soil samples of 30 cm profile depth were collected from the experimental plot and a composite sample was used for the determination of the soil properties. The important physico -chemical properties of soil are presented in Table 1. The soil of the experimental site belonged to the textural class of sandy clay loam with a pH of 4.4. It was medium in organic carbon and available nitrogen and medium in available phosphorus and potassium.

Table 1. Soil characteristics of the experimental site

A. **Mechanical composition**

SI No.	Fractions	Content in soil (%)	Methods used
1	Fine sand	10.77	International pipette method (Piper,1950)
2	Coarse sand	47.69	
3	Silt	8.92	
4	Clay	32.62	
	Soil texture	Sandy clay loam	

B. **Physical property**

Sl.No.	Parameter	Value	Methods
1	Particle density (g cc^{-1})	2.41	(Black, 1965)
2	Bulk density (g cc^{-1})	1.43	Core method (Gupta and Dakshinamoorthi, 1980)
3	Porosity (%)	40.7	(Black, 1965)

C. Chemical composition

SI No.	Fractions	Content in soil	Methods used
1	Organic carbon (%)	1.34	Walkley and Black Rapid Titration Method (Walkley and Black, 1934)
2	Soil Reaction (pH)	4.4	1:2.5 Soil water ratio using pH meter with glass electrode (Jackson,1973)
3	Available N (kg ha^{-1})	264.44	Microkjeldahl method (Jackson,1973)
4	Available P (kg ha^{-1})	27.4	Bray Colorimetric Method (Jackson,1973)
5	Available K (kg ha^{-1})	137.54	Neutral Normal Ammonium Acetate Method (Jackson,1973)
6	Available Fe (kg ha^{-1})	108.4	Atomic Absorption Spectrophotometer (Lindsay and Norwell, 1978)

3.1.4 Cropping History of the Field

The area was under bulk crop of rice during the previous season.

Plate 1. General view of the experimental field

Plate 2. Seedlings raised under mat nursery

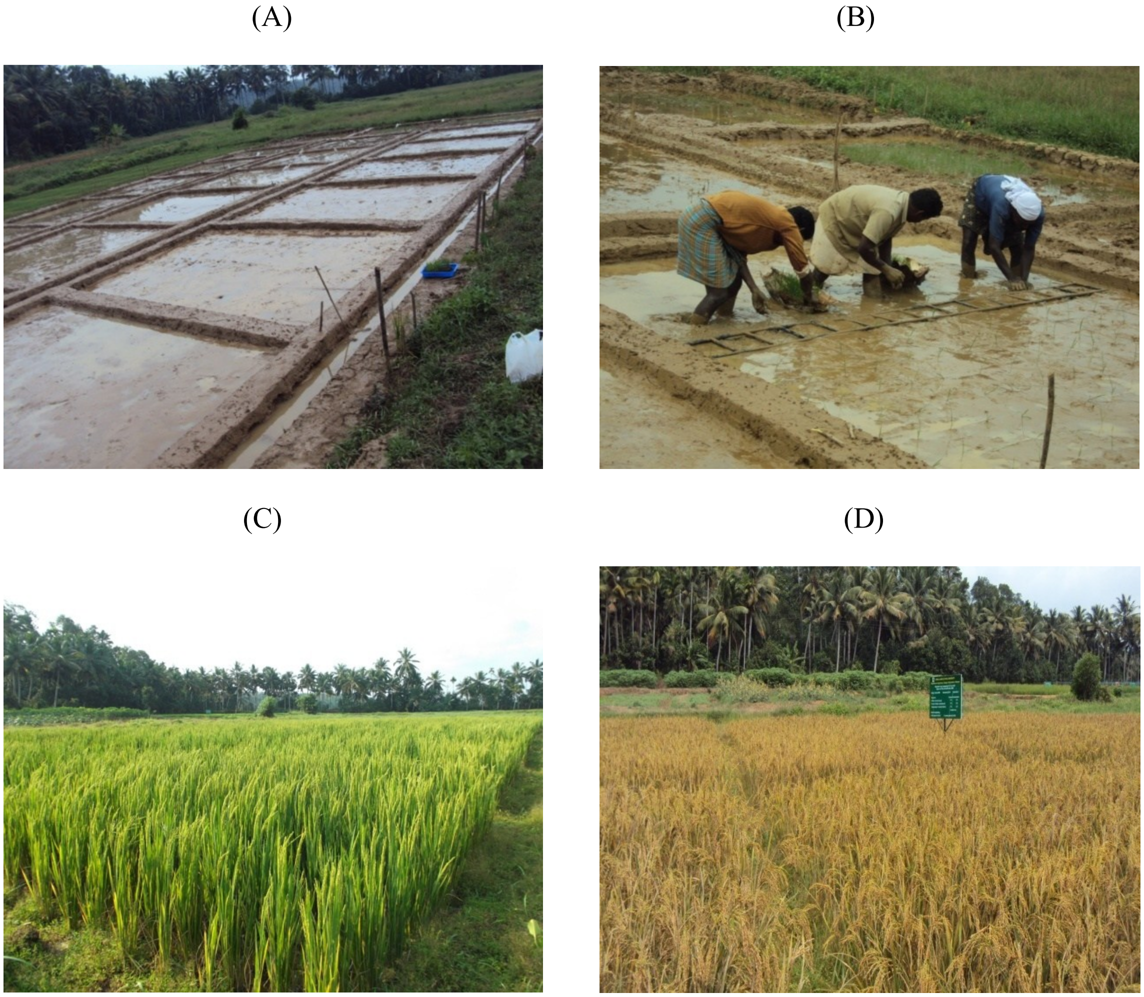

Plate 3. Field view (A) Layout (B) Transplanting single seedlings in SRI plots (C) At panicle initiation stage (D) At harvesting stage

3.2 MATERIALS

3.2.1 Crop Variety

The rice variety used for the experiment was Uma (MO 16), the most popular rice variety of the state developed by Kerala Agricultural University, Rice Research Station, Moncompu. Grain is red and medium bold. Average duration is 115-120 days during Mundakan and 120- 135 days during Virippu. The variety is moderately resistant to Brown Plant Hopper and gall midge. It is tolerant to adverse soil conditions and has a dormancy of 3 weeks.

3.2.2 Source of seed material

The seeds of rice variety Uma were obtained from Rice Research Station, Moncompu.

3.2.3 Manures and Fertilizers

Urea (46% N), Factomphos (20-20-0-15) and MOP (60% K_2O). Vermicompost (1.5 % N, 0.4 % P_2O_5 and 1.4% K_2O) were used for the experiment.

3.2.4 Liming materials

Powdered $CaCO_3$ was used for liming the soil (600 kg ha^{-1}).

3.2.5 Irrigation water

Water from Vellayani lake pumped through irrigation pipe line was used for irrigating the experimental field.

3.2.6 Plant protection chemicals

Integrated Pest Management practices as per Package of Practice recommendations: Crops- 2013 of Kerala Agricultural University were followed for pest and disease control. Acephate @ 2g l^{-1} was applied to control leaf roller and rice bug was controlled by spraying malathion @ 2ml l^{-1} with 500 g garlic emulsion.

3.3 METHODS

3.3.1 Design and Layout

Design: Factorial RBD

Treatments: (3x2) +1=7

Replication: 3

Plot size: 5 m x 4 m =20 m^2 (Gross plot size)

Total number of plots: 21

The experiment was laid out in Factorial Randomized Block Design with 7 treatments and three replications.

3.3.1.1 *Treatment details*

A. Seed priming (P)

P_1-Primed seeds

P_2-Non primed seeds

- Seed priming by soaking seeds in water for 12 hours and drying back to original moisture level.

B. Crop Management (F)

F_1- RFD of N, P_2O_5 and K_2O (90-45-45 kg ha^{-1}) as fertilizers

F_2- RFD of N, P_2O_5 and K_2O (90-45-45 kg ha^{-1}) as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer.

F_3- Seventy five per cent of RFD (N, P_2O_5 and K_2O @ 67.5-33.75-33.75 kg ha^{-1}) as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer.

C. Standard Check- Conventional flooded transplanted rice at 20 cm x 10 cm spacing following KAU POP, 2013 recommendations.

- 5t ha^{-1} FYM is applied in all plots including SRI and conventional treatments.

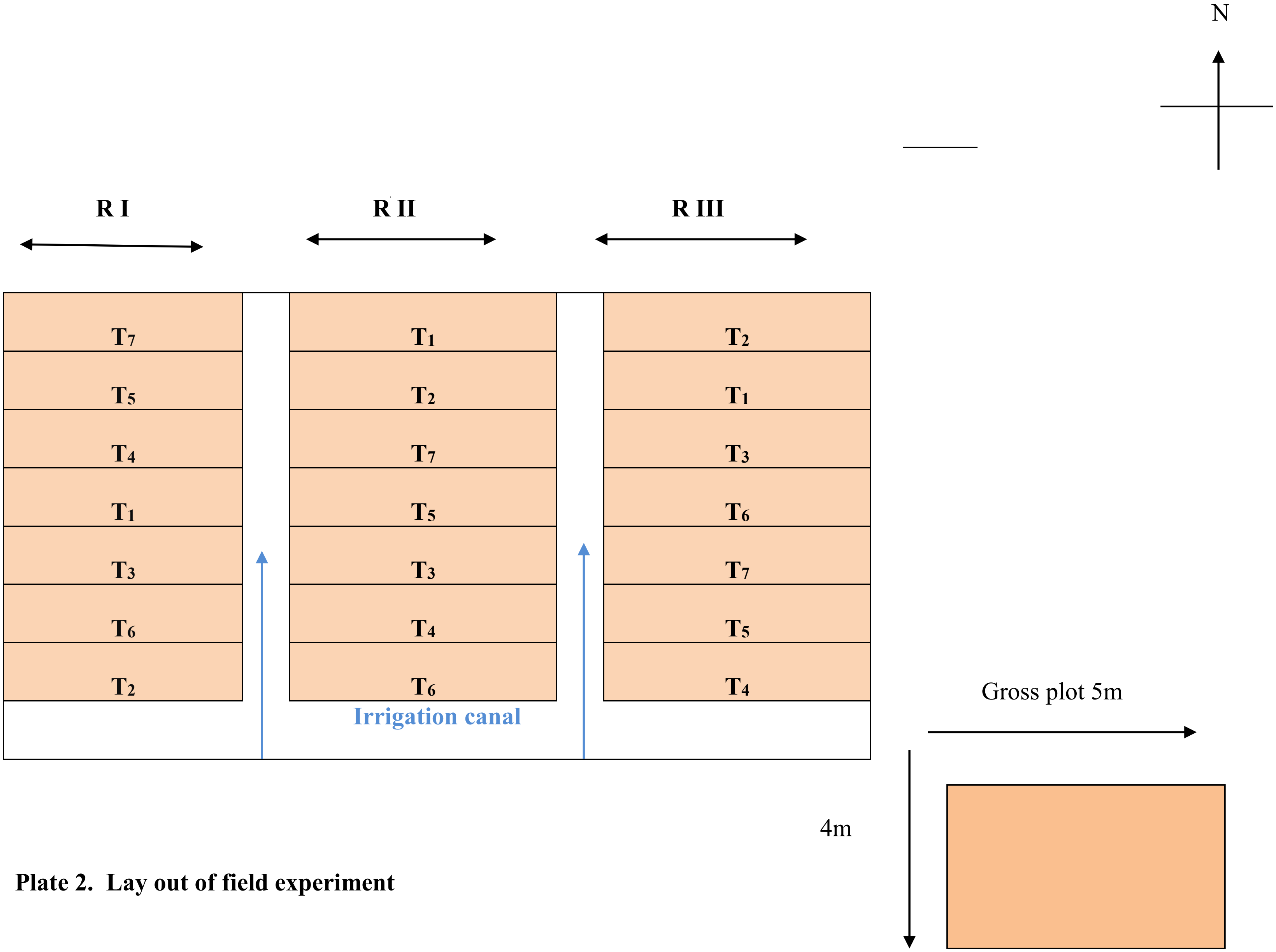

Plate 2. Lay out of field experiment

3.3.1.2 *Treatment Combinations*

Six combinations of two factors, *viz.,* two seed priming and three crop management practices along with control constituted the seven treatments as follows.

1. T_1- p_1f_1
2. T_2- p_1f_2
3. T_3- p_1f_3
4. T_4- p_2f_1
5. T_5- p_2f_2
6. T_6- p_2f_3
7. T_7- Control

3.3.2 Field culture

3.3.2.1 *Nursery*

3.3.2.1.1 Mat nursery for SRI plots

Special mat nursery was prepared for raising seedlings for the SRI method of transplanting; fallow rice field was dug to a fine tilth, levelled and pressed firmly.

The levelled bed was covered with a polythene sheet. The sheet was covered to a depth of 7.5 cm with a mixture of soil and dry powdered cow dung in 3:1 ratio. The bed was levelled and pressed. The seed bed was moistened to saturation level and compacted. Pre germinated seed was sown at 7.5 kg per 100 m^2 nursery area (1 per cent main field area) for each ha main field area.

The bed was covered with coconut fronds to protect from scorching sun for first 3 days after sowing. The nursery was watered gently with a rose can to near saturation level till the seedlings were ready for transplanting, and monitored for pest and disease incidence.

3.3.2.1.2 Wet nursery for control treatment

Ten per cent of the control treatment area was taken as the nursery area for conventional planting. The nursery was cleared of weeds and stubbles, and dug thoroughly to a puddle. Raised beds of 10 cm height 1m width and 6 m length were prepared. Pre germinated seeds (@ 75 kg per 1000 m^2 nursery area for 1ha main field) were sown and covered with coconut fronds for first 3 days. The water level in the nursery bed was adjusted with the growth of seedlings to have a very shallow submergence of the nursery bed. Nursery was monitored for pest and disease occurrence.

3.3.2.2 Main Field Preparation

The experimental area was well ploughed, weeds and stubbles removed puddled and levelled. The field was laid out into three replications with seven plots each. The plots were formed with bunds of 30 cm width and 25 cm height in a row to form blocks. Irrigation channels of 40 cm width were provided between the blocks. Individual plots were perfectly levelled. The conventional treatment (control) plots were provided with double channel bunds to avoid cracking and to keep soil continuously flooded.

3.3.2.3 Manures and Fertilizers

Vermicompost analyzing 1.5 % N, 0.4 % P and 1.4 % K respectively was used as the organic manure. Urea (46% N), Factomphos (20-20-0-15), Muriate of potash (60% K_2O) were used as inorganic fertilizers for the experiment.

3.3.2.4 Transplanting

3.3.2.4.1 SRI Method

12 days old seedlings were transplanted in the main field in square pattern at a spacing of 25 cm x 25 cm with single seedling $hill^{-1}$. The day before removing the seedlings, nursery beds were thoroughly irrigated but not to standing water level.Seedlings were removed singly from nursery along with a ball of soil that enclosed the seed sac and roots. The seedlings were separated carefully to avoid any damage to roots. These seedlings were immediately transplanted shallow at 2cm

2cm depth in the main field with gentle placement taking due care to place the roots horizontally in 'L' shape. Never plant with root ends pointing upwards.

