RESPONSE OF MEDICINAL RICE (*Oryza sativa* L.) cv NJAVARA TO SRI AND OTHER MANAGEMENT SYSTEMS

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DECLARATION

I hereby declare that this thesis entitled "**Response of medicinal rice (Oryza sativa L.) cv Njavara to SRI and other management systems**" is a bonafide record of research work 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, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Response of medicinal rice (Oryza sativa L.) cv Njavara to SRI and other management systems**" is a record of research work done independently by Mrs. S. Rani (2006-21-102) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CONTENTS

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	–	Per cent
°C	–	Degree Celsius
@	–	At the rate of
2,4-D	–	2,4 D-dichloro phenoxy acetic acid
a.i	–	Active ingredient
BCR	–	Benefit-cost ratio
CD	–	Critical difference
cv.	–	Cultivar
DAS	–	Days after sowing
DAT	–	Days after transplanting
et al.	–	And others
Fig.	–	Figure
Fe	–	Iron
FYM	-	Farm yard manure
F.P.	-	Farmers' Practice
g cc	-	Gram per cubic centimeter
G	–	Gram
Ha	–	Hectare
i.e.	–	That is
ICM	-	Integrated crop Establishment Method
K	–	Potassium
Kg	–	Kilogram
M	–	Metre
Me	–	Manganese
Mg	–	Milligram
N	–	Nitrogen
NS	–	Non significant
P	–	Phosphorus
Ppm	–	Parts per million
PoP	-	Package of practices
Rs.	–	Rupees
S	–	Sulphur
SRI	-	System of Rice Intensification
viz.	–	Namely
Zn	–	Zinc

Introduction

1. INTRODUCTION

Rice continues to be the staple food in India and Kerala, and its demand is ever increasing. Rice area in the country increased from 36.46 million hectares in 1960s to 43.76 million hectares in 2007-2008, production from 39.31 million tonnes in 1964-65 to 96.43 million tonnes in 2007-08 and productivity increased from 1078 kg ha^{-1} to 2204 kg ha^{-1} during the same period. The area and production of rice in Kerala was also steadily increasing till the mid seventies touching the peak of 8.81 lakh ha and 13.76 lakh tonnes in 1974-75. From 1974-1975 area and production have been steadily declining to the present 2.29 lakh ha and 5.28 lakh tonnes (2007-2008). But productivity has increased from 1520 kg ha^{-1} to 2308 kg ha^{-1}. Low economic returns from unit area is one of the reasons why farmers are stopping rice cultivation (CMIE, 2009).

Cultivation of specialty rices like medicinal rice which fetches substantially higher prices is more profitable. Kerala has its own medicinal rice variety Njavara, which is being cultivated in limited area for use in Ayurveda. Njavara is widely used for internal consumption as an efficient health food as well as for external application under Panchakarma treatment. Ayurvedic physicians use Njavara for a wide range of ailments including rheumatism, arthritis, cerebral palsy, muscular dystrophy, blood pressure and also for the relaxation and rejuvenation of weak muscles in aged. 'Njavarakizhi' is a kind of 'Pinda Svedam', a warm sweating treatment in which the body is gently massaged with a linen bag containing Njavara grains cooked in milk and a herbal decoction of 'Kurumthotti' (*Sida rhombifolia* var. retusa), after thorough application of oil all over the body. This treatment is very effective for muscle wasting, nerve weakness, rheumatic complaints and reinvigorating the body. 'Njavaratheppu', Njavara rice applied as a paste on the body of the patients for a period of one or two hours, is used for patients who are weak and are not able to be exposed to Njavarakizhi. It is highly recommended against tuberculosis.

'Shashtikathailam' is oil prepared from Njavara bran and is used in nervous diseases, body aches, numbness and wasted muscles due to polio myletes, myopathies and motor neuron diseases (Swaminathan, 2004).

At present Njavara cultivation is confined to some pockets mainly in the northern part of Kerala. No other medicinal rice is used in the world as widely as Njavara is used in Ayurveda (Thomas *et al*., 2006). It is considered as 'God's precious gift to the God's own country'. Production is not sufficient even to meet the indigenous demand. At present, Njavara is exported to a very small extend. Its importance as a health food offers opportunity to establish niche global market (Balachandran *et al*., 2006). Under the conventional management system followed by the farmers this short duration land race is low tillering and low yielding. Increase in the yield of Njavara even in small increments is of great relevance in the present rice production scenario.

Intensification of rice production systems will be required for increasing the productivity of rice and net returns from unit area. System of rice intensification (SRI) techniques which envisages transplanting of younger single seedling in a square pattern at wider spacing are known to increase rice yield (50-100%) with concurrent substantial savings in seed rate (90%) and water requirement (25-50%) in high yielding varieties (Uphoff, 2006). Njavara is a drought tolerant cultivar and cost of pure seeds is as high as Rs.250 per kg. So far no study has been taken up on the response of Njavara to SRI techniques. If these techniques produce the same positive effects on Njavara as on other varieties, the management package developed incorporating these techniques can reduce the cost of cultivation substantially and help the farmers to a great extent. Integrated crop establishment method (ICM) is a farmer friendly management package. It combines recommended practices and farmer's practices. Kerala Farmers' cultivation practices of producing Njavara include broadcasting of pre-germinated seeds, manual weeding, nutrient supply through organic sources and conventional water management.

Njavara is presently cultivated organically under the belief that organically produced rice is of better medicinal quality than inorganically produced one. Organically produced Njavara had the highest protein (33.43 mg g^{-1}) and free amino acid content (0.79 mg g^{-1}) than inorganic Njavara (The Hindu, 2008). Soluble carbohydrates and total free amino acid content of Njavara grains are higher compared to other land races such as Ptb10, Chitteni, Kunjukunju etc. (Nair, 2004). The presence of high content of methionine, which is probably involved in thiamine biosynthesis, appears to contribute to the medicinal quality of Njavara. Both black and yellow glumed Njavara types are physiologically active with high amounts of chlorophyll and carotenoids especially in black glumed Njavara, which is an indication of higher photosynthetic efficiency. (Menon and potty, 1999).

Keeping all the above in view, the present investigation was undertaken to formulate the ideal crop production package for Njavara rice in low lands.

The objectives of the study were

- To study the response of medicinal rice Njavara to nutrient sources under management systems like SRI, ICM, PoP of KAU and Farmers' practice.
- To evolve an ideal crop production package for Njavara rice in lowlands.
- To assess the bio-chemical constituents of organically and inorganically produced Njavara.
- To study the developmental phenology of Njavara under different management systems.

Review of Literature

2. REVIEW OF LITERATURE

Njavara, the medicinal rice is an exceptional rice cultivar in the genus *Oryza* and is indigenous to Kerala. The ancient Indian documents showed that the cultlivar has been under cultivation in Kerala for about 2500 years since the time of Susruta, the great Indian pioneer in medicine and surgery (Kumari, 2004). No other medicinal rice is used in the world as widely as Njavara is used in Ayurveda (Thomas et al., 2006). Under the conventional management system followed by the farmers this short duration land race is low tillering and low yielding. Increase in the yield of Njavara even in small increments is of great relevance in the present rice production scenario. Therefore possibility of improving productivity and quality of Njavara by SRI was studied in the experiment.

The System of rice intensification (SRI) is a revolutionary system of cultivation for increasing rice productivity. It is literally a system or methodology rather than a technology and is a combination of plant, soil, water and nutrient management practices. SRI methodology is reported to promote measurably root growth, with correspondingly observable increase in tillering, resulting in greater grain filling and grain weight. This system is reported to realize rice yields up to 15 t ha^{-1} on relatively poor soils, with greatly reduced rates of irrigation and without external inputs. Inspite of the poor soil fertility, small farmers using SRI methods have obtained average rice yields of 8 to 9 t ha^{-1} (Hirsch, 2000).

Integrated crop establishment method (ICM) is a farmer friendly management package. It combines recommended practices and farmer’s practices. Farmers’ cultivation practices of producing Njavara include broadcasting of seeds, manual weeding, nutrient supply through organic sources and conventional water management. SRI and ICM are two modified systems of rice cultivation which were reported to increase tillering and productivity of several rice varieties. Being medicinal in nature Njavara seed fetches higher price in the market than other varieties of rice. Therefore attempt to increase grain yield in Njavara even to a small extent by manipulating the management system is worth trying. So the present study was undertaken to study the response of medicinal rice (*Oryza sativa* L.) cv. Njavara to SRI and other management systems like ICM, PoP and Farmer's practice when supplied with differed nutrient sources.

2.1 EFFECT OF SEEDLING AGE

2.1.1 Effect of seedling age on growth components

Singh and Singh (1999) reported that transplanting 30 to 45 days old seedlings produced taller plants at maturity than transplanting 60 days old seedlings in short duration variety (Rasi - 115 days) in clay loam soil at Hyderabad during *rabi* season. The reason was that 60 days old seedling remained in the nursery for longer period till it attained maximum tillering stage and transplanting at this stage did not provide sufficient nutrients for vegetative growth, which led to reduction in plant height.

Barison (2002) opined that in SRI appearance of more nodal roots for every newly formed tiller led to a more developed root system which was the joint effect of better soil aeration by different water management practices and transplanting of young seedling. In SRI, transplanting very young seedlings of eight to ten days old and not more than 15 days old registered better tillering and rooting and this was reduced when transplanting was done after the fourth phyllochron usually about 15 days after emergence (Uphoff, 2002; Kumar and Shivay, 2004; Shanmuganathan and Sharmila, 2005).

Mahender (2006) reported that rice seedlings lose much of their growth potential when transplanted beyond 15 days of age and this potential was preserved by early transplanting in SRI. Increase in plant height by transplanting 14 days old seedlings was observed by Gokila (2005) and Sivakumar (2006). Rajani (2006) reported that transplanting

16 day old seedlings produced taller plants compared to 8, 10, 12 and 14 days old seedlings.

Kumari et al. (2008) suggested that recommended stage of transplanting in SRI (8-12days) is not applicable for all the varieties. It may change depending upon the stored food in the endosperm and formation of fourth leaf stage in respective varieties.

2.1.2 Effect of seedling age on yield attributes and yield

Singh and Singh (1999) found that grain yields of 4.92, 4.64 and 4.22 t ha^{-1} could be realized by transplanting of 25, 35 and 45 day old seedlings respectively. Krishna (2000) observed significantly higher yield attributes like panicle length (14.6 cm), productive tillers (385 m^{-2}) and test weight (15.5 g) in a crop planted with 30 day old seedlings as compared to 51 day old seedlings and direct seeding of sprouted seeds.

Devi and Singh (2000) recorded more number of tillers when 20 day old seedlings were transplanted and was comparable with that of 27 day old seedlings and the lowest number of tillers was found in 41 and 48 day old seedlings during *kharif* season in rice variety Norin 18 at Imphal, Manipur, India.

Transplanting younger seedlings preserves the potential for tillering and root growth (Balasubramanian et al., 2005). Anitha (2005) found that planting of single seedling $hill^{-1}$ in straight rows both ways, alternate wetting and drying, early and frequent weeding using a mechanical weeder encouraged the proliferation of microorganisms that symbiotically enhanced the plant capability to produce more tillers, with vigorous and healthy root growth, and a larger number of panicles heavily laden with grains. With a more vigorous root growth, plant get better access to the nutrients and water they need to produce tillers and grains.

As per the recommendation of KAU, 18 day old seedlings in short duration varieties, 20 to 25 day old seedlings in medium duration varieties and 30 to 35 day old seedlings in long duration varieties are transplanted for realizing high yield (KAU, 2007). Transplanting of very young seedlings (14 days old) raised in modified mat nursery with integrated approach of nursery treatment like seed fortification with 1% KCl + Pseudomonas 6 g m^{-2} + powdered DAP 50 g m^{-2} + 0.5% DAP drenching on 9^{th} day + Azophos 20g m^{-2} + VAM 50 g m^{-2} + vermicompost 0.5 kg m^{-2} and transplanting in zig zag pattern (25 x 25 cm) was the best agronomic option for getting higher yield in hybrid rice under SRI technique. (Veeramani, 2007)

Mishra et al. (2008) found that number of panicles per m^2 was 5.2 per cent higher in 12 days old seedlings than that in 25days old seedlings. Similar values for 1000 grain weight and grain yield were 2.2 and 10.6% respectively. Singh et al. (2008) reported that yield attributes such as number of panicles per m^2 (318), fertile grains $panicle^{-1}$ (98.3) and 1000 grain weight (24.76 g) recorded by SRI were significantly better than those in standard transplanting, direct seeding by broadcasing and line sowing by drum seeder.

2.1.3 Effect of seedling age on nutrient uptake

Manoharan (1981) found that N uptake by rice planted with 45 day old seedlings was less than that planted with 25 and 35 day old seedlings. Reddy and Reddy (1991) reported that the uptake of N, P and K by grain and straw were significantly higher when younger seedlings (30 days) were transplanted than older seedlings (45 and 60 days old) in clay loam soil of Warangal. Kumar et al. (1995) opined that N uptake in crops obtained by planting of 25 and 40 days old seedlings were at par during *kharif* season in sandy clay loam soil.

Sahoo and Rout (2004) reported that planting of six week old seedlings had lower utilization efficiency in respect of N, P and K than four and five week old seedlings planted during *kharif* season. Gokila

(2005) reported that transplanting of 14 days old seedlings from dapog nursery recorded increased nutrient uptake than 20 days old seedlings. Increased nutrient uptake by transplanting young seedlings was noticed by several workers (Vijayakumar et al., 2005; Francis and Lokanadhan, 2006; Prema, 2007; Veeramani, 2007).

Salokhe (2008) reported that younger seedlings performed better than older seedlings when transplanted in either flooded or non-flooded soils with greater uptake of nitrogen and manganese than older seedlings.

2.2 EFFECT OF NUMBER OF SEEDLINGS PER HILL

2.2.1 Effect of number of seedlings per hill on growth components

Transplanting single seedling hill^{-1} at a spacing of 20 x 15 cm had been suggested as the general practice but it was location specific (Siddiq, 1995). Ramasamy and Babu (1997) stated that planting less number of seedlings hill^{-1} enabled the plant to produce new tillers which undergoes normal physiological growth resulting in more healthy panicles. Barkelaar (2001) opined that transplanting of single seedling rather than in clumps reduced competition with other rice plants for light and nutrients in soil. General recommendation for rice in Kerala is transplanting two to three seedlings hill^{-1} in rows (KAU, 2007).

Obulamma and Reddy (2002) found that rice hybrid cv.APRH2 planted with one seedling hill $^{-1}$ registered higher dry matter production. Based on experiments in SRI, Uphoff (2002) reported that planting three or more seedlings hill^{-1} retarded growth due to plant competition below and above ground. Planting of single seedling rather than in clumps helped to avoid root competition and promoted vigorous root growth (Uphoff and Randriamiharisoa, 2002).

2.2.2 Effect of number of seedlings per hill on yield attributes and yield

Padhi (1999) and Shrirame et al. (2000) reported that transplanting of two seedlings hill^{-1} produced significantly higher number of total tillers hill^{-1} over one seedling but the harvest index was highest with single seedling hill^{-1}. Rice hybrid cv. APRH 2 planted with one seedling hill^{-1} recorded higher grain yield but it was on par with that of two seedlings hill^{-1} as reported by Dongarwar et al (2002). Similar result was also reported by Obulamma and Reddy (2002) in hybrid rice.

Wang et al, (2002) noticed that the percentage of filled grains and thousand grain weight with one seedling hill^{-1} tended to be higher than with two seedlings hill^{-1}. Nayak et al. (2003) reported that planting of two seedlings hill^{-1} was beneficial with a yield advantage of 8.2 per cent over one seedling hill^{-1}. Singh and Singh (2005) reported that planting of single seedling hill^{-1} performed better in respect of length of panicle, number of grains per panicle, test weight and grain yield as compared to two or three seedlings hill^{-1}.

2.3 EFFECT OF SPACING

2.3.1 Effect of spacing on growth components

Fu et al. (2000) observed that the extended growth period and increased plant height, number of tillers and leaves with increased plant spacing. Shrirame et al. (2000) noticed that the plant height was not affected by spacing in rice, but reducing the plant density resulted in increase in number of functional leaves and maximum leaf area. Jacob (2002) reported that spacing of 20 x10 cm recorded the highest value in terms of plant height, number of tillers hill^{-1}, LAI at panicle initiation stage and dry matter production compared to 15 x 10 cm.

Uphoff (2002) opined that providing a spacing of 25x25 cm (16 plants m^{-2}) or 50 x 50 cm (4 plants m^{-2}) in SRI could ensure optimum care to each seedling, resulting in enhanced tillering. Iqbal (2004) reported that a spacing of at least 22.5x22.5 cm helped more root growth and better tillering in SRI. Islam et al. (2005) noticed increase in tiller number hill^{-1} with increase in spacing, but tiller number per unit area decreased. The full potential of the plant for tillering could be captured by early transplanting and spacing of at least 25 x 25 cm (Uprety, 2005).

Sathish (2006) reported that closer spacing of 20 x 20 cm recorded highest value in terms of LAI, LAD and dry matter production compared to 25 x 25 cm and 30 x 30 cm.

2.3.2 Effect of spacing on yield attributes and yield

Geethadevi et al. (2000) reported that higher grain yield of hybrid rice was obtained with wider spacing of 20 x 10 cm, than with 15 x 10 cm. They also reported significant positive correlations between grain yield and spikelet number per panicle, panicle length, thousand grain weight and weight of panicle. Shrirame et al. (2000) observed that the grain and straw yields were not influenced by spacing in rice. In humid tropic environment, high plant density of rice resulted in excessive vegetative growth. The resulting inter and intra plant competition and low radiation during anthesis and grain filling caused high rate (40-70%) of tiller abortion, delay in flowering of late tillers, low percentage of filled spikelets and low yield, despite a high biomass production (Tuong et al., 2000).

According to Bindra and Kalia (2000), increasing the normal plant stand of 20 x 10 cm by 33 per cent could not exhibit positive effect on grain yield. Crusciol et al. (2000) obtained more number of stalks and panicles per unit area with decreasing row spacing resulting in higher yield.

Vijayakumar (2003) reported that the yield attributes namely panicle length, number of panicles hill^{-1} and total number of grains per panicle were higher when planted at a spacing of 25 x 25 cm in SRI. Yield increase was observed in traditional rice varieties of Kerala when planted at a wider spacing of 20 x 20 cm and 30 x 30 cm (Girijan, 2004). Kumar et al. (2005) noticed that, following a wider spacing of 25 x 25 cm in SRI resulted in yield improvement from the traditional method of rice cultivation in Andhra Pradesh. Rajani (2006) reported that the yield attributes namely number of productive tillers m^{-2}, weight of panicle and number of spikelets per panicle when planted at a spacing of 25 x 25 cm in SRI.

Thavaprakaash et al. (2008) found that the number of productive tillers per hill and grain yield were higher at a spacing of 30 x 30 cm (12.1 t ha^{-1}) followed by 25 x 25 cm (11.7 t ha^{-1}) in ADT 43. Rice hybrid ADTRH-1 planted with spacing of 25 x 25 cm recorded higher yield by 75 and 47 per cent compared to that of random planting and line planting (15 x 10 cm) respectively (Natarajan et al**.,** 2008).

2.3.3 Effect of Spacing on Weed flora

Estornios and Moody (1983) found that under identical management practices, weed dry weight was the lowest at closer spacing. Ghosh and Singh (1996) proved that the reduction of plant density enhanced weed infestation. Singh et al. (1999) reported that among the three spacings tried (10 x 10 cm, 15 x 10 cm and 20 x 10 cm), the weed population increased significantly with increase in spacing.

Lourduraj et al. (2000) found that weed count and weed dry weight were higher under wider planting of 33 hills m^{-2} (20 x 15 cm) compared to closer planting of 50 hills m^{-2} (20 x 10 cm). Yong and Seije (2000) indicated that high planting density of rice was favorable for competing with barnyard grass in paddy fields. Barnyard grass produced more tillers at lower rice density (Guo and Yong, 2001). They also reported that when the rice density was increased, the growth rate and LAI of barnyard grass decreased. Jacob (2002) reported that a spacing of 20 x 10 cm registered the lowest value of total absolute density of weed compared to 15 x 15 cm and 15 x 10 cm spacings.

2.4 WEED MANAGEMENT TECHNIQUES

Weed management is essentially a skillful combination of prevention, control and eradication measures to manage weeds in a crop or environment. The various methods of weed management are grouped under three broad categories: traditional, chemical and biological. Reliance on a single method of weed control such as continuous use of the same or similar herbicides could create serious problems by perennial weeds and may also result in weed shift. So the recent approach in weed management is the development of integrated weed management techniques using a combination of effective herbicides along with other methods without affecting the soil flora and fauna and without any residue problem.

2.4.1 Mechanical weed control

In the recent past weed control is effected more by chemical means supplemented by hand weeding. Increasing demand for labour and escalating cost of agrochemicals together with phytotoxicity effects forced the farming community to think of mechanical measures, which will help the rice production to free itself from the scourge of weed menace with limited labour. Mechanical weeding is generally economical, nonpolluting without residual problems and is relatively safe to the operator as well as to the environment.

Dinesh and Manna (1990) studied the effect of different weed management practices in transplanted rice grown under shallow condition and they found that in summer crop suppression of weeds by hoeing with the use of Japanese rotary weeder two times effectively controlled the weeds and increased the grain yield by 29.7 per cent over no hoeing. In wet season, no response to different hoeing or other weed control methods could be observed due to continuous water stagnation.

Srivastava and Solanki (1993) observed a higher grain yield and N uptake in lowland rice at Jabalpur with the integration of rotary weeding and manual weeding. Singh and Mehta (1998) reported that the use of paddy weeder at 15 DAT produced significantly higher grain yield than three tyne wheel hoe and sweep hoe and was at par with two hand weedings (20 and 40 DAT) in low land transplanted rice in Uttar Pradesh, India. Rotary weeder was effective in controlling the weeds present in inter-row space, but failed to control the weeds in intra-row space or those in the vicinity of the crop (Choubey et al., 1998).

Randriamiharison (2002) reported that mechanical weeding using a hand rotating hoe with small toothed wheels, following a square or rectangular pattern of transplantation in lines, increased the number of pores. So that roots and microorganisms could more easily gain access to oxygen. The tiller production was also significantly higher in the plots where weeding was done using rotary hoe, four times.

Thiyagarajan et al. (2002) reported that incorporation of weeds and disturbance of the soil with a cono weeder significantly increased grain yield to 6.7 t ha $^{-1}$ vis-a- vis conventional weeding practices which yielded 6.1 t ha $^{-1}$. Repeated use of rotating hoe with its wheels that aerate the top horizon of the soil leads to better development of the rice ecosystem (Randriamiharison, 2002). Thiyagarajan et al. (2002) found that mechanical weed control resulted in significantly higher yields of 10 and 3 per cent in wet and dry seasons respectively compared to manual weeding.

Uphoff (2002) emphasized that early and frequent weeding is essential in rice when fields are not covered with standing water. In his view, using a rotary hoe that churns up the surface soil, removes weeds and provides additional soil aeration compared to hand weeding or use of herbicides. He also reported that use of a simple, inexpensive mechanical hand pushed weeder (rotating hoe) developed at IRRI in 1960s would help to serve the purpose. The nutrients are not lost as they are returned to the soil due to decomposition of weeds. Use of a rotary hoe or cono weeder for weeding helped in better soil aeration on the soil surface that promoted vigorous growth and tillering (Uphoff and Fernandes, 2002)

An evaluation of Transformed Rice Cultivaiton (TRC) components revealed that, mechanical weeding + soil stirring by cono weeder significantly increased the grain yield by 1.4 t and 1.2 t ha^{-1} (24 and 22%) at Tamil Nadu Rice Research Station, Aduthurai and SWMRI Research Farm, Tanjavur respectively over the traditional practice of hand weeding (no soil stirring) (Rajendran et al., 2003). Sudhalakshmi et al. (2003) reported a relatively higher uptake of nutrients (N, P, K and Zn) and yield enhancement in rice hybrids under cono weeding.

The incorporation of weed biomass into the soil by cono weeding resulted in enrichment of carbon dioxide near the root zone, increased the biological activity of soil resulting in better nutrient availability in soil and uptake by plants (Iqbal, 2004). Anitha (2005) reported that following a wider spacing 25 x 25 cm and early and frequent weeding using a mechanical weeder encouraged the proliferation of microorganisms that symbiotically enhanced the capacity of plants to produce more tillers, with vigorous and healthy root growth and a large number of panicles heavily laden with grains. Nagarajan (2005) opined that use of rotary weeder not only incorporated the weeds into the soil, but also converted it into good green manure.

According to Saha et al. (2005) mechanical weed control using weeder combined with one hand weeding proved to be more cost effective over hand weeding twice. Kavitha et al. (2008) reported that transplanting of 14 days old seedlings with pre emergence application of pretilachlor @0.75 kg a.i ha^{-1} + one mechanical weeding at 30 DAT reduced weed population and weed dry matter and improved growth characters, yield attributes and yield.

2.4.2 Hand Weeding

The manual method of weed control is laborious, back breaking and time consuming (Mani and Gautam, 1973). Ravindran (1976) pointed out that hand weeding on the 20^{th} and 40^{th} day after transplanting although gave higher yield, the net profit was lower due to increased labour charge compared to herbicide and unweeded treatments.

Chandrakar and Chandrawanshi (1985) opined that hand weeded plots recorded the highest number of panicles per m^2, grain yield and the least dry weight of weeds. Singh (1985) showed that hand weeding provided fairly good control of weeds because weeds from both inter and intra rows are removed, but it was very laborious and expensive.

The cost-benefit ratio showed a negative figure mainly due to very high cost of labour input. Raju and Reddy (1986) reported that hand weeding reduced weed dry weight by 88 per cent. However the re-emergence of sedges could not be avoided by hand weeding (Verma et al., 1987).

Moody (1991) reported manual weeding as the most common method of weed control in rice in Asia. Manual weeding by hand or hand tools is very effective but require more time and labour. Hand weeding registered higher grain yield of rice in a number of experiments (Singh et al., 1992; Singh et al., 1994). Kathiresan and Surendran (1992) observed a higher weed control efficiency of 81.9 per cent by hand weeding twice.

Singh et al. (1992) recorded significantly lower dry weight of weeds, higher weed control efficiency and maximum grain yield under hand weeding twice at 30 and 60 DAT. Prasad et al. (1992) opined that use of herbicide could save upto 75 per cent energy input and increased energy use efficiency than hand weeding. Balasubramanian (1996) pointed out that number of productive tillers in rice was enhanced by hand weeding twice. Pandey et al. (1997) reported that maximum grain yield and net profit of Rs.6704 ha^{-1} was obtained from hand weeded plots. Maximum grain yield was recorded with hand weeding treatment but it was comparable to anilofos @0.3 kg ha^{-1} + one hand weeding. Higher weed control efficiency was also recorded with hand weeding twice (AICRPWC, 1997). Hand weeding was more effective and was the most common tool to control weeds in transplanted rice (Muthukrishnan et al., 1997). According to Rao (2000) manual weeding is effective against annuals and biennials but do not control perennials and is expensive in areas where labour is scarce.

Hand weeding is done by physical pulling out or removal of weeds by hand or removal by hand operated implements like khurpi which resembles the sickle. It is probably the oldest method of controlling weeds and is still a practical method for eliminating weeds from cropped and non cropped lands (Rao, 2000).

Hand weeding continues to be the most common method of weed management in any system of rice culture.

Laxminarayan and Mishra (2001) observed that hand weeding at 15, 30 and 40 DAT resulted in higher crop drymatter compared to anilofos @ 0.4 kg ai ha^{-1}. Two hand weedings at 20 and 40 DAT could control almost all categories of weeds (Bhowmick, 2002). Hand weeding twice recorded the least weed count and highest weed control efficiency (69.9 and 70.1 per cent) during first and second season respectively (Gnanavel and Kathiresan, 2002). Rekha et al. (2002) reported that hand weeding twice at 20 and 40 DAT resulted in lower weed density and dry weight compared to herbicide treatment and unweeded control. Pal et al. (2002) observed that hand weeding twice and ethoxysulfuron + anilofos resulted in higher grain yield and less weed growth. According to Singh et al. (2003) hand weeding at 30 and 50 DAT recorded significantly lower weed population and dry matter accumulation of weeds over weedycheck. Kathirvelan and Vaiyapuri (2003) pointed out that hand weeding (20 and 40 DAT) recorded higher grain yield and straw yield (5.81 and 7.26 t ha^{-1}).

2.4.3 Chemical Weed Control

The weed control efficiency of various chemicals has been studied extensively and many herbicides are now available for rice growers. Several workers have evaluated the bioefficacy of herbicides for weed control in rice and it seems that herbicides will play a major role in controlling weeds in rice culture.

Economic benefits of herbicide application over manual weed control were reported earlier (Rangiah et al., 1975; Versteeg and Maldonado, 1978; Lekshmi, 1983). Chemical weed control is indispensable in rice culture due to severity of weed problem, hike in labour wages and non-availability of labour during peak periods of cultivation. Chemical weed control can be considered as a better alternative to traditional hand weeding. Today the sales of herbicides have outstripped those of all other classes of pesticides.

Currently herbicides constitute 45 per cent of the world pesticide market (Rao, 2000). Rajkhowa et al. (2001) pointed out that application of herbicides increased available N and K due to reduction in nutrient removal by weeds. Corroboratory results were reported by Jacob (2002) and Seema (2004). Narwal et al. (2002) explained that all herbicidal treatments gave significantly higher yield and better yield attributes than weedy check. Sharma et al. (2003) observed that all herbicidal treatments significantly reduced the density and dry weight of weeds over weedy check. Integrated weed control gave significantly more yield (3.7 t/ha) than chemical weed control (Gill and Singh, 2008).

2.5 WATER MANAGEMENT PRACTICES

2.5.1 Water management practices on growth and yield attributes

Hirasawa (2001) found that early leaf senescence at ripening stage and water stress around midday decreased the rate of photosynthesis in leaves, causing the lower NAR. These physiological responses of the plants were responsible for the reduction in the dry matter production and grain yield in the intermittent irrigation treatments. Sepaskhah and Maftoun (2004) found that intermittent flooding irrigation at 2-day intervals was as effective as continuous flooding for grain yield, showing high water use efficiency (WUE).

Xu-FengYing et al., 2005 reported that SRI improved rice quality, increased the rate of milled and head milled rice, and reduced the percentage of chalky kernel and chalkiness. Plants grown under SRI recorded higher chlorophyll content, resulting in higher photosynthetic rate and photosynthate contents, slow senescence and high rate of transport of dry matter from the stems and sheaths to the panicles during the grain-filling period.

XueMing (2005) reported that root activity, leaf chlorophyll content, N absorption, dry matter accumulation at the late growth stage, yield and water use efficiency were greater under intermittent irrigation than under flooded irrigation. Under dry cultivation, root activity and leaf chlorophyll content were also increased, but N absorption, dry matter accumulation at the late growth stage, total number of spikelets, number of effective tillers and yield were much lower than those under flooded irrigation. Tabbal et al, (2005) found that water stress reduced total chlorophyll and to increase proline contents as well as total soluble sugar of the two wheat cultivars. [T. durum]) cultivars (Hourani and Petra).

XueMing (2005) observed that under dry cultivation, root activity and leaf chlorophyll content were increased, but N absorption, dry matter accumulation at the late growth stage, total number of spikelets, number of effective tillers and yield were much lower than those under flooded irrigation. Controlled irrigation with farmers' fertilizer rates resulted in higher yields than uncontrolled irrigation supplemented with recommended fertilizer rates or farmers' fertilizer rates (Kundu and Kannan, 2007)

Geethalakshmi et al. (2008) suggested that cultivation of rice through SRI increased the grain yield by 5%, saved water by 14.5% and increased water productivity by 19.4% compared to conventional method of rice cultivaiton under wet land ecosystem. Krishnaji et al. (2008) pointed out that water use efficiency was 8.16 kg/mm under SRI and 5.84 kg/mm in conventional method with a saving of 47.6 per cent. Tabbal et al. (2005) found that water stress reduced total chlorophyll and increased proline contents as well as total soluble sugar of two wheat cultivars. [T. durum]) (Hourani and Petra)

Kushwaha (2008) found that the second transplanting on 30 June with 120 kg N ha^{-1} and irrigation at 3 days after disappearance of ponded water is most suitable for Pusa Sugandha-3. Compared with continuous flooding, intermittent irrigation delayed tillering by 5-7 days, reduced the leaf transpiration rate, and enhanced the leaf photosynthetic rate and leaf area index, thus, improving water use efficiency. The leaf transpiration rate declined more rapidly than the photosynthetic rate and water use efficiency was relatively higher under semi-dry cultivation.(JinPing, 2008).

GuiBin (2009) observed that the values of internode plumpness of rice stem under controlled irrigations were bigger than that under regular irrigation, and the values of wall thickness of rice stem under controlled irrigation much superior to that under regular irrigation by 0.15 and 0.35 mm. He also pointed out that the values of rice stem coefficient under controlled irrigations were lower than that under regular irrigation. Therefore, the rice stem under controlled irrigation is much better in lodging resistance.

2.5.3 Water management practices on weed growth and biomass

Tuong et al, (2000) found that genotypes with high tillering ability were more competitive against weeds. Weed population and growth were generally higher during the rainy season than the winter season. Irrigation at 5 cm depth one day after disappearance of ponded water in transplanted rice recorded the lowest number and dry weight of weeds and lower water regimes recorded the maximum weed population and biomass (Balasubramanian and Krishnarajan, 2001). Subbulakshmi and Pandian (2002) reported that continuous submergence at a depth of 5 cm reduced weed density and dry matter due to reduced weed population caused by possible inhibition of weed germination.

In the wet season (WS), deep water (5 to 7 cm) introduced at 8 days after sowing (DAS) fairly controlled the weeds without affecting seedling emergence. In the dry season (DS), Pretilachlor at 1.5 lit/ha sprayed at 3 DAS controlled the weeds in both the continuously flooded and intermittent irrigation treatments. (Javier et al., 2005). Dutta et al. (2005) reported that continuous submergence of 5+ or -2 cm depth of water considerably reduced the weed crop competition, and increased the grain yield and decreased the dry matter production of total weeds over irrigation 3 days after disappearance of ponded water in hybrid rice.

2.6 EFFECT OF ORGANIC MANURES ON THE GROWTH AND YIELD OF RICE

2.6.1 Effect of organic manures on growth attributes

Incorporation of organic residues @ 10 t ha^{-1} could influence the DMP in rice at maturity stage (Subbaiah et al., 1983). Sharma (1994) opined that plants with FYM application were taller with more tillers and dry matter than those grown without FYM. Significant increase in plant height, LAI and dry matter accumulation in medium duration rice variety Pavizham with FYM @ 10 t ha^{-1} has been reported by Babu (1996). According to Sudha (1999) different levels and sources of organic manure application had no significant effect on LAI at any stage of growth of rice but showed significant influence on DMP at all growth stages of rice.

Singh et al. (2000) reported that application of FYM @ 6.5 t ha^{-1} on dry weight basis increased the root length and root density significantly over control. Bridgit and Potty (2002a) stated that raising of FYM levels increased the root number per plant and average root length and thereby paved way for improved crop growth.

Application of FYM @ 10 t ha^{-1} produced better growth in terms of taller plants and more dry matter accumulation (Singh et al., 2002). The favourable effect of organic manures in improving the growth attributes of rice has also been reported by Kumar et al. (2002) and Mahavishnan et al. (2004).

2.6.2 Effect of organic manures on yield attributes

Prakash et al. (1990) observed that the considerable reduction in the chaff percentage of rice due to organic manure addition. FYM as a source of organic manure was effective in increasing the number of panicles m^{-2} in rice (Zia et al., 1992). Sharma and Sharma (1994) and Rathore et al. (1995) observed that significant higher grain number $panicle^{-1}$, panicle number m^{-2} and thousand grain weight in rice with FYM application. But Ranwa and Singh (1999) and Dwivedi and Thakur (2000) reported that organic manure application had no significant effect on thousand grain weight.

Sudha (1999) observed that organic manure application at different levels and through different sources could not produce any significant impact on the total and filled grains $panicle^{-1}$ in rice. Pandey et al. (2001) observed the beneficial effect of organic manures in influencing the panicle weight of rice.

Bridgit and Potty (2002b) observed significant influence of FYM in increasing the number of filled grains and filling percentage.

2.6.3 Effect of organic manures on Yield

2.6.3.1 Grain yield

Kuppuswamy et al. (1992) observed that application of FYM @ 10 t ha^{-1} increased the grain yield to 7.33 t ha^{-1} from 6.61 t ha^{-1} and also significantly enhanced the straw yield. Sharma and Mittra (1992) and Zia et al. (1992) reported that higher grain yields of rice with organic manuring through FYM. Anilkumar et al. (1993) reported that continuous application of cattle manure alone in the first crop season gave 24 per cent more yield than the complete chemical fertilizer source. Brar and Dhillon (1994) observed that the grain yield of rice reached up to 6.7 t ha^{-1} using 4 t ha^{-1} of FYM as against 4.1 t ha^{-1} in control plot.

Sharma (1994) observed 26 per cent increase in yield of rice with the application of 10 t ha^{-1} of FYM. Sharma and Sharma (1994) also obtained significantly higher grain yields of rice through FYM incorporation. There was a linear increase in the yield of rice with the increasing levels of FYM, the maximum being with FYM at 10 t ha^{-1} (Tiwari et al., 2001).

Natarajan et al. (2005) observed that application of 75 kg N ha^{-1}as FYM and 25kg ha^{-1}as neem cake gave the highest grain yield of rice (5.02 t ha^{-1}) and milling recovery (74.7%).

2.6.3.2 Effect of organic manures on straw yield and harvest index

Singh and Verma (1990) reported that application of FYM at the same level of fertilizers increased the grain and straw yields significantly as compared to the grain and straw yield recorded without FYM. Sharma and Sharma (1994) reported significant increase in the straw yield of rice with FYM incorporation. Babu (1996) could observe significant increase in the straw yield of rice variety Pavizham with FYM addition @ 10 t ha^{-1}. However, he could not observe any significant impact on harvest index.

Hemalatha et al. (2000) reported that the incorporation of dhaincha at 12 t/ha increased the straw yield of rice compared to sunnhemp and farmyard manure. Sindhu (2002) reported that different levels and sources of organic manures could not significantly influence straw yield and harvest index. Tulasi (2007) reported that application of 100% fertilizer substitution with FYM gave the highest straw yield (3.01 t/ha) than 50% fertilizer substitution with FYM.

2.7 EFFECT OF ORGANIC MANURES ON NUTRIENT UPTAKE AND AVAILABLE NUTRIENT STATUS OF THE SOIL

2.7.1 Effect of organic manures on nutrient uptake

Rao and Prasad (1980) observed that neem cake + urea reduced leaching losses of nitrogen. It was also shown to reduce NH_3 volatilization losses and thus improve the nitrogen use efficiency. Tiwari et al. (1980) reported an increase in the nitrogen uptake due to application of organic manure application. Varma and Dixit (1989) and Sharma and Mittra (1991) reported that in rice based cropping systems incorporation of FYM with or without chemical nitrogen, increased the NPK uptake in rice.

Rathore et al. (1995) reported that application of organic manures including FYM could increase NPK uptake in rice. Tiwari et al. (2001) reported that the concentration of N,P and K in grain and straw increased significantly with the application of FYM@ 5 t ha^{-1}.

