STANDARDISATION OF NUTRIENT AND WEED MANAGEMENT TECHNIQUES FOR ORGANIC RICE

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DECLARATION

I hereby declare that this thesis entitled **"Standardisation of nutrient and weed management techniques for organic rice"** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS

@	At the rate of
°C	Degree Celsius
%	Per cent
AMF	Arbuscular Mycorrhizal Fungi
BCR	Benefit Cost Ratio
BNF	Biological Nitrogen Fixation
BPH	Brown plant hopper
CD	Critical difference
CEC	Cation exchange capacity
cm	Centimetre
cm^2	Square centimetre
C:N	Carbon Nitrogen ratio
CO_2	Carbon dioxide
DAT	Days after transplanting
DMP	Dry matter production
°E	East
et al.	And others
Fe	Iron
Fig	Figure
FYM	Farmyard manure
g	Gram
$g\ m^{-2}$	Gram per meter square
ha	Hectare
ha^{-1}	Per hectare
IAA	Indole Acetic Acid
i.e.,	That is
INM	Integrated Nutrient Management
K	Potassium
K_2O	Potassium oxide

KAU	Kerala Agricultural University
Kg	Kilogram
Kg ha^{-1}	Kilogram per hectare
LAI	Leaf Area Index
m	Metre
m^{-1}	Per meter
m ha	Million hectare
mg	Milligram
mg kg^{-1}	Milligram per kilogram
mm	Millimeter
MOP	Muriate of potash
m t	Metric ton
N	Nitrogen
^{o}N	North
NPK	Nitrogen-Phosphorous-Potassium
NS	Non significant
P	Phosphorous
P_2O_5	Phosphorous pentoxide
PGPR	Plant Growth Promoting Rhizobacteria
PSB	Phosphorous solubilizing bacteria
POP	Package of Practices
RDF	Recommended Dose of Fertilizer
RDN	Recommended Dose of Nutrients
Rs.	Rupees
SE	Standard Error
sq.m	Square meter
t	Tonnes
t ha^{-1}	Tonnes per hectare
VAM	Vesicular Arbuscular Mycorrhizae
Vs.	Versus
Zn	Zinc

Introduction

1. INTRODUCTION

Rice (*Oryza sativa*), the prince among cereals is the premier food crop not only in India but in world too (Chhabra, 2002). It is the world's most important staple food for more than two billion people in Asia and hundreds of millions in Africa and Latin America (Ladha *et al.,* 1997). Among the rice growing countries, India stands first in area (44.8 m ha) and second in production (91.0 m t) next to China.

With the release of short/mid duration high yielding varieties of rice in early seventies, the production of rice in India has increased from 20.6 m t in 1996 to 89.5 m t in 2000 (FAI, 2000). Most of the growth in rice production during this period is attributed to release of high yielding varieties and use of higher dose of fertilizer, but the use of higher dose of high analysis fertilizers (containing high amounts of N, P and K only) and insufficient use of organics has created deficiencies of secondary and micronutrients particularly Zn and Fe (Takkar, 1996). The soils are showing signs of fatigue, as judged by decline in the yields of rice as well as a lower response to applied chemical fertilizers (Yadav *et al.*, 1998). Other aspects of food quality have also been changed to the worse. Instead of recycling our wastes back into the soil as the source of nutrients we burn them to pollute our environment. We use non-renewable energy resources to produce chemical fertilizers. In future, we may force to make radical adjustment in such agricultural practices.

Paddy soil system favours fertility maintenance and build-up of organic matter in soils, and is the backbone of long-term sustainability of the wetland rice systems (Sahrawat, 2004). Nitrogen (N) status of soils was sustained by maintaining equilibrium between N loss of crop harvest and N gain from biological N fixation in primary rice farming of the pre-chemical period (Ladha and Peoples, 1995). However, in current intensive rice monocropping systems, this equilibrium has been disturbed with inputs of mineral fertilizers now playing a significant role (Ladha *et al.,* 2000). The application of chemical fertilizers is costly and gradually lead to the environmental problems. Organic residue recycling is becoming an increasingly important aspect of environmentally sound sustainable agriculture. Now-a-days, agriculture production is based on organic applications of growing in interest and the demands for the resulting products are increasing. Therefore, the effective use of organic materials in rice farming is also likely to be promoted.