3.3.2.4.2 Conventional method (control)

Twenty one days-old seedlings were uprooted from the wet nursery bed and transplanted at a spacing of 20 cm x 10 cm with two to three seedlings hill^{-1}, at around 3-4 cm depth.

3.3.2.5 Weed Management

3.3.2.5.1 Weed management in SRI method

Weeding was done mechanically with a conoweeder and the weeds were incorporated into the soil. First conoweeding was done at 10 days after transplanting followed by three subsequent weeding at 10 days interval. Weeds growing very close to rice plant and at corners and over the sides of plot bunds were removed manually.

3.3.2.5.2 Weed management in control plot

Weeds were removed from the control plot by hand weeding twice, first at 20 DAT and second at 40 DAT.

3.3.2.6 Water management

3.3.2.6.1 Water management for conoweeding in SRI

A shallow depth of below 1cm was maintained for conoweeding to avoid mud sticking on to the cone gaps.

3.3.2.6.2 Water management for SRI treatments

Transplanting was done in well drained field. Experimental plots were kept drained after transplanting till hair cracks appeared on soil surface due to moisture loss. The field was irrigated to a shallow depth in installments such that by evening only about 1cm depth of water remained in the plots. Next irrigation was done at hair crack stage of the soil till panicle initiation stage. The quantity of water required for irrigation of selected plot in each replication was measured by irrigation from laid out pipe system in the adjacent garden land through hose connected with water meter. Treatment plots were continuously flooded to a depth of 5cm for the rest of plant growth stage till 10 days before harvest.

3.3.2.6.3 Water management for conventional method

Water level was maintained at about 1.5 cm during transplanting. Thereafter it was increased gradually to about 5cm and maintained throughout the cropping period, with occasional drainage for top dressing of fertilizer or plant protection. The field was drained 10 days before harvest.

3.3.2.7 *Harvest*

The crop was harvested when the straw just turned yellow and more than 85 per cent of grain panicle^{-1} matured. The net plot area of individual treatments leaving the two border rows was harvested separately, threshed, dried, winnowed and weight of grain and straw from individual plots were recorded.

3.4 OBSERVATIONS

Ten plants were selected at random from the net plot area of each plot and tagged. The following observations were recorded from these sample plants and the mean values were worked out.

3.4.1 Growth and growth analysis

3.4.1.1 *Tillers hill^{-1} at PI stage*

Tiller count was taken from the tagged sample hills at panicle initiation stage and expressed as number of tillers hill^{-1}.

3.4.1.2 *Latent tillers at flowering stage*

The late emerged young tillers observed at flowering stage among the sample hills were counted and mean number hill^{-1} worked out.

3.4.1.3 *Leaf Area Index (LAI) at flowering stage*

LAI was computed using the method described by Gomez (1972). The maximum width 'w' and length 'l' of all the leaves of the middle tillers of ten sample hills were recorded and LAI was calculated using the relationship

Leaf area of a single leaf = $l \times w \times k$

K - Adjustment factor (0.75 at flowering)

Leaf area hill^{-1} = leaf area of middle most tiller X total number of tillers

$$\text{LAI} = \frac{\text{Sum of leaf area of 10 sample hills (cm}^2\text{)}}{\text{Area of land covered by the 10 sample hills (cm}^2\text{)}}$$

3.4.1.4 *Relative Growth Rate (RGR) (PI to 50 per cent flowering)*

RGR for the period of panicle initiation to 50 per cent flowering was determined based on the formula of Williams (1946) and expressed in g g^{-1} day^{-1}

$$\text{RGR} = \frac{\text{Log}_e\, w_2 - \text{Log}_e\, w_1}{t_2 - t_1}$$

w_1 and w_2 – plant dry weight (g) at time t_1 and t_2 respectively

t_1 and t_2 - time interval in days

3.4.1.5 *Root length (maximum)*

Sample hills were carefully uprooted at the time of harvest from each plot without breaking the roots. Roots were washed well and root length was taken from the base of the root to the tip of the longest root and expressed in cm.

3.4.1.6 *Root volume*

Root volume hill^{-1} was found out by displacement method as stated below. The roots of ten sample plants were washed with water and were placed in an empty 1000 ml measuring cylinder. Measure1000 ml water in a second 1000 ml measuring cylinder. Pour water from this measured volume in to the cylinder containing the root, till water reaches the 1000 ml mark. The volume of water left in the second measuring cylinder (without roots) was recorded. This volume of water was taken as volume of the root and expressed in cm^3 hill^{-1}

3.4.1.7 *Root biomass*

The roots of ten sample plants were washed free of adhering soil with water, roots were separated, cleaned, dried and weighed. The mean value was calculated and expressed in g hill^{-1}.

3.4.1.8 *Total biomass*

Leaves, stem, root and panicle biomass of ten sample plants collected from the sampling area at harvest were recorded and summed up on dry weight basis and the average worked out.

3.4.1.9 *SPAD reading at flowering*

SPAD reading were recorded with the help of Chlorophyll meter (Konica Minolta Model SPAD 502) from the ten sample hills at flowering stage and the mean value was calculated.

3.4.2 Yield attributes and yield

3.4.2.1 *Productive tillers hill^{-1} and m^{-2}*

At harvest, the number of productive tillers was recorded from ten observational plants and was expressed as mean number of productive tillers hill^{-1}.

Plate 4. SPAD meter reading at flowering stag

The number of productive tillers per square meter was calculated by multiplying the mean number of tiller hill^{-1} with the number of hills m^{-2}.

3.4.2.2 *Mean panicle weight*

All the panicles of the ten labelled sample plants were collected, oven dried at 80°C for 24 hrs and the total weight and number were recorded. The mean panicle weight was computed and expressed in grams panicle^{-1}.

3.4.2.3 *Mean number of grains panicle^{-1}*

All the panicles from the ten sample hills were threshed. Separate grains from chaff and dried to 14 per cent moisture and weighed. Three lots of 1000 grain each were counted out and weighed and mean weight of 1000 grain recorded and the mean number of grains per gram worked out. The total number of grains per 10 hills is obtained by multiplying the number of grains per gram with the total weight of grains in gram of all the 10 hills. The mean number of grains panicle^{-1} was worked out by dividing the total number of grains by the total number of panicles in the 10 hills.

3.4.2.4 *Mean number of spikelet's panicle^{-1}*

All the chaff separated while determining the mean number of grains in procedure 3.4.2.3 was collected and the total number counted and summed to the total number of grains per 10 hill and the total number of florets per 10 hills obtained. The mean number of florets per panicle is obtained by dividing the total florets number by the total number of panicle per 10 hills.

3.4.2.5 *Thousand grain weight*

From the total number of grains collected in procedure 3.4.2.3 and dried to 14 per cent moisture content three lots of 1000 grains were counted out and weighed in a sensitive electronic balance and mean expressed in g.

3.4.2.6 *Grain yield*

The net plot area was harvested individually, threshed, cleaned and dried to 14 per cent moisture level and weight recorded. Grain yield was expressed in kg ha^{-1}.

3.4.2.7 *Straw yield*

Straw harvested from each net plot was dried under sun to a constant weight and the weight was expressed in kg ha^{-1}

3.4.2.8 *Harvest index*

Harvest index was computed using the following equation as suggested by Donald and Hamblin (1976)

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

3.4.3 Water productivity (grain)

Grain water productivity was worked out by dividing the economic yield in kg ha^{-1} by the total quantity of water applied both by irrigation and precipitation in m^3 ha^{-1} or effective rainfall used by the crop and expressed in units of kg m^{-3}.

3.4.4 Pest and disease scoring

The pest and disease incidences did not reach the economic threshold level and hence uniform score was given to all plots. Scoring for leaf roller and earhead bug intensity was done using the score chart (given in Appendix II) developed by International Rice Research Institute (IRRI, 1981).

3.4.5 Soil analysis

3.4.5.1 *Soil chemical properties (pre and post planting)*

3.4.5.1.1 Organic carbon

The wet digestion method suggested by Walkley and Black (1934) was employed for the estimation of organic carbon. It was expressed as percentage (%).

3.4.5.1.2 Soil reaction

The pH was determined in a 1:2.5 soil water suspension using ELICO digital pH meter (Jackson, 1973).

3.4.5.1.3 Available nitrogen

Available nitrogen content of the soil was estimated by Microkjeldahl method (Jackson, 1973) and expressed as kg ha $^{-1}$.

3.4.5.1.4 Available phosphorus

Available phosphorus in soil was determined by Bray I (0.03 N ammonium fluoride in 0.025 N hydrochloric acid) method as described by Jackson (1973) and readings were taken in spectrophotometer and expressed as kg ha^{-1}.

3.4.5.1.5 Available potassium

Available potassium was determined in the neutral normal ammonium acetate extract and estimated using EEL flame photometer (Jackson, 1973) and expressed as kg ha^{-1}.

3.4.5.1.6 Available iron

Available iron content of the soil samples were determined by the method of extraction using 0.1 N HCl and read in AAS and expressed as kg ha^{-1}.

3.4.6 Plant analysis

3.4.6.1 *Nutrient content*

Sample plants collected from each plot at harvest were separated into straw and grain, sun dried, and then oven dried at 60$\pm$ 5^{0}C to a constant weight in a hot air oven and the samples were ground and passed through 0.5mm sieve digested and used for analysis of nutrient content. The required quantity of sample was weighed out accurately in an electronic balance.

3.4.6.1.1 Total nitrogen content

Total nitrogen content was estimated by modified Microkjeldal method (Jackson, 1973) and expressed as percentage.

3.4.6.1.4 Total phosphorus content

Total phosphorus content was found out using spectrophotometer method and expressed as percentage (Jackson, 1973).

3.4.6.1.3 Total potassium content

Total potassium content in plant was determined by using EEL flame photometer (Jackson, 1973) and expressed as percentage.

3.4.6.1.4 Total iron content

Iron content in diacid extract (Nitric- perchloric acid (9:4)) digestion samples were estimated using atomic absorption spectrophotometer (Lindsay and Norwell, 1978) and expressed as ppm.

3.4.6.2 *Uptake of nutrients*

Nutrient uptake of N, P, K and Fe at harvest was worked out using the following equation and expressed as kg ha^{-1}.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x DMP (kg ha}^{-1}\text{)}}{100}$$

3.4.7 Economic analysis

The economics of cultivation was worked out based on the cost of cultivation and prevailing price of the crop produce.

3.4.7.1 *Net income*

Net income was computed using the formula

Net income (Rs ha^{-1}) = Gross income – Total expenditure

3.4.7.2 *Benefit Cost Ratio (BCR)*

Benefit –Cost ratio was computed using the formula,

$$BCR = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.4.8 Statistical analysis

Data relating to different characters were analyzed statistically by applying the technique of analysis of variance for factorial experiment in Randomized Block Design (Panse and Sukhatme, 1978). Wherever the F values were found significant, critical difference were worked out at five per cent probability level.

Results

4. RESULTS

The experiment entitled "Integrated crop management of rice under System of Rice Intensification (SRI)" was carried out at College of Agriculture Vellayani during December 2012 to April 2013, to evaluate the efficacy of integrated input management for increasing the soil, crop and water productivity of transplanted rice grown under SRI in an economically viable mode. The experiment data were subjected to statistical analysis and the results obtained are presented here.

4.1 GROWTH AND GROWTH ANALYSIS

4.1.1 Tillers hill^{-1} at Panicle Initiation (PI) Stage

The data presented in Table 2 revealed that seed priming had no significant effect on the number of tillers hill^{-1} at panicle initiation stage. But the different fertilizer combinations tried had a highly significant effect on the tillers hill^{-1} at PI stage. Treatment F_1 (Recommended Fertilizer Dose (RFD) of N, P and K @ 90-45-45 kg ha $^{-1}$) recorded the highest value of 32.63 and was significantly superior to the other fertilizer combinations. The treatment F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} supplied as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) recorded 28.03 tillers. The treatment F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer) recorded 27.28 tillers hill^{-1}. Both treatments F_2 and F_3 were on par in tiller production.

The interaction effect of treatments had no influence on the tillers hill^{-1} at PI stage. The control treatment of conventional transplanting recorded significantly lower number of tillers hill^{-1}.

4.1.2 Latent tillers at flowering stage

The data presented in Table 2 revealed that seed priming had no significant effect on latent tillers at flowering stage. The fertilizer combinations

Table 2. Effect of seed priming, fertilizer combinations and their interaction on tillers hill^{-1} and latent tillers hill^{-1}

Treatments	Tillers hill $^{-1}$ (PI stage)	Latent tillers hill^{-1} (flowering stage)
Seed priming		
P_1	29.85	3.08
P_2	28.78	3.14
SE	0.437	0.214
CD	NS	NS
Fertilizer combinations		
F_1	32.63	3.71
F_2	28.03	2.93
F_3	27.28	2.71
SE	0.535	0.262
CD (0.05)	1.648	0.809
Interaction effect of treatment combinations		
p_1 f_1	32.20	3.92
p_1 f_2	28.72	2.83
p_1 f_3	28.62	2.50
p_2 f_1	33.07	3.50
p_2 f_2	27.33	3.02
p_2 f_3	25.93	2.92
SE	0.756	0.371
CD	NS	NS
Control	8.76	0.67
Treated vs Control CD (0.05)	2.330	1.144

tried had significant impact. Treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha-^{1} as fertilizers) recorded the highest value of 3.71 latent tillers which is significantly higher than the other treatments, followed by F_2 (RFD of N, P and K @ 90-45-45 kg ha $^{-1}$ as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) which was on par with F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha $^{-1}$ as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer).

The interaction effect of seed priming and fertilizer combinations on latent tiller production at flowering stage was not significant. Control treatment showed highly significant variation on the latent tillers at flowering stage compared to the treatment interactions and recorded the least value of 0.67 hill^{-1}.

4.1.3 Leaf Area Index at flowering stage

The data on LAI at flowering stage presented in Table 3 indicated that neither the different priming treatments nor the fertilizer combination treatments tried had any significant effect on LAI. However the priming treatment (P_1) recorded numerically higher value than non primed (P_2) treatments.

The interaction effect also had no significant effect on LAI at flowering stage. However LAI of the control treatment was significantly inferior to that of all the treatment combinations.

4.1.4 Relative Growth Rate (PI to 50 per cent flowering)

Data presented in Table 3 revealed that seed priming had no significant impact on relative growth rate of SRI rice for the period of panicle initiation to 50 per cent flowering. The different fertilizer combinations tried also had no significant impact on RGR. Both the interaction effect of treatment combinations and the control treatments also did not vary significantly in RGR during PI to 50 per cent flowering.

4.1.5 SPAD Reading at 50 per cent flowering

The data revealed that neither the treatments nor their interaction had any

Table 3. Effect of seed priming, fertilizer combinations and their interaction on leaf area index, relative growth rate and SPAD reading

Treatments	LAI (flowering stage)	RGR (PI to 50 per cent flowering) (g g^{-1} day^{-1}	SPAD reading (50 per cent flowering)
Seed priming			
P_1	4.75	0.008	42.21
P_2	4.66	0.010	43.09
SE	0.067	0.001	0.475
CD	NS	NS	NS
Fertilizer combinations			
F_1	4.72	0.010	42.83
F_2	4.68	0.009	42.58
F_3	4.72	0.008	42.53
SE	0.082	0.001	0.582
CD	NS	NS	NS
Interaction effect of treatment combinations			
p_1 f_1	4.84	0.009	42.77
p_1 f_2	4.69	0.007	41.67
p_1 f_3	4.73	0.008	42.20
p_2 f_1	4.59	0.012	42.90
p_2 f_2	4.68	0.011	43.50
p_2 f_3	4.72	0.007	42.87
SE	0.116	0.002	0.823
CD	NS	NS	NS
Control	3.78	0.006	41.73
Treated vs Control CD (0.05)	0.356	NS	NS

significant effect on the SPAD reading at 50 per cent flowering time. The control treatment also did not vary significantly in SPAD values compared to the values of the treatment combinations.