Application of 10 t of FYM ha^{-1} to *Rabi* crops (potato, mustard and wheat) in rice based cropping systems could supplement 25 percent NPK requirement of all component crops and increased the uptake of N, P and K by the crops (Khanda et al., 2005). Khan et al. (2006) observed that the application of FYM increased the total nitrogen uptake and attributed it to the favourable effects of organic manures on the physico-chemical properties of the soil

2.7.2 Effect of organic manures on available nutrient status of the soil

Muthuvel et al. (1990) reported higher available N contents of soils under FYM application. Waghmer (1998) reported higher available NPK content in soil with the application of FYM @ 10 t ha^{-1}. Considerable improvement in available N status of soil due to the application of FYM has been reported by Gupta et al. (1998). Chellamuthu et al. (1998) found that K availability in soils increased significantly by FYM application.

Application of organic wastes, irrespective of the sources recorded higher available K status of soil over no organics (Chithra and Janaki, 1999). Sudha (1999) reported that organic manure addition at different levels could maintain the available N, P and K status of soil well above the original status before the experiment.

Charjan and Gaikwad (2005) stated that application of nutrients through organic manures reduced the losses of nutrients and ultimately increased the NPK balance of the soil. Roul and Mahapatra (2006) reported a continuous supply of nitrogen by organic manures and tying up of inorganic soil nitrogen, preventing its loss through denitrification, volatilization or leaching. Further, nitrogen enriched manures maintained a higher level of available N and P in soil for a longer period than fertilizer alone. They also found that cattle manure improved the organic carbon, P and K contents of soil. Khan et al. (2006) also reported an enhanced soil nitrogen supply due to FYM application. Misra and Chandra (2007) reported that application of organic manures improved the physical and chemical properties of soil.

2.8 EFFECT OF INM ON GROWTH AND YIELD

Integrated nutrient management involves the judicious use of organic, chemical and / or microbial sources so as to sustain optimum yields and to improve or sustain the soil health to provide crop nutrition packages which are technically sound, economically attractive, practically feasible and environmentally safe (Ahlawat, 1997).

2.8.1 Effect of INM on growth attributes

Mathew et al. (1994) observed that higher plant height and tiller count in rice with the combined use of FYM @ 10 t ha^{-1} along with chemical fertilizers. Peeran and Sreeramulu (1995) found that application of FYM along with urea gave significantly taller plants than urea alone. Babu (1996) observed that integration of FYM @ 10 t ha^{-1}along with chemical fertilizers could increase the plant height, tiller count, LAI and DMP of rice.

Singh et al. (2000) opined that the combined application of FYM @ 6.5 t ha^{-1} and recommended dose of NPK (120:60:40 kg N, P_2O_5, K_2O) produced almost double the root mass than NPK alone. The growth parameters *viz*., plant height, number of tillers and dry matter content were significantly improved by the application of 100 per cent RDN through urea + 25 per cent RDN through FYM. This was attributed to the adequate quantity of nitrogen made available to the crop, which in turn favored vigorous and luxuriant growth.

Application of organic manure promoted growth of rice by increasing plant height (Bayan, 2000). Jha et al. (2004) reported that the application of inorganic fertilizers at 30:20:15 kg NPK ha^{-1} in combination with cow - dung urine mix at 3 t ha^{-1} significantly increased the plant height. The growth was more with NPK + FYM as compared to 100 per cent NPK. Organic manures in combination with inorganic fertilizers were superior to application of inorganic fertilizers alone, in promoting growth of rice (Ganapathy et al., 2006).

2.8.2 Effect of INM on yield attributes

Mathew et al. (1994) and Mondal et al. (1994) observed an increase in panicle number m^{-2}, grain number $panicle^{-1}$ and thousand grain weight in rice with 10 t ha^{-1} FYM along with chemical fertilizers. Singh et al. (1998) noted an increase in the grain number $panicle^{-1}$ and thousand grain weight of rice with high NPK rates along with 7.5 t ha^{-1} FYM. Panicle length, number of filled grains $panicle^{-1}$ and 1000 grain weight increased significantly due to combined application of 100 per cent RDN through urea + 25 per cent RDN through FYM (Dwivedi and Thakur, 2000).

Bastia (2002) reported that the number of panicles m^{-2}, weight $panicle^{-1}$, total grain $panicle^{-1}$, filled grains $panicle^{-1}$, test weight and grain yield were maximum for the treatment, FYM (5 t ha^{-1}) + half the RD of fertilizers (30:15:15 kg NPK ha^{-1}). Incorporation of composted coir pith @12.5 t ha^{-1} along with inorganic fertilizers increased the productive tillers $hill^{-1}$, grains $panicle^{-1}$and test weight of rice (Parasuraman et al., 2003).

2.8.3 Effect on yield

2.8.3.1 Grain yield

According to the increased tiller number, panicle m^{-2}, panicle length and grains per panicle observed under integrated nutrition lead to increased grain and straw yields (Dixit and Gupta, 2000 ; Pandey et al., 2001). The results of a long term trial in a rice-rice cropping system in Kerala, Orissa and Andhra Pradesh revealed that the application of 25-50 percent fertilizers in organic form gave the best yield stability (Katyal et al., 2000). Raju and Reddy (2000) found that application of 50:50 and 75:25 (compost N: inorganic N) produced 8.5 percent and 5.7 percent more rice grain yield than 100 per cent inorganic N.

Singh et al. (2000) observed that FYM with recommended dose of NPK (120:60:40 kg ha^{-1}) gave the highest grain yield. Combined application of FYM contributed to yield increase of up to 50 percent than recommended NPK. Sindhu (2002) observed that a fertilizer dose of 90:45:67.5 kg NPK ha^{-1} with 50 percent N applied as FYM and 50 percent as chemical fertilizer could be recommended for maximizing yield in basmati rice.

Higher yield and N uptake in rice crop could be achieved by the combined application of 100 percent RDN through urea + 25 percent RDN through FYM (Mrudhula et al., 2005). Barik et al. (2006) observed that the highest grain and straw yields were obtained in crops under 50 percent recommended fertilizer dose along with 10 tonnes of vermicompost per ha, which was significantly higher than 100 percent recommended NPK fertilizers. Application of organic manures was reported to maintain soil fertility and to sustain higher crop yield levels in rice-rice crop sequence.

Panda et al. (2007) reported that higher yield was obtained in the NPK + FYM treatment and also concluded that balanced use of N, P and K fertilizers in conjunction with FYM was the best nutrient management option for obtaining higher and sustainable rice yield and for promoting soil health.

2.8.3.2 Straw yield

Babu (1996) observed that significant increase in the straw yield of medium duration rice variety Pavizham up to 7.3 t ha^{-1} by the combined use of organic manures and inorganic fertilizers. Maximum straw yield for rice variety Kanchana was obtained during *Kharif* season through an integrated management, which provided 50 percent recommended N through FYM and the rest through NPK fertilizers (Deepa, 1998; Pandey et al., 2001). Lower straw yields by FYM treatments than 50 percent FYM + NP treatment have been reported by Sengar et al. (2000).

Solunke et al. (2006) reported a significant increase in the straw yield and biological yield of basmati rice with FYM addition @ 5 t ha^{-1} + 100% recommended dose of fertilizer (75:37.5:37.5 kg NPK/ha) than other integrated nutrient management.

2.9 EFFECT OF INM ON NUTRIENT UPTAKE AND AVAILABLE NUTRIENT STATUS OF THE SOIL

2.9.1 Effect of INM on nutrient uptake

Combined use of organic manures and inorganic fertilizers was found to be significantly better than inorganic fertilizers alone for N uptake (Pandey et al., 2001). Singh et al. (2001a) reported that the available soil N in case of 100 percent N treated plots was higher than urea + FYM plots after rice harvest. But the organic carbon trend was reverse. The authors also found that substituting 50 percent of the recommended N through various sources like FYM and green manure did not show any significant variation in the total uptake of N, P and K by rice.

Sujathamma et al. (2001) recorded the highest P uptake with 25 percent substitution with organic source. Ranjini (2002) reported that the highest uptake of nitrogen and potassium registered when 90 kg N ha^{-1} was applied with 25 percent substitution through vermicompost whereas maximum phosphorus uptake was obtained upon the application of 90 kg ha^{-1} with 50 percent substitution through vermicompost. Sindhu (2002) could not observe significant difference in the NPK uptake with different sources and levels of nitrogen.

Chettri and Mondal (2005) reported that N, P and K uptake was highest when the rice crop was fertilized with 75 percent of the recommended dose of N, P and K through chemical fertilizers along with 10 t ha^{-1} FYM applied at both *Kharif* and *Boro* seasons.

2.9.2 Effect of INM on available nutrient status of the soil

FYM used alone or in combination with chemical fertilizers improved the available N and P status of soil than the initial status (Sengar et al., 2000). Singh et al. (2001b) observed a slight increase in the available N status of soil, by incorporating either total or part of N through organic sources as compared to N applied solely through prilled urea.

Katyal et al. (2001) showed that application of FYM at 5 t ha^{-1} in addition to RD of nitrogen @ 120 kg ha^{-1} tended to increase the available soil P and K. While Sindhu (2002), in her study with different sources and levels of nitrogen in basmati rice, observed significant variation in the available K status of the soil, whereas, the available N and P remained unaffected. Selvi et al. (2003) reported that the total nitrogen content, exchangeable Ca and Mg, available P and available K increased in plots receiving combined application of 100 percent NPK (90:45:45 kg ha^{-1}) + FYM (10 t ha^{-1}). Increase in organic carbon and available phosphorus was pronounced in the treatments receiving organic manures in combination with chemical fertilizers (Reddy et al., 2006).

2.10 EFFECT OF NUTRIENT SOURCES ON NUTRITIONAL QUALITIES OF GRAIN

Unnever et al. (1992) reported that rice grain quality was a multi dimensional character, composed of many components such as eating quality, cooking quality and nutritional quality. Veenapal and Pandey (2000) could not observe any definite trend in the rice quality with the application of different sources of nutrients. According to the farmers' perception, organic manures produce grains of better quality compared to inorganic (Singh and Singh, 2003). Organic farming has been reported to favorably affect the rice qualities under long term application (Dhiman et al., 2003). Integrated nitrogen management resulted in higher values of quality parameters as compared to control (Adhikari et al., 2005).

2.10.1 Effect of nutrient sources on crude protein of rice grain

In tropical Asia, rice is the single and most important source of protein because major part of the diet is comprised of rice or rice based products. Hence protein of rice was considered as an indicator of its nutritional quality (Juliano, 1978). The protein of rice is one of the most nutritious among all the cereals. In milled rice protein content was relatively low (about 7% at 14% moisture). A large portion of the total variability in protein was attributable to environment.

Sikka et al. (1993) found that with increasing doses of nitrogen fertilizer, there was an increase in protein content. Devi et al. (1997) stated that proteins present in food were a mixture of several fractions and each fraction varied in its solubility. Pillai (1998) observed higher crude protein in rice, with 75 percent of the recommended dose of nitrogen as inorganics and 25 percent as FYM. Hemalatha et al. (1999) reported that incorporation of organic fertilizers along with the application of inorganic N significantly increased the crude protein content and optimum cooking time of rice grains.

Hemalatha et al. (2000) observed higher crude protein content in rice grains from plots treated with organic manures *viz*. FYM, dhaincha and sunhemp, than control plots. They also reported that incorporation of organics increased the optimum cooking time of rice over control and the highest value was recorded by the incorporation of dhaincha @ 12 t ha^{-1}. Sources of nitrogen did not produce any significant difference in the protein content of rice (Sindhu, 2002). In Njavara grains protein content ranged from 9.47 to 13.39 per cent (Reddy, 2000). He classified Njavara genotypes into three groups based on protein content in grain viz.,low (up to 10 per cent), medium (10 to 12 per cent) and high (>12 per cent). Majority of the Njavara genotypes expressed high protein content (9.24 to 13.39%) than Ptb-10 (9.43%) (Kumar, 2006).

2.10.2 Effect of nutrient sources on free amino acids

Cagampang et al. (1982) inferred that the concentration of free aminoacids in the developing grain of high protein lines was higher than that in the grain of lines low in protein. During the embryo differentiation stage, free amino acids in rice were dominated by serine, alanine, aspartate and glutamate, whereas, in the maturation stage serine, alanine, arginine and lysine were the main components constituting free amino acid content (Zhang and Tang, 1986).

Njavara cultivars grown under wetland conditions exhibited free amino acid contents of 0.316 mg g^{-1} in black glumed type and 0.089 mg g^{-1} in golden yellow glumed type (Menon et al., 1997). Black glumed Njavara contained the amino acids DL-2-amino-n-butyric acid and DL-iso-Ieucine while, golden yellow glumed Njavara contained L-Histidine monochloride, L-ornithine monochloride and DL-iso-Ieucine.

Menon and Potty (1999) reported that black-glumed and yellow glumed Njavara had an inverse relationship between yield and quality. The black-glumed plant type had a special capacity to absorb Mn and translocate it to the grain. This type had higher quality but with a very low productivity. The golden yellow-glumed plant type, though inferior in quality, was superior in yield, and did not have this Mn preference. There was a relationship between Mn accumulation and amino acid synthesis.

The free amino acid content in Njavara grains ranged from 0.090 mg g^{-1} to 0.190 mg g^{-1}. Free amino acids coupled with soluble carbohydrates may be contributing to the production of active protein and secondary metabolites (Reddy, 2000).

2.10.3 Effect of nutrient sources on total starch, Amylose and Amylopectin

Indian varieties were generally high amylose types (Lin et al. 1969 and Sharma, 1989). Raghavaiah and Kaul (1970) reported that varieties grown in plains had higher amylose content. High amylose content was a dominant and highly heritable character (Govidaswami and Gosh, 1972). The Japonica varieties of temperate regions had low amylose content. Intermediate amylose rice is the preferred type in most of the rice areas of the world (IRRI, 1979). Singh (1993) stated that starch is a mixture of amylose and amylopectin. Starch, the nutritional reservoir in rice exists in two different forms; amylose, the unbranched type of starch with glucose residues with 1-4 linkage and amylopectin, the branched form with 1-4 and 1-6 cross linkage makes up the remainder of the starch (Aberg, 1994). Degree of flakiness and volume expansion were observed to be determined by amylose content (Chikkalingaiah et al*.,* 1997). Juliano (1998) reported starch as the major constituent of rice and as such, starch and protein accounted for 98.5 percent of the constituents of milled rice.

In the waxy rice, amylose is almost absent. Such rice does not expand in volume, are glossy and sticky and remain firm when cooked (Cruz and Kush, 2000). Nonwaxy rice may have high (25 to 30 per cent), low (10 to 20 per cent) or intermediate (20 to 25 per cent) amylose content. Amylose content ranged from 9-37 percent in the starch, corresponding to 63-91 percent amyopectin. Amylose content was therefore regarded as an index of amylose/ amylopectin ratio (Dela and Khush, 2000). The protein and amylose content varied significantly with the application of FYM in conjunction with chemical fertilizers (Reddy and Reddy, 2003).

Mandoza (2004) reported that grain protein content increased with increasing amount of N applied, and with a delay in the N dressing date at the mid-growing stage. Grain starch viscosity was significantly affected by the different N rates applied during the mid-growth stage, but not by the different N dressing dates. Most of the Njavara genotypes tested had intermediate amylose content (18.88-23.27%) and Ptb10 had 24.43% amylose. So they had consumer preference (Kumar, 2006).

2.11 EFFECT OF NUTRIENT MANAGEMENT ON SOIL ENZYMES

Inorganic fertilizers, especially nitrogen (N), phosphorus (P) and potassium (K) not only serve to maintain or improve crop yields, but their application also directly induces changes in soil chemical, physical and biological properties. These changes in the long term are believed to have significant influences on the quality and productive capacity of the soil (Acton and Gregorich, 1995).

Dehydrogenase activity was highly sensitive to the inhibitory effects associated with large amount of fertilizer additions (Simek et al., 1999). Fertilizer has a trivial influence on soil urease activity and the total, intracellular, extracellular and specific urease activities in soil were significantly affected by crop rotation, but not by N fertilization (Klose and Tabatabai, 2000).

The highest dehydrogenase activity was observed in soil treated with manure, while lowest in the control or NP treated plots. The addition of FYM and NPK + FYM enhanced and promoted dehydrogenase enzyme activity. (Parham et al*.,* 2002). A positive correlation were found between urease, acid phosphatase and dehydrogenase activities with clay, organic carbon, available nitrogen and phosphorus and negative correlation were observed with soil pH, EC and cation exchange capacity. (Gupta and Raha, 2003).

Saraswathy and Bama (2004) found that acid phosphatase and alkaline phosphatase enzyme activities were higher in unplanted soil (0.06 and 0.09 mg/min of incubation/g of soil, respectively) than that of root zone soil (0.03 and 0.04 mg/min of incubation/g of soil) due to water logging and high nitrogen content. In both acid and alkali soils, the soluble phosphorus content was low in unplanted condition.

Reddy et al. (2007) observed that application of fly ash @ 15 t/ha alongwith FYM @ 10 t/ha has resulted in highest urease, dehydrogenase and cellulase activity at 30 DAT (4.48 μg of NH_4^+ released/g soil/h, 5.37 mg of TPF produced/g/soil/d and 3.50 mg of glucose released/g soil/d), 60 DAT (4.80 micro g of NH_4^+ released/g soil/h, 5.47 mg of TPF produced/g soil/d and 3.32 mg of glucose released/g soil/d) and at harvest (2.53 micro g of NH_4^+ released/g soil/h, 3.07 mg of TPF produced/g soil/d and 2.16 mg of glucose released/g soil/d) respectively, which was on par with application of fly ash @ 10 t/ha alongwith FYM @ 10 t/ha and significantly higher over control. The acid and alkaline phosphatase activity was not influenced by fly ash levels at all the stages viz., 30, 60 DAT and at harvest.

Conversion of organic phosphorus to inorganic phosphorus is essential for the effective utilization of phosphate by the plant. The mineralization of organic P is mediated by phosphatases that hydrolyze C-O-P ester bonds. Increase in phosphomenoesterase (acid and alkaline phosphatase) acivity after FYM application due to increase in the amount of easily decomposable organic compounds originating from either bacterial cell or plant residues in FYM. (Kaleeswari, 2007).

2.12 EFFECT OF NUTRIENT MANAGEMENT ON PEST AND DISEASE INCIDENCE

Parcer and Chahal (1963) reported that heavy application of nitrogenous fertilizers increased the incidence of fungal diseases of rice. Phenolic and other compounds produced during decomposition of organic matter absorbed by the plants, conferred protection against pathogenic organisms (Flaig, 1984). Reddy et al. (1989) observed that the aromatic rice variety, Pusa Basmati-1 is highly susceptible to bacterial leaf blight. Bacterial leaf blight disease was found to be more serious under irrigated conditions and was a widely distributed and devastating disease of aromatic rice (Devadath, 1992). Vijaya and

Balasubramanian (2002) reported that supply of 50% of the required nitrogen through FYM and remaining 50% through urea reduced the rice blast disease severity to a maximum extent and produced maximum grain yield.

Bhadoria et al. (2003) reported that the tolerance of rice plants to pathogens, measured in terms of grain yield was highest in the treatments with FYM. Integrated use of organics and inorganics, in general, reduced the incidence of most of the diseases in rice (Khan et al., 2004). Rekhi et al. (2004) reported that application of optimum doses of chemical fertilizers increased the incidence of sheath blight (*Rhizoctonia solani*) and sheath rot (*Sarocladium oryzea* and *Fusarium moniliforme* (*Gibberella moniliformis*) as well as whitebacked planthoppers (*Sogatella furcifera*) and leaf folders (*Cnaphalocrocis medinalis*).

Heong (2005) reported that organic manures generally enhanced the growth and yield of rice and minimized the outbreak of insect pests and diseases, such as brown plant hopper (*Nilaparvata lugens*), leaf folder (*Cnaphalocrocis medinalis*), blast (*Pyricularia oryzea*) and sheath blight (*Rhizoctonia solani*)

75% of recommended dose of N, P and K along with 25% N through Neemtex or FYM gave better results with significant effect. Potassium content showed negative correlation with disease infestation (Mondal, 2007). Roul et al., (2008) found that least insect pests and disease infestations were recorded with foliar application of pot manure prepared from cow urine 1 litre+ cow dung 1kg + pongamia leaves 1kg.

The review indicated that age of seedlings and number of seedlings hill^{-1} had significant effect on performance of crop. Younger seedlings produced better growth and yield with higher nutrient uptake compared to older seedlings. Crop planted with single seedling hill^{-1} performed better with respect to yield and yield parameters compared to two or three seedlings hill^{-1}. Weed control by different methods increased availability of nutrients for the crop. Growth and yield of rice was better under controlled and intermittent irrigation than under flooded irrigation. Application of organic manures improved growth, yield and nutrient uptake by crop, physico – chemical properties of soil and soil enzyme activity. INM was superior to inorganic nutrient management in the context of crop growth, yield and grain quality.

Materials and Methods

3. MATERIALS AND METHODS

The investigation entitled "Response of medicinal rice (*Oryza sativa* L.) cv Njavara to SRI and other management systems" was taken up at the Cropping Systems Research Centre, Karamana, Thiruvananthapuram, Kerala. The main objective of the study was to evolve the ideal crop production package for Njavara rice in lowlands and assess the bio-chemical constituents of organically and inorganically produced Njavara. Study of the developmental phenology of Njavara under different management systems was also envisaged in the study. The details regarding the materials used and the methods adopted for the study are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was conducted in the wet lands of the Cropping Systems Research Centre, Karamana, Thiruvananthapuram, Kerala Agricultural University. The research station is located at 8º 29'N latitude and 76º 58' E longitude, at an altitude of 33 m above mean sea level.

3.1.1 Soil

The soil of the experimental site was sandy clay loam, belonging to the taxonomical order Typic tropo fluvent. It was acidic in reaction, high in organic carbon content, medium in available nitrogen, medium in available phosphorus and medium in available potassium status. The mechanical composition, physic-chemical properties and enzymes of soil are given in Table 1.

Table 1. Soil characteristics of the experimental site

A. Mechanical composition

Sl.No.	Fractions	Content in soil (%)	Method used
1	Fine sand	13.05	International Pipette Method (Piper, 1950)
2	Coarse sand	54.9	
3	Silt	7.5	
4	Clay	22.5	

Textural class: Sandy clay loam

B. Physico-chemical properties

Sl. No.	Fractions	Content in soil		Method used
		2007	2008	
1	Available N ($kg\ ha^{-1}$)	271.23 (medium)	252.62 (medium)	Alkaline Permanganate Method (Subbiah and Asija, 1956)
2	Available P ($kg\ ha^{-1}$)	22.34 (medium)	21.80 (medium)	Bray Colorimetric Method (Jackson,1973)
3	Available K ($kg\ ha^{-1}$)	142.16 (medium)	138.24 (medium)	Neutral Normal Ammonium Acetate Method (Jackson,1973)
4	Organic carbon (%)	1.27 (High)	1.19 (High)	Walkley and Black Rapid Titration Method (Jackson,1973)
5	Soil reaction (pH)	5.5 (acidic)	5.4 (acidic)	1:2.5 Soil solution ratio using pH meter with glass electrode
6	Bulk density ($g\ cc^{-1}$)	1.40	1.29	Core Method (Gupta and Dakshinamoorthy, 1980)
7	CEC($cmol\ kg^{-1}$)	6.35	6.33	Neutral Normal Ammonium Acetate Method (Jackson, 1973)
8	Sulphur (ppm)	3.05	4.23	Turbidimetric Method (Chesnin and Yien, 1950)
9	Iron (ppm)	6.4	6.52	Atomic Absorption Spectrophotometer (Lindsay and
10	Zinc (ppm)	0.29 (Low)	0.25 (Low)	Atomic Absorption Spectrophotometer (Lindsay and
11	Manganese (ppm)	1.33 (Medium)	1.42 (Medium)	Atomic Absorption Spectrophotometer (Lindsay and Norwell, 1978

C. Soil enzymes

Sl.No	Enzymes	Content in soil		Methods used
		2007	2008	
1.	Urease (ppm of urea hydrolysed g^{-1} soil h^{-1})	52.42	53.44	Tabatabai, (1982)
2.	Phosphatase (µg P-nitrophenol g^{-1} soil h^{-1})	37.65	39.80	Eivazi and Tabatabai (1977)
3.	Dehydrogenase (µg of Tri Phenyl Formazan hydrolysed g^{-1} soil 24 h^{-1})	43.46	47.72	Tabatabai, (1982)

3.1.2 Climate

Data on weather parameters like temperature, rainfall, relative humidity and evaporation was obtained from the meteorological observatory at College of Agriculture, Vellayani. The average values of weekly weather parameters recorded during the two cropping periods (summer 2007 and summer 2008 - January to April) are given in Appendix I and II and graphically presented in Fig 1a and 1b.

3.1.3 Season

The experiments were conducted during the summer season of 2007 and 2008 (January to April).

3.1.4. Cropping history of the experimental site

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

3.2 MATERIALS

3.2.1. Crop variety

Njavara, a traditional land race, known for its medicinal value was used for the study. Of the two types (black and yellow glumed) black glumed type was

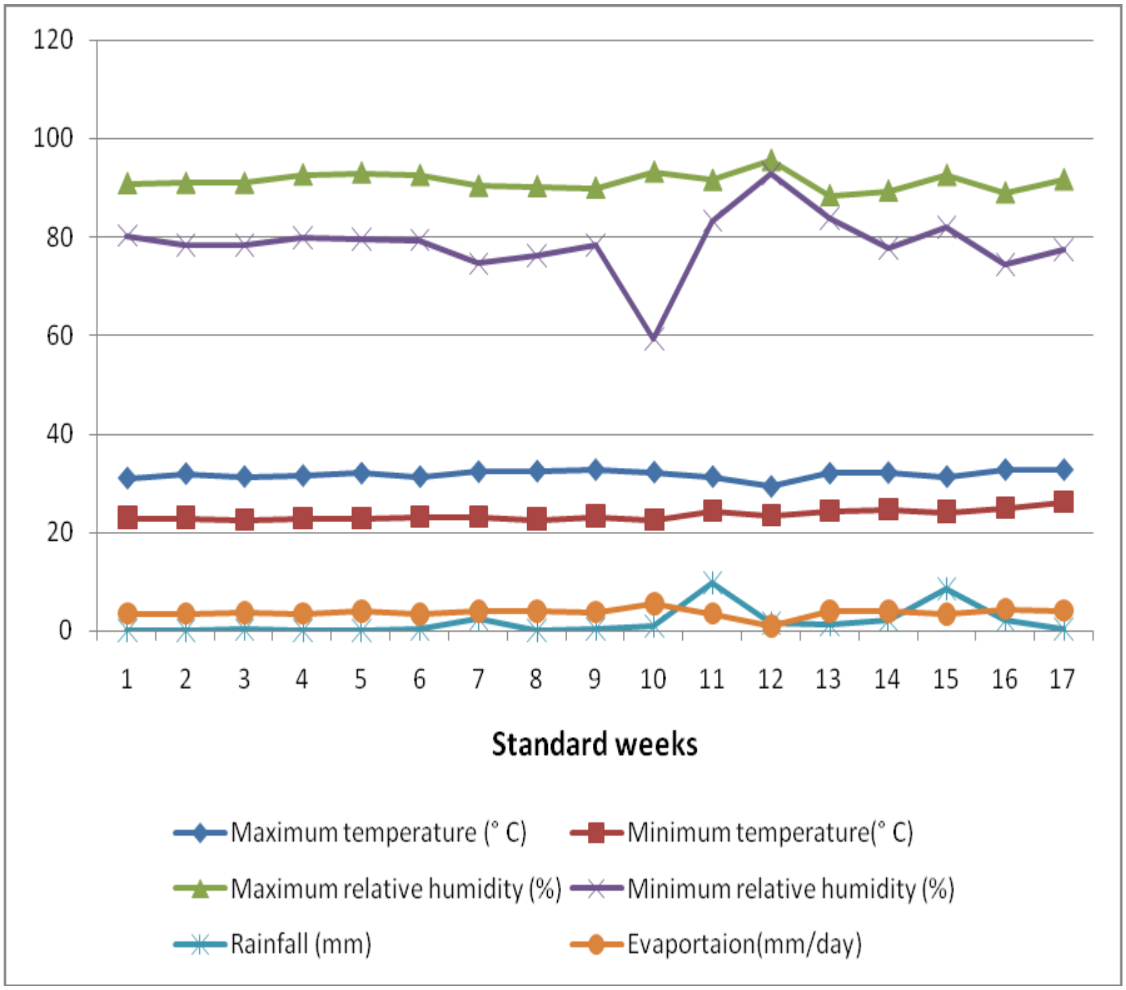


Fig. 1a. Weather parameters - Summer season 2007 – January to April

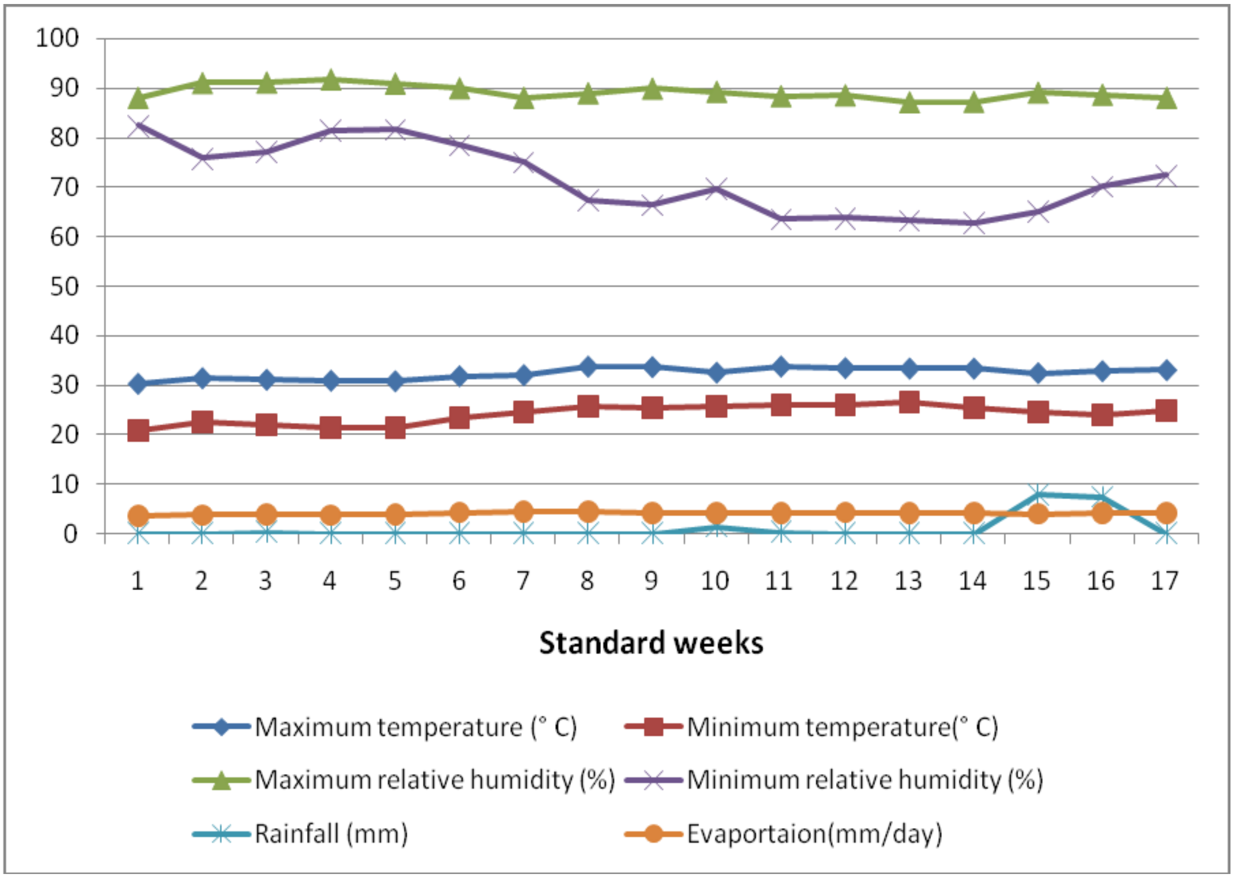


Fig. 1b. Weather parameters - Summer season 2008 – January to April

selected as the test crop. This tall indicas has extra short duration (60-100 days), drought tolerance and a wide yield range. Most of the plants lodge before maturity due to weak culm. Thousand grain weight is in the range of 9.04g – 11.08g.

3.2.2 Source of seed material

The seeds for the study were obtained from the Navara Eco Farm, Karukamani kalam, Chittur College (post), Pallakkad, Kerala.

3.2.3 Manures and fertilizers

Farm yard manure, rock phosphate and wood ash were used as the organic sources of nutrient for the experiment. Urea (46 per cent N), rock phosphate (20 per cent P_2O_5) and Muriate of Potash (60 per cent K_2O) were used as the inorganic sources of N, P and K respectively. Nutrient content of FYM & wood ash are given below.

Table 2. Nutrient content of FYM and wood ash

Sl.No	Parameter	Organic manures	
		FYM	Wood Ash
1	N (%)	0.50	0.008
2	P_2O_5 (%)	0.31	0.23
3	K_2O (%)	0.54	1.32
4	Sulphur (%)	0.25	1.65
5	Iron (ppm)	18.10	10.10
6	Manganese (ppm)	10.00	12.41
7	Zinc (ppm)	1.92	1.07
8	Phenols (mg g^{-1})	0.63	-

3.3 METHODS

3.3.1 Design and layout

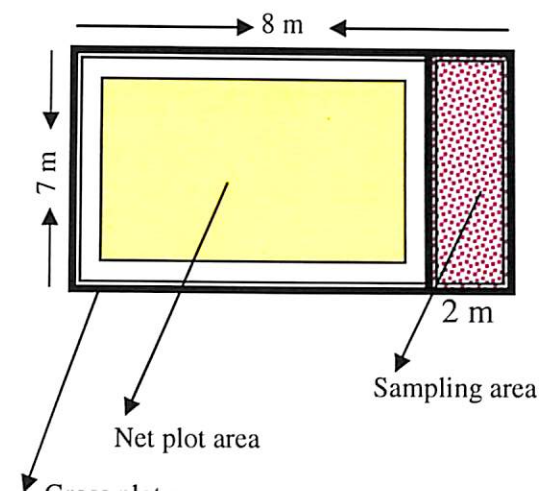
The study was conducted for two consecutive seasons *i.e.*, summer/third crop/puncha season of 2007 and 2008. Design, layout, field culture and observations were the same for both the seasons. The detailed layout plan of the experiment is given in Fig 2.

Fig. 2. Layout of the experimental field

N

R I			R II			R III			R IV		
M_3S_1	M_3S_2	M_3S_3	M_1S_2	M_1S_3	M_1S_1	M_2S_1	M_2S_3	M_2S_2	M_4S_3	M_4S_2	M_4S_1
M_1S_3	M_1S_2	M_1S_1	M_3S_3	M_3S_2	M_3S_1	M_4S_2	M_4S_3	M_4S_1	M_2S_2	M_2S_1	M_2S_3
M_2S_3	M_2S_2	M_2S_1	M_4S_1	M_4S_3	M_4S_2	M_1S_1	M_1S_3	M_1S_2	M_3S_3	M_3S_1	M_3S_2
M_4S_2	M_4S_3	M_4S_1	M_2S_1	M_2S_3	M_2S_2	M_3S_3	M_3S_2	M_3S_1	M_1S_2	M_1S_1	M_1S_3

Structure of micro plot



Experimental design : Split Plot design

Number of treatments : 12

Number of replications : 4

Gross plot size : 8.0 m x 7.0 m

Total number of plots : 48

Two rows of plants were left as border on all the sides and the observations were taken from the net plot area. An area of $4m^2$ was set apart in all the plots for destructive sampling.

3.3.2 Treatment Details

Main plot treatments - Management systems (M): 4

M_1 – SRI (System of Rice Intensification) - Transplanting 8 days old single seedling $hill^{-1}$ at spacing of 20x20 cm, weeding at 10 days interval using rotary weeder up to panicle initiation and limited irrigation.

M_2 – ICM (Integrated Crop Establishment Method) - Transplanting 12 days old 2 seedlings $hill^{-1}$ at spacing of 20x20 cm, weeding on 10 DAT and 20 DAT using rotary weeder and one hand weeding on 35 DAT and water management of keeping a thin film of water throughout the crop growth period.

M_3 – PoP (Package of Practices) recommendations of Kerala Agricultural University for local variety - Transplanting 18 days old 3 seedlings $hill^{-1}$ at spacing of 15x10 cm, manual weeding on 15 DAT + 2, 4 D @ 1 kg a.i/ha on 25 DAT and water management of keeping thin film of water at transplanting and 5cm of water until 10 days of harvest.

M_4 – F.P (Farmers' practice) - Broadcasting pre-germinated seeds, two manual weedings and conventional irrigation.

Sub plot treatments - Nutrient Sources (S): 3

S_1 – Organic sources (FYM, rock phosphate and wood ash)

S_2 – Integrated sources (FYM + urea, rock phosphate and muriate of potash)

S_3 – Inorganic sources (urea, rock phosphate and muriate of potash)

Treatment combination

M_1 S_1 – SRI with organic sources.

M_1 S_2 – SRI with integrated nutrient sources

M_1 S_3 – SRI with inorganic sources.

M_2 S_1 – ICM with organic sources.

M_2 S_2 – ICM with integrated nutrient sources

M_2 S_3 – ICM with inorganic sources.

M_3 S_1 – PoP with organic sources.

M_3 S_2 – PoP with integrated nutrient sources

M_3 S_3 – PoP with inorganic sources.

M_4 S_1 – Farmers' practice with organic sources.

M_4 S_2 – Farmers' practice with integrated nutrient sources

M_4 S_3 – Farmers' practice with inorganic sources.

3.4 CROP HUSBANDRY

3.4.1 Nursery preparation

The nursery area was ploughed, puddled and levelled after removing the weeds and stubbles. Dapog nursery was prepared for SRI treatments.

3.4.2 Seeds and Sowing

Pre germinated seeds at a seed rate of 60kg ha^{-1} were broadcast in the nursery area for ICM and PoP treatments. Pre germinated seeds at a seed rate of 7kg ha^{-1} were sown on the dapog nursery for SRI treatments. Nursery was

Plate 1. General view of the experimental field

irrigated as per requirement. Nursery sowings were scheduled in such a way that seedlings of required age (8, 12 and 18 days) were ready on the common transplanting day.

3.4.3 Main field preparation

The experimental area was well ploughed, puddled, levelled and weeds and stubbles were removed. The field was laid out into four replications with 12 plots each.

3.4.4 Transplanting

Eight, twelve and eighteen days old seedlings as per treatments were transplanted on 1st February at the rate of 1, 2 and 3 seedlings per hill at 20x20 cm, 20x20 cm and 15x10 cm spacings in SRI, ICM and PoP treatments respectively. In Farmers' practice treatment pre germinated seeds were broadcasted on the same day.

3.4.5 Manures and fertilizers

Nutrient management recommendation of Package of Practices: Crops (2007) of Kerala Agricultural University was adopted. For wet land local varieties the recommendation is 5t FYM + 40:20:20 kg NPK per ha. Full FYM + 2/3 N + Full P + ½ K were to be applied as basal. 1/3 N + ½ K were to be applied at panicle initiation. Three types of nutrient management were involved in the technical programme. In the organic treatments 40:20:20 kg NPK ha^{-1}were supplied through FYM, rock phosphate and wood ash. 5t FYM ha^{-1} was also applied. In integrated nutrient management treatments 40: 20: 20 kg NPK ha^{-1} were supplied through urea, rock phosphate and muriate of potash along with 5t FYM. In the inorganic treatments NPK contribution by 5t FYM was calculated and they were supplied through urea, rock phosphate and muriate of potash. NPK was also applied at the rate of 40:20:20 kg ha^{-1} respectively.

