Management options in modified system of rice intensification (SRI) during summer season

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CERTIFICATE-I

*This is to certify that the thesis entitled "***Management Options in Modified System of Rice Intensification (SRI) During Summer Season",** *submitted in partial fulfilment of the requirements for award of the degree of* **Master of science in agriculture (Agronomy)** *to the Orissa University of Agriculture and Technology, Bhubaneswar is an authentic record of the bonafide research work carried out by* **Lipsa Nayak** *under my direct supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

It is further certified that that help and assistance received as well as sources of information availed during the course of this investigation have been duly acknowledged.

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CERTIFICATE-II

*This is to certify that the theses entitled "***Management Options in Modified System of Rice Intensification (SRI) During Summer Season***", Submitted by* **Lipsa Nayak** *to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for award of the degree of* **MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)** *has been approved by the students Advisory Committee and external examiner.*

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DATE: ***(Lipsa Nayak)***

Place: Bhubaneswar

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ABSTRACT

A field experiment was conducted in the Agronomy research farm of the College of Agriculture, Bhubaneswar in the summer season of 2014-2015 to study the" **Management options in modified system of rice intensification(SRI) during summer season".** The soil was sandy loam in texture and nearly neutral in reaction

The experiment was laid out in Randomised Block Design(RBD) .Four management options; modification of planting technique(age of seedling, number of seedlings,and spacing), water management,weed management and nutrient management were assigned as sixteen treatments in different combinations.The crop was sown on 16th January for conventional system and 29th January for modified system which were transplanted on 11th February 2014. The fertilizer application,weed management and water management were conducted as per the treatment specification.

The investigation revealed that when only one factor was modified T_3 (modified water management) recorded maximum grain yield (4.94 t ha^{-1}) ,when two factors were modified T_6 (modified planting and water management) recorded the maximum grain yield (3.99 t ha^{-1}) ,and when three factors were modified T_{13} (modified planting,water and nutrient management) recorded maximum grain yield (4.85 t ha^{-1}). Among all the treatments T_3 (modified water management) recorded maximum grain yield (4.94 t ha^{-1}) which was 41% higher than T_1 and 2.06% higher than T_{16} ,where as T_{13} (modified planting,water and nutrient management) recorded maximum straw yield (6.06 t ha^{-1}),which was 1% and 4.1% higher than T_1 and T_{16} respectively where as maximum harvest index (0.48) was recorded in T_{11} (modified weed and nutrient management) .

Highest Nitrogen uptake(98.71 kg ha^{-1}) and phosphorous uptake(30.15 kg ha^{-1}) was noticed in T_{13}(modified planting ,water and nutrient management) where as highest potassium uptake (114.72 kg ha^{-1}) was noticed in T_6 (modified planting and water management) and the highest total NPK uptake was recorded in T_{13}(modified planting,water management and nutrient management).

The maximum cost of production (Rs. 36566 ha^{-1}) was recorded with T_5 (modified nutrient management) and T_3 (modified weed and nutrient management) recorded the highest gross return (Rs.62244 ha^{-1}) ,where as highest net return(Rs. 30952 ha^{-1}) and highest B:C (1.98).

INTRODUCTION

Agriculture is the mainstay of state economy and substance of life of the people. The growth of agriculture sector is important for ensuring food security and reduction of poverty in rural areas of the state. Odisha is an agrarian state where nearly 60% people earn their livelihood through agriculture and allied activities.

Rice is a unique creation of crop domestication; it is unique in having cultivars of maturity duration varying from less than 80 days to more than 180 days and showing adaptability to a wide range of land situation and water regimes including conditions of water stagnation where no other crop could possibly be grown. The importance and explicit role of rice to meet current food crisis is yet again challenged, as it accounts for over 20 percent of the global calorie intake providing 66-70 percent of body calorie intake of the consumers.

World rice production nearly doubled from the 1960s to the 1980s mainly due to the technological advancement through the green revolution. The green revolution comprised the replacement of traditional cultivars and the increased use of external inputs that included mineral fertilizer, irrigation water and pesticides. As a result of excessive use of these inputs the cost of cultivation escalated. This is more so in irrigated crops like paddy, the spectacular increase in production of paddy was restricted to irrigated belts of the country. After wide spread green revolution throughout irrigated paddy fields in Asia, the increase rice yield has slackened, reflected by the decline in the normal rate of rice yield increase from 2.7% in the 1980s to 1.1% in the 1990s.

Rice(oryza sativa L.) is a semi-aquatic annual grass and is the most important cereal crop in India. India ranked first in area under paddy(45.2 million hectares)and second next only to china,in terms of production(105.24 million tones); 93.2 million tones in kharif and 12.6 million tones in rabi),with productivity of 2.4t ha^{-1} during 2012-13 . Rice being the staple food for 65 percent of Indian population, it occupies about 24 percent of total food grain production as well as 45 percent of total cereal production. (Indian Grain and Feed Annual,2013).

The targeted demand of rice for Indian population has been set at 115 million tones by the year 2025 (Manzanilla et al.,2011). The major rice growing states West Bengal, Uttar Pradesh,Andharpradesh,Punjab,Tamil nadu,Odisha,Bihar and Chhatishgarh together contribute about 72% of the total area and 76% of the total production in the country that feeds about 680 million people(India Grain and Feed Annual,2013)

In Odisha rice is synonymous with food; agriculture in Odisha to a considerable extent means growing rice. Age old social customs and festivals in Odisha have strong relevance to different phases of rice cultivation: Akhyatrutiya in May-June marks the sowing of rice, Rajasankranti marks the completion of sowing,Garbhanasankranti in October symbolizes reproductive phase of rice while Nua khaee and Laxmipuja coincide with harvesting of upland and lowland rice respectively. Makarsankranti in mid January is celebrated as Chaita Parab by tribal people as by this time rice is threshed and brought to the granary (Das,2012).

In odisha rice crop is grown in about 70% and 50% of the gross cropped area during kharif(rainy) and rabi(winter) seasons respectively. It is grown in about 4.2 m ha with a production about 9.4 million tones and productivity of 2361 kg ha^{-1} it occupies 91% of the area of under cereals contributing about 93% of total cereal production in the state (Odisha Agriculture Statistics,2012-13).In Odisha rice is grown under diverse ecosystem and wide range of climatic conditions. Immense diversity in growth condition makes classification and characterization of the rice environment, challenging task.

A conservative statistics indicates that about 21% extra production is to be ensured to feed the population by the year 2025,(Bhuiyan et.al.2002), as there is no opportunity to increase the rice area ; much have to come from higher average yield on existing land. Experts believe that since rice growing area reached a plateau of 45 million hectares, the only way to expand production to meet the growing demand is to improve productivity.

Clearly, it will require adoption of new technology such as better management package, high yielding cultivar and higher input use efficiency.(Wang et al.,2002).Therefore many coordinated efforts are needed to focus on rationalization and proper utilization of limited resources. To effectively address the trilemma of productivity, environmental and natural resources it is essential to develop and practice improved technologies that enhances crop productivity through efficient resource use in sustainable manner which will be very effective to break the yield plateau.

In order to increase and sustain the production soil is the most important component. Soil considered as the store house of all plant nutrients. A fertile soil encourages good plant growth producing good yield with better quality. Due to immense pressure of increasing population and the stress upon researcher to feed every mouth, the scientists stressed upon to increase the productivity without protecting the health of soil which is degrading at a faster pace. This has broken the balance between the soil-water-plant-atmosphere chain.

Misuse of soil and water,along with imbalance fertilizer use has depleted the native resources. The degradation of soil health has forced the scientists to extract the importance of balanced nutrition and use of organic manures. However ,despite the proven beneficial effect of organic manure,the use of FYM in rice is declining due to obvious reasons. Passing a long path , now the stress is being given to the concept of Integrated Nutrient Management (INM) conjuctively with organic sources, Hedge(1998).

“With less water,less seed,no fertilizer,no pesticide,more soil organic matter and more soil aeration, the productive potential of rice can be unleased”. As a new way of looking at rice cultivation and solely driven by the innovative farmers, System of Rice Intensification(SRI) has emerged as an alternative to conventional water and chemical intensive rice cultivation(Rao,2006).

In general,SRI is understood as a set of agronomic and Natural Resources Management (NRM) principles without prescribing a standardized tool kit (stoop et al.,2002).On one hand,this might seem risky for farmers for whom a fixed technology package may be easier to understand and implement; on the other hand, on-farm participatory experimentation offers opportunities for better adaptation to local conditions ,which may reduce adaptation risk in the long run. Nonetheless, SRI involves a set of core components,which may be flexibly extended by additional practices.

Yield is a function of dry matter and harvest index. Yield can be increased by increasing either biomass or harvest index or both. In other words the physiological efficiency of crop plants broadly includes higher biomass production and efficient translocation of dry matter for realization of higher yield. This could be achieved by high photosynthetic area, slow leaf senescence, high nitrate assimilation and high nitrate reductase activity,low respiration and photo-respiration ,high accumulation of nitrogen and mineral during early phases of growth, large and active sink(high grain number per unit area and stability in grain number, high grain weight and lower spikelet sterility),greater nitrogen use efficiency which results from higher root absorption potential, greater shoot N-use capacity and more efficient N-translocation as well as their positive interactions, thus reflecting high harvest index and increased yield.

Father Heneri de Laulanie,who developed SRI in Madagascar observed that,rice plant has very great tillering potential and the best yield of rice is obtained with soil aeration.Based on these two observations, he formulated the following principles(Uphoff and Randriamiharisoa,2002)

I. Rice seedlings loose much of their growth potential if they are not transplanted before the start of fourth phyllochron of growth , so early transplanting should be practiced.
II. Trauma to seedlings and roots should be minimized during transplanting.
III. Wider spacing of plants lead to grater root growth and tillering.
IV. Soil aeration and organic matter create beneficial condition for plant root growth,plant vigour and health,to resist damage from pest and diseases.
V. Rice is not an aquatic plant; even though rice can survive under flooded conditions, most of the rice plant’s root remain in top 6cm of soil and most of them degenerated by the time rice plants enter into reproductive phase under continuous submeregence.

Based on the above principles, the following practices are developed under SRI.

- Transplanting very young seedlings of 8-12 days old with just 2 small leaves.
- Transplanting seedlings carefully and quickly to give minimum trauma to roots.

- Transplanting, one seedling per hill instead of 3-4 together which causes root competition, that encourages greater root and canopy growth.
- Transplanting in square pattern in wider spacing of 25cm×25cm 30cm×30cm,40cm×40cm or even up to 50cm×50cm with the best quality soil.
- Keeping the soil well drained than continuously flooded up to vegetative growth period.
- Early and frequent weeding with rotary cono weeder.
- Application of organic manures.

Indian researcher have begun to make significant contributions to the international scientific debates on SRI,both by evaluating theoretical and conceptual arguments in favour of SRI.

Satyanarayan(2004) argues that planting young seedlings carefully and at wider spacing gives rice plants more time and space for tillering and rooting growth, careful water management, keeping the field wet and not flooded,gives better yield because it supports healthy root growth.Weeding of rice fields with a rotary weeder helps by churning the soil and incorporating the biomass as it aerates the root zone which encourages microorganisms to proliferate and promotes healthy soil. Supply of major nutrients (NPK) mainly through chemical fertilizers has helped to double the productivity of rice,so integrated use of inorganic and organic nutrient sources may help the SRI method to peak (Raju and Reddy.,2003).

The well accepted and widely granted method of SRI is a profitable,productive and prosperous way of growing rice if all principles of rice followed carefully. However variants of SRI have also been tested in which only some of basic components were practiced.

Age of seedlings at transplanting most often depends on the availability of water, labor and other inputs in farmers' fields. In tropical lowland rice, farmers transplant seedlings at distinct ages, most of the time from 25 to 50 days after germination (De Datta, 1981; Wagh et al., 1988 and Singh and Singh, 1999). Growing of mat nursery and transplanting of younger seedlings carefully in the field is a problematic issue in non irrigated area as land preparation depends on rainfall.

Wider spacing of 25cm X 25cm, 30cm X 30cm or more is another principle of SRI which facilitate cono weeding, better phylochrone development and increase nutrient use efficiency. Undoubtly more spacing gives maximum number of effective tillers per hill but total number of effective tillers is very less than the closer spacings of 15cm X 10cm or 20cm X 15cm if an unit area is considered which is the most important factor for higher grain yield. The opportunity to increase yields with reduced rates of irrigation could be a major bonus for rice farmers and for others laying a claim on this water particularly in a country like India.

In view of the huge diversity in the world's rice production system in terms of their relative access to land, labour and capital, as well as their adaption to very diverse agro-ecological environments, SRI can never be introduced as a standardized technological package. Yet the SRI approach offers principles and components that could – if properly applied and integrated – permit increased yields as well as savings on external inputs for a wide range of production system,(Andrianaivo and Joelibarison, 1999).

Based on the agronomic principles, SRI is apparently a standardized technological package.However, the advocates of SRI rather suggests it a set of general principles that can be fine tuned into locally adapted practices in direct response to farmers need and conditions.Taking all these points into careful consideration, this research was planned to investigate the Management options in modified system of rice intensification(SRI) during summer season under the agro-ecological situation at Bhubaneswar, Odisha, Orissa university of Agriculture and Technology, Bhubaneswar with following objectives:

1. To study the stated principles in system of Rice Intensification to find out the contribution of different component factors to growth and yield.
2. To compare the yield potential under different modifications in conventional system and SRI
3. To study the nutrient uptake pattern and production economics under different management options.

REVIEW OF LITERATURE

Global rice production must reach 800 million ton from the present figure to meet the demand by 2025. In order to meet this global requirement, enhancing the yield potential of rice will be a key priority for rice breeders, agronomist as well as for farmers. Therefore different approaches and technologies are coming up to increase the productivity. SRI (System of Rice Intensification) is one of the sustainable technology to promote higher rice productivity. Considerable work has been done in this region and the pertinent literatures on effect of different management options (planting technique, water management, weed management and nutrient management) in modification of system of rice intensification have been reviewed in this chapter.

System of Rice Intensification (SRI)

As an alternative, SRI has emerged as a new hope. SRI is a set of practices and principles rather than a "technology package" (Uphoff, 2004). It is a system for managing plant, soil, water or nutrient together in a mutually beneficial ways, creating synergies (Laulanie, 1993). SRI management practices control or modify the microenvironment so that existing genetic potentials can be fully expressed and realized.

Major SRI principles include (1) raising seedlings in carefully managed nutrient rich nurseries, (2) careful transplanting of single, young (8–15 days old) seedlings at wider plant spacing (starting at 25 cm X 25 cm, but going up to 50 cm X 50 cm), (3) intermittent irrigation to avoid permanent flooding during the vegetative growth phase, (4) addition of nutrients to the soil, preferably in organic forms such as compost instead of chemical fertilizer, and (5) intensive manual or mechanical weed control without herbicide use. It should be noted, however, that SRI is not a "standard package‘‘of specific practices, but rather represents empirical practices that may vary to reflect local conditions (Uphoff, 2002). Variants of SRI have also been tested in which only some of the basic components were practiced. Conventionally rice is cultivated under submergence where in the poor soil aeration is used to affect the crop growth and yield adversely (Drew, 1983).

Ramakrishnayya et al., (1990) reported that increased duration of submergence resulted in reduction in oxygen supply and led to poor nitrogen uptake and photosynthesis. However irrespective of the influence on agricultural productivity SRI has certainly increased discussion over optimal rice cultivation practices. SRI is not development of a standardized package,but instead of formulation of a set of general principle that are to be fine tuned subsequently with locally adopted practices in direct response to farmer's needs and condition.(Uphoff,2007). MC.Donald et.al.,(2005) reported that yield advantage is more in conventional best management practices than SRI. Sheen et.al. ,(2003) summarized a result that ,SRI has no inherent advantages over the conventional system.

2.1 Effect of age of seedlings

Transplanting of younger seedling produced more tiller per hill and filled grains per panicle. Pasuquin et.al.,(2007) reported that young age seedling(7-15 days old) produced maximum no.of tillers, flowered earlier than 21 days old seedling, subsequently Patel et.al.,(2010) reported that 12 days old seedling resulted in highest tillers per plant,no.of.grain per panicle.

Uphoff (2002) reported that in SRI, young seedlings should be transplanted quickly and carefully so that root tips do not bend upward and resume quick downward growth to have more number of phyllochrons for massive tillering. On the other hand, Kirk & Soilvas (1997) reported that under conventional planting older seedlings are planted keeping root tips upwards. It takes 1-2 week period of plant recovery to resume downward growth, depriving the plant of its most prolific intervals of tiller and growth.

Kumar and Shivay (2004) reported that SRI has its own methodology of planting young and single seedling hill^{-1} at a wider spacing in a square pattern to facilitate mechanical weeding, permitting greater root growth, more LAI, tillering and yield. Mishra (2002) studied the response of hybrid rice Pusa RH-6 and Pusa RH-10 to different age of seedlings on sandy clay loam soil of IARI, New Delhi, during wet season and noticed significant difference in growth parameters like plant height, leaf number, LAI, dry matter production and straw yield. Twenty days old seedling produced significantly the higher straw yield and harvest index over that of 25 or 30 days old seedlings in both the hybrids.

Pillai (1958) summarized the results of several studies and found that short and long duration rice varieties are required to be transplanted at 3-4 and 5-6 weeks age, respectively for their optimum performance. Subsequently Roy and Sattar (1992) noticed negative correlation of tillering with seedling age. Further Nayak and Choudhury (1997) from their study at Bhubaneswar, Odisha reported that the number of productive tillers is inversely related to the age of seedling.

Studies on age of seedlings and spacing schedule adopted under SRI were taken up at Seed Research and Technology Center, Rajendranagar during Kharif, 2008 using popular rice cultivar, Swarna (MTU 7029). The results indicated that yield components, yield and seed quality parameters differed significantly due to age of seedlings and spacing schedule. Twelve days old seedlings planted at 30 X 30 cm spacing recorded significantly higher number of productive tillers per plant (26.7). Seed yield ha^{-1} was significantly higher with 14 days aged seedlings (6100 kg ha^{-1}). The seed yield increased by 52.43% over 12 days aged seedlings followed by 16 days (25.11%) and 27 days (21.44%) old seedlings. Treatment combination of 14 days aged seedlings planted at 20cm X 20cm spacing recorded maximum yield of 6470 kg ha^{-1} followed by the same aged seedlings at 30cm X 30cm recorded high establishment of 100%, more vigorous with respect to seedling length (26.12 cm) (Durga, 2012).

Nayak and Choudhury (1997) from their study at Bhubaneswar, reported that number of productive tillers is inversely related with the age of seedling. It was in conformity to the reports of Japanese worker Takano et al. (1990) who observed equal or higher grain yield than those produced by older seedlings. However, Biswas et al., (2001) studied the effect of 30, 45, 60 and 75 day old seedlings on BRRI dhan 32 in Rangpur district of Bangladesh and found significant difference in yield due to various seedlings age with 30 days old producing the highest grain yield. Similarly Kumar et al., (2002) found at transplanting of 20 days old seedling in scented

(Pusa RH-10) and non-scented (Pusa RH-6) rice hybrids during kharif in New Delhi, India. While rice variety Ranbir Basmati and Basmati 370 produced highest grain yield with 30 days old seedlings (Bhagat et al., 1991) and long duration rice varieties Savitri and Gayatri performed well with 80 days old seedlings (Mohapatra et al. 1990).

Satyanarayana and Babu (2004) observed that higher plant population in conventional planting produced interplant competition and higher age of seedlings reduced tiller production which contributed to lower grain yield. Similar findings were also supported by Thavaprakash et al., (2008). Stoop et al., (2002) reported that increased grain yield in SRI was mainly due to synergistic effects of applying various cultivation practices simultaneously i.e. use of young and single seedling hill^{-1}, wider spacing, limited irrigation and frequent loosening of top soil to stimulate aerobic soil conditions. Rajesh and Thanunathan (2003) reported that young single seedling hill^{-1} in square planting could be one reason to have more number of grains panicle^{-1} and productive tillers hill^{-1}. Similar findings were also reported by Premsekhar (2008).

Vijay Kumar et al., (2004) revealed that the yield attributes (panicle length, number of panicles hill^{-1}, total number of grains panicle^{-1}) as well as grain yield were significantly higher in the treatment involving 14 days old seedlings than 21 days old seedlings. Though not significant, this has reflected nearly 4% increase in the yield hill $^{-1}$ over older seedlings. Maximum photosynthesis rate and leaf area were recorded during reproductive phase with wider spacing in SRI. SRI method recorded maximum grain yield per hill. This was further confirmed by Natesan et. al. (2008) contributed that planting of 15 days old seedling at 25 x 25 spacing exhibited its supremacy in recording highest plant height, total and productive tillers per unit area, yield attributing characters and seed yield over that of normal transplanting. Dalai (2012) also recorded higher no.of. grains per panicle in 14 days old seedlings.

Behera (2014) reported that maximum plant height was observrd in conventional system modified with 12 days old seedlings,saturation, and cono weeding.

2.2 Effect of number of seedlings hill^{-1}

In case of SRI, Makarim et al., (2002) observed that planting of single seedling at wider spacing was found to be superior to produce more tillers than two or more seedlings hill^{-1} recorded higher grain yield than 3 seedlings hill^{-1} but was at par with 2 seedlings hill^{-1}. Sridevi and Chellamuthu (2008) too noted that among different treatment combinations, the combination of younger seedling, single seedling hill^{-1} and square planting at 25 x 25cm spacing produced taller plants, more tillers m^{-2}, more DMP, less number of days to 50% flowering, more root length, root dry weight root volume, grain and straw yield with more harvest index in rice crop grown under SRI.

Mishra and Shaloke(2010) recorded 23% higher yield in 20X20 cm with spacing with single seedling per hill than 2 seedlings transplanted per hill with (25X25) cm spacing. Deb dalai (2012) conducted an experiment by taking(6,10,14,18, and 28) days old seedling with spacing of (25X25)cm resulted that production tillers are less in single seedling transplanting than more seedling transplanting of 28 days old seedling. Total no.of grains highest in 14 days old seedlings.

Ramaswamy et al., (1987) reported that one seedling hill^{-1} recorded highest values of growth attributes. Saha et. al., (1991) have also reported that height of rice plant was inversely related to the number of seedlings hill^{-1} in northern India. Obulamma et. al., (2002) reported that the CGR and NAR were mere significantly higher with one seedlings hill^{-1} but LAI,LAD, and dry matter production were higher with 3 seedlings hill^{-1}. Swain et. al., (2006) from their study at CRRI, Cuttack observed that one seedling hill^{-1} was optimum for growth expression in hybrid rice; It produced taller plants, higher LAI, specific leaf weight and total dry matter production.