4.1.6 Root length (maximum) in cm

The data on maximum root length hill^{-1} presented in Table 4 revealed that the treatments seed priming and fertilizer combinations tried had no significant effect. The interaction effect of treatment combinations was also not significant.

However, the seed priming treatment (P_1), the fertilizer combination F_1 (RFD of N, P and K @ 90-45-45 kg ha $^{-1}$ as fertilizers) and the treatment combination p_1f_1 recorded numerically higher values than the rest of the treatments.

The root length of all the treatment combinations was significantly superior to that of the control treatment. The control treatment recorded the lowest value of 15.57 cm which was only 65 per cent of the numerically highest value of 23.83 recorded by the treatment combination p_1f_1.

4.1.7 Root volume (cc hill^{-1})

The result presented in Table 4 showed that the seed priming had no significant influence on root volume. Also the fertilizer combinations tried and the treatment interactions had no significant impact on root volume.

However, the seed priming treatment (P_1), the fertilizer combination F_1 (RFD of N, P and K @ 90-45-45 kg ha $^{-1}$ as fertilizers) and the treatment combination p_1f_1 recorded numerically higher values than the rest of the treatments. However, the root volume hill^{-1} of all the treatment combinations was significantly superior to that of the control treatment. The control treatment had recorded 11.3cc hill^{-1} which was only 44 per cent of that of the treatment combination p_1f_1 that recorded numerically highest root volume of 25.57cc hill^{-1}.

4.1.8 Root biomass (g m $^{-2}$)

Seed priming treatment P_1 (primed seeds) recorded significantly higher root biomass than P_2 (non primed seeds).

Among the fertilizer combination treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha $^{-1}$ as fertilizers) recorded significantly higher root biomass than F_2 (RFD of N, P and K @ 90-45-45 kg ha $^{-1}$ as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) and F_3 (seventy five per cent of RFD of N,P and K @ 67.5- 33.75 -33.75 kg ha $^{-1}$ as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer) . However F_2 and F_3 were on par.

Treatment combinations did not have any significant influence on root biomass, though p_1f_1 had the numerically highest root biomass, recording 897.6 g m^{-2}. The control treatment had equally good root biomass as compared to the other treatment combinations.

4.1.9 Total dry matter production (DMP) (g m^{-2})

Data presented in Table 4 indicated that seed priming had no significant influence on total DMP of rice through primed treatment produced 5 per cent more DMP than non primed treatment. But fertilizer combinations tried had significant influence on DMP. F_1 (RFD of N, P and K @ 90-45-45 kg ha $^{-1}$ as fertilizers) recorded the highest value of 2629.17 g m^{-2} which was significantly superior to F_2 (2312.80 g m^{-2}). The treatments F_2 and F_3 were on par.

The interaction effect of treatment combinations had no significant influence on DMP of rice. However the treatment combination p_1f_1 recorded the numerically highest value of 2682.33 g m^{-2}. The control treatment produced equally good total DMP as that of the treatment combinations (2286.17 g m^{-2}).

4.2 YIELD ATTRIBUTES AND YIELD

4.2.1 Productive tillers hill^{-1}

The data presented in Table 5 revealed that priming treatments had no significant effect on productive tillers hill^{-1}. However the P_1 (primed seeds)

Table 4. Effect of seed priming, fertilizer combinations and their interaction on root length, root volume, root biomass and dry matter production

Treatments	Root length (cm)	Root volume (cc hill^{-1})	Root biomass (g m^{-2})	Total DMP (g m^{-2})
Seed priming				
P_1	23.22	23.97	829.2	2494.5
P_2	22.93	23.94	700.6	2378.9
SE	0.421	0.613	28.15	57.17
CD (0.05)	NS	NS	86.75	NS
Fertilizer combinations				
F_1	23.70	25.05	860.5	2629.2
F_2	23.13	23.97	714.4	2312.8
F_3	22.40	22.85	719.7	2368.0
SE	0.515	0.751	34.48	176.18
CD (0.05)	NS	NS	106.24	215.77
Interaction effect treatment combinations				
$p_1 f_1$	23.83	25.57	897.6	2682.3
$p_1 f_2$	23.17	23.40	825.1	2406.9
$p_1 f_3$	22.67	22.93	764.8	2394.1
$p_2 f_1$	23.57	24.53	823.5	2576.0
$p_2 f_2$	23.10	24.53	603.7	2218.7
$p_2 f_3$	22.13	22.77	674.7	2341.9
SE	0.729	1.062	48.76	99.02
CD	NS	NS	NS	NS
Control	15.57	11.30	735.0	2286.2
Treated vs Control CD (0.05)	2.245	3.271	NS	NS

produced numerically higher number of productive tillers than P_2 (non primed seeds) treatment, the difference being 4.3 per cent. The different fertilizer combination treatments tried had significant impact on productive tillers hill^{-1}. F_1 (RFD of N, P and K @ 90-45-45 kg ha $^{-1}$ as fertilizers) had 27.80 tillers hill^{-1}and was significantly superior to F_2 (RFD of N, P and K @ 90-45-45 kg ha $^{-1}$ as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) and F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 - 33.75 kg ha $^{-1}$ as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer). F_2 and F_3 were on par.

There was no significant interaction effect. However the treatment combinations p_1f_1 (27.87) and p_2f_2 (27.73) recorded numerically higher values than the rest of the treatment combinations. The control treatment recorded significantly lowest number of productive tillers hill^{-1} (7.42) compared to the SRI treatment combinations.

4.2.2 Productive tillers m^{-2}

The data presented in Table 5 revealed that seed priming had no significant influence on the number of productive tillers m^{-2}. But fertilizer combinations had high significant impact on the no. of productive tillers m^{-2}. The treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded highest value (444.80) which was significantly superior to the treatments. Lowest value was recorded by F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75- 33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer). But it was on par with F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer).

The interaction effect of treatment combinations was not significant. Numerically highest number of productive tillers m^{-2} (445.87) was recorded in treatment combination p_1f_1 (445.87) followed by p_2f_1 (443.73) and the least in p_2f_3 (352).

Table 5. Effect of seed priming , fertilizer combinations and their interaction on productive tillers

Treatments	Productive tillers hill^{-1}	Productive tillers m^{-2}
Seed priming		
P_1	25.66	410.60
P_2	24.60	393.60
SE	0.418	6.717
CD	NS	NS
Fertilizer combinations		
F_1	27.80	444.80
F_2	24.49	391.89
F_3	23.10	369.60
SE	0.512	8.226
CD (0.05)	1.577	25.350
Interaction effect of treatment combinations		
p_1 f_1	27.87	445.87
p_1 f_2	24.92	398.72
p_1 f_3	24.20	387.20
p_2 f_1	27.73	443.73
p_2 f_2	24.07	385.07
p_2 f_3	22.00	352.00
SE	0.724	11.634
CD	NS	NS
Control	7.42	371.00
Treated vs Control CD (0.05)	2.230	35.850

However the control treatment produced significantly lower number of productive tillers compared to treatments p_1f_1 and p_2f_1 but was on par with the rest of the treatment combinations.

4.2.3 Mean panicle weight

The data presented in Table 6 revealed that seed priming had no significant influence on mean panicle weight. However P_1 (primed seeds) produced numerically higher values than P_2 (non primed seeds), the difference being 5 per cent. Likewise the fertilizer combination and its interaction with seed priming also had no significant influence on mean panicle weight. The control treatment also had panicle weight statistically on par with all the other treatment combinations.

4.2.4 Thousand grain weight

Data presented in Table 6 revealed that thousand grain weight was not influenced by seed priming, fertilizer combinations and their interactions. The control treatment was also statistically on par with all other treatment combinations.

4.2.5 Mean number of spikelets panicle^{-1}

The data summarized in Table 7 showed that seed priming had no significant influence on mean number of spikelets panicle^{-1}. However the P_1, the seed priming treatment recorded numerically higher number of spikelets panicle^{-1} (181.67) than P_2 the non primed treatment, the difference being 4.3 per cent.

Different fertilizer combinations had significant impact on mean number of spikelets panicle^{-1}. Treatment F_2 (RFD of N, P and K @ 90-45-45 kg ha $^{-1}$ as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) recorded the highest value (182.67) and was on par with F_1 (RFD of N, P and K @ 90-45-45 kg ha $^{-1}$ as fertilizer) (182.67). They were significantly superior to the spikelet production in F_3 (seventy five per cent of RFD N, P and K

Table 6. Effect of seed priming, fertilizer combinations and their interaction on mean panicle weight and thousand grain weight

Treatments	Mean panicle weight (g)	Thousand grain weight (g)
Seed priming		
P_1	2.33	25.07
P_2	2.22	25.08
SE	0.074	0.052
CD	NS	NS
Fertilizer combinations		
F_1	2.17	25.03
F_2	2.29	25.13
F_3	2.37	25.08
SE	0.090	0.064
CD	NS	NS
Interaction effect of treatment combinations		
p_1 f_1	2.35	25.06
p_1 f_2	2.36	25.10
p_1 f_3	2.28	25.05
p_2 f_1	1.99	25.00
p_2 f_2	2.22	25.15
p_2 f_3	2.46	25.10
SE	0.128	0.090
CD	NS	NS
Control	2.10	25.00
Treated vs Control CD	NS	NS

Table 7. Effect of seed priming, fertilizer combinations and their interaction on spikeletes panicle^{-1} and grains panicle^{-1}

Treatments	Spikeletes panicle^{-1}	Grains panicle^{-1}
Seed priming		
P_1	181.67	84.30
P_2	174.28	80.97
SE	2.729	2.871
CD	NS	NS
Fertilizer combinations		
F_1	181.75	78.93
F_2	182.67	82.93
F_3	169.50	86.03
SE	3.343	3.516
CD (0.05)	10.301	NS
Interaction effect of treatment combinations		
p_1 f_1	185.00	85.23
p_1 f_2	183.33	85.13
p_1 f_3	176.67	82.53
p_2 f_1	178.50	72.63
p_2 f_2	182.00	80.73
p_2 f_3	162.33	89.53
SE	4.727	4.973
CD	NS	NS
Control	115.33	76.20
Treated vs Control CD (0.05)	14.567	NS

@ 67.5- 33.75 -33.75 kg ha $^{-1}$ as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer).

The control plot recorded a value of 115.33 which was significantly inferior to all the SRI treatment combinations.

4.2.6 Mean number of grains panicle^{-1}

The results are presented in Table 7. The data revealed that the treatments, seed priming (P), fertilizer combinations (F) and their interactions had no significant influence on the mean number of grains panicle^{-1}. However the priming treatment P_1 (primed seeds) had numerically higher number of grains panicle^{-1} (84.3) than the non primed treatment P_2 and difference was of 4.1 per cent.

The treatment F_3 (seventy five per cent of RFD of N, P and K @ 67.5-33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer) had numerically highest number of grains panicle^{-1} (86.03) and treatment combinations p_2f_3 recorded the highest number of grains panicle^{-1} (89.53). The mean grain number panicle^{-1} of the control treatment was also statistically on par with that of all the SRI treatment combinations.

4.2.7 Grain yield

The results are presented in Table 8. The effect of seed priming on the grain yield was significant. Among the seed priming treatments primed seeds (P_1) recorded significantly higher grain yield of 6261 kg ha^{-1} over non primed seed treatment P_2 (5705 kg ha^{-1}). The primed seed treatment, recorded a yield advantage of 556 kg ha^{-1} over the non primed seed treatment P_2, a difference of 9.7 per cent.

The fertilizer combinations tried had no significant influence on the grain yield but had economically significant effect. The numerically highest grain yield 6342 kg ha^{-1} was obtained by fertilizer combination treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) and the lowest grain yield of 5731 kg ha^{-1}

was recorded by treatment F3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer). The difference in grain yield between these two treatments being 611 kg ha^{-1}. The interaction effect of seed priming and fertilizer combinations on grain yield was not statistically significant on grain yield.

However numerically highest grain yield was recorded by the treatment combination p_1f_1 which yielded 6870 kg ha^{-1} where as the lowest was by p_2f_2 (5593 kg ha^{-1}). The treatment combination effect was economically significant, the yield difference between p_1f_1 and p_2f_2 being 1277 kg ha^{-1}.

The control treatment recorded the lowest grain yield of 5090 kg ha^{-1} and was significantly lower than the treatment combinations p_1f_1 (6869 kg ha^{-1}) and p_2f_2 (6155 kg ha^{-1}). Economically the conventional treatment was inferior to all the SRI treatment combinations, the least difference being 503 kg ha^{-1} and the highest being 1780 kg ha^{-1}.

4.2.8 Straw yield

It is evident from the data summarized in the Table 8 that seed priming, fertilizer combinations and their interactions had no significant effect on the straw yield. However the non primed seed treatment P_2, fertilizer combination F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) and treatment combination p_2f_1 recorded numerically highest straw yield. Control treatment didn’t vary significantly with the treatment combinations in straw yield.

4.2.9 Harvest index (HI)

The result presented in Table 8 revealed that different seed priming treatments had significant effect on harvest index. The primed seeds (P_1) recorded significantly higher value of HI (0.52) over the non primed treatments, P_2. Neither the fertilizer combinations nor the interactions had any significant effect on HI. However the least HI values were observed in fertilizer combination F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination

Table 8. Effect of seed priming, fertilizer combinations and their interaction on grain yield, straw yield and harvest index

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Seed priming			
P_1	6261	5749	0.52
P_2	5705	6408	0.48
SE	178.032	301.066	0.015
CD (0.05)	548.619	NS	0.047
Fertilizer combinations			
F_1	6342	6435	0.50
F_2	5874	5651	0.52
F_3	5732	6149	0.49
SE	218.044	368.729	0.019
CD	NS	NS	NS
Interaction effect of treatment combinations			
p_1 f_1	6870	5999	0.54
p_1 f_2	6155	5255	0.54
p_1 f_3	5757	5991	0.49
p_2 f_1	5815	6870	0.46
p_2 f_2	5593	6047	0.49
p_2 f_3	5706	6306	0.48
SE	308.361	521.461	0.026
CD	NS	NS	NS
Control	5090	6093	0.45
Treated vs Control CD (0.05)	950.235	NS	NS

of vermicompost to supply 30 kg N equivalent and rest as fertilizer) and treatment combination p_2f_1. On comparing the treatment combinations with control, no significant variation was observed.

4.3 WATER PRODUCTIVITY (GRAIN)

The data presented in table 9 revealed that the seed priming treatment had significant impact on water productivity. The treatment P_1 (primed seeds) had significantly higher water productivity (0.77 kg m^{-3}).