The application of organic materials is fundamentally important because, they supply various kinds of plant nutrients including micronutrients, improve soil physical and chemical properties and hence nutrient holding and buffering capacity, and consequently enhance the microbial activities (Suzuki, 1997). N is the most limiting nutrient in irrigated rice systems, but P and K deficiencies are also the constraints increasing yield for consecutive planting of rice. Therefore, use of livestock wastes in agriculture has been an increasing interest due to the possibility of recycling valuable components such as organic matter, N, P and K. An advantage of farm application of organic wastes is that they usually provide a number of nutritive elements to crops with little added cost.

Organic farming is referred to the cultivation of crops without addition of synthetic materials. It is generally preferred because of improvement in quality of foodgrain by reducing the cost of cultivation. The global area under organic production accounts more than 31 m ha (Yadav, 2007). The Asian region constitutes 4.1 m ha which includes China, India and Russia. In India, organic production is practiced in 2,775 ha. The annual organic rice production in India is 3,500 t. The total organic produce in India is around 14,000 t and rice constitutes 24 per cent of the total organic produce.

Use and management of crop residues, FYM and green manures are becoming an increasingly important aspect of environmentally sound sustainable agriculture (Timsina and Connor, 2001). The long term addition of organic materials to soil results, increase in organic matter, crop productivity and soil biological activity (Collins *et al.*, 1992), also quality of the produce. Application of organic manures for increasing soil fertility has gained importance in recent years due to high cost and adverse impact of fertilizers. Incorporation of organic manures has given a hope to reduce the cost of cultivation and minimize adverse effects of chemical fertilizers.

Keeping these views under consideration the present investigation entitled "Standardisation of nutrient and weed management techniques for organic rice" was undertaken to standardise the nutrient schedule, spacing and weed management techniques for organic rice with its economic feasibility.

Review of Literature

2. REVIEW OF LITERATURE

Rice is the staple food for about 50 per cent of the world's population that resides in Asia. India, with the maximum area under rice in Asia, has 29.4 per cent of the global rice area (Tiwari, 2004). The annual organic rice production in India is 3,500 tons. Total organic produces in India is around 14,000 tons and rice constitutes 24 per cent of the total organic produce.

In Kerala organic production of rice lack sufficient research attention and published work is rather limiting. However, available literature on this crop is cited. Wherever sufficient information is not available in rice, citations on other related crops are included.

2.1 EFFECT OF SPACING ON CROP AND WEED

Spacing is one of the important factors in planting pattern design. Proper plant spacing helps in getting maximum benefit cost ratio from the rice field.

2.1.1 Effect of spacing on crop growth characters of rice

Wang (1970) observed that with increase in plant spacing, plant height and number of tillers plant^{-1} were decreased. Murthy and Murthy (1980) reported that rice grown at closer spacing (10 cm x 10 cm) provided more leaf area index, more number of tillers and more dry matter production. However, all these progressively decreased with wider spacing. Balasubramaniyan and Vaithialingam (1983) observed that the plant height was not influenced by spacing. Research conducted by Raju *et al.* (1984) on the effect of spacing on dry matter production, revealed that dry matter production per plant decreased at closer spacing.

Studies conducted by Reddy and Reddy (1986) showed that plant height was more under closer spacing of 10 cm x 10 cm than under wider spacing. Results of experiments conducted at the Directorate of Rice Research, Hyderabad revealed that rice planted at a closer spacing of 15 cm x 15 cm produced more number of tillers m^{-2} and leaf area index than the crop planted at wider spacing (DRR, 1991). Rice cv. K39 was observed to attain maximum height and tiller count when planted at closer spacing of 10 cm x 10 cm and minimum plant height at 20 cm x 20 cm (Shah *et al.*, 1991). Dry matter production was maximum at a closer spacing of 10 cm x 10 cm as against wider spacing of 20 cm x 10 cm and 20 cm x 20 cm (Dhal and Mishra, 1994). Kanungo and Roul (1994) also reported similar effects for spacing in rice.