2.3 Effect of spacing

Instead of planting seedlings densely, as in common, because having more plants seem likely to produce more rice, with SRI seedlings are planted widely spaced, in a square pattern (to facilitate weeding as well as to give more space between plants), 25 by 25 cm or more widely, up to 50 by 50 cm. Siddique et al., (1999) at Raipur found taller plants (100cm) but less number of ear bearing tillers per m^2 (229) under a plant spacing of 20cm x 10cm. Under close spacing of 10cm x 10cm, however the trend was reversed and the plants were shorter (97cm) but the EBT were more (281/m^2). Haque (2002) found the highest plant height from wider spacing.

Shrirame et al., (2000) reported that the square planting with wider spacing have more soil area for improved root characters to have taller plants with more photosynthetic activity. Similarly, Jiaguo Zeng et al., (2002) reported that wider spacing and less plant population per unit area, resulted in increased root volume, root length, and root dry weight due to abundant availability of nutrients, light intensity and water. Krishna et. al., (2008) found that wider spacing of 40cm X 40cm had significant influence on growth parameters.

SRI requires a wider spacing of at least 25 cm X 25 cm than conventional spacing. This is to allow room for optimum root and tiller development, which suggestively will support more profuse flowering, greater grain filling and ultimately higher yield (Uphoff, 1999). Although it was difficult to accurately estimate the plant spacing used in the study areas, farmers generally agreed that they used a slightly narrower spacing than 25 x 25 cm; this was preferred as a higher density gives them more straw, which is an important source of fodder for their cattle. similarly Shrirame et al., (2000) reported that the number of functional leaves, leaf area and total number of tillers hill^{-1} were higher at wider spacing which increased the photosynthetic rate leading top taller plants. Devi and Singh (2000) reported from their experiment conducted at Imphal during wet seasons, that the highest number of tillers hill^{-1} were (15.0 and 11.5) with the widest spacing 20cm x 20cm, which were significantly higher than the closer spacing of 20 x 15 cm and 20 x 10cm. Similar findings were also reported earlier by Verma et al., (1991).

Moreover, transplanting at wider spacing does not guarantee higher yield per unit area due to compensatory relationships, and because the optimum plant density may vary among plots with different bio-physical conditions. Thakur et al., (2010) investigated the effects of different plant spacing in SRI systems and found that optimum yield is obtained at 20 x 20 cm, with 32% lower yields at 25 x 25 cm and 53% less at 30 x 30 cm. Likewise, Latif et. al., (2009) found that a spacing of 25 x 15 cm produced the highest rice yields, and decreasing the plant density to 25 x 25 cm and 30 x 30 cm reduced yields by 8% and 19%, respectively.

Singh et.al., (2014) reported that spacing of (25X25) cm reported a 17.8 % higher yield than (20X20)cm spacing, similarly Dass and Chandra,(2013) reported that a 17% higher grain yield was obtained with (25X25) cm spacing. Than (20X20) cm spacing.

Nayak et al,. (2002) reported after conducting an experiment at Bhubaneswar during wet seasons of 1999 and 2000 that all the growth and yield attributing characters were maximum with wider spacing of 20cm x 15cm and minimum with closer spacing of 20cm x 10cm. Whereas the LAI, LAD sterile spikelet ear^{-1} and sterility percentage, were higher with closer spacing. Similar findings were also reported by Padmaja and Reddy (1998).

Wider spacing improves the canopy's photosynthesis which leads to greater root growth and accompanying productive tillering percentage and the spikelet number per panicle, provided that other favourable conditions for growth such as soil aeration are provided (Yuan, 2002).

However while evaluating the purpose to evaluate the effect of different planting densities on the yield of rice (Oryza sativa) a trial was carried out during the dry season from January to May 2007 at the farm Santa Barbara, located at the Santa Rosalia Municipality, Portuguesa State. The treatments were different planting densities (80, 110, 140 and 170 kg seed ha^{-1}). The variables evaluated were: number of plants m^{-2}, plant height, number of tillers per plant, number of panicles m^{-2}, number of grains per panicle, 1000-grain weight, grain sterility percentage and yield of rice paddy (kg ha^{-1}) with a humidity of 12%. The statistical analysis showed that planting density caused no significant effect on the evaluated variables, except for number of plants m^{-2} (Jimenez et al.,2009).

Singh et al., (2006) compared the performance of SRI under different planting geometry and observed highest grain and straw yield with 25cm X 25cm spacing. Mishra et.al., (2008) found that maximum number of tillers hill^{-1} was obtained at 60 DAP in SRI practices with 25 X25 spacing and one seedling of 12 days old hill^{-1}. The yield attributing characters like number of panicles m^{-2} and test weight were significantly influenced by higher spacing and 12 days old seedlings.

Shukla et. al. (1999) found square planting with 15cm x 15cm spacing as more effective in dry matter production (1235 g/m^2) at harvest of crop along with high values of NAR (0.40 mg/m^2/day), CGR (1771 g/d/m^2) and RGR (0.0466 g/g/d) at 60 days after transplanting than the rectangular planting (22.5cm to 10 cm) in C.v. Kranti. Whereas, Srivastava et. al. (1999) found 15cm x 10cm spacing equally good for high yielding and hybrids of rice, while Chopra (2000) found a spacing of 30cm x 15cm to be the optimum with regards to yield of rice.

2.4 Effect of water management

Intermittent irrigation is suitable for exploring the yield potential of rice by increasing the no.of effective tillers. Ali et.al.,(2013) conducted a research to find out the effect of seedlings age and water management on tillering behavior, growth dynamics, yield and yield contributing characters ; Fifteen-days old seedlings provided greater ability of tiller production, dry matter accumulation and more leaf area than those of 30 days old seedlings but the ability was influenced more with intermittent irrigation than continuous flooding. Transplanting of younger seedlings provided more effective tillers hill^{-1}, filled grains panicle^{-1}, thousand grain weight and finally grain yield than those of the older one but the younger seedlings interacted with intermittent irrigation significantly to explore all of these parameters. Fifteen days old seedlings took shorter time to mature than 30 days old seedlings in both continuous flooded and intermittent irrigated condition. Again the crop matured 2 days earlier in intermittent irrigated plots than continuous flooded plots for both 15 and 30 days old seedlings.

Tabbal et al., (2002) stated that there were alternatives for saving water that may be more promising for Asian rice systems. In their study, with continuous flooding, wet-seeded rice yielded higher than transplanted rice (3–17%), but required 19% less water, increasing water productivity by 25–48%. Keeping the soil at saturation saved 35% water, but at the cost of small (5%) yield loss. Intermittent irrigation further saved water, but at the expense of relatively large yield losses.

Most publications on SRI indicated the large yield increases compared to “conventional‘‘ or “traditional‘‘ management of irrigated rice (Stoop et al., 2002). Fernandes and Uphoff (2002) recently summarized SRI reports from 17 countries. Unweighted average grain yields in all these studies were 6.8 Mg ha^{-1} for SRI as compared to just 3.9 Mg ha^{-1} for control treatments that represented the recommended conventional irrigated rice management at these sites. The extraordinary yields reported from Madagascar have, however, not been achieved elsewhere. Although yield advantages were claimed for the majority of reports, there were also examples for no yield increases over the control in Bangladesh, China, India, Myanmar, Nepal, and Thailand.

Saving water has become one of the priorities of rice research (Barker et al., 2000) and many water-saving irrigation techniques are being studied. Instead of keeping fields flooded, the soil can be kept near saturation, or alternate wetting and drying regimes are imposed through intermittent irrigation (Bouman and Tuong, 2001; Tabbal et al., 2002). However, it is necessary to differentiate between environments in which growing rice under flooded conditions is most sustainable and those where periodical aeration or oxygenation can be the single-most important management factor for increasing yields. The former appears to apply to more fertile lowland rice environments, whereas the latter is mainly the case on marginal soils with need for aeration to improve oxygen supply to roots, and to avoid accumulation of toxic concentrations of reduced substances such as ferrous iron (Fe_2^+) or hydrogen sulfide (H_2S).

The key physiological principle behind the principal SRI measures is to provide optimal growing conditions to individual rice plants so that tillering is maximized and phyllochrons are shortened, which is believed to accelerate growth rates (Nemoto et al.,1995). It was also observed that tiller mortality is reduced. Furthermore, intermittent irrigation is believed to improve oxygen supply to rice roots, thereby decreasing aerenchyma formation and causing a stronger, healthier root system with potential advantages for nutrient uptake (Stoop . 2002). Kar et al., (1974), Stoop et al., (2002) and in other SRI papers as indicated a serious (78%) root deterioration at flowering under flooded conditions, which is likely to negatively affect the efficiency of nutrient uptake and consequently yield .

However, Kar et al., (1974) revealed that total root number, root dry weight, and shoot dry weight of rice grown under flooded condition were much larger than under unsaturated condition. Iida et al (1990) also found a decreased percentage of decayed roots with reduced flooding. Kirk and Solivas (1997) also reported that when rice plants were grown in continuously saturated paddy soils, their growth was diminished and their function compromised by premature decay of the root system. They also observed that about 75% of rice roots remained in the top 6 cm of soil where oxygen was more available.

Reddy and Kuladaivelu (1992) observed that root volume and root-dry weight were higher under continuous submergence or at irrigation to submergence after reaching the soil-saturation point than under drier upland moisture regimes.

The effectiveness of organic manure to improve root growth and nutrient uptake by rice plants was significantly different between the continuously and alternately flooded conditions. Continuous water logging significantly decreased the improvement of root morphology and root activity due to the integrated use of inorganic and organic fertilizers. This demonstrates that adoption of appropriate water management is as important to improve rice root growth as organic amendments. Continuous flooding has been proved to be detrimental to rice root growth (Sahrawat, 2000). Under continuously flooded condition, rice yields tend to be very low on soils with this unfavourable physico-chemical environment, particularly due to limited rice growth during the vegetative phase of rice (Vizier, 1990).

A key justification for promoting intermittent irrigation as part of SRI is the stated assumption that rice is not an aquatic plant, and that under continuous submergence most of the rice plant‘s roots remain in the top few cm of soil and degenerate by the reproductive phase (Stoop et al., 2002).

Flooded conditions increase nutrient availability and decrease competition from other species (De Datta, 1987; Dobermann, 2004), however SRI results suggest that moist soil provides the best conditions for rice during the vegetative stage, particularly root development (Uphoff, 1999). Alternating flooding and drainage is thus recommended in SRI (Stoop et al., 2002; Uphoff, 1999). The ability of farmers to apply such water control measures was constrained by several factors such as the topographical conditions of paddy fields, infrastructure and rainfall patterns. Farmers area rely often prefer not to take the risk of draining water from the fields given that the next rainfall may be delayed which is possible at any time during the growing season. These constraints are common in rain-fed lowland rice ecosystems (Balasubramanian, 1998). Even in Santuk where there is a large irrigation system (Stung Chinit Irrigation System), farmers still do not have full control of water due to the prevailing flat topography, variable micro-elevation within the plots, and poorly established quaternary canals which connect individual rice plots to the tertiary canals.

2.5 Effect of weed management

The adverse effects of weeds on rice yield and the subsequent economic losses are well-documented (Ampong-Nyarko and De Datta, 1991; Dobermann, 1994; Smith, 1983, 1988). In rain-fed lowlands, yield losses due to uncontrolled weed growth were reported to be between 60% and 75% in direct seeding and about 50% in transplantation (Ampong-Nyarko and De Datta, 1991). Transplanting seedlings into muddy soils in SRI creates favourable conditions for weeds to grow; hence well-prepared land and intensive weed control are thus often applied in SRI. In the current study, disadoption of SRI was partly attributed to yield losses at the first year trial due to weed infestation.

Weeds cause relative yield losses between 28 and 84% in transplanted lowland rice in sub-Saharan Africa (Rodenburg and Johnson, 2009), and are a primary constraint (Demont et al., 2009; Diallo and Johnson, 1997). Traditionally, rice farmers practiced flooding to suppress weeds, as many species do not germinate under anaerobic conditions. Reductions in flood water depth and duration could therefore result in profound changes in weed flora and competition (Rodenburg et al.,2011), with poorly understood implications for agricultural productivity. SRI can also be described as "risk-prone" because aspects of the system render it weakly weed competitive (Haden et al., 2007). Transplanting single seedlings at reduced densities, for instance, could delay early season canopy closure, a characteristic essential for weed competitiveness (Zhao et al., 2006a). Alternate wetting drying as practiced in SRI entails periods of no standing water, which could also increase weed germination (Rodenburg and Johnson, 2009). SRI could therefore stimulate weed growth and increase weeding labor demand (Krupnik et al., 2012a; Latif et al., 2009), potentially offsetting the economic advantages gained from reduced water and thus energy consumption. Haden et al., (2007) therefore suggested that SRI should be combined with weed competitive genotypes. Weed competitiveness is composed of weed suppressive ability, the capability to reduce weed growth, and weed tolerance, the ability to maintain high yields under weed competition (Zhao et al., 2006b).

In order to ensure a consistent plant density, it is recommended to use a square grid pattern for transplanting in SRI. One of the advantages of this practice is to facilitate the mechanical weeding (Uphoff, 1999). This component of the system has not been adopted by the farmers in the study areas; not only would it require additional labour input during the labour peak in the transplanting time, but since nearly all farmers weed by hand, exact plant spacing is not so consequential.

Ramesh et.al.,(2007) conducted an experiment on different weeding method and weeding efficiency. Cono weeding having a weeding efficiency 64 % better than manual weeding. Under present day constraint and scarcity of labours Mohanty et.al.,(2010) reported a highest yield of 5.6 t ha -1 and 5.0 t ha-1 weeded with cono weeder at 10,20,35 days after trasnsplanting.

Behera(2014)reported thant minimum weed dry weight(g) was observed with 12 days seedling and cono weeding.

2.6 Effect of nutrient management

Several workers have found beneficial effect of FYM application in rice (Rajput and Warsi, 1991; Sharma and Mitra, 1991). Mondal et al., (1994) found the influence of FYM on crop yield to be more pronounced under low land condition.

Mineral fertilizers were used in early SRI experimentation in Madagascar, but the addition of nutrients is not considered a requirement with SRI because it is assumed that higher yields can be achieved by using SRI practices without amendments, at least for several years (Uphoff, 2002). It is also assumed that chemical fertilizers do not contribute much over time to soil quality, so that the use of organic amendments, primarily as large amounts of compost, is encouraged. This is also the common practice at sites for which the largest SRI yields have been reported (Uphoff, 2002).

Very often it is recommended that rice under SRI should be cultivated only with organics. But Uday kumar (2005) reported that application of FYM and recommended fertilizer dose significantly increased the number of tillers in SRI.

Myths and science often tend to get mixed up when benefits of organic amendments are discussed in comparison with a recommended (mineral) fertilizer treatment. Effects of organic amendments and recommended use of mineral fertilizer on absolute yield levels and long-term yield trends over time were recently reviewed for 25 long term experiments in Asia (Dawe et al., 2003).

Rathore (1996) found application of FYM alone could register an extra net income by Rs. 876 ha^{-1} over that of control (Rs. 3081 ha^{-1}) in farmer‘s field in Bilaspur,. The physiochemical properties of soil deteriorate on exclusive application of inorganic fertilizers. Hansen (1996) indicated the importance of organic manure application to reduce soil compaction which influences the plant yield strongly. High levels of organic soil amendment in the form of compost improve soil structure by increasing porosity and reducing the bulk density of an amended soil.

A study conducted to determine the influence of combined application of farmyard manure and different levels of inorganic fertilizer on growth, yield and yield components in the System of Rice Intensification in Mali indicated significant yield benefit of the SRI .Significant interaction between row spacing and soil fertility level occurred showing that row spacing as wide as 30cm X 30cm could be used in SRI system when soil fertility was high. However, when soil fertility level is low, it is reasonable to use row spacing of 25cm X 25cm or narrower. (Bagayoko, 2012).

Application of FYM benefits the soil chemical characteristics. The increase in total carbon in the form of organic matter leads to an increase in CEC thereby increasing the number of exchange sites for mineral nutrients available for plant uptake. Carbon from an initial application may be cycled too quickly to be observed in the first year. In a study, soil total C in the first year was not affected by a single application of 22 tonnes FYM ha^{-1}, but in the second year was 28% greater than the no composted control (Grandy et al., 2002).

During its whole life period through various growth stages rice absorbs different nutrients from the soil. Thus, depending upon the magnitude of removal, rapid and gradual depletion of various nutrients takes place from the soil. So for sustainable production it is necessary to return the plant nutrients removed from the soil. As early as in late sixties, (Patnaik ,2010)reported that the high yielding rice varieties removed 2 to 2.5 times the amount of nitrogen and phosphorus and 4 to 4.5 times the amount of potassium than conventional rice and suggested to apply a balance dose of N, P, K especially under continual intensive cropping.

Productivity of Organic agriculture‘s productivity and potential contribution to feeding 9 billion people is not only a crucial question, but also one of its most contentious issues (Padel and Lampkin, 1994). Statements on the feasibility of feeding the world with organic agriculture are often directly or indirectly based on comparisons of organic and conventional yields.

The nutrients uptake was significantly higher in integrated application than single inoculation of bio-inoculants. Meena et.al.,(2013) studied the effects of plant growth promoting rhizobacteria (PGPR) inoculation in different combinations with N-levels through urea and compost on yield and nutrient uptake by rice and toria. Results showed that highest grain (5.02 t/ha) and straw (8.87 t/ha) yield was obtained with the application of 2/3N (80 kg N/ha) + bacterial inoculant (BI) + cyanobacteria inoculant (CI) + compost (5.0 t/ha). The uptake of N in grain (69.1 kg/ha) and straw (60.5 kg/ha) were the highest along with highest uptake of P, K, Fe, Zn and Cu in rice grain and straw.

Similarly Behera(2014) studied thant maximum LAI was obtained with modification of conventional system with respect to planting(12 days old seedlings) and organic nutrient management.

2.6 Nutrient uptake

Rao and Raju (1987) reported that young seedling were found to contain more nitrogen which helped in producing new roots, better root growth and more tillers that resulted in higher drymatter production than older seedlings. So also, Sonj et. al. (1990) reported that the wider spacing with continuous availability of nutrients and better source sink relationships, might have helped with higher carbohydrate synthesis and translocation to the yield synthesis and translocation to the yield attributing points. In a similar line, Wang Shao-Hua et. al. (2002) reported that higher translocation and conversion rates of stored matter from vegetative organs was of significant importance for enhanced grain filling and spike weight in SRI rice.

Zhang et al., (1990) studied nutrient uptake in lowland and upland rice cultivars and found that the cortex was more developed in the lowland cultivar,which was related to adaptation to water logging. Hypoxia decreased root growth, Ca and P uptake but had no effect on N uptake in either NO_3^- or NH_4^+ form. The decreases in root growth and P and Ca uptake were greater in the upland cultivars,which was related to their different capacities for oxygen transport to the roots.

In contrast, high-yielding irrigated rice systems on favourable land in subtropical and tropical Asia are geared for maximum performance over a short time (100–110 days). This includes maximum capacity for uptake of surface-applied nutrients because there is less opportunity to incorporate large amounts of organic materials into the soil and limited growth time. Soils are often heavy in texture and of predominantly 2:1 layer clays. Only relatively shallow tillage can be performed and soil physical properties often limit rooting depth. Root systems are very fibrous and about 80 to 90% of the root biomass is typically found in the top 20 cm of soil (Cassman et al., 1998), but there is little evidence for poorly functioning roots, except on marginal soils that are prone to toxicities under anoxic conditions.

On fertile rice soils, the formation of superficial roots is a key performance factor. Some of the highest short-term nitrogen uptake rates were those for rice during the period from panicle initiation to flowering , after about 6 to 9 weeks of continuous flooding (Peng and Cassman, 1998).

Recent work also suggests that rice is efficient in absorbing and utilizing both nitrate- and ammonium-N and that a mixed nutrition may have synergistic effects on growth (Kirk, 2001;Kirk and Kronzucker, 2000; Kronzucker et al., 1998; Kronzucker et al., 2000 and Yang et al., 1999). Significant amounts of nitrate may be formed by nitrification of ammonium in the rhizosphere (Briones et al., 2003), even under submerged conditions. Superficial roots, not deep roots, appear to play a key role in this under warmer conditions, but genotypic variation must also be considered. Hybrid rice, for example, has an increased capacity to form a superficial root mat, which in turn appears to be efficient in absorbing N, much of it perhaps as nitrate-N (Yang et al., 1999;Yang and Sun, 1991).

Datta.et.al.,(2014) studied the effect of inorganic fertilizer, vermicompost, phosphate solubilizing bacteria and Azotobacter on the yield of boro rice and its impact upon soil nutrient status and uptake. The higher yield was recorded with full recommended dose of fertilizer along with vermicompost at 2.5 t ha-1, PSB and Azotobacter,which was at par with 75% inorganic fertilizer along with vermicompost at 2.5 t ha^{-1} aong with PSB and Azotobacter.

2.7 Economics

Even though SRI has been widely promoted, partial adoption and discontinuance are common (Moser and Barrett, 2006; Senthilkumar et al., 2008). This may be related to the mixed yield experience. Furthermore, Moser and Barrett (2003) showed that the additional labour requirement associated with SRI may represent a constraint for smallholders facing seasonal labour shortages.

SRI practices of planting younger seedlings, with wider spacing and intermittent irrigation, lead to increased yields with concomitant rise in the income . Possibly further increases in net benefit could come with enhanced availability of mechanical weeders and using organic material for fertilization. Matti et.al.,(2013) reported SRI giving a higher benefit–cost ratio of 1.76 and 1.88 in the first and second seasons, respectively, compared to 1.3 and 1.35 for conventional practices.

Contrary to most lowland rice-growing practices in Madagascar and throughout the world, the SRI field is not continuously flooded and is instead treated with intermittent irrigation. It has been speculated that drying the fields allows for good aeration of the soil and better root growth. In order to achieve the necessary level of water control, a level field and a functioning irrigation system offering the ability to let water in and out of the field as needed is essential. The combination of wide spacing and less water, however, provides ideal conditions for weed growth, which needs frequent weeding. The few studies of its labor requirements show that the method requires an estimated 38–54% more labor than traditional methods (ATS, 1995; Rakotomalala, 1997). According to Rakotomalala (1997), 62% of the extra labor needed for SRI for weeding and 17% for transplanting.