3.4.6 After cultivation

Uniform crop establishment was ensured. Gap filling was done one week after transplanting. Thinning was done two weeks after sowing in broadcast crop. Five plants were selected randomly from each plot and tagged as observational plants.

3.4.7 Weed management

SRI – First rotary weeding was done on 10 DAT and three more weeding were done at 10 days interval.

ICM – Two rotary weedings were done on 10 DAT and 20 DAT followed by one hand weeding on 35 DAT.

PoP – One manual weeding on 15 DAT and application of 2, 4 D @ 1 kg a.i/ha on 25 DAT

Farmers' practice – Two manual weedings were done on15 and 35 DAS.

3.4.8 Water management

SRI – Irrigation at hair line crack appearance upto panicle initiation followed by 5cm standing water until 10 days before harvesting.

ICM – A thin film of water was maintained in these plots until 10 days before harvest

PoP – Water level was maintained at about 1.5cm during transplanting. Thereafter it was increased gradually to about 5cm until 10 days before harvest. The field was drained 10 days before harvest.

Farmers' practice – A thin film of water was maintained up to 20 days of sowing after which water level was raised to 5 cm. Field was drained 10 days before harvest.

3.4.2.7 Plant protection

Incidence of pests and diseases were regularly monitored till harvest.

3.4.2.8 Harvest

The crop was harvested when the straw just turned yellow. The net plot area was harvested separately, threshed, dried, winnowed and weight of grain and straw from individual plot were recorded.

3.5 OBSERVATIONS

Plant sampling

Five plants were selected randomly from the net plot area of each plot as observation plants. Two rows from all sides were left as border rows.

3.5.1 Crop growth characters

3.5.1.1 Plant height

Plant height was recorded at panicle initiation and at physiological maturity (at physiological maturity the crop will have maximum dry matter. After physiological maturity senescence starts and lose of dry matter occurs) using the method described by Gomez (1972). Height was measured from the base of the plant to the tip of the longest leaf or tip of the longest ear head, whichever was longer and the average of five plants was recorded in centimetres.

3.5.1.2 Leaf number hill^{-1}

Leaf count was taken from the five tagged observation hills at panicle initiation and physiological maturity and mean was expressed as number of leaves hill^{-1}.

3.5.1.3 Leaf area index

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

Leaf area of a single leaf = l x w x k

K - Adjustment factor (0.75 at maximum tillering, panicle initiation and flowering and 0.67 at harvest stage).

$$LAI = \frac{\text{Sum of leaf area of 6 sample hills (cm}^2\text{)}}{\text{Area of land covered by the 6 sample hills (cm}^2\text{)}}$$

3.5.1.4 Leaf area duration

LAD was calculated using the formula suggested by Watson (1947)

$$LAD = \frac{L_i + (L_i + 1) \times (t_2 - t_1)}{2}$$

L_i - LAI at first stage

$L_i + 1$ – LAI at second stage

$(t_2 - t_1)$ – Time interval between stages

3.5.1.5 Culm strength

The procedure of Atkins (1938) was adopted for computing culm strength. Five plants were selected randomly and cut at ground level, leaf lamina and panicle (at physiological maturity) were removed. Remaining culms were dried for two days under shade. The culms were cut into pieces of uniform length and weighed. Average culm strength was worked out as dry weight cm^{-1} and expressed as g cm^{-1}.

3.5.1.6 Flag leaf area

Flag leaf area at panicle emergence and physiological maturity was calculated by leaf product method. The factor (K) used were 0.75 and 0.67 respectively.

Leaf area (cm^2) = Length (cm) x Maximum width (cm) x K

3.5.1.7 Chlorophyll content of leaves

The total chlorophyll content was estimated from the fully expanded second leaf from the top, at panicle emergence stage by the method suggested by Arnon (1949) and expressed in mg g^{-1} fresh weight of leaves.

3.5.1.8. Number of tillers m^{-2}

Number of tillers m^{-2} was recorded at weekly interval during the period between two to seven weeks of transplanting/sowing (maximum tillering) and at physiological maturity.

3.5.1.9. Root biomass $hill^{-1}$

Root biomass production from five sample plants collected from sampling area were recorded on dry weight basis and the average worked out at weekly interval from fourth week of transplanting/sowing till physiological maturity.

3.5.2 Yield and yield attributes

3.5.2.1 Productive tillers m^{-2}

Number of productive tillers m^{-2} was recorded at physiological maturity.

3.5.2.2 Panicle length

Five panicles were selected randomly from the net plot and the length was measured and the mean value was computed as pancile length and expressed in centimetres.

3.5.2.3 Grains panicle^{-1}

Grains from five panicles collected randomly from the net plot were counted and the mean value was expressed as number of grains per panicle.

3.5.2.4 Number of filled grains panicle^{-1}

The central panicle from each sample hill was threshed separately and the numbers of filled and unfilled grains were recorded.

3.5.2.5 Thousand grain weight

Weight of 1000 grains collected from the cleaned and dried produce from each treatment was recorded in grams.

3.5.2.6Grain yield

The net plot area was harvested individually, threshed, winnowed, dried, weighed and expressed in kg ha^{-1}.

3.5.2.7 Straw yield

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

3.5.2.8 Harvest index (HI)

From grain yield and straw yield values, the harvest index was worked out using the following equation suggested by Donald and Hamblin (1976).

$$HI = \frac{\text{Economic Yield}}{\text{Biological Yield}}$$

3.5.2.9 Dry matter partitioning

Dry matter partitioning was done at harvest. The sample plants were uprooted, washed, plant parts (root, straw and panicle) separated, dried under shade and later oven dried to a constant weight. Dry weight of each plant part was recorded separately using an electronic balance, and expressed as the percentage of the total dry weight.

3.5.2.10 Sterility percentage

Sterility percentage was worked out using the following relation ship.

$$\text{Sterility percentage} = \frac{\text{Number of unfilled grains per panicle}}{\text{Total number of grains per panicle}} \times 100$$

3.5.2.11 Paddy grain ratio

Weight of paddy and grain obtained from the paddy on milling were recorded and paddy grain ratio was worked out.

3.5.2.12 Grain husk ratio

Weight of grain and husk were recorded and grain husk ratio was worked out.

3.5.2.13 Crop duration

Duration from sowing to harvest of the crop from each treatment was recorded and expressed in days.

3.5.3 Bio chemical properties of grain

3.5.3.1 Crude protein content of grain

Crude protein content was computed by multiplying the nitrogen content of grains with the factor 6.25 (Simpson *et al*., 1965).

3.5.3.2 Total starch content of grain

Starch was estimated by the Ferric cyanide method suggested by Aminoff *et al*. (1970).

3.5.3.3 Amylose content of grain

Amylose content was estimated by the method of Mc Cready and Hassid (1943).

3.5.3.4 Amylopectin content of grain

Amylopectin content of grains was determined as the difference between the total starch content and the amylose content of the grains (Sadasivam and Manickam, 1992).

3.5.3.5 Phenols in grain

Total phenol content in grain was estimated by the method of Swain and Hillis (1955).

3.5.4 Observations on weeds

In the sampling area of each plot, quadrat of size 25 x 25 cm was placed at random and weed samples were collected.

3.5.4.1 Weed Flora

Major weed species that infested the experiment were identified and grouped into grasses, sedges and broad leaved weeds.

3.5.6.2 Weed Dry Matter

Weed samples were pulled out along with roots, washed and dried under shade and later they were oven dried at 60 ^{0}C to a constant weight. The dry weight of weeds was recorded in whole units and expressed in g m^{-2}.

3.5.4 Soil properties

Soil samples collected before and after the experiments were dried in shade, sieved through 2mm sieve and analysed to determine the various physico-chemical properties.

3.5.5.1 Bulk density

Bulk density was determined by the Core method (Gupta and Dakshinamoorthy, 1980) and expressed in g cc^{-1}.

3.5.5.2 Soil reaction (pH)

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

3.5.5.3 Cation exchange capacity (CEC)

The neutral normal ammonium acetate method suggested by Jackson (1973) was used for estimating CEC and expressed as cmol kg^{-1}.

3.5.5.4 Organic Carbon (%)

Organic carbon content of soil was estimated by Walkley and Black rapid titration method (Jackson, 1973) and expressed in percentage.

3.5.5.5 Available nitrogen

Available nitrogen content of the soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956) and expressed in kg ha^{-1}.

3.5.5.6 Available phosphorus

Available phosphorus content of the soil (kg ha^{-1}) was determined by Dickman and Bray's molybdenum blue method using spectrophotometer. The soil was extracted with Bray's reagent No.1 (0.03NH_4F in 0.025 N HCL) (Jackson, 1973).

3.5.5.7 Available potassium

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

3.5.5.8 Available sulphur

Available sulphur was determined adopting the procedure suggested by Chesnin and Yien (1951). The extraction was carried out using Morgan's extraction solution and expressed as ppm.

3.5.5.9 DTPA extractable micronutrients

DTPA extractable micronutrients-Fe, Zn and Mn in the digested sample were determined by using atomic absorption spectrophotometer (Lindsay and Norwell, 1978) and expressed as ppm.

3.5.6 Plant analysis

Sample plants collected from each plot at harvest were separated into straw and grain, sun dried, and then oven dried to a constant weight and the samples were ground, digested and used for analysis of nutrient content. Nutrient uptake was worked out using the following equation and expressed as kg ha^{-1}.

$$\text{Nutrient uptake} = \frac{\text{Nutrient content x Dry matter production}}{100}$$

Table 3. Plant analysis methods

SL.No	Nutrient	Method	References
1.	Nitrogen	Microkjeldahl method	Jackson,1973
2.	Phosphorus	Diacid extract estimated colorimetrically in a Spectronic-20 Spectrophotometer by Vanadomolybdophosphoric yellow colour method	Jackson,1973
3.	Potassium	Diacid extract method using Flame photometer	Jackson,1973
4.	Sulphur	Turbidimetric method using Spectronic-20 spectrophotometer	Williams et al. 1959
5.	Fe, Mn and Zn	Diacid extract method using atomic absorption spectrophotometer (Perkin Elmer model)	Jackson,1973

3.5.7 Soil enzyme activity assay

3.5.7.1 Urease activity

The urease activity was determined by the method described by Tabatabai (1982). 25g of soil was weighed into an Erlen Meyer flask, to which 5ml of urea substrate solution was added. Enough water was added to each flask to maintain a tension of 1/3 bar and incubated for 24 hours at 30^0 C. Then the flasks were removed, saturated $CaSo_4$ solution was added to make up the volume to 100ml. Shake the sample for ½ hour and allow it to settle. About 15ml of the supernatant was taken and colour was developed by adding 10 ml of P-dimethyl amino benzaldehyde, which was read in a spectrophotometer at a wavelength of 420nm. Standards were also prepared by using urea solution of known concentrations (0, 0.25, 0.5, 1, 2, 3, 4, 5, 8 and 10 ml of 0.4% urea solution). The results were expressed in terms of urea hydrolysed g^{-1} of soil hr^{-1} in ppm.

3.5.7.2 Phosphatase activity

The phosphatase activity was determined by following the procedure described by Eivazi and Tabatabai (1977). To 1g soil in a 50 ml Erlen Meyer Flask, 0.2 ml toluene, 4 ml modified universal buffer (pH-6.5) and 1ml p-nitrophenyl phosphate solution were added and incubated at 23^0C for one hour. After incubation, 0.5 M $CaCl_2$ (1ml) and 0.05 M NaOH (4ml) were added. The contents were swirled and filtered and the intensity of the yellow colour developed was read in a spectrophotometer at 420 nm wavelength. One per cent solution of p-nitrophenyl phosphate was used for the preparation of standards. The results were expressed in terms of p-nitrophenyl hydrolysed g^{-1} of soil hr^{-1} in µg.

3.5.7.3 Dehydrogenase activity

The soil dehydrogenase activity was measured by adopting the procedure described by Tabatabai, (1982).

Five grams of fresh soil (particle size <0.02 mm) was taken in a 100 ml beaker. To this 0.05g of calcium carbonate was added and mixed thoroughly. One ml of 3% aqueous solution of 2, 3, 5 triphenyl tetrazolium chloride (TTC) and 2.5 ml of distilled water were added. The soil was completely saturated with water, mixed well with a glass rod and covered with aluminium foil to make air tight and then incubated at 37 ^{o}C for 24 hrs. The reddish colour Tri Phenyl Formazan (TPF) was extracted by transferring the soil with the aid of methanol from each beaker to a funnel plugged with absorbent cotton. The extract was collected till the filtrate ran colourless. The final volume was made up to 100 ml with methanol. The intensity of the reddish colour was measured by using a spectrophotometer at 485nm with methanol as blank. Standard graph was drawn using TPF in methanol. The dehydrogenase activity was expressed as µg of TPF formed per gram of soil on dry weight basis for 24 hrs.

3.5.8 Phenological study

Phenological studies were conducted under four management systems. Four plots of 9 m^2 size were laid out along with the main field experiments in 2007 and 2008. The management systems were allotted randomly in the four plots. Destructive sampling of five plants at weekly interval was done for recording observations on root length and root biomass. Growth characters like plant height, number of leaves $hill^{-1}$, length and width of leaf and number of tillers $hill^{-1}$ were recorded from five tagged plants. Average of the observations taken in two years was used for interpretation. Growth stages like panicle initiation, maximum tillering, booting, flowering and physiological maturity were fixed based on observations recorded at 3 days intervals.

3.5.9 Economics of cultivation

The economics of cultivation was worked out based on the costs of the various inputs and produce at the time of experimentation. Total cost of cultivation of the treatments was a sum of basic cost of cultivation, cost involved for management systems and cost involved for nutrient sources.

3.5.9.1 Net income

Net income was computed using the formula.

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

3.5.9.2 Benefit cost ratio

Benefit Cost Ratio was computed using the formula

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

3.5.10 Statistical analysis

The data recorded during the field investigation, on various characters were statistically analyzed with split plot design method as suggested by Gomez and Gomez (1984) for test of significance. Wherever the treatment differences were found significant, the critical differences were worked out at 5 per cent probability level and the values furnished. Treatment differences that were not significant are denoted as NS.

Results

4. RESULTS

The result of the field experiment conducted at Cropping Systems Research Centre, Karamana, Thiruvananthapuram, Kerala during Summar 2007 and 2008 to investigate the response of medicinal rice (*Oryza sativa* L.) cv Njavara to SRI and other management systems are presented in this chapter.

4.1 CROP GROWTH CHARACTERS

Observations on crop growth characters like height of plant, number of leaves, leaf area index, leaf area duration, culm strength and flag leaf area, root dry matter hill^{-1} and tiller production m^{-2} were recorded.

4.1.1 Plant Height

Effect of different management systems on plant height at panicle initiation was significant only in 2008 and that on plant height at physiological maturity was significant both in 2007 and 2008 (Table 4). Effect of nutrient sources and interaction effect with respect to plant height at panicle initiation and physiological maturity were not significant in both the years.

Plant height at panicle initiation (2008) was highest (44.39 cm) in Farmers' practice which was significantly superior to other management systems. Farmers' practice was followed by PoP (43.37 cm) which was on par with SRI (43.32 cm) and ICM (42.76 cm).

During 2007 and 2008 at physiological maturity plant height was maximum in Farmers' practice which was significantly superior to other management systems. In 2007, plant height in all the management systems differed significantly from one another. Plant height in Farmers' practice was 108.74 cm in 2007 and 112.60 cm in 2008. In both the years plant height was highest in Farmers' practice which was followed by PoP, SRI and ICM respectively. Least plant height recorded in ICM was 92.10 cm in 2007 and 98.92 cm in 2008.

Table 4. Effect of management systems and nutrient sources on plant height and number of leaves hill^{-1}

	Plant height (cm)				Number of leaves hill^{-1}			
Treatments	**2007**		**2008**		**2007**	**2008**	**2007**	**2008**
Management systems	**PI (Panicle Initiaton)**	**PM (Physiological Maturity)**	**PI (Panicle Initiaton)**	**PM (Physiological Maturity)**	**PI (Panicle Initiaton)**	**PM (Physiological Maturity)**	**PI (Panicle Initiaton)**	**PM (Physiological Maturity)**
M_1 (SRI)	41.92	98.53	43.32	103.13	9.28	22.05	9.33	22.02
M_2 (ICM)	41.67	92.10	42.76	98.92	9.48	23.15	9.34	22.81
M_3 (PoP)	42.80	101.92	43.37	105.82	10.51	24.60	10.39	23.70
M_4 (F.P)	42.96	108.74	44.39	112.60	10.68	25.24	10.47	24.88
SEd	**0.515**	**1.000**	**0.435**	**2.896**	**0.110**	**0.245**	**0.253**	**0.591**
CD (0.05)	**NS**	**2.488**	**0.984**	**6.551**	**0.25**	**0.554**	**0.572**	**1.337**
Nutrient sources								
S_1 (Organic)	42.70	101.26	43.73	104.79	9.95	23.86	10.07	23.62
S_2 (Integrated)	42.17	100.09	43.24	106.66	9.94	24.01	9.72	23.57
S_3 (Inorganic)	42.13	99.62	43.41	103.90	10.08	23.41	9.86	22.88
SEd	**0.435**	**1.138**	**0.460**	**2.023**	**0.100**	**0.259**	**0.208**	**0.478**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

4.1.2 Number of leaves hill^{-1}

The data presented in table 4 shows the effect of management systems and sources of nutrients on number of leaves hill^{-1} at panicle initiation and physiological maturity in 2007 and 2008 respectively.

Effect of management systems on number of leaves hill^{-1} at panicle initiation and physiological maturity was significant in both the years. Nutrient sources and interaction effects did not influence the number of leaves hill^{-1} in 2007 and 2008.

In both the years number of leaves hill^{-1} (at both the stages) was in the following order i.e. Farmers' practice > PoP > ICM > SRI.

At panicle initiation, Farmers' practice recorded maximum number of leaves hill^{-1} of 10.68 (2007) and 10.47 (2008) respectively which was on par with PoP (10.51 in 2007 10.39 in 2008). Farmers' practice and PoP were followed by ICM (9.48 in 2007 and 9.34 in 2008) which was on par with SRI management systems (9.28 in 2007 and 9.33 in 2008).

In 2007 number of leaves hill^{-1} at physiological maturity in all the management systems differed significantly from one another, whereas that in Farmers' practice and PoP were on par in 2008. Maximum number of leaves hill^{-1} was recorded in Farmers' practice (25.24 in 2007 and 24.88 in 2008) and minimum number of leaves hill^{-1} was recorded in SRI (22.05 in 2007 and 22.02 in 2008).

4.1.3 Leaf Area Index

Effect of management systems and different sources of nutrients on leaf area index at panicle initiation and physiological maturity in 2007 and 2008 are presented in table 5.

Effect of management systems on leaf area index at panicle initiation and physiological maturity was significant in both the years. Effects of

Table 5. Effect of management systems and nutrient sources on leaf area index and leaf area duration

Treatments	Leaf area index				Leaf area duration	
	2007		2008			
Management systems	**PI** (Panicle Initiaton)	**PM** (Physiological Maturity)	**PI** (Panicle Initiaton)	**PM** (Physiological Maturity)	**2007**	**2008**
M_2 (ICM)	0.12	0.77	0.21	0.78	15.54	16.00
M_3 (PoP)	0.47	1.08	0.50	1.09	27.53	28.42
M_4 (F.P)	0.65	1.46	0.69	1.48	37.03	41.03
SEd	**0.032**	**0.018**	**0.017**	**0.590**	**8.488**	**0.798**
CD (0.05)	**0.071**	**0.041**	**0.038**	**1.337**	**NS**	**1.806**
Nutrient sources						
S_2 (Integrated)	0.34	1.06	0.41	1.04	25.44	25.49
S_3 (Inorganic)	0.34	0.99	0.39	1.00	23.16	25.69
SEd	**0.019**	**0.013**	**0.017**	**0.478**	**7.548**	**0.429**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

nutrient sources and interactions did not influence on leaf area index in both the years.

During both the years at both growth stages Farmers' practice recorded the maximum leaf area index. At panicle initiation Farmers' practice recorded the highest leaf area index (0.65 in 2007 and 0.69 in 2008) which was significantly superior to other management systems. This was followed by PoP (0.47 in 2007 and 0.50 in 2008). The leaf area index in SRI (0.11 in 2007 and 0.21 in 2008) was on par with that in ICM (0.12 in 2007 and 0.21 in 2008).

At physiological maturity stage effect of all the management systems differed significantly from one another. Highest leaf area index was recorded in Farmers' practice (1.46 in 2007 and 1.48 in 2008)) which was followed by PoP (1.08 in 2007 and 1.09 in 2008), SRI (0.83 in 2007 and 0.82 in 2008) and ICM (0.77 in 2007 and 0.78 in 2008) respectively.

4.1.4 Leaf Area Duration (LAD)

Leaf area duration was calculated for the period from panicle initiation to physiological maturity. The values are presented in table 5.

During 2007 effect of management systems, nutrient sources and interactions were not significant on leaf area duration.

During 2008 management systems alone significantly influenced the leaf area duration. It was maximum under farmers' practice (41.03), which was significantly superior to all other management systems. Icm recorded the lowest leaf area duration (16.00) which was on par with sri (16.89).

4.1.5 Culm strength

The data summarized in Table 6 show that effect of management systems and sources of nutrients on culm strength at panicle initiation and physiological maturity in 2007 and 2008 respectively.

Table 6. Effect of management systems and nutrient sources on culm strength and flag leaf area

	Culm strength (g cm^{-1})				Flag leaf area (cm^2)			
Treatments	**2007**		**2008**		**2007**	**2008**	**2007**	**2008**
Management systems	**PI (Panicle Initiaton)**	**PM (Physiological Maturity)**	**PI (Panicle Initiaton)**	**PM (Physiological Maturity)**	**PI (Panicle Initiaton)**	**PM (Physiological Maturity)**	**PI (Panicle Initiaton)**	**PM (Physiological Maturity)**
M_1 (SRI)	0.04	0.13	0.04	0.13	6.35	7.11	6.43	7.21
M_2 (ICM)	0.04	0.10	0.04	0.11	6.04	7.12	6.15	7.22
M_3 (PoP)	0.03	0.07	0.03	0.07	6.36	7.47	6.50	7.50
M_4 (F.P)	0.03	0.06	0.03	0.06	6.57	7.65	6.75	7.69
SEd	**0.0005**	**0.002**	**0.0004**	**0.002**	**0.294**	**0.032**	**0.290**	**0.017**
CD (0.05)	**0.001**	**0.003**	**0.0009**	**0.003**	**NS**	**0.071**	**NS**	**0.039**
Nutrient sources								
S_1 (Organic)	0.04	0.09	0.03	0.09	6.46	7.42	6.46	7.42
S_2 (Integrated)	0.04	0.09	0.04	0.10	6.53	7.41	6.53	7.41
S_3 (Inorganic)	0.04	0.08	0.04	0.09	6.39	7.39	6.39	7.39
SEd	**0.0004**	**0.001**	**0.0004**	**0.013**	**0.259**	**0.017**	**0.259**	**0.017**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

Effect of management systems on culm strength was significant at both the stages in both the years. Sources of nutrient and interactions effect were not significant on culm strength at both the stages in both the years.

At panicle intitiation stage SRI and ICM recorded higher culm strength of 0.04 g cm^{-1} and Farmers' practice and PoP recorded lower culm strength of 0.03 g cm^{-1} in both the years. SRI and ICM were on par and PoP and Farmers' practice were also on par.

At physiological maturity culm strength in all the management systems differed significantly from one another. Highest culm strength was recorded in SRI (0.13 g cm^{-1} in 2007 and 2008), which was followed by ICM (0.10 g cm^{-1} in 2007 and 0.11 g cm^{-1} in 2008), PoP (0.07 g cm^{-1} in 2007 and 2008) and Farmers' practice (0.06 g cm^{-1} in 2007 and 2008).

4.1.6 Flag Leaf Area

The influence of management systems and nutrient sources on flag leaf area at panicle emergence and physiological maturity during 2007 and 2008 of experimentation are presented in Table 6.

During both the years at flag leaf area at flowering was not influenced by the treatment variation. At physiological maturity effect of management systems on flag leaf area was significant in both the years. during 2007 and 2008 effect of nutrient sources and interactions were not significant on flag leaf area.

Farmers' practice recorded the highest flag leaf area (7.65cm^2 in 2007 and 7.69 cm^2 in 2008) which was significantly superior to other management systems. This was followed by PoP (7.47 cm^2 in 2007 and 7.50 cm^2 in 2008) which was significantly higher than ICM (7.12 cm^2 in 2007 and 7.22 cm^2 in 2008) and SRI (7.11 cm^2 in 2007 and 7.21 cm^2 in 2008) which was on par with each other.

4.1.7 Chlorophyll content of leaves

Table 7 shows that in Njavara management systems and sources of nutrients significantly influenced the leaf chlorophyll content at panicle initiation in both the years and interaction effects were not significant.

Both in 2007 and 2008 chlorophyll content of leaf was in the order SRI > ICM > Farmers' practice > PoP.

SRI recorded the highest chlorophyll content of 1.31 mg g^{-1} in 2007 and 1.34 mg g^{-1} in 2008 which was significantly higher than other three management systems which in turn were on par with one another. The lowest content of chlorophyll was recorded in PoP 1.23 mg g^{-1} in 2007 and 1.29 mg g^{-1} in 2008.

Organic source recorded the highest content of chlorophyll (1.34 mg $g^{-}1$ in 2007 and 1.37 mg $g^{-}1$ in 2008) which was significantly superior to integrated sources (1.25 mg $g^{-}1$ in 2007 and 1.29 mg $g^{-}1$ in 2008) and inorganic source (1.23 mg $g^{-}1$ in 2007 and 1.26 mg g^{-1} in 2008) and which in turn were on par with each other.

4.1.8 Root dry matter production hill^{-1}

Data on root dry matter production hill^{-1} recorded at weekly intervals is presented in table 8.

Root dry matter production hill^{-1} recorded at weekly intervals from 4th WAT/WAS till physiological maturity was significantly influenced by management systems. At the early stages (4-6 WAT/WAS) root dry matter production hill^{-1} was in the order SRI >ICM > Farmers' practice > PoP which changed to SRI> ICM > PoP > Farmers' practice from 7th week onwards. Throughout the crop growth all the management systems differed significantly from one another. Increase in root dry matter occurred up to 9 WAS/WAT. By fourth week SRI recorded the highest root dry matter hill^{-1} (0.26 g in 2007 and 2008) which was significantly higher than that in the other three management systems. This was followed by ICM (0.17g in 2007 and 2008),

Table 7. Effect of management systems and nutrient sources on leaf chlorophyll content

Treatments	Chlorophyll content (mg g^{-1})	
Management systems	**2007**	**2008**
M_1 (SRI)	1.31	1.34
M_2 (ICM)	1.27	1.30
M_3 (PoP)	1.23	1.29
M_4 (F.P)	1.26	1.30
SEd	**0.014**	**0.014**
CD (0.05)	**0.032**	**0.032**
Nutrient sources		
S_1 (Organic)	1.34	1.37
S_2 (Integrated)	1.24	1.29
S_3 (Inorganic)	1.23	1.26
SEd	**0.013**	**0.014**
CD (0.05)	**0.028**	**0.029**

Interaction effect not significant

Table 8. Effect of management systems and nutrient sources on root dry matter production hill^{-1}

Root dry matter production hill^{-1} (g)																
Treatments	**4th week**		**5th week**		**6th week**		**7th week**		**8th week**		**9th week**		**10th week**		**Physiological Maturity**	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	0.26	0.26	0.30	0.31	0.38	0.35	0.44	0.45	0.45	0.47	0.51	0.50	0.51	0.50	0.51	0.50
M_2 (ICM)	0.17	0.17	0.28	0.27	0.31	0.31	0.31	0.30	0.42	0.42	0.42	0.40	0.42	0.40	0.41	0.40
M_3 (PoP)	0.15	0.14	0.18	0.17	0.20	0.21	0.29	0.28	0.33	0.32	0.39	0.38	0.38	0.38	0.36	0.37
M_4 (F.P)	0.16	0.17	0.20	0.19	0.22	0.23	0.25	0.26	0.28	0.28	0.32	0.33	0.32	0.30	0.27	0.28
SEd	**0.006**	**0.006**	**0.008**	**0.007**	**0.005**	**0.005**	**0.010**	**0.005**	**0.008**	**0.010**	**0.007**	**0.008**	**0.014**	**0.007**	**0.010**	**0.014**
CD (0.05)	**0.015**	**0.015**	**0.018**	**0.016**	**0.011**	**0.011**	**0.023**	**0.011**	**0.018**	**0.023**	**0.016**	**0.018**	**0.033**	**0.016**	**0.023**	**0.031**
Nutrient sources																
S_1 (Organic)	0.19	0.19	0.24	0.24	0.28	0.28	0.33	0.33	0.37	0.38	0.41	0.40	0.41	0.40	0.40	0.39
S_2 (Integrated)	0.19	0.19	0.24	0.23	0.27	0.27	0.32	0.32	0.37	0.37	0.41	0.40	0.41	0.40	0.38	0.38
S_3 (Inorganic)	0.18	0.18	0.23	0.23	0.27	0.27	0.32	0.32	0.36	0.36	0.40	0.40	0.41	0.40	0.38	0.38
SEd	**0.008**	**0.007**	**0.010**	**0.010**	**0.009**	**0.018**	**0.010**	**0.009**	**0.008**	**0.010**	**0.008**	**0.008**	**0.018**	**0.008**	**0.010**	**0.019**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

Farmers' practice (0.16 g in 2007 and 0.17 g in 2008) and PoP (0.15 g in 2007 and 0.14 g in 2008) respectively. ICM and Farmers' practice were on par whereas PoP was significantly lower than other management systems. Root dry matter recorded in the different management systems at 5th week differed significantly from one another during both 2007 and 2008. Highest root dry matter hill^{-1} was recorded in SRI (0.30 g in 2007 and 0.29 g in 2008) followed by ICM (0.28 g in 2007 and 0.27 g in 2008), Farmers' practice (0.20 g in 2007 and 0.19 g in 2008) and PoP (0.18 g in 2007 and 0.17 g in 2008) respectively. In both the years root dry matter recorded at 6th week in the different management systems differed significantly from one another. Highest root dry matter hill^{-1} was recorded in SRI (0.38 g in 2007 and 0.35 g in 2008) followed by ICM (0.31 g in 2007 and 2008), Farmers' practice (0.22g in 2007 and 0.23 g in 2008) and PoP (0.20 g in 2007 and 0.21 g in 2008). Root dry matter hill^{-1} recorded at 7th week in all the management systems differed significantly from one another in both the years. Highest root dry matter hill^{-1} was recorded in SRI (0.44 g in 2007 and 0.45 g in 2008) followed by ICM (0.31 g in 2007 and 2008), PoP (0.29 g in 2007 and 0.28 g in 2008) and Farmers' practice (0.25 g in 2007 and 0.26 g in 2008) respectively. At 8th week root dry matter hill^{-1} recorded in all the management systems differed significantly from one another in both the years. Highest root dry matter hill^{-1} was recorded in SRI (0.45 g in 2007 and 0.47 g in 2008) followed by ICM (0.42 g in 2007 and 2008), PoP (0.33 g in 2007 and 0.32 g in 2008) and Farmers' practice (0.28 g in 2007 and 2008) respectively.

Root dry matter hill^{-1} recorded at 9th week in all the management systems differed significantly from one another in both the years. Highest root dry matter hill^{-1} was recorded in SRI (0.51 g in 2007 and 0.50 g in 2008) and it was followed by ICM (0.42 g in 2007 and 2008), PoP (0.39 g in 2007 and 0.38 g in 2008) and Farmers' practice (0.32 g in 2007 and 0.33 g in 2008) respectively. Root dry matter hill^{-1} remained the same in both 10th and 11th week. Root dry matter production hill^{-1} in all the management systems differed significantly from one another at 10th and

11^{th} week in both the years. Highest root dry matter $hill^{-1}$ was recorded in SRI (0.51 g in 2007 and 0.50 g in 2008) and it was followed by ICM (0.42 g in 2007 and 0.40 g in 2008), PoP (0.38 g in 2007 and 2008) and Farmers' practice (0.32 g in 2007 and 0.30 g in 2008) respectively. During 2007 and 2008 root dry matter $hill^{-1}$ recorded at physiological maturity in all the management systems differed significantly from one another. Highest root dry matter $hill^{-1}$ was recorded in SRI (0.51 g in 2007 and 0.50 g in 2008) and it was followed by ICM (0.41 g in 2007 and 0.40 g in 2008), PoP (0.36 g in 2007 and 0.37 g in 2008) and Farmers' practice (0.27 g in 2007 and 0.28 g in 2008) respectively.

4.1.8 Number of tillers m^{-2}

Data on tiller production m^{-2} is presented in table 9.

Number of tillers m^{-2} recorded at weekly intervals were significantly influenced by management systems alone in both the years. Through out the crop growth tiller number m^{-2} in all the management systems differed significantly from one another in both the years. Tiller number m^{-2} was recorded from 2WAT/WAS to physiological maturity. In the second and third week number of tillers m^{-2} was in the order PoP > Farmers' practice > ICM >SRI and from 4^{th} week to physiological maturity the order was Farmers' practice > PoP > ICM >SRI. Number of tiller m^{-2} at 2^{nd} week in all the management systems differed significantly from one another in both the years. Highest tiller number m^{-2} was recorded in PoP (267.2 in 2007 and 266.7 in 2008) and it was followed by Farmers' practice (194.1 in 2007 and 190.7 in 2008), ICM (49.8 in 2007 and 49.9 in 2008) and SRI (24.7 in 2007 and 24.8 in 2008) respectively.

At 3^{rd} week tiller number $hill^{-1}$ in all the management systems differed significantly from one another in both the years. Highest tiller number m^{-2} was recorded in PoP (400.9 in 2007 and 400.1 in 2008) and it was followed by Farmers' practice (392.3 in 2007 and 390 in 2008), ICM

Table 9. Effect of management systems and nutrient sources on number of tillers m^{-2}

	Tiller number m^{-2}													
Treatments	**2nd week**		**3rd week**		**4th week**		**5th week**		**6th week**		**7th week**		**Physiological Maturity**	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	24.7	24.8	24.7	24.8	49.3	48.7	48.9	48.5	73.7	72.7	98.0	96.9	96.0	95.5
M_2 (ICM)	49.8	49.9	99.4	99.2	124.4	123.8	149.2	148.8	148.8	147.2	172.7	171.1	146.7	146.7
M_3 (PoP)	267.2	266.7	400.9	400.1	400.9	397.6	462.5	463.5	524.7	526.7	655.9	662.5	591.1	587.8
M_4 (F.P)	194.1	190.7	392.3	390.0	588.6	588.0	883.7	881.2	1074.5	1074.3	1074.2	1078.4	981.4	976.4
SEd	**0.252**	**0.800**	**1.031**	**1.419**	**1.513**	**1.485**	**4.505**	**2.225**	**4.581**	**1.851**	**4.935**	**3.436**	**4.020**	**2.156**
CD (0.05)	**0.569**	**1.809**	**2.331**	**3.209**	**3.424**	**3.358**	**10.191**	**5.034**	**10.365**	**4.187**	**11.163**	**7.772**	**9.095**	**4.878**
S_1 (Organic)	134.4	133.7	230.1	229.5	291.9	290.4	385.5	386.3	453.9	455.3	498.2	504.3	454.7	450.7
S_2 (Integrated)	133.9	132.5	228.3	227.4	289.3	288.9	385.1	384.0	454.9	454.2	500.1	500.3	452.0	451.5
S_3 (Inorganic)	133.5	133.2	229.6	228.6	291.2	289.2	387.7	386.3	457.5	456.3	502.3	503.4	453.9	452.7
SEd	**0.416**	**0.631**	**0.700**	**0.882**	**0.976**	**1.432**	**2.557**	**1.593**	**4.127**	**3.241**	**4.183**	**1.808**	**3.962**	**2.161**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

(99.4 in 2007 and 99.2 in 2008) and SRI (24.7 in 2007 and 24.8 in 2008) respectively. Tiller number m^{-2} at 4th week in all the management systems differed significantly from one another in both the years. Highest tiller production m^{-2} was recorded in Farmers' practice (588.6 in 2007 and 588.0 in 2008) and it was followed by PoP (400.9 in 2007 and 397.6 in 2008), ICM (124.4 in 2007 and 123.8 in 2008) and SRI (49.3 in 2007 and 48.7 in 2008) respectively. During 2007 and 2008 tiller number m^{-2} at 5th week in all the management systems differed significantly from one another. Highest tiller production m^{-2} was recorded in Farmers' practice (883.7 in 2007 and 881.2 in 2008) and it was followed by PoP (462.5 in 2007 and 463.5 in 2008), ICM (149.2 in 2007 and 148.8 in 2008) and SRI (48.9 in 2007 and 48.5 in 2008) respectively. At 6th week tiller number $hill^{-1}$ in all the management systems differed significantly from one another in both the years. Highest tiller production m^{-2} was recorded in Farmers' practice (1074.5 in 2007 and 1074.3 in 2008) and it was followed by PoP (524.7 in 2007 and 526.7 in 2008), ICM (148.8 in 2007 and 147.2 in 2008) and SRI (73.7 in 2007 and 72.7 in 2008) respectively.

Tiller number m^{-2} at 7th week (maximum tillering stage) in the management systems differed significantly from one another in both the years. Highest tiller production m^{-2} was recorded in Farmers' practice (1074.2 in 2007 and 1078.4 in 2008) and it was followed by PoP (655.9 in 2007 and 662.5 in 2008), ICM (172.7 in 2007 and 171.1 in 2008) and SRI (98.0 in 2007 and 96.9 in 2008) respectively. Tiller number m^{-2} at physiological maturity in the management systems differed significantly from one another in both the years. Highest tiller production m^{-2} was recorded in Farmers' practice (981.4 in 2007 and 976.4 in 2008) and it was followed by PoP (591.1 in 2007 and 587.8 in 2008), ICM (146.7 in 2007 and 2008) and SRI (96.0 in 2007 and 95.5 in 2008) respectively.

4.2 CROP YIELD CHARACTERS

4.2.1 NUMBER OF PRODUCTIVE TILLERS M^{-2}

The data on number of productive tillers m^{-2} is presented in Table 10. Number of productive tillers m^{-2} during both the years of experimentation was significantly influenced by management systems. Nutrient sources and interaction effects were not significant.

Number of productive tillers m^{-2} in the management systems indicated that there was significant difference from one another. The Farmers' practice recorded the highest number of productive tillers m^{-2} (491.6 in 2007 and 489.7 in 2008). This was followed by PoP (445.1 in 2007 and 445.8 in 2008, ICM (133.0 in 2007 and 133.5 in 2007) and SRI (95.7 in 2007 and 95.5 in 2008).

4.2.2 Panicle length (cm)

Data presented in Table 10 indicate the effect of management systems and sources of nutrients on panicle length in 2007 and 2008.

Effect of management systems on panicle length was significant in both the years. Effect of nutrient sources and interactions effect were not significant on panicle length in both the years.

Panicle length was maximum in SRI followed by ICM, Farmers' practice and PoP respectively. SRI recorded maximum panicle length of 22.41cm in 2007 and 23.76cm in 2008 respectively which was on par with ICM (21.83cm in 2007 and 22.68cm in 2008. Panicle length was lowest in PoP (20.84 cm in 2007 and 19.86 cm in 2008) which was on par with Farmers' practice (21.40 cm in 2007 and 21.30 cm in 2008) and significantly lower than SRI and ICM.