Neither the fertilizer combinations tried nor their interaction with seed priming treatment had no significant impact on water productivity. However the fertilizer combination F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded numerically the highest water productivity among the fertilizer combination treatments (0.78 kg m^{-3}). The treatment combination p_1f_1 recorded numerically highest values (0.84 kg m^{-3}) over all the other treatment combinations. The least water productivity was recorded by p_2f_2 (0.69 kg m^{-3}).

The control treatment of conventional transplanting had the lowest water productivity and it was significantly inferior to all the SRI treatment combinations. The SRI treatment combinations p_1f_1, which recorded the numerically highest water productivity of 0.84 kg m^{-3} was 175 per cent of the water productivity of the control treatment.

4.4 PEST INCIDENCE

There was no severe incidence of any pests. But there was only a mild to moderate level of leaf roller and rice bug incidence (Appendix-II).

4.5 POST HARVEST SOIL PROPERTIES

4.5.1 Soil reaction

The data on soil reaction is presented in table 10. The data revealed that the soil was highly acidic in reaction. The treatments seed priming (P) and fertilizer combinations (F) had no significant effect on soil reaction. Interaction

Table 9. Effect of seed priming, fertilizer combinations and their interaction on water productivity

Treatments	Water productivity (kg m^{-3})
Seed priming	
P_1	0.77
P_2	0.70
SE	0.022
CD (0.05)	0.067
Fertilizer combinations	
F_1	0.78
F_2	0.72
F_3	0.70
SE	0.026
CD	NS
Interaction effect of treatment combinations	
p_1 f_1	0.84
p_1 f_2	0.76
p_1 f_3	0.71
p_2 f_1	0.71
p_2 f_2	0.69
p_2 f_3	0.70
SE	0.037
CD	NS
Control	0.48
Treated vs Control CD (0.05)	0.115

effect of treatment combination and control treatments also were on par in soil reaction.

4.5.2 Soil organic carbon

The data on soil organic carbon is presented in Table 10. Soil organic carbon was not significantly influenced by the priming treatments. But the fertilizer combination treatments differed significantly in soil organic carbon content. The treatment F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) recorded the highest organic carbon values (1.76) which was on par with F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75- 33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer) and significantly superior to the treatment F_1.

The interaction of treatment combination had no significant effect on soil organic carbon content. However the treatment combination p_1f_2 recorded numerically highest value of 1.76 per cent, whereas p_1f_1 recorded the least value of 1.22 per cent.

The control treatment recorded significantly lower organic carbon than the treatment combinations p_1f_2, p_1f_3, p_2f_2 and p_2f_3 and was on par with p_1f_1 and p_2f_1.

4.5.3 Available Iron in soil

The data on available iron content is presented in Table 10. Soil Fe content was not significantly influenced by any of the treatments or interaction effect of treatment combinations and was on par with that of the control treatment.

4.5.4 Available nitrogen in soil

The data presented in Table 11 revealed that available nitrogen content in soil was not significantly influenced by the priming treatment. The different fertilizer combination treatments significantly influenced the post harvest nitrogen content in soil. The treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as

Table 10. Effect of seed priming, fertilizer combinations and their interaction on soil reaction, soil organic carbon and available iron of post harvest soil

Treatments	pH	OC (%)	Fe (kg ha^{-1})
Seed priming			
P_1	4.32	1.56	56.59
P_2	4.26	1.56	55.70
SE	0.118	0.023	1.307
CD	NS	NS	NS
Fertilizer combinations			
F_1	4.32	1.22	54.99
F_2	4.27	1.76	59.00
F_3	4.28	1.70	54.43
SE	0.145	0.029	0.601
CD (0.05)	NS	0.088	NS
Interaction effect of treatment combinations			
p_1 f_1	4.37	1.22	56.04
p_1 f_2	4.30	1.76	58.88
p_1 f_3	4.30	1.70	54.83
p_2 f_1	4.27	1.27	53.96
p_2 f_2	4.23	1.75	59.12
p_2 f_3	4.27	1.66	54.02
SE	0.205	0.040	2.264
CD	NS	NS	NS
Control	4.23	1.3	56.52
Treated vs Control CD (0.05)	NS	0.125	NS

fertilizer) recorded the highest post harvest nitrogen content in soil and it was on par with treatment F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer). Those two treatment had significantly higher available nitrogen content in soil than the treatment F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 - 33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer).

The interaction effect of treatment combinations was not significant. The control treatment had soil N content on par with treatment combinations except treatment p_1f_2 and p_2f_3 which had significantly lower soil N content.

4.5.5 Available phosphorus in soil

The data on available phosphorus in soil presented in Table 11. The priming treatment had no effect on post harvest soil P, whereas the fertilizer combinations had a significant effect. The fertilizer combinations F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) and F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) were on par and significantly superior to F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer) in available soil phosphorus content.

The interaction effect had no significant influence on the post harvest available soil phosphorus. However numerically highest value was recorded by p_2f_1 (23.66 kg ha^{-1}) and the least by p_1f_3 (20.37 kg ha^{-1}) and p_2f_3 (21.13 kg ha^{-1}). The control treatment did not significantly vary with the SRI treatments.

4.5.6 Available potassium in soil

The data on available potassium presented in Table 11. The priming treatment had no effect on post harvest soil potassium. The fertilizer combination treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded the

Table 11. Effect of seed priming, fertilizer combinations and their interaction on available N, P and K of post harvest soil

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Seed priming			
P_1	232.27	22.21	119.75
P_2	232.46	22.48	119.11
SE	0.991	0.405	0.915
CD	NS	NS	NS
Fertilizer combinations			
F_1	241.58	23.56	130.70
F_2	239.11	22.74	127.55
F_3	216.40	20.75	100.05
SE	1.213	0.496	1.121
CD (0.05)	3.739	1.530	3.453
Interaction effect of treatment combinations			
$p_1 f_1$	241.72	23.46	132.00
$p_1 f_2$	216.70	22.81	128.07
$p_1 f_3$	238.38	20.37	99.17
$p_2 f_1$	241.44	23.66	129.39
$p_2 f_2$	239.85	22.66	127.02
$p_2 f_3$	216.09	21.13	100.94
SE	1.716	0.702	1.585
CD	NS	NS	NS
Control	241.09	21.77	128.85
Treated vs Control CD (0.05)	5.288	NS	4.883

highest available soil K and it was on par with F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer). Both were significantly superior to treatment F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer).

There was no significant variation among the treatment combinations in the post harvest soil K. However the treatment combination p_1f_3 and p_2f_3 had significantly lower soil K content than the control treatment. The control treatment was on par with the rest of the SRI treatment combinations.

4.6 PLANT ANALYSIS

4.6.1 Plant uptake of nitrogen

Data presented in Table 12 revealed that priming treatment had no significant impact on nitrogen uptake. The effect of the different fertilizer combination treatments tried was also not significant. However, the primed seed treatment P_1, fertilizer combination treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) and the treatment interaction p_1f_1 recorded numerically highest values than the rest. The interaction effects did not have any significant variation in nitrogen uptake. The control treatment recorded the lowest nitrogen uptake but was also on par with the SRI treatments.

4.6.2 Plant uptake of phosphorus

The result presented in Table 12 revealed that seed priming treatment had no significant effect on phosphorus uptake. Also the different fertilizer combinations tried had no significant impact on phosphorus uptake. The interaction effect did not vary significantly for phosphorus uptake. However, the primed seed treatment P_1 and the fertilizer combination treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded numerically higher values than other treatments. The treatment combination p_1f_1 recorded numerically highest uptake values. The control treatment and SRI treatments did not vary significantly in phosphorus uptake.

Table 12. Effect of seed priming, fertilizer combinations and their interaction on N, P, K and Fe uptake

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Fe (kg ha^{-1})
Seed priming				
P_1	106.23	18.27	139.50	0.91
P_2	104.40	17.82	151.67	0.93
SE	2.582	0.435	6.275	0.056
CD	NS	NS	NS	NS
Fertilizer combinations				
F_1	111.59	19.12	154.15	0.94
F_2	101.35	17.40	136.30	0.94
F_3	103.01	17.61	146.32	0.89
SE	3.162	0.533	7.686	0.069
CD	NS	NS	NS	NS
Interaction effect of treatment combinations				
p_1 f_1	114.56	19.74	146.60	0.93
p_1 f_2	101.87	17.57	128.83	0.98
p_1 f_3	102.27	17.51	143.09	0.83
p_2 f_1	108.62	18.50	161.71	0.94
p_2 f_2	100.83	17.23	143.77	0.90
p_2 f_3	103.76	17.72	149.54	0.95
SE	4.472	0.754	10.869	0.097
CD	NS	NS	NS	NS
Control	95.60	16.27	143.23	0.88
Treated vs Control CD	NS	NS	NS	NS

4.6.3 Plant uptake of potassium

The data indicated in Table 12 revealed that seed priming had no significant effect on potassium uptake. The different fertilizer combinations tried also had no significant impact on K uptake. The treatment combinations also did not vary significantly in potassium uptake. However the non primed seed treatment P_2 and fertilizer combinations F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded numerically higher values than the other treatments. The treatment combination p_2f_1 recorded numerically highest potassium uptake, among the SRI treatments. The control treatment was also on par with the SRI treatments.

4.6.4 Plant uptake of iron

The data presented in Table 12 revealed that different seed priming treatments tried had no significant effect on the iron uptake. Also the different fertilizer combinations tried had no significant effect on iron uptake. The interaction effect and the control treatment also did not vary significantly.

4.7 ECONOMIC ANALYSIS

4.7.1 Net income

The treatment priming had statistically no significant effect on the net income. Data furnished in Table 13. But the fertilizer combinations tried significantly influenced net income. The treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded significantly higher value (Rs. 35044) for net income than F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) and F_3 (seventy five per cent of RFD N, P and K @ 67.5- 33.75 -33.75 kg ha $^{-1}$ as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer). The difference in net profit between fertilizer combination treatments F_1 and F_2 was Rs. 22508/- ha^{-1}. The variation in net income among the treatment combinations was not statistically significant. The treatment p_1f_1 recorded the highest net income of Rs. 41556/- ha^{-1} and yielded additional profit of Rs. 32165/-

Table 13. Effect of seed priming, fertilizer combination and their interaction on net income and benefit cost ratio

Treatments	Net income (Rs. ha $^{-1}$)	Benefit cost ratio
Seed priming		
P_1	23340	1.33
P_2	16873	1.23
SE	2486.94	0.032
CD	NS	NS
Fertilizer combinations		
F_1	35044	1.53
F_2	12536	1.16
F_3	12740	1.16
SE	3045.861	0.039
CD (0.05)	9386.037	0.119
Interaction effect		
$p_1 f_1$	41556	1.62
$p_1 f_2$	15680	1.19
$p_1 f_3$	12783	1.16
$p_2 f_1$	28531	1.43
$p_2 f_2$	9391	1.12
$p_2 f_3$	12698	1.16
SE	4307.498	0.055
CD	NS	NS
Control	16839	1.25
Treated vs Control CD	NS	NS

over p_2f_2 which recorded the least net income of Rs.9391/- ha^{-1}. The net income of the control treatment of conventional planting (Rs. 16839/- ha^{-1}) also did not vary significantly from the SRI treatments. However net income of the best SRI treatment combination p_1f_1 was 247 per cent of that of the control treatment.

4.7.2 Benefit cost ratio

The data furnished in Table 13 revealed that priming had no significant influence on benefit cost ratio. However different fertilizer combinations tried had significant effect on BCR. The treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded significantly higher benefit cost ratio of 1.53 over the treatments F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) and F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer), which were on par. The treatment interaction had no significant effect on benefit cost ratio. On comparing the treatment combinations with control, no significant variation was observed.

However the B: C ratio of the best SRI treatment p_1f_1 (1.62) was 147 per cent of the treatment p_2f_2 (1.12). The B: C ratio of the conventional planting (1.25) was statistically on par with that of the SRI treatments, but was only 77 per cent of that of the best SRI treatment p_1f_1.

Discussion

5. DISCUSSION

The results of the experiment entitled “Integrated crop management of rice under System of Rice Intensification (SRI)” carried out at College of Agriculture Vellayani during December 2012 to April 2013, to evaluate the efficacy of integrated input management for increasing the soil, crop and water productivity of transplanted rice grown under SRI in an economically viable mode are discussed below.

5.1 GROWTH AND GROWTH ANALYSIS

5.1.1 Tillers hill^{-1} at panicle initiation (PI) stage

The data (presented in Table 2) revealed that seed priming though recorded numerically higher number of tillers at PI stage did not differ significantly from non primed treatment on the number of tillers hill^{-1} at panicle initiation stage.

Seed priming has been reported to yield beneficial effect on growth and yield attributes of rice, especially under conditions of sub optimal conditions. Since the growing conditions provided for the primed and non primed treatments were the same, the positive effect of priming could not be projected to the level of statistical significance. The result is corroborated by the earlier reports of Harris *et al*. (2001).

The different fertilizer combinations tried had a highly significant effect on the tillers hill^{-1} at PI stage. Treatment F_1 (Recommended Fertilizer Dose (RFD) of N, P and K @ 90-45-45 kg ha^{-1}) recorded the highest value of 32.63 and was significantly superior to the other fertilizer combinations F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} (30 kg N equivalent as vermicompost) and F_3 (seventy five per cent of RFD (30 kg N equivalent as vermicompost), which were on par.

Optimum nutrient supply at early growth stage is a pre requisite for proper tillering of rice plant. Nutrient supplied through chemical fertilizer was readily available for the young rice seedlings and hence the treatment F_1 could produce significantly higher number of tillers at PI stage. Since N was scheduled as half basal and the rest half as two equal splits , the basally applied organic manure-vermicompost- covered two third of the N applied as basal and only one third of basal N was supplied through readily available chemical fertilizer. Delay in mineralization in relation to the seedling need might have limited the nutrient supply to the seedlings. This might be the cause for the significant difference in tiller production noted in the treatments F_2 and F_3. The results are in accordance with the earlier reports of Udaykumar (2005) and Vijayakumar *et al.* (2006).

The interaction effect of treatments had no influence on the tillers hill^{-1} at PI stage. The control treatment of conventional transplanting recorded significantly lower number of tillers hill^{-1}.

All the treatment interactions were managed as per the SRI method of cultivation and hence all produced higher number of tillers and were on par. However the conventional planting was devoid of the benefits of SRI and hence produced significantly less number of tillers at PI stage. This is well in line with the findings of the above scientists.

5.1.2. Latent tillers at flowering stage

The results (data presented in Table 2) revealed that seed priming treatments had no significant effect on latent tillers at flowering stage, though numerically the primed seeds (P_1) produced lesser latent tillers.

Since the primed seeds produced numerically more tillers at PI stage there might have been more competition for the partitioning of assimilates to the reproductive organs which might have restricted nutrients supply for further production of latent tillers

The fertilizer combinations tried had significant impact. Treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizers) recorded the highest value of 3.71 latent tillers which is significantly higher than the treatment, F_3 (seventy five per cent of RFD with 30 kg N equivalent as vermicompost)

The strong demand for assimilates for the initiation and development of the panicle might have redirected most of phoyosynthate to the sink and restricted further development of vegetative tillers in the treatment F_3, rather than in treatments F_1 and F_2 which had the full supply of RFD.