The socioeconomic and agronomic issues involved in water-saving irrigation are complex. Such techniques are relatively difficult to implement, because they require excellent land preparation, timely availability of irrigation water during critical periods of growth, good irrigation infrastructure, and efficient methods of weed control, particularly in areas with larger field sizes. Although the quality of land leveling at this site was considered to be good, numerous small areas with higher micro-elevation occurred within this field, at which soil aeration or even drought stress occurred occasionally during the growing season. As a result, nutrient availability decreased and weed populations increased at these locations as compared to continuously flooded areas within the same field, resulting in significantly smaller panicles and grain yield (Dobermann, 1994). This significantly increases the labour or herbicide demand for

weed control and is likely to be even larger so in systems such as SRI because of the wide plant spacing and prolonged period until canopy closure. Other potential uncertainties include increases in greenhouse gas emissions (N_2O) in systems with alternate wet-dry conditions (Bronson et al., 1997b).

Rathore (1996) found application of FYM alone could register an extra net income by Rs. 876 ha^{-1} over that of control (Rs. 3081 ha^{-1}) in farmer‘s field in Bilaspur,. The physiochemical properties of soil deteriorate on exclusive application of inorganic fertilizers. Hansen (1996) indicated the importance of organic manure application to reduce soil compaction which influences the plant yield strongly. High levels of organic soil amendment in the form of compost improve soil structure by increasing porosity and reducing the bulk density of an amended soil.

. Meena et.al.,(2013) studied the effects of plant growth promoting rhizobacteria (PGPR) inoculation in different combinations with N-levels through urea and compost on yield and nutrient uptake by rice and toria. Results showed that highest grain (5.02 t/ha) and straw (8.87 t/ha) yield was obtained with the application of 2/3N (80 kg N/ha) + bacterial inoculant (BI) + cyanobacteria inoculant (CI) + compost (5.0 t/ha). The uptake of N in grain (69.1 kg/ha) and straw (60.5 kg/ha) were the highest along with highest uptake of P, K, Fe, Zn and Cu in rice grain and straw . Even with the additional costs, the returns to labor still seem to far outweigh those of traditional methods (Uphoff, 2000) .

MATERIALS AND METHOD

A filed experiment was conducted to study the “Management options in modified system of rice intensification (SRI) during summer season". The details of experimental materials used, methods and procedures including techniques followed during the course of investigation are briefly described in this chapter.

3.1 Experimental site

The field experiment was conducted in the Agronomy Research Farm, of the Central Research Station of the College of Agriculture, Bhubaneswar, Orissa University of Agriculture and Technology. The site is located at 20^{0}15’55.86”N latitude, 85^{0}48’22.65”E longitude and 25.9 meter above the mean sea level. It is situated at about 64 km away from the Bay of Bengal within the East and South Eastern Costal plain agro-climatic zone of Odisha and falls under the East Coastal Plains and Hills zone of the humid tropics of India.

3.2 Soil characteristics

During the field layout, soil samples were collected at random from 0-15 cm depth and mixed thoroughly, out of which composite samples were drawn for mechanical and chemical analysis. After careful mixing, the samples were air dried at room temperature and sieved through 2 mm sieve and analysed for different properties.

The particulars of physicochemical properties and the methods employed for analysis are present in Table 3.2a and 3.2b. The results reveal that the soil is sandy loam in texture, near neutral in reaction, low in organic carbon, medium in nitrogen, high in available phosphorus and medium in available potassium.

Table 3.2a Mechanical composition of the soil of the Experimental site

Mechanical Constituent	% composition on air dry basis	Method adopted
Sand	69.1	Bouyoucos hydrometer method (Piper, 1950)
Silt	14.1	
Clay	16.8	
Textural class	Sandy Loam	

Table 3.2b Chemical composition of the soil of the Experimental site

Particular soil characteristics	% composition on air dry basis	Method adopted
pH	6.2	Digital pH meter with 1:25, soil: water (Jackson, 1973)
EC (dSm^{-1})	0.65	Conductivity meter (Jackson, 1973)
Organic carbon (g kg^{-1})	4.2	Walkely& Black's rapid titration method (Jackson, 1973)
Available nitrogen (kg ha^{-1})	365.2	Micro kjeldhal method (Jakson, 1973)
Available phosphorus (kg ha^{-1})	46.2	Olsen‘s method (Jackson, 1973)
Available potassium (kg ha^{-1})	253.3	Flame photometer method (Jackson, 1973)

3.3 Cropping history of the experimental site

The cropping history of the experimental plot during the preceding years is Presented in table 3.3.

Table 3.3 Cropping history

Year	Wet Season (Kharif)	Dry Season (Rabi)
2005-2006	RICE	RICE
2006-2007	RICE	RICE
2007-2008	RICE	RICE
2008-2009	RICE	RICE
2009-2010	RICE	RICE
2010-2011	RICE	RICE
2011-2012	RICE	RICE
2012-2013	RICE	RICE
2013-14	RICE	RICE
2014-2015	EXPERIMENT(SUMMER)	

3.4 Climate and weather condition

The climate of the area is warm and moist with hot humid summer and mild winter. Broadly the climate falls in the group of moist hot type (Lenka, 1976). Meteorological data (mean of 10 years) from the period 2005-2014 presented in Table 3.4a. The mean annual precipitation is 1532.4 mm of which 89.1% (1438.2 mm) is received between June and November and rest 10.9% (176.1 mm) between December and May. The southwest monsoon in Odisha usually sets in around mid June and recedes by end of October. August is the rainiest month with 337.2 mm rainfall while March is the driest month with mean rainfall of 9.4 mm. The rainfall code of Bhubaneswar has been coded as D_1E_3 $(B_1A_2B_1)$C1D1E2 (Lenka, 1976). The monthly maximum temperature remains over 30^0C in all the months except January and December, when it comes down to 27.7^0C. April is the hottest month with mean maximum temperature of 39.8^0C, while December and January are the coldest months with mean minimum temperature of 27.7^0C, that rises gradually to39.2^0C in May.

The Relative Humidity (RH) in fore noon hours varies in between 87% and 95% in different months but in the afternoon hours it shows wide variations ranging from 40% in December to 82% in July.

The sky remains mostly clear during the day hours with bright sunshine hour ranging from 2.6 hours day^{-1} in July to 8.3 hours day^{-1} in April .

The mean monthly evaporation from the USDA pan evaporimeter varies from 2.5 mm day^{-1} in December to 8 mm day^{-1} in May. The mean monthly wind velocity varies from 3 km hr^{-1} in November to 8 km hr^{-1} in May. The mean annual wind velocity was 4.0 km hr^{-1}.

Table3.4a. Mean monthly meterological data during preceding ten years,(January 2005 to December 2014)

Month	Total Rainfall (mm)	No. of Rainy days	Evaporation (mm d$^{\bar{1}}$)	Atmospheric mean temperature		Relative Humidity		BSH (d^{-1})	Wind Velocity (km hr^{-1})
				Max. (^{0}C)	Min. (^{0}C)	M (%)	AN (%)		
January	9.9	-	2.6	28.8	17.5	92	45	4.5	2.6
February	13.4	1	3.4	32.0	15.5	92	46	7.8	3.4
March	9.1	3	4.1	35.0	17.0	91	50	7.6	4.1
April	38.7	1	6.2	39.8	21.4	88	45	8.3	6.2
May	94.7	6	8.0	39.2	24.4	87	48	7.7	8.0
June	180.5	10	6.1	36.6	25.7	87	61	5.1	6.1
July	300.9	22	5.5	31.4	26.3	94	82	2.6	5.5
August	337.2	22	4.8	33.1	24.7	94	79	4.7	4.8
September	314.4	20	3.4	31.6	24.7	95	77	4.4	3.4
October	193.3	10	3.3	31.8	24.2	93	64	6.3	3.3
November	31.1	-	2.3	30.9	22.1	90	44	7.2	2.5
December	4.2	-	2.5	27.7	18.0	88	40	5.8	2.5
Total/Mean	1532.4	95	4.4	32.2	21.9	91	56	7.2	4.0

Meteorological data during the cropping season

The mean monthly data of the cropping year and mean weekly data of the cropping season collected from “B‖” class observatory located near the experimental site are presented in the Table 3.4b and 3.4c respectively.

3.4.1 Rainfall

The total rainfall received during the cropping season i.e. January to June was 397.5 mm with 21 rainy days. The highest rainfall of 202.1mm (6 rainy days) received during the month of May. Whereas there was no rainfall in the month of January.

Table 3.4b Mean Monthly meteorological data during the cropping year(January to December 2014)

Month	Total Rainfall (mm)	No. of Rainy days	Evaporation (mm d^{-1})	Atmospheric temperature		Relative Humidity		BSH d^{-1}	Wind Velocity km hr^{-1}
				Max. (^{0}C)	Min. (^{0}C)	M (%)	AN (%)		
January	0	0	3.3	29.7	15.1	91	43	6.1	2.6
February	21.8	1	4.2	32.3	16.7	90	37	7.3	2.6
March	53.2	3	5.9	37.8	21.6	89	32	7.5	4.6
April	9.4	1	8.3	38.8	24.5	90	44	7.4	7.2
May	202.1	6	8.4	39.4	27.7	88	54	7.8	10.2
June	111.0	10	6.1	34.8	25.7	92	68	4.7	6.3
July	410	22	3.3	32.2	25.3	93	82	2.3	4.4
August	261.7	22	3.4	32.2	25.2	94	79	3.4	3.8
September	383.1	20	3.1	32.6	24.4	95	77	3	3
October	163	10	2.7	30.5	22.9	96	78	2.9	5
November	0	0	3.6	29.9	18	85	51	4.6	3.1
December	0	0	3.2	28.9	14.4	87	38	3.8	2.6
Total/Mean	1415.3	95	4.37	33.15	21.4	91	56	6.0	4.4

3.4.2 Evaporation

During the cropping season evaporation data recorded from the USWB Class-I open pan evaporimeter showed that within the months of January to June ,it was lowest in January (2.6 mm day^{-1}) and highest in the month of May (8.4 mm day^{-1}).

3.4.3 Temperature

The maximum mean monthly temperature during the cropping season varied between 29.7^{0}C and 39.4^{0}C. The minimum mean monthly temperature of 15.1^{0}C was recorded in January that increased gradually and attained highest in May(27.7^{0}c).

3.4.4 Relative humidity

The mean monthly morning relative humidity (RH) during the cropping season varied from 88% during May to 92% during June. RH in afternoon hours in different months were low and varied between 32 in March to 68%. In June.

3.4.5 Bright sunshine hour

Sunshine hour day^{-1} during the cropping season varied between in 4.7 d $^{-1}$ in June to 7.8 d $^{-1}$ in May.

3.4.6 Wind velocity

During the cropping season the monthly mean wind velocity varied from 2.6 km hr^{-1} in January to 8 km hr^{-1} in May.

Table 3.4c Weekly meteorological data during the cropping season, (15th January to 15th june. 2015)

Met. Week No.	Date	Rain fall (mm)	No. of Rainy days	Evaporation (mm d^{-1})	Atmospheric temperature		Relative Humidity		BSH $_{d}$-1	Wind Velocity km hr^{-1})
					Max. (^{0}C)	Min. (^{0}C)	M (%)	N (%)		
3	**15-21 Jan**	0	0	3.6	31.6	17.3	90	85	2.6	3.8
4	**22-28 Jan**	0	0	3.3	30.7	18.3	95	88	1.1	3.5
5	**29-04 Feb**	0	0	3.4	34.5	15.9	93	81	2.6	5.7
6	**5-11 Feb**	0	0	3.4	35.5	17.4	96	83	1.2	5.2
7	**12-18 Feb**	21.8	1	3.4	33.2	21.2	95	73	3.7	3
8	**19-25 Feb**	0	0	3.6	32.5	22.5	92	72	3.1	3
9	**26-04 Mar.**	0	0	3.3	32	23.8	87	77	3.4	4.4
10	**05-11 Mar**	0	0	2.9	35.1	23.9	95	76	2.4	2.9
11	**12-16 Mar**	26	1	3.4	33.7	24	91	77	4.9	3
12	**17-23 Mar**	0	0	3.9	32.6	25.8	87	80	1.7	2.4
13	**24-30 Mar**	0	0	2.8	39.5	25.3	91	75	3.1	3.7
14	**01-06 Apr.**	0	0	6.3	41.7	23.9	92	76	3.5	2.8
15	**07-13 Apr**	0	0	4.7	40.4	23.9	81	81	2.6	2.8
16	**14-20 Apr**	0	0	6.8	39.1	23.2	95	75	3.1	9.2
17	**21-27 Apr**	0	0	6.9	36.7	25.7	98	43	1.5	3
18	**28-04 May**	26	0	6.4	41.2	26.3	91	44	5	5.7
19	**05-11 May**	0	0	7.6	42.3	28.0	91	54	4.2	2.5
20	**12-18 May**	0	0	8.6	39.8	26.7	79	50	4.4	2.4
21	**19-25 May**	166.6	0	6.7	37.9	27.9	82	53	3.3	3.7
22	**26-01 june**	77	1	6.7	35.4	29	87	53	3	3.9

23	**02-08 June**	98	2	6.5	34.8	23.9	75	34	4	3
24	**09-15 June**	120	0	7.7	36.7	24.3	84	37	3.3	3.5
	Mean	142	5	6.5	38.4	23.4	91	66.8	3.04	4.0

3.5 Experimental details

The field experiment was laid out in a Randomised Block Design (RBD) design with three replications (Fig. 3.4.).

There were altogether 16 treatment combinations. The treatment details are presented in

Table 3.5.1

Design of experiment : Randomised Block Design

1. Number of treatments : 16
2. Number of replications : 3
3. Total number of plots : 48
4. Gross plot size : 15.75 sq. m. (4.5 m × 3.5 m)
5. Net plot size : 14.25 sq. m.
6. Variety tested : Lalat

The test variety Lalat (ORS 26-2014-4, IET 9947) having parentage (obs 677/IR2071/VIKRAM/W1263) is a release from OUAT, Bhubaneswar.

It has maturity duration of 125-130 days. The variety is photosensitive, semi dwarf having long slender grains and translucent white kernel. The average grain yield is 4.2t ha^{-1}. It is adapted to both rainfed and irrigated conditions during both kharif and rabi seasons. It is suitable for endemic areas of gall midge and brown plant hopper. It is resistant to blast, sheath blight, sheath rot, rice tungro virus, stem borer, bacterial leaf blight and green leaf hopper.

Table 3.5.1 Details of treatment

Treatment	Treatment details	Treatment description
T_1	C (Conventional method)	21 days old seedlings planted , 3 seedlings hill^{-1} at 15 cm X 10 cm spacing, Inorganic nutrient source, Flooded irrigation, manual/chemical weeding)
T_2	$C+F_1$ (Modification in planting technique)	10 days seedlings planted with one seedling hill^{-1}
T3	$C+F_2$ (Water management)	Raised bed, maintaiin saturation
T4	$C+F_3$ (Weed management)	Cono weeding, Seedlings planted at 25 cm X 25 cm spacing
T_5	$C+F_4$ (Modified nutrient management)	Nutrient supplied through FYM and Vermicompost
T_6	$C+F_1+F_2$ (Modified planting and Water management)	
T_7	$C+F_1+F_3$ (Modified planting and Weed management)	
T_8	$C+F_1+F_4$ (Modified planting and Nutrient management)	
T_9	$C+F_2+F_3$ (Modified Water management and Weed management)	
T10	$C+F_2+F_4$ (Modified Water management and Nutrient management)	
T11	$C+F_3+F_4$ (Modified Weed management and Nutrient management)	
T12	$C+F_1+F_2+F_3$ (Modified planting, Water management and Weed management)	
T13	$C+F_1+F_2+F_4$ (Modified planting, Water management and Nutrient management)	
T14	$C+F_1+F_3+F_4$ (Modified Water management, Weed Management and Nutrient management)	
T15	$C+F_2+F_3+F_4$ (Modified Water management, Water management and Nutrient management)	
T16	$C+F_1+F_2+F_3+F_4$ (System of Rice Intensification -SRI)	

3.6 Details of field operations

3.6.1 Nursery raising

Seedlings were raised in the nursery using wet bed method. Seed beds of 5 m x 1.5 m size were prepared to accommodate the seeds. Prior to sowing of seeds in the nursery beds, the seeds were soaked for at least 24 hours and incubated for 36 hours for sprouting. After the seed bed preparation FYM was applied. For conventional method of rice cultivation sprouted seeds were sown on 16th January to get 21 days old seedling by the date of transplanting. In the same way for modified methods sprouted seeds were sown on 29th January to get 12 days old seedling by the date of transplanting. Four days after sowing 1-2 cm of standing water was maintained in the nursery bed. The seed rate used was 5kg ha^{-1} for modified method of planting and 50 kg ha^{-1} for conventional method of planting.

3.6.2 Field preparation and layout

The field was ploughed and cross ploughed by mould board plough (3 times) in dry condition a week before transplanting. Puddling, levelling, bunding and layout of drainage & irrigation channels were drawn as per the plan, one day before transplanting. Twenty four raised beds were prepared keeping 30 cm wide water channel in the middle of plot and 5 cm wide channel surrounding the plot for modified water management.

3.6.3 Nutrient application

Farmyard manure @ 5 t ha^{-1} was uniformly applied to all plots during final land preparation. Farm yard manure @ 10 t ha^{-1}and Vermicompost @ 1.25 t ha $^{-1}$ was applied as basal and 0.5 t ha^{-1} at the time of third cono-weeding in modified nutrient management. Nitrogen, phosphorous and potassium was supplied (through Urea, SSP and MOP) @ 80:40:40 kg N: P_2O_5: K_2O ha^{-1} in Conventional nutrient management. Full dose of phosphorous, half of potassium and one fourth nitrogen were applied as basal; half dose of N applied at tillering i.e.25 DAT and rest one forth N along with half of K were applied a PI stage. N, P_2O_5 and K_2O

content (%) of various materials,
used in the experiment are provided in table 3.6a .

Table 3.6a Nutrient content of the used source

SOURCE	N (%)	P_2O_5 (%)	K_2O (%)
FYM	0.54	0.46	0.26
Vermicompost	2.09	1.25	0.76
Urea	46.0	-	-
SSP	-	16.0	-
MOP	-	-	60.0

3.6.4 Transplanting and gap filling

The seedlings were uprooted from the nursery bed on the day of transplanting. Twenty one days old seedlings with three seedlings per hill were transplanted in the plots following conventional system whereas twelve days old seedling with one seedling per hill were transplanted in 24 plots following modified planting. Seedlings were transplanted in north-south direction. The plot following modified weed management and plot following conventional weed management were transplanted with 25cm x 25cm and 15cm x 10cm spacings respectively. The seedlings were transplanted on 11th February, 2014. A week after transplanting, gap filling was carried out following above specification to maintain uniform plant population in every plot.

3.6.5 Weed management

Weeds were incorporated through criss-cross run of cono weeder at 15, 25 and 35 days after transplanting in plots following modified weed management. Whereas, in plots following Conventional weed management herbicide (Butachlor) was applied after 4 days of transplanting followed by 3 hand weedings carried at 15, 25 and at 35 DAT..

3.6.6 Water management

A thin film of water was maintained at the time of transplanting. The plot following modified water management were kept saturated up to panicle initiation stage by suitably maintaining the water level in intraplot channels. Thereafter, a thin film of water was allowed to stay over the beds up to 10 days before the harvest of the crop. However, standing water up to 5cm was maintained in plots following conventional water management up to 10 days before the harvest of the crop. The water was drained out completely 10 days before harvest to facilitate ripening and harvesting in all the plots.

3.6.7 Plant protection

No major insect pest and disease incidence was noticed in organic block. However as a prophylactic measure Triazophos @ 3.4 l ha^{-1}, Thiomethaxon @ 260 g ha^{-1}, Mancozeb @ 2.7 kg ha^{-1}, Chloropyriphos @ 300 ml ha^{-1}, Hexaconazole @ 1.7 l were sprayed once before PI stage to save the crop from possible infestation.

3.6.8 Harvesting and threshing

The crop was harvested on maturity, when approximately 80 percent of the grains turned straw yellow in colour and were free from greenish tint. Harvesting was done manually leaving the border plants (three rows all around). The individual net plot was measured, harvested and left in the field for drying for 3 days and then threshed separately treatment wise. The grain and straw yield were recorded after final sun drying for 3-4 days to have 14% moisture content in grains.

Table 3.6b Calendar of operation

SL. NO.	Operation	Date	DAT for rice
1	Soaking of seedbed for germination	14-01-2014 & 27-01-2014	-
2	Seed Bed Preparation for Conventional Method	16-01-2014	-
3	Sowing of seed for Conventional Method	16-01-2014	-
4	Seed Bed Preparation for Modified Method	29-01-2014	-
5	Sowing of seed for Modified Method	29-01-2014	-
6	Main filed Preparation	07-02-2014	-
a	Layout of experiment	11-02-2014	-
b	Basal Application of Manure	11-02-2014	-
c	Application of Basal fertilizer	11-02-2014	-
7	Transplanting	11-02-2014	1
8	1st Manual weeding in plot following conventional weed management	24-02-2014	13
9	1st Cono weeding in plots following modified weed management	26-02-2014	15
10	2nd Manual weeding in plot following conventional weed management	06-03-2014	23
11	2nd Dose of manure and fertilizer application	08-03-2014	25
12	2nd Cono weeding plot following modified weed management	08-03-2014	25
13	3rd Cono weeding plot following modified weed management	18-03-2014	35
14	3rd dose of fertilizer application	22-03-2014	39
15	Spraying of agrochemicals	23-03-2014	40
16	Harvesting	12-06-2014	116
17	Threshing	15-06-2014	
18	Drying and weighing	18-06-2014	
❖	Water management from time to time		

3.7 Biometric observation

3.7.1 Sampling technique

Five clumps in the middle rows of each plot were randomly selected and observations on plants height and number of tillers hill^{-1} were recorded from all the sample hills in each plot. Destructive samples were drawn from the third row form the border on each side of the plots. Observation on leaf area and dry matter accumulation were recorded from five contiguous clumps from each plot at the time of each observation from the row selected for destructive sampling. Border rows were not sampled to avoid border effects.

3.7.2 Pre-harvest studies

Biometric observations on different growth parameters were recorded at 15 days interval from transplanting till harvest.

3.7.2.1 Plant height

Five clumps were tagged in the middle row of each plot from which plant heights were recorded. The height was measured from the ground surface of each plant to the tip of the top most leaf of the tallest plant during successive growth stages and during maturity, it was measured from the ground surface to the tip of the panicle. The plant height was expressed in centimetre (cm).