Table 10. Effect of management systems and nutrient sources on productive tillers m^{-2} and panicle length

Treatments	**Productive tillers m^{-2}**		**Panicle length (cm)**	
Management systems	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	95.7	95.5	22.41	23.76
M_2 (ICM)	133.0	133.5	21.83	22.68
M_3 (PoP)	445.1	445.8	20.84	19.86
M_4 (F.P)	491.6	489.7	21.40	21.30
SEd	**0.967**	**1.759**	**0.414**	**0.750**
CD (0.05)	**2.188**	**3.979**	**0.936**	**1.697**
Nutrient sources				
S_1 (Organic)	291.5	291.4	21.50	21.77
S_2 (Integrated)	290.3	291.1	22.26	22.47
S_3 (Inorganic)	291.9	292.1	21.10	21.47
SEd	**0.783**	**1.265**	**0.325**	**0.461**
CD (0.05)	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

4.2.3 Number of grains panicle^{-1}

Influence of management systems, nutrient sources and their interactions on number of grains per panicle were significant in both the years. The results are presented in Table 11.

In both the years the management systems differed significantly from one another. Maximum number of grains per panicle was recorded in SRI (57.73 in 2007 and 60.13 in 2008) which was followed by ICM (52.05 in 2007 and 54.20 in 2008), PoP (47.76 in 2007 and 49.58 in 2008) and Farmers' practice (45.63 in 2007 and 47.15 in 2008) respectively.

During 2007 and 2008, integrated nutrient source recorded the maximum grains per panicle (51.77 in 2007 and 54.39 in 2008). It was significantly higher than organic source (50.76 in 2007 and 52.42 in 2008) and inorganic source having the least value (49.85 in 2007 and 51.49 in 2008). Organic and inorganic source were on par.

In both the years SRI with organic source (M_1S_1) registered the maximum grains per panicle (58.76 in 2007 and 61.34 in 2008) which was on par with SRI with integrated nutrient source (M_1S_2) and SRI with inorganic source (M_1S_3) (Table 12). The minimum number of grains per panicle (44.98 in 2007 and 45.85 in 2008) was recorded in Farmers' practice with inorganic source (M_4S_3) which was on par with Farmers' practice with integrate nutrient source (M_4S_2) and Farmers' practice with organic source (M_4S_1). All other interactions were significantly superior to these three interactions.

4.2.4 Number of filled grains panicle^{-1}

Management systems, nutrient sources and their interactions exerted significant influence on number of filled grains panicle^{-1} during both the years of experimentation. The results are presented in Table 11.

Number of filled grains panicle^{-1} in all the management systems differed significantly from one another in both the years. Maximum number

Table 11. Effect of management systems and nutrient sources on grains panicle^{-1} and filled grain panicle^{-1}

Treatments	Grains panicle^{-1}		Filled grains panicle^{-1}	
Management systems	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	57.73	60.13	53.49	55.67
M_2 (ICM)	52.05	54.20	47.93	49.63
M_3 (PoP)	47.76	49.58	43.75	45.45
M_4 (F.P)	45.63	47.15	41.58	42.74
SEd	**0.572**	**0.559**	**0.530**	**0.548**
CD (0.05)	**1.294**	**1.264**	**1.190**	**1.240**
Nutrient sources				
S_1 (Organic)	50.76	52.42	46.62	48.04
S_2 (Integrated)	51.77	54.39	47.59	50.02
S_3 (Inorganic)	49.85	51.49	45.86	47.14
SEd	**0.433**	**0.559**	**0.380**	**0.518**
CD (0.05)	**0.894**	**1.264**	**0.790**	**1.070**

of filled grains panicle^{-1} was recorded in SRI (53.49 in 2007 and 55.67 in 2008) and it was followed by ICM (47.93 in 2007 and 49.63 in 2008), PoP (43.75 in 2007 and 45.45 in 2008) and Farmers' practice (41.58 in 2007 and 42.74 in 2008) respectively.

Integrated nutrient source recorded the maximum filled grains panicle^{-1} (47.59 in 2007 and 50.02 in 2008). Integrated nutrient source was significantly higher than organic (46.62 in 2007 and 48.04 in 2009) and inorganic source (45.86 in 2007 and 47.14 in 2008) which in turn were on par with each other.

In both the years SRI with organic source (M_1S_1) registered the maximum filled grains panicle^{-1} (54.47 in 2007 and 56.64 in 2008) (Table 12). The interactions SRI with inorganic (M_1S_3) and SRI with integrated nutrient source (M_1S_2) were found to be statistically on par with M_1S_1. The minimum filled grains panicle^{-1} was recorded by Farmers' practice with inorganic source (M_4S_3) (41.04 in 2007 and 41.82 in 2008).

4.2.5 Sterility percentage

The results on sterility percentage are presented in Table 13. Effect of management systems on sterility percentage was significant in both the years. Nutrient sources and interactions effect were not significant on sterility percentage in both the years.

During 2007 and 2008 sterility percentage was highest in Farmers' practice followed by PoP, ICM and SRI respectively. In 2007 sterility percentage in all the management systems differed significantly from one another. Highest sterility percentage was recorded in Farmers' practice (8.87% in 2007 and 9.34% in 2008) and lowest sterility percentage was recorded in SRI (7.34% in 2007 and 7.41% in 2008).

Table 12. Interaction effect of management systems and nutrient sources on grains panicle^{-1} and filled grains panicle^{-1}

	Grains panicle^{-1}		Filled grains panicle^{-1}	
Interaction effects	**2007**	**2008**	**2007**	**2008**
M_1S_1	58.76	61.34	54.47	56.64
M_1S_2	57.51	59.85	53.10	55.36
M_1S_3	56.92	59.19	52.90	55.01
M_2S_1	51.11	52.66	47.04	48.44
M_2S_2	55.55	58.95	51.25	54.50
M_2S_3	49.48	50.99	45.51	45.96
M_3S_1	47.78	49.18	43.75	45.05
M_3S_2	47.50	49.65	43.50	45.83
M_3S_3	48.00	49.92	44.00	45.76
M_4S_1	45.39	46.49	41.20	42.03
M_4S_2	46.51	49.10	42.50	44.37
M_4S_3	44.98	45.85	41.04	41.82
SEd	**1.090**	**1.112**	**1.000**	**1.036**
CD (0.05)	**2.250**	**2.296**	**2.080**	**2.138**

Table 13. Effect of management systems and nutrient sources on sterility percentage of panicle and thousand grain weight

Treatments	**Sterility percentage**		**Thousand grain weight (g)**	
Management systems	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	7.34	7.41	10.30	10.65
M_2 (ICM)	7.90	8.47	10.20	10.55
M_3 (PoP)	8.38	8.14	10.33	10.64
M_4 (F.P)	8.87	9.34	10.22	10.46
SEd	**0.076**	**2.302**	**0.11**	**0.113**
CD (0.05)	**0.173**	**5.208**	**NS**	**NS**
Nutrient sources				
S_1 (Organic)	**8.23**	**8.42**	**10.25**	**10.55**
S_2 (Integrated)	**8.11**	**8.09**	**10.29**	**10.58**
S_3 (Inorganic)	**8.04**	**8.51**	**10.26**	**10.59**
SEd	0.084	1.745	0.11	0.113
CD (0.05)	NS	NS	NS	NS

Interaction effect not significant

4.2.6 Thousand grain weight (g)

Analysis of the data on thousand grain weight showed no significant influence of management systems, nutrient sources and their interactions on this attribute during both the years of experimentation and the results are presented in Table 13.

4.2.7 Grain yield

Data on grain yield as influenced by management systems, nutrient sources and their interactions in 2007 and 2008 are given in Table 14.

Effect of management systems, nutrient sources and interaction effect on grain yield were significant in both the years.

In both the years the management systems differed significantly from one another. Maximum grain yield was recorded in Farmers' practice (1041.43 kg ha^{-1} in 2007 and 1038.44 kg ha^{-1} in 2008) which was followed by PoP (897.25 kg ha^{-1} in 2007 and 899.67 kg ha^{-1} in 2008), SRI (840.80 kg ha^{-1} in 2007 and 821.58 kg ha^{-1} in 2008) and ICM (729.25 kg ha^{-1} in 2007 and 756.21 kg ha^{-1} in 2008) respectively.

During 2007 and 2008 integrated nutrient source recorded the highest grain yield which was significantly superior to organic and inorganic source , which in turn were on par with each other. Grain yield in integrated nutrient source were 928.69 kg ha^{-1} in 2007 and 920.50 kg ha^{-1} in 2008. Lowest grain yield was recorded in inorganic source (857.35 kg ha^{-1} in 2007 and 858.48 kg ha^{-1} in 2008). Grain yield in organic source were 872.08 kg ha^{-1} in 2007 and 857.95 kg ha^{-1} in 2008.

Among the interactions Farmers' practice with Integrated nutrient source (M_4S_2) recorded the highest grain yield (1206.25 kg ha^{-1} in 2007 and 1189.75 kg ha^{-1} in 2008) which was significantly superior to all other interactions (Table 15). Lowest grain yield was obtained in ICM with inorganic source (M_2 S_3) (729.25 kg ha^{-1} in 2007 and 736.00 kg ha^{-1} in 2008).

Table 14. Effect of management systems and nutrient sources on grain yield and straw yield (kg ha^{-1})

Treatments	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})	
Management systems	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	840.80	821.58	1234.76	1209.66
M_2 (ICM)	764.68	756.21	1126.03	1115.04
M_3 (PoP)	897.25	899.67	1338.44	1323.57
M_4 (F.P)	1041.43	1038.44	1685.07	1696.66
SEd	**9.411**	**9.278**	**15.679**	**15.425**
CD (0.05)	**21.291**	**20.988**	**35.468**	**34.895**
Nutrient sources				
S_1 (Organic)	872.083	857.95	1285.18	1265.8
S_2 (Integrated)	928.686	920.50	1494.44	1496.55
S_3 (Inorganic)	857.346	857.48	1258.59	1246.77
SEd	**9.256**	**9.065**	**14.256**	**34.895**
CD (0.05)	**19.103**	**18.710**	**29.424**	**28.592**

Table 15. Interaction effect of management systems and nutrient sources on grain yield and straw yield (kg ha^{-1})

	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})	
Interaction effects	**2007**	**2008**	**2007**	**2008**
M_1S_1	860.25	825.60	1270.00	1218.20
M_1S_2	835.50	832.25	1223.75	1224.00
M_1S_3	826.64	806.90	1210.52	1186.79
M_2S_1	784.54	791.63	1161.34	1173.71
M_2S_2	780.25	741.00	1143.25	1088.70
M_2S_3	729.25	736.00	1073.50	1082.72
M_3S_1	863.50	845.00	1270.00	1244.60
M_3S_2	892.75	919.00	1370.00	1411.10
M_3S_3	935.50	935.00	1375.31	1315.00
M_4S_1	980.05	969.57	1439.40	1424.10
M_4S_2	1206.25	1189.75	2240.75	2262.40
M_4S_3	938.00	956.00	1375.05	1402.57
SEd	**18.511**	**18.130**	**28.513**	**27.707**
CD (0.05)	**38.205**	**50.992**	**58.847**	**57.184**

4.2.8 Straw yield

The results are presented in Table 14. Significant variation in straw yield was observed in management systems, nutrient sources and their interactions during both the years of study.

Management systems differed significantly from one another in both the years. Maximum straw yield was recorded in Farmers' practice (1685.07 kg ha^{-1} in 2007 and 1696.66 kg ha^{-1} in 2008) which was followed by PoP (1338.44 kg ha^{-1} in 2007 and 1323.57 kg ha^{-1} in 2008), SRI (1234.76 kg ha^{-1} in 2007 and 1209.67 kg ha^{-1} in 2008) and ICM (1126.03 kg ha^{-1} in 2007 and 1115.04 kg ha^{-1} in 2008) respectively.

Integrated nutrient source recorded the highest straw yield which was significantly superior to inorganic and organic source, which in turn were on par with each other in both the years. Straw yield in integrated nutrient source were 1494.44 kg ha^{-1} in 2007 and 1496.55 kg ha^{-1} in 2008. Lowest straw yield was in inorganic source (1258.59 kg ha^{-1} in 2007 and 1246.77 kg ha^{-1} in 2008) which was on par with organic source with a straw yield of 1285.18 kg ha^{-1} in 2007 and 1265.38 kg ha^{-1} in 2008.

Among the interactions Farmers' practice with Integrated nutrient source (M_4S_2) recorded the highest straw yield (2240.75 kg ha^{-1} in 2007 and 2262.40 kg ha^{-1} in 2008 which was significantly superior to all other interactions (Table 15). Lowest straw yield was obtained in ICM with inorganic source (M_2 S_3) (1073.50 kg ha^{-1} in 2007 and 1082.72 kg ha^{-1} in 2008).

4.2.9 Dry matter partitioning

The results on dry matter partitioning at harvest are presented in Tables 16.

The management systems had significant influence on the dry matter partitioning into percentage of root, straw and panicle in both the years. Effect of nutrient sources and interaction effects were not significant.

Table 16. Effect of management systems and nutrient sources on dry matter partitioning

Dry matter partitioning (%)						
Treatments	**Root weight**		**Straw weight**		**Panicle weight**	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	22.19	22.92	49.82	51.48	28.24	25.59
M_2 (ICM)	21.50	22.23	48.39	50.01	30.02	27.77
M_3 (PoP)	20.43	20.90	47.42	49.00	32.16	30.10
M_4 (F.P)	19.66	20.13	47.23	48.33	33.02	31.54
SEd	**0.230**	**0.516**	**0.516**	**0.534**	**0.316**	**0.590**
CD (0.05)	**0.519**	**1.167**	**1.167**	**1.208**	**0.715**	**1.336**
Nutrient sources						
S_1 (Organic)	20.97	21.61	48.13	49.58	30.78	28.81
S_2 (Integrated)	21.01	21.63	48.33	49.78	30.66	28.59
S_3 (Inorganic)	20.84	21.39	48.18	49.76	31.14	28.85
SEd	**0.223**	**0.244**	**0.511**	**0.528**	**0.327**	**0.730**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

Effect of management systems on dry matter accumulation into roots and straw showed the same trend whereas dry matter accumulation in panicle showed a different in trend. SRI recorded the highest percentage of dry matter accumulation in roots (22.19% 2007 and 22.92% in 2008 and straw 49.82% in 2007 and 51.48% in 2008) and they were significantly higher than that in all other management systems. This was followed by the ICM, PoP and Farmers' practice respectively. The least root (19.66% in 2007 and 20.13% in 2008) and straw dry matter accumulation (47.23% in 2007 and 48.33% in 2008) were observed in Farmers' practice. Percentage of root dry matter accumulation in all the management systems differed significantly from one another.

Dry matter accumulation into panicles showed the reverse trend compared to that of dry matter accumulation in roots and straw. Percentage of dry matter accumulation in panicle in the various management systems differed significantly from one another.

Farmers' practice recorded highest percentage of panicle dry matter accumulation (33.02% in 2007 and 31.54% in 2008). Farmers' practice was followed by PoP, ICM and SRI respectively. SRI recorded the lowest percentage of panicle dry matter accumulation (28.24% in 2007 and 25.59% in 2008), which was significantly lower than that in all other management systems.

4.2.10 Harvest Index

The results on harvest index are presented in Table 17. Effect of management systems, nutrient sources and their interaction on harvest index were significant in both the years.

In 2007 the highest harvest index of 0.405 was observed in SRI and ICM which was significantly higher than PoP (0.402) and Farmers' practice (0.387). In 2008 SRI and PoP recorded the highest harvest index of 0.405 which was on par with ICM (0.404) and all the three were significantly higher than Farmers' practice (0.385)

Table 17. Effect of management systems and nutrient sources on harvest index, paddy grain ratio and grain husk ratio

Treatments	**Harvest index**		**Paddy grain ratio**		**Grain husk ratio**	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	0.405	0.405	1.35	1.25	2.25	2.24
M_2 (ICM)	0.405	0.404	1.46	1.17	2.17	2.27
M_3 (PoP)	0.402	0.405	1.40	1.31	2.30	2.32
M_4 (F.P)	0.387	0.385	1.42	1.30	2.21	2.23
SEd	**0.0004**	**0.0002**	**0.065**	**0.111**	**0.112**	**0.116**
CD (0.05)	**0.0008**	**0.0003**	**NS**	**NS**	**NS**	**NS**
Nutrient sources						
S_1 (Organic)	0.404	0.404	1.32	1.20	2.26	2.30
S_2 (Integrated)	0.389	0.387	1.43	1.26	2.24	2.28
S_3 (Inorganic)	0.405	0.401	1.48	1.31	2.20	2.21
SEd	**0.0002**	**0.0001**	**0.112**	**0.116**	**0.033**	**0.056**
CD (0.05)	**0.0005**	**0.0003**	**NS**	**NS**	**NS**	**NS**

Effect of all the nutrient sources differed significantly from one another in both the years. Highest harvest index (0.405 in 2007 and 0.408 in 2008) was recorded in inorganic source which was followed by organic source (0.404 in 2007 and 2008) and integrated nutrient source (0.389 in 2007 and 0.387 in 2008) respectively.

Among the interactions in 2007 the highest harvest index of 0.406 was noticed in SRI with integrated nutrient management (M_1S_2) which was on par with all interactions except PoP X Integrated nutrient source (M_3S_2) and Farmers' practice with Integrated nutrient source (M_4S_2) (Table 18). In 2008 PoP X inorganic source (M_3S_3) recorded highest harvest index of 0.416 which was significantly superior to all other interactions. The lowest harvest index was observed in Farmers' practice with integrated nutrient source (M_4S_2) in both the years (0.350 in 2007 and 0.345 in 2008).

4.2.11 Paddy grain ratio

Analysis of the data on paddy grain ratio showed no significant influence of management systems, nutrient sources and their interactions during both the years of study and the results are presented in Table 17.

4.2.12 Grain husk ratio

The results presented in Table 17 show no significant influence of management systems, nutrient sources and interaction effect on grain husk ratio during both the years of study.

4.2.13 Crop duration

Management systems and nutrient sources had significant effect on crop duration during both years of study and the results are presented in Table 19. Interaction effect was not significant on duration of crop in both the years.

In both the years, the management systems and nutrient sources differed significantly from one another. Minimum duration of crop was

Table 18. Interaction effect of management systems and nutrient sources on harvest index

	Harvest index	
Interaction effects	**2007**	**2008**
M_1S_1	0.404	0.404
M_1S_2	0.406	0.405
M_1S_3	0.406	0.405
M_2S_1	0.403	0.403
M_2S_2	0.406	0.405
M_2S_3	0.405	0.405
M_3S_1	0.405	0.404
M_3S_2	0.395	0.394
M_3S_3	0.405	0.416
M_4S_1	0.405	0.405
M_4S_2	0.350	0.345
M_4S_3	0.406	0.405
SEd	**0.0005**	**0.003**
CD (0.05)	**0.0010**	**0.0006**

Table 19. Effect of management systems and nutrient sources on crop duration

Treatments	Crop duration (days)	
Management systems	**2007**	**2008**
M_1 (SRI)	96.5	95.1
M_2 (ICM)	100.0	95.6
M_3 (PoP)	108.2	104.4
M_4 (F.P)	87.2	85.2
SEd	**0.178**	**0.148**
CD (0.05)	**0.399**	**0.335**
Nutrient sources		
S_1 (Organic)	94.7	94.7
S_2 (Integrated)	97.4	97.4
S_3 (Inorganic)	97.7	98.2
SEd	**0.147**	**0.141**
CD (0.05)	**0.304**	**0.291**

Interaction effect not significant

observed in Farmers' practice (87.2 days in 2007 and 85.2 days 2008) followed by SRI (96.5 days in 2007 and 95.1 days in 2008), ICM (100.0 days in 2007 and 95.6 days in 2008) and PoP (108.2 days in 2007 and 104.4 days in 2008).

Organic source recorded the lowest duration of crop (94.7 days in both the years) which was followed by integrated nutrient source (97.4 days in both the years) and inorganic source (97.7 days in 2007 and 98.2 in 2008) respectively.

4.3 BIOCHEMICAL PROPERTIES

The biochemical properties that govern the nutritional quality of the grains were assessed in terms of the total free amino acid, phenols, crude protein, total starch, amylose and amylopectin contents.

4.3.1 TOTAL FREE AMINO ACID IN GRAIN

Perusal of the data presented in Table 20 revealed that management systems significantly influenced total free amino acid content of grain in both the years. Effect of nutrient sources and interaction effects were not significant.

During 2007 and 2008 SRI recorded highest free amino acid content and was on par with ICM and both were significantly higher than PoP and Farmers' practice which in turn differed significantly from each other.

SRI recorded free amino acid content of 32.85 mg $100g^{-1}$ in 2007 and 31.66 mg $100g^{-1}$ in 2008 and ICM recorded 32.16 mg $100g^{-1}$ in 2007 and 30.10 mg $100g^{-1}$ in 2008. Total free amino acid content of grain in PoP was 30.02 mg $100g^{-1}$ in 2007 and 27.77 mg $100g^{-1}$ in 2008. The lowest total amino acid content was recorded in Farmers' practice (28.24 mg $100g^{-1}$ in 2007 and 25.59 mg $100g^{-1}$ in 2008).

Table 20. Effect of management systems and nutrient sources on total free amino acid and phenols content of grain

Treatments	Total free amino acids (mg $100g^{-1}$)		Phenols (mg $100g^{-1}$)	
Management systems	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	32.85	31.54	9.47	9.65
M_2 (ICM)	32.16	30.10	9.20	9.55
M_3 (PoP)	30.02	27.77	9.33	9.64
M_4 (F.P)	28.24	25.59	9.22	9.46
SEd	**0.334**	**0.767**	**0.198**	**0.113**
CD (0.05)	**0.756**	**1.736**	**NS**	**NS**
Nutrient sources				
S_1 (Organic)	31.03	28.86	9.38	9.55
S_2 (Integrated)	30.65	28.59	9.27	9.56
S_3 (Inorganic)	30.78	28.81	9.26	9.59
SEd	**0.324**	**0.730**	**0.151**	**0.113**
CD (0.05)	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

4.4.2 Phenols in grain

Phenols in grain was estimated and data presented in Table 20. Effect of management systems, nutrient sources and interaction effects on phenol content of grain was not significant during both the years of study.

4.3.3 Starch in grain

Data on starch content of grain presented in Table 21 showed that nutrient sources alone significantly influenced the starch content of grain in 2008. Management systems

and interaction effects were not significant with respect to starch content of grain in both the years.

Organic source recorded the highest starch content of grain (52.07% in 2008) which was significantly higher than inorganic (50.77% in 2008) and that was on par with integrated nutrient source (50.95% in 2008). Integrated nutrient source (50.95%) was on par with inorganic source (50.77%).

4.3.4 Crude Protein In Grain

Data on crude protein content of grain presented in Table 21 showed that nutrient sources alone significantly influenced the crude protein content of grain during both the years of experimentation. Management systems and interaction effects were not significant.

Effect of all the nutrient sources differed significantly from one another. Highest content of crude protein was recorded in organic source (7.98% in 2007 and 8.23% in 2008) which was followed by inorganic source (7.58% in 2007 and 7.74% in 2008) and integrated nutrient source (6.00% in 2007 and 6.17% in 2008) respectively.

4.3.5 Amylose in grain

The results presented in Table 22 showed that no significant influence of management systems, nutrient sources and interaction effects on amylose content of grain was observed during both the years of study.

Table 21. Effect of management systems and nutrient sources on starch and crude
protein content of grain

Treatments	Starch (%)		Crude protein (%)	
Management systems	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	51.20	50.68	7.21	7.33
M_2 (ICM)	51.79	51.11	7.27	7.52
M_3 (PoP)	51.70	52.22	7.05	7.27
M_4 (F.P)	52.00	51.06	7.22	7.39
SEd	**0.546**	**0.537**	**0.078**	**0.079**
CD (0.05)	**NS**	**NS**	**7.94**	**NS**
Nutrient sources				
S_1 (Organic)	52.14	52.07	7.98	8.23
S_2 (Integrated)	51.70	50.95	6.00	6.17
S_3 (Inorganic)	51.18	50.77	7.58	7.74
SEd	**0.549**	**0.548**	**0.077**	**0.079**
CD (0.05)	**1.130**	**1.131**	**5.94**	**0.162**

Interaction effect not significant

Table 22. Effect of management systems and nutrient sources on amylose and amylopectin content of grain

Treatments	Amylose (%)		Amylopectin (%)	
Management systems	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	21.74	22.44	29.45	28.24
M_2 (ICM)	21.26	22.51	30.53	28.60
M_3 (PoP)	21.65	22.62	29.77	29.60
M_4 (F.P)	21.53	22.53	30.47	28.52
SEd	**0.223**	**0.346**	**0.318**	**0.781**
CD (0.05)	**NS**	**NS**	**0.719**	**NS**
Nutrient sources				
S_1 (Organic)	21.52	22.45	30.62	29.62
S_2 (Integrated)	21.81	22.74	29.89	28.21
S_3 (Inorganic)	21.31	22.39	29.65	28.39
SEd	**0.228**	**0.223**	**0.320**	**0.498**
CD (0.05)	**NS**	**NS**	**0.661**	**1.028**

Interaction effect not significant

4.3.6 Amylopectin in grain

Data on the effect of management systems, sources of nutrients and interaction effects on amylopectin content of grain in 2007 and 2008 are presented in Table 22.

Effect of management systems on amylopectin was significant only in 2007. Effect of nutrient sources on amylopectin was significant in both the years but interaction effects were not significant in both the years.

In 2007 highest amylopectin was recorded in ICM (3053%) which was significantly higher than the other three management systems. ICM was followed by Farmers' practice (30.47%), PoP (29.77%) and SRI (29.45%) respectively. Farmers' practice was on par with PoP which in turn was on par with SRI.

Both in 2007 and 2008, organic source recorded the highest content of amylopectin (30.62% and 29.62% respectively) which was significantly superior to integrated nutrient source (29.89% in 2007 and 28.21% in 2008) and inorganic source (29.65% in 2007 and 28.39% in 2008) which in turn were on par with each other.

4.4 OBSERVATIONS ON WEEDS

4.4.1 Major Weed Flora in Experimental Field

The different weed species found in the experimental field were collected during the period of experimentation and identified. The weeds were classified into grasses, sedges and broad leaved weeds and are presented in Table 23. The important species of weeds during 2007 were *Isachne miliacea* Roth ex Roem. et Schult., *Echinochloa colona* (L.) Link (among grasses), *Cyperus iria* L., *Cyperus difformis* L., *Fimbristylis miliacea* (L.) Vahl. (among sedges), *Monochoria vaginalis* (Burm. F), *Marsilea quadrifolia* L. and *Sphenoclea zeylanica* (among broad leaved weeds). The same weed species were observed during 2008 also.

Table 23. Major weed flora observed in experimental field

Scientific name	Common name	Family
Grasses		
Isachne miliacea Roth ex Roem. et Schult	Blood grass	Poaceae
Echinochloa colona (L.) Link	Jungle rice	Poaceae
<u>Sedges</u>		
Cyperus iria L.	Yellow nut sedge	Cyperaceae
Cyperus difformis L.	Umbrella sedge	Cyperaceae
Fimbristylis miliacea (L.)	Globe fingerush	Cyperaceae
<u>Broadleaved weeds</u>		
Monochoria vaginalis (Burm. F.)	Monochoria	Pontenderiaceae
Marsilea quadrifolia L.	Airy Pepper wort	Marsileaceae
Sphenoclea zeylanica	Goose weed	Sphenocleaceae

4.4.2 **Weed Dry Matter Production**

The data on weed dry matter was recorded at 15 and 35 das/dat in both the years of experimentation and are presented in table 24.

The data revealed the significant effect of management systems on weed dry matter during both stages and both the years of experimentation. Nutrient sources and interaction effects were not significant on weed dry matter during both the stages in both the years.

Weed dry matter production in the different management systems at both 15 DAS/DAT and 35 DAS/DAT differed significantly from one another.

During 2007 and 2008 at 15 DAS/DAT weed dry matter production was in the following order i.e. Farmers' practice, PoP, SRI and ICM. At 35 DAS/DAT the order of weed dry matter production was Farmers' practice, ICM, PoP and SRI. At 15DAS/DAT weed dry matter in Farmers' practice was 24.09 g m^{-2} in 2007 and 24.56 g m^{-2} in 2008, in PoP was 23.03 g m^{-2} in 2007 and 23.79 g m^{-2} in 2008, in SRI was 21.72 g m^{-2} in 2007 and 22.45 g m^{-2} in 2008. The lowest weed dry matter was recorded in ICM (18.71 g m^{-2} in 2007 and 19.34 g m^{-2} in 2008).

At 35 DAS/DAT weed dry matter in Farmers' practice was 57.96 g m^{-2} in 2007 and 58.51 g m^{-2} in 2008, in ICM was 54.06 g m^{-2} in 2007 and 54.21 g m^{-2} in 2008, in PoP was 43.03 g m^{-2} in 2007 and 43.25 g m^{-2} in 2008 and the lowest weed dry matter was recorded in SRI (24.09 g m^{-2} in 2007 and 24.38 g m^{-2} in 2008).

4.5 PLANT ANALYSIS

4.5.1 Nutrient content of grain

The data showed that source of nutrients significantly influenced the n, k and fe contents of grain in both the years. Management systems significantly influenced only the fe content of grain in both the years.

Table 24. Effect of management systems and nutrient sources on weed dry matter production (g m^{-2})

Treatments	Weed dry matter (g m^{-2}) (15DAS/DAT)		Weed dry matter (g m^{-2}) (35DAS/DAT)	
Management systems	2007	2008	2007	2008
M_1 (SRI)	21.72	22.45	24.09	24.38
M_2 (ICM)	18.71	19.34	54.06	54.21
M_3 (PoP)	23.03	23.79	43.03	43.25
M_4 (F.P)	24.09	24.56	57.96	58.51
SEd	**0.217**	**0.227**	**0.487**	**0.426**
CD (0.05)	**0.491**	**0.514**	**1.101**	**0.963**
Nutrient sources				
S_1 (Organic)	22.36	22.02	45.43	45.44
S_2 (Integrated)	21.80	22.47	44.87	45.15
S_3 (Inorganic)	21.51	22.1	44.05	44.68
SEd	**0.234**	**0.241**	**0.546**	**0.324**
CD (0.05)	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

Interaction effects were not significantly differing in the content of nutrients in grains.

4.5.1.1 Nitrogen content of grain

Effect of the nutrient sources differed significantly from one another. (Table 25). More nitrogen content was recorded in organic source (1.28% in 2007 and 1.32% in 2008) which was followed by inorganic source (1.21% in 2007 and 1.24% in 2008) and integrated nutrient source (0.96% in 2007 and 0.99% in 2008) respectively.

4.5.1.2 Potassium content of grain

Organic source recorded the highest potassium content of 0.33% both in 2007 and 2008 which was significantly higher than integrated nutrient (0.32% in 2007 and 2008) and inorganic source (0.31% in 2007 and 0.32% in 2008) which in turn were on par with each other. (Table 25)

4.5.1.3 Iron content of grain

Iron content of grain was significantly influenced by nutrient sources alone in both the years. (Table 26)

Both in 2007 and 2008 highest iron content of grain was recorded in organic source (36.05ppm in 2007 and 35.87ppm in 2008) and it was on par with integrated nutrient source (35.50ppm in 2007 and 34.76ppm in 2008). Both organic source and integrated sources were significantly higher than inorganic source (32.53ppm in 2007 and 32.80ppm in 2008).

4.5.2 Nutrient uptake by grain

Data on uptake of N, P, K, S, Fe, Zn and Mn by grain as influenced by management systems and source of nutrients are presented in Tables 27 to 30.

Effect of management systems, sources of nutrients and interactions were not significant on uptake of sulphur and zinc in both the years.

Table 25. Effect of management practices and nutrient sources on N, P, K and S content of grain

Treatments	N (%)		P (%)		K (%)		S (%)	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	1.15	1.17	0.12	0.12	0.31	0.32	0.07	0.08
M_2 (ICM)	1.16	1.20	0.12	0.12	0.32	0.32	0.07	0.08
M_3 (PoP)	1.13	1.16	0.12	0.13	0.33	0.31	0.07	0.08
M_4 (F.P)	1.16	1.18	0.12	0.14	0.31	0.33	0.07	0.07
SEd	**0.016**	**0.013**	**0.007**	**0.009**	**0.008**	**0.004**	**0.007**	**0.005**
CD (0.05)	**NS**	NS	**NS**	NS	**NS**	NS	**NS**	NS
Nutrient sources								
S_1 (Organic)	1.28	1.32	0.13	0.14	0.33	0.33	0.07	0.08
S_2 (Integrated)	0.96	0.99	0.12	0.13	0.32	0.32	0.07	0.08
S_3 (Inorganic)	1.21	1.24	0.11	0.12	0.31	0.32	0.07	0.07
SEd	**0.012**	**0.013**	**0.005**	**0.008**	**0.004**	**0.004**	**0.001**	**0.007**
CD (0.05)	**0.025**	**0.026**	**NS**	**NS**	**0.008**	**0.007**	**NS**	**NS**

Interaction effect not significant

Table 26. Effect of management practices and nutrient sources on Fe, Zn and Mn content of grain

Treatments	**Fe (ppm)**		**Zn(ppm)**		**Mn(ppm)**	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	34.59	34.31	336.37	332.78	74.25	74.08
M_2 (ICM)	35.54	33.91	320.86	323.20	72.67	72.75
M_3 (PoP)	34.33	34.12	326.14	327.64	73.54	73.95
M_4 (F.P)	34.30	35.58	319.49	326.16	73.42	73.25
SEd	**0.547**	**0.763**	**38.790**	**40.159**	**2.209**	**2.101**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient sources						
S_1 (Organic)	36.05	35.25	329.83	330.07	73.05	72.67
S_2 (Integrated)	35.50	34.76	350.85	349.67	71.75	72.06
S_3 (Inorganic)	32.53	32.80	296.47	302.59	75.61	75.80
SEd	**0.748**	**0.760**	**40.711**	**37.956**	**1.768**	**1.711**
CD (0.05)	**1.545**	**1.568**	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

4.5.2.1 Uptake of N by grain

Effect of management systems, source of nutrients and interaction effects on uptake of N by grain was significant in both the years. (Table 27).

Result indicated that N uptake by grain in management systems significantly differed from one another both in 2007 and 2008. During both the years uptake of N was highest in Farmers' practice (11.91 kg ha^{-1} in 2007 and 12.16 kg ha^{-1}). This was followed by PoP (10.11 kg ha^{-1} in 2007 and 10.44 kg ha^{-1}), SRI (9.71 kg ha^{-1} in 2007 and 9.64 kg ha^{-1}) and ICM (8.89 kg ha^{-1} in 2007 and 9.12 kg ha^{-1} in 2008).

During 2007 and 2008 N uptake in all the three nutrient sources differed significantly from one another. In both the years N uptake was highest in organic source (11.14 kg ha^{-1} in 2007 and 11.30 kg ha^{-1}) followed by inorganic source (10.39 kg ha^{-1} in 2007 and 10.62 kg ha^{-1} in 2008 and integrated nutrient source (8.94 kg ha^{-1} in 2007 and 9.11 kg ha^{-1} in 2008) respectively.

In both the years of study interaction of Farmers' practice with organic source (M_4S_1) recorded highest N uptake by grain (12.52 kg ha^{-1} in 2007 and 12.68 kg ha^{-1} in 2008) which was on par with Farmers' practice with integrated nutrient source (M_4S_2) (11.95 kg ha^{-1} in 2007 and 12.14 kg ha^{-1} in 2008) (Table 28). The least value of N uptake by grain (7.65 kg ha^{-1} in 2007 and 7.57 kg ha^{-1} in 2008) was recorded in ICM with integrated nutrient source (M_2S_2). M_2S_2 was on par with M_1S_2 and M_3S_2 in 2007 and with M_1S_2 in 2008.

4.5.2.2 Uptake of P by grain

Management systems alone had a significant effect on uptake of P. Nutrient sources and interaction effect were not significant in both the years (Table 27)

Both in 2007 and 2008 Farmers' practice recorded significantly higher P uptake by grain than the other three systems. Highest P uptake by

Table 27. Effect of management practices and nutrient sources on N, P, K and S uptake of grain

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	9.71	9.64	1.09	1.01	2.64	2.67	0.57	0.62
M_2 (ICM)	8.89	9.12	0.99	0.90	2.45	2.44	0.52	0.59
M_3 (PoP)	10.11	10.44	1.14	1.09	2.92	2.76	0.62	0.63
M_4 (F.P)	11.91	12.16	1.25	1.50	3.25	3.43	0.70	0.78
SEd	**0.151**	**0.224**	**0.013**	**0.087**	**0.088**	**0.061**	**0.064**	**0.048**
CD (0.05)	**0.340**	**0.507**	**0.028**	**0.198**	**0.198**	**0.138**	**NS**	**NS**
Nutrient sources								
S_1 (Organic)	11.14	11.30	1.15	1.16	2.83	2.82	0.58	0.66
S_2 (Integrated)	8.94	9.11	1.13	1.17	2.95	2.95	0.62	0.70
S_3 (Inorganic)	10.39	10.62	1.07	1.03	2.67	2.71	0.61	0.61
SEd	**0.210**	**0.215**	**0.012**	**0.083**	**0.047**	**0.058**	**0.089**	**0.070**
CD (0.05)	**0.433**	**0.443**	**0.024**	**NS**	**0.097**	**0.120**	**NS**	**NS**

Table 28. Interaction effect of management practices and nutrient sources on N uptake of grain

	N uptake (kg ha^{-1})	
Interaction effects	**2007**	**2008**
M_1S_1	10.94	10.91
M_1S_2	10.91	8.08
M_1S_3	10.91	9.93
M_2S_1	10.11	10.52
M_2S_2	10.52	7.57
M_2S_3	10.52	9.28
M_3S_1	10.97	11.08
M_3S_2	11.08	8.65
M_3S_3	11.08	11.60
M_4S_1	12.52	12.68
M_4S_2	12.68	12.14
M_4S_3	12.68	11.66
SEd	**0.419**	**0.430**
CD (0.05)	**0.866**	**0.887**

grain in Farmers' practice (1.25 kg ha^{-1} in 2007 and 1.50 kg ha^{-1} in 2008) was followed by PoP (1.14 kg ha^{-1} in 2007 and 1.09 kg ha^{-1} in 2008), SRI (1.09 kg ha^{-1} in 2007 and 1.01 kg ha^{-1} in 2008) and ICM (0.99 kg ha^{-1} in 2007 and 0.90 kg ha^{-1} in 2008). In 2007 all the management systems differed significantly from one another. In 2008 uptake of P was highest in Farmers' practice which was on par with PoP which in turn was on par with SRI. ICM recorded the lowest P uptake.

4.5.2.3 K uptake by grain

Management systems and source of nutrients had a significant influence on potassium uptake in both the years. The interaction effect was not significant in both the years. (Tables 27)

In both the years M_4 (Farmers' practice) was significantly higher than the other management practices. In 2007 M_3 (PoP) was significantly higher than M_1 (SRI) and M_2 (ICM) which in turn were on par. In 2008 M_3 (PoP) and M_1 (SRI) were on par and were significantly higher than M_2 (ICM).