Maske *et al.* 1997 reported that plant height and leaf area index with plant spacing of 15 cm x 10 cm were higher than of 15 cm x 15 cm or 15 cm x 20 cm spacing. An experiment conducted by Om *et al.* (1998) showed that rice cv. Basmati 370 planted at closer spacing of 15 cm x 15 cm recorded maximum plant height than that at wider spacing of 22.5 cm x 15 cm and 30 cm x 15 cm. Fu *et al.* (2000) observed a reduction in plant height with decreasing plant spacing. He also opined that with a reduction in plant density, the number of tillers and leaves increased and the growth period was extended.

Shrirame *et al.* (2000) noticed that the plant height was not affected due to spacing in rice, but reducing the plant density resulted in increase in number of functional leaves and maximum leaf area. Jacob (2002) reported that spacing of 20 cm x 10 cm recorded the highest value in terms of plant height, number of tillers hill^{-1}, LAI at panicle initiation stage and dry matter production. Naser Mohammadian Roshan *et al.* (2011) reported that the higher plant height (128.71cm) was obtained with plant spacing of 20 cm x 20 cm. The plant height was found to be lower in 25 cm x 25 cm spacing.

2.1.2 Effect of spacing on yield and yield attributes of rice

Murthy and Murthy (1980) reported that rice grown at closer spacing (10 cm x 10 cm) provided higher yield and spikelets m^{-2}. However, these progressively decreased with wider spacing. Sahu *et al.* (1980) observed that the harvest index was less at closer spacing (20 cm x 20 cm) than at wider spacing (60 cm x 60 cm) in both dry (53.2 per cent) and wet (48.2 per cent) seasons. Among the medium group cultures CR-10-4128 showed high harvest index even at closer spacing. Venkateshwaralu and Mahatinsingh (1980) found no significant differences in grain yield in rice between the two spacing (15 cm x 15 cm and 23 cm x 23 cm).

Bari *et al.* (1984) showed that the plant density at spacing of 20 cm x 20 cm was more effective and gave significantly higher grain yield per plot than the other two plant densities at other spacing (15 cm x 15 cm and 25 cm x 25 cm) and was, therefore, most suitable for obtaining maximum yields. Mohapatra *et al.* (1989) reported that plant spacing of 20 cm x 20 cm was better than those of 15 cm x 15 cm or 15 cm x 20 cm under normal soil for rice productivity.

Studies conducted by Srinivasan (1990) revealed that raising rice cv. Bhavani at a closer spacing of 15 cm x 10 cm resulted in higher number of productive tillers m^{-2}, than wider spacing of 20 cm x 10 cm and 25 cm x 10 cm. Significantly higher grain yield was recorded with a spacing of 20 cm x 10 cm over 15 cm x 15 cm and 20 cm x 15 cm which was on par with 15 cm x 10 cm (Reddy and Reddy, 1994). Pandey and Tripathi (1995) reported that a closer spacing of 15 cm x 10 cm resulted in more grain yield than wider spacing of 20 cm x 10 cm. Maske *et al.* 1997 reported that yield and yield components of rice with plant spacing of 15 cm x 10 cm were higher than of 15 cm x 15 cm or 15 cm x 20 cm spacing. Patel (1999) observed that hill spacing of 20 cm x 20 cm in comparison with 20 cm x 15 cm and 20 cm x 10 cm spacing recorded perceptible increase in number of panicles m^{-2}, grain and straw yield. Also, number of grains $panicle^{-1}$ and 1000-grain weight were not affected by spacing. Baloch *et al.* (2002) reported that the spacing of 22.5 cm x 22.5 cm gave more panicle density and higher grain yield than other two spacing (20 cm x 20 cm and 25 cm x 25 cm).