3.7.2.2 Tiller number

The number of tillers form five tagged plants were counted out in the field at different growth stages of crop and averaged out to find out tiller number per hill; the data was then converted and expressed in tillers per square meter area. However, during maturity only panicle bearing tillers were counted and recorded as effective tillers.

3.7.2.3 Leaf area index

Five clumps were collected from destructive sampling zone for dry matter analysis in the laboratory. These samples were collected from the 3rd border rows from each side at each stage of growth. Three leaves from each hill (small, medium and large) were measured by the help of automatic leaf area meter. Total leaf area was estimated by multiplying average leaf area with number of leaves in a clump. Leaf area index (LAI) was calculated by dividing the leaf area per sample plant by the land area occupied by the sample plant as indicated below (Tanaka et al., 1966).

$$\textbf{LAI=}\ \frac{\text{Total leaf area(cm2)}}{\text{corresponding ground area(cm2)}}$$

3.7.2.4 Dry matter accumulation

The five samples collected from destructive sampling zone for LAI analysis were also used to study the dry matter accumulation at different stages of growth. The leaves, culms and panicles (during panicle emergence stage) of each clump were separated at these different growth stages. These parts were first air dried in the shade and then dried in the hot air oven at 85^0C till a constant weight was obtained. The dry weight of the individual portion was recorded and sums of their dry weights were taken as total dry weight per hill. Dry matter accumulation was expressed in grams per hill (g hill^{-1}).

3.7.2.5 Crop growth rate

It is defined as the increase in dry weight of the plant per unit area of land per unit time. It can be calculated using the formula postulated by Leopold and Kriedemann (1975).

$$\textbf{CGR=}\frac{W_2-W_1}{t_2-t_1}(\text{gm}^{-2}\ \ \text{Days}^{-1})$$

Where, W_1 and W_2 are the total plant dry weight (g m^{-2}) at time t_1 and t_2 respectively (the interval between t_1 and t_2 being in days).

3.7.2.6 Relative growth rate

It indicates the increase in dry weight in unit time over unit weight of the plant (Watson,1952).

$$\mathbf{RGR=}\frac{\ln W_2-\ln W_1}{t_2-t_1}(\mathrm{mg}^{-1}\ \mathrm{day}^{-1})$$

Where, W_1 and W_2 are the plant dry weight at time t_1 and t_2 respectively (the interval between t_1 and t_1 being in days).

3.7.2.7 Root volume

Root volume of five sample hills from each plot were determined periodically and averaged out to find out the mean root volume per hill.

3.7.2.8 Weed dry weight g m^{-2}

Weeds from square meter area from each plot were uprooted at 15, 25, 45 and 60 days after transplanting and washed thoroughly. The samples were air dried and subsequently oven dried at 70^{0}C to a constant weight to measure the weed dry weight(g m^{-2}).

3.7.3 Post harvest study (Study on yield parameters)

3.7.3.1 Panicle number

At harvest the number of ear bearing tillers were counted from sample hills and divided by the land area to find out the number of panicle produced per square meter area.

3.7.3.2 Panicle length

Panicle lengths was recorded from ten samples, five from the previously tagged samples and additional five were randomly collected from each plot and measured in centimetre (cm) from the neck node to the tip of the top most grain and averaged out to get the mean length of the panicle(cm).

3.7.3.3 Number of fertile & sterile spikelet

The panicles initially used for recording panicle length were also used for the purpose of counting fertile and sterile spikelets per panicle. The number of fertile and sterile grains of the panicleswere counted separately and average was estimated to obtain the number of fertile and sterile spikelets per panicle and the percentage of each one was calculated.

3.7.3.4 Spikelet sterility

It was worked out from the number of fertile and sterile spikelets per panicle and expressed in percent as stated below.

$$\text{sterility percentage} = \frac{\text{No.of spikelets/ panicle}}{\text{Total no.of spikelets /panicle}}$$

3.7.3.5 1000-grain weight

Thousand well filled grains were randomly collected from the harvest sample panicles of each treatment plot and counted separately using fertile grain counter and weighed on an electric balance and the weight was recorded. The weight was expressed in gram (g) as 1000 grain weight or test weight.

3.7.3.6 Grain and straw yield

Before harvest all the border rows were removed. The net plot areas of individual plots were harvested manually. The produce from the net plot of each treatment was left in the field for sundrying . Then the bundles were taken to the threshing floor where it was threshed plot wise using power operated thresher. The grains were cleaned and sundried for at least 3-4 days. The weight of grain, straw and chaffs were recorded separately. The grain weight of five sample hills collected from each plot for post-harvest studies was added to respective net plot yield The grain and straw weight of three replications were averaged out number (Donald, 1962).

The yield was finally calculated in tons per hectare (t ha^{-1}) at 14 percent moisture content.

3.7.3.7 Grain-straw ratio

Grain yield from each plot area was divided by the corresponding straw yield to obtain the grain-straw ratio which is expressed in dimensionless factor.

3.7.3.8 Harvest index

Harvest index (HI) is obtained by dividing the grain yield by the total biomass yield (plant weight) excluding the underground portion (roots) and expressed in dimensionless.

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

Where, economic yield is grain yield (t ha^{-1}) and biological yield is the total biomass (grain + straw + chaff) yield in t ha^{-1}.

3.8 Chemical studies

3.8.1 Soil analysis

The soil sample from each treatment plot was collected separately to a depth of 15cm. The soil sample from respective treatments under each replication were mixed together and composite samples were drawn, dried under shade, ground and passed through a 2 mm sieve for analysis of both mechanical and chemical composition.

3.8.2 Plant analysis

3.8.2.1 Nitrogen, Phosphorus and Potassium content

At harvest, plant samples were collected randomly and analyzed for N, P and K content of rice grain and straw separately. A composite sample of each treatment from the three replications was taken for this purpose. The oven dried samples were finely ground and analysed for estimation of nitrogen, phosphorus and potassium content using the appropriate methods.

Total nitrogen in plant material was determined by modified micro-kjeldahl distillation method (Jackson, 1973) after digestion of 0.1 g of oven dry (70^0C) finely ground straw samples and 0.25 g of oven dry whole grain sample. The total phosphorus and potassium content was determined after digestion of 0.1 g straw and 0.2 g of grain in nitric acid (HNO_3) and perchloric acid ($HClO_3$) and diluting the digested material after filtering to a standard solution. Phosphorus was determined by Colorimeter and potassium by Flame photometer method (Jackson, 1973).

3.8.2.2 Nitrogen, Phosphorous and Potassium uptake

The nutrient content in grain and straw obtained from plant analysis was multiplied with the grain and straw yield to get the nutrient uptake in (kg ha^{-1}).

Uptake (kg ha^{-1}) = Nutrient content (%) X Yield (kg ha^{-1}) on oven dry basis.

3.9 Economics

Studies on economics of production was made by keeping a record on operation carried out, number of labourers engaged, power and inputs utilized. The standard cost of cultivation and their basis of calculation are given in Appendix I. Gross return were calculated using prevailing market price. Net return per hectare and return per rupee invested were also worked out as per the following formula.

I. Net return = Gross return- Cost of production

II. Return per rupee invested = Gross return / Total cost of production

3.10 Statistical analysis

All the biometric data recorded in pre and post-harvest studies were compiled in appropriate tables and were subjected to statistical analysis as per the procedure prescribed for Randomised Block Design(RBD) to obtain the analysis of variance table. The treatment variations were tested for significance by ‘F’ test. The standard error of mean SE (m)± and critical difference CD at P=0.05 level were calculated (Gomez and Gomez, 1984).

EXPERIMENTAL RESULTS

Observations on the effect of management options on growth parameters, yield attributes, yield, nutrient uptake and economics were recorded during the period of study. The data on these parameters were statistically analyzed to determine the variation among different treatments and are presented in this chapter.

4.1 Plant height

The data on plant height (cm) as influenced by management options were measured at 15, 30, 45, 60, 75, 90 days after transplanting (DAT) and at harvest, statistically analyzed and presented in Table 4.1. The plant height increased rapidly up to 60 DAT and slowly then after, till harvest.

The average plant height increased from 33.5 cm at 15 DAT 66.5, 81.4, 97.1, 105.6, 112.4 and 116.2 cm at 30, 45, 60, 75, 90 DAT and at harvest, respectively. The effect of management options on plant height was significant during all the growth stages. However T_1 (conventional system) recorded plant height of 34.4 , 65.6, 82.6, 97.5,104.5 ,114.8 and 118.7 cm at 15, 30, 45, 60, 75, 90 DAT and at harvest, respectively where as T_{16} (SRI) recorded plant height of 31.7 ,65.5 ,82, 97.3, 106.5,109.5 and 113 cm at 15, 30, 45, 60, 75, 90 DAT and at harvest, respectively.

When single factor was modified T_3 (modified water management) recorded maximum plant height (123.1 cm) at harvest which was significantly higher than all other treatments in all the growth stages and was at par with T_1,T_2,T_4 at 30 and 60 DAT. At harvest this was 3.57% higher than T_1 (conventional system, 118.7 cm) and 8.2 % higher than T_{16} (SRI, 113 cm). When two factors were modified T_6 (modified planting technique and water management) recorded maximum plant height (122.4 cm) which was significantly higher than all other treatments in all the growth stages but was at par with T_8 and T_{10} at 60 DAT , 15 DAT respectively. This was 3.02% higher than T_1 and 7.6 % higher than T_{16} at harvest. When three factors were modified T_{13} (modified planting, water management and nutrient management) recorded maximum plant height of 113.3 cm at harvest and was at par with T_{12},T_{14},T_{15} and T_{16} . At harvest, it was 4.7% higher than T_1 and 0.86 % higher than T_{16} However T3(modified water management) produced the longest plant of 123.1 cm while T_{14} (modified planting, weed management, nutrient management) produced the shortest plant (108.5 cm).

Table 4.1. Effect of management options on plant height (cm)

Treatment	**Days after transplanting**						**At maturity**
	15	**30**	**45**	**60**	**75**	**90**	
T_1 – C	34.4	65.6	82.6	97.5	104.5	114.8	118.7
T_2 – C+F_1	35.5	66.1	83.7	97.9	107.6	115.9	121.4
T_3 – C+F_2	36.6	66.8	86.7	98.9	111.6	119.2	123.1
T_4 – C+F_3	32.9	64.7	76.5	95.5	101.8	111.9	116.6
T_5 – C+F_4	35.4	66.0	81.4	97.1	105.8	116.3	119.6
T_6 – C+F_1+F_2	37.3	70.5	85.6	98.5	110.4	118.8	122.4
T_7 – C+F_1+F_3	33.6	65.7	78.2	96.1	102.8	110.3	115.6
T_8 – C+F_1+F_4	35.6	65.9	81.3	97.1	105.6	114.2	118.6
T_9 – C+F_2+F_3	34.1	65.5	80.1	96.7	103.1	112.4	116.6
T_{10} – C+F_2+F_4	36.6	68.3	82.7	97.6	107.5	116.8	120.7
T_{11} – C+F_3+F_4	31.8	63.4	76.5	95.5	101.3	105.8	108.7
T_{12} – C+F_1+F_2+F_3	30.6	64.1	81.8	97.3	105.2	108.8	112.8
T_{13} – C+F_1+F_2+F_4	32.9	67.5	84.3	98.1	108.3	110.1	113.3
T_{14} – C+F_1+F_3+F_4	27.9	62.2	78.5	96.2	103.7	105.6	108.5
T_{15} – C+F_2+F_3+F_4	29.4	61.5	81.6	97.2	105.3	108.0	110.2
T_{16} – F_1+F_2+F_3+F_4	31.7	65.5	82.0	97.3	106.5	109.5	113.0
SEm±	0.307	0.769	0.567	0.599	0.395	0.422	0.291
CD(0.05)	0.92	2.31	1.71	1.80	1.19	1.27	0.87

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

4.2 Number of tillers

Number of tillers produced per square meter area was measured at 15 days interval commencing from 15 to 90 DAT and at harvest. The data on number of tillers produced as influenced by management options are given in Table 4.2 . The number of tillers per m^2 recorded progressive increase up to 45 DAT and then gradually declined up to harvest.

On an average the crop produced 154, 455, 591, 530, 485, 454 and 396 tillers m^{-2} at 15, 30, 45, 60, 75, 90 DAT and at harvest, respectively. The effect of management options on tillers m^{-2} was significant among all the treatments at all stages of growth. However T_1 (conventional system) produced 142 , 429 ,659 ,511 ,499 ,429 and 365 tillers m^{-2} at 15, 30, 45, 60, 75, 90 DAT and at harvest, respectively where as T_{16} (SRI) produced 303, 811, 1049, 936, 825, 781 and 524 tillers m^{-2} at 15, 30, 45, 60, 75, 90 DAT and at harvest respectively.

When single factor was modified T_3 (modified water management) produced highest numbers of tillers m^{-2} (464) at harvest which was significantly higher among all other treatments at all stages of growth. At harvest it was 21.3% higher than T_1 (conventional system, 365 tillers m^{-2}) and 11.4% higher than T_{16} (SRI, 524 tillers m^{-2}). When two factors were modified T_6 (modified planting method and water management) produced maximum tillers m^{-2} (524) which was significantly higher than all other treatments at all the growth stages was at par with T_7 at 60 ,45,30 DAT. It recorded 30.3% more tillers than T_1 and 0.73% more than T_{16} at harvest. When three factors were modified T_{13} (modified planting, water management and nutrient management) produced maximum tillers (563 m^{-2} at harvest) which was significantly higher than all other treatments at all the growth stages and at harvest it was 17.5 % higher than T_1 and 6.9% higher than T_{16}.

Table 4.2. Effect of management options on tiller m-^{2}

Treatment	Days after transplanting						At maturity
	15	30	45	60	75	90	
T1 - C	142	429	659	511	499	429	365
T2 - $C+F_1$	145	455	525	505	486	443	424
T3 - $C+F_2$	178	508	691	624	584	522	464
T4 - $C+F_3$	107	246	365	346	331	324	302
T5 - $C+F_4$	123	415	615	557	466	431	401
T6 - $C+F_1+F_2$	165	524	616	602	571	543	524
T7 - $C+F_1+F_3$	201	711	881	601	571	511	364
T8 - $C+F_1+F_4$	135	395	451	431	424	420	434
T9 - $C+F_2+F_3$	139	378	456	441	420	421	390
T10 - $C+F_2+F_4$	215	585	703	586	520	535	451
T11 - $C+F_3+F_4$	128	354	415	386	311	281	170
T12 - $C+F_1+F_2+F_3$	156	403	510	480	440	394	360
T13 - $C+F_1+F_2+F_4$	148	607	770	761	645	602	563
T14 - $C+F_1+F_3+F_4$	86	259	351	330	310	310	295
T15 - $C+F_2+F_3+F_4$	90	198	406	380	355	320	310
T16 - $F_1+F_2+F_3+F_4$	303	811	1049	936	825	781	524
SE m±	0.821	0.798	0.495	0.597	0.498	0.61	0.5
CD(0.05)	2.47	2.40	1.49	1.79	1.50	1.83	1.50

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

4.3 Root volume

The data on root volume (cc hill^{-1}) as influenced by management options were measured at 15 days interval starting from 15 to 90 DAT and at harvest which are presented in Table 4.3. There was progressive increase in root volume hill^{-1} up to 75 DAT and then gradually declined up to harvest.

The mean root volume was 10.35 , 21.06, 43.25, 69.27 , 74.13, 61.96 and 53.12 cc hill^{-1} at 15, 30, 45, 60, 75, 90 DAT and at harvest, respectively. Effect of management options on root volume differed significantly among all the treatments at all stages of growth. However T_1 (conventional system) recorded root volume of 12.15 , 16.40, 39.67, 57.67, 66.32, 54.23, and 45.24 cc hill^{-1} where as T_{16} (SRI) recorded root volume of 12.38 , 22.17, 44.97 , 75.37, 81.33, 66.35 and 58.70 cc hill^{-1} at 15, 30, 45, 60, 75, 90 DAT and at harvest, respectively.

When single factor was modified T_3 (modified water management) recorded highest root volume at all stages of growth and was at par with T_1 ,T_2 and T_5 at 15 DAT, respectively. At harvest root volume recorded by T_3 (63.43 cc hill^{-1}) was 28% higher than T_1 (conventional system, 45.24 cc hill^{-1}) and 7.4% higher than T_{16} (SRI, 58.70 cc hill^{-1}) at harvest. When two factors were modified T_{11} (modified weed management and nutrient management) recorded highest root volume from 45 DAT (50.13 cc hill^{-1}) to harvest (69.32 cc hill^{-1}), maximum being 86.83 cc hill^{-1} at 75 DAT among all the treatments. When three factors were modified T_{13}(modified planting, water management and nutrient management) recorded highest root volume hill^{-1} from 30 DAT (27.90 cc hill^{-1}) to harvest (72.41 cc hill^{-1}), maximum being 87.18 cc hill^{-1} among all the treatments but was at par with T_{12} , T_{15} and T_{16} at 75 and 90 DAT respectively.

The maximum root volume recorded by T_{13} (modified planting, water and nutrient management) was 37% higher than T_1 and 18.9 % higher than T_{16} at 75 DAT, Where as the lowest root volume (34.42 cc hill^{-1}) was obtained from T_4 (modified weed management).

Table 4.3 Effect of management options on root volume(cc)

Treatment	**Days after transplanting**						**At Maturity**
	15	**30**	**45**	**60**	**75**	**90**	
T_1 – C	12.15	16.40	39.67	57.67	66.32	54.23	45.24
T_2 – C+F_1	8.5	16.77	42.13	68.8	72.3	59.80	47.25
T_3 – C+F_2	12.75	28.84	46.77	85.75	82.36	70.93	63.43
T_4 – C+F_3	8.43	16.41	35.43	50.02	55.05	46.38	34.42
T_5 – C+F_4	10.32	19.57	40.63	67.47	71.67	56.33	45.25
T_6 – C+F_1+F_2	11.25	17.80	44.33	71.35	78.38	62.28	56.33
T_7 – C+F_1+F_3	10.02	16.60	38.79	57.25	62.25	52.19	41.17
T_8 – C+F_1+F_4	13.59	29.12	49.53	80.63	85.17	75.78	68.52
T_9 – C+F_2+F_3	8.58	17.37	38.13	55.22	59.14	50.43	39.31
T_{10} – C+F_2+F_4	9.07	18.15	42.32	66.37	74.17	60.33	50.75
T_{11} – C+F_3+F_4	8.68	26.14	50.13	82.03	86.83	76.53	69.32
T_{12} – C+F_1+F_2+F_3	11.48	22.57	44.28	74.00	80.29	64.18	57.38
T_{13} – C+F_1+F_2+F_4	10.31	27.90	51.63	83.47	87.18	78.32	72.41
T_{14} – C+F_1+F_3+F_4	9.55	17.97	40.27	58.73	64.10	52.80	42.33
T_{15} – C+F_2+F_3+F_4	8.61	23.17	43.03	74.15	79.47	64.56	58.05
T_{16}-F_1+F_2+F_3+F_4	12.38	22.17	44.97	75.37	81.33	66.35	58.70
SE m±	0.231	0.295	0.195	0.921	8.457	6.778	0.243
CD (0.05)	0.69	0.88	0.59	2.73	24.44	18.41	0.72

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

4.4 Leaf area index

Data recorded on leaf area index are presented in Table 4.4. Leaf area index (LAI) increased progressively up to 45 DAT and then declined gradually. There was significant difference in LAI among all the treatments at all stages of growth. Average LAI was 1.18, 2.50, 6.95, 6.37, 5.69, 4.86, and 1.62 at 15, 30, 45, 60, 75, 90 DAT and at harvest, respectively. The LAI for T_1 (conventional system) was 1.29, 2.85,9.35,8.48,7.66,6.21, and 2.05 where as for T_{16} (SRI) it was 0.94, 1.76, 4.84, 4.19, 3.65, 3.38 and 1.07 at 15, 30, 45, 60, 75, 90 DAT and at harvest, respectively.

When a single component was modified T_3 (modified water management) produced maximum LAI at 45 DAT , which was significantly higher among all other treatments at all the growth stages, which was 0.74 % higher than T_1 (conventional system) and 48.6 % higher than T_{16}(SRI) at 45 DAT . When two components were modified T_{11} (modified weed and nutrient management) recorded maximum LAI (9.91) at 45 DAT, which was at par with T_6 at 90 DAT. It was 5.9% higher than T_1 and 104.7% higher than T_{16}. When three components were modified T_{13} (modified planting, water management and nutrient management) recorded maximum LAI (9.92) at 45 DAT, which was significantly higher than others at all the growth stages. It was 6.09% higher than T_1 and 104.9% higher than T_{16}.

Among all the treatments T_{13}(modified planting,water and nutrient management) recorded highest LAI at 45 DAT, At 45 DAT it was 6.09% higher than conventional system and 104.9 % higher than SRI.

Table 4.4. Effect of management options on leaf area index

Treatment	Days after transplanting						At maturity
	15	30	45	60	75	90	
T_1 – C	1.29	2.85	9.35	8.48	7.66	6.21	2.05
T_2 – C+F_1	1.34	3.41	9.25	8.4	7.64	6.66	2.22
T_3 – C+F_2	1.55	3.58	9.42	8.44	7.83	6.31	2.35
T_4 – C+F_3	0.97	1.72	4.31	4.17	3.38	2.94	0.96
T_5 – C+F_4	1.63	3.61	9.63	9.08	8.1	6.65	2.21
T_6 – C+F_1+F_2	1.53	3.16	9.61	8.6	7.94	6.82	2.28
T_7 – C+F_1+F_3	0.77	1.44	4.26	4.2	3.44	3.17	0.96
T_8 – C+F_1+F_4	1.46	3.35	9.13	8.63	7.93	6.86	2.3
T_9 – C+F_2+F_3	0.69	1.37	3.95	3.6	3.19	2.86	0.95
T_{10} – C+F_2+F_4	1.17	1.46	4.58	3.95	3.6	3.19	1.04
T_{11} – C+F_3+F_4	1.61	3.92	9.91	9.21	8.3	6.7	2.33
T_{12} – C+F_1+F_2+F_3	0.67	1.43	4.17	3.75	3.22	3.0	0.95
T_{13} – C+F_1+F_2+F_4	1.37	3.66	9.92	9.13	8.21	6.86	2.24
T_{14} – C+F_1+F_3+F_4	0.95	1.66	4.31	3.92	3.43	2.94	0.94
T_{15} – C+F_2+F_3+F_4	0.86	1.66	4.63	4.13	3.56	3.24	1.06
T_{16} – F_1+F_2+F_3+F_4	0.94	1.76	4.84	4.19	3.65	3.38	1.07
SE m±	0.019	0.014	0.029	0.034	0.033	0.04	0.07
CD(0.05)	0.05	0.04	0.08	0.10	0.09	0.12	0.22

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

4.5 Weed dry weight

Data on weed dry weight was taken per square meter area at 15, 25, 45 and 60 DAT, statistically analyzed and presented in Table 4.5. The weed dry weight increased progressively up to 45 DAT and declined thereafter. There was significant difference in weed dry weight among all the treatments. Average weed dry weight at 15, 25, 45, 60 DAT was 7.68, 7.33, 7.77, 7.21 g m^{-2} respectively. T_1(conventional system) recorded weed dry weight of 6.9,8.9,9.3 and 8.8 g m^{-2} at 15, 25, 45 and 60 DAT respectively, where as T_{16} (SRI) recorded weed dry weight of 8.3,6.3,7.4, and 7.4 g m^{-2} at 15, 25, 45 and 60 DAT respectively.