During 2007 and 2008 K uptake was maximum in Farmers' practice (3.25 kg ha^{-1} in 2007 and 3.43 kg ha^{-1} in 2008) followed by PoP (2.92 kg ha^{-1} in 2007 and 2.76 kg ha^{-1} in 2008), SRI (2.64 kg ha^{-1} in 2007 and 2.67 kg ha^{-1} in 2008)

Integrated nutrient source recorded maximum K uptake by grain (2.95 kg ha^{-1} in 2007 and 2008) which was significantly superior to organic (2.83 kg ha^{-1} in 2007 and 2.82 kg ha^{-1} in 2008) and inorganic source (2.67 kg ha^{-1} in 2007 and 2.71 kg ha^{-1} in 2008). In 2007 S_1, S_2 and S_3 differed significantly from one another. In 2008 S_1 (organic) and S_3 (inorganic) were on par.

4.5.2.4 Fe uptake

Management systems and sources of nutrients significantly influenced the uptake of Fe by grain in both the years and the interaction effects were not significant (Table 29).

Table 29. Effect of management practices and nutrient sources on Fe, Zn and Mn uptake of grain

Treatments	Fe uptake (kg ha^{-1})		Zn uptake (kg ha^{-1})		Mn uptake (kg ha^{-1})	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	0.04	0.04	0.28	0.27	0.06	0.06
M_2 (ICM)	0.04	0.04	0.25	0.25	0.06	0.06
M_3 (PoP)	0.05	0.05	0.29	0.30	0.07	0.07
M_4 (F.P)	0.06	0.06	0.34	0.34	0.08	0.08
SEd	**0.006**	**0.002**	**0.038**	**0.039**	**0.003**	**0.002**
CD (0.05)	**0.014**	**0.005**	**NS**	**NS**	**0.006**	**0.004**
Nutrient sources						
S_1 (Organic)	0.03	0.03	0.29	0.28	0.07	0.06
S_2 (Integrated)	0.07	0.07	0.33	0.33	0.07	0.07
S_3 (Inorganic)	0.04	0.04	0.25	0.26	0.07	0.07
SEd	**0.006**	**0.001**	**0.038**	**0.036**	**0.002**	**0.002**
CD (0.05)	**0.012**	**0.003**	**NS**	**NS**	NS	NS

Maximum uptake of Fe was recorded in Farmers' practice (0.035 kg ha^{-1} in 2007 and 0.037 in 2008) which was followed by PoP (0.031 kg ha^{-1} in 2007 and 2008), SRI (0.030 kg ha^{-1} in 2007 and 0.029 kg ha^{-1} 2008) and ICM (0.027 kg ha^{-1} in 2007 and 0.026 kg ha^{-1} in 2008). In both years M_4 (Farmers' practice) was significantly higher than the other three management systems. M_3 (PoP) and M_1 (SRI) were on par and significantly higher than M_2 (ICM).

Effect of all the nutrient sources differed significantly from one another in both the years. Integrated nutrient source recorded the highest Fe uptake by grain (0.034 kg ha^{-1} in 2007 and 0.033 kg ha^{-1} 2008) followed by organic source 0.031 kg ha^{-1} in 2007 and 2008) and inorganic source (0.028 kg ha^{-1} in 2007 and 2008).

4.5.2.5 Mn uptake by grain

Management systems and interaction effect had a significant influence on Mn uptake by grain in both the years. Sources of nutrients were found to be not significant in both the years. (Table 29)

In both the years maximum uptake of Mn was recorded in Farmers' practice (0.08 kg ha^{-1} in 2007 and 2008) and was significantly higher than other three management systems. Farmers' practice was followed by PoP (0.07 kg ha^{-1} in 2007 and 2008), ICM (0.06 kg ha^{-1} in both the years) and SRI (0.06 kg ha^{-1} in 2007 and 2008). PoP was significantly higher than ICM and SRI which in turn recorded the same uptake.

Farmers' practice with integrated nutrient source (M_4S_2) recorded highest uptake of Fe (0.09 kg ha^{-1} in 2007 and 2008) which was significantly superior to all other interactions (Table 30). The least uptake value of 0.06 kg ha^{-1} was recorded by six interactions viz. M_1S_2, M_1S_3, M_2S_1, M_2S_2, M_2S_3 and M_3S_2 in 2007. In 2008 ICM with integrated nutrient source (M_2S_2) recorded least Mn uptake value of 0.05 kg ha^{-1}.

Table 30. Interaction effect of management practices and nutrient sources on Mn uptake of grain

	Mn uptake (kg ha^{-1})	
Interaction effects	**2007**	**2008**
M_1S_1	0.07	0.06
M_1S_2	0.06	0.06
M_1S_3	0.06	0.06
M_2S_1	0.06	0.06
M_2S_2	0.06	0.05
M_2S_3	0.06	0.06
M_3S_1	0.07	0.06
M_3S_2	0.06	0.07
M_3S_3	0.07	0.07
M_4S_1	0.07	0.07
M_4S_2	0.09	0.09
M_4S_3	0.07	0.07
SEd	**0.004**	**0.005**
CD (0.05)	**0.009**	**0.009**

4.5.3 Nutrient content of straw

Percentage content of N, P, K, S, FE, ZN and Mn in straw as influenced by management systems, nutrient sources and their interactions are presented in tables 31 and 32.

The data showed that effect of sources of nutrients on zn content of straw alone was significant in both the years. Management systems and interaction effects were not significant with respect nutrient content in straw in both the years.

4.5.3.1 Zn content of straw

Zn content of straw was highest in integrated nutrient source (464.37ppm in 2007 and 490.88ppm in 2008) and it was significantly higher than organic and inorganic (Table 32). Integrated nutrient source was followed by organic (353.37ppm in 2007 and 413.99ppm in 2008) and inorganic source (343.73ppm in 2007 and 403.18ppm in 2008). In 2007 nutrient sources differed significantly from one another. In 2008 organic source was on par with inorganic source.

4.5.4 Nutrient uptake by straw

Data on the uptake of N, P, K, S, Fe, Zn and Mn by straw as influenced by management systems, sources of nutrients and their interactions are presented in Tables 33 to 36.

Effect of management systems, sources of nutrients and interactions on uptake of all nutrients except S were significant in both the years.

4.5.4.1 N uptake by straw

N uptake by straw was significantly influenced by management systems in both years. Sources of nutrients and interactions had no significant influence on N uptake by straw in both the years. (Table 33)

Highest N uptake by straw was recorded by Farmers' practice (8.52 kg ha^{-1} in 2007 and 8.25 kg ha^{-1} in 2008) which was significantly higher than

Table 31. Effect of management practices and Nutrient sources on N, P, K and S content of straw

Treatments	N (%)		P (%)		K (%)		S (%)	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	0.55	0.49	0.04	0.05	1.45	1.51	0.09	0.10
M_2 (ICM)	0.51	0.44	0.04	0.04	1.38	1.55	0.09	0.11
M_3 (PoP)	0.55	0.47	0.03	0.03	1.36	1.56	0.10	0.10
M_4 (F.P)	0.52	0.49	0.04	0.04	1.33	1.48	0.09	0.10
SEd	**0.067**	**0.056**	**0.008**	**0.008**	**0.093**	**0.114**	**0.011**	**0.011**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient sources								
S_1 (Organic)	0.56	0.49	0.04	0.04	1.36	1.60	0.09	0.10
S_2 (Integrated)	0.48	0.44	0.05	0.05	1.42	1.58	0.10	0.10
S_3 (Inorganic)	0.57	0.49	0.03	0.03	1.36	1.40	0.09	0.10
SEd	**0.074**	**0.055**	**0.007**	**0.008**	**0.116**	**0.083**	**0.019**	**0.024**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 32. Effect of management practices and Nutrient sources on Fe, Zn and Mn content of straw

Treatments	**Fe (ppm)**		**Zn(ppm)**		**Mn(ppm)**	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	574.98	594.00	387.78	441.96	581.75	618.39
M_2 (ICM)	554.41	598.70	387.78	432.01	573.65	610.07
M_3 (PoP)	559.33	595.49	386.93	441.36	576.08	642.75
M_4 (F.P)	564.54	595.01	386.13	428.74	573.87	612.49
SEd	**37.719**	**42.528**	**4.146**	**26.255**	**39.717**	**43.112**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient sources						
S_1 (Organic)	468.53	499.65	353.37	413.99	544.52	585.82
S_2 (Integrated)	601.66	646.20	464.37	490.88	565.37	607.25
S_3 (Inorganic)	619.76	641.55	343.7	403.18	619.13	647.20
SEd	**74.361**	**90.208**	**4.146**	**4.146**	**72.373**	**86.054**
CD (0.05)	**NS**	**NS**	**8.557**	**8.557**	**NS**	**NS**

Table 33. Effect of management practices and nutrient sources on N, P, K and S uptake of straw

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	6.86	5.91	0.48	0.55	17.83	18.27	1.15	1.24
M_2 (ICM)	5.74	4.97	0.45	0.45	15.55	17.23	1.07	1.17
M_3 (PoP)	7.34	6.27	0.42	0.46	18.17	20.72	1.33	1.30
M_4 (F.P)	8.52	8.25	0.68	0.73	22.73	25.13	1.53	1.68
SEd	**0.452**	**0.743**	**0.094**	**0.097**	**1.097**	**1.336**	**0.158**	**0.139**
CD (0.05)	**1.073**	**1.594**	**NS**	**NS**	**2.480**	**3.022**	**NS**	**NS**
Nutrient sources								
S_1 (Organic)	7.21	6.26	0.48	0.53	17.50	17.63	1.20	1.35
S_2 (Integrated)	6.96	6.67	0.69	0.71	21.16	23.44	1.43	151
S_3 (Inorganic)	7.16	6.11	0.35	0.41	17.05	19.94	1.17	1.25
SEd	**0.956**	**0.772**	**0.076**	**0.049**	**1.609**	**1.267**	**0.267**	**0.188**
CD (0.05)	**NS**	**NS**	**0.156**	**0.101**	**3.321**	**2.614**	**NS**	**NS**

all other management systems in both the years. M_4 was followed by PoP (7.34 kg ha^{-1} in 2007 and 6.27 kg ha^{-1} in 2008) and SRI (6.86 kg ha^{-1} in 2007 and 5.91 kg ha^{-1} in 2008) and ICM (5.74 kg ha^{-1} in 2007 and 4.97 kg ha^{-1} in 2008) respectively.

4.5.4.2 P uptake by straw

Effect of nutrient sources on P uptake by straw was significant in both the years. (Table 33). Effect of management systems and interaction effects on P uptake by straw were not significant in 2008.

In 2007 and 2008 integrated nutrient source recorded the highest P uptake (0.69 kg ha^{-1} in 2007 and 0.71 kg ha^{-1} in 2008) which was significantly superior to organic source (0.48 kg ha^{-1} in 2007 and 0.53 kg ha^{-1} in 2008) and inorganic source (0.35 kg ha^{-1} in 2007 and 0.41 kg ha^{-1} in 2008) which in turn were on par with each other.

4.5.4.3 K uptake by straw

Effect of management systems, sources of nutrients and interaction effects on uptake of K by straw was significant in both the years (Table 33)

During both the years uptake of K by straw was highest in Farmers' practice (22.73 kg ha^{-1} in 2007 and 25.13 kg ha^{-1} in 2008) which was significantly superior to all other management systems. Farmers' practice was followed by PoP (18.17 kg ha^{-1} in 2007 and 20.72 kg ha^{-1} in 2008), SRI (17.83 kg ha^{-1} in 2007 and 18.27 kg ha^{-1} in 2008) and ICM (15.55 kg ha^{-1} in 2007 and 17.23 kg ha^{-1} in 2008). PoP was on par with SRI which in turn was on par with ICM.

In 2007 and 2008 K uptake by straw was highest in integrated nutrient source (21.16 kg ha^{-1} in 2007 and 23.44 kg ha^{-1} in 2008) and it was significantly superior to organic source (17.50 kg ha^{-1} in 2007 and 17.63 kg ha^{-1} in 2008) and inorganic source (17.05 kg ha^{-1} in 2007 and 19.94 kg ha^{-1} in 2008) which in turn were on par with each other.

Farmers' practice with integrated nutrient source (M_4S_2) resulted in highest K uptake by straw (31.88 kg ha^{-1} in 2007 and 33.89 kg ha^{-1} in 2008), which was significantly superior to all other interaction effects (Table 34). The least value of K uptake by straw (14.30 kg ha^{-1}) was recorded in ICM with inorganic source (M_2S_3) in 2007 and in ICM with integrated nutrient source (M_2S_2) (17.40 kg ha^{-1}) in 2008.

4.5.4.4 Fe uptake by straw

Management systems and sources of nutrients had significant influence on Fe uptake by straw in both the years. Interaction effects were not significant in both the years. (Table 35)

During 2007 and 2008 Fe uptake by straw was maximum (0.96 kg ha^{-1} in 2007 and 1.02 kg ha^{-1} in 2008) in Farmers' practice and it was significantly superior to other management systems. In both the years, Fe uptake was higher in Farmers' practice which was followed by PoP (0.76 kg ha^{-1} in 2007 and 0.80 kg ha^{-1} in 2008) SRI (0.71 kg ha^{-1} in 2007 and 0.72 kg ha^{-1} in 2008) and ICM (0.63 kg ha^{-1} in 2007 and 0.67 kg ha^{-1} in 2008). In both years PoP was on par with SRI and SRI was on par with ICM

Integrated nutrient source recorded maximum Fe uptake of 0.90 kg ha^{-1} in 2007 and 0.97 kg ha^{-1} in 2008 which was on par with inorganic source (0.78 kg ha^{-1} in 2007 and 0.80 kg ha^{-1} in 2008). In both the years inorganic source was on par with least value of Fe uptake recorded by organic source (0.61 kg ha^{-1} in 2007 and 0.64 kg ha^{-1} in 2008).

4.5.4.5 Zn uptake by straw

Effect of management systems, sources of nutrients and interaction effects on uptake of Zn by the straw was significant (Table 35).

During both the years uptake of Zn was highest in Farmers' practice (0.67 kg ha^{-1} in 2007 and 0.74 kg ha^{-1}). This was followed by PoP (0.52 kg ha^{-1} in 2007 and 0.59 kg ha^{-1}) and SRI (0.48 kg ha^{-1} in 2007 and 0.54 kg ha^{-1} in 2008) and the least value of Zn uptake was obtained in ICM (0.44 kg ha^{-1}

Table 34. Interaction Effect of management practices and nutrient sources on K uptake of straw

	K uptake (kg ha^{-1})	
Interaction effects	**2007**	**2008**
M_1S_1	18.43	16.60
M_1S_2	17.73	19.26
M_1S_3	17.35	18.95
M_2S_1	16.15	16.82
M_2S_2	16.20	17.40
M_2S_3	14.30	17.48
M_3S_1	15.03	17.62
M_3S_2	18.83	23.20
M_3S_3	20.65	21.33
M_4S_1	20.40	19.47
M_4S_2	31.88	33.89
M_4S_3	15.90	22.02
SEd	**3.218**	**2.533**
CD (0.05)	**6.642**	**5.229**

Table 35. Effect of management practices and nutrient sources on Fe, Zn and Mn uptake of straw

Treatments	Fe uptake (kg ha^{-1})		Zn uptake (kg ha^{-1})		Mn uptake (kg ha^{-1})	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	0.71	0.72	0.54	0.42	0.75	0.72
M_2 (ICM)	0.63	0.67	0.48	0.37	0.68	0.65
M_3 (PoP)	0.76	0.80	0.59	0.47	0.82	0.78
M_4 (F.P)	0.96	1.02	0.74	0.47	1.04	0.97
SEd	**0.050**	**0.013**	**0.013**	**0.033**	**0.057**	**0.061**
CD (0.05)	**0.113**	**0.028**	**0.028**	**0.074**	**0.129**	**0.137**
Nutrient sources						
S_1 (Organic)	0.61	0.64	0.46	0.53	0.70	0.75
S_2 (Integrated)	0.90	0.97	0.70	0.73	0.85	0.91
S_3 (Inorganic)	0.78	0.80	0.43	0.50	0.78	0.80
SEd	**0.105**	**0.012**	**0.012**	**0.043**	**0.102**	**0.122**
CD (0.05)	**0.216**	**0.024**	**0.024**	**0.089**	**NS**	**NS**

in 2007 and 0.48 kg ha^{-1} in 2008. In both the years Farmers' practice was significantly superior to all other management systems. In 2007 the management systems differed significantly from one another. In 2008 PoP and SRI, ICM were on par.

During 2007 and 2008, Zn uptake was highest in integrated nutrient source (0.70 kg ha^{-1} in 2007 and 0.73 kg ha^{-1} in 2008) and it was significantly superior to organic source (0.46 kg ha^{-1} in 2007 and 0.53 kg ha^{-1} in 2008) and inorganic source (0.43 kg ha^{-1} in 2007 and 0.50 kg ha^{-1} in 2008) which in turn were on par with each other.

Among the interactions Farmers' practice with integrated nutrient sources (M_4S_2) recorded the highest Zn uptake by straw (1.05 kg ha^{-1} in 2007 and 1.09 kg ha^{-1} in 2008), which was significantly superior to all other interaction effects (Table 36). The least value of Zn uptake (0.37 kg ha^{-1} in 2007 and 0.43 kg ha^{-1} in 2008) was recorded in ICM with inorganic source (M_2S_3).

4.5.4.6 Mn uptake by straw

Mn uptake by straw was significantly influenced by management systems in both the years. Sources of nutrients and interaction effect had no significant influence on Mn uptake in both the years. (Table 35)

Highest Mn uptake by straw was recorded by Farmers' practice (0.97 kg ha^{-1} in 2007 and 1.04 kg ha^{-1} in 2008) which was significantly higher than all other management systems. Farmers' practice was followed by PoP (0.78 kg ha^{-1} in 2007 and 0.82 kg ha^{-1} in 2008), SRI (0.72 kg ha $^{-1}$ in 2007 and 0.75 kg ha^{-1} in 2008) and ICM (0.65 kg ha^{-1} in 2007 and 0.68 kg ha^{-1} in 2008) which were on par with one another.

4.5.5 Total uptake of nutrients

Data on the total uptake of N, P, K, S, Fe, Zn and Mn by Njavara as influenced by management systems, sources of nutrients and their interactions are presented in Tables 37 to 40.

Table 36. Interaction effect of management practices and nutrient sources on Zn uptake of straw

	Zn uptake (kg ha^{-1})	
Interaction effects	**2007**	**2008**
M_1S_1	0.46	0.52
M_1S_2	0.58	0.61
M_1S_3	0.42	0.48
M_2S_1	0.41	0.49
M_2S_2	0.53	0.53
M_2S_3	0.37	0.43
M_3S_1	0.45	0.52
M_3S_2	0.64	0.71
M_3S_3	0.47	0.54
M_4S_1	0.51	0.58
M_4S_2	1.05	1.09
M_4S_3	0.47	0.56
SEd	**0.023**	**0.086**
CD (0.05)	**0.048**	**0.178**

4.5.5.1 Total N uptake

Total N uptake was significantly influenced by management systems in the both years. Sources of nutrients and interactions had no significant influence on total N uptake. (Table 37)

Highest total N uptake was recorded by Farmers' practice (20.42 kg ha^{-1} in 2007 and 2008) which was significantly higher than all other management systems in both the years. In both the years PoP and SRI were on par. In 2007 ICM was significantly lower than all other management systems. But in 2008 it was on par with SRI. Farmers' practice was followed by PoP (17.45 kg ha^{-1} in 2007 and 16.71 kg ha^{-1} in 2008), SRI (16.56 kg ha^{-1} in 2007 and 15.54 kg ha^{-1} in 2008) and ICM (14.62 kg ha^{-1} in 2007 and 16.71 kg ha^{-1} in 2008).

4.5.5.2 Total P uptake

Management systems and sources of nutrients had significant influence on total P uptake in both the years. Interaction effects were not significant in both the years. (Table 37)

During 2007 and 2008 total P uptake was maximum (1.93 kg ha^{-1} in 2007 and 2.20 kg ha^{-1} in 2008) in Farmers' practice and it was significantly superior to other management systems. In both the years SRI (1.57 kg ha^{-1} in 2007 and 1.53 kg ha^{-1} in 2008) and PoP (1.56 kg ha^{-1} in 2007 and 2008) were on par. In both years ICM (1.44 kg ha^{-1} in 2007 and 1.36 kg ha^{-1} in 2008) recorded the lowest P uptake.

In both the years integrated nutrient source recorded maximum total P uptake of 1.82 kg ha^{-1} in 2007 and 1.89 kg ha^{-1} in 2008 which was on par with organic source (1.63 kg ha^{-1} in 2007 and 1.88 kg ha^{-1} in 2008). Least value of total P uptake recorded by inorganic source (1.42 kg ha^{-1} in 2007 and 1.44 kg ha^{-1} in 2008) was significantly lower than S_2 and S_1.

Table 37. Effect of management practices and nutrient sources on total uptake of N, P, K and S of Njavara

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		S uptake (kg ha^{-1})	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	16.56	15.54	1.57	1.53	20.47	20.93	1.85	1.71
M_2 (ICM)	14.62	14.08	1.44	1.36	17.99	19.67	1.76	1.58
M_3 (PoP)	17.45	16.71	1.56	1.56	21.09	23.47	1.93	1.95
M_4 (F.P)	20.42	20.42	1.93	2.20	25.98	28.56	2.46	2.22
SEd	**0.927**	**0.893**	**0.097**	**0.128**	**1.070**	**1.310**	**0.287**	**0.288**
CD (0.05)	**2.096**	**2.019**	**0.111**	**0.290**	**2.421**	**2.965**	**NS**	**NS**
Nutrient sources								
S_1 (Organic)	18.35	17.56	1.63	1.88	20.33	20.44	1.78	1.93
S_2 (Integrated)	15.90	15.78	1.82	1.89	24.11	26.38	2.05	2.21
S_3 (Inorganic)	17.55	16.73	1.42	1.44	19.72	22.65	1.77	1.86
SEd	**1.024**	**0.875**	**0.049**	**0.107**	**1.608**	**1.289**	**0.343**	**0.179**
CD (0.05)	**NS**	**NS**	**0.101**	**0.222**	**3.319**	**2.661**	**NS**	**NS**

4.5.5.3 Total K uptake

Effect of management systems, sources of nutrients and interaction effects on total uptake of K was significant in both the years (Table 37)

During both the years total uptake of K was highest in Farmers' practice (25.98 kg ha^{-1} in 2007 and 28.56 kg ha^{-1} in 2008) which was significantly superior to all other management systems. Farmers' practice was followed by PoP (21.09 kg ha^{-1} in 2007 and 23.47 kg ha^{-1} in 2008), SRI (20.47 kg ha^{-1} in 2007 and 20.93 kg ha^{-1} in 2008) and ICM (17.99 kg ha^{-1} in 2007 and 19.67 kg ha^{-1} in 2008). In both years PoP was on par with SRI which in turn was on par with ICM.

In 2007 and 2008 total K uptake was highest in integrated nutrient source (24.11 kg ha^{-1} in 2007 and 26.38 kg ha^{-1} in 2008) and it was significantly superior to organic source (20.33 kg ha^{-1} in 2007 and 20.44 kg ha^{-1} in 2008) and inorganic source (19.72 kg ha^{-1} in 2007 and 22.65 kg ha^{-1} in 2008) which in turn were on par with each other.

Farmers' practice with integrated nutrient source (M_4S_2) resulted in highest total K uptake (35.62 kg ha^{-1} in 2007 and 37.82 kg ha^{-1} in 2008), which was significantly superior to all other interaction effects (Table 38). The least value of total K uptake (16.06 kg ha^{-1}) was recorded in ICM with inorganic source (M_2S_3) in 2007 and in ICM with organic source (M_2S_1) (19.43 kg ha^{-1}) in 2008.

4.5.5.4 Total S uptake

Effect of management systems, sources of nutrients and interaction effects on total uptake of S were not significant in both the years (Table 37)

4.5.5.5 Total Fe uptake

Management systems and sources of nutrients had significant influence on total Fe uptake in both the years. Interaction effects were not significant in both the years. (Tables 39)

Table 38. Interaction effect of management practices and nutrient sources on total K uptake of Njavara

Interaction effects	K uptake (kg ha^{-1})	
	2007	2008
M_1S_1	21.14	19.25
M_1S_2	20.34	22.01
M_1S_3	19.93	21.55
M_2S_1	18.72	19.43
M_2S_2	18.73	19.75
M_2S_3	16.56	19.83
M_3S_1	20.94	20.32
M_3S_2	21.76	25.96
M_3S_3	23.57	24.13
M_4S_1	23.51	22.76
M_4S_2	35.62	37.82
M_4S_3	18.81	25.08
SEd	**3.216**	**2.578**
CD (0.05)	**6.638**	**5.322**

During 2007 and 2008 total Fe uptake was maximum (0.99 kg ha^{-1} in 2007 and 1.06 kg ha^{-1} in 2008) in Farmers' practice and it was significantly superior to other management systems. Farmers' practice was followed by PoP (0.78 kg ha^{-1} in 2007 and 0.83 kg ha^{-1} in 2008), SRI (0.74 kg ha^{-1} in 2007 and 0.75 kg ha^{-1} in 2008) and ICM (0.65 kg ha^{-1} in 2007 and 0.69 kg ha^{-1} in 2008) respectively. In both years PoP was on par with SRI which was on par with ICM

Integrated nutrient source recorded maximum total Fe uptake of 0.93 kg ha^{-1} in 2007 and 1.00 kg ha^{-1} in 2008 which was on par with inorganic source (0.81 kg ha^{-1} in 2007 and 0.83 kg ha^{-1} in 2008). In both the years inorganic source was on par with total Fe uptake recorded by organic source (0.63 kg ha^{-1} in 2007 and 0.66 kg ha^{-1} in 2008).

4.5.5.6 Total Zn uptake

Effect of management systems, sources of nutrients and interaction effects on total uptake of Zn was significant. (Table 39)

During both the years total uptake of Zn was highest in Farmers' practice (1.00 kg ha^{-1} in 2007 and 1.08 kg ha^{-1}). This was followed by PoP (0.81 kg ha^{-1} in 2007 and 0.88 kg ha^{-1}), SRI (0.76 kg ha^{-1} in 2007 and 0.81 kg ha^{-1} in 2008) and ICM (0.68 kg ha^{-1} in 2007 and 0.73 kg ha^{-1} in 2008) respectively. In both years PoP was on par with SRI which was on par with ICM

During 2007 and 2008, total Zn uptake was highest in integrated nutrient source (1.02 kg ha^{-1} in 2007 and 1.06 kg ha^{-1} in 2008) and it was significantly superior to organic source (0.74 kg ha^{-1} in 2007 and 0.81 kg ha^{-1} in 2008) and inorganic source (0.68 kg ha^{-1} in 2007 and 0.76 kg ha^{-1} in 2008) which in turn were on par with each other.

Among the interactions Farmers' practice with integrated nutrient sources (M_4S_2) recorded the highest total Zn uptake (1.44 kg ha^{-1} in 2007 and 1.49 kg ha^{-1} in 2008), which was significantly superior to all other

Table 39. Effect of management practices and nutrient sources on total uptake of Fe, Zn and Mn of Njavara

Treatments	**Fe uptake (kg ha^{-1})**		**Zn uptake (kg ha^{-1})**		**Mn uptake (kg ha^{-1})**	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	0.74	0.75	0.76	0.81	0.78	0.81
M_2 (ICM)	0.65	0.69	0.68	0.73	0.70	0.74
M_3 (PoP)	0.78	0.83	0.81	0.88	0.84	0.88
M_4 (F.P)	0.99	1.06	1.00	1.08	1.04	1.11
SEd	**0.049**	**0.053**	**0.048**	**0.059**	**0.056**	**0.062**
CD (0.05)	**0.111**	**0.120**	**0.109**	**0.135**	**0.128**	**0.140**
Nutrient sources						
S_1 (Organic)	0.63	0.66	0.74	0.81	0.77	0.81
S_2 (Integrated)	0.93	1.00	1.02	1.06	0.91	0.97
S_3 (Inorganic)	0.81	0.83	0.68	0.76	0.85	0.87
SEd	**0.105**	**0.127**	**0.043**	**0.054**	**0.102**	**0.122**
CD (0.05)	**0.262**	**0.216**	**0.089**	**0.111**	**NS**	**NS**

interaction effects (Table 40). The least value of Zn uptake (0.59 kg ha^{-1} in 2007 and 0.66 kg ha^{-1} in 2008) was recorded in ICM with inorganic source (M_2S_3).

4.5.5.7 Total Mn uptake

Total Mn uptake was significantly influenced by management systems alone in both the years. Sources of nutrients and interactions had no significant influence on total Mn uptake. (Table 39)

Highest total Mn uptake was recorded by Farmers' practice (1.04 kg ha^{-1} in 2007 1.11 kg ha^{-1} and 2008) which was significantly higher than all other management systems in both the years. M_4 (Farmers' practice) was followed by PoP (0.84 kg ha^{-1} in 2007 and 0.88 kg ha^{-1} in 2008), SRI (0.78 kg ha^{-1} in 2007 and 0.81 kg ha^{-1} in 2008) and ICM (0.70 kg ha^{-1} in 2007 and 0.74 kg ha^{-1} in 2008) respectively.

4.6 SOIL FERTILITY STATUS AFTER THE EXPERIMENT

The fertility status of soil after the experiment was studied in terms of available nitrogen, available phosphorus, available potassium, available sulphur, organic carbon, available iron, available zinc and available manganese status. (Tables 41 to 43)

4. 6.1 Available nitrogen

The results pertaining to the available nitrogen status of the soil after the experiments are presented in Table 41. The data revealed significant influence of sources of nutrients on available nitrogen in both the years. Management systems and interaction effects were not significant in both the years of experimentation.

In both the years effect of nutrient sources on available N status of soil differed significantly from one another. Organic source recorded highest available nitrogen 243.46 kg ha^{-1} in 2007 and 250.77 kg ha^{-1} in 2008 which was followed by integrated nutrient source (235.64 kg ha^{-1} in 2007

Table 40. Interaction effect of management practices and nutrient sources on total Zn uptake of Njavara

	Zn uptake (kg ha^{-1})	
Interaction effects	**2007**	**2008**
M_1S_1	0.75	0.80
M_1S_2	0.85	0.89
M_1S_3	0.68	0.74
M_2S_1	0.67	0.74
M_2S_2	0.79	0.78
M_2S_3	0.59	0.66
M_3S_1	0.73	0.79
M_3S_2	0.98	1.07
M_3S_3	0.72	0.79
M_4S_1	0.82	0.89
M_4S_2	1.44	1.49
M_4S_3	0.74	0.86
SEd	**0.086**	**0.107**
CD (0.05)	**0.177**	**0.221**

Table 41. Effect of management systems and nutrient sources on available N, P and K

Treatments	**Available N (Kg/ha)**		**Available P (Kg/ha)**		**Available K (Kg/ha)**	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	235.29	243.24	21.47	21.55	139.21	138.37
M_2 (ICM)	234.38	242.26	21.36	21.83	131.65	129.15
M_3 (PoP)	232.82	240.54	22.09	22.31	133.75	134.58
M_4 (F.P)	236.22	241.83	22.26	22.76	137.78	139.45
SEd	**2.473**	**2.583**	**1.702**	**2.134**	**2.827**	**3.502**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient sources						
S_1 (Organic)	243.46	250.77	20.75	21.20	141.22	141.22
S_2 (Integrated)	235.64	242.81	22.13	22.30	135.13	135.76
S_3 (Inorganic)	224.94	232.33	22.65	22.85	130.44	129.19
SEd	**2.487**	**2.592**	**2.175**	**2.078**	**4.981**	**4.902**
CD (0.05)	**5.133**	**5.349**	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

and 242.81 kg ha^{-1} in 2008) and inorganic source (224.94 kg ha^{-1} in 2007 and 232.33 kg ha^{-1} in 2008) respectively.

4.6.2 Available phosphorus, potassium and sulphur

The results on the available phosphorus, potassium and sulphur status of the soil after the experiment (Tables 41 and 42) revealed non-significant effect for management systems, sources of nutrients and their interaction in both the years of study.

4.6.3 Organic carbon

Nutrient sources had significant effect on organic carbon content of the soil. Management systems and interactions did not influence the organic carbon content in both the years. (Table 42)

In 2007 and 2008, organic source recorded the highest content of organic carbon (1.22% in 2007 1.16% in 2008) which in turn were on par with integrated nutrient source (1.17% in 2007 and 1.14% in 2008). The least organic carbon content of soil was recorded in inorganic source (1.08% in 2007 and 1.09% in 2008) which was significantly lower than organic and integrated sources.

4.6.4 Available iron, zinc and manganese

The management systems, nutrient sources and their interactions had no significant effect on the available iron, zinc and manganese of the soil in both the years and the results are presented in Tables 43.

4.7 SOIL ENZYMES ACTIVITY

4.7.1 Urease activity

Estimation of enzyme activity showed that among the treatments of different nutrient sources alone showed significant influence on urease activity in soil during both the years of experimentation and the results are presented in Table 44.

Table 42. Effect of management systems and nutrient sources on organic carbon content

Treatments	Organic Carbon (%)		Available Sulphur (%)	
Management systems	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	1.17	1.14	4.13	4.34
M_2 (ICM)	1.15	1.08	4.16	4.47
M_3 (PoP)	1.16	1.14	4.23	4.35
M_4 (F.P)	1.16	1.15	4.18	4.23
SEd	**0.036**	**0.028**	**0.170**	**0.028**
CD (0.05)	**NS**	**NS**	**NS**	**NS**
Nutrient sources				
S_1 (Organic)	1.22	1.16	4.26	4.48
S_2 (Integrated)	1.17	1.14	4.15	4.23
S_3 (Inorganic)	1.08	1.09	4.12	4.33
SEd	**0.037**	**0.019**	**0.143**	**0.019**
CD (0.05)	**0.077**	**0.040**	**NS**	**0.040**

Interaction effect not significant

Table 43. Effect of management systems and nutrient sources on available Fe, Mn and Zn

Treatments	Available Fe(ppm)		Available Zn(ppm)		Available Mn (ppm)	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	6.76	6.96	0.23	0.23	1.30	1.65
M_2 (ICM)	6.28	6.72	0.26	0.26	1.24	1.55
M_3 (PoP)	6.52	7.03	0.24	0.26	1.33	1.64
M_4 (F.P)	6.68	6.64	0.24	0.24	1.22	1.46
SEd	**0.359**	**0.321**	**0.009**	**0.003**	**0.109**	**0.113**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient sources						
S_1 (Organic)	6.44	6.69	0.25	0.25	1.25	1.55
S_2 (Integrated)	6.60	7.14	0.26	0.26	1.32	1.56
S_3 (Inorganic)	6.63	6.67	0.23	0.23	1.26	1.59
SEd	**0.261**	**0.461**	**0.008**	**0.008**	**0.101**	**0.113**
CD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Interaction effect not significant

Effect of nutrient sources on urease activity differed significantly from one another. Highest activity of urease was recorded in organic source (57.98 µg of NH_4/g/24hr in 2007 and 58.23 µg of NH_4/g/24hr**)** which was followed by inorganic source (57.58 µg of NH_4/g/24hr in 2007 and 57.74 µg of NH_4/g/24hr in 2008) andintegrated nutrient source (56.00 µg of NH_4/g/24hr in 2007 and 56.17 µg of NH_4/g/24hr in 2008) respectively.

4.7.2 PHOSPHATASE ACTIVITY

Estimation of the activity of phosphatase enzyme showed significant influence of management systems and nutrient sources during both the years of experimentation and the results are presented in Table 44. Interaction effects were not significant in the activity of phosphatase enzyme.

Phosphatase activity was in the order SRI, ICM, PoP and Farmers' practice. SRI recorded highest activity of phosphatase (42.80 µg p-nitrophenol/g/hr in 2007 and 44.22 µg p-nitrophenol/g/hr in 2008) which was on par with ICM (42.53 µg p-nitrophenol/g/hr in 2007 and 43.93 µg p-nitrophenol/g/hr in 2008). PoP recorded phosphatase activity of 41.77 µg p-nitrophenol/g/hr in 2007 and 43.15 µg p-nitrophenol/g/hr in 2008 which was on par with ICM and Farmers' practice (41.56 µg p-nitrophenol/g/hr in 2007 and 42.53 µg p-nitrophenol/g/hr in 2008).

Effect of the nutrient sources differed significantly from one another. Highest activity of phosphatase was recorded in organic source (44.07 µg p-nitrophenol/g/hr in 2007 and 45.39 µg p-nitrophenol/g/hr in 2008) which was followed by integrated nutrient source (42.20 µg p-nitrophenol/g/hr in 2007 and 43.46 µg p-nitrophenol/g/hr in 2008) and inorganic source (40.23 µg p-nitrophenol/g/hr in 2007 and 41.54 µg p-nitrophenol/g/hr in 2008) respectively.

4.7.3 Dehydrogenase activity

Estimation of enzyme activity revealed that nutrient sources alone had significant influence on dehydrogenase activity during both the years of

Table 44. Effect of management systems and nutrient sources on urease, phosphatase and dehydrogenase enzymes activity

Treatments	**Urease (µg of NH_4/g/24hr)**		**Phosphatase (µg p-nitrophenol/g/hr)**		**Dehydrogenase (µg TPF/g/24 hrs)**	
Management systems	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
M_1 (SRI)	57.21	57.33	42.80	44.22	62.82	55.12
M_2 (ICM)	57.27	57.52	42.53	43.93	62.53	54.52
M_3 (PoP)	57.05	57.27	41.77	43.15	61.76	53.97
M_4 (F.P)	57.22	57.39	41.56	42.53	61.55	53.72
SEd	**0.078**	**0.079**	**0.391**	**0.468**	**0.453**	**0.586**
CD (0.05)	**NS**	**NS**	**0.885**	**1.059**	**NS**	**NS**
Nutrient sources						
S_1 (Organic)	57.98	58.23	44.07	45.39	64.06	59.75
S_2 (Integrated)	56.00	56.17	42.20	43.46	62.22	55.35
S_3 (Inorganic)	57.58	57.74	40.23	41.54	60.22	47.89
SEd	**0.077**	**0.079**	**0.465**	**0.465**	**0.450**	**0.593**
CD (0.05)	**0.159**	**0.162**	**0.959**	**0.960**	**0.929**	**1.224**

Interaction effect not significant

experimentation and the results are presented in Table 44. Management systems and interaction effects were not significant.

Effect of the nutrient sources differed significantly from one another. Organic source recorded the highest activity of dehydrogenase (64.06 µg TPF/g/24 hr in 2007 and 59.75 µg TPF/g/24 hr in 2008) followed by integrated nutrient source (62.22 µg TPF/g/24 hr in 2007 and 55.35 µg TPF/g/24 hr in 2008) and inorganic source (60.22 µg TPF/g/24 hr in 2007 and 47.89 µg TPF/g/24 hr in 2008) respectively.

4.8 PHENOLOGICAL STUDY

4.8.1 Plant height

Data on plant height is presented in table 45.

In all the management systems plant height gradually increased upto panicle initiation stage (45 DAT in SRI, 42 DAT in ICM, 40 DAT in PoP and 32 DAS in Farmers' practice). From panicle initiation to flowering (65 DAT in SRI, 61 DAT in ICM, 59 DAT in PoP and 53 DAS in Farmers' practice) increase in plant height was faster in all the management systems. Increase in plant height was very slow after the flowering. Height of plant did not show any increase after 70 days of transplanting/ sowing. Maximum plant height was recorded in Farmers' practice (105.00 cm). This was followed by PoP (102.50 cm), SRI (93.00 cm) and ICM (91.50 cm).