Omina, EL-Shayieb (2003) showed that narrow spacing of 10 cm x 20 cm gave the higher grain yield and yield components of Giza 177 rice cultivar compared with 20 cm x 20 cm or 30 cm x 30 cm. The higher number of filled grains $panicle^{-1}$, test weight, lower spikelet sterility percentage were obtained at a wider spacing of 20 cm x 15 cm (Padmavathi *et al.*, 1998; Obulamma *et al.*, 2004). Higher grain yield and straw yield of rice was recorded by Obulamma *et al.* (2004) at 20 cm x 10 cm as compared to 15 cm x 10 cm in rice. Veeramani (2011) reported significant higher number of filled grains $panicle^{-1}$ and lower spikelet sterility percentage at wider row spacing of 30 cm x 25 cm compared with closer spacing of 25 cm x 25 cm.

Naser Mohammadian Roshan *et al.* (2011) reported that the higher grain yield of 5,582 kg ha^{-1} was obtained with plant spacing of 20 cm x 20 cm. The lower grain yield of 4,470 kg ha^{-1} was found from plant spacing of 25 cm x 25 cm. Bagayoko (2012) reported that without fertilizer application, rice yield was lower at wider row spacing (30 cm x 30 cm) than narrow row spacing (25 cm x 25 cm). With half recommended fertilizer application, rice yield was similar for both row spacing. At recommended fertilizer rate, rice yield increased with wider row spacing compared with narrower one.

In general it was observed that closer spacing is favourable for both growth and yield and wider spacing for certain yield characters and sometimes the yield.

2.1.3 Effect of spacing on weed flora

In recent years, attempts have been made to introduce weed-competitive cultivars of rice. In transplanted rice, use of competitive cultivars in conjunction with higher seed rates and shallow submergence has reduced weed competition.

Ghosh and Sarkar (1975) had shown that as the distance between hills of transplanted rice was reduced, the crop became more competitive and weed population was reduced. The yield of semi-dwarf cultivars could be increased and weed competing ability improved by decreasing the spacing from 25 cm x 25 cm to 15 cm x 15 cm (IRRI, 1976). Estornios and Moody (1983) found that under identical management practices, weed dry weight was the lowest at closer spacing.

Ghosh and Singh (1996) proved that reduction of plant density enhanced weed infestation. Relative weed density of each species increased with increase in spacing from 20 cm x 10 cm to 30 cm x 20 cm (Khondaker and Sato, 1996). They further pointed out that weed growth increased significantly with increase in spacing and weed growth rate was higher at 25 DAT than at 45 DAT. In lowland transplanted rice, closer spacing resulted in fewer weeds (Gogoi, 1998). Singh *et al.* (1999) reported that among the three spacing tried (10 cm x 10 cm, 15 cm x 10 cm and 20 cm x 10 cm), the weed population increased significantly with increase in spacing. They also opined that weed control efficiency increased from 61.60 per cent in 20 cm x 10 cm spacing to 66.40 per cent in 10 cm x 10 cm spacing. Lourduraj *et al.* (2000) found that weed count and weed dry weight were higher under wider planting of 33 hills m^{-2} (20 cm x 15 cm) compared to closer planting of 50 hills m^{-2} (20 cm x 10 cm). Jacob (2002) reported that a spacing of 20 cm x 10 cm registered the lowest value of total absolute density of weed compared to 15 cm x 15 cm and 15 cm x 10 cm spacing.

2.2 EFFECT OF WEED MANAGEMENT PRACTICES ON CROP AND WEED

Lowland transplanted rice is grown under the condition which is favourable for growth and multiplication of weed species. Selection of an appropriate method of weed control technology should be based not on the degree of weed control or the cost of weed control alone. Both these factors should be considered in deciding the weed control method.

2.2.1 Effect of stale seedbed on crop growth and yield of rice

Sindhu *et al.* 2010 reported that the yield attributes such as panicle length, number of filled grains, 1000-grain weight and number of productive tillers was improved by the adoption of stale seedbed technique for 14 days in rice.