When only one factor was modified T_3 (modified water management) recorded lowest weed dry weight (4.4 g m^{-2}) which was significantly lower among all other treatments at all the growth stages. At 60 DAT. It was 50% lower than T_1 (conventional system, 8.8 g m^{-2}) and 68.1% lower than T_{16} (SRI, 7.4 g m^{-2}). When two factors were modified T_7 (modified planting and weed management) recorded lowest weed dry weight at all the growth stages. At 60 DAT it was 5.8 g m^{-2} which was 34% lower than T_1 and 27.5% lower than T_{16}. When three factors were modified T_{15} (modified water management, weed management and nutrient management) recorded lowest weed dry weight of 6.4 g m^{-2} at 60 DAT which was 37.5% lower than T_1 and 15.6% lower than $T_{16.}$

Among all the treatments T_3 (modified water management) recoded lowest weed dry weight. However T_{11} (modified planting,weed and nutrient management) recorded the highest weed dry weight (10.9 m^{-2}) among all the treatments at 60 DAT.

Table 4.5. Effect of management options on weed dry weight (gm m-^{2})

Treatment	Days after transplanting			
	15	25	45	60
T_1 – C	6.9	8.9	9.3	8.8
T_2 – C+F_1	3.6	5.6	6.6	4.6
T_3 – C+F_2	3.4	5.3	5.8	4.4
T_4 – C+F_3	8.5	10.4	10.5	8.9
T_5 – C+F_4	5.4	5.2	6.1	5.6
T_6 – C+F_1+F_2	8.8	10.0	9.4	8.8
T_7 – C+F_1+F_3	4.4	5.9	6.3	5.8
T_8 – C+F_1+F_4	9.4	6.9	6.7	6.8
T_9 – C+F_2+F_3	7.7	8.3	9.2	8.9
T_{10} – C+F_2+F_4	11.5	6.6	6.7	6.8
T_{11} – C+F_3+F_4	6.3	10.4	11.2	10.9
T_{12} – C+F_1+F_2+F_3	8.8	7.4	7.5	7.6
T_{13} – C+F_1+F_2+F_4	10.2	6.4	7.6	6.9
T_{14} – C+F_1+F_3+F_4	10.4	7.1	6.7	6.8
T_{15} – C+F_2+F_3+F_4	9.3	6.6	7.3	6.4
T_{16} – F_1+F_2+F_3+F_4	8.3	6.3	7.4	7.4
SE m±	0.141	0.169	0.134	0.138
CD (0.05)	0.42	0.50	0.40	0.41

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

4.6 Dry matter production

Dry matter production (per square meter area) as influenced by management options were recorded at 15, 30, 45, 60, 75, 90 DAT and at harvest. The statistically analyzed data are shown in Table 4.6. The dry matter production m^{-2} increased progressively till the maturity of the crop.The average dry matter production was 117, 428, 797, 1304, 1576, 1736 and 1874 g m^{-2} at 15, 30, 45, 60, 75, 90 DAT and at harvest, respectively. The effect of management options on dry matter production was significant at all the growth stages. However T_1 (conventional system) recorded dry matter production of 116, 475, 887, 1526, 1946, 2149 and 2255 g m^{-2} where as T_{16} (SRI) recorded 91, 332, 635, 1033, 1208, 1304 and 1391 g m^{-2} at 15, 30, 45, 60, 75, 90 DAT and at harvest, respectively.

When only one factor was modified T_3 (modified water management) recorded significantly higher dry matter production(2514 g m^{-2})than all other treatments. At harvest T_3 was 10.3% higher than T_1 (conventional system) and 44.60% higher than T_{16} (SRI). When two factors were modified T_{11} (modified planting and nutrient management) recorded higher dry matter production (2807 g m^{-2}) at harvest than all other treatments at all the growth stages. At harvest T_{11} was 24.4% higher than T_1 and 101.7% higher than $T_{16.}$ When three factors were modified T_{13} (modified planting, water management and nutrient management) recorded maximum dry matter production (2647 g m^{-2}) at harvest than all other treatments at all the growth stages. It was 17.3% higher than T_1 and 90.29% higher than T_{16} at harvest.

Among all the treatments T_{11}(modified weed and nutrient management) recoded highest dry matter production At harvest it was 19% higher than conventional system and 50.4% higher than SRI. However T_9 (modified water and weed management) recorded lowest dry matter production (1152 g m^{-2}).

Table 4.6. Effect of management options on Drymatter production (gm m^{-2})

Treatment	Days after transplanting						At maturity
	15	30	45	60	75	90	
T_1 – C	116	475	887	1526	1946	2149	2255
T_2 – C+F_1	138	492	1018	1662	2028	2237	2453
T_3 – C+F_2	224	565	1090	1734	2117	2326	2514
T_4 – C+F_3	100	302	578	936	1107	1030	1266
T_5 – C+F_4	104	454	857	1450	1855	2062	2260
T_6 – C+F_1+F_2	125	518	932	1620	1950	2176	2316
T_7 – C+F_1+F_3	103	346	602	974	1150	1255	1344
T_8 – C+F_1+F_4	156	575	1042	1709	2056	2304	2469
T_9 – C+F_2+F_3	75	308	518	836	994	1094	1152
T_{10} – C+F_2+F_4	94	326	556	998	1170	1286	1366
T_{11} – C+F_3+F_4	165	602	1248	1991	2385	2593	2807
T_{12} – C+F_1+F_2+F_3	86	318	537	852	1060	1186	1245
T_{13} – C+F_1+F_2+F_4	143	655	1176	1824	2140	2436	2647
T_{14} – C+F_1+F_3+F_4	80	295	524	813	1024	1160	1236
T_{15} – C+F_2+F_3+F_4	75	296	564	914	1081	1182	1267
T_{16} – F_1+F_2+F_3+F_4	91	332	635	1033	1208	1304	1391
SE m±	1.067	0.91	1.111	1.213	0.917	0.83	1.115
CD(0.05)	3.21	2.74	3.35	3.63	2.76	2.56	3.36

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

4.7 Crop growth rate

The data on crop growth rate (g day^{-1} m^{-2}) as influenced by management options are calculated and presented in Table 4.7 and illustrated in fig 4.1. It was calculated by taking the rate of change in dry matter production per square meter area per day between 15-30, 30-45, 45-60, 60-75, 75-90 DAT and 90 DAT to harvest where the mean crop growth rate (CGR) was 20.7, 24.6, 33.78, 18.3, 11.1 and 8.49 g day^{-1} m^{-2}, respectively. The effect of management options on CGR varied significantly among all the treatments and at all growth stages. T_1 (conventional system) recorded crop growth rate of 23.9, 27.5, 42.6, 28 ,13.5 and 7.1 g day^{-1} m^{-2} during 15-30, 30-45, 45-60, 60-75, 75-90 DAT and at 90 DAT to harvest, respectively where as T_{16} (SRI) recorded crop growth rate of 16.1, 20.2, 26.5, 11.7, 6.4 and 5.8 g day^{-1} m^{-2}, respectively.

When a single factor was modified T_3 (modified water management) recorded higher CGR at all the growth stages except 60-75 and 75-90 DAT 90DAT-harvest and was at par with $T_{1,}$ T_2 and T_5 at all growth stages. It recorded maximum CGR (42.9 g day^{-1} m^{-2}) at 45-60 DAT which was 0.7% higher than T_1 (conventional system) and 61.8% higher than T_{16} (SRI). When two factors were modified T_{11} (modified weed and water management) recorded significantly higher CGR(49.5) and was at par with T_1,T_2,T_5 at all other treatments. At 45-60 DAT the CGR was maximum which was 16.1% higher than T_1 and 86.1% T_{16}. When three factors were modified T_{13} (modified planting, water management and nutrient management) recorded maximum CGR among all other treatments at all the growth stages. At 45-60 DAT it was maximum (43.2 g day^{-} m^{-2}) which was 1.4% higher than T_1 and 63 % higher than $T_{16.}$

Among all the treatments T_{11} (modified weed and nutrient management) and recorded maximum crop growth rate from 29.1,43.1,49.5 g m^{-2} d^{-1}15-30 DAT,30-45 DAT and 45-60 DAT,respectively.

Table 4.7. Effect of management options on Crop growth rate (g day^{-1} m^{-2})

Treatment	Days after transplanting					
	15-30	30-45	45-60	60-75	75-90	90- Harvest
T_1 – C	23.9	27.5	42.6	28.0	13.5	7.1
T_2 – C+F_1	23.6	35.1	42.9	24.4	13.9	14.4
T_3 – C+F_2	22.7	35.0	42.9	25.5	13.9	12.5
T_4 – C+F_3	13.5	18.4	23.9	11.4	6.2	4.4
T_5 – C+F_4	23.3	26.9	39.5	27.0	13.8	13.2
T_6 – C+F_1+F_2	26.2	27.6	45.9	22.0	15.1	9.3
T_7 – C+F_1+F_3	16.2	17.1	24.8	11.7	7.0	5.9
T_8 – C+F_1+F_4	27.9	31.1	44.5	23.1	16.5	11.0
T_9 – C+F_2+F_3	15.5	14.0	21.2	10.5	6.7	3.9
T_{10} – C+F_2+F_4	15.5	15.3	29.5	11.5	7.7	5.3
T_{11} – C+F_3+F_4	29.1	43.1	49.5	26.3	13.9	14.3
T_{12} – C+F_1+F_2+F_3	15.5	14.6	21.0	13.9	8.4	3.9
T_{13} – C+F_1+F_2+F_4	34.1	34.7	43.2	21.1	19.7	14.1
T_{14} – C+F_1+F_3+F_4	14.3	15.3	19.3	14.1	9.1	5.1
T_{15} – C+F_2+F_3+F_4	14.7	17.9	23.3	11.1	6.7	5.7
T_{16} – F_1+F_2+F_3+F_4	16.1	20.2	26.5	11.7	6.4	5.8
SEm ±	0.427	1.156	1.245	1.243	1.213	0.460
CD (0.05)	1.28	3.46	3.73	3.72	3.63	1.38

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

4.8 Relative growth rate

The relative growth rate (RGR) declined gradually from 15 DAT to harvest as presented in Table 4.8. Significant variation observed among all the treatments and growth stages except at 75-90 DAT and 90 DAT to harvest. The mean RGR values at 15-30, 30-45, 45-60, 60-75, 75-90 DAT and at 90 DAT to harvest were 0.089, 0.043, 0.038, 0.016, 0.009 and 0.008 g g^{-1} day^{-1}, respectively. However T_1 (conventional system) recorded RGR value of 0.094, 0.042, 0.036, 0.016, 0.007 and 0.003 g g^{-1} day^{-1} where as T_{16} (SRI) recorded RGR value of 0.086, 0.043, 0.032, 0.010, 0.005 g g^{-1} day^{-1} and 0.004 g g^{-1} day^{-1}, at 15-30, 30-45, 45-60, 60-75, 75-90 DAT and at 90 DAT to harvest, respectively.

When single factor was modified T_5 (modified nutrient management) recorded maximum RGR(0.098 g g^{-1} d^{-1}) at all the growth stages, it was 4.25% higher than T_1 (conventional system, 0.094 g g^{-1} day^{-1}) and 13.9 % higher than T_{16} (SRI, 0.086 g g^{-1} day^{-1}) 30-45 DAT. When two factors were modified T_6 (modified planting and water management) recorded maximum RGR of 0.095 g g^{-1} day^{-1} at 15-30 DAT . When three factors were modified T_{13} (modified planting, water management and nutrient management) recorded maximum RGR up to 45-60 DAT and was highest (0.101 g g^{-1} day^{-1}) at 15-30 DAT.

Among all the treatments T_{13} and recorded maximum RGR at all the growth stages except at 15-30 DAT and 30-45 DAT. There was no significance variation in RGR value beyond 90 DAT.

Table 4.8. Effect of management options on relative growth rate(g day^{-1} m-^{2})

Treatment	Days after transplanting					
	15-30	30-45	45-60	60-75	75-90	90-Harvest
T$_1$ – C	0.094	0.042	0.036	0.016	0.007	0.003
T$_2$ – C+F$_1$	0.085	0.048	0.033	0.013	0.007	0.006
T$_3$ – C+F$_2$	0.062	0.044	0.031	0.013	0.006	0.005
T$_4$ – C+F$_3$	0.074	0.043	0.032	0.011	0.003	0.006
T$_5$ – C+F$_4$	0.098	0.042	0.035	0.016	0.007	0.006
T$_6$ – C+F$_1$+F$_2$	0.095	0.039	0.037	0.012	0.007	0.004
T$_7$ – C+F$_1$+F$_3$	0.081	0.037	0.032	0.011	0.006	0.005
T$_8$ – C+F$_1$+F$_4$	0.087	0.040	0.033	0.012	0.008	0.005
T$_9$ – C+F$_2$+F$_3$	0.094	0.035	0.032	0.012	0.006	0.003
T$_{10}$ – C+F$_2$+F$_4$	0.083	0.036	0.039	0.011	0.006	0.004
T$_{11}$ – C+F$_3$+F$_4$	0.086	0.049	0.031	0.012	0.006	0.005
T$_{12}$ – C+F$_1$+F$_2$+F$_3$	0.087	0.035	0.031	0.015	0.007	0.003
T$_{13}$ – C+F$_1$+F$_2$+F$_4$	0.101	0.039	0.029	0.011	0.009	0.006
T$_{14}$ – C+F$_1$+F$_3$+F$_4$	0.087	0.038	0.029	0.015	0.008	0.004
T$_{15}$ – C+F$_2$+F$_3$+F$_4$	0.092	0.043	0.032	0.011	0.006	0.005
T$_{16}$ – F$_1$+F$_2$+F$_3$+F$_4$	0.086	0.043	0.032	0.010	0.005	0.004
SE m±	0.0042	0.002	0.0019	0.0008	0.0007	0.0002
CD (0.05)	0.01	0.01	0.06	0.02	NS	NS

c-Conventional,F$_1$-Planting technique,F$_2$-Water management,F$_3$-Weed management,F$_4$-Nutrient management

4.9 Study of phenophases

The important phenophases of rice i.e. number of days taken from nursery sowing to panicle initiation, 50% flowering and physiological maturity were recorded .The mean number of days required for panicle initiation, 50% flowering and physiological maturity of rice variety Lalat under the influence of different management options varied from 50-58, 74-86 and 117-128 days, respectively. The data reveals that T_1 (conventional system) had taken 54, 81, 122 days for panicle initiation, 50% flowering and physiological maturity respectively, whereas T_{16} (SRI) had taken 54, 80, 122 days for panicle initiation, 50% flowering and physiological maturity, respectively.

When single factor was modified T_3 (modified water management) recorded longest period for panicle initiation (58 days), 50% flowering (86 days) and physiological maturity (128 days) followed by T_3, T_4, T_5 which was higher than T_1 (conventional system) and T_{16} (SRI) also. When two factors were modified, T_6 (modified planting and water management) took maximum time for panicle initiation (57 days), 50% flowering (84 days) and physiological maturity (127 days) whereas followed by T_{10} and T_8, also took more time than T_1 and T_{16}. When three factors were modified T_{13} (Modified planting, water management and nutrient management) recorded longest duration for panicle initiation (56 days), 50% flowering (82 days) and physiological maturity (124 days) followed by T_{12}, T_{15} and T_{14} which was longer than T_1 and T_{16} also.

Among all the treatments T_3 took longer time period (58, 86 and 128 days) for panicle initiation , 50% flowering and physiological maturity , respectively. It took more time (4, 5, 6 days) than conventional system and (4, 6, 6 days) for panicle initiation, 50% flowering and physiological maturity respectively. T_{11}(modified weed management and nutrient management) recorded shortest period for panicle initiation (51 days), 50% flowering (74 days) and physiological maturity (117 days), respectively.

Table 4.9. Effect of management options on phenology

Treatment	Occurance of phenophases (days from nursery sowing)		
	Panicle initiation	50% flowering	Physiological maturity
$\mathbf{T_1}$ – C	54	81	122
$\mathbf{T_2}$ – C+F_1	56	84	126
$\mathbf{T_3}$ – C+F_2	58	86	128
$\mathbf{T_4}$ – C+F_3	52	79	119
$\mathbf{T_5}$ – C+F_4	55	82	124
$\mathbf{T_6}$ – C+F_1+F_2	57	84	127
$\mathbf{T_7}$ – C+F_1+F_3	52	77	118
$\mathbf{T_8}$ – C+F_1+F_4	54	80	124
$\mathbf{T_9}$ – C+F_2+F_3	53	78	122
$\mathbf{T_{10}}$ – C+F_2+F_4	55	82	125
$\mathbf{T_{11}}$ – C+F_3+F_4	51	74	117
$\mathbf{T_{12}}$ – C+F_1+F_2+F_3	53	79	121
$\mathbf{T_{13}}$ – C+F_1+F_2+F_4	56	82	124
$\mathbf{T_{14}}$ – C+F_1+F_3+F_4	50	75	117
$\mathbf{T_{15}}$ – C+F_2+F_3+F_4	51	77	119
$\mathbf{T_{16}}$ – F_1+F_2+F_3+F_4	52	80	122

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

4.10 Yield attributes

4.10.1 Number of effective tillers m^{-2}

The data on production of number of effective tillers m^{-2} as influenced by management options are presented in Table 4.10 and illustrated in Fig. 4.2. The number of tillers ranged from 272 to 431 m^{-2} with an average of 342 tillers m^{-2}. There was significant variation in number of tillers m^{-2} among different treatments.

T_1 (conventional system) produced 334 tillers m^{-2} where as T_{16} (SRI) produced 296 tillers m^{-2}. When single factor was modified, highest number of tillers (431 m^{-2}) were obtained from T_3 (modified water management) .It was 29% higher than T_1 and 45% higher than $T_{16.}$ When two factors were modified T_6 (modified planting and water management) recorded maximum tillers (384) m^{-2} .It was 14.9% higher than the T_1 and 22.9% higher than $T_{16.}$ When three factors were modified T_{14} (modified planting, weed management and nutrient management) recorded maximum tillers (426) m^{-2},which was 27.5% than T_1 and 30.5% higher than $T_{16.}$

Among all the treatments T_3(modified water management) recorded maximum numbers of effective tillers m^{-2}(431) which was 29% than conventional system and 45% higher than SRI. It was 12.2 % than T_6 and was at par with T_{14}. However T_4 (modified weed management) produced lowest numbers of effective tillers (272 m^{-2})

4.10.2 Panicle length

The data on panicle length of rice as influenced by management options are presented in Table 4.10 and illustrated in Fig. 4.2. The panicle length ranged from 21.7 cm to 28.8 cm with an average length of 25.9 cm. There was not much significant variation in panicle length among different treatments.

The T_1 (conventional system) recorded a panicle length of 27.9 cm where as T_{16} (SRI) recorded panicle length of 27 cm. When single factor was modified, T_3 (modified water management) produced longest panicle (34.1 cm) which was at par with the panicle length of all other treatments. However it was 22.2% longer than T_1 and 26.2% shorter than T_{16} (SRI). When two factors were modified, T_6 (modified planting and water management) produced longest panicle (28.8 cm) which was at par with the panicle length of all other treatments whereas it was 3.2% longer than the T_1 and 6.6% longer than $T_{16.}$ When three factors were modified, T_{14} (modified planting, weed management and nutrient management) produced longest panicle (28.5 cm) and was at par with that of all other treatments; it was 21.15% longer than T_1 and 5.5% shorter than $T_{16.}$

Among all the treatments longest panicle (34.1 cm) was produced by T_3 which was

22.2% longer than conventional system and 26.2% SRI. It was 3.2% and 1.05% longer than the longest panicle obtained, when two factors and three factors were modified respectively. However T_8(modified planting and nutrient management) produced the shortest panicle (21.7 cm).

4.10.3 Number of grains

The data on number of grains panicle^{-1} as influenced by management options are presented in Table 4.10 and illustrated in Fig. 4.2. The number of grains ranged from 123 to 140 panicle^{-1} with an average of 128.9. There was significant variation in number of grains per panicle among different treatments.

The T_1 (conventional system) produced 127 grains panicle^{-1} and T_{16} (SRI) produced 101 numbers of grains panicle^{-1}. When single factor was modified T_3 (modified water management),it produced maximum number of grains (140 panicle^{-1}) having significant difference from other treatments where as it produced 22.2 % more grains panicle^{-1} than T_1 and 26.2% less than $T_{16.}$ When two factors were modified, T_6 (modified planting and water management) produced maximum number of grains (137 panicle^{-1}) . It was 7.8% higher than T_1 and 10.4% lower than $T_{16.}$ When three factors were modified, T_{14} (modified planting, weed management and nutrient management) produced maximum number of grains (136 panicle^{-1}) .It produced 7% more grains panicle^{-1} than T_1 and 9.6% less than $T_{16.}$

Among all the treatments highest number of grains (140 panicle^{-1}) was produced from T_3 which was 2% and 2.9% higher than the maximum number of grains obtained panicle^{-1}, when two factors and three factors were modified respectively. However T_{15} (modified water, weed and nutrient management) recorded lowest numbers of grains panicle^{-1} (123 panicle^{-1}).