The interaction effect of seed priming and fertilizer combinations on latent tiller production at flowering stage was not significant. Control treatment showed highly significant variation on the latent tillers at flowering stage compared to the treatment interactions and produced the least value of 0.67 hill $^{-1}$.

The treatment interactions had SRI package of crop management and hence had similar growing conditions and restrictions. However in the conventional planting the inherent tillering capacity was restricted and there was severe competition between hills for nutrients and assimilates that naturally prevented latent tiller production. These findings are in line with the reports of Dofing and Karlsson (1993) and Fageria *et al*. (1997 b).

5.1.3 Leaf Area Index at flowering stage

The results (data presented in Table 3) indicated that neither the different priming treatments nor the fertilizer combination treatments tried had any significant effect on LAI. However the priming treatment (P_1) recorded numerically higher value than non primed (P_2) treatments.

As discussed earlier seed priming had beneficial effect on growth and yield attributes of rice, especially under situations of sub optimal conditions. Since the growing conditions provided for the primed and non primed treatments were the same and in the SRI method of rice cultivation, the positive effect of priming could not be projected to the level of statistical significance. The result is corroborated by the earlier reports of Harris *et al*. (2001).

The different fertilizer combinations tried were sufficient to promote the proper development of the ‘source’ for photosynthate production in rice under SRI. Hence no significant variations were noted among the fertilizer levels tried.

The interaction effect also had no significant effect on LAI at flowering stage. However LAI of the control treatment was significantly inferior to that of all the treatment combinations.

Since the treatments individually did not vary significantly among themselves, their interaction was also not found significant. In conventional planting the tiller production was significantly lower than that in SRI. Hence it had significantly lower LAI compared to the treatments under SRI. These findings are corroborated by the reports of Thakur *et al*. (2009).

5.1.4. Relative Growth Rate (PI to 50 per cent flowering)

The results (data presented in Table 3) revealed that seed priming had no significant impact on relative growth rate of SRI rice for the period of panicle initiation to 50 per cent flowering. The different fertilizer combinations tried also had no significant impact on RGR. Both the interaction effect of treatment combinations and the control treatments also did not vary significantly in RGR during PI to 50 per cent flowering.

The RGR values tend to be more at early growth stage in the season and showed a decreasing trend with the advancement of plant age irrespective of treatments. Flowering is the advanced stage of plant growth. Hence this result. Alam *et al*. (2009) reported similar results.

5.1.5. SPAD Reading at 50 per cent flowering

The results (data presented in Table 3) revealed that neither the treatments nor their interaction had any significant effect on the SPAD reading at 50 per cent flowering time. The control treatment also didn’t vary significantly in SPAD values compared to the values of the treatment combinations, which is acclaimed to produce lush growth of rice even under limited resources. Hence the SPAD reading of leaf of the different treatments plants were on par. The conventional planting treatment received the RFD and hence there was no limitation of growth inputs. So it also had same level of chlorophyll content as that of treatment under SRI. Geethalakshmi *et al*. (2009) reported similar results.

5.1.6 Root length (maximum) in cm

The results (data presented in Table 4) revealed that the treatments seed priming and fertilizer combinations tried had no significant effect on root length. The interaction effect of treatment combinations was also not significant. The control treatment (conventional planting) had significantly shallower roots than all the SRI treatments

The different treatments and their combinations were grown under the SRI method of rice cultivation, which provided ample potential for deeper root growth of rice. This SRI effect on root growth masked the potential of individual treatments which might have been expressed under non SRI rice growing situations. Hence the treatments were on par.

Rice in the control treatment (conventional planting) had continuous flooded condition, which resulted in shorter roots and hence the root length of all the treatment combinations under SRI was significantly superior to that of the control treatment. These results are in line with the findings of Yang *et al*. (2004).

5.1.7 Root volume (cc hill^{-1})

The results (data presented in Table 4) showed that the seed priming had no significant influence on root volume. Also the fertilizer combinations tried and the treatment interactions had no significant impact on root volume. However, the root volume hill^{-1} of all the treatment combinations was significantly superior to that of the control treatment.

The different treatments and their combinations were grown under the SRI method of rice cultivation, which provided ample potential for profuse root growth of rice. This SRI effect on root growth masked the potential of individual treatments which might have been expressed under non SRI rice growing situations. Hence the treatments were on par.

Rice in the control treatment (conventional planting) had continuous flooded condition, which resulted in shorter roots and less number of roots, hence the root volume of all the treatment combinations under SRI was significantly superior to that of the control treatment. These results are in line with the findings of Thyagarajan *et al.* (2002) and Wang *et al.* (2006).

5.1.8 Root dry matter production (DMP) (g m^{-2})

The results (data presented in Table 4) revealed that seed priming treatment P_1 (primed seeds) recorded significantly higher root DMP than P_2 (non primed seeds).

Among the fertilizer combination treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizers) recorded significantly higher root DMP than F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} (30 kg N equivalent as vermicompost) and F_3 (seventy five per cent of RFD (30 kg N equivalent as vermicompost), which were on par.

The drained soil condition under SRI facilitated through alternate wetting and drying mode of irrigation might have favoured root thickening as aerenchymatous tissues were minimized, resulting in denser roots that increased the root dry matter production. Roots of plants from primed seeds might have had increased cytokinine production and enhanced root activity that lead to higher root DMP.

The treatment F_1 had consistently recorded numerically highest values for root length and root volume among the fertilizer combination treatments-though not to the level of statistical significance- that enabled the plants to forage a much larger volume of soil. This coupled with the ready availability of plant nutrients through chemical fertilizers right from the very early stage of seedling growth enabled the F_1 treatment plants to accumulate significantly higher root DMP than F_2 and F_3.

Treatment combinations did not have any significant influence on root DMP, though p_1f_1 had the numerically highest root DMP, recording 897.6 g m^{-2}. The control treatment had equally good root DMP as compared to the other treatment combinations.

All the treatment combination enjoyed the same soil aerating SRI management practices that equally enabled all combinations to produce denser roots. Though individual hills in the control treatment had significantly lower root DMP, the closer spacing adopted compensated this low root DMP by the many fold increase in the number of hills per unit area and cumulatively produced root DMP comparable to the SRI treatments. The above findings are in line with the reports of Kirk and Solivas (1997), Drew (1997), Wang *et al.* (2002) and Stoop (2005).

5.1.9 Total dry matter production (TDMP) (gm^{-2})

Results (data presented in Table 4) revealed that seed priming had no significant influence on TDMP of rice though primed treatment, P_1 produced 5 per cent more TDMP than non primed treatment, P_2.

As discussed earlier in 5.1.3, seed priming yield beneficial effect on growth and yield attributes of rice, especially under situations of sub optimal growing conditions. Since the growing conditions provided for the primed and non primed treatments were the same and were grown under SRI method of rice cultivation, the positive effect of priming on TDMP could not be projected to the level of statistical significance. The result is corroborated by the earlier reports of Harris *et al.* (2001).

But fertilizer combinations tried had significant influence on TDMP. The Treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizers) recorded the highest value of 2629 g m^{-2} which was significantly superior to F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} (30 kg N equivalent as vermicompost) and F_3 (seventy five per cent of RFD (30 kg N equivalent as vermicompost), which were on par.

The treatment F_1 had consistently recorded numerically highest values for root length, root volume and recorded significantly higher root DMP than treatments F_2 and F_3. As discussed in 5.1.8, the favorable conditions of growth under SRI coupled with the ready availability of nutrients enabled the F_1 treatment plants to accumulate significantly higher TDMP than F_2 and F_3. These results are corroborated by the findings of Reddy *et al.* (1984), Devasenamma *et al.* (1999) and Rajesh and Thanunathan (2002)

The interaction effect of treatment combinations had no significant influence on DMP of rice. However the treatment combination p_1f_1 recorded the numerically highest value of 2682.3 g m^{-2}. The control treatment produced equally good total DMP as that of the treatment combinations.

As discussed in 5.1.8 all the treatment combinations were subjected to SRI management that enabled the plants under each of the above treatments to perform equally. Hence no significant variation was noted between them in TDMP. The closer spacing adopted in the control treatment compensated for low TDMP and cumulatively produced TDMP comparable to the SRI treatments.

These results are in line with the reports of Doberman (2004) and stoop (2005).

5.2 YIELD ATTRIBUTES AND YIELD

5.2.1 Productive tillers hill^{-1}

Results revealed that (data presented in Table 5) priming treatments had no significant effect on productive tillers hill^{-1}.

As discussed earlier in 5.1.8 above seed priming yield beneficial effect on yield attributes of rice, especially under situations of sub optimal conditions. Since the growing conditions provided for the primed and non primed treatments were the same and in the SRI method of rice cultivation, the positive effect of priming on productive tillers could not be projected to the level of statistical significance. However the P_1 (primed seeds) produced numerically higher number of productive tillers than P_2 (non primed seeds) treatment, the difference being 4.3 per cent. The findings of Harris *et al.* (2001) and Farooq *et al.* (2006 c) corroborate this result.

The different fertilizer combination treatments tried had significant impact on productive tillers hill^{-1}. F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizers) had 27.80 tillers hill^{-1}and was significantly superior to F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} (30 kg N equivalent as vermicompost) and F_3 (seventy five per cent of RFD (30 kg N equivalent as vermicompost)), which were on par.

As discussed in item 5.1.9 above, the treatment F_1 had consistently recorded numerically highest values for root length, root volume and recorded significantly higher root DMP and vegetative tillers at PI stage than treatments F_2 and F_3. The favourable conditions of growth under SRI coupled with the ready availability of nutrients enabled the F1 treatment plants to have an early start in growth and complete other phenological events earlier and produce more productive tillers than F_2 and F_3. These results are corroborated by the findings of Anil *et al.* (1989), Pandey and Tripathy (1994), Paladugu *et al.* (2004), Bhowmick *et al.* (2013).

There was no significant interaction effect. However the treatment combinations p_1f_1 (27.87) and p_2f_2 (27.73) recorded numerically higher values than the rest of the treatment combinations. The control treatment recorded significantly lowest number of productive tillers hill^{-1} (7.42) compared to the SRI treatment combinations.

As discussed in 5.1.9 all the treatment combinations were subjected to SRI management that enabled the plants under each of the above treatments to perform in a similar way. Hence no significant variation was noted between them in productive tillers hill^{-1}. The closer spacing and the management package adopted for the control treatment resulted in competition between hills for growth factors thereby limiting the number of productive tillers hill^{-1}. The reports of Ravi and Sreevastva (1997) and Abu Yameb (2002) are also in agreement with this result.

5.2.2 Productive tillers per m^{2}

Results revealed that (data presented in Table 5) priming treatments had no significant effect on productive tillers hill^{-1}.

But fertilizer combinations had high significant impact on the number of productive tillers m^{-2}. The treatment F$_1$ (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded highest value (444.80) which was significantly superior to the treatments F$_2$ (RFD of N, P and K @ 90-45-45 kg ha^{-1} (30 kg N equivalent as vermicompost) and F$_3$ (seventy five per cent of RFD with 30 kg N equivalent as vermicompost) which were on par.

The interaction effect of treatment combinations was not significant. Numerically highest number of productive tillers m^{-2} (445.87) was recorded in treatment p_1f_1 followed by p_2f_1 (443.73) and the least in p_2f_3 (352).

However the control treatment produced significantly lesser number of productive tillers compared to treatments p_1f_1 and p_2f_1 but was on par with the rest of the treatment combinations.

The treatment effects followed the same pattern as in 5.2.1 above except that in the control treatment, productive tillers m^{-2} was significantly inferior to treatments p_1f_1 and p_2f_1 only. This was due to the higher number of hills m^{-2} due to the closer spacing adopted in the control treatment.

5.2.3 Mean panicle weight

Results revealed that (data presented in Table 6) seed priming had no significant influence on mean panicle weight. However P$_1$ (primed seeds) recorded mean panicle weight 5 per cent higher values than P$_2$ (non primed seeds). Likewise the fertilizer combination and its interaction with seed priming also had no significant influence on mean panicle weight. The control treatment also had panicle weight statistically on par with all the other treatment combinations.

Seed priming provide beneficial effect on yield attributes of rice, especially under situations of sub optimal growing conditions. Since the growing conditions provided for the primed and non primed treatments were the same and also in the SRI method of rice cultivation, the positive effect of priming on productive tillers could not be projected to the level of statistical significance. However the P_1 (primed seeds) produced numerically higher mean panicle weight than P_2 (non primed seeds) treatment, the difference being 5.0 per cent. These results are in line with the findings of Harris *et al.* (2001) and Farooq *et al.* (2006 c).

Due to the afore said reasons, the fertilizer combination and its interaction with seed priming also had no significant influence on mean panicle weight

5.2.4 Thousand grain weight

Results (data presented in Table 6) revealed that thousand grain weight was not influenced by seed priming, fertilizer combinations and their interactions. The control treatment of conventional planting was also statistically on par with all other treatment combinations.

Thousand grain weight of rice is mainly a genetic character and it may vary with the variety. The genetic potential will be expressed only under the most congenial growing conditions, where it will be the maximum. Under situations of sub optimal growing conditions the variations in the extent of the limiting factor may limit the full expression of the genetic potential. However Since the growing conditions provided for the primed and non primed treatments were the same and also in the SRI method of rice cultivation, the positive effect of priming, fertilizer combinations and their interactions on thousand grain weight could not be projected to the level of statistical significance. These results are in line with the findings of Barthakur and Gogoi (1974), Latchanna *et al.* (1989), Ashraf *et al.* (1999).

5.2.5 Mean number of spikelets panicle^{-1}

Results (data presented in Table 7) revealed that that seed priming had no significant influence on mean number of spikelets panicle^{-1}. However the P_1, the seed priming treatment recorded numerically higher number of spikelets panicle^{-1} (181.67) than P_2 the non primed treatment, the difference being 4.3 per cent.

As discussed in 5.2.3, above seed priming produce beneficial effect on yield attributes of rice, especially under situations of sub optimal growing conditions. Since the growing conditions provided for the primed and non primed treatments were the same and also in the SRI method of rice cultivation, the positive effect of priming on spikelet production could not be projected to the level of statistical significance. However the P_1 (primed seeds) produced numerically higher mean number of spikelets panicle^{-1} than P_2 (non primed seeds) treatment, the difference being 4.3 per cent. These results are in line with the findings of Harris *et al*. (2001) and Farooq *et al*. (2006 c).

The results revealed that the fertilizer combination treatments had significant impact on mean number of spikelets per panicle. The treatments F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} with 30 kg N equivalent as vermicompost and rest as chemical fertilizer) and F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) were significantly superior to the spikelet production in F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer).

The higher number of panicles produced under the SRI method of rice cultivation might have necessitated a higher amount of plant nutrients especially during the reproductive stage of the crop for the proper development of the sink. The lesser quantity of the nutrients in the treatment F_3 and its mode of application might have limited the nutrients readily available to the crop at panicle formation stage of the crop. This might have resulted in the production of significantly lower number of spikelet panicle^{-1} in F_3 compared to that in treatments F_1 and F_2.