2.2.2 Effect of stale seedbed on weed control

All *et al.* (1979) and Sumner *et al.* (1981) reported that stale seedbed practice prior to planting reduced the weed population. Hosmani and Meti (1983) observed that stale seedbed encouraged a flush of new weed seedlings, which can be controlled very easily prior to planting and reduced the crop-weed competition in succeeding crops. Moorthy (1992) reported that appropriate land preparation and sowing seeds on a stale seedbed could be effectively used for the integrated management of weeds in rainfed upland rice. Saikia and Pathak (1993) showed that stale seedbed suppressed weeds better than the conventional seedbed method and allowed better crop growth. Sindhu *et al.* 2010 reported that stale seedbed technique is an efficient tool for the management of weeds under wet seeded condition.

2.2.3 Effect of hand weeding on crop growth and yield of rice

Ravindran (1976) reported that though hand weeding on 20th and 40th DAT in rice gave higher yield, the net profit was lower due to increased labour charges. Chandrakar and Chandrawanshi (1985) pointed out that the hand weeded plots recorded the higher number of panicles m^{-2} and higher grain yield. Preliminary evaluation of weed control practices in transplanted rice revealed that yield increase due to hand weeding in the farmer's fields ranged from 4 per cent to 29 per cent (Elliot *et al.*, 1985). Singh *et al.* (1992) recorded maximum grain yield under hand weeding at 30 and 60 DAT. Pandey *et al.* (1997) reported that maximum grain yield and net profit of Rs.6,704 ha^{-1} was obtained from hand weeded plots. Kathirvelan and Vaiyapuri (2003) reported that hand weeding (20 and 40 DAT) recorded higher grain and straw yield (5.81 t ha^{-1} and 7.26 t ha^{-1} respectively).

2.2.4 Effect of hand weeding on weed control

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

According to Crafts and Robbins (1973), hand pulling of weeds was an efficient method of eliminating annual and biennial weeds, which do not reappear again. Manual weeding methods are most effective in young weeds whereas older weeds especially perennials with underground structures are difficult to control (Moody, 1977). Moody (1980) suggested that in transplanted rice, one manual weeding (at the most two) was sufficient to control weeds adequately. He also observed that manual weeding methods are most effective on young weeds. Chandrakar and Chandrawanshi (1985) pointed out that the hand weeded plots recorded the least dry weight of weeds. Raju and Reddy (1986) reported that hand weeding reduced weed dry weight by 88 per cent. However the re-emergence of sedges could not be controlled by hand weeding (Verma *et al.*, 1987). Moody (1991) reported manual weeding as the most common method of weed control in rice in Asia. Manual weeding by hand or hand tools is very effective but require more time and labour. Kathiresan and Surendran (1992) observed a higher weed control efficiency of 81.9 per cent by hand weeding twice.

Singh *et al.* (1992) reported significantly lower dry weight of weeds and higher weed control efficiency under hand weeding twice at 30 and 60 DAT. Khare and Jain (1995) found that hand weeding gave the lower weed biomass and higher weed control efficiency (60 kg ha^{-1} and 91.6 per cent respectively). Higher weed control efficiency was also recorded with hand weeding twice (AICRP, 1997). Hand weeding was more effective and the most common tool to control weeds in transplanted rice (Muthukrishnan *et al.*, 1997). According to Rao (2000) manual weeding is effective against annuals and biennials but do not control perennials and is expensive in areas where labour is scarce. Two hand weeding at 20 and 40 DAT were able to control almost all categories of weeds (Bhowmick, 2002). Hand weeding twice recorded the least weed count and the highest weed control efficiency (69.9 and 70.1 per cent) during the first and second season respectively (Gnanavel and Kathiresan, 2002). Singh *et al.* (2003) reported that hand weeding at 30 and 50 DAT recorded significantly lower weed population and dry matter accumulation of weeds over weedy check.

It can be observed that both stale seedbed and hand weeding are equally effective in controlling weeds in rice but the economics has also to be taken into consideration before reaching a final conclusion.