4.10.5 Number of filled grains

The data on number of filled grains produced panicle^{-1} as influenced by management options are presented in Table 4.10 and illustrated in Fig. 4.2. The number of filled grains per panicle ranged from 85 to 128 panicle^{-1} with an average of 100.5 panicle^{-1}. There was significant variation in number of filled grains panicle^{-1} among all the treatments.T_1 (conventional system) produced 98 numbers of filled grains panicle^{-1} where as T_{16} (SRI) registered of 101 filled grains per panicle. When single factor was modified T_3(modified water management) produced maximum number of filled grains panicle^{-1}(128) which was significantly different from other treatments. It was 30.6% higher than T_1(conventional system) and 26.7% higher than T_{16} (SRI). When two factors were modified, T_6 (modified planting and water management) produced maximum number of filled grains per panicle (106) which was significantly different from others. Whereas it was8.16% higher than T_1 (conventional system) and 4% lower than T_{16} (SRI). When three factors were modified T_{14} (modified planting, weed management and nutrient management) recorded maximum number of filled grains per panicle (114) but was at par with all other treatments. However it was 16.3% higher than T_1 (conventional system) and 12.8% lower than T_{16} (SRI).

Among all the treatments highest number of filled grains panicle^{-1} (128) was recorded from T_3, which was 20% and 12.2% higher than the maximum filled grains panicle^{-1} produced, when two factors and three factors were modified, respectively. However lowest numbers of filled grains panicle^{-1} (85) was recorded from T_4 (modified weed management).

4.10.6 Sterility

Data on sterility (%) was calculated from total number of grains per panicle. It was statically analyzed and presented in Table 4.10 and illustrated in fig. 4.2. The sterility percent ranged from 8 to 31 with an average of 21.5. There was significant variation in sterility among different treatments.T_1 (conventional system) recorded of 23% sterility where as T_{16} (SRI) recorded 29% sterility. When single factor was modified T_3 (modified water management) recorded minimum sterility (8%), which was 34% lower than T_1 and 6.8% lower than T_{16}. When two factors were modified, T_{11} (modified planting and nutrient management) recorded minimum sterility (21%), which was 17.3% lower than the T_1 12% higher than $T_{16.}$ When three factors were modified, T_{14} (modified planting ,weed management and nutrient management) recorded minimum sterility (15%), which was 34% lower than T_1 and 26% lower than $T_{16.}$

Among all the treatments minimum sterility (8%) was recorded by T_3 , which was 61.9% and 46.6% lower than the minimum sterility obtained when two factor and three factors were modified, respectively. However T_4 recorded maximum sterility (31%).

4.10.8 1000 grain weight

1000 grain weight was significantly affected by different management options. It is presented in Table 4.10 and illustrated in Fig.4.2 . The 1000 grain weight varied from 22.5g to 26.9 g with mean weight of 24.7 g. The T_1 (conventional system) and T_{16} (SRI) recorded 1000 grain weight of 23.3g and 25.5 g, respectively. When single factor was modified, T_3 (modified water management) recorded maximum test weight (26.9 g) and . It was 15.4% higher than T_1 and 5.4% lower than $T_{16.}$ When two factors were modified, T_6 (modified planting and water management) recorded maximum test weight (26.8 g) and was at par with T_{10}, T_8 and T_7 respectively. whereas it was 15.02% higher than the T_1 and 5.09% lower than T_{16} .When three factors were modified T_{13} (modified planting, water management and nutrient management) recorded maximum test weight (26.7 g). It was at par with T_{15} and T_{14}, but14.5% higher than T_1 and 4.7% higher than $T_{16.}$

Among all the treatments maximum 1000 grain weight was recorded by T_3 (26.9 g) which was 15.4% higher than the conventional system and 5.4% higher than T_{16} .However it was 0.37%, and 0.74% higher than the maximum 1000 grain weight obtained when two factors and three factors were modified, respectively. However T_4 (modified weed management)recoded lowest 1000 grain weight (22.5 g).

Table 4.10.Effect of management options on yield attributes.

Treatment	#Effective tillers m^{-2}	Panicle length (cm)	#Grains Per panicle	#Filled grains Per panicle	#Sterile grains per panicle	Sterility(%)	1000 grain wt(g)
T_1 – C	334	27.9	127	98	29	23	23.3
T_2 – C+F_1	352	27.4	125	105	20	16	25.5
T_3 – C+F_2	431	34.1	140	128	12	8	26.9
T_4 – C+F_3	272	27.1	125	85	40	31	22.5
T_5 – C+F_4	342	28.1	133	103	30	22	24.2
T_6 – C+F_1+F_2	384	28.8	137	106	31	21	26.8
T_7 – C+F_1+F_3	341	27.5	125	89	36	29	23.5
T_8 – C+F_1+F_4	351	21.7	123	96	33	27	24.7
T_9 – C+F_2+F_3	350	28.2	131	90	35	26	24.1
T_{10} – C+F_2+F_4	381	28.1	131	102	29	22	25.2
T_{11} – C+F_3+F_4	283	26.7	125	87	28	21	23.0
T_{12} – C+F_1+F_2+F_3	296	27.6	127	106	21	16	24.8
T_{13} – C+F_1+F_2+F_4	370	28	131	107	24	18	26.7
T_{14} – C+F_1+F_3+F_4	426	28.5	136	114	22	15	24.4
T_{15} – C+F_2+F_3+F_4	277	26.3	123	91	32	26	24.5
T_{16} – F_1+F_2+F_3+F_4	296	27	124	101	23	19	25.5
SE m ±	0.222	1.168	1.254	0.634	0.453	0.410	0.418
CD(0.05)	6.69	3.52	3.78	1.91	1.37	1.24	1.24

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

4.11 Yield

4.11.1 Grain yield

The data on grain yield of rice as influenced by management options are presented in Table 4.11 and illustrated in Fig.4.3.The yield recorded ranged from 2.23 to 4.94 t ha $^{-1}$with an average yield of 3.1 t ha^{-1}. There was significant variation in grain yield among the treatments. The treatment T_1 (conventional system) recorded a grain yield of 3.48 t ha^{-1} where as T_{16} (SRI) recorded 4.84 t ha $^{-1}$.

When single factor was modified, highest grain yield (4.94 t ha^{-1}) was obtained from T_3 (modified water management) which was significantly different from all other treatments and was 41.9% higher than T_1 and 2.06% higher than $T_{16.}$ When two factors were modified, T_6 (modified planting and water management) recorded highest grain yield (3.99 t ha^{-1}) which was at par with T_{10}, T_9 and T_8. It was 14.6% higher than the T_1 and 17.5% lower than $T_{16.}$ When three factors were modified, T_{13} (modified planting, water management and nutrient management) recorded highest grain yield (4.85 t ha^{-1}) which was 39.3% higher than T_1 and was at par with SRI.

Among all the treatments T_3(modified water management) recorded highest grain yield (4.94 t ha^{-1}) which was at par with T_{13} but 23.08%, and 1.85% higher than the maximum grain yield obtained when two factor and three factors were modified. The lowest grain yield(2.23 t ha^{-1})however was obtained from T_{14}(modified planting, weed management and nutrient management).

4.11.2 Straw Yield

The data on straw yield of rice as influenced by management options are presented in Table 4.11 and illustrated in Fig. 4.3. The straw yield ranged from 4.57 t ha^{-1} to 6.06 t ha^{-1} with an average of 5.6 t ha^{-1}. There was significant variation in straw yield among the treatments.

The treatment T_1 (conventional system) recorded a straw yield 6 t ha^{-1} ,where as T_{16} (SRI) recorded 5.82 t ha^{-1}. When single factor was modified, highest straw yield (6.03 t ha^{-1}) was obtained from T_2 (modified planting) which was at par with T_4 and T_5 and it was 0.5 % and 3.6% higher than T_1 and T_{16} respectively. When two factors were modified T_{11} (modified weed management and nutrient management) recorded maximum straw yield (5.99 t ha^{-1}) which was 0.16% lower than T_1 and 2.9% higher than T_{16}. When three factors were modified T_{13} (modified planting, water management and nutrient management) registered maximum straw yield (6.06 t ha^{-1}) which was 1% higher than T_1 and 4.1% higher than T_{16}.

Among all the treatments T_{13} (modified planting,weed and nutrient management) recorded highest straw yield (6.06 t ha^{-1}) which was 1% higher than Conventional system and 4.16% higher than SRI. It was 0.66% and 0.49% higher than the maximum straw yield obtained when two factors and single factors were modified respectively. T_{14} (modified planting ,weed and nutrient management) however, recorded the lowest straw yield of (4.57 t ha^{-1}).

4.11.3 Harvest index

The data on harvest index (HI) of rice as influenced by management options are presented in Table 4.11. The HI ranged from 0.33 to 0.48 with an average index of 0.40. It varied significantly among the entire treatments. In T_1 (conventional system) the HI recorded was 0.37 harvest index where as in T_{16} (SRI) it was 0.45.

When single factor was modified, maximum HI (0.47) was recorded in T_3 (modified water management) which was at par with T_2 but 27 % than higher than T_1 and 4.4% higher than T_{16}. When two factors were modified, T_{11} (modified weed and nutrient management) recorded maximum HI (0.48) which was at par with T_6 but 29.7% higher than the T_1 and 6.6% higher than T_{16}.When three factors were modified T_{13} (modified planting, water management and nutrient management) recorded maximum index (0.45) which was at par with T_{14}. It was 21.6% higher than T_1 and same as T_{16}.

Among all the treatments T_{11}(modified weed and nutrient management) recorded highest harvest index (0.48) which was 29.7% higher than Conventional system and 6.6% higher than SRI. It was 2.1% and 6.6% higher than the maximum harvest index recorded when one factor and three factors were modified, respectively. However T_{10} (modified water management and nutrient management) recorded the lowest HI (0.32).

Table 4.11. Effect of management options on yield

Treatment	**Grain yield (t ha^{-1})**	**Straw yield (t ha-^{1})**	**Harvest index**
T_1 – C	3.48	6.00	0.37
T_2 – C+F_1	4.15	6.03	0.41
T_3 – C+F_2	4.94	5.77	0.47
T_4 – C+F_3	3.14	5.22	0.37
T_5 – C+F_4	3.81	5.79	0.41
T_6 – C+F_1+F_2	3.99	5.19	0.43
T_7 – C+F_1+F_3	2.90	5.77	0.35
T_8 – C+F_1+F_4	3.89	5.98	0.40
T_9 – C+F_2+F_3	2.40	5.80	0.29
T_{10} – C+F_2+F_4	2.91	5.99	0.33
T_{11} – C+F_3+F_4	4.40	5.99	0.48
T_{12} – C+F_1+F_2+F_3	3.49	4.73	0.42
T_{13} – C+F_1+F_2+F_4	4.85	6.06	0.45
T_{14} – C+F_1+F_3+F_4	2.23	4.57	0.32
T_{15} – C+F_2+F_3+F_4	2.73	5.72	0.32
T_{16} – F_1+F_2+F_3+F_4	4.84	5.82	0.45
SE m±	0.038	0.120	0.008
CD(0.05)	0.11	0.36	0.02

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

4.12 Nutrient content

The data on nutrient content are presented in Table 4.12.

4.12.1 Nitrogen content

Nitrogen content in grain and straw revealed marked difference in some treatment due to effect of management options, with the mean nitrogen content of 1.36% in grain and 0.45% straw. However T_1 (conventional system) recorded nitrogen content of 1.28% in grain and 0.41% in straw and T_{16} (SRI) recorded 1.34% in grain and 0.50% in straw respectively. When single factor was modified T_3 (modified water management) recorded the maximum nitrogen content both in grain (1.38%) and straw (0.45%). When two factors were modified among the treatmentsT_6 (modified planting and water management) recorded highest nitrogen content both in grain (1.41%) and straw (0.49%). When three factors were modified T_{13} (modified planting, water management and nutrient management) recorded highest nitrogen content both in grain (1.41%) and straw (0.50%). However among all 16 treatments, T_{13} recorded the highest nitrogen content in grain (1.41%) and in straw (0.50%) whereas T_4 recorded the lowest(1.17% in grain and 0.39% in straw).

4.12.2 Phosphorus content

Similar to N content, P content also found to be different in some treatments due to effect of management options. The average phosphorus content was 0.35% in grain and 0.18% in straw. However T_1 (conventional system) recorded 0.23% phosphorus content in grain and 0.12% in straw where as T_{16} (SRI) recorded 0.36% in grain and 0.17% in straw. When single factor was modified among all treatments T_3 (modified water management) recorded the maximum phosphorus content both in grain (0.37%)

and straw (0.17%). When two factors were modified T_6(modified planting and water management) recorded maximum phosphorus content both in grain (0.38%) and straw (0.18%). When three factors were modified among all treatments T_{13} (modified planting, water management and nutrient management) recorded maximum phosphorus content both in grain (0.41%) and straw (0.17%) .However T_6 recorded highest among all treatments.

4.12.3 Potassium content

Difference in potassium (K) concentration in rice grain and straw was observed in some treatments due to effect of management options. The average potassium content was 0.21% in grain and 1.66% in straw. However T_1 (conventional system) recorded potassium content in 0.21% grain and 1.68 % in straw where asT_{16} (SRI) recorded 0.23% in grain and 1.64% in straw. When single factor was modified T_3 (modified water management) recorded highest potassium content both in grain (0.23%) and straw (1.77%) and when two factors were modified among all treatments T_6 (modified planting and water management) recorded maximum potassium content in grain (0.23%) and straw (1.76%). When three factors were modified among all treatments T_{13} (modified planting, water management and nutrien management) recorded highest potassium content both in grain (0.24%) and straw (1.67%) which also highest among all the sixteen treatments.

4.13 Nutrient uptake

The nutrient uptake (kg ha^{-1}) studies were made with respect to major nutrients (Nitrogen, Phosphorus and Potassium) which are presented in Table 4.13.

Nitrogen uptake

All the treatments under the influence of different management options reflected significant variation in N uptake by grain and straw. The average nitrogen uptake was

51.11 kg ha^{-1} in grain and 25.33 kg ha^{-1} in straw. However nitrogen uptake by T_1 (conventional system) was 44.54 kg ha^{-1}in grain and 23.74 kg ha^{-1}in straw, where as in T_{16} (SRI),it was 54.81 kg ha^{-1} in grain and 29.29 kg ha^{-1} in straw. When single factor was modified T_3 (modified water management) recorded maximum nitrogen uptake (68.01 and 25.97 kg ha^{-1}) by grain and straw, respectively among all other treatments when two factors were modified T_6 (modified plantind and water management) recorded highest nitrogen uptake both by grain (59.08 kg ha^{-1}) and straw (29.15 kg ha^{-1}). When three factors were modified T_{13}(modified planting, water management and nutrient management) recorded highest nitrogen uptake (68.41 and 30.30 kg ha^{-1}) by grain and straw, respectively.

Among all the treatments T13 recorded highest nitrogen uptake in grain(68.49 kg/ha) and straw(30.30 kg/ha)

Phosphorus uptake

All the treatments under the influence of different management options reflected significant variation P uptake by grain and straw. The average phosphorus uptake was 12.33 kg ha^{-1} in grain and 8.43 kg ha^{-1} in straw. However phosphorus uptake by T_1(conventional system) was 8.00 kg ha^{-1} in grain and 7.2 kg ha^{-1} in straw where in T_{16} (SRI) it was 14.72 kg ha^{-1} by grain and 10.09 kg ha^{-1} by straw. When single factor was modified T_3 (modified water management) recorded highest phosphorus uptake 18.28 kg ha^{-1} by the grain and 9.62 kg ha^{-1} by straw. When two factors were modified T_6 (modified planting and water management) recorded highest phosphorus uptake both by grain (15.78 kg ha^{-1}) and straw (10.58 kg ha^{-1}). When three factors were modified T_{13} (modified planting, water management and nutrient management) recorded highest phosphorus uptake both by grain (19.84 kg ha^{-1}) and straw (10.30 kg ha^{-1}). However among all the treatments T_{13}

recorded highest phosphorus uptake by grain(19.84 kg/ha) and straw(10.30 kg/ha).

Potassium uptake

Potassium uptake by grain and straw varied significantly among all the treatments. The average uptake was 8.25 kg ha^{-1} in grain and 94.59 kg ha^{-1} in straw. However potassium uptake by T_1 (conventional system) was 7.31 kg ha^{-1} in grain and 97.4 kg ha^{-1} in straw where as in T_{16} (SRI) recorded potassium uptake 9.41 kg ha^{-1} by grain and 95.06 kg ha^{-1} by straw. When single factor was modified among all other treatments T_3(modified water management) recorded highest uptake of potassium by the grain (11.20 kg ha^{-1}) and straw (106.40 kg ha^{-1}). When two factors were modified T_6 (modified planting and water management) recorded highest potassium uptake of 9.5 kg ha^{-1} in grain and 105.22 kg ha^{-1} in straw. When three factors were modified T_{13} (modified planting, water management and nutrient management) recorded highest potassium uptake (8.19 kg ha^{-1} and 88.47 kg ha^{-1}) in grain and straw, respectively. However T_{13}recorded highest potassium uptake in grain(11.62) and T3 recorded highest potassium uptake in straw(106.4 kg ha^{-1}) ,

4.14 Total NPK uptake

There was marked difference in total NPK uptake by different treatments due to differential management options which are presented in Table 4.14 and illustrated in Fig.4.4. The average NPK uptake by the crop was 199.95 kg ha^{-1}, however the total NPK uptake by T_1 (conventional system) was 196.86 kg ha^{-1} while in T_{16} (SRI) it was 213.38 kg ha^{-1}.

When single factor was modified T_3 (modified water management) recorded maximum NPK uptake (233.08 kg ha^{-1}) which was 15.5 % higher than T_1 (conventional system) and 8.4% higher than T_{16} (SRI). When two factors were modified T_6 (modified planting and water management and nutrient management) recorded maximum NPK uptake (229.32kg ha^{-1}) which was 14.15% higher than T_1 (conventional system) and 6.9% higher

Treatment	Nitrogen(%)	Phosphorous(%)	Potassium(%)

than T_{16} (SRI). When three factors were modified maximum NPK uptake (239.85 kg ha^{-1}) was recorded by T_{13} (modified planting, water management and nutrient management) which was 17.9% higher than T_1 (conventional system) and 11.03% higher than T_{16} (SRI).

Among all the treatments T_{13} (modified planting,weed and nutrient management) recorded highest NPK uptake (239.85 kg ha^{-1}). It was 17.9% higher than conventional system and 11.03% higher than SRI,but was at par with T_3 and T_6.

	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T_1 – C	1.28	0.41	0.23	0.12	0.21	1.68
T_2 – C+F_1	1.28	0.42	0.32	0.16	0.22	1.73
T_3 – C+F_2	1.38	0.45	0.37	0.17	0.23	1.77
T_4 – C+F_3	1.17	0.39	0.23	0.12	0.19	1.68
T_5 – C+F_4	1.25	0.41	0.27	0.15	0.21	1.71
T_6 – C+F_1+F_2	1.41	0.49	0.38	0.18	0.23	1.76
T_7 – C+F_1+F_3	1.26	0.43	0.28	0.14	0.18	1.61
T_8 – C+F_1+F_4	1.31	0.45	0.33	0.16	0.22	1.68
T_9 – C+F_2+F_3	1.26	0.43	0.31	0.15	0.19	1.66
T_{10} – C+F_2+F_4	1.34	0.46	0.37	0.15	0.23	1.73
T_{11} – C+F_3+F_4	1.21	0.42	0.23	0.14	0.17	1.51
T_{12} – C+F_1+F_2+F_3	1.31	0.47	0.31	0.15	0.21	1.63
T_{13} – C+F_1+F_2+F_4	1.41	0.52	0.41	0.17	0.24	1.67
T_{14} – C+F_1+F_3+F_4	1.23	0.44	0.25	0.13	0.19	1.55
T_{15} – C+F_2+F_3+F_4	1.28	0.46	0.29	0.13	0.19	1.55
T_{16} – F_1+F_2+F_3+F_4	1.34	0.50	0.36	0.17	0.23	1.64
SE m±	0.008	0.01	0.006	0.83	0.006	0.08
CD(0.05)	0.02	NS	0.02	NS	0.02	NS

Table 4.12. Effect of management options on Nitrogen ,Phosphorous and Potash content

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

Table 4.13.Effect of management options on Nitrogen,Phosphorus,Potassium Uptake(kg ha^1)

Treatment	**Nitrogen**		**Phosphorus**		**potassium**	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T$_1$ – C	44.54	23.74	8.00	7.20	7.31	97.4
T$_2$ – C+F$_1$	52.98	25.33	13.14	9.07	8.72	101.51
T$_3$ – C+F$_2$	68.01	25.97	18.28	9.62	11.20	106.40
T$_4$ – C+F$_3$	36.84	20.18	7.22	6.09	5.97	89.09
T$_5$ – C+F$_4$	47.75	24.4	10.29	8.84	8.51	100.01
T$_6$ – C+F$_1$+F$_2$	59.08	29.15	15.78	10.58	9.50	105.22
T$_7$ – C+F$_1$+F$_3$	45.23	24.75	10.05	8.00	6.25	92.90
T$_8$ – C+F$_1$+F$_4$	50.44	26.35	12.71	9.17	8.47	99.12
T$_9$ – C+F$_2$+F$_3$	48.13	25.35	11.81	8.46	7.24	96.28
T$_{10}$ – C+F$_2$+F$_4$	54.40	27.51	15.06	9.28	9.23	101.40
T$_{11}$ – C+F$_3$+F$_4$	42.10	24.23	7.98	7.89	6.10	90.50
T$_{12}$ – C+F$_1$+F$_2$+F$_3$	50.18	26.5	11.90	7.10	8.19	88.47
T$_{13}$ – C+F$_1$+F$_2$+F$_4$	68.41	30.30	19.84	10.30	11.62	99.38
T$_{14}$ – C+F$_1$+F$_3$+F$_4$	44.65	20.11	8.98	5.94	6.92	73.32
T$_{15}$ – C+F$_2$+F$_3$+F$_4$	50.18	22.07	11.50	7.25	7.32	76.17
T$_{16}$ – F$_1$+F$_2$+F$_3$+F$_4$	54.81	29.29	14.72	10.09	9.41	95.06
SE m±	0.637	0.962	0.428	6.074	0.430	3.114
CD(0.05)	1.92	2.90	1.92	NS	1.29	NS

c-Conventional,F$_1$-Planting technique,F$_2$-Water management,F$_3$-Weed management,F$_4$-Nutrient management

Table 4.14. Total Nitrogen, Phosphorus and potassium uptake(kg ha-^{1})

Treatment	**Nitrogen (kg ha^{-1})**	**Phosphorus (kg ha^{-1})**	**Potassium (kg ha^{-1})**	**TOTAL**
T_1 – C	68.94	15.20	105.9	196.86
T_2 – C+F_1	78.31	21.99	111.21	210.51
T_3 – C+F_2	93.97	27.89	113.71	233.08
T_4 – C+F_3	57.03	13.31	95.05	165.39
T_5 – C+F_4	71.49	19.36	110.22	197.82
T_6 – C+F_1+F_2	88.23	26.36	114.72	229.32
T_7 – C+F_1+F_3	69.98	19.33	99.72	191.70
T_8 – C+F_1+F_4	76.79	21.16	107.59	205.54
T_9 – C+F_2+F_3	73.48	19.81	102.38	201.93
T_{10} – C+F_2+F_4	81.91	24.23	99.72	205.86
T_{11} – C+F_3+F_4	66.34	15.87	98.95	181.15
T_{12} – C+F_1+F_2+F_3	72.25	19.00	95.79	191.21
T_{13} – C+F_1+F_2+F_4	98.71	30.15	111.00	239.85
T_{14} – C+F_1+F_3+F_4	64.76	14.92	81.51	162.76
T_{15} – C+F_2+F_3+F_4	76.68	18.74	83.08	172.76
T_{16} – F_1+F_2+F_3+F_4	84.10	24.81	104.47	213.38
SE m$\pm$	4.470	1.626	3.299	7.573
CD(0.05)	13.47	4.90	9.94	22.83

c-Conventional,F_1-Planting technique,F_2-Water management,F_3-Weed management,F_4-Nutrient management

4.15 Economics

Studies on economics of production was carried out by keeping a record on operations carried out, number of man days, power and inputs utilized. The cost of production and return were calculated by using the prevailing market price. The data so obtained are presented in Table 4.15illustrated in Fig.4.5.