The control plot recorded a value of 115.33 which was significantly inferior to all the SRI treatment combinations. The conventional rice cultivation practice that promoted production of shallower roots might have limited the quantity of nutrients foraged by the crop during the panicle formation stage even when the recommended dose of fertilizers were applied to the soil. The extreme acidic condition of the field might have further aggravated the situation. This might have resulted in the production of significantly lower number of spikelets panicle^{-1} in the control plot compared to all the SRI treatments. These results are in conformation with the findings of Wang *et al*. (2002) and Yamah (2002).

5.2.6 Mean number of grains panicle^{-1}

The results (data presented in Table 7) revealed that the treatments, seed priming (P), fertilizer combinations (F) and their interactions had no significant influence on the mean number of grains panicle^{-1}. However the treatment P_1 (primed seeds) had numerically higher number of grains panicle^{-1} (84.3) than the non primed treatment P_2 and difference was of 4.1 per cent.

As discussed elsewhere, the seedlings of primed and non primed seeds were grown under similar ideal growing conditions and hence the inherent beneficial effect of seed priming though expressed could not reach the level of statistical significance.

Neither the fertilizer combinations treatments nor the interaction of the treatment combinations varied significantly in the number of grains panicle^{-1}.The mean number of grain panicle^{-1} of the control treatment was also statistically on par with that of all the SRI treatment combinations.

Since the leaf area index of all the treatments and treatment combinations and the control treatment was statistically on par there was no significant variation in the source capacity among them. Also the mean panicle weight of all these treatments was statistically on par. Significant variations in mean number of grains panicle^{-1} can be expected only when treatments of sub optimal growing conditions are co pared with treatments of optimal growing conditions, as discussed earlier. Since all these treatments were provided optimal growing conditions they did not vary significantly in the mean number of grains panicle^{-1}. These results are corroborated with the reports of Paladugu *et al*. (2004) and Wijebandara *et al*. (2009).

5.2.7. Grain yield

The results (data presented in Table 8) revealed that seed priming had significant effect on the grain yield. The primed seed treatment (P_1) recorded significantly higher grain yield of 6261 kg ha^{-1} over non primed seed treatment P_2 (5705 kg ha^{-1}). The primed seed treatment recorded and yield advantage of 556 kg ha^{-1} over the non primed seed treatment P_2 a difference of 9.7 per cent.

Though the yield attributes of rice *viz*., mean number of productive tillers panicle^{-1}, mean panicle weight, mean number of filled grains panicle^{-1} of rice crop from both primed seed treatment $P_{1,}$ and non primed seed treatment P_2 were statistically on par, values for all these attributes were consistently numerically higher in the primed seed treatment P_1 than in the non primed seed treatment $P_{2.}$ The possible reasons for the non significant effect of these attributes have already been discussed elsewhere. The cumulative interaction effect of the numerically higher values of this yield attributes in the primed seed treatment P_1 had finally added up and resulted in a significant yield increase over the non primed seed treatment $P_{2.}$

The fertilizer combinations tried had no significant influence on the grain yield but had economically significant effect. The numerically highest grain yield of 6342 kg ha^{-1} was obtained by fertilizer combination treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) and the lowest grain yield of 5731 kg ha^{-1} was recorded by treatment F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer). The difference in grain yield between these treatments was 611 kg ha^{-1}. This result is probably the reflection of the treatment effect on the mean number of productive tillers, wherein the F_1 treatment had recorded significantly higher values than treatments F_2 and F_3 and the treatments showed a linear decrease in mean value.

The interaction effect of seed priming and fertilizer combinations on grain yield was not statistically significant on grain yield. However the treatment combination effect was economically significant, the yield difference between p_1f_1 and p_2f_2 being 1277 kg ha^{-1}. This result is probably the reflection of the treatment's integrated effect of the mean number of productive tillers, mean panicle weight and mean number of grains $panicle^{-1}$.

The control treatment recorded the lowest grain yield of 5090 kg ha^{-1} and was significantly lower than the treatment combinations p_1f_1 (6870 kg ha^{-1}) and p_2f_2 (6155 kg ha^{-1}). Economically the conventional treatment was inferior to all the SRI treatment combinations, the least difference being 503 kg ha^{-1} and the highest being 1780 kg ha^{-1}. This result is probably the reflection of treatment effect on the production of the mean number of productive tillers m^{-2}.

5.2.8 Straw yield

The results (data presented in Table 8) revealed that seed priming, fertilizer combinations and their interactions had no significant effect on straw yield. However the non primed seed treatment P_2, fertilizer combination F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) and treatment combination p_2f_1 recorded numerically highest straw yield. Control treatment didn't vary significantly with the treatment combinations in straw yield. This result is the probable reflection of the numerically higher values of latent tiller production recorded by the corresponding treatments at flowering stage of the crop.

5.2.9 Harvest index (HI)

The result presented in Table 8 revealed that different seed priming treatments had significant effect on harvest index. The primed seeds (P_1) recorded significantly higher value of HI (0.52) over the non primed treatment, P_2. Neither the fertilizer combinations nor the interactions had any significant effect on HI.

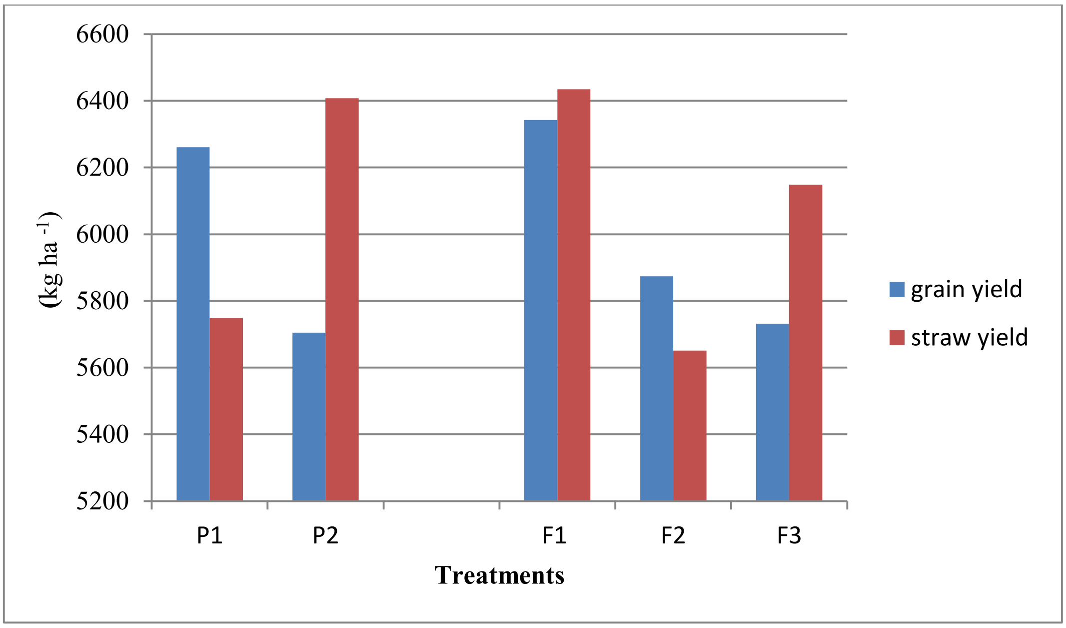

Fig. 2. Effect of priming and fertilizer combinations in grain yield and straw yield of rice (kg ha $^{-1}$)

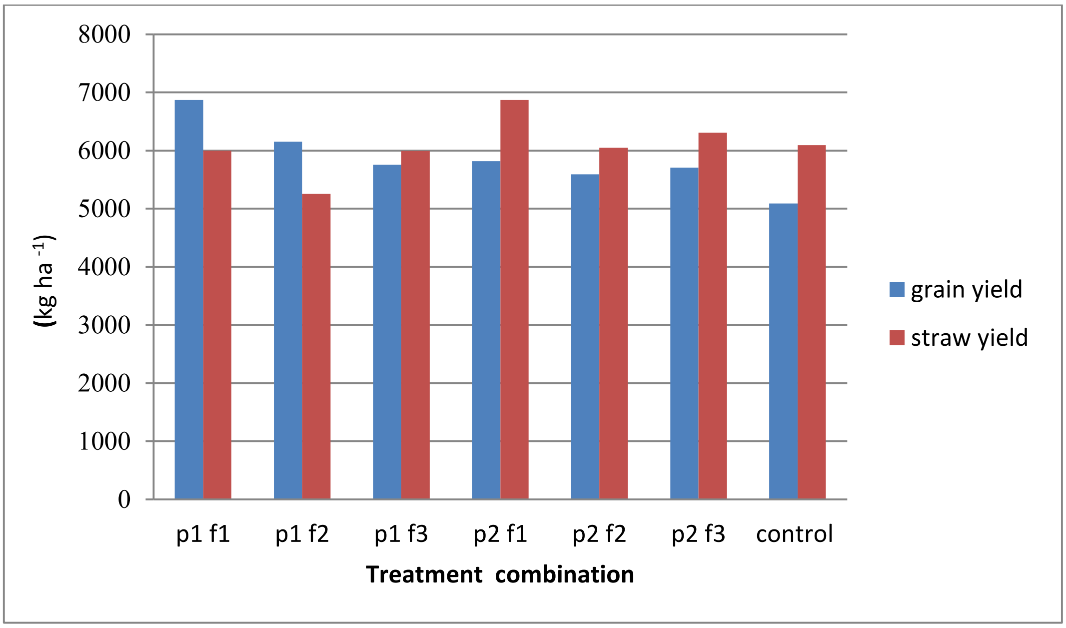

Fig. 3. Interaction effect of seed priming and fertilizer combinations on the grain yield and straw yield of rice (kg ha $^{-1}$)

This is due to the integrated effect of the total dry matter production of the treatments concerned and its partitioning to grain and vegetative parts.

The total dry matter production in the seed primed treatment P_1 was higher than that in the non seed primed treatment P_2, though not to the level of statistical significance. The yield attributes viz., mean number of productive tillers, mean panicle weight and grains panicle^{-1} was numerically higher in treatment P_1 than in treatment P_2. Their combined effect resulted in significantly higher grain yield in treatment P_1 than in treatment P_2. Also the mean number of latent tillers, which contribute only to vegetative yield, was lower in treatment P_1 than in treatment P_2. All this added up to tip the balance towards partitioning a higher proportion of the photosynthate produced to grain than to straw and hence resulted in significantly higher HI in treatment P_1 than in treatment P_2. These results are in line with the findings of Ceesay (2004), Farooq *et al.* (2006), Rehman *et al.* (2006) and Hassanein (2012).

5.3 GRAIN WATER PRODUCTIVITY

The results (data presented in table 9) revealed that the primed seed treatment P_1 had significantly higher grain water productivity (0.77 kg m^{-3}) than the non seed primed treatment P_2. This is because of the higher grain production achieved in the treatment P_1 compared to the treatment P_2 at the same level of water use due to the reasons already discussed in 5.2.9 above.

The water productivity of the fertilizer combinations tried and all the treatment combinations were on par and did not vary significantly.

The control treatment of conventional transplanting had the lowest water productivity and it was significantly inferior to all the SRI treatment combinations. The SRI treatment combination p_1f_1, which recorded the numerically highest water productivity of 0.84 kg m^{-3} was 175 per cent of the water productivity of the control treatment.

This is due to the fact that conventional water management involved continuous flooding of the planted field from planting till ripening that used up

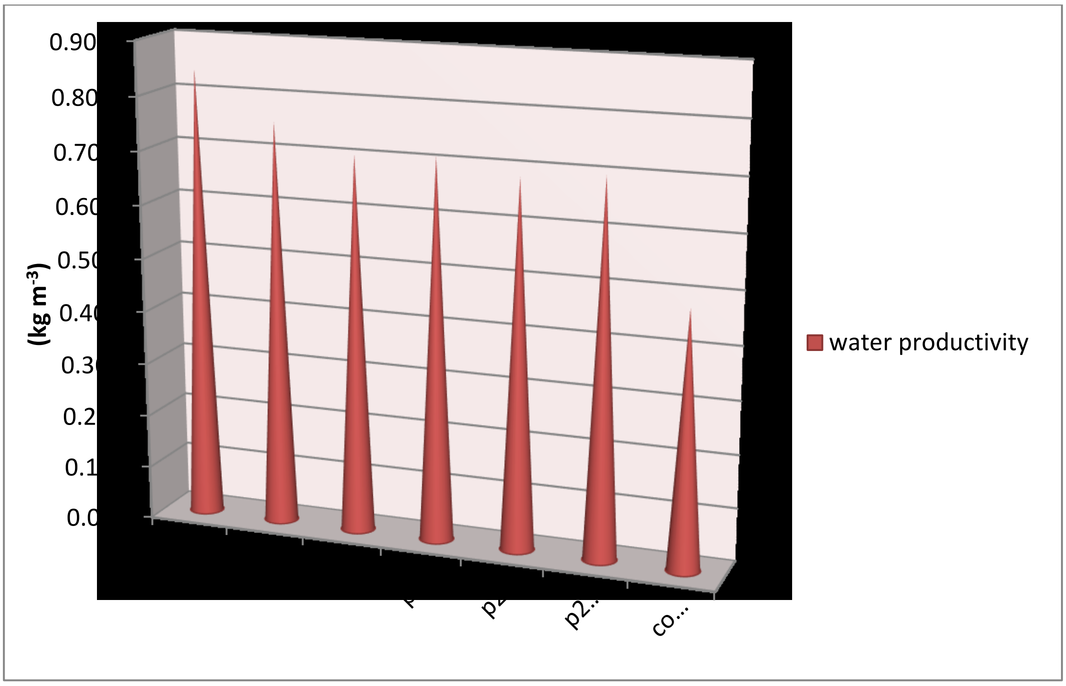

Fig. 4. Interaction effect of seed priming and fertilizer combinations on the water productivity of rice (kg m^{-3})

more water than the SRI technique where saturation moisture is maintained throughout the vegetative growth stage and retained standing water thereafter. This result is in line with the reports of Ramamoorthy *et al*. (1993), Tajima (1995), Belder (2004), Sato and Uphoff (2007), Africare *et al*. (2010) and Vibhu Nayar and Ravichandran (2012).

5.4 PEST INCIDENCE

5.4.1 Leaf roller incidence

The treatment seed priming and fertilizer combinations tried had no significant variation on leaf roller incidence. The interaction effect was also not significant. The control treatment however had significantly lower leaf roller incidence. These results are corroborated by the reports of Batuvitage (2002) and Karthikeyan *et al*. (2008)

5.4.2 Rice bug incidence

The treatment seed priming had no significant impact on rice bug incidence. Fertilizer combinations tried and the interaction also had no significant impact. The control treatment also did not vary significantly with respect to rice bug incidence.

The field condition in all treatments – both SRI and conventional planting- were identical and the pest incidence was over the canopy on emerged panicles.

5.5 POST HARVEST SOIL PROPERTIES

5.5.1 Soil reaction

The results **(**data presented in Table 10) revealed that the soil is highly acidic in reaction. The treatments seed priming (P) and fertilizer combinations (F) had no significant effect on soil reaction. Interaction effect of treatment combination and control treatments also were on par in soil reaction.

This was so because no soil ameliorants were included treatment wise other than the blanket application.

5.5.2 Soil organic carbon

The results (data presented in Table 10) revealed that soil organic carbon was not significantly influenced by the seed priming treatments as it involves no soil treatment.