4.8.2 Number of leaves hill^{-1}

Seedlings were transplanted at 2 to 3 leaf stage in SRI and ICM at 4 to 5 leaf stage in PoP. Number of leaves increased upto 9th week of transplanting/ 8th week of sowing (Table 46). Maximum number of leaves hill^{-1} was recorded in Farmers' practice and PoP (25) followed by SRI (23) and ICM (22) respectively.

Table 45. Phenological study in Njavara – Pattern of change in plant height as influenced by management systems

Weeks after transplanting/sowing	Plant height (cm)			
	SRI (M_1)	ICM (M_2)	PoP (M_3)	Farmers' practice (M_4)
1	10.30	17.60	22.00	-
2	12.50	20.70	24.60	7.00
3	18.50	22.50	27.30	20.00
4	22.60	28.60	31.60	37.00
5	30.70	32.00	32.60	46.00
6	48.90	48.20	47.30	50.30
7	62.50	58.30	58.20	58.60
8	72.00	70.80	75.60	91.50
9	88.00	86.70	100.70	102.50
10	93.00	91.50	102.50	105.40
11	93.00	91.50	102.50	105.40
12	93.00	91.50	102.50	105.00
13	93.00	91.00	102.00	-

Table 46. Phenological study in Njavara – Leaf production pattern under different management systems

Weeks after transplanting/sowing	Number of leaves hill^{-1}			
	SRI (M_1)	ICM (M_2)	PoP (M_3)	Farmers' practice (M_4)
1	2	2	3	-
2	4	3	4	4
3	6	5	7	9
4	6	5	12	14
5	6	7	15	17
6	8	9	16	20
7	10	14	17	24
8	15	20	22	25
9	23	22	24	25
10	21	21	23	24
11	21	20	23	24
12	20	20	22	23
13	20	18	20	-

4.8.3 Leaf area

Leaves were narrow and long. Later produced leaves were larger than the earlier produced ones (Table 47). Leaf area recorded at physiological maturity was less than that recorded during grain filling and milky stage. Maximum leaf area was recorded in Farmers' practice and Pop (14.84 cm^2) followed by SRI and ICM (14.07 cm^2).

4.8.4 Number of tillers hill^{-1}

Eight, twelve and eighteen days old seedlings were transplanted at the rate of 1,2 and 3 seedlings per hill in SRI, ICM and PoP treatments respectively. Broadcasting was followed in Farmers' practice. Number of tillers hill^{-1} increased up to 7WAT/6WAS (Table 48). Maximum number of tillers per hill^{-1} was observed in Farmers' practice (11.2) followed by PoP (10.2), ICM (7.0) and SRI (4.0) respectively.

4.8.5 Root length

Length of roots increased up to 9 weeks after transplanting/sowing. Length of roots recorded at physiological maturity (13th week) was less than that recorded in 9th week (Table 49). Maximum root length of 22.00 cm was recorded in SRI followed by ICM (20.00 cm), Pop (15.50 cm) and Farmers' practice (14.00cm) respectively.

4.8.6 Root dry matter production ill^{-1}

. Root dry matter production increased up to 9 weeks after transplanting or sowing (Table 50). Highest root dry matter hill^{-1} was recorded in SRI (0.52 g) followed by ICM (0.43 g), PoP (0.39 g) and Farmers' practice (0.28 g) respectively. Root dry matter recorded at physiological maturity was less than that recorded in the 9th week.

4.8.7 Growth stages of Njavara

Data on growth stages of Njavara under different management systems is presented in Table 51.

Table 47. Phenological study in Njavara – Pattern of leaf area development as influenced by management systems

Weeks after transplanting/sowing	Leaf area (cm^2)			
	SRI (M_1)	ICM (M_2)	PoP (M_3)	Farmers' practice (M_4)
1	0.23	0.24	0.38	-
2	0.71	0.76	1.39	0.31
3	0.75	0.92	1.60	1.32
4	3.00	2.70	3.66	1.60
5	5.63	5.04	5.62	4.71
6	5.96	5.92	6.08	7.03
7	5.43	5.71	6.43	7.74
8	7.68	8.58	10.72	11.52
9	11.26	14.07	14.84	11.79
10	14.07	13.40	14.40	14.84
11	11.26	10.72	11.26	11.79
12	10.99	10.72	10.99	11.52
13	10.99	10.72	10.99	-

Table 48. Phenological study in Njavara – Pattern of tiller production hill^{-1} undr different management systems

Weeks after transplanting/sowing	Number of tillers hill^{-1}			
	SRI (M_1)	ICM (M_2)	PoP (M_3)	Farmers' practice (M_4)
1	1.0	2.0	3.0	1.0
2	1.0	2.2	4.2	2.2
3	1.0	4.4	6.0	4.0
4	2.2	5.2	6.4	6.4
5	2.4	6.0	7.2	9.4
6	3.2	6.2	8.0	11.0
7	3.8	7.0	10.0	11.2
8	3.8	7.0	10.2	11.0
9	4.0	7.0	10.0	11.0
10	4.0	7.0	10.0	10.2
11	4.0	7.0	9.8	10.0
12	4.0	7.0	9.2	10.0
13	4.0	6.8	9.0	-

Table 49. Phenological study in Njavara – Pattern of change in root length as influenced by different management systems

Weeks after transplanting/sowing	Root length (cm)			
	SRI (M_1)	ICM (M_2)	PoP (M_3)	Farmers' practice (M_4)
1	3.00	7.00	7.30	
2	5.20	7.30	7.86	3.40
3	7.50	8.50	8.40	5.20
4	9.50	11.20	9.20	6.00
5	15.40	13.40	10.50	7.80
6	16.00	15.00	11.60	10.20
7	16.50	18.00	12.00	11.80
8	18.00	19.00	13.60	12.00
9	22.00	20.00	15.50	14.00
10	22.00	20.00	15.50	14.00
11	21.50	20.00	15.50	13.50
12	21.00	20.00	15.00	13.00
13	21.00	20.00	15.00	-

SRI ICM PoP Farmers' practice

Plate 2. Root development $hill^{-1}$ under different management systems.

Table 50. Phenological study in Njavara - Pattern of root dry matter production hill^{-1} under different management systems

Weeks after transplanting/sowing	Root dry matter production hill^{-1} (g)			
	SRI (M_1)	ICM (M_2)	PoP (M_3)	Farmers' practice (M_4)
1	-	-	-	-
2	-	-	-	-
3	0.25	0.18	0.12	-
4	0.28	0.19	0.16	0.18
5	0.31	0.28	0.18	0.19
6	0.38	0.31	0.20	0.20
7	0.45	0.35	0.29	0.25
8	0.46	0.38	0.33	0.28
9	0.52	0.43	0.39	0.32
10	0.52	0.42	0.38	0.29
11	0.52	0.42	0.37	0.28
12	0.52	0.42	0.37	0.28
13	0.52	0.42	0.36	-

Farmers' practice recorded minimum crop duration of 86 days followed by SRI (96 days), ICM (98 days) and PoP (106 days) respectively. Panicle initiation occurred at 32 DAS in Farmers' practice, 40 DAT in PoP, 42 DAT in ICM and 45 DAT in SRI. Maximum tillering stage occurred at 36 DAS in Farmers' practice, 45 DAT in PoP, 46 DAT in ICM and 49 DAT in SRI. Booting stage occurred at 46 DAS in Farmers' practice, 51 DAT in PoP, 53 DAT in ICM and 57 DAT in SRI. Flowering stage occurred at 53 DAS in Farmers' practice, 59 DAT in PoP, 60 DAT in ICM and 64 DAT in SRI. Maturity stage occurred at 86 DAS in Farmers' practice, 88 DAT in PoP, 86 DAT in ICM and 88 DAT in SRI.

4.9 ECONOMICS OF CULTIVATION

Effect of management systems, nutrient sources and their interactions on cost of cultivation, gross income, net income and BCR were significant (Table 53). The management systems differed significantly from one another with respect to all these parameters. Nutrient sources also differed significantly from one another with respect to cost of cultivation, net income and BCR.

Among the management systems cost of cultivation was highest in SRI (31,774 Rs ha^{-1}) which was followed by ICM (27,689 Rs ha^{-1}), PoP (26,659 Rs ha^{-1}) and Farmers' practice (25,925 Rs ha^{-1}) respectively. Among the nutrient sources highest cost of cultivation was recorded in organic source (31,719 Rs ha^{-1}) followed by integrated nutrient source (26,538 Rs ha^{-1}) and inorganic source (25,777 Rs ha^{-1}). Among the interactions highest cost of cultivation was recorded in SRI x organic source (M_1S_1) (35,246 Rs ha^{-1}) and the least cost of cultivation was in Farmers' practice with inorganic source (M_4S_3) (20,965 Rs ha^{-1}).

Among the management systems, highest gross income (44,979 Rs ha^{-1}), net income (19,053 Rs ha^{-1}) and BCR (1.76) was recorded in Farmers' practice. Among the nutrient sources highest gross income (39,974 Rs ha^{-1}), net income (13,436 Rs ha^{-1}) and BCR (1.53) recorded in integrated nutrient

Table 51. Growth stages in Njavara under different management systems

Stages	SRI (M_1)	ICM (M_2)	PoP (M_3)	Farmers' practice (M_4)
	DAT	**DAT**	**DAT**	**DAS**
Panicle Initiation (DAT/DAS)	45	42	40	32
Maximum Tillering (DAT/DAS)	49	46	45	36
Booting (DAT/DAS)	57	53	51	46
Flowering (DAT/DAS)	64	60	59	53
Maturity (DAT/DAS)	88	86	88	86
Nursery days	**8**	**12**	**18**	**-**
Total duration (days)	**96**	**98**	**106**	**86**

Table 52. Effect of management systems, nutrient sources and their interactions on total cost of cultivation

Interaction effects	Basic cost of cultivation (BCC) (Rs ha^{-1})	Cost of cultivation due to management systems (Rs ha^{-1})	Cost of cultivation due to nutrient sources (Rs ha^{-1})	Total cost of cultivation (Rs ha^{-1})
M_1S_1	9830	17,250	8166	35,246
M_1S_2	9830	17,250	3406	30,486
M_1S_3	9830	17,250	2510	29,590
M_2S_1	9830	13,415	8166	31,411
M_2S_2	9830	13,415	3406	26,651
M_2S_3	9830	13,41	2510	25,755
M_3S_1	9830	13,505	8166	31,561
M_3S_2	9830	13,505	3406	26,801
M_3S_3	9830	13,505	2510	25,905
M_4S_1	9830	8,625	8166	27,221
M_4S_2	9830	8,625	3406	21,861
M_4S_3	9830	8,625	2510	20,965

BCC: The term BCC refers to cost of the different type of components uniformly involved in all the treatments)

Plate 3. Crop under SRI

Plate 4. Crop under ICM

Plate 5. Crop under PoP

Plate 6. Crop under Farmers' practice

Table 53. Effect of management systems, nutrient sources and their interactions on gross income, net income and benefit cost ratio

Treatments	Total cost of cultivation (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	BCR
Management systems				
M_1(SRI)	31,774	35,692	3918	1.13
M_2(ICM)	27,689	32,658	4969	1.19
M_3(PoP)	26,659	38,600	11941	1.47
M_4(F.P)	25,925	44,979	19053	1.76
SEd		**403.880**	**403.880**	**0.015**
CD (0.05)		**913.661**	**913.661**	**0.034**
Organic sources				
S_1(organic)	31,719	37,151	5431	1.18
S_2(integrated)	26,538	39,974	13436	1.53
S_3(inorganic)	25,777	36,821	11044	1.45
SEd		**393.864**	**393.864**	**0.014**
CD (0.05)		**812.898**	**812.898**	**0.028**
Interaction effects				
M_1S_1	35,246	36,205	959	1.03
M_1S_2	30,486	35,802	5,316	1.17
M_1S_3	29,590	35,068	5,478	1.18
M_2S_1	31,411	33,858	2,447	1.08
M_2S_2	26,651	32,657	6,006	1.23
M_2S_3	25,755	31,461	5,706	1.22
M_3S_1	31,561	36,684	5,123	1.16
M_3S_2	26,801	39,016	12,215	1.45
M_3S_3	25,905	40,100	14,195	1.55
M_4S_1	27,221	41,857	14,636	1.54
M_4S_2	21,861	52,423	30,562	2.40
M_4S_3	20,965	40,658	19,693	1.94
SEd		**787.729**	**787.728**	**0.027**
CD (0.05)		**1625.796**	**1625.796**	**0.057**

sources. Farmers' practice with integrated nutrient source (M_4S_2) recorded highest gross income (52,423 Rs ha^{-1}), net income (30,562 Rs ha^{-1}) and BCR (2.40). Lowest gross income was recorded in ICM, inorganic source and their interactions (M_2S_3). Lowest net income and BCR were recorded in SRI, organic source and their interactions.

Discussion

5. DISCUSSION

Field experiments were conducted during the summer seasons of 2007 and 2008 (January to April) to study the response of medical rice (Oryza stiva L.) ev Njavara to SRI (system of Rice Intensification), ICM (Integrated Crop Establishment Method), PoP (Package of Practices recommendation of Kerala Agricultural University) as well as the Crop Management Practices of Farmers. Effect of three nutrient sources viz. organic, inorganic and integrated nutrient sources on the performance of Njavara, under these management systems were of the experiments are discussed in this chapter.

5.1 EFFECT OF MANAGEMENT SYSTMES

5.1.1 Effect of management systems on growth and yield of Njavara

Management systems like SRI, ICM, PoP and Farmers' practice showed significant influence on the performance of the crop (growth and yield) of black glumed Njavara in both the years of study. Treatment effects were almost the same during both the years of experiment, with slight variation in the magnitude of influence.

In SRI treatments single, eight day old seedlings were transplanted at 20 x 20cm spacing. Four weedings with rotary weeder were given at 10 days interval starting from 10DAT to panicle initiation (45 days). Soil was kept at field capacity up to panicle initiation and then onwards 5cm standing water was allowed in the field till 10 days before harvesting. In ICM treatments two seedlings of 12 days age were transplanted at 20 X 20 cm spacing. Two rotary weedings on 10 and 20 DAT were given followed by one hand weeding on 35 DAT. A thin film of water was kept in the field till 10 days before harvesting. In PoP treatments three seedlings of 18 days age were transplanted at 15 X 10cm spacing. Weed control was achieved through one manual weeding on 15 DAT and application of 2, 4-D @ 1 kg a.i ha^{-1} on 25 DAT. Water level was maintained at about 1.5cm during transplanting. Thereafter it was increased gradually to about 5cm. Intermittent draining and reflooding was done. Field was drained 10 days before harvesting. In Farmers' practice pre germinated seeds were broadcasted @ 80 kg ha^{-1}. A thin film of water was maintained up to 10 DAS after which water level was raised up to 5cm and field was drained 10 days before harvest. Two manual weedings were done at 15 and 35 DAS. The crop receiving Farmers' practice showed lodging during grain development stage. The transplanted crops in SRI, ICM and PoP did not show lodging.

Growth parameters like height of plants, number of leaves $hill^{-1}$, leaf area index (LAI), culm strength, root dry matter and number of tillers per unit area were significantly influenced by management systems. Leaf area duration and flag leaf area showed significant variation only in 2008. All the yield attributes except 1000 grain weight were significantly influenced by management systems resulting in significant variation in the crop yield (grain and straw). Crop duration showed significant variation among the management treatments. Paddy grain ratio and grain husk ratio remained unaffected by the management systems.

Number of leaves $hill^{-1}$, leaf area index, flag leaf area, number of tillers m^{-2} (from 4 WAS/WAT to physiological maturity), number of productive tillers m^{-2}, per cent dry matter accumulation in panicle and sterility percentage were in the order Farmers' practice > PoP > ICM >SRI. Among these characters, leaf number per plant at physiological maturity in 2007, number of tillers m^{-2}, number of productive tillers m^{-2}, percentage of dry matter accumulation in panicle and sterility percentage in the four management systems differed significantly from one another. Duration of the crop also followed the same order and the treatments differed significantly from one another.

Plant height and leaf area index at physiological maturity and crop yield (grain and straw) in the management systems were in the order Farmers' practice

> PoP > SRI > ICM and they all differed significantly from one another. Pooled data on crop yield (grain and straw) also showed the same pattern of effect.

Culm strength, root dry matter production hill^{-1}, number of grains panicle^{-1}, number of filled grains panicle^{-1} and percentage of dry matter accumulation in root and straw and harvest index in 2007 were in the order SRI > ICM > PoP > Farmers' practice. All the characters except culm strength and harvest index in 2007 differed significantly from one another. Length of panicle and chlorophyll content of leaves (at panicle initiation) were in the order SRI > ICM > Farmers' practice > PoP. Hereafter effect of management systems on individual growth and yield parameters are discussed in detail.

Plant height was recorded at panicle initiation and physiological maturity. Plant height at panicle initiation showed significant variation only in 2008 whereas height of plants at physiological maturity varied significantly in both the years. At both panicle initiation and physiological maturity height of plants were in the order Farmers' practice > PoP > SRI > ICM (Table 4). Height difference of plants in Farmers' practice, PoP, SRI and ICM were significantly different from one another. Tallest plants were produced in Farmers' practice (108.74/112.60cm in 2007/2008 which was 18/14% higher in 2007/2008 than ICM (92.10/98.92cm in 2007/2008). Earlier reports were also available on the tendency of broadcast crop to grow taller and accumulate more dry matter compared to transplanted rice (Rathore et al, 1995). Plants growing taller can be one of the reasons for the lodging tendency showed by the crop receiving Farmer's Management Practices.

In both the years number of leaves hill^{-1} (at both panicle initiation and physiological maturity) was in the order Farmers' practice > PoP > ICM >SRI (Table 4). Maximum number of leaves hill^{-1}were produced in Farmers' practice (25.24/24.88 in 2007/2008) and it was 14/13% higher in 2007/2008 than the number of leaves produced in SRI (22.05/22.02 in 2007/2008). Farmers' practice produced significantly higher number of leaves hill^{-1} than all the other management systems. Increase in plant height and tiller number in Farmers' practice might have contributed to a corresponding increase in the number of leaves. Similar result was reported by Thomas (2000).

Influence of management systems on leaf area index (at panicle initiation and physiological maturity) was significant (in both the years) (Table 5). Leaf area index was highest (1.46/1.48 at physiological maturity in 2007/2008) in Farmers' practice and it was followed by PoP (1.08/1.09 in 2007/2008), ICM (M_2) (0.77/0.78 in 2007/2008) and SRI (0.77/0.78 in 2007/2008) (Fig. 3). Farmers' practice had significantly higher LAI than all other management systems. LAI in PoP was significantly higher than ICM and SRI. But Leaf area index in ICM and SRI were on par. Leaf area index in Farmers' practice was 89/90% higher in 2007 and 2008 than the least leaf area index in ICM (0.77/0.78 in 2007/2008). These results are in conformity with the findings of Anilkumar (1989) and Murty and Murty (1980). Anilkumar (1989) reported that broadcasted crop realised slightly higher LAI than transplanted crop and Murty and Murty reported that LAI was higher at a spacing of 10 X 10 cm and reduced progressively with increased spacing.

Leaf area duration (LAD) for the period from panicle initiation to physiological maturity (Table 5) in 2008 was significantly influenced by management systems. Leaf area duration was maximum in Farmers' practice (41.03) followed by PoP (28.42), SRI (16.89) and ICM (16.00) respectively. Leaf area duration in Farmers' practice was 44/142/156% higher than PoP/SRI/ICM respectively. Satish (2006) also reported higher LAD in closer planted crop.

Among the vegetative growth characters, increased plant height, number of leaves, leaf area index, leaf area duration and number of tillers m^{-2} in Farmers' practice might have helped in better interception and utilization of sunlight contributing to higher photosynthetic efficiency and resultant yield. Similar observations were also made by Satish (2006).

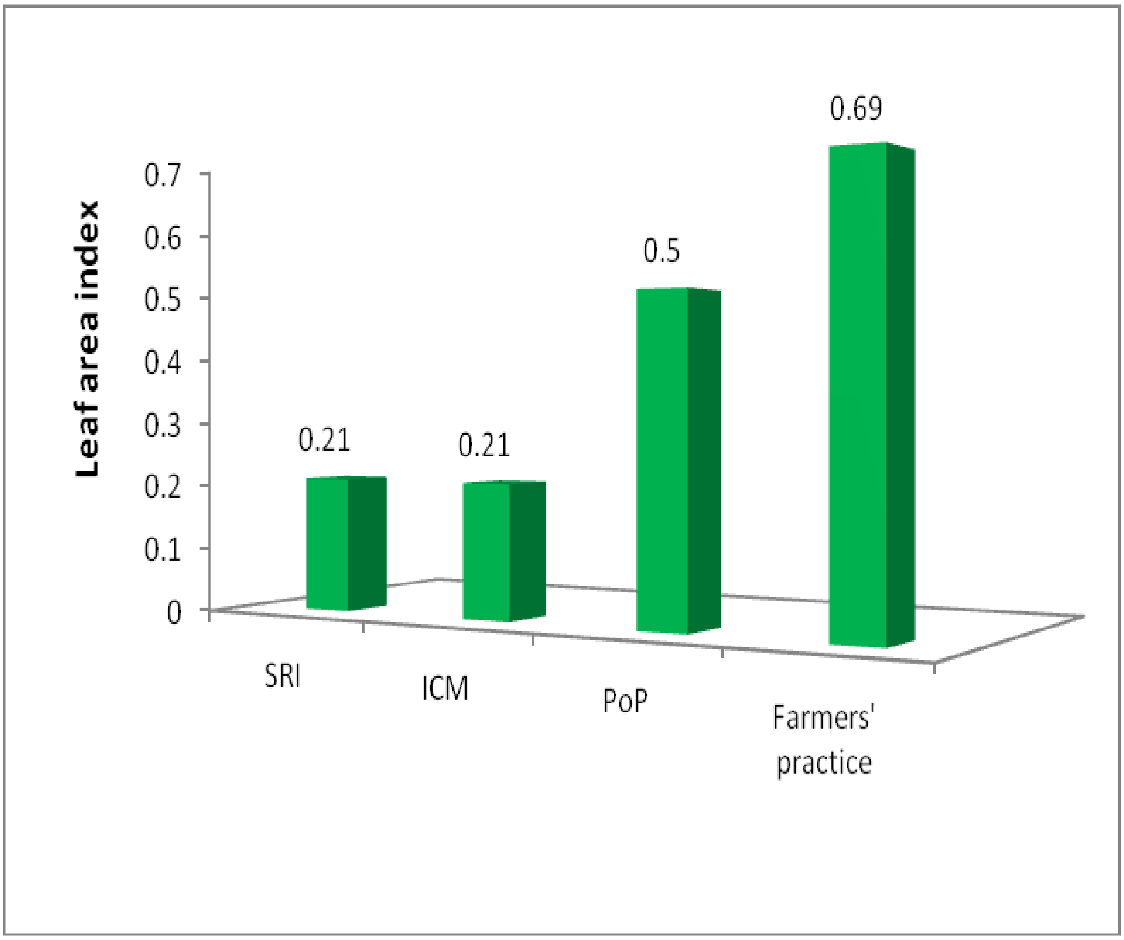


Fig. 3. Effect of management systems on leaf area index at panicle initiation (2008

Culm strength in SRI and ICM were same at panicle initiation and they were significantly higher than that in PoP and Farmers' practice (Fig. 4). But at physiological maturity culm strength in all the management systems differed significantly from one another. Both at panicle initiation and physiological maturity SRI had the highest culm strength and the Farmers' practice had the lowest (Table 6). At physiological maturity culm strength was in the order SRI > ICM > PoP > Farmers' practice in both the years. In this study, transplanted crops and wider planted crops had better culm strength than broadcast crop and closer planted crop respectively. Culm strength in SRI (0.13 g cm^{-1}) was 86% higher than that in Farmers' practice (0.06 g cm^{-1}). In the present study culm strength and percentage dry matter partitioning into straw in the management systems followed the same pattern. Poor assimilation of photosynthates in the culm can be attributed as one of the reasons for weaker culm strength. This is in conformity with the results reported by Kumar, 2000. The low culm strength may be one of the reasons for lodging in the broadcast crop that received Farmer's management practices.

Flag leaf area (at physiological maturity) was significantly influenced by management systems in both the years. Flag leaf area was in the order Farmers' practice > PoP > ICM > SRI. Farmers' practice had significantly higher flag leaf area (7.65/7.69 cm^2 in 2007/2008) than other three management systems. PoP had significantly higher flag leaf area (7.47/7.50 cm^2 in 2007/2008) than ICM (7.12/7.22 cm^2) and SRI (7.11/7.21 cm^2 in 2007/2008) which were on par with each other (Table 6). Highest flag leaf area recorded in Farmers' practice was 2/3% higher in 2007/2008 than that in PoP and 8/7% higher in 2007/2008 than the least flag leaf area recorded in SRI. Highest flag leaf area in Farmers' practice may be one of reasons for highest grain yield in this treatment. This is supported by Bashar et al, 1991 who opined that flag leaf area had significant effect on grain yield.

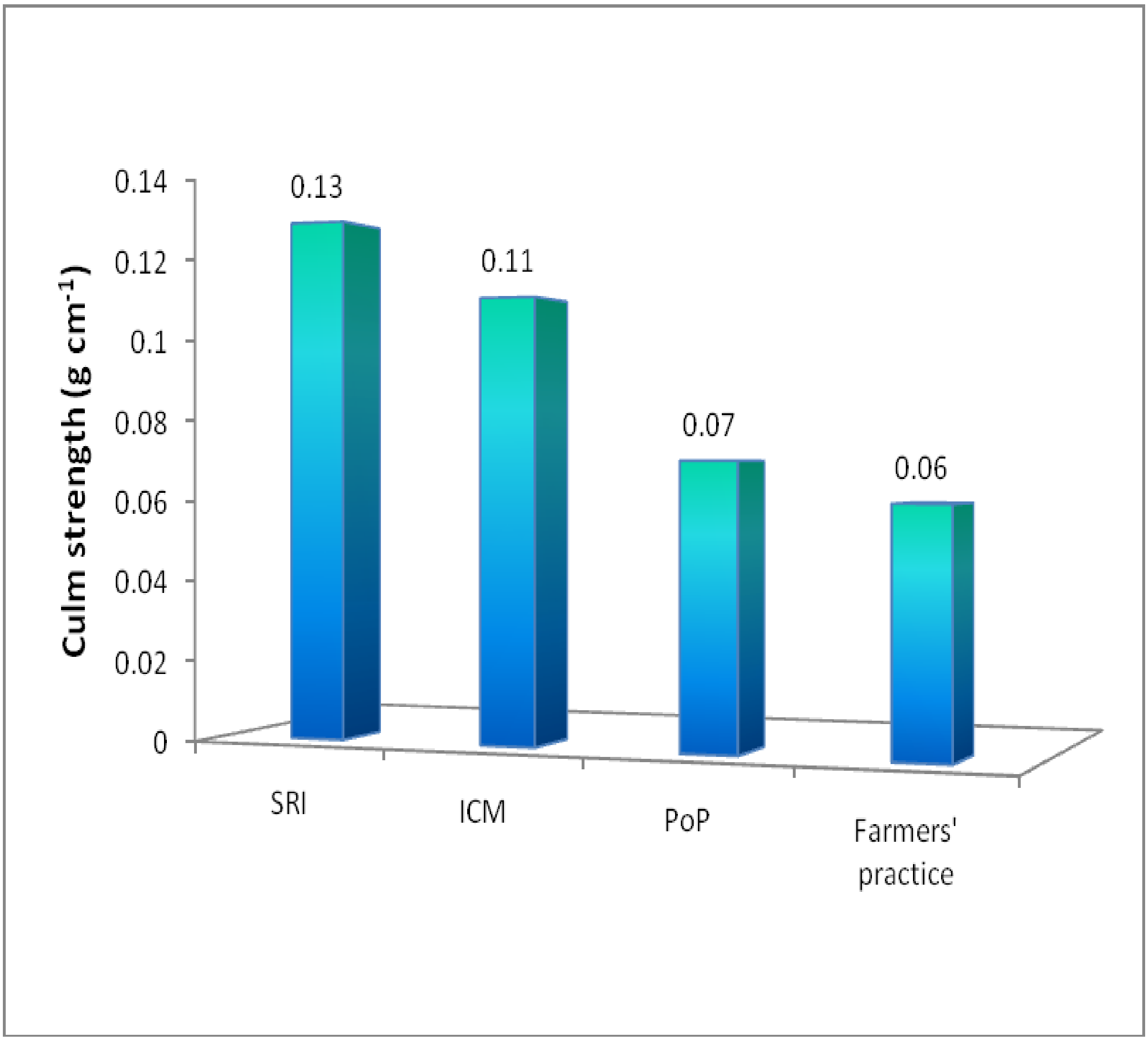


Fig. 4. Effect of management systems on culm strength at physiological maturity (2008)

Chlorophyll content of leaf at panicle initiation was in the order SRI > ICM > Farmers' practice > PoP (Table 7). Highest chlorophyll content of leaves (1.31/1.34 mg g^{-1} in 2007/2008) was significantly higher in SRI than other management systems which in turn were on par with one another. Chlorophyll content in SRI was 7/4% higher in 2007/2008 than PoP (1.23/1.29 mg g^{-1} in 2007/2008). XuFeng Ying et al. (2005) also reported that rice crop raised under SRI had high leaf chlorophyll content.

Root dry matter production in Njavara was significantly influenced by management systems. Root dry matter $hill^{-1}$ was recorded at weekly interval from 4th WAT/WAS till physiological maturity (Table 8). At the early stages (4-6 WAT/WAS) root dry matter production $hill^{-1}$ was in the order SRI >ICM > Farmers' practice > PoP which changed to SRI > ICM > PoP > Farmers' practice from 7th week onwards. Throughout the crop growth period all the management systems differed significantly from one another in root dry matter $hill^{-1}$. Increase in root dry matter occurred up to 9 WAS/WAT.

Maximum root dry matter (at 9th WAS/WAT) was recorded in SRI (0.51/0.50 g $hill^{-1}$ in 2007/2008) and it was 21/25% higher in 2007/2008 than ICM (0.42/0.60 g $hill^{-1}$ in 2007/2008) and 31/32% higher in 2007/2008 than PoP (0.39/0.38 g $hill^{-1}$ in 2007/2008) and 59/52% higher in 2007/2008 than Farmers' practice (0.32/0.33 g $hill^{-1}$ in 2007/2008) respectively.

Increase in root dry matter in SRI and ICM may be attributed to increased aeration in soil due to stirring of soil by rotary weeder. Rotary weeder was operated four times in SRI treatments and two times in ICM treatments. Till 6th week root dry matter production in Farmers' practice was higher than that in PoP which may be attributed to the earlier establishment and root development in the broadcast crop. But from 7th week onwards root development occurred at faster rate in PoP compared to Farmers' practice which might be due to availability of more space for individual hill under transplanted condition. This would have reduced the competition for nutrients and water. Root development was least in Farmers' practice which combined with least culm strength might have resulted in lodging of the crop.

Tiller production in Njavara was significantly influenced by management systems in both the years (Table 9). Throughout the crop growth tiller number m^{-2} in all the management systems differed significantly from one another in both the years. Tiller number m^{-2} was recorded from 2WAT/WAS to physiological maturity at weekly interval. In the second and third week number of tillers m^{-2} was in the order PoP > Farmers' practice > ICM > SRI and from 4^{th} week to physiological maturity the order was Farmers' practice > PoP > ICM > SRI. In the early stages of crop growth tiller production was more in PoP than in Farmers' practice. But after 3 weeks of transplanting/sowing tiller production in Farmers' practice increased at a faster rate than in PoP and this trend continued till maximum tillering stage. Tiller count per unit area at physiological maturity also was highest in Farmers' practice. At maximum tillering stage number of tillers m^{-2} was highest in Farmers' practice (1074.2/1078.4 in 2007/2008) and this was 64/65% higher in 2007/2008 than PoP (655.9/662.5 in 2007/2008), 520/536% higher in 2007/2008 than ICM (172.7/171.1 in 2007/2008) and 996/1021% higher in 2007/2008 than SRI (98.0/96.9 in 2007/2008) respectively.

Number of productive tillers m^{-2} was influenced significantly by management systems (Table 10) and they differed significantly from one another in both the years of study. Number of productive tillers m^{-2} was in the order Farmers' practice > PoP > ICM > SRI (Fig. 5). Highest number of productive tillers was produced in Farmers' practice (491.6/489.7 in 2007/2008) and it was 11/10% higher in 2007/2008 than in PoP (445.1/445.8 in 2007/2008), 270/266% higher in 2007/2008 than ICM (133.0/133.5 in 2007/2008) and 413/410% higher in 2007/2008 than SRI (95.7/95.5 in 2007/2008). Highest number of productive tillers in Farmers' practice may be attributed to the highest number of tillers and hills per unit area in this treatment. But percentage productivity (number of

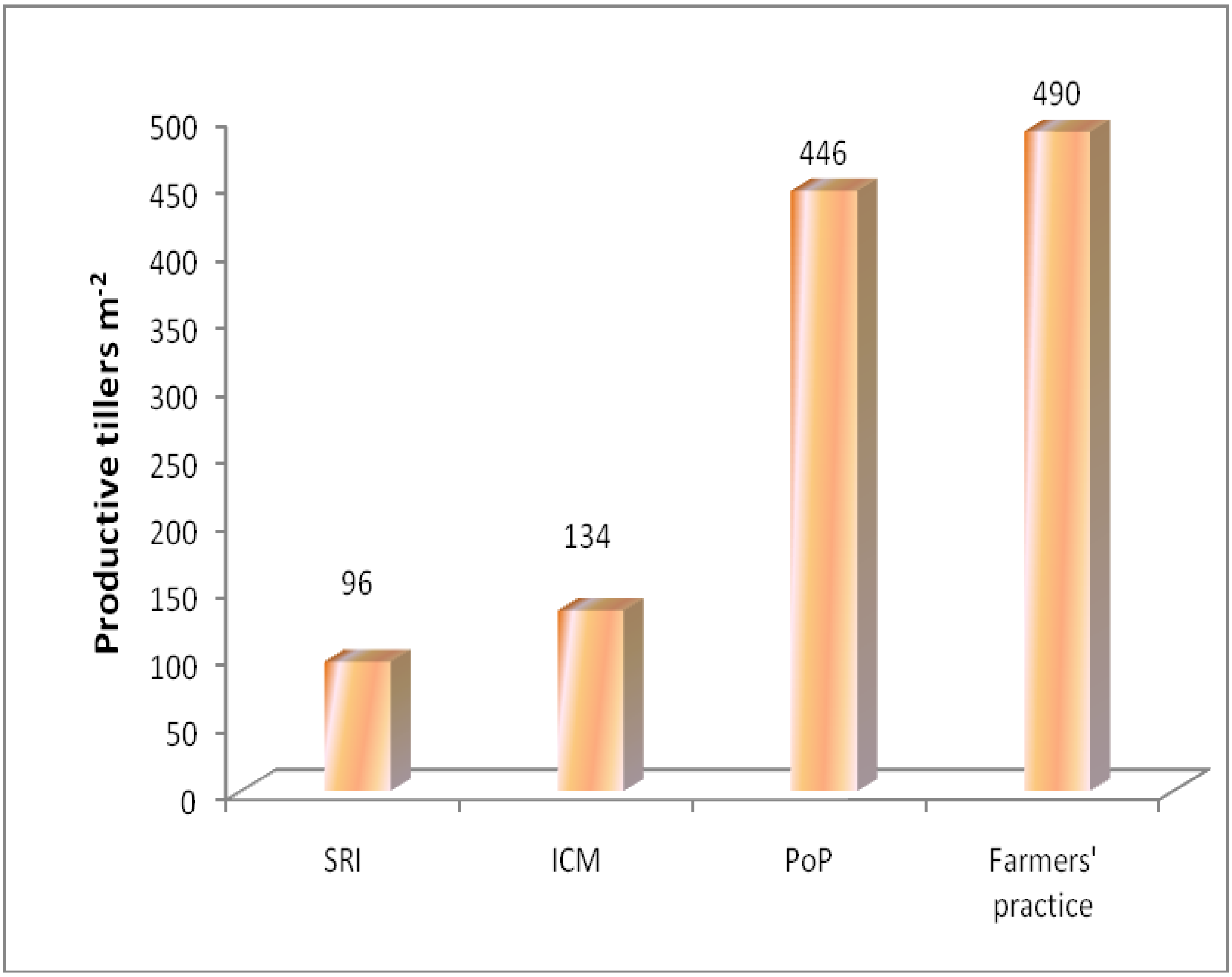


Fig. 5. Effect of management systems on number of productive tillers m^{-2}

productive tiller m^{-2}/ number of total tillers m^{-2}) was only 51/50 (in 2007/2008) in Farmers' practice whereas it was 75/76% (in 2007/2008) in PoP, 91% (in 2007 and 2008 in ICM and 100% (in 2007 and 2008) in SRI. Even though Njavara did not respond to SRI and ICM to the same extent in tillering like other varieties all the tillers produced in SRI were productive tillers and 91% of the tillers produced in ICM bore panicles. It is observed that in transplanted crops (SRI, ICM and PoP) number of productive tillers per hill increased with increase in number of seedlings per hill. Similar results were reported earlier by Obulamma and Reddy (2002).

Length of panicle was significantly influenced by management systems in both the years (Table 10). Length of panicle was in the order SRI > ICM > Farmers' practice > PoP. Longest panicles were produced in SRI (22.41/23.76cm in 2007/2008) and it was 3/5% higher in 2007/2008 than ICM (21.83/22.68cm in 2007/2008) and 5/12% higher in 2007/2008 than Farmers' practice 21.40/21.30cm in 2007/2008) and 8/20% higher in 2007/2008 than PoP (20.84/19.86cm in 2007/2008). Length of panicle in SRI and ICM were on par and that in Farmers' practice and PoP were also on par. The increase in length of panicle in SRI and ICM may be attributed to lower competition between plants for production factors like moisture, light and nutrients. Vijayakumar (2003) reported that the yield attributes namely panicle length, number of panicles $hill^{-1}$ and total number of grains per panicle were higher when planted at a spacing of 20 x 20 cm in SRI. Singh and Singh (2005) also reported increased panicle length in SRI.

No of grains per panicle differed significantly from one another in the management systems in both the years (Table 11). Number of grains per panicle were in the order SRI > ICM > PoP > Farmers' practice. Highest number of grains per panicle was recorded in SRI (57.73/59.19 in 2007/2008) and it was 11/16% higher in 2007/2008 than ICM (52.05/50.99 in 2007/2008), 21/19% higher in 2007/2008 than PoP (47.76/49.92 in 2007/2008) and 27/29% higher in

2007/2008 than Farmers' practice (45.63/45.85 in 2007/2008). Similar results were reported by several workers. Singh and Singh (2005) reported that in SRI planting of single seedling hill^{-1} performed better with respect to number of grains per panicle as compared to two or three seedlings hill^{-1}.

Number of filled grains per panicle in the management systems differed significantly from one another in both the years (Table 11). Number of filled grains per panicle were in the order SRI > ICM > PoP > Farmers' practice. Highest number of filled grains per panicle was recorded in SRI (53.49/55.27 in 2007/2008) and it was 12% higher in 2007 and 2008 than ICM (47.93/49.23 in 2007/2008), 22% higher in 2007 and 2008 than PoP (43.75/45.15 in 2007/2008) and 29/31% higher in 2007/2008 than Farmers' practice (41.58/42.34 in 2007/2008).