2.3 EFFECT OF NUTRIENT SCHEDULE ON CROP GROWTH AND YIELD

2.3.1 Farm yard manure (FYM)

Farm yard manure occupies an important position among bulky organic manures and conventionally used since centuries. FYM supplies both major and minor plant nutrients, improves physical condition in the soil and supplies substances that stimulate plant growth. Among the different sources, FYM is the best known and commonly used traditional organic manure in India (Gaur, 1994). Meerabai and Raj (2001) estimated that an average dressing of 25 t ha^{-1} FYM supplies 112 kg N, 56 kg P_2O_5 and 112 kg K_2O. Halemani *et al.* (2004) analyzed different organic manures for their nutrient composition and found that the FYM contained 0.64 per cent N, 0.31 per cent P_2O_5 and 0.55 per cent K_2O.

2.3.1.1 *Effect of FYM on crop growth characters of rice*

Sharma (1994) opined that plants with FYM application were taller with more tillers and dry matter than those grown without FYM. Significant increase in plant height and LAI, of medium duration rice variety Pavizham with FYM @ 10 t ha^{-1} has been reported by Babu (1996). Shanmugam and Veeraputhran (2001) revealed that application of FYM @ 12.5 t ha^{-1} significantly increased the growth of paddy. Application of FYM @ 10 t ha $^{-1}$ produced better growth in terms of taller plants and more dry matter accumulation (Singh *et al.*, 2002). Bhattacharya *et al.* (2003) recorded the higher plant height at 45 and 90 days after transplanting with FYM @ 9 t ha^{-1}. Under rice-wheat cropping sequence, application of 10 tons of FYM ha^{-1} to rice crop increased the plant height, LAI, crop growth rate (CGR) and dry matter accumulation (Singh and Sharma, 2005).

2.3.1.2 *Effect of FYM on yield and yield attributes of rice*

Kuppuswamy *et al.* (1992) observed that application of FYM @ 10 t ha^{-1} increased the grain yield (from 6.61 t ha^{-1} to 7.33 t ha^{-1}) and also significantly enhanced the straw yield. Sharma and Mittra (1992) have also reported increase in rice grain yield by FYM. FYM as a source of organic manure was effective in increasing the number of panicle m^{-2} in rice (Zia *et al.,* 1992). Brar and Dhillon (1994) observed that grain yield of rice reached up to 6.7 t ha^{-1} using 4 t ha^{-1} of FYM as against 4.1 t ha^{-1} in control plot. Tanveer *et al.* (1993) and Thakur and Patel (1998) reported that incorporation of FYM @ 5 t ha^{-1} significantly increased the yield and yield attributing characters of rice over control. Sharma and Sharma (1994) and Rathore *et al.* (1995) observed significantly higher grains number $panicle^{-1}$, panicle number m^{-2} and grain yield in rice with FYM application. Babu (1996) could observe significant increase in the straw yield of rice variety Pavizham with FYM addition @ 10 t ha^{-1}. However, he could not observe any significant impact on harvest index.

Shanmugam and Veeraputhran (2001) revealed that application of FYM @ 12.5 t ha^{-1} significantly increased the yield attributes and yield of rice. Bridgit and Potty (2002) observed significant influence of FYM in increasing the number of filled grains and grain filling percentage. Nguyen Van Quyen *et al.* (2002) reported that application of FYM @ 10 t ha^{-1} alone produced grain yield of rice (4.20 t ha^{-1}) significantly higher than the control (3.68 t ha^{-1}). Under rice-wheat cropping sequence, application of FYM @ 10 t ha^{-1} to rice crop resulted in higher grain yield (43.51 q ha^{-1}) and straw yield (60.48 q ha^{-1}) than the control (Singh and Sharma, 2005). Kharub (2008) reported that rice productivity was at par under inorganic and organic fertilization where FYM application was 22.5 t ha^{-1} in rice.