But the fertilizer combination treatments F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) recorded the highest organic carbon values (1.76) which was on par with F_3 (seventy five per cent of RFD of N, P and K @ 67.5-33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer) and significantly superior to the treatment F_1.

Since treatments F_2 and F_3 involved specific application of vermicompost to supply 30 kg of N there was more organic content in those treatments over the fertilizer treatment alone. More over it indicates that the whole of the applied vermicompost was not completely decomposed during the crop growth period.

The interaction of treatment combination had no significant effect on soil organic carbon content. The control treatment recorded significantly lower organic carbon than the treatment combinations p_1f_2, p_1f_3, p_2f_2 and p_2f_3 which received extra dose of vermicompost as nutrient source to supply N.

These results are in accordance with the reports of Yadvinder Singh *et al.* (1995), Titilola (2006) and Oo *et al.* (2010).

5.5.3 Available Iron in soil

The results (data presented in Table 10) revealed that available iron content was not significantly influenced by any of the treatments or interaction effect of treatment combinations and was on par with that of the control treatment.

This was so because the inherent acidic nature of the soil has a buffering effect on soil Fe content and cause release of ample quantities of Fe in soluble form irrespective of addition or no addition of organic matter to soil.

5.5.4 Available nitrogen in soil

The results (data presented in Table 11) revealed that available nitrogen content in soil was not significantly influenced by the priming treatment.

The on par result of the priming treatment on available post harvest soil N is due to the averaging effect of the treatments over all levels of fertilizer combinations.

The different fertilizer combination treatments significantly influenced the post harvest nitrogen content in soil. The treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded the highest post harvest nitrogen content in soil and it was on par with treatment F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer). Those two treatment had significantly higher available nitrogen content in soil than the treatment F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer)

The crop's requirement of N could be met at levels of RFD, whether supplied entirely through fertilizers or in combination with vermicompost and some amount is left in the soil as residue also. Whereas when N level is limited to seventy five per cent of RFD and that through fertilizer and vermicompost, the quantity available in the soil is absorbed by the crop with little quantity left in the soil as residue. Hence the post harvest N content of the soil was higher in treatments with RFD level of N and significantly lower in treatment with reduced levels of RFD.

The interaction effect of treatment combinations was not significant. The control treatment had soil N content on par with treatment combinations except treatment p_1f_2 and p_2f_3 which had significantly lower soil N content.

The control treatment was given the RFD level of N and hence its parity in post harvest soil N with the above treatment combinations. However the total DMP of p_1f_2 and p_2f_3 were the second highest in the primed seed treatment and non primed treatment combinations. Nitrogen in p_1f_2 was in combination of fertilizer N and as vermicompost. The organic source might not have been fully mineralized and hence the entire released N might have been used up by the crop, thereby leaving little quantity as residue in soil. Similarly the comparatively higher demand of N in treatment p_2f_3, where the total quantity supplied is limited to 75 per cent of RFD, and that too as combination of fertilizer and vermicompost, limited the residual N in soil after harvest. Hence they recorded significantly lower post harvest soil N than the control treatment.

5.5.5. Available phosphorus in soil

The results (data presented in Table 11) revealed that seed priming treatment had no effect on post harvest soil P, whereas the fertilizer combinations had a significant effect. The fertilizer combinations F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) and F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) were on par and significantly superior to F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer) in available soil phosphorus content.

Seed priming treatments did not contribute to any soil nutrient input. However, the seed primed rice hills (P_1) had higher root spread that foraged more of the rhyzosphere phosphorus and resulted in numerically lower post harvest soil phosphorus than the non primed seed treatment (P_2).

The fertilizer combination treatments F_3 (seventy five per cent of RFD @ N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer) also successfully produced grain and straw yield on par with F_1 and F_2 that received 100 per cent RFD. Hence the crop in F_3 treatment used almost the same amount of soil phosphorus as F_1 and F_2 from a lesser supply to the soil. Hence F_3 treatment had significantly lower quantity of post harvest soil phosphorus.

The interaction effect had no significant influence on the post harvest available soil phosphorus. However numerically highest value was recorded by p_2f_1 (23.66 kg ha^{-1}) and the least by p_1f_3 (20.37 kg ha^{-1}) and p_2f_3 (21.13 kg ha^{-1}). The control treatment did not vary significantly with the SRI treatments.

The significantly lower post harvest phosphorus content in soil in the fertilizer combination level F_3 was buffered by the interaction with seed priming treatments under SRI mode of rice cultivation to the level of parity with all other treatment combinations. More over more of phosphorus might have been made available to the treatment combination with f_3 from the soil pool. These results are corroborated by the reports of Benjamin *et al.* (2001) and Singh *et al.* (2007).

5.5.6. Available potassium in soil

The results (data presented in Table 11) revealed that seed priming treatment had no significant effect on post harvest soil potassium, whereas the fertilizer combination treatments had significant effect. The fertilizer combination treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded the highest available soil K and it was on par with F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer). Both were significantly superior to treatment F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer).

The results of post harvest soil potassium showed similar trend as in post harvest soil phosphorus discussed in 5.5.4 above. All the three fertilizer combination treatments produced statistically on par grain yield warranting almost equal removal of K from soil. Hence in treatment F_3 which received only 75 per cent of that in F_1 and F_2, proportionately larger portion of the K supplied was lost through crop uptake leaving significantly lower soil K in the post harvest soil.

There was no significant variation among the treatment combinations in the post harvest soil K. The control treatment was on par with the above SRI treatments, except p_1f_3 and p_2f_3, which had significantly lower soil K content.

Since the treatments p_1f_3 and p_2f_3 were supplied with only 75 per cent of the recommended dose of K, a good portion of it was used by the crop that left only a lesser amount of K in the post harvest soil compared to the treatments that received 100 per cent of the recommended dose of K including the control plot.

5.6 PLANT ANALYSIS

5.6.1 Plant uptake of nitrogen

The results (data presented in Table 12) revealed that seed priming treatment had no significant impact on nitrogen uptake of rice. The effect of the different fertilizer combination treatments and the treatment combination interaction tried was also not significant. However, the primed seed treatment P_1, fertilizer combination treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) and the treatment combination interaction p_1f_1 recorded numerically higher values than the rest. The control treatment recorded the lowest nitrogen uptake but was also statistically on par with the SRI treatments.

The above results closely follow the effect of the treatments and treatment combination interactions on the total dry matter production (grain, straw and roots) at harvest (data presented in table 4). However, the fertilizer combination treatment F_1, that recorded significantly higher total dry matter production over that of F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) and F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer) was only on the average of significance in N uptake.

5.6.2 Plant uptake of phosphorus

The results (data presented in Table 12) revealed that seed priming treatment had no significant impact on phosphorus uptake. Also the different fertilizer combinations tried had no significant impact on phosphorus uptake. The effect of treatment combination and interaction didn't vary significantly in phosphorus uptake. However, the primed seed treatment P_1 and the fertilizer combination treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded numerically higher values than other treatments. The treatment combination p_1f_1 recorded numerically highest uptake values. The control treatment and SRI treatments did not vary significantly in phosphorus uptake.

The above results, as discussed in 5.6.1 above, closely follow the effect of the treatments and treatment combination interactions on the total dry matter production (grain, straw and roots) at harvest (data presented in table 4).

5.6.3 Plant uptake of potassium

The results (data presented in Table 12) revealed that seed priming treatment had no significant impact on potassium uptake by the rice crop. The different fertilizer combinations tried also had no significant impact on K uptake. The treatment combinations also didn't vary significantly in potassium uptake. However the non primed seed treatment P_2 and fertilizer combinations F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded numerically higher values than the other treatments. The treatment combination p_2f_1 recorded numerically highest potassium uptake, among the SRI treatments. The control treatment was also on par with the SRI treatments.

The above results closely follow the effect of the treatments and treatment combination interactions on straw yield of rice at harvest (data presented in table 8).

5.6.4 Plant uptake of iron

The results (data presented in Table 12) revealed that seed priming treatment had no significant impact on iron uptake by the rice crop. Also the different fertilizer combinations tried had no significant effect on iron uptake. The treatment combination interaction effect and the control treatment also did not vary significantly in iron uptake.

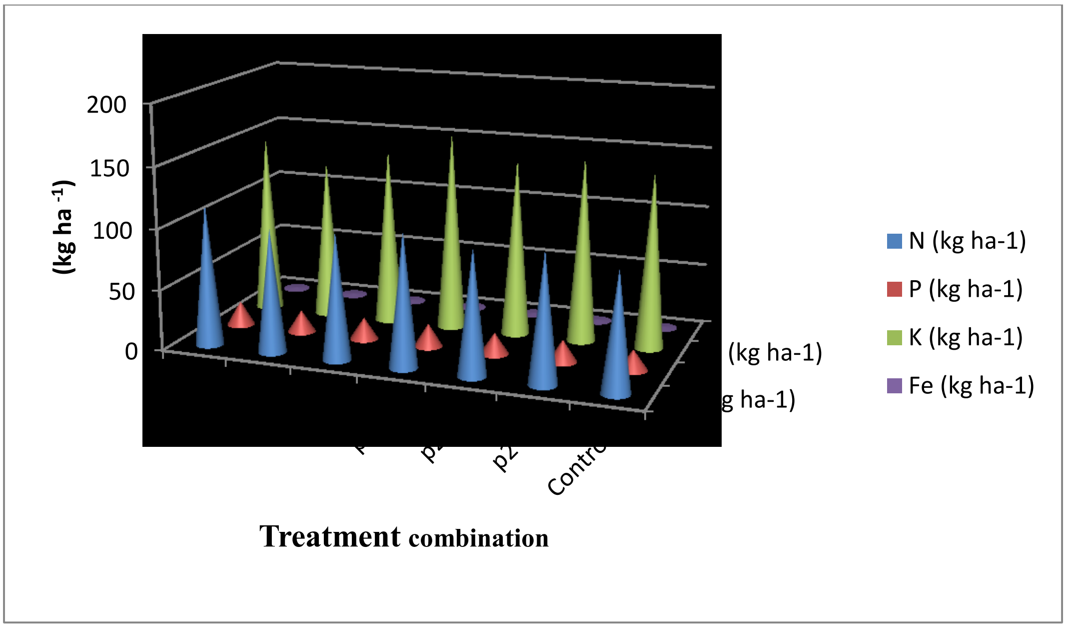

Fig. 5. Interaction effect of seed priming and fertilizer combinations on N, P, K and Fe uptake (kg ha $^{-1}$)

The above results closely follow the effect of the treatments and treatment combination interactions on the total dry matter production (grain, straw and roots) at harvest (data presented in table 4).

5.7. ECONOMIC ANALYSIS

5.7.1. Net income

The seed priming treatment had statistically no significant effect on the net income but yielded an additional income of Rs. 6467/- over the non priming treatment. But the fertilizer combinations tried had significant impact on the net income. The treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded significantly higher value (Rs. 35044) for net income than F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) and F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer). The difference in net profit between fertilizer combination treatments F_1 and F_2 was Rs. 22508/- ha^{-1}.

The numerically lower grain yield and the higher cost of the vermicompost per unit of nitrogen supplied in fertilizer combination treatments F_2 and F_3 resulted in their significantly lower net income compared to the fertilizer combination treatment $F_{1.}$

The variation in net profit among the treatment combinations was not statistically significant. The treatment p_1f_1 recorded the highest net profit of Rs. 41556/- ha $^{-1}$ and yielded additional profit of Rs. 32165/- over p_2f_2 which recorded the least net profit of Rs.9391/- ha^{-1}.

The numerically highest grain yield and lowest cost of production recorded in treatment combination p_1f_1 awarded the highest net income for this treatment. Whereas, the lowest grain yield recorded in the treatment combination p_2f_2 coupled with the high cost of organic input resulted in the very narrow margin in net profit.

The net income of the control treatment of conventional planting (Rs. 16839/- ha $^{-1}$) also did not vary significantly from the SRI treatments. However net income of the best SRI treatment p_1f_1 was 247 per cent of that of the control treatment.

The control treatment recorded the least grain yield and hence the least income. But the adoption of cheaper inputs resulted in comparatively lower cost of production and moderately higher net income.

5.7.2. Benefit cost ratio (BCR)

The results (data presented in Table 13) revealed that seed priming treatment had no significant influence on benefit cost ratio. However different fertilizer combinations tried had significant effect on BCR. The treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded significantly higher benefit cost ratio of 1.53 over the treatments F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) and F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha $^{-1}$ as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer), which were on par. The treatment combination interaction had no significant effect on benefit cost ratio. On comparing the treatment combinations with control, no significant variation was observed.

The results of the benefit cost ratio followed the same pattern as the net income. And hence the reasons for these results are as discussed in 5.7.2 above.

Summary

6. SUMMARY

The present study entitled "Integrated crop management of rice under system of rice intensification (SRI)" was carried out at College of Agriculture, Vellayani during December 2012 to April 2013, to evaluate the efficacy of integrated input management for increasing the soil, crop and water productivity of transplanted rice grown under SRI in an economically viable mode.

The experiment was laid out in Factorial RBD with seven treatments and three replications. The treatments consisted of two levels of seed priming, *viz*, primed seeds (P_1) and non primed seeds (P_2), three levels of fertilizer combinations *viz*, recommended fertilizer dose (RFD) of N, P and K @ 90-45-45 kg ha^{-1} as fertilizers (F_1), RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer (F_2) and seventy five per cent of RFD of N, P and K @ 67.5- 33.75 - 33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer (F_3) and standard check (conventional flooded transplanted rice at 20 cm x 10 cm spacing following POP recommendations).

The priming treatment had no significant influence on growth attributes like tiller $hill^{-1}$ at panicle initiation stage, latent tiller production, leaf area index, relative growth rate, root length and total dry matter production. But it significantly influenced the root dry matter production. The yield attributes like productive tillers, mean panicle weight, mean number of spikelets $panicle^{-1}$ and mean number of grains $panicle^{-1}$ were not significantly influenced by seed priming treatment. However the values of all these yield attributes were consistently higher in the seed primed treatment P_1 compared to the non primed treatment P_2. Grain yield was significantly influenced by seed priming treatment. The seed priming treatment P_1 had no significant effect on straw yield and nutrient uptake. The seed priming treatment had significant impact on water productivity. The treatment P_1 (primed seeds) had significantly higher water productivity.

The treatment priming had no significant impact on net income but yielded an additional profit of Rs. 6467/- over the non primed treatment P_2. The benefit cost ratio though not significantly different was higher in P_1 than P_2.

Fertilizer combinations tried had significant impact on growth attributes like tiller hill^{-1} at panicle initiation stage, latent tiller production, root dry matter production and total dry matter production. The treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizer) recorded significantly higher tiller hill^{-1} at panicle initiation stage and latent tillers at flowering stage. Both treatments F_2 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) and F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer) were on par. Yield attributes like number of productive tillers, and mean number of spikelets panicle^{-1} were significantly influenced by fertilizer combinations. The treatment F_1 (RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizers) had significantly higher productive tillers. The treatments F_2 and F_3 were on par. The fertilizer combination had no significant influence on water productivity. But the fertilizer combinations tried had significant impact on the net income. The treatment F_1 (RFD of N, P and K (90-45-45 kg ha^{-1} as fertilizer) recorded significantly higher net income. The treatment F_2 (RFD of N, P and K 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer) and F_3 (seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer) were on par.