Cost of production

Different management options registered difference in cost of production. The mean cost was Rs. 30023 ha^{-1}. T_1 (conventional system) accounted an expenditure of Rs. 31048 ha^{-1} and T_{16} (SRI) Rs. 33566 ha^{-1}. When single factor was modified T_5 (modified nutrient management) recorded the highest cost of production (Rs.36556 ha^{-1}) where as T_4 (modified weed management) recorded the lowest (Rs. 29358 ha^{-1}). When two factors were modified T_{10} (modified water management and nutrient management) recorded the highest cost of production (Rs. 36008 ha^{-1}) where as T_7 (modified planting and weed management) recorded the lowest cost of production Rs. 27338 ha^{-1}. When three factors were modified T_{15} (modified water management, weed management and nutrient management) recorded highest cost of production (Rs. 35126) where as T_{12} (modified planting, weed management and water management) recorded the lowest (Rs. 28850 ha^{-1}) among all other respective set of treatments. Among all the treatments T_5 accounted for highest cost of production which was Rs. 5516 and Rs. 2990 higher than that of conventional system and SRI, respectively where as it was Rs. 548 and Rs. 1430 higher than highest cost of cultivation involved in treatments following two factors modification T_{10} and three factors modification T_{15}, respectively.The treatment T_7 recorded the lowest cost of production(Rs. 27338 ha-1) which was Rs.3702 less than conventional system and Rs.6228 lower than SRI.

Gross return

Differences in gross return were marked clearly due to effect of management options. The average gross return was Rs. 46583 ha^{-1}. T_1 (conventional system) realised gross return of Rs. 43848 ha^{-1} and in T_{16} (SRI) it was of Rs. 60984 ha^{-1}. When one factor was modified T_3 (modified water management) recorded highest gross return (Rs.62294 ha^{-1}) which was 42% higher than T_1 (conventional system) and 2.15% higher than T_{16} (SRI). When two factors were modified T_{11} (modified weed and nutrient management) recorded highest return (Rs. 55440 ha^{-1}) which was 26.4% higher than T_1 (conventional system) and 10 % lower than T_{16} (SRI). When three factors are modified T_{13} (modified planting, water management and nutrient management) recorded highest return (Rs. 61110 ha^{-1}) which was 39.3% higher than T_1 (conventional system) and 0.20 % higher than T_{16} (SRI).

Among all the treatments T_3 realized highest gross return(Rs.62244) among all the treatments. which was Rs. 6804 and Rs. 1134 higher than highest gross return obtained from treatments following two factors modification T_{11} and three factors modification T_{13}, respectively.

Net return

The differences in net return were observed due to different management options. The average net return among all the treatment was Rs. 14905 ha^{-1}. T_1 (conventional system) realised a net return of Rs. 12808 ha^{-1} where as in T_{16} (SRI) it was and Rs. 27418 ha^{-1}. When single factor was modified T_3 (modified water management) recorded highest net return

(Rs.30952 ha^{-1}) which was 141.7 % higher than T_1 (conventional system) and 12.8 % higher than T_{16} (SRI). When two factors were modified T_6 (modified planting and water management) recorded highest net return (Rs. 21802 ha^{-1}) which was 158 % higher than

T_1 (conventional system) and 20.9 % higher than T_{16} (SRI). When three factors were modified T_{13} (modified planting, water management and nutrient management) recorded highest net return (Rs. 26662 ha^{-1}) which was 108.1% higher than T_1 (conventional system) and 2.7% lower than T_{16} (SRI). Among all the treatments T_{11} realized highest net return among all the treatments which was Rs. 20358 and Rs. 5748 higher than T_1 and T_{16} respectively, where as it was Rs. 2214 and Rs. 6504 higher than highest gross return realized from treatments following single factor modification T_3 and three factors modification T_{13}, respectively.

Table 4.15. Effect of management options on economics

Treatment	Economics (Rs. ha^{-1})			
	Cost of production	Gross Return	Net Return	Benefit: Cost
T$_1$ – C	31040	43848	12808	1.41
T$_2$ – C+F$_1$	28220	52290	24070	1.85
T$_3$ – C+F$_2$	31292	62244	30952	1.98
T$_4$ – C+F$_3$	29358	39564	10206	1.35
T$_5$ – C+F$_4$	36556	48006	11450	1.31
T$_6$ – C+F$_1$+F$_2$	28472	50274	21802	1.77
T$_7$ – C+F$_1$+F$_3$	27338	36540	9202	1.34
T$_8$ – C+F$_1$+F$_4$	32936	49014	16078	1.49
T$_9$ – C+F$_2$+F$_3$	30410	30240	-170	0.99
T$_{10}$ – C+F$_2$+F$_4$	36008	36666	658	1.02
T$_{11}$ – C+F$_3$+F$_4$	34874	55440	20566	1.58
T$_{12}$ – C+F$_1$+F$_2$+F$_3$	28850	43974	15124	1.52
T$_{13}$ – C+F$_1$+F$_2$+F$_4$	34448	61110	26662	1.77
T$_{14}$ – C+F$_1$+F$_3$+F$_4$	28314	28098	-216	0.99
T$_{15}$ – C+F$_2$+F$_3$+F$_4$	35126	34398	-728	0.98
T$_{16}$ – F$_1$+F$_2$+F$_3$+F$_4$	33566	60984	27418	1.82

C- Conventional, F$_1$- Planting technique, F$_2$- Water management, F$_3$- Weed management, F$_4$- Nutrient management

Benefit -cost ratio

Different management options registered difference in B-C ratio. The B-C ratio was 1.41 in T_1 (conventional system) and 1.82 in T_{16} (SRI) when single factor was modified T_3 (modified water management) realised maximum B-C ratio (1.98), When two factors were modified T_6 (modified planting and water management) recorded maximum B-C ratio 1.77 and when three factors were modified T_{13} (modified planting, water management and nutrient management) recorded maximum B-C ratio (1.77).

Among all the treatments T_3 realised highest B-C ratio of 1.98 which was 40.5% higher than T_1 and 8.8 % higher than T_{16}. Whereas it was 11.8 % higher than maximum B-C ratio obtained from treatments following two factor modification (T_6) and three factors modification (T_{13}), respectively.

DISCUSSION

The experiment entitled ―"Management options in modified system of rice intensification (SRI) during Summer season" was conducted in Agronomy research farm of the College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar during the summer season of 2014, to study the effect of modification of different management principles in system of rice intensification. Four management options in modification of planting technique (age of seedling, number of seedlings per hill and spacing), water management, weed management and nutrient management were assigned to sixteen treatments in different combination. The treatment was formulated by taking the conventional system and SRI as sole, and with single factor modification, double factors modification and triple factors modification considering the four stated management principles as individual factor. A spacing of 25 cm X 25 cm was maintained in modified weed management while 15 cm X 10 cm was followed in all other treatments. The experiment was carried out with three replications for better investigation. Rice variety Lalat of maturity duration (120-125 days) was taken for this experiment. The soil of the experimental site was sandy loam in texture, near neutral in reaction (pH 6.2), low in organic carbon (4.2 kg ha^{-1}), medium in available nitrogen (365.2 kg ha^{-1}),and potassium(253.3 kg ha^{-1}) high in available phosphorus (46.2 kg ha^{-1}). The experiment was laid out in a randomized block design with sixteen treatments and three replications.

The data on growth parameters and yield attributes at different period of crop growth and at harvest, weed count, post harvest observations, grain and straw yield, nutrient content and uptake as well as economics of the production as influenced by management options are presented in the preceding chapter. In this chapter however an attempt has been made to assign possible scientific reasons and discuss the findings so as to establish the cause and effect relationship in different treatments for variation in aforesaid parameters resulting from the effect of management options.

5.1 Crop and weather

Temperature, solar radiation (light intensity and duration) and relative humidity significantly influence and control the growth as factors of weather elements. It accounts for 76 per cent of variation in crop productivity (Ram Krishna et al., 2000). Rice plant is highly adoptable to its environment and can grow under variety of seasonal variations. However, higher yield can only be achieved with optimum interplay of various weather elements, a condition of atmosphere at a given time and space.

Rice is considered as a tropical region crop, comprises of tropic of Cancer ($23^0$27' NL) and tropic of Capricorn (23^0 27' SL). The experimental site (20^0 15' NL) being close to the tropical region provides a typical environment for the growth of the plants. Extreme temperatures are destructive for plant growth. Depending on growth stages, injury to rice may occur when the daily mean temperature drops below 20^0C or rise above 35^0C (Yoshida, 1981). During the period of rice growth, the average daily temperature ranged between 29.7^0c to 39.4^0C. Both the maximum (T_{max}) and minimum (T_{min}) temperatures govern the growth as well as the yield of rice. Rice crop require average temperature of 26.5^0C to 29.5^0 for blooming but during that period the average temperature of 31.7^0C was recorded. This might be the reason for increased sterility and low yield.

The crop received 397.5 mm of rainfall in 31 days during the experimental period. Highest rainfall of 202 mm was received during June in 6 days which was 62.6% lower than the normal rainfall in last 10 years which acted as a barrier in fertilization and grain filling resulting higher number of chaffy grains per panicle. The lowest rain fall of 9.4 mm in 1 day in April. During May highest rainfall(202 mm) were received which maximum attention was paid on draining out the water in the plots where practice was modified water management to prevent standing water and thereby maintaining saturation. Quantitatively, the total rainfall was not sufficient to meet the water need of the crop and unequal distribution necessitated the need of proper management at times.

Bright sunshine is the source of energy to produce and accumulate food in different sinks at different times of growth. Moomaw and Vergara (1964) reported that the accumulated sunshine hours should be around 240 hrs from flower initiation to physiological maturity for higher dry matter accumulation in rice grains. The mean bright sunshine hours ranged from 4.7 hours in January to 7.8 hrs in May which is justify the yield.

Angladette (1966) considered a range of 72-80 per cent relative humidity as the favourable range for growth and production of rice. During the cropping season the relative humidity ranged from 87-92 per cent during forenoon hours and 40-68 per cent during afternoon hours.which is little higher than the normal. The average evaporation was 4.4 mm per day. The average wind velocity was normal (5.06 km hr^{-1}) during the crop growth period but higher mean wind velocity (8 km hr^{-1}) during grain filling period must have resulted failure in fertilization leads to increased chaffyness/ sterility.

5.2 Growth and development

Crop is an organism which is grown for obtaining high yield. Normally growth of a plant is the permanent and irreversible increase in size and form and it differs from the plant grown individually and that under a community where it is influenced by mutual interference of resources. Development, on the other hand, is passing of the plant through successive morphological stages (Mohanty, 2011)

The magnitude of growth of a plant is the result of expression of greater potential under a set of environmental conditions like soil and its nutrient status, soil moisture regime, solar radiation, day length and temperature besides management practices. Elongation of plant (plant height), tiller number, leaf area index, dry matter accumulation are the most important growth parameters recorded under the present investigation at 15 days interval commencing from 15 days after transplanting (DAT) till harvest.

Growth in height, irrespective of modification in management practices continued till maturity stage following the general relationship between growth and time. The growth in height was maximum (2.1 cm per day) between 15 to 30 DAT. Low light intensity might have induced more auxin production which, as an growth hormone, resulted better growth in height.

The growth in height was rapid up to 60 DAT followed by a period of slow growth. The increased height coincided with the panicle initiation to flowering stage of the crop growth. During the reproduction growth phase speedy segregation of nodes and elongation of internodes must have resulted further elongation of plant height up to 60 DAT. Thereafter the rate of elongation decreased due to diversion of photosynthesis from vegetative to reproductive parts and subsequently accumulated as starch in grains which is the major economic part of the rice plant. Mohmud et al. (2012) also observed an progressive increase in plant height up to flowering.

Maximum plant height (123.1 cm) was recorded when conventional system was modified with respect to water management. This was 3.57% higher than conventional system and 8.2% higher than SRI where as 0.56% and 0.86% higher than the highest plant height obtained when two factors and three factors were modified respectively. Saturation resulted aerobic condition which facilitated better root growth there by more nutrient uptake resulting taller plant. However when two factors were modified maximum plant height(122.4cm) noticed in modified planting technique and water management due to the difference in age of seedling at the time of planting as 21 days older seedlings grow significantly taller than 12 days old seedlings at the initial stage. Later on as the age of the plant advanced the rate of increase in height of older seedlings declined,whereas on the other hand the younger seedlings of 12 days old maintained higher rate of increase.When three factors were modified maximum plant height (113.3cm) noticed in modified planting technique,water management and nutrient management. Wider spacing followed in weed management which facilitate easy cono-weeding operation resulted more root growth might have penetrated deep into soil to exploit more nutrients and water resulting in increased height. Haque (2002) found the highest plant height from wider spacing. Similar results were also reported by Akita and Tanka (1992).

The number of panicles per unit area depends largely on the number of tillers. The development of tillers during the tillering stage therefore is important for the yield of rice. (Matsuo and Hoshikawa, 1993).

In the present experiment that tillering continued till 45 DAT and then decreased up to harvest. The decline in tiller number would have occurred due to mortality of the late formed tillers. The rate of tiller production was highest during 15-30 DAT which reduced to a negative figure up to harvesting stage. This was because the tillers developed in early growth stages grew vigorously, produced panicle and finally contributed to the yield as productive tillers. Matsuo and Hoshikawa (1993) also observed similar results.

Maximum tillers (563m^{-2}) were recorded when conventional system was modified with respect to planting technique, water management and nutrient management practices. This was 17.5% higher than conventional system and 6.9% higher than SRI. It was 21.3% and 17.4% higher than the maximum tillers m^{-2} obtained when two factors and three factors were modified, respectively..

When single seedlings of 12 days old were planted could produce more tillers due to more phyllochrons, proper root growth and nutrition avoiding competition as in conventional closer planting. But when total number of tiller per unit area was considered. Closer spacing produced more tillers. This was because more number hills (66 m^{-2}) were planted with closer spacing (15 cm X 10 cm) as against 16 hills m^{-2} with wider spacing (25 cm X 25 cm). It can be concluded that higher spacing increase the number of tillers hill^{-1} but total number of tillers per unit area was found to be low because of decrease in the number of plants per square meter. Mazid et al., (2003) also found same results.

When single factor was modified conventional system with respect to modified water management recorded highest tillers m^{-2} (464), field saturation created aerobic situation which favours more tillers per hill than continuous flooding and when two factors were modified conventional system with respect to modified planting method and water management recorded highest tillers m^{-2} (524). More numbers of total tillers were noticed with 12 days old seedlings because younger seedlings have more number of phyllochrons for massive tillering (Uphoff, 2002). Higher effective tillers m^{-2} was recorded in inorganic nutrient management than organic sources. This is due to faster nitrogen supply during active tillering stage as nitrogen plays an important role in increase number of tillers (Sravankumar et al., 2008).

Root volume play vital role in higher growth and biomass production. The root volume hill^{-1} showed progressive increase up to 75 DAT and then gradually declined up to harvest. Maximum root volume hill^{-1} (72.41 cc) was recorded at harvest when conventional system was modified with respect to planting, water management and nutrient management. This was 60% higher than conventional system and 23% higher than SRI. The treatment following modified weed management recorded lowest root volume (34.42 cc) hill^{-1} at harvest. When only one factor was modified highest root volume (63.43 cc) was recorded with modified water management. When two factors were considered highest root volume (69.32 cc) was noticed with respect to modified nutrient and weed management.Seedlings of 12 days old seedling with single seedling per hill recorded less root volume than the 21 days old seedling with three seedlings per hill up to 30 DAT, but after that inverse relation were found till harvest. This is confirming with Uphoff (2002). Additionally, saturation condition might have favoured root activity due to proper aeration which might have been further facilitated by running of cono-weeder. Proliferative root growth been further facilitated by organic nutrient management.

The higher productivity of a crop depends on the persistence of high LAI over a greater part of its vegetative phase. The rate of photosynthesis depends on the LAI. After germination LAI increases and reaches the peak levels and then declines due to increase senescence (Katiya, 1980). LAI increased up to 45 DAT and then declined. It was highest at 45 DAT.

Till flowering the leaf growth was very active which must have resulted in accumulation of photosynthates for transmission to sink during the grain filling to ripening stage of the crop. The gradual decline in leaf growth after 60 DAT might be due to death of some ineffective tillers resulting in shortage of solar radiation required to carry out photosynthetic activity. To compensate this shortage of solar radiation it is often advised to keep standing water during the late reproductive stage (flowering to maturity) so that solar radiation being intercepted by foliage and touching the water surface would reflect back and that reflected solar energy would be utilized to carry out photosynthesis by the lower leaves to a great extent.

When only one factor was modified maximum LAI (9.42) was noticed due to modified water management. This might be due to saturation resulting better root growth leading to better nutrition and biomass production. When two factors were modified highest LAI (9.91) was recorded by modified weed and nutrient management. When three factors were modified highest LAI (9.92) was however recorded when conventional system was modified with respect to planting method, water management and nutrient management. This produced highest LAI among all the treatments. This was 6.09% higher than conventional system and 104.9% higher than SRI. This might be due to leaf production was significant but towards later part higher LAI was recorded under 12 days old seedlings. This might be due to increased tillering in young seedlings. This corroborated the earlier findings of Kumar and Shivay (2004).

Higher LAI was observed from closer spacing than the wider spacing this might be due to more number of plants per unit area. This finding was also supported by Shrirame et al., (2000).

Investigations on dry weight of weed at different growth stage were recorded. It was observed that the weed population reduced after 45 DAT due to wider canopy. Minimum weed dry weight (4.4 g m^{-2}) resulted from modified water management which was at par with modified planting. weed population more in organic nutrient management due to lower biomass production,plots treated with herbicide initially resulted less weed than cono weeding plots.

Rate of dry matter accumulation is the product of total incident solar radiation, the absorption of incident solar radiation by the crop canopy, and the efficiency of conversion of absorbed solar radiation into plant dry matter (www.uoguelph. ca/plant/ courses/ pbio-3110/lectures).

Results on dry matter production indicated that it increased as the crop growth advanced. When only one factor was considered maximum dry weight (2514 g m^{-2}) was produced when conventional system was modified with respect to water management. Saturation condition must have favored better root activity due to proper aeration resulting higher nutrition and biomass production. Accumulation was highest (2807 g m^{-2}) when conventional system was modified with respect to modified planting and water management. This was 24.4% higher than conventional system and 101.7% higher than SRI. At harvest it was 11.6% and 6.04% higher than the maximum dry weight obtained when single factor and three factors were modified respectively.

Shrirame et al., (2000) reported that the number of functional leaves, leaf area and total number of tillers hill^{-1} were higher at wider spacing which increased the photosynthetic rate leading to higher dry matter accumulation. But due to less plant population m^{-2} the dry matter production was quite less than closer spacing. Seedlings of 21 days old due to well grown seedlings that to with higher plant population with 2-3 seedlings hill^{-1} recorded highest dry matter at 15 DAT but thereafter more dry matter at production was noticed from younger seedling with one seedlings hill^{-1} might be due to more phyllochron development and tiller production.

When the weeding factor was added, in modified weed management the plant population was less due to wider spacing maintained to facilitate cono weeding; this resulted lower biomass production (1266 g m^{-2}) per unit area. Therefore maximum dry matter (2647 g m^{-2}) was produced when conventional system was modified with respect to planting method, water management and nutrient management. But it was less than the treatment receiving inorganic nutrition. From the investigation it was cleared that the inorganic sources of nutrient than organic source, Especially N plays an important role in vigorous vegetative growth resulting with high dry matter accumulation.

The crop growth rate was maximum (49.5 g m^{2} day^{-1}) between 45-60 DAT and the minimum at ripening stage (3.9 g m^{2} day^{-1}). Verma et al. (2008) noticed an increase in Crop growth rate (CGR) only up to 60 DAT and there after decreased with crop age.

The crop growth rate at harvest was highest (14.4 g day^{-1}) when conventional system was modified with respect to modified planting method and was at par with modified weed and nutrient management. This was 10.2% higher than conventional system and 148% higher than SRI. It was 30.9% and 20.12% higher than the maximum dry weight obtained when single factor and three factors were modified, respectively.

Highest CGR recorded in 12 days old seedling has the maximum potential of tillers with inorganically managed plot than organically managed due to higher N use efficiency and maximum biomass production. wider spacing produced higher no. of tillers m^{-2} and high drymatter accumulations. Saturation resulted higher CGR than flooding irrigation because of higher dry matter production due to better root activity and nutrition.

It is measured as the mass increases per aboveground biomass per day. The relative growth rate gradually declined from 15 DAT to harvest stage. Maximum RGR (0.101 g g^{-1} day^{-1}) was recorded at 15-30 DAT. Maximum relative growth rate (0.019 g g^{-1} day^{-1}) was recorded by conventional system at 60-75 DAT. There was no significant effect of various treatments on RGR after 75 DAT. Maximum RGR was recorded by closer spacing and inorganically fertilization. This is because of higher rate of biomass production.

5.2 Yield and yield attributes

Yield is a function of the yield attributes of a plant. The major yield contributing characters are number of ear bearing effective tillers, number of grains per panicle, percent filled grains per panicle and test weight. Usually, there exists a positive relation of these parameters with yield. But, this is not always true as negative correlation may also exist beyond a certain level.