Sterility percentage in the management systems were in the order Farmers' practice > PoP > SRI > ICM in both the years (Table 13). In the first year sterility percentage in the management systems differed significantly from one another but in the second year Farmers' practice and PoP were on par and PoP , ICM and SRI were also on par. The highest sterility percentage was recorded in Farmers' practice (8.90/14.73% in 2007/2008) and it was 42/111% higher in 2007/2008 than SRI (6.27/6.89 in 2007/2008), 12/62% higher in 2007/2008 than ICM (7.93/9.07 in 2007/2008) and 6/35% higher in 2007/2008 than PoP (8.38/10.92 in 2007/2008). Gautam and Sharma (1983) also reported that high plant density resulted in higher percentage of unfilled grains. Wang et al, (2002) observed lower sterility percentage with single seedling per hill than with two seedling hill^{-1}.

Grain yield in the management systems differed significantly from one another in both the years. Grain yield was in the order Farmers' practice > PoP > SRI > ICM (Table 22) (Fig 6a). Maximum grain yield recorded in Farmers' practice (1041.43/1038.44 kg ha^{-1} in 2007/2008) was 16/15% higher in 2007/2008 than PoP (897.25/899.67 kg ha^{-1} in 2007/2008), 24/26% higher in

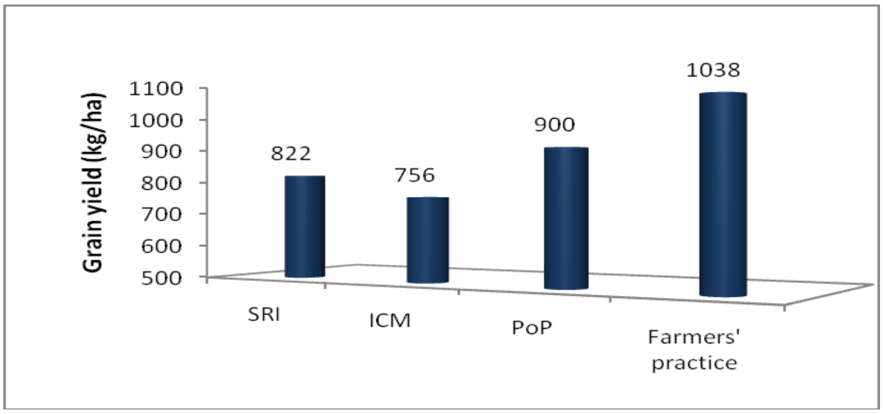


Fig. 6a. Effect of management systems on grain yield (2008)

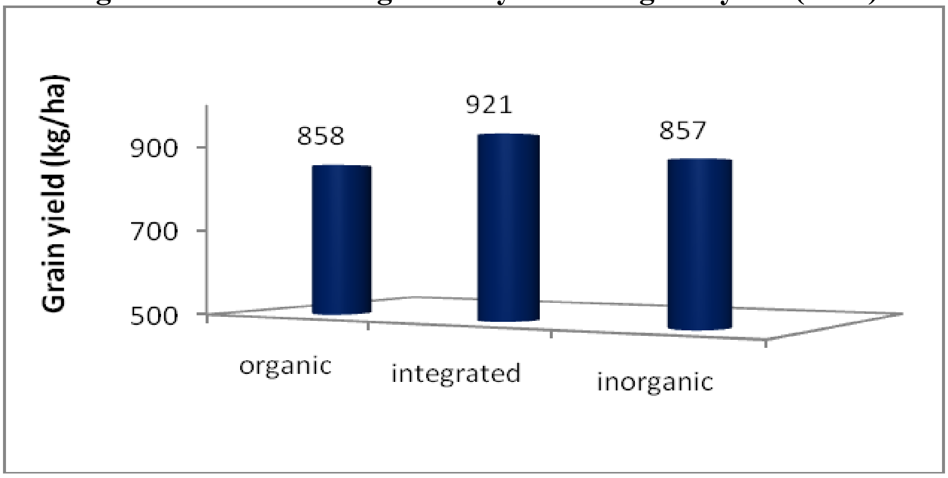


Fig. 6b. Effect of nutrient sources on grain yield (2008)

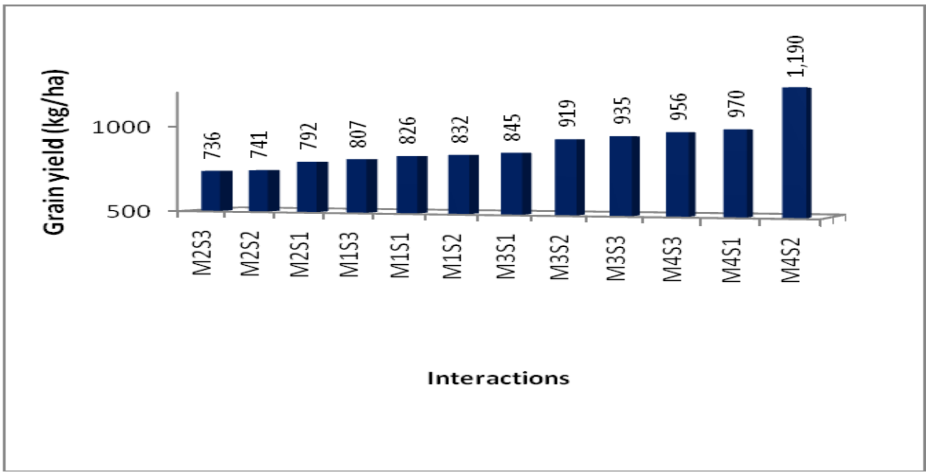


Fig. 6c. Effect of interactions on grain yield (2008)

2007/2008 than in SRI (840.80/821.58 kg ha^{-1} in 2007/2008) and 36/37% higher in 2007/2008 than ICM (764.68/756.21 kg ha^{-1} in 2007/2008).

Grain yield in PoP was significantly higher than SRI and ICM. PoP realized 7/10% higher grain yield in 2007/2008 than SRI and 17/19% higher grain yield in 2007/2008 than ICM. Yield in SRI was significantly higher than ICM and difference between them were 10/9% in 2007/2008 respectively (Table 14). Significantly higher grain yield realized in Farmers' practice may be attributed to the significantly better growth and yield parameters realized in this treatment compared to other management systems. Significantly higher growth characters like leaf number per plant, leaf area index, flag leaf area, tiller number per unit area and leaf area duration might have resulted in increased photosynthesis and production of photosynthates which finally transformed into significantly higher number of panicles per unit area and higher relative accumulation of dry matter in the panicles. Significantly higher productive tillers per unit area in Farmers' practice was 413/410% higher in 2007/2008 than SRI, 270/266% higher in 2007/2008 than ICM and 10/11% higher in 2007/2008 than PoP. It also recorded higher percentage dry matter partitioning into panicles (33.02/31.54% in 2007/2008 Vs 28.24/25.59% in 2007/2008 in SRI, 30.02/27.77% in 2007/2008 in ICM and 32.16/30.10% in 2007/2008 in PoP). Farmers' practice realized 17/23% higher dry matter accumulation in panicle in 2007/2008 than that in SRI. All these desirable characters may be due to the significantly higher nutrient uptake (N, P, K, Fe, Zn and Mn) realized under this management systems. Similar yield trend was earlier reported by Anil Kumar (1989) who got higher grain yield (3381 kg ha^{-1}) in broadcast crop than transplanted rice (3287 kg ha^{-1}).

Straw yield in the management systems also differed significantly from one another in both the years (Table 14). Straw yield recorded was in the order Farmers' practice > PoP > SRI > ICM. Maximum straw yield recorded in Farmers' practice (1685.07/1696.66 kg ha^{-1} in 2007/2008) was 26/28% higher in

2007/2008 than PoP (1338.44/1323.57 kg ha^{-1} in 2007/2008), 36/40% higher in 2007/2008 than SRI (1234.76/1209.67 kg ha^{-1} in 2007/2008) and 50/52% higher in 2007/2008 than ICM (1126.03/1115.04 kg ha^{-1} in 2007/2008). PoP produced 8/9% more straw yield in 2007/2008 than SRI and 19/18% more straw yield than ICM in 2007/2008. Straw yield increase in SRI over ICM was 10/8% in 2007/2008 respectively. Significantly higher straw yield in Farmers' practice may be attributed to higher plant population and tiller production per unit area. This result was supported by Lal et al, 1982. Increase in plant density increase in straw yield were due to increased plant population per unit area. Chandramohan and Mohammadali (1976) also reported that direct sown crop recorded 1.7% increase in straw yield over transplanted crop.

Dry matter partitioning into root, straw and panicle was significantly influenced by management systems in both the years (Table 16). Percentage of dry matter accumulation in root and panicle differed significantly from one another whereas the percentage of dry matter accumulation in straw in ICM, PoP and Farmers' practice were on par. Percentage dry matter accumulation in root and straw were in the order SRI > ICM > PoP > Farmers' practice and that in panicle was exactly in the reverse order. Highest percentage of dry matter accumulation in root occurred in SRI (22.19/22.92% in 2007/2008) and it was 13/14% higher in 2007/2008 than the least percentage recorded in Farmers' practice (19.66/20.13% in 2007/2008), 9/10% higher in 2007/2008 than PoP (20.13/20.10% in 2007/2008) and 3% higher in 2007 and 2008 than ICM (21.50/22.23 in 2007/2008).

Highest percentage of dry matter accumulation in straw was recorded in SRI (49.82/51.48% in 2007/2008) and it was significantly higher than the other three management systems. SRI was 5/7% higher in 2007/2008 than the least percentage recorded in Farmers' practice (47.23/48.33% in 2007/2008), 5% higher in 2007 and 2008 than PoP (47.42/49.00% in 2007/2008) and 3% higher in 2007 and 2008 than ICM (48.39/50.01% in 2007/2008). Less interplant competition would have enabled the plants to have more physiological activity. In square planting with wider spacing, more soil area was available for foraging leading to improved root characters viz., root length, root volume and root dry weight resulting in more photosynthetic activity. This might be reason for higher root and straw dry matter in SRI. Similar result was reported by Shrirame et al., 2008.

Relative distribution of dry matter in panicle was in the following order i.e. Farmers' practice > PoP > ICM > SRI. Highest percentage of dry matter accumulation in panicle recorded in Farmers' practice (33.02/31.54% in 2007/2008) was 17/23% higher in 2007/2008 than the least percentage recorded in SRI (28.24/25.59% in 2007/2008), 10/14% higher in 2007/2008 than ICM (30.02/27.77% in 2007/2008) and 3/5% higher in 2007/2008 than PoP (32.16/30.10% in 2007/2008). High relative dry matter accumulation in panicle in Farmers' practice and PoP might have contributed to higher grain yield in these treatments.

Management systems showed significant influence on harvest index. Even though order of the effect varied in both the years the highest harvest index (0.405 in 2007 and 2008) was in SRI and lowest (0.387/0.385 in 2007 and 2008) in Farmers' practice (Table 17). Harvest index in SRI and ICM were on par in both the years. Harvest index in SRI was 5% higher than that in Farmers' practice in both the years. Satish (2006) observed that translocation of assimilates from leaf, sheath and conversion percentage of stored assimilates before heading were higher under SRI system leading to improvement in harvest index. Similar result was reported by Wang et al., 2002.

Crop duration (sowing to harvest) also showed significant difference between the different management systems (Table 19). Crop raised under PoP had the longest duration (108 days) followed by ICM with 98 days, SRI with 94/95 days (2007/2008) and Farmers' practice with 87 days. When crop period in the main field is considered it was 90 days for PoP, 86 days each for ICM and

SRI and 87 days for Farmers' practice. Longer duration in the nursery did not reduce the crop period in the main field. On the other hand older seedlings took more days to overcome the transplanting shock and to establish in the main field resulting in higher crop duration. Thus the transplanted crops PoP, ICM and SRI had longer duration than the broadcast one. In spite of low duration crop yield (grain and straw) was highest in the broadcast crop.

5.1.2 Effect of management systems on biochemical properties of grain

Among the biochemical properties of grain total free amino acid content in both years and amylopectin content in 2007 were significantly influenced by management systems whereas phenols, starch, crude protein and amylose content remained unaffected (Tables 20 to 22). Total free amino acid content of grain were in the order SRI > ICM > PoP > Farmers' practice. Amylopectin (2007) was in the order ICM > Farmers' practice > PoP > SRI . Grains of crop raised under SRI had highest total free amino acid and least amylopectin content.

SRI recorded highest free amino acid content (32.85/31.54 mg 100 g^{-1} in 2007/2008) and it was on par with ICM (32.16/30.10 mg 100g^{-1} in 2007/2008) and both were significantly higher than PoP (30.02/27.77 mg 100 g^{-1}in 2007/2008) and Farmers' practice (28.24/25.59 mg 100g^{-1} in 2007/2008) which in turn differed significantly from each other (Table 20). Total free amino acid content in SRI was 19/23% higher in 2007/2008 than that in Farmers' practice, 9/14% higher in 2007/2008 than that on PoP and 2/5% higher in 2007/2008 than that in ICM. The result is in conformity with the finding of RenQuan (2008) who reported that cultivation of hybrid rice under control of damp irrigation increased amino acid content of grain than submerged irrigation regimes.

In 2007 highest amylopectin was recorded in ICM (30.53%) which was significantly higher than the other three management systems (Table 22). ICM was followed by Farmers' practice (30.47%) which was on par with PoP (29.77%) which in turn was on par with SRI (29.45%).

5.1.3 Effect of management systems on weed dry matter production

Weed dry matter at 15 and 35 DAS/DAT in the management systems differed significantly from one another. Weed dry matter production recorded at 15 DAS/DAT were in the order Farmers' practice > PoP > SRI > ICM and that at 35 DAS/DAT were in the order Farmers' practice > ICM > PoP > SRI (Table 24). Highest weed dry matter production at 15 DAS/DAT recorded in Farmers' practice (24.09/24.56 g m^{-2} in 2007/2008) was 29/27% higher than lowest weed dry matter recorded in ICM (18.71/19.34 g m^{-2} in 2007/2008), 11/9% higher in 2007/2008 than in SRI (21.72/22.45 g m^{-2} in 2007/2008) and 5/3% higher in 2007/2008 than in PoP (23.03/23.79 g m^{-2} in 2007/2008).

Highest weed dry matter production at 35 DAS/DAT recorded in Farmers' practice (57.96/58.51 g m^{-2} in 2007/2008) was 141/139% higher in 2007/2008 than lowest weed dry matter recorded in SRI (24.09/24.38 g m^{-2} in 2007/2008), 35% higher in 2007 and 2008 than PoP (43.03/43.25 g m^{-2} in 2007/2008) and 7/8% higher in 2007/2008 than ICM (54.06/54.21 g m^{-2} in 2007/2008)

5.1.4 Effect of management systems on uptake of nutrients

Management systems showed significant influence on nutrient uptake by grain (N, P, K, Fe and Mn), by straw (N, K, Fe, Mn and Zn) and total uptake by the crop (N, P, K, Fe, Mn and Zn) in both the years (Tables 27 to 40). Sulphur uptake by the crop (grain + straw), P uptake by straw and Zn uptake by grain were not significantly influenced by management systems. Nutrient uptake by grain, straw and total uptake by crop showed more or less the same trend in both the years. Therefore total nutrient uptake by the crop is discussed here.

Nutrient uptake (N, K, Fe, Mn and Zn) was in the order Farmers' practice > PoP > SRI > ICM. P uptake was in the order Farmers' practice > SRI > PoP > ICM. Uptake of all the nutrients in Farmers' practice was significantly higher than that in the other three management systems. Uptake of all nutrients in PoP and ICM were on par and that in SRI and ICM were also on par. Effect of management systems on crop uptake of individual nutrient is discussed below.

Highest total N uptake was recorded in Farmers' practice (20.42 kg ha^{-1} in 2007 and 2008) and it was 40/45% higher in 2007/2008 than ICM (14.62/14.08 kg ha^{-1} in 2007/2008), 23/31% higher in 2007/2008 than SRI (16.56/15.54 kg ha^{-1} in 2007/2008) and 17/22% higher in 2007/2008 than PoP (17.45/16.71 kg ha^{-1} in 2007/2008).

Highest total P uptake was recorded in Farmers' practice (1.93/2.20 kg ha^{-1} in 2007 and 2008) and it was 34/62% higher in 2007/2008 than ICM (1.44/1.36 kg ha^{-1} in 2007/2008), 24/41% higher in 2007/2008 than PoP (1.56 kg ha^{-1} in 2007 and 2008) and 23/43% higher in 2007/2008 than SRI (1.57/1.53 kg ha^{-1} in 2007/2008).

Total uptake of K was highest in Farmers' practice (25.98/28.56 kg ha^{-1} in 2007 and 2008) and it was 44/45% higher in 2007/2008 than ICM (17.99/19.67 kg ha^{-1} in 2007/2008), 27/36% higher in 2007/2008 than SRI (20.47/20.93 kg ha^{-1} in 2007/2008) and 23/22% higher in 2007/2008 than PoP (21.09/23.47 kg ha^{-1} in 2007/2008).

Total Fe uptake was highest in Farmers' practice (0.99/1.06 kg ha^{-1} in 2007 and 2008) and it was 52/54% higher in 2007/2008 than ICM (0.65/0.69 kg ha^{-1} in 2007/2008), 34/41% higher in 2007/2008 than SRI (0.74/0.75 kg ha^{-1} in 2007/2008) and 27/28% higher in 2007/2008 than PoP (0.78/0.83 kg ha^{-1} in 2007/2008).

Highest total Zn uptake occurred in Farmers' practice (1.00/1.08 kg ha^{-1} in 2007 and 2008) and it was 47/48% higher in 2007/2008 than ICM (0.68/0.73 kg ha^{-1} in 2007/2008), 31/33% higher in 2007/2008 than SRI (0.76/0.81 kg ha^{-1} in

2007/2008) and 23% higher in 2007 and 2008 than PoP (0.81/0.88 kg ha^{-1} in 2007/2008).

Highest total Mn uptake occurred in Farmers' practice (1.04/1.11 kg ha^{-1} in 2007 and 2008) and it was 49/50% higher in 2007/2008 than ICM (0.70/0.74 kg ha^{-1} in 2007/2008), 33/37% higher in 2007/2008 than SRI (0.78/0.81 kg ha^{-1} in 2007/2008) and 24/26% higher in 2007/2008 than PoP (0.84/0.88 kg ha^{-1} in 2007/2008).

5.1.5 Effect of management systems on available nutrient status of soil and activity of soil enzymes

Management systems did not show any influence on the available nutrient status of soil estimated after the experiments (Table 44).

Among the soil enzymes urease, phosphatase and dehydrogenase only phosphatase activity was influenced significantly by the management systems (Table 56). Phosphatase activity was in the order SRI > ICM > PoP > Farmers' practice in both the years. Phosphatase activity in SRI and ICM were on par and that in PoP and Farmers' practice were also on par. Highest activity of phosphatase recorded in SRI (42.80/44.22 µg p-nitrophenol g^{-1} hr^{-1} in 2007/2008) was 3/4% higher in 2007/2008 than Farmers' practice (41.56/42.53 µg p-nitrophenol g^{-1} hr^{-1} in 2007/2008), 2% higher in 2007 and 2008 than PoP (41.77/43.15 µg p-nitrophenol g^{-1} hr^{-1} in 2007/2008) and 0.63/0.66% higher in 2007 and 2008 than ICM (42.53/43.93 µg p-nitrophenol g^{-1} hr^{-1} in 2007/2008).

5.2 EFFECT OF NUTRIENT SOURCES

5.2.1 Effect of nutrient sources on growth and yield of Njavara

Sources of nutrients did not influence growth characters in Njavara (Tables 4to9). Chlorophyll content of leaves was significantly influenced by nutrient sources. Yield attributing characters like number of grains $panicle^{-1}$, number of filled grains panicle^{-1} and crop yield (grain and straw) as well as harvest index were significantly influenced by sources of nutrients (Tables 11 and 14). Duration of the crop also showed significant variation due to variation in sources of nutrients. During both the years consistent pattern of influence was noticed on the effect of nutrient sources on all these characters. Highest number of grains panicle^{-1}, filled grains panicle^{-1} and crop yield (grain and straw) realised in integrated nutrient source were significantly higher than organic and inorganic sources which in turn were on par with each other. Effect of nutrient sources on yield attributing parameters and crop yield (individual years and pooled analysis) were in the order integrated nutrient source > organic source > inorganic source and the order was just the reverse with respect to harvest index (inorganic source > organic source > integrated nutrient source) . Crop duration was in the order inorganic source > integrated nutrient source > organic source (Table 19). The different sources of nutrients showed significant difference from one another with respect to their influence on harvest index and crop duration. Effects of nutrient sources on individual characters are discussed in detail below.

Highest leaf chlorophyll content was realized in organic sources (1.34/137 mg g^{-1} in 2007/2008) and this was significantly higher than that recorded in integrated and inorganic sources which in turn were on par with each other (Table 7). Highest chlorophyll content was recorded in organic sources which was 9% higher in 2007 and 2008 than inorganic sources.

Highest number of grains panicle^{-1} (51.77/54.39 in 2007/2008) were obtained in integrated nutrient source which was followed by organic source (50.76/52.42 in 2007/2008) and inorganic source (49.85/51.49 in 2007/2008) respectively (Table 11). Effect of integrated nutrient source was significantly higher than organic source and inorganic source which in turn were on par. Number of grains panicle^{-1} in integrated nutrient source was 4/6% higher in 2007/2008 than that in inorganic source and 2/4% higher in 2007/2008 than that in organic source. Bastia (2002) also reported that number of grains panicle^{-1} was maximum in integrated nutrient source.

Highest number of filled grains panicle^{-1} was recorded in integrated nutrient source (47.59/50.02 in 2007/2008) (Table 11). It was significantly higher than organic source (46.62/48.04 in 2007/2008) and inorganic source (45.86/47.14 in 2007/2008) which in turn were on par. Integrated nutrient source was 4/6% higher in 2007/2008 than inorganic nutrient sources and 2/4% higher in 2007/2008 than organic source. Dwivedi and Thakur, 2000 and Bastia, 2002 also observed that number of filled grains panicle^{-1} increased significantly due to integrated nutrient management in rice.

Highest grain yield (928.69/920.50 kg ha $^{-1}$ in 2007/2008) was obtained in integrated nutrient source which was followed by organic source (872.08/857.95 kg ha $^{-1}$ in 2007/2008) and inorganic source (857.35/857.48 kg ha $^{-1}$ in 2007/2008) respectively (Table 14) (Fig 6b). Grain yield in integrated nutrient source was significantly higher than that in organic source and inorganic source which in turn were on par. Grain yield in integrated nutrient source was 4/3% higher in 2007/2008 than that in inorganic source and 6/7% higher in 2007/2008 than that in organic source.

Dwivedi and Thakur, 2000 and Bastia, 2002 reported higher grain yield in rice was due to integrated nutrient management. Panda et al. (2007) reported that higher yield was obtained in the NPK + FYM treatment and also concluded that balanced use of N, P and K fertilizers in conjunction with FYM was the best nutrient management option for obtaining higher and sustainable rice yield and for promoting soil health.

Effect of nutrient sources on grain and straw yields also showed the same order. Integrated nutrient source recorded the highest straw yield (1494.44/1496.55 kg ha^{-1} in 2007/2008) and it was followed by organic source (1285.18/1265.38 kg ha $^{-1}$ in 2007/2008) and inorganic source (1258.59/1246.77 kg ha^{-1} in 2007/2008)

(Table 14). Straw yield in integrated source was significantly higher than that in organic source and inorganic source which in turn were on par. straw yield in integrated nutrient source was 19/20% higher in 2007/2008 than that in inorganic source and 16/18% higher than that in inorganic sources.

Solunke et al. (2006) reported a significant increase in the straw yield and biological yield of basmati rice with FYM addition @ 5 t ha^{-1} + 100% recommended dose of fertilizer (75:37.5:37.5 kg NPK/ha) than other integrated nutrient management.

Effect of nutrient sources on harvest index differed significantly from one another. Effect of nutrient sources on harvest index was in the order inorganic source > organic source > integrated nutrient source in both the years (Table 17). Highest harvest index (0.405 in 2007 and 0.408 in 2008) was recorded in inorganic source which was 0.3/0.9% higher than organic source (0.404 in 2007 and 2008) and 4/5% higher than integrated nutrient source (0.389 in 2007 and 0.387 in 2008).

Crop duration in the nutrient sources differed significantly from one another and they were in the order inorganic source > integrated nutrient source > organic source in both the years (Table 19). Organic source recorded the lowest duration of crop (95 days in 2007 and 2008) followed by integrated nutrient source (97 days in 2007 and 2008) and inorganic source (98 days in 2007 and 2008) respectively.

5.2.2 Effect of nutrient sources on biochemical of grain

Among the biochemical properties starch (2008), crude protein (2007 and 2008) and amylopectin (2007 and 2008) were significantly influenced by nutrient sources whereas total free amino acids, phenols and amylose content of grain remained unaffected. Starch and amylopectin content of grain were in the order organic nutrient source > integrated nutrient source > inorganic nutrient source. Crude protein content of grain was in the order organic nutrient source > inorganic nutrient source > integrated nutrient source in both the years.

The highest starch content of grain (52.07%) was realized in organic source and this was significantly higher than that recorded in inorganic source (50.77%) but was on par with the starch content obtained in integrated nutrient source (50.95%) (Table 21). Starch content in integrated nutrient source was on par with that in inorganic source. Organic source recorded 3% higher starch content than inorganic nutrient source.

Effect of all the nutrient sources on crude protein content differed significantly from one another (Table 21). Highest content of crude protein was recorded in organic source (7.98/8.23% in 2007/2008) which was 5/6% higher in 2007/2008 than inorganic source (7.58/7.74% in 2007/2008) and 33% higher in 2007 and 2008 than integrated nutrient source (6.00% in 2007 and 6.17% in 2008). This result is supported by the finding of Hemalatha et al. (2000) who reported that crude protein content in rice grain from plants treated with organic manures was higher than that in control plot.

Highest content of amylopectin (30.62/29.62% in 2007/2008) was recorded in organic source which was significantly superior to integrated nutrient source (29.89/28.21% in 2007/2008) and inorganic source (29.65/28.37% in 2007/2008) which in turn were on par with each other (Table 22). Amylopectin recorded in organic source was 3/4% higher than inorganic source and 2/5% higher than integrated source in 2007/2008 respectively.

5.2.3 Effect of nutrient sources on nutrient content of grain and straw

Sources of nutrients significantly influenced N, K and Fe contents of grain and Zn content of straw in both the years (Tables 25, 26, 31 and 32). N content of grain and Zn content of straw differed significantly from one another in both the years. N content of grain was in the order organic source > inorganic source > integrated source . K and Fe content of grain was in the order organic source > integrated source > inorganic source in both the years. N and K content of organically produced grain were significantly higher than those in the grain produced with integrated and inorganic nutrient sources whereas Fe content of grain in organic and integrated nutrient sources were on par but significantly superior to inorganic sources. Effect of nutrient sources on individual nutrient content of grain and straw are discussed below.

Highest N content of grain was recorded in organic source (1.28/1.32% in 2007/2008) which was 6% (2007 and 2008) higher than inorganic source (1.21/1.24% in 2007/2008) and 33% higher in 2007 and 2008 than integrated nutrient source (0.96/0.99% in 2007/2008).

Organic source recorded the highest K content of grain (0.33% in 2007 and 2008) and it was significantly higher than integrated nutrient source (0.32% in 2007 and 2008) and inorganic source (0.31% in 2007 and 0.32% in 2008) which in turn were on par with each other. Highest K content in grain recorded in organic source was 6/3% higher in 2007/2008 than inorganic source.

Highest Fe content of grain was recorded in organic source (36.05/35.87ppm in 2007/2008) and it was on par with integrated nutrient source (35.50/34.76ppm in 2007/2008). Both organic source and integrated source were significantly higher than inorganic source (32.53/ 32.80ppm in 2007/2008). Fe content of organically produced grain was 11/9 % higher in 2007/2008 than that in inorganically produced grain whereas grains produced with integrated nutrient source contained 2/3% higher Fe in 2007/2008 than inorganic sources.

Highest Zn content of straw (464.37/490.88ppm in 2007/2008) was realized in integrated nutrient source which was significantly higher than that in organically and inorganically produced straw. Zn content in straw in integrated nutrient source was followed by organic (353.37/413.99ppm in 2007/2008) and inorganic sources (343.73/403.18ppm in 2007/2008) respectively. Zn content of straw in organically and inorganically produced crop differed significantly in 2007 but were on par in 2008. Zn content of straw in integrated nutrient source was 31/19% higher in 2007/2008 than organic source and 35/22% higher in 2007/2008 than inorganic source.

5.2.4 Effect of nutrient sources on uptake of nutrients

Nutrient sources showed significant influence on nutrient uptake by grain (N, K and Fe), by straw (P, K, Fe and Zn) and total uptake by the crop (P, K, Fe and Zn) in both the years. Nutrient sources showed no significant influence on S, Zn and Mn uptake by grain and N, S and Mn uptake by straw and the crop. Effect of nutrient sources on uptakes of individual nutrient is discussed in the following paragraphs.

Highest N uptake by the grain occurred in organic source and highest K and Fe uptake occurred in integrated nutrient source. Effect of nutrient sources on N and Fe uptake of grain differed significantly from one another (Tables 27 and 29). Grain uptake of N in the nutrient sources was in the order organic source > inorganic source > integrated nutrient source in both the years. Grain uptake of K and Fe was in the order integrated nutrient source > organic source > inorganic source in both the years.

Highest P, K, Fe and Zn uptake by the straw and highest total P, K, Fe and Zn uptake by the crop (grain + straw) occurred in integrated nutrient source and organic and inorganic source were on par (Tables 31 to 40). Straw uptake of P and Zn and total uptake of P, K and Zn were in the order integrated nutrient source > organic source > inorganic source . Straw and crop uptake of Fe was in the order integrated nutrient source > inorganic source > organic source .

Highest total P uptake (1.82/1.89 kg ha $^{-1}$ in 2007/2008) was obtained in integrated nutrient source which was followed by organic source (1.63/1.88 kg ha $^{-1}$in 2007/2008) and inorganic source (1.42/1.44 kg ha $^{-1}$ in 2007/2008). Effect of integrated nutrient source and organic source were on par. Total P uptake in integrated nutrient source was 22/16% higher in 2007/2008 than that in inorganic source.

Total K uptake was highest (24.11/26.38 kg ha $^{-1}$ in 2007/208) in integrated nutrient source which was significantly higher than other two nutrient sources. It was followed by organic source (20.33/20.44 kg ha $^{-1}$ in 2007/2008) and inorganic source (19.72/22.65 kg ha $^{-1}$in 2007/2008) which in turn were on par with each other. Total K uptake in integrated nutrient source was 47/51% higher in 2007/2008 than that in inorganic source.

Highest total Fe uptake (0.93/1.00 kg ha $^{-1}$ in 2007/2008) was obtained in integrated nutrient source which was followed by inorganic source (0.81/0.83 kg ha $^{-1}$in 2007/2008) and organic source (0.63/0.66 kg ha $^{-1}$ in 2007/2008). Effect of integrated nutrient source and inorganic source were on par and inorganic source and organic source were also on par. Total Fe uptake in integrated nutrient source was 47/51% higher in 2007/2008 than that in organic source.

Total Zn uptake was highest (1.02/1.06 kg ha $^{-1}$ in 2007/2008) in integrated nutrient source which was significantly higher than organic and inorganic nutrient sources. It was followed by organic source (0.74/0.81 kg ha $^{-1}$ in 2007/2008) and inorganic source (0.68/0.76 kg ha $^{-1}$in 2007/2008) respectively. Effect of organic source and inorganic source were on par. Total Zn uptake in integrated nutrient source was 50/39% higher in 2007/2008 than that in inorganic source.

5.2.5 Effect of sources of nutrients on available nutrient status of soil and activity of soil enzymes

Among the soil nutrients available N content and organic carbon content were influenced significantly by sources of nutrients. Available N status of soil supplied with different nutrient sources differed significantly from one another in both the years. Organic carbon content in soils receiving organic and integrated nutrient sources were on par and significantly higher than that in soil receiving only inorganic source of nutrients. Both available N content and organic carbon content of soil after the experiment were in the order organic sources > integrated sources > inorganic sources.

Organic source recorded highest available N content (243.46/250.77 kg ha^{-1} in 2007/2008) and it was followed by integrated nutrient source (235.64/242.81 kg ha^{-1} in 2007/2008) and inorganic source (224.94/232.33 kg ha^{-1} in 2007/2008) respectively (Table 41). Highest available N recorded in organic source was 8/7% higher in 2007/2008 than organic source and 3% higher in 2007 and 2008 than integrated nutrient source.

Soil organic carbon was highest in soil that received only organic source (1.22/1.16% in 2007/2008) and it was followed by soil that received integrated nutrient source (1.17/1.14% in 2007/2008) and inorganic nutrient sources (1.08/1.09% in 2007/2008) (Table 42). Effect of organic source and integrated nutrient sources on soil organic carbon content were on par. Organic carbon content in the soil supplied fully with organic source was 13/6% higher than that in the soil receiving only inorganic source.

Activity of soil enzymes such as urease, phosphatase and dehydrogenase in the soil receiving different sources of nutrients differed significantly from one another in both the years. Effect of nutrient sources on urease activity of soil was in the order organic source > inorganic source > integrated nutrient source whereas that on phosphatase and dehydrogenase activity were in the order organic source > integrated nutrient source > inorganic source.

Highest activity of urease was recorded in soil that received only organic source (57.98/58.23 µg NH_4/g/24hr in 2007/2008) and it was followed by that in soil receiving inorganic nutrient source (57.58/57.74 µg of NH_4/g/24hr in 2007/2008) and integrated nutrient source (56.00/56.17 µg of NH_4/g/24hr in 2007/2008) respectively (Table 44). Urease activity in soils receiving full organic source was 3/4% higher in 2007/2008 than that in the soil receiving integrated nutrient source and 0.7/0.8% higher in 2007/2008 than that in the soil receiving only inorganic nutrient sources. Similar result was reported by Reddy (2002) who opined that urease is one of the soil enzyme which influence the availability of plant utilizable forms of nitrogen in soils fertilized with nitrogen carriers especially urea. Urease and disimilatory nitrate activity increased with increase in organic carbon in soils. The increase in urease activity due to increased organic manure might be due to the presence of extra cellular urease adsorbed on finer components of organic matter. Yet, another reason is that the higher organic matter in soil stimulates the ureolytic microorganicsms by serving as source of carbon, energy and other nutrients essential for microbial growth and multiplication.

Highest activity of phosphatase was recorded in organic source (44.07/45.39 µg p-nitrophenol/g/hr in 2007/2008) and it was followed by integrated nutrient source (42.20 µg p-nitrophenol/g/hr in 2007/2008) and inorganic source (40.23/41.54 µg p-nitrophenol/g/hr in 2007/2008) respectively (Table 44). Effect of phosphatase activity in organic source was 9% higher in 2007 and 2008 than inorganic source and 4% higher in 2007 and 2008 than integrated nutrient source.

Conversion of organic phosphorus to inorganic phosphorus is essential for the effective utilization of phosphate by the plant. The mineralization of organic P is mediated by phosphatases that hydrolyze C-O-P ester bonds. Increase in phosphomenoesterase (acid and alkaline phosphatase) acivity after FYM application was due to increase in the amount of easily decomposable organic compounds originating from either bacterial cell or plant residues in FYM (Kaleeswari 2007).

Organic source recorded the highest activity of dehydrogenase (64.06/59.75 µg TPF/g/24 hr in 2007/2008) and it was followed by integrated nutrient source (62.22/55.35 µg TPF/g/24 hr in 2007/2008) and inorganic source (60.22/47.89 µg TPF/g/24 hr in 2007/2008) respectively (Table 44). Effect of dehydrogenase activity in organic source was 6//25% higher in 2007/2008 than inorganic source and 3/8% in higher in 2007/2008 than integrated nutrient source. Gupta and Raha (2003) found that urease, acid phosphatase and dehydrogenase activity had positive correlation with organic carbon in the soil.

5.3 EFFECT OF INTERACTIONS OF MANAGEMENT SYSTEMS AND NUTRIENT SOURCES

5.3.1 Effect of interactions on growth and yield of Njavara

Growth characters in Njavara were not significantly influenced by the interaction effect of management systems and nutrient sources. Yield attributes like number of grains panicle^{-1}, number of filled grains panicle^{-1}, harvest index and crop yield (grain + straw) were significantly influenced by interaction effect in both the years. SRI treatment supplied with organic nutrient source realized highest number of grains panicle^{-1} and number of filled grains panicle^{-1} whereas Farmers' practice with inorganic sources recorded lowest number of grains panicle^{-1} and number of filled grains panicle^{-1}. Crops that received Farmers' practice with integrated nutrient source recorded highest grain and straw yield and the lowest grain and straw yield were realized in crop receiving ICM with inorganic source. Highest harvest index was noticed in SRI with integrated nutrient source (2007) and in PoP with inorganic nutrient sources (2008) whereas lowest harvest index was noticed in Farmers' practice with integrated nutrient source in both the years. Effects of interactions on individual attributes are discussed in the following paragraphs.

Maximum number of grains panicle^{-1} (58.76/61.34 in 2007/2008) was obtained in SRI with organic source and it was 31/34% higher in 2007/2008 than the minimum number of grains panicle^{-1} (44.98/45.85 in 2007/2008) obtained in Farmers' practice with inorganic source (Table 12).

Maximum filled grains panicle^{-1} (54.47/56.64 in 2007/2008) was obtained in SRI with organic source and it was 32/35% higher in 2007/2008 than minimum filled grains panicle^{-1} (41.04/41.82 in 2007/2008) recorded in Farmers' practice with inorganic source (Table 12).

Highest grain yield (1206.25/1189.75 kg ha^{-1} in 2007/2008) was obtained in Farmers' practice with integrated nutrient source and it was 65/62% higher in 2007/2008 than the lowest grain yield (729.25/736.00 kg ha^{-1} in 2007/2008) obtained in ICM with inorganic source (Table 15) (Fig 6c).

Highest straw yield (2240.75/2262.40 kg ha^{-1} in 2007/2008) was obtained in Farmers' practice with integrated nutrient source and it was 109% higher (in 2007 and 2008) than the lowest straw yield (1073.50/1082.72 kg ha^{-1} in 2007/2008) obtained in ICM with inorganic source (Table 15).

Highest harvest index (0.406) was worked out in SRI with integrated nutrient management and it was 16% higher than the lowest harvest index (0.350) realized in Farmers' practice with integrated nutrient source in 2007 (Table 18). In 2008 highest harvest index (0.416) was obtained in PoP with integrated nutrient source and it was 21% higher than lowest harvest index (0.345) recorded in Farmers' practice with integrated nutrient source

5.3.2 Effect of interactions on uptake of nutrients

Interaction effect showed significant influence on nutrient uptake by grain (N and Mn), straw (K and Zn) and total uptake by the crop (K and Zn) in both the years. Nutrient uptake by crop (K and Zn) was highest in Farmers' practice with integrated nutrient source. Highest N uptake (12.52/12.68 kg ha^{-1} in 2007/2008) by grain was recorded in Farmers' practice with organic source and it was 64/67% higher in 2007/2008 than lowest N uptake (7.65/7.57 kg ha^{-1} in 2007/2008) recorded in ICM with integrated nutrient source (Table 28). Highest Mn uptake (0.09 kg ha^{-1} in 2007 and 2008) by grain was recorded in Farmers' practice with integrated nutrient source and it was 50/80% higher in 2007/2008 than lowest Mn uptake recorded in ICM with integrated nutrient source (Table 30). Highest K uptake (31.88/33.89 kg ha^{-1} in 2007/2008) and Zn uptake (1.05/1.09 kg ha^{-1} in 2007/208) by straw were recorded in Farmers' practice with integrated nutrient source (Table 34 and 36).