The interaction of treatment combinations had no significant effect on the growth attributes like tiller hill^{-1} at panicle initiation stage, latent tiller production, leaf area index, relative growth rate, root length, root dry matter production and total dry matter production. But the treatment combination p_1f_1 recorded numerically highest value for LAI, root DMP and total DMP. For yield attributes like productive tillers hill^{-1} and m^{-2}, mean number of spikelets panicle^{-1} and grains panicle^{-1} p_1f_1 recorded highest value. The treatment combination p_1f_1 again recorded numerically highest values for water productivity over all the other treatment combinations. Also p_1f_1 recorded highest grain yield. The net return and B: C ratio was highest in p_1f_1.

The control treatment of conventional transplanting recorded significantly lower number of tillers hill^{-1}. Control treatment showed highly significant variation on the number of latent tillers at flowering stage compared to the treatment interactions and produced the least value. LAI of the control treatment was significantly inferior to that of all the SRI treatment combinations. The root length and root volume of all the SRI treatment combinations were significantly superior to that of the control treatment. The control treatment recorded significantly lowest number of productive tillers hill^{-1} compared to the SRI treatment combinations. This treatment recorded a significantly inferior value for mean number of spikelets panicle $^{-1}$. The control treatment recorded the lowest grain yield and was significantly lower than other SRI treatment combinations. However the control treatment didn't vary significantly with the SRI treatment combinations in straw yield. On comparing the SRI treatment combinations with control, no significant variation was observed for harvest index. The control treatment of conventional transplanting had the lowest water productivity and it was significantly inferior to all the SRI treatment combinations. On comparing the SRI treatment combinations with control, statistically significant variation was not observed for net income and benefit cost ratio. However the treatment combination p_1f_1 yielded an additional profit of Rs. 24717/- over the control.

SRI method of rice cultivation can significantly increase productivity, profitability and water productivity over conventional method of transplanting. Nutrient supply in SRI can be successfully practiced economically with chemical fertilizers. Seed priming in combination with recommended fertilizer dose produced the highest B: C ratio of 1.62 compared to 1.25 for conventional transplanting. Source integration for nutrient supply (fertilizers+ vermicompost) did not give any additional yield advantage, but was costlier. There was water savings of 23.3 per cent (2449 m^3 ha^{-1}) in SRI compared to the conventional transplanting. Water productivity in SRI (0.84 kg m^{-3}) was 175 per cent of that of conventional method (0.48 kg m^{-3}). Water management in SRI in acidic soils is conducive for increasing soil acidity and may affect soil productivity.

Recommended integrated crop management for SRI under Vellayani conditions follows

1. Seed priming along with following SRI management practices.
    - Transplanting singly 12 days old seedling raised in mat nursery
    - Spacing 25 cm X 25 cm
    - Intermittent irrigation to keep soil at saturated soil moisture condition through vegetative stage followed by continuous submergence as in conventional planting
    - Mechanical weeding with rotary weeder 3- 4 times at 10 days interval starting from 10th day of transplanting
2. Nutrient supply

   Supply nutrients @ 90-45-45 kg ha^{-1} N, P_2O_5 and K_2O along with basal 5 t FYM. Nutrient supply in SRI need not be solely by organic source.
3. Proper liming of the soil as per soil test data is to be followed as aerobic cultivation increases soil acidity.

Future line of work

Studies on integration of proper scheduling and incorporation of soil ameliorants along with foliar fertilization of N, P and K for further enhancement of productivity of rice under SRI is to be taken up.

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Appendices

APPENDIX- I

Weather parameters during cropping period (December2012 to April 2013)

Standard weeks	Maximum temperature (^0C)	Minimum temperature (^0C)	Maximum relative humidity (%)	Minimum relative humidity (%)	Sun shine hours	Rainfall (mm)
49	30.5	22.6	99	66.3	8.7	0.5
50	30.6	22.1	99	62.4	8.9	0
51	31.1	22.8	91.4	60.3	8.2	0
52	30.5	23.5	99	71.9	7.9	40
1	32.3	23.7	91.4	75.4	9.8	17.5
2	30	22.6	96.4	74.6	8.5	24
3	30.1	20.8	96	75.1	9.4	0
4	30.5	21.3	96.1	73.6	9.4	0
5	30.4	20.8	94.3	75.1	9.3	0
6	31.2	22.9	93.3	74.3	9.2	5
7	32	23	92.4	75.7	9.3	33
8	31.4	21.8	89.9	74.9	9.3	0
9	32	21.4	91.3	67.4	9.5	0
10	32.1	24.3	94.7	80.6	9.3	21
11	32.3	23.9	93.4	81.3	9.3	34
12	32.3	23.7	91.4	75.4	9.8	0
13	32.6	25.3	92.6	76.3	9.9	31
14	32.9	26	92.7	77	9.9	0
15	32.8	25.6	89.9	71.4	9.7	1.5
16	33.2	25.1	84.8	76	10.2	0

APPENDIX- II

Scoring of pests

1. Leaf roller

Scale	Percentage damage
0	No damage
1	<1
3	1-15
5	16-30
7	31-50
9	>51

2. Rice bug

Scale	Percentage damage
0	No damage
1	1-10
3	11-20
5	21-30
7	31-50
9	>50

APPENDIX- III

Average input costs and market price of produce

SI No.	Items	Cost
	INPUTS	
a	**Labour**	
1	Man labourer	Rs. 325day^{-1}
2	Women labourer	Rs. 250day^{-1}
b	**Cost of manures and fertilizers**	
1	Urea	Rs. 6.5 kg^{-1}
2	Factomphose	Rs. 10 kg^{-1}
3	MOP	Rs. 17 kg^{-1}
4	Vermicompost	Rs. 8 kg^{-1}
	OUTPUT	
1	Market price of paddy	Rs.14 kg^{-1}
2	Market price of straw	Rs.2 kg^{-1}

Irrigation data

- Water requirement for SRI plots : 8140 m^3 ha^{-1}
- Water requirement for conventional plots : 10589 m^3 ha^{-1}

INTEGRATED CROP MANAGEMENT OF RICE UNDER SYSTEM OF RICE INTENSIFICATION (SRI)

by

ASHA SASI

(2011 - 11 - 149)

Abstract of the thesis

Submitted in partial fulfillment of the
requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY
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2014

ABSTRACT

The present investigation on “Integrated crop management of rice under System of Rice Intensification (SRI)” was conducted at Department of Agronomy, College of Agriculture, Vellayani during 2012-2013 for evaluating the efficacy of integrated input management for increasing the soil, crop and water productivity of transplanted rice grown under SRI in an economically viable mode.

The experiment was laid out in Factorial RBD with seven treatments and three replications. The treatments consisted of two levels of seed priming, *viz*, primed seeds (P_1) and non primed seeds (P_2), three levels of fertilizer combinations viz, RFD of N, P and K @ 90-45-45 kg ha^{-1} as fertilizers (F_1), RFD of N, P and K @ 90-45-45 kg ha^{-1} as combination of vermicompost to supply 30 kg N equivalent and rest as chemical fertilizer (F_2) and seventy five per cent of RFD of N, P and K @ 67.5- 33.75 -33.75 as combination of vermicompost to supply 30 kg N equivalent and rest as fertilizer (F_3) and standard check (conventional flooded transplanted rice at 20 cm x 10 cm spacing following POP recommendations). The results of the investigation are summarised below.

The growth attributes like tillers hill^{-1} at panicle initiation stage, LAI, RGR, root length and total dry matter production were not significantly influenced by the treatment priming but it significantly influenced the root dry matter production. Grain yield was significantly influenced by seed priming treatment. The other yield attributes like productive tillers hill^{-1} and m^{-2}, mean panicle weight, mean number of grains panicle^{-1}, mean number of spikelets panicle^{-1} and straw yield were not significantly influenced by seed priming.

Fertilizer combinations had significant influence on growth attributes like tillers hill^{-1} at panicle initiation stage, latent tillers at flowering stage, root DMP and total DMP. Yield attributes like number of productive tillers hill^{-1} and m^{-2} and mean number of spikelets panicle^{-1} were significantly influenced by fertilizer

combinations. Fertilizer combination F_1 produced significantly higher number of productive tillers hill^{-1} and m^{-2}.

The treatment combination p_1f_1 recorded highest value for growth attributes like LAI, root DMP and total DMP. For yield and yield attributes like productive tillers hill^{-1} and m^{-2}, mean number of spikelets panicle^{-1} and grains panicle^{-1} p_1f_1 recorded highest value. Also p_1f_1 recorded highest grain yield. The net return and B: C ratio was the highest in p_1f_1.

There was 23.3 per cent savings (2449 m^3 ha^{-1}) in the water requirement of the crop under SRI. Nutrient supply in SRI can be successfully practiced economically with chemical fertilizers. Source integration for nutrient supply (fertilizers+ vermicompost) did not give any additional yield advantage, but was costlier. Seed priming in combination with N, P and K at level of RFD is advantageous as it yielded the highest B: C ratio of 1.62 compared to 1.25 for conventional transplanting. Water productivity in SRI (0.84 kg m^{-3}) was 175 per cent of that of conventional method (0.48 kg m^{-3}). However soil productivity was not favorably influenced as prolonged soil exposure contributes to higher soil acidity problems.

From the study it can be concluded that SRI method of rice cultivation can significantly increase rice productivity, profitability and water productivity over conventional method of transplanting.

സംഗ്രഹം

ഒറ്റഞാർ കൃഷിയിൽ സംയോജിത വിള പരിപാലനത്തെ സംബന്ധിച്ചുള്ള ഒരു പരീക്ഷണം 2012-13 ലെ മൂന്നാം വിളകാലത്ത് കാർഷികകോളേജ് വെള്ളായണിയിൽ നടത്തപ്പെടുകയുണ്ടായി. മണ്ണ്, വിള, വെള്ളം എന്നിവയുടെ ഉല്പാദകത്വത്തെ സാമ്പത്തിക ദൃഷ്ട്യാ അനുയോജ്യമായ സംയോജിത വിള പരിപാലനത്തിലൂടെ ഒറ്റഞാർ കൃഷിയിൽ ആവിഷ്ക്കരിക്കുക എന്നതായിരുന്നു പരീക്ഷണത്തിന്റെ ഉദ്ദേശ്യം.

പ്രസ്തുത പരീക്ഷണത്തിന് ഫാക്ടോറിയൽ റാൻഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന പരീക്ഷണ രീതിയാണ് അവലംബിച്ചത്. 2 തരം വിത്ത് പരിചരണവും 3 തരം വള പ്രയോഗങ്ങളും കൂടാതെ താരതമ്യ പഠനത്തിനായി പരമ്പരാഗത പറിച്ചുനടീൽ കൃഷിയും മൂന്നുതവണ ആവർത്തിക്കപ്പെട്ടു.വിത്ത് പരിചരണം നടത്തിയ വിത്ത് (P1), വിത്ത് പരിചരണം നടത്താത്ത വിത്ത് (P2) എന്നീ വിത്ത് പരിചരണ മാർഗ്ഗങ്ങളും, ശുപാർശ ചെയ്ത അളവിലെ വളപ്രയോഗം (പാക്യജനകം: ഭാവകം:ക്ഷാരം 90:45:45 കിലോ ഗ്രാം ഹെക്ടറാണ്) രാസ വളം ഉപയോഗിച്ച് നൽകുന്നത്. (F1), ശുപാർശ ചെയ്ത അളവിലെ വളപ്രയോഗം ഇതിൽ 30 കി.ഗ്രാം പാക്യജനകത്തിന് തുല്യമായ വളം മണ്ണിര കമ്പോസ്റ്റിലൂടെയും ശിഷ്ടം രാസവളം ഉപയോഗിച്ചു നൽകുന്നത് (F2), ശുപാർശ ചെയ്ത അളവിന്റെ 75 ശതമാനം (പാക്യജനകം: ഭാവകം:ക്ഷാരം 67.5-33.75-33.75 കി.ഗ്രാം ഹെക്ടറിന്) വളപ്രയോഗം ഇതിൽ 30 കി.ഗ്രാം പാക്യജനകത്തിന് തുല്യമായി വളം മണ്ണിര കമ്പോസ്റ്റിലൂടെയും ശിഷ്ടം രാസവളം ഉപയോഗിച്ച് നൽകുന്നത് (F3) എന്നിവയായിരുന്നു പഠന വിധേയമാക്കിയ വളപ്രയോഗമാർഗ്ഗങ്ങൾ.

വിത്ത് പരിചരണം മുഖേന നെല്ലിന്റെ വളർച്ചാ മാനദണ്ഡമായ വേരിന്റെ ഉണക്കുമ്പോഴുള്ള തൂക്കം, നെല്ലിന്റെ വിളവ് എന്നിവയിൽ ഗണ്യമായ വർദ്ധനവ് രേഖപ്പെടുത്തി.

നെൽച്ചെടിയുടെ വളർച്ചാ മാനദണ്ഡങ്ങളായ ചിനപ്പുകളുടെ എണ്ണം, ചെടിയുടെ ഉണക്കുമ്പോഴുള്ള തൂക്കം, വേര് ഉണക്കുമ്പോഴുള്ള തൂക്കം ഇവ താരതമ്യപ്പെടുത്തുമ്പോൾ ശുപാർശ ചെയ്ത അളവിലെ വളപ്രയോഗം രാസവളത്തിലൂടെ നൽകുന്നത് കൂടുതൽ ഫലപ്രദമായി കണ്ടു. മേൽപ്പറഞ്ഞ രീതി നെല്ലിന്റെ വിളവും വർദ്ധിപ്പിക്കുന്നു. കൂടാതെ അറ്റാദായവും വരവ് - ചെലവ് അനുപാതവും ഈ രീതിയിൽ ഗണ്യമായ വർദ്ധനവ് രേഖപ്പെടുത്തി.

ഒറ്റഞാർ കൃഷിയിൽ വെള്ളത്തിന്റെ ആവശ്യകത പരാമ്പരാഗത നെൽകൃഷിയെ അപേക്ഷിച്ച് 23.3 ശതമാനം കുറവും ജലത്തിന്റെ ഉല്പാദകത്വം 175 ശതമാനം കൂടുതലുമാണ്.

പരമ്പരാഗത നെൽകൃഷിയെ അപേക്ഷിച്ച് ഒറ്റഞാർ കൃഷി ഉൽപ്പാദക ക്ഷമവും ലാഭകരവും ആണെന്നതുകൂടാതെ ജലത്തിന്റെ ഉല്പാദകത്വവും വർദ്ധിപ്പിക്കുന്നു. വിത്ത് പരിചരണം നടത്തിയ വിത്തിന്റെ ഉപയോഗവും ശുപാർശ ചെയ്ത അളവിലെ വളപ്രയോഗം രാസവളപ്രയോഗത്തിലൂടെ നൽകുന്നതുവഴിയും ഒറ്റഞാർ കൃഷി കൂടുതൽ ലാഭകരമാണെന്ന് ഈ പഠനത്തിൽ നിന്നും ബോധ്യപ്പെട്ടു.