Number of effective tillers per unit area is the primary attribute for obtaining good yield in rice as yield is function of number of ear bearing tillers per unit area. Among all the treatments highest number of effective tillers (431) m^{-2} was noticed when conventional system was modified with respect to water management which was 29% higher than conventional system and 45% higher than SRI. It was even higher than the other treatments when additional factors were modified . The reason for more number of effective tillers might be due to higher leaves m^{-2}, higher LAI resulting in increased photosynthetic ability and dry matter accumulation as well as slow release and effective absorption of mineral nutrients due to favourable soil condition in non-flooded aerated situation because of profused root growth.

Higher effective tillers per unit area recorded from younger seedling with one seedling $hill^{-1}$ and from closer spacing. When single factor was modified conventional system with respect to modified water management recorded highest tillers m^{-2} (431), field saturation created aerobic situation which favours more tillers per hill than continuous flooding and when two factors were modified conventional system with respect to modified planting method and water management recorded highest tillers m^{-2} (384). More numbers of total tillers were noticed with 12 days old seedlings because younger seedlings have more number of phyllochrons for massive tillering (Uphoff, 2002). Higher effective tillers m^{-2} was recorded in inorganic nutrient management than organic sources. This is due to faster nitrogen supply during active tillering stage as nitrogen plays an important role in increase number of tillers (Sravankumar et al., 2008).

Gasparillo et al., (2001) noted significant variation of panicle length between the SRI and non-SRI methods. Chowhan (2003) and Hossain et al., (2003) reported that the SRI produced the highest panicle length than the conventional planting method. Maximum panicle length (34.1 cm) was observed when conventional system was modified with water management. However shortest panicle (21.7 cm) was noticed when conventional system was modified with respect to planting technique and nutrient management and organics produced the shortest panicles this may be due to insufficient nutrient supply from organic sources as and when needed.

The total number of grains per panicle (filled grains) is an important factor which contributes towards grain yield. The mean value of grains per panicle and sterility percent were 100.5 and 21.5%, respectively. Maximum number of grains per panicle (140) was recorded when conventional system was modified with water management, which was 10.2% higher than the conventional system and 12.9% higher than SRI. Minimum sterility percent (8%) was noticed from modified water management practices. The sterility percent increased with addition of factors and with modified nutrient management, sterility was highest (29%) in combination of modified planting and modified weed management. It was observed from different combination of management options that modified nutrient management reduced number of grains per panicle with high sterility percent. Insufficient nutrient supply from organic sources must have adversely affected grain filling to which the inorganically grown treatments.Profuse root growth under non flooded condition and release of nitrogen from inorganics might have helped in achieving more filled grains per panicle. The increase in shoot dry matter production might have supported improvement in yield components and filled grains per panicle. Better translocation permitting situations of accumulated photosynthates for grain filling might be also one of the reasons of more grains per panicle.

Grain weight, an important yield determining component, is a genetic character least influenced by environment (Ashraf et al., 1999). However favourable environment at grain filling stage ensures higher grain weight.1000-grain weight reportedly varied from 22.5g when conventional method was modified with respect to weed management to 26.8g in modified planting and water management practices . Hosaain et al., (2003) observed higher 1000-grain weight under SRI compared to farmer‘s practices. 1000-grain weight (26.17 g) was noticed with modified weed and nutrient management. When three factors were modified maximum 1000-grain weight (26.7g) was noticed with modified planting, water management and nutrient management. During the study it was observed that though sterility percentage was affected by climatic hazards but the 1000-grain weight remained unaffected. But the 1000-grain weight varied significantly with the combination of different management options. It was observed that organically treated plots resulted lower 1000-hrain weight than the inorganically treated ones, this might be due to assimilation of photosynthates or translocation of plant synthates could not be proper with organic nutrient management. Higher 1000-grain weight was observed in wider spacing than the closer spacing. Aziz and Hasan (2000) reported higher 1000-grain weight with wider spacing.

Grain yield is a function of interplay of various yield components such as a number of productive tillers per unit area, spikelets per panicle and 1000-grain weight. It is also a cumulative effect of several growth regulating factors consisting mainly of genetic, environmental and management aspects dovetailed one into other to meet the optimum need of the crop at different stages of growth. Maximum grain yield (4.94 t ha^{-1}) was recorded when conventional system was modified with respect to water management , which was 41.9% higher than Conventional system and 2.06% higher than SRI. When two factors are modified maximum grain yield (3.99 t ha-1) was recorded with modified planting and water management practices. However when three factors are modified maximum grain yield of(4.85 t ha-1) which were 14.6%,39.3% higher than conventional and 17.5% higher than SRI,and at par with SRI,respectively.

Seedling of 21 days produced 8.7% higher grain than 12 days seedlings. This could be possibly due to significantly more number of ear bearing tillers, total grains and filled grains per panicle may be due to summer season .However contradiction results have also been reported by Patel et al., (2008).But Jati (1999) also opined that seedling number did not have much bearing on yield attributes and yield of rice crop. However, 34.6% higher grain yield of was obtained from closer spacing of 15 cm X 10 cm than wider spacing of 25 cm X 25 cm because of higher plant population that resulted more number of panicle bearing tillers per unit area though the size of the panicle and number of filled grains per panicle is less.As a result closer plant spacing gave higher yield in comparison with wider spacing. Similar results were reported by Karmakar et al. (2004). Wider spacing increased yield per plant, but lead to a decrease in grain yield per unit area (Zadeh and Mirlohi, 1998; Bist et al., 1999; Wu et al., 1997; Lie et al., 1997). Modified water management practices produced 8.9% higher yield than the flooding method where as inorganically managed plot resulted 30% higher yield than modified nutrient management may be due to climatic compulsion in summer. When only one factor was modified the contribution of the factors was higher than their average contribution when combined with other factor because when more than one factor was modified, their contribution was shared.When conventional system was modified by one factor only, their effect on yield was significantly different from other treatment with modifications.

The low yield in treatments with modified weed management due to poor plant stand because of wider spacing to facilitate cono-weeding.

It was observed that conventional nutrient management with more number of seedlings per hill and 21 days old seedling with field saturation by modified water management and weed management, resulted maximum straw yield (6.06 t ha^{-1}) which was 1% higher than Conventional system and 4.12% than SRI. This might be due to faster availability of nutrient especially from inorganic source immediately after application of fertilizer which in turn resulted in higher straw weight than grain weight. This was also supported by Pandey (2013) in line of findings of Yoshida (1977). Higher seedling per hill and closer spacing resulted more straw yield. Similar observations were also reported by Husain et al, (2003) and Roknuzzaman (1997).

Therefore when conventional system when modified with SRI principles produced highest grain yield (4.94 t ha-1) with sraw yield (5.77 t ha-1),(334) no.of effective tillers and 26.9 g 1000 grain weight.

Maximum harvest index (0.48) was noticed in conventional system with modified weed and nutrient management which was 29.7% higher than Conventional system and 6.6% higher than SRI. Modified water management and nutrient management lowest index (0.29). Maximum harvest index because of higher grain yield might have resulted due to proper availability of nutrient in all the growth stages by inorganic sources which ultimately led to higher LAI, high dry matter accumulation, higher panicle bearing tillers per unit area and more number of filled grains per panicle.This is in confirmity of findings of Roknuzzaman (1997).

Nutrient content and uptake

Conventional system recorded nitrogen content (1.28%) in grain and in straw

(0.41%) where as SRI system recorded 1.34% in grain and 0.50% in straw. where as highest nitrogen content in grain(1.41%) and straw(0.50%) recorded when conventional system modified with respect to planting technique,water and nutrient management. This might be due to the younger seedlings produced new roots (Rao and Raju,1987) for better nitrogen uptake consistently from organic nutrients which must have reduced compaction,improved soil structure by increasing porosity and reducing bulk density(Hansen,1996),saturated soil condition also must have made the soil condition more favourable towards nitrogen uptake due to proper aeration.

Conventional system recorded phosphorus 0.23% in grain and 0.12% in straw while SRI recorded 0.36% in grain and 0.17% in straw. Maximum phosphorus content both in grain (0.38%) and straw (0.18%) was recorded from modified planting and water management practices. This must be due to profused root system consistently produced by young seedlings which have become more active under favourable moisture status by modifying the water management and maintain saturation. Reddy and Murthy (1988) reported that high phosphorus content in grain was an indicative of preferential migration of this nutrient.

Conventional system recorded potassium content (0.12%) in grain and (1.68%) in straw, SRI recorded (0.23%) in grain and (1.64%) in straw. Highest potassium content in grain (0.23%) and in straw (1.77%) was recorded when conventional system was modified with respect to water management practice. Higher potassium content in straw than grain indicated the lesser migration of this nutrient. Rao and Raju (1987) and Sonj et al., (1990) had explained the effect in the light of active root system, profused root growth and continuously availability of nutrients resulting in higher nutrient content.

The uptake of nitrogen was 44.54 kg ha^{-1} in grain,23.74 kg ha^{-1} in straw ,phosphorus, 8 kg ha^{-1} in grain,7.2 kg ha^{-1} in starw and potassium 21 kg ha^{-1} in grain and

97.4 kg ha^{-1} in straw in conventional system,however in SRI nitrogen uptake was 54.81 kg ha^{-1},29.29kg ha^{-1} in grain and straw,14.71 kg ha^{-1},10.09 kg ha^{-1}) phosphorus in grain and straw and ,9.41 kg ha^{-1},95.06 kg ha^{-1}potassium in grain and straw respectively.

Highest nitrogen ,phosphorus, potassium uptake in grain(30.30 kg ha^{-1},19.84 kg ha^{-1} and 11.62 kg ha^{-1}) were recorded when conventional system was modified with respect to planting, water and nutrient management, and was at par with modified water management because of moreover higher grain yield was noticed with this management practices. However highest uptake of nitrogen and phosphorus in straw (30.30 kg ha^{-1},10.30 kg ha^{-1}) was noticed when conventional system was modified with respect to planting, water and nutrient management practices due to higher straw yield. But highest potassium uptake in straw(106.4 kg ha^{-1}) was recorded with modified water management practices, but not significantly different from others. However highest total NPK uptake 239.85 kg ha^{-1} was recorded as (modified planting,weed and nutrient management). Morita and Yamazaki (1993) have also shown through a series of photos on the effect of compost application on root systems of rice, suggesting an increase in fine roots that has probably caused by the need to capture slow releasing nutrients from the compost.

5.4 **Economics**

The economics of production is the most important aspect of the study since no farmer shall follow a practice that is not remunerative even if the yield and gross return becomes high and soil fertility is maintained. Hence, the cost of production and return were worked out on the basic of prevailing market price.

In conventional system the total production cost, gross return and net return was Rs. 31040,Rs. 43848 and Rs.12808 ha^{-1} respectively, with B: C ratio of 1.41 where as in SRI practice these were Rs. 33566,Rs. 60984 and Rs.29515 ha^{-1}, respectively with B: C ratio of 1.82. Maitti et.al (2013) reported higher B-C ratio of 1.76 and 1.88 in SRI in 1st and 2nd season compared to 1.3 and 1.35 in conventional practices. But in the present study when only two factors were modified with respect to planting and weed management the minimum cost of production(Rs.27338) was obtained. But maximum gross return(Rs.62244),net return (Rs.30952) and B-C ratio(1.98) was noticed in modified water management practices.This is because of cost effective/ modification in production process. This was treated as the best combination.

According to Rakotomalala (1997) ,62% extra labour needed for weeding and 17% extra for transplanting in SRI.

However maximum cost of production (Rs. 36556ha $^{-1}$) was recorded in treatment comprising of modified nutrient management because of high cost of organics than inorganics. Closer spacing recorded higher cost of production than wider spacing due to high plant population.

SUMMARY AND CONCLUSION

The experiment entitled" Management options in modified system of rice intensification (SRI) during summer season" was conducted in Agronomy research farm of the College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar. Four management options; modification of planting technique (age of seedling, number of seedlings and spacing), water management, weed management and nutrient management were assigned as sixteen treatments in different combinations. The soil of the experimental site was sandy loam in texture, near neutral in reaction (pH 6.2), low in organic carbon and medium in available nitrogen, high in available phosphorus and medium in available potassium. The experiment was laid out in a randomized block design with sixteen treatments and three replications.

The growth and yield attributing characters were recorded at different period of crop growth and at harvest, weed count, post harvest observations, grain and straw yield, nutrient content and uptake as well as economics of the production are summarized and presented in this chapter.

1. Maximum plant height (123.1 cm) was recorded when conventional system was modified with respect to water management . This was 3.57% higher than the conventional system and 8.2% higher than the SRI. When only two factors were modified maximum plant height (122.4 cm) was noticed in modified planting and water management practice and when three factors were modified maximum plant height (113.3 cm) was noticed in modified planting, water and nutrient management practice.
2. Maximum tillers (563 m^{-2}) were observed when conventional system was modified with respect to modified planting, water and nutrient management. This was 35% higher than the conventional system and 6.9% higher than the SRI. When only one factor was modified maximum tillers (464 m^{-2}) were noticed in modified water management practice. When two factors were modified, maximum tillers (524 m^{-2})

were recorded from modified planting, water management practice.

3. Maximum root volume (72.41 cc) hill^{-1} was recorded when conventional system was modified with respect to planting, water management and nutrient management practice. This was 37% higher than the conventional system and 18.9% higher than the SRI. When only one factor was modified highest root volume (63.43 cc) hill^{-1} was noticed in modified water management practice. When two factors were modified highest root volume (69.32 cc) hill^{-1} was noticed in modified weed and nutrient management.
4. The maximum (9.92) leaf area index (LAI) was recorded when conventional system was modified with respect to planting technique,water and nutrient management . This was 6.09% higher than the conventional system and 104.9% higher than SRI. When two factor were modified, highest LAI (9.91) was recorded by modified weed and nutrient management. When only one factor was modified highest LAI (9.42) was recorded by modified,water management.
5. The minimum weed dry weight (4.4 g m^{-2}) was recorded when conventional system was modified with respect to water management . This was 50% lower tha conventional and 68.1% lower than SRI.When two factor were modified minimum weed dry weight (5.8 g m^{-2}) was recorded by modified planting and weed management. When three factors were modified planting and weed management recorded minimum weed dry weight (5.8 g m^{-2}) and when three factors were modified minimum weed dry weight (6.4 g m^{-2}) was recorded by modified water, weed and nutrient management practice.
6. A progressive increase in dry matter production was noticed till the maturity of the crop. Maximum dry matter (2807 g m^{-2}) was accumulated when conventional system was modified with respect to modified weed and nutrient management practice. This was 10.3% higher than conventional system and 44.6% higher than SRI. When only one factor was modified maximum dry matter (2514 g m^{-2}) was produced by modified water management practice and when three factors were

modified maximum dry matter (2647 g m^{-2}) was accumulated by modified planting method, water management and nutrient management practices.

7. The crop growth rate (CGR) was highest (49.5 g day^{-1} m^{-2}) at 45-60 DAT when conventional system was modified with respect to modified weed and nutrient management practices. This was 16.1% higher than conventional system and 86.7% higher than SRI. When only one factor was modified maximum CGR (42.9 g day^{-1} m^{-2}) was recorded by modified nutrient management method at 45-60 DAT. When three factors were modified crop growth rate (43.2 g day^{-1} m^{-2}) was recorded at 45-60 DAT by modified planting method, water management and nutrient management.

8. The maximum relative growth rate(RGR) was maximum at 15-30 DAT(0.101 g g^{-1} day^{-1})when conventional system was modified with respect to planting, weed and nutrient management practice. 1.9% higher than the conventional system and 9.5% higher than SRI. When only one factor was modified maximum RGR (0.098 g g^{-1} day^{-1}) at 15-30 DAT was noticed in modified nutrient management and when two factors were modified highest relative growth rate (0.095 g g^{-1} day^{-1}) at 15-30 DAT was recorded by modified planting, water management practices.

9. The phenological study revealed that when conventional system was modified with respect to water management it took 58 days for panicle initiation, 86 days for 50% flowering and 128 days for physiological maturity,whereas it recorded (4, 5, 6) more days than conventional system and (4, 6, 6) more days than SRI to reach at panicle initiation, 50% flowering and physiological maturity stage, respectively. When two factors were modified maximum period (127 days) was taken for maturity by modified planting and water management practice and when three factors were modified also a maximum of 124 days were taken for maturity by modified planting, water management and nutrient management practices.

10. The maximum number of effective tillers (431 m^{-2}) was recorded when conventional system was modified with respect to water management which was 29% higher than the conventional system and 45% higher than the SRI. When two factors were modified maximum effective tillers (384 m^{-2}) were noticed by modified planting and water management practice and when three factors were modified maximum effective tillers (426 m^{-2}) were noticed by modified planting, weed management and nutrient management practice.

11. The longest panicle (34.1 cm) was produced by modified water management practice which was 22.2% longer than conventional system (27.9 cm). When two factor were modified longest panicle (28.8 cm) was produced by modified planting and water management. When three factors were modified longest panicle (28.5 cm) was produced by modified planting weed management and nutrient management practices.
12. The highest number of grains per panicle (140 $panicle^{-1}$) was noticed in modified water management practice which was 10.2% higher than that of conventional system and 12.9% higher than SRI. When two factors were modified, highest number of grains (137$panicle^{-1}$) was noticed in modified planting and water management practice. When three factors were modified highest grains (136$panicle^{-1}$) were noticed in modified planting and weed management and nutrient management practice.
13. The maximum number of filled grains (128 $panicle^{-1}$) was recorded from modified water management practice. It was 30.6% higher than that of the conventional system. When two factor were modified, highest number of filled grains (106 $panicle^{-1}$) was noticed in modified planting and water management practice. When three factors were modified, highest number of filled grains (114$panicle^{-1}$) was noticed in modified planting, weed management and nutrient management practice.
14. Minimum sterility (8%) was noticed in modified water management practice which

was 65.2% lower than conventional system and 57.8% lower than SRI. When two factors were modified, minimum sterility (21%) was noticed in modified planting and nutrient management, and modified weed and nutrient management. When three factors were modified minimum sterility (15%) was noticed in modified planting, weed management and nutrient management practice.

15. Maximum 1000 grain weight (26.9 g) was recorded by modified water management practice which was 15.4% higher than the conventional system. When two factors were modified maximum 1000-grain weight (26.8 g) was noticed in modified planting and water management. When three factors were modified maximum 1000-grain weight (26.7 g) was noticed in modified planting, water and nutrient management.
16. The maximum grain yield (4.94 t ha^{-1}) was recorded when conventional system was modified with respect to modified water management. It was 41.9% higher than Conventional system and 2.06% higher than SRI. When two factors were modified maximum grain yield (3.99 t ha^{-1}) was recorded by modified planting and water management where as when three factors were modified maximum grain yield (4.85 t ha^{-1}) was recorded by modified planting,water and nutrient management practice.
17. The straw yield was highest (6.06 t ha^{-1}) when conventional system was modified with respect to planting ,water, nutrient management which was 1% higher than the conventional system and 4.1% higher than the SRI. When only one factor was modified highest straw yield (6.03 t ha^{-1}) was recorded by modified planting. When two factors were modified highest straw yield (5.99 t ha^{-1}) was recorded by modified weed management and nutrient management practice.
18. The highest harvest index (0.48) was noticed when conventional system was modified with respect to weed and nutrient management practice. When only one factor was modified maximum HI (0.47) was recorded by modified water

management where as when three factors were modified, maximum HI (0.45) was recorded by modified planting, water management and nutrient management practice.

19. The maximum nitrogen content in grain(1.38%) and straw(0.45%) was noticed in modified water management practices respectively, while maximum phosphorus content in grain (0.45%) and in straw (0.38%) was noticed when conventional system was modified with respect to planting and water management . But maximum potassium content in grain (0.23%) and straw (1.77%) was noticed when conventional system was modified with water management practice.
20. Maximum nitrogen uptake both by grain (68.41 kg ha^{-1}) and straw (30.30 kg ha^{-1}) was recorded when conventional system was modified with respect to modified planting, water management and nutrient management while maximum phosphorus uptake both by grain (15.78 kg ha^{-1}) and straw (10.58 kg ha^{-1}) was recorded when conventional system was modified with water management. However maximum potassium uptake by grain (11.62 kg ha^{-1}) and was noticed in modified planting, water and nutrient management practice and maximum potassium uptake in straw (106.40 kg ha^{-1}) was noticed in modified water management practice.
21. The total NPK uptake (239.85 kg ha^{-1}) was highest when conventional system was modified with respect to planting ,water and nutrient management where as it was lowest (162.76 kg ha^{-1}) with respect to planting, weed management and nutrient management . The conventional system recorded a total NPK uptake (196.86 kg ha^{-1}) where as SRI recorded total NPK uptake (213.38 kg ha^{-1})
22. The maximum cost of production (Rs.36556 ha^{-1}) was recorded when conventional system was modified with respect to nutrient management where as modified water management recorded highest gross return (Rs.62244 ha^{-1}), and net return (Rs.30952 ha^{-1}) with maximum B-C ratio (1.98)

Conclusion

From the above experiment it is concluded that modification of conventional system with water management practice produced highest grain yield (4.94 t ha^{-1}) and 5.77 t ha^{-1} straw yield with the harvest index of 0.47. It removed 93.97 kg nitrogen, 27.89 kg phosphorus and 113.71 kg potassium amounting to a total uptake of 233.08 kg NPK ha^{-1}. The highest gross return was Rs. 62244 as against the cost of production of Rs. 31292 ha^{-1} and so recorded maximum net return of Rs. 30952,and B-C ratio 1.98 in modified water management practice with grain yield of 4.94 t ha^{-1},and straw yield 5.77 t ha^{-1}.When three factors were modified maximum gross return(Rs.61110 ha^{-1}) was noticed in modified planting, water and nutrient management with net return Rs.26662 ha-1 ,B-C ratio 1.77,with grain yield (4.85 t ha^{-1}) and straw yield (6.06 t ha^{-1}), respectively.

Hence in field condition where maintaining all those principles of SRI is not feasible. The farmers can go for planting younger seedlings with closer spacing and maintain the saturated condition to get higher yield or at least can opt for only maintaining saturation to get significantly higher yield and return as compared to conventional system in summer season.

Future line of work

The study could establish the alternate management options for modification of SRI. But more research is needed to standardize spacing so as to ensure mechanical weeding without compromising on the plant population. In summer season it is very difficult to manage the weed population and cono weeding needs high soil moisture for better operation. This investigation needs to be standardized. It also needs to be replicated at multiple locations in different agro climatic zones to formulate a conclusive modification in management options in system of rice intensification. This trial may be carried out on long term basis to study the rhizospehere dynamics under various alternate optionsto establish the science behind the fact.

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