In 2007 highest K uptake by crop (35.62 kg ha^{-1}) was recorded in Farmers' practice with integrated nutrient source and it was 115% higher than lowest crop uptake (16.56 kg ha^{-1}) recorded in ICM with inorganic source (Table 38). In 2008 highest crop uptake of K (37.82 kg ha^{-1}) was recorded in Farmers' practice with integrated nutrient source and it was 96% higher than lowest total K uptake (19.25 kg ha^{-1}) recorded in SRI with organic source.

Highest Zn uptake by crop (1.44/1.49 kg ha^{-1}) was recorded in Farmers' practice with integrated nutrient source and it was 144/125% higher in 2007/2008 than lowest total Zn uptake (0.59/0.66 kg ha^{-1} in 2007/2008) recorded in ICM with inorganic source (Table 40).

Phenological study

The developmental phenology of Njavara rice under different management systems was studied. Height of plant, number of leaves hill^{-1}, leaf area, number of tillers hill^{-1}, root length, root dry matter production hill^{-1} and growth stages of Njavara were monitor under the different management systems. Plant height increased gradually up to panicle initiation and it became very fast upto flowering, after which it slowed down upto 70 DAS/DAT (Fig 7a). Number of leaves increased upto 9th week of transplanting /8th week of sowing (Fig 7b). Later produced leaves were larger than the earlier produced ones (Fig 8a). Tiller production continued upto 7WAT/6WAS (Fig 8b). Length of root and root dry matter production increased up to 9 WAS/WAT (Fig 9a and 9b). Panicle initiation occurred at 32 DAS in Farmers' practice, 40 DAT in PoP, 42 DAT in ICM and 45 DAT in SRI. Maximum tillering stage occurred at 36 DAS in Farmers' practice, 45 DAT in PoP, 46 DAT in ICM and 49 DAT in SRI. Booting stage occurred at 46 DAS in Farmers' practice, 51 DAT in PoP, 53 DAT in ICM and 57 DAT in SRI. Flowering stage occurred at 53 DAS in Farmers' practice, 59 DAT in PoP, 60 DAT in ICM and 64 DAT in SRI. Maturity stage occurred at 86 DAS in Farmers' practice, 88 DAT in PoP, 86 DAT in ICM and 88 DAT in SRI.

Economics of crop production

Cost of cultivation, gross income, net income and BCR among the management systems, nutrient sources and interactions differed significantly. Cost of cultivation was highest in SRI, organic nutrient source and SRI with organic nutrient source. Gross income, net income and BCR were highest in Farmer's practice, integrated nutrient source and Farmer's practice with integrated nutrient source.

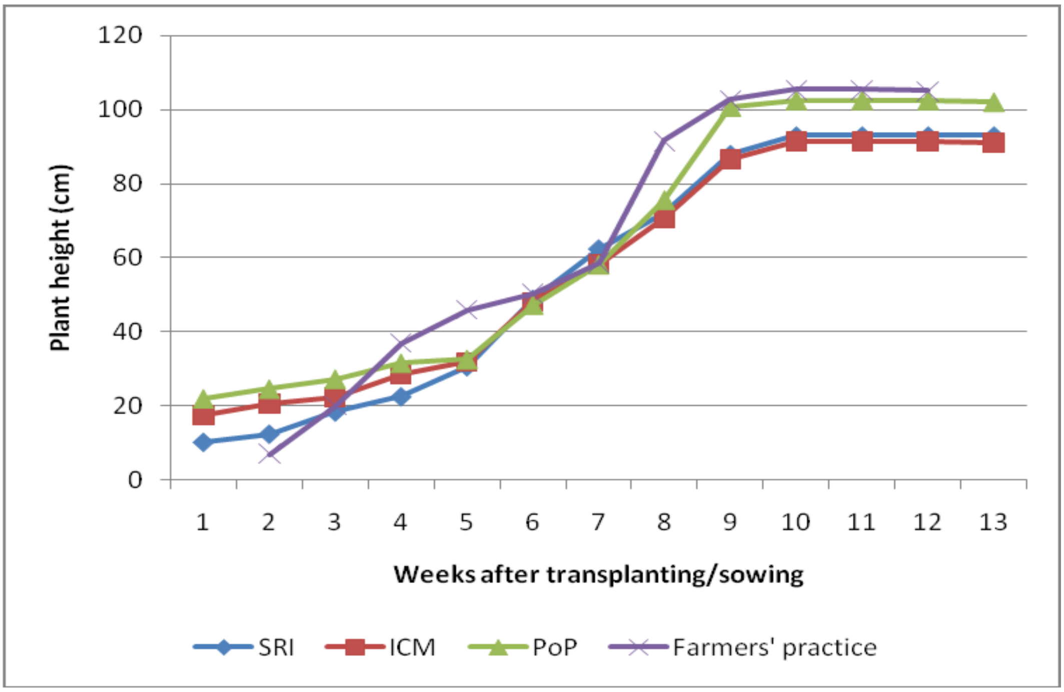


Fig. 7a. Pattern of change in plant height as influenced by management systems

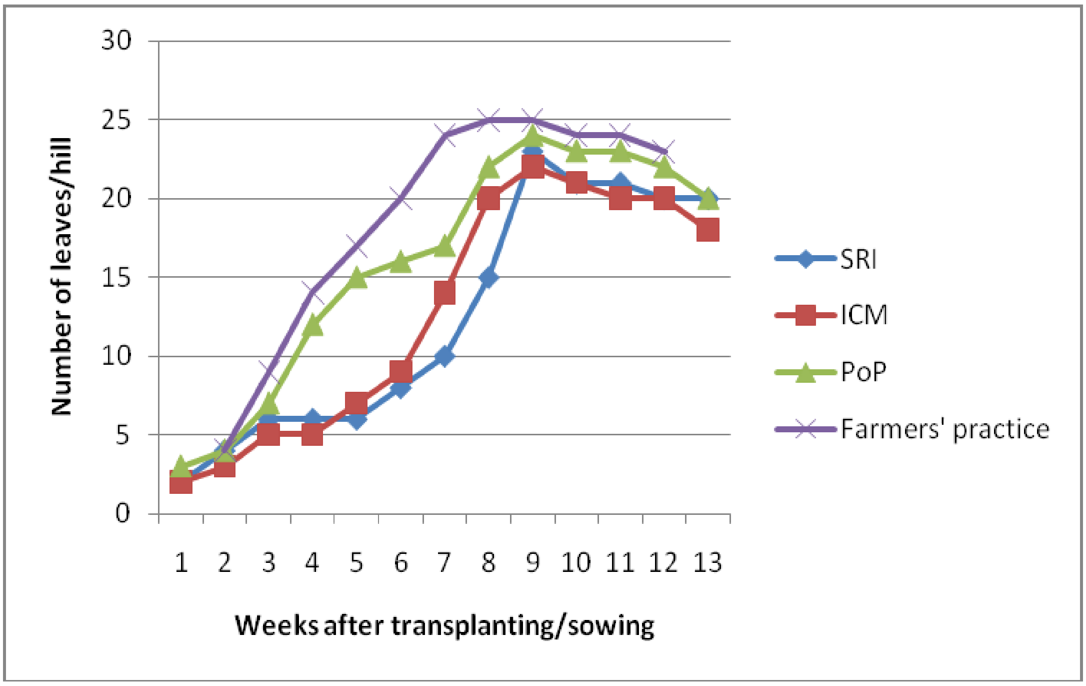


Fig. 7b. Leaf production pattern under different management systmes

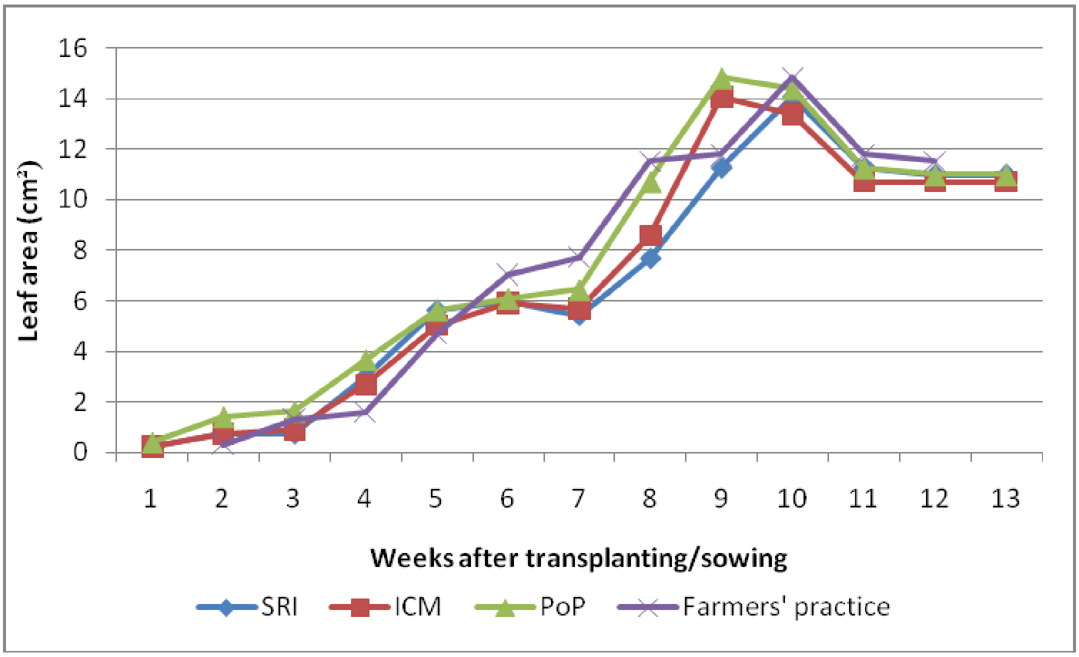


Fig. 8a. Leaf area development as influenced by management systems

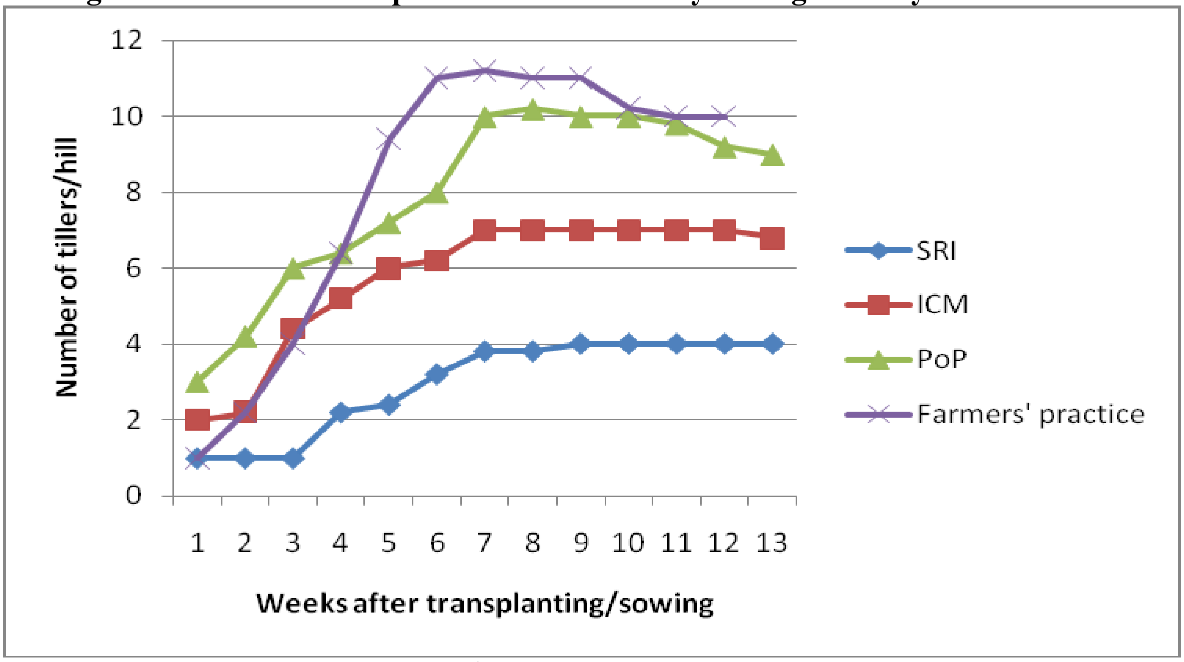


Fig. 8b. Tiller production hill^{-1} under different management systems

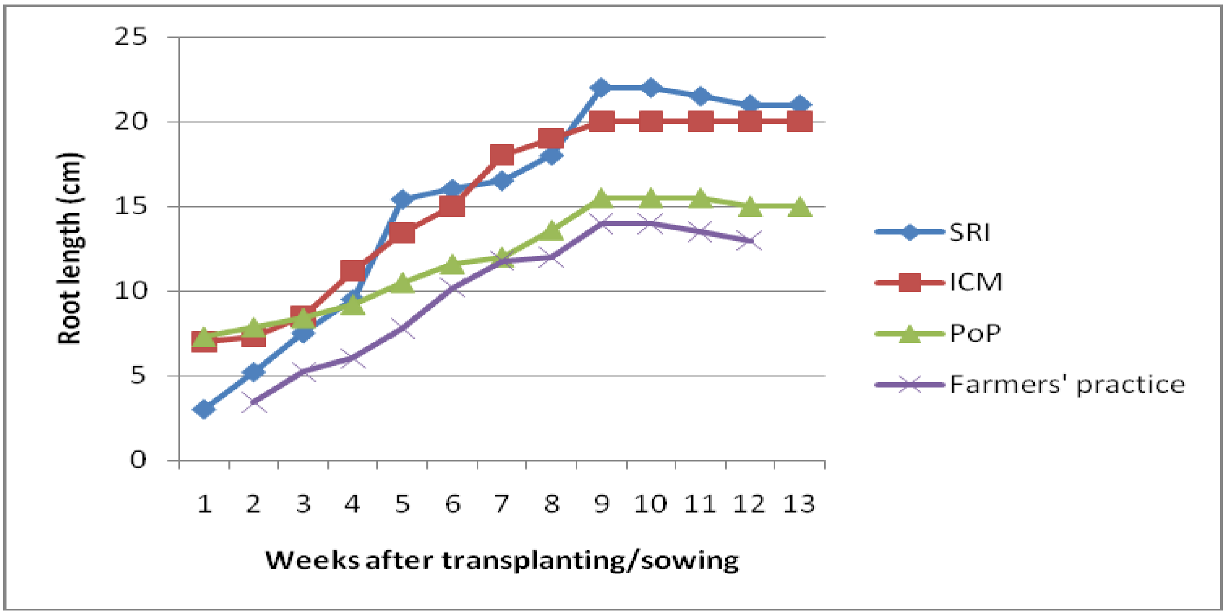


Fig. 9a. Root length development as influenced by different management systems

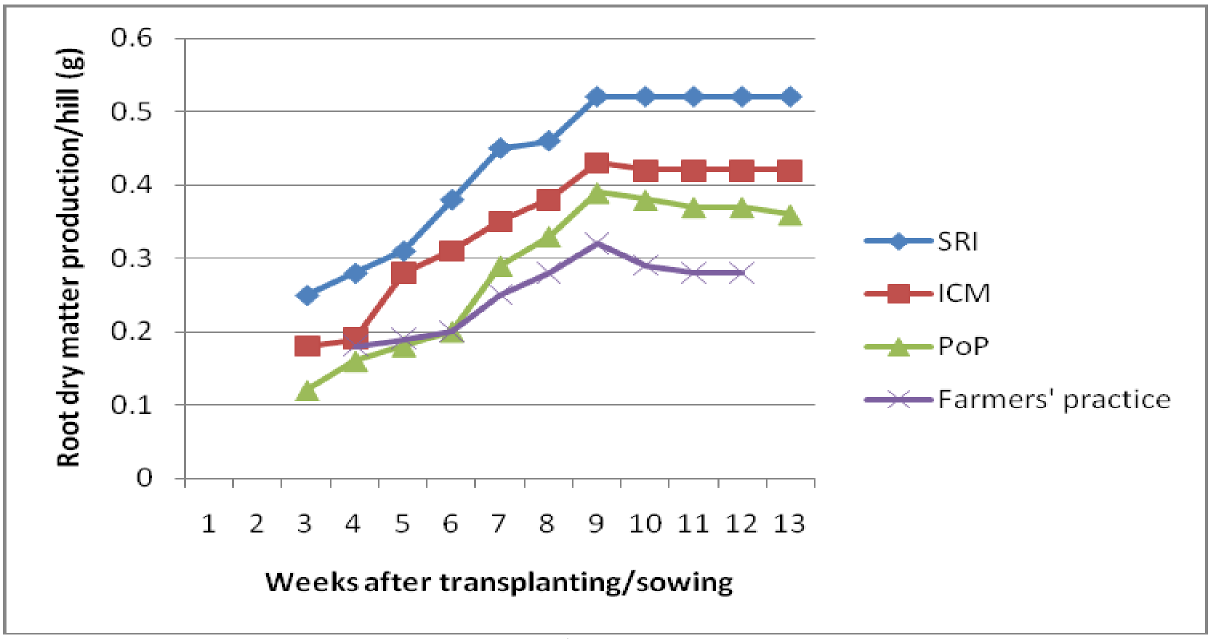


Fig. 9b. Root dry matter production hill^{-1} under different management systems

Summary

6. SUMMARY

Field experiments were conducted at Cropping Systems Research Center, Karamana, Thiruvananthapuram, Kerala, during the summer seasons of 2007 and 2008 (January to April) to study the response of medicinal rice (*Oryza sativa* L.) cv Njavara to nutrient sources under different management systems like SRI, ICM, PoP of KAU and Farmers' practice. The experiment was laid out in split plot design with four replications. The treatments consisted of four management systems viz., SRI (M_1) , ICM (M_2), PoP (M_3) of KAU and Farmers' practice (M_4) in main plots. Nutrient sources viz., organic sources (S_1), integrated nutrient sources (S_2) and inorganic sources (S_3) were the sub plot treatments.

Growth components viz., plant height, number of leaves hill^{-1}, leaf area index (LAI), leaf area duration (LAD), culm strength, number of tillers m^{-2}, root dry matter production hill^{-1} and flag leaf area were recorded. The data on yield attributes like number of productive tillers m^{-2}, panicle length, number of grains panicle^{-1}, number of filled grains panicle^{-1}, 1000 grain weight, harvest index, sterility percentage, dry matter partitioning, paddy grain ratio, grain husk ratio were also worked out. Yield and uptake of nutrients (N, P, K,S Fe, Mn and Zn by grain, straw and crop (grain + straw) were also recorded. Biochemical components such as total free amino acids, phenols, starch, amylose, amylopectin and crude protein content of grain were estimated. Data on weed dry matter production and weed flora and crop duration in the treatments were also recorded. Soil enzymes (urease, phosphatase and dehydrogenase) and soil fertility status were assessed after the harvest of the crop.

The inference and conclusions drawn from the results of the experiments are summarized below.

A. Effect of management systems

1. Growth parameters like height of plants, number of leaves hill^{-1}, leaf area index (LAI), culm strength, root dry matter and number of tillers m^{-2} were significantly influenced by management systems. Leaf area duration and flag leaf area showed significant variation only in 2008.

2. Plant height and leaf area index (at physiological maturity) were in the following order i.e. Farmers' practice > PoP > SRI > ICM and they differed significantly from one another.

3. Number of leaves hill$^{-1,}$ leaf area index at panicle initiation, flag leaf area and tiller production m^{-2} (from 4 weeks after sowing (WAS)/weeks after transplanting (WAT) till physiological maturity) were in the order Farmers' practice > PoP > ICM >SRI . Tiller production m^{-2} in the four management systems differed significantly from one another.

4. All the management systems differed significantly from one another in culm strength (physiological maturity) and root dry matter production. Culm strength and root dry matter production (7 WAS/WAT to physiological maturity) were in the order of SRI > ICM > PoP > Farmers' practice.

5. All the yield attributes except 1000 grain weight were significantly influenced by management systems resulting in significant variation in the crop yield (grain and straw). Paddy grain ratio and grain husk ratio remained unaffected by the management systems.

6. Number of productive tillers m^{-2}, sterility percentage and dry matter accumulation in panicle were in the order of Farmers' practice > PoP > ICM > SRI and they all differed significantly from one another.

7. Grain and straw yield in the management systems differed significantly from one another and their order was Farmers' practice > PoP > SRI > ICM.

8. Number of grains panicle^{-1}, number of filled grains panicle^{-1} and dry matter partitioning in root and straw were in the order of SRI > ICM > PoP > Farmers' practice. All the characters except dry matter partitioning in straw differed significantly from one another.

9. Among the biochemical properties of grain, total free amino acid content and amylopectin content (2007) were significantly influenced by management systems. Free amino acid content of grain was in the order of SRI > ICM > PoP > Farmers' practice. Amylopectin (2007) was in the order ICM > Farmers' practice > PoP > SRI .

10. Weed dry matter production at 15 and 35 days after sowing (DAS)/ days after transplanting (DAT) in the management systems differed significantly from one another. Weed dry matter production recorded at 15 DAS/DAT were in the order of Farmers' practice > PoP > SRI > ICM and that at 35 DAS/DAT was Farmers' practice > ICM > PoP > SRI.

11. Management systems showed significant influence on nutrient uptake by grain (N, P, K, Fe and Mn), by straw (N, K, Fe, Mn and Zn) and total uptake by the crop (N, P, K, Fe, Mn and Zn). S uptake by the crop (grain + straw), P uptake by straw and Zn uptake by grain were not significantly influenced by management systems. Uptake of all the nutrients in Farmers' practice was significantly higher than that in the other three management systems.

12. Management systems did not show significantly influence on the available nutrient status of soil after the experiments. Among the soil enzymes phosphatase activity was influenced significantly by the management systems and was in the order SRI > ICM > PoP > Farmers' practice in both the years.

13. Crop raised under PoP had the longest duration (108 days) followed by ICM with 98 days, SRI with 94/95 days (2007/2008) and Farmers' practice with 87 days.

14. Farmers' practice realized highest crop yield which was significantly higher than PoP, SRI and ICM with respect to growth characters like plant height, number of leaves hill^{-1}, leaf area index, leaf area duration, flag leaf area and tiller production and yield characters like number of productive tillers, percentage of dry matter accumulation in panicle. Duration of the crop was lowest in Farmers' practice and it was significantly lower than all other management systems.

B. Effect of nutrient sources

1. Sources of nutrients did not influence the growth characters in Njavara. Yield attributing characters like number of grains panicle^{-1}, number of filled grains panicle^{-1} and harvest index as well as crop yield (grain and straw) were significantly influenced by sources of nutrients.

2. Highest number of grains panicle^{-1} , filled grains panicle^{-1} and crop yield (grain and straw) were realised in integrated nutrient source and then were significantly higher than organic and inorganic sources. Effect of nutrient sources on yield attributing parameters and crop yield were in the order integrated nutrient source > organic source > inorganic source and the order was just the reverse with respect to harvest index (inorganic source > organic source > integrated nutrient source) .

3. Duration of the crop also showed significant variation due to variation in sources of nutrients and it was in the order inorganic source > integrated nutrient source > organic source.

4. Among the biochemical properties starch (2008), crude protein and amylopectin were significantly influenced by nutrient sources whereas total free amino acids, phenols and amylose content of grain remained unaffected. Starch and amylopectin content of grain were in the order of organic nutrient source > integrated nutrient source > inorganic nutrient source. Crude protein content of grain was in the order of organic nutrient source > inorganic nutrient source > integrated nutrient source in both the years.

5. Available N status and organic content of soil were in the order organic sources > integrated sources > inorganic sources. Available N status of soil supplied with different nutrient sources differed significantly from one anther. Organic carbon content in soils receiving organic and integrated nutrient sources were on par and significantly higher than that in soil receiving only inorganic source of nutrients.

6. Soil enzyme activity (urease, phosphatase and dehydrogenase) was influenced significantly by nutrient sources and it differed significantly from one another. Effect of nutrient sources on urease activity was in the order of organic source > inorganic source > integrated source and on phosphatase and dehydrogenase activity were in the order organic source > integrated source > inorganic source.

7. Highest total nutrient (P, K, Fe and Zn) uptake by crop (grain + straw) occurred in integrated nutrient source. Crop uptake of K and Zn in integrated source was significantly higher than that in other nutrient sources. The organic and inorganic sources were on par.

C. Interaction effect

1. Effect of interactions did not influence growth characters in Njavara.

2. Yield attributing characters like number of grains panicle^{-1}, number of filled grains panicle^{-1}, crop yield (grain + straw) and harvest index were significantly influenced by interaction effect in both the years.

3. SRI with organic source and Farmers' practice with inorganic source recorded highest and lowest value of number of grains panicle^{-1} and number of filled grains panicle^{-1}.

4. Farmers' practice with integrated nutrient source recorded highest (1198.00/2251.57 kg ha^{-1} grain/straw yield) and ICM with inorganic source recorded lowest grain and straw yields (788.08/1167.52 kg ha^{-1} grain/straw yield).

5. Interaction effect showed significant influence on nutrient uptake by grain (N and Mn), straw (K and Zn) and total uptake by the crop (K and Zn). Nutrient uptake by crop (K and Zn) was highest in Farmers' practice with integrated nutrient source.

Phenological study

The developmental phenology of Njavara rice under different management systems was studied. Height of plant, number of leaves hill^{-1}, leaf area, number of tillers hill^{-1}, root length, root dry matter production hill^{-1} and growth stages of Njavara were monitor under the different management systems. Plant height increased gradually up to panicle initiation and it became very fast up to flowering, after which it slowed down up to 70 DAS/DAT. Number of leaves increased up to 9th week of transplanting /8th week of sowing. Later produced leaves were larger than the earlier produced ones. Tiller production continued up to 7WAT/6WAS. Length of root and root dry matter production increased up to 9 WAS/WAT. Panicle initiation occurred at 32 DAS in Farmers' practice, 40 DAT in PoP, 42 DAT in ICM and 45 DAT in SRI. Maximum tillering stage occurred at 36 DAS in Farmers' practice, 45 DAT in PoP, 46 DAT in ICM and 49 DAT in SRI. Booting stage occurred at 46 DAS in Farmers' practice, 51 DAT in PoP, 53 DAT in ICM and 57 DAT in SRI. Flowering stage occurred at 53 DAS in Farmers' practice, 59 DAT in PoP, 60 DAT in ICM and 64 DAT in SRI. Maturity stage occurred at 86 DAS in Farmers' practice, 88 DAT in PoP, 86 DAT in ICM and 88 DAT in SRI.

Economics of crop production

Cost of cultivation, gross income, net income and BCR among the management systems, nutrient sources and interactions differed significantly. Cost of cultivation was highest in SRI, organic nutrient source and SRI with organic nutrient source. Gross income, net income and BCR were highest in Farmer's practice, integrated nutrient source and Farmer's practice with integrated nutrient source.

Conclusion

- Njavara responded to management systems and nutrient sources. Crop yield was highest in Farmer's practice followed by PoP, SRI and ICM. Among the nutrient sources integrated nutrient source was the best followed by organic and inorganic, with respect to crop yield.

- Farmer's management practices coupled with integrated nutrient source can be considered as the ideal crop production package for Njavara rice in lowlands. This production package realised the highest crop yield (grain and straw), gross income ha^{-1}(Rs 52,423), net income ha^{-1} (Rs 28,027) and BCR (2.15).

- The biochemical constituents of organically and inorganically produced Njavara grains did not vary except in crude protein, starch and amylopectin content. Organically produced Njavara grains were significantly superior to inorganically produced ones with respect to crude protein, starch and amylopectin content.

- Crop raised under different management systems showed variations in the pattern of growth and development. Under Farmer's management practices panicle initiation, maximum tillering stage, booting, flowering and maturity occurred earlier compared to other management systems.

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Appendices

APPENDIX - I

Weather data for the cropping period (summer season 2007)

Month	Standard Week	Temperature (^0C)		RH (%)		Rainfall (mm)	Evaporation (mm day^{-1})
		Max.	Min.	Max.	Min.		
Jan 08	1	31.0	22.9	90.9	80.3	0.0	3.5
	2	31.9	22.9	91.0	78.4	0.0	3.5
	3	31.3	22.5	91.0	78.3	0.2	3.6
	4	31.5	22.8	92.7	79.9	0.0	3.5
Feb 08	5	32.0	22.8	93.1	79.6	0.0	3.9
	6	31.3	23.0	92.6	79.4	0.3	3.4
	7	32.3	23.1	90.4	74.6	2.5	3.9
	8	32.4	22.6	90.3	76.3	0.0	4.0
	10	32.2	22.5	93.3	59.3	0.9	5.5
	11	31.3	24.2	91.6	83.3	9.7	3.5
	12	29.3	23.4	95.7	92.9	1.6	0.9
Apr 08	13	32.0	24.3	88.4	83.7	1.3	4.0
	14	32.1	24.6	89.4	77.7	2.0	4.0
	15	31.3	24.1	92.6	81.9	8.5	3.3
	16	32.7	24.9	89.0	74.4	2.1	4.4
	17	32.7	26.0	91.7	77.4	0.4	4.1

APPENDIX – II

Weather data for the cropping period (summer season 2008)

Month	Standard week	Temperature (^{0}C)		RH (%)		Rainfall (mm)	Evaporation (mm day^{-1})
		Max.	Min.	Max.	Min.		
Jan 09	1	30.3	20.9	88.1	82.4	0.0	3.5
	2	31.4	22.7	91.0	75.7	0.0	3.7
	3	31.1	22.0	91.1	77.1	0.4	3.8
	4	30.9	21.4	91.7	81.4	0.0	3.7
Feb 09	5	30.8	21.6	90.9	81.6	0.0	3.9
	6	31.8	23.5	90.0	78.4	0.0	4.3
	7	32.0	24.6	88.1	75.0	0.0	4.4
	8	33.7	25.7	89.0	67.4	0.0	4.5
	10	32.5	25.7	89.3	69.6	1.4	4.1
	11	33.7	25.9	88.4	63.5	0.4	4.2
	12	33.4	26.1	88.6	63.7	0.0	4.3
	13	33.3	26.6	87.2	63.2	0.0	4.2
Apr 09	14	33.3	25.5	87.3	62.7	0.0	4.2
	15	32.4	24.6	89.1	65.1	7.9	4.0
	16	32.8	24.0	88.7	70.1	7.4	4.2
	17	33.0	24.9	88.1	72.3	0.0	4.2

RESPONSE OF MEDICINAL RICE (*Oryza sativa* L.) cv NJAVARA TO SRI AND OTHER MANAGEMENT SYSTEMS

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ABSTRACT

Field experiments were conducted at Cropping Systems Research Center, Karamana, Thiruvananthapuram, Kerala, during the summer seasons of 2007 and 2008 (January to April) to study the response of medicinal rice (*Oryza sativa* L.) cv Njavara to nutrient sources under different management systems like SRI, ICM, PoP of KAU and Farmers' practice. The experiment was laid out in split plot design with four replications. The treatments consisted of four management systems viz., SRI (M_1), ICM (M_2), PoP (M_3) of KAU and Farmers' practice (M_4) in main plots. Nutrient sources viz., organic sources (S_1), integrated sources (S_2) and inorganic sources (S_3) were the sub plot treatments.

Growth components viz., plant height, number of leaves hill^{-1}, leaf area index (LAI), leaf area duration (LAD), culm strength, number of tillers m^{-2}, root dry matter production hill^{-1} and flag leaf area were recorded. The data on yield attributes like number of productive tillers m^{-2}, panicle length, number of grains panicle^{-1}, number of filled grains panicle^{-1}, 1000 grain weight, harvest index, sterility percentage, dry matter partitioning, paddy grain ratio, grain husk ratio were also worked out. Yield and uptake of nutrients (N, P, K,S Fe, Mn and Zn by grain, straw and crop (grain + straw) were also recorded. Biochemical components such as total free amino acids, phenols, starch, amylose, amylopectin and crude protein content of grain were estimated. Data on weed dry matter production and weed flora and crop duration in the treatments were also recorded. Soil enzymes (urease, phosphatase and dehydrogenase) and soil fertility status were assessed after the harvest of the crop.

D. Effect of management systems

Growth parameters like height of plants, number of leaves hill^{-1}, leaf area index (LAI), culm strength, root biomass and number of tillers m^{-2} were significantly influenced by management systems. Leaf area duration and flag leaf

area showed significant variation only in 2008. Plant height and leaf area index (at physiological maturity) were in the order Farmer's practice > PoP > SRI > ICM and they differed significantly from one another. Number of leaves hill^{-1}, leaf area index at panicle initiation, flag leaf area and number of tillers m^{-2} (from 4 WAS/WAT till physiological maturity) were in the order Farmer's practice > PoP > ICM >SRI . Number of tillers m^{-2} in the four management systems differed significantly from one another. Culm strength (physiological maturity) and root biomass production all the management systems differed significantly from one another. Culm strength and root biomass production (7 WAS/WAT to physiological maturity) were in the order SRI > ICM > PoP > Farmer's practice.

All the yield attributes except 1000 grain weight were significantly influenced by management systems resulting in significant variation in the crop yield (grain and straw). Number of productive tillers m^{-2}, sterility percentage and dry matter accumulation in panicle were in the order Farmer's practice > PoP > ICM > SRI and they all differed significantly from one another. Grain and straw yield in the management systems differed significantly from one another and their order was Farmer's practice > PoP > SRI > ICM. Number of grains panicle^{-1}, number of filled grains panicle^{-1} and dry matter partitioning in root and straw were in the order SRI > ICM > PoP > Farmer's practice. All the characters except dry matter partitioning in straw differed significantly from one another.

Among the biochemical properties of grain total free amino acid content and amylopectin content (2007) were significantly influenced by management systems. Free amino acid content of grain was in the order SRI > ICM > PoP > Farmer's practice. Amylopectin (2007) was in the order ICM > Farmer's practice > PoP > SRI .

Weed biomass at 15 and 35 DAS/DAT in the management systems differed significantly from one another. Weed biomass recorded at 15 DAS/DAT were in the order Farmer's practice > PoP > SRI > ICM and that at 35 DAS/DAT Farmer's practice > ICM > PoP > SRI.

Management systems showed significant influence on nutrient uptake by grain (N, P, K, Fe and Mn), by straw (N, K, Fe, Mn and Zn) and total uptake by the crop (N, P, K, Fe, Mn and Zn). Uptake of all the nutrients in Farmer's practice was significantly higher than that in the other three management systems.

Management systems did not show significant influence on the available nutrient status of soil after the experiments. Among the soil enzymes phosphatase activity was influenced significantly by the management systems and it was in the order SRI > ICM > PoP > Farmer's practice. Crop raised under PoP had the longest duration (108 days) followed by ICM with 98 days, SRI with 94/95 days (2007/2008) and Farmer's practice with 87 days.

Farmer's practice which realized highest crop yield was significantly higher than PoP, SRI and ICM with respect to many growth characters (plant height, number of leaves hill^{-1}, leaf area index, leaf area duration, flag leaf area and tiller production) and yield characters (number of productive tillers, percentage of dry matter accumulation in panicle). Duration of the crop was lowest in Farmer's practice and it was significantly lower than that in all other management systems.

Effect of nutrient sources

Sources of nutrients did not influence growth characters in Njavara. Yield attributing characters like number of grains panicle^{-1}, number of filled grains panicle^{-1} and harvest index as well as crop yield (grain and straw) were significantly influenced by nutrient sources. Highest number of grains panicle^{-1}, filled grains panicle^{-1} and crop yield (grain and straw) were realized in integrated nutrient source and they were significantly higher than organic and inorganic sources. Effect of nutrient sources on yield attributing parameters and crop yield (individual years and pooled analysis) were in the order integrated nutrient source > organic source > inorganic source and the order was just the reverse with respect to harvest index (inorganic source > organic source > integrated nutrient source). Duration of the crop also showed significant variation due to variation in sources of nutrients and it was in the order inorganic source (98 days) > integrated nutrient source (97 days) > organic source (95 days).

Among the biochemical properties starch (2008), crude protein and amylopectin were significantly influenced by nutrient sources whereas total free amino acids, phenols and amylose content of grain remained unaffected. Starch and amylopectin content of grain were in the order organic nutrient source > integrated nutrient source > inorganic nutrient source. Crude protein content of grain was in the order organic nutrient source > inorganic nutrient source > integrated nutrient source.

Available N status and organic content of soil were in the order organic sources > integrated sources > inorganic sources. Available N status of soil supplied with different nutrient sources differed significantly from one another. Organic carbon content in soils receiving organic and integrated nutrient sources were on par and significantly higher than that in soil receiving only inorganic source of nutrients.

Soil enzyme activity (urease, phosphatase and dehydrogenase) was influenced significantly by nutrient sources and it differed significantly from one another. Effect of nutrient sources on urease activity was in the order organic source > inorganic source > integrated source and on phosphatase and dehydrogenase activity were in the order organic source > integrated source > inorganic source.

Highest total nutrient (P, K, Fe and Zn) uptake by crop (grain + straw) occurred in integrated nutrient source. Crop uptake of K and Zn in integrated source was significantly higher than that in other nutrient sources and organic and inorganic sources were on par.

Interaction effect

Effect of interactions did not influence growth characters in Njavara. Yield attributing characters like number of grains panicle^{-1}, number of filled grains panicle^{-1}, crop yield (grain + straw) and harvest index were significantly influenced by interaction effect. SRI with organic source and Farmer's practice with inorganic source recorded highest and lowest value of number of grains panicle^{-1} and number of filled grains panicle^{-1}. Farmer's practice with integrated nutrient source recorded highest (1198.00/2251.57 kg ha^{-1} grain/straw yield) and ICM with inorganic source recorded lowest grain and straw yields (788.08/1167.52 kg ha^{-1} grain/straw yield). Interaction effect showed significant influence on nutrient uptake by grain (N and Mn), straw (K and Zn) and total uptake by the crop (K and Zn). Nutrient uptake by crop (K and Zn) was highest in Farmer's practice with integrated nutrient source.

Phenological study

The developmental phenology of Njavara rice under different management systems was studied. Panicle initiation occurred at 32 DAS in Farmers' practice, 40 DAT in PoP, 42 DAT in ICM and 45 DAT in SRI. Maximum tillering stage occurred at 36 DAS in Farmers' practice, 45 DAT in PoP, 46 DAT in ICM and 49 DAT in SRI. Booting stage occurred at 46 DAS in Farmers' practice, 51 DAT in PoP, 53 DAT in ICM and 57 DAT in SRI. Flowering stage occurred at 53 DAS in Farmers' practice, 59 DAT in PoP, 60 DAT in ICM and 64 DAT in SRI. Maturity stage occurred at 86 DAS in Farmers' practice, 88 DAT in PoP, 86 DAT in ICM and 88 DAT in SRI.

Economics of crop production

Cost of cultivation, gross income, net income and BCR among the management systems, nutrient sources and interactions differed significantly. Cost of cultivation was highest in SRI, organic nutrient source and SRI with organic nutrient source. Gross income, net income and BCR were highest in Farmer's practice, integrated nutrient source and Farmer's practice with integrated nutrient source.

Farmer's management practices coupled with integrated nutrient source can be considered as the ideal crop production package for Njavara rice in lowlands. This production package realised the highest crop yield (grain and straw), gross income ha^{-1}(Rs 52,423), net income ha^{-1} (Rs 28,027) and BCR (2.15).