2.3.1.3 Effect of FYM on soil properties

Chellamuthu *et al.* (1989) found that FYM application could increase the available N and P contents of soil. Ganal and Singh (1990) obtained an increase in available K status of soil upon incorporation of FYM. Muthuvel *et al.* (1990) reported higher available N contents of soils under FYM application. Considerable improvement in available N status of soil due to the application of FYM has been reported by Gupta *et al.* (1998). Waghmer (1998) reported higher available NPK content in soil with the application of FYM @ 10 t ha^{-1}. Sharma *et al.* (2000) reported a pronounced decrease in soil pH, increase in CEC and organic carbon in FYM treated plots. Incorporation of FYM decreased the bulk density and increased the soil porosity and thus increased the water holding capacity of soil (Parihar, 2004). He added that hydraulic conductivity of soil increased significantly due to the incorporation of FYM and crop residues and opined that organic substances having high C:N ratio is known to improve soil physical properties.

Application of FYM significantly increased the ammonical nitrogen content of soil and the increase reported was from 30.1 to 110.1 mg kg^{-1} soil (Duhan *et al.*, 2005). Another report by Singh *et al.* (2005) suggested that lowest amount of K was leached from FYM treatment (1.8 per cent) as compared to poultry manure (17.3 per cent), fertilizer K (15.8 per cent) and rice straw (14.4 per cent), thus conserving its availability in soil. Khan *et al.* (2006) also reported an enhanced soil nitrogen supply due to FYM application. Water holding capacity of the soil was progressively improved with the application of organic manure as compared to inorganic fertilizers. Among the organic manures, application of FYM recorded higher water holding capacity of soil, followed by poultry manure and pig manure as observed by Laxminarayana (2006).

2.3.1.4 Effect of FYM on plant nutrient content

Varma and Dixit (1989) and Sharma and Mittra (1991) reported that in rice based cropping systems incorporation of FYM with or without chemical nitrogen, increased the NPK uptake in rice. Rathore *et al.* (1995) reported that application of organic manures including FYM could increase NPK uptake in rice. On the contrary, Babu (1996) reported that the uptake of N, P and K by rice was not influenced by the application of organic manures, even @ 10 t ha^{-1}. Modak and Chavan (2000) studied the response of rice to FYM in black calcareous soil of Palghar (Thane) and found that the uptake of N, P and K by grain and straw increased due to application of FYM. Quyen and Sharma (2003) studied the comparative effects of organic and conventional farming on scented rice at research farm, IARI, New Delhi and reported that application of FYM significantly increased N and P uptake by both grain and straw over control.

2.3.2 Vermicompost

Vermicompost is an aerobically degraded organic matter, which would further be disintegrated by the enzymatic activity in the gut of earth worms and hence associated with enzymes of microbial population (Kale *et al.*, 1992). It is rich in both macro and micro nutrients. It contains 0.56 per cent N, 1.48 per cent P_20_5 and 0.36 per cent K_2O besides having plant growth promoting substances, humus forming microbes and nitrogen fixers (Shinde *et al.*, 1992). Joshi and Prabhakara setty (2005) reported that vermicompost contains 0.9 to 1.0 per cent N, 0.8 per cent P_20_5 and 0.6 per cent K_2O and micronutrients.

2.3.2.1 Effect of vermicompost on crop growth and yield of rice

Application of vermicompost in rice, resulted an increase in the number of panicles m^{-2} and as well as grain number $panicle^{-1}$ (Senapathi *et al.*, 1985). Kale and Bano (1986) observed that the seedling growth of rice in nursery increased significantly due to vermicompost application. Vermicompost application resulted in

10 per cent increase in effective tillering in rice (Shuxin *et al.,* 1991). Janaki and Hari (1997) reported that vermicompost @ 2.5 t ha^{-1} increased the plant height, two times increase in panicle number $plant^{-1}$ and grain number $panicle^{-1}$ in rice. Mirza Hasanuzzaman *et al.* (2010) reported that among the manures, vermicompost @ 8 t ha^{-1} produced better grain yield compared to other organic manures in rice.

2.3.2.2 Effect of vermicompost on soil properties

Vermicompost application in cereals resulted in 37 per cent more N, 66 per cent more P and 10 per cent K in soil (Bhawalkar, 1992). The nutrient availability to vermicompost applied crop is more as vermicompost contained more amounts of essential plant nutrients than FYM (Rahudkar, 1993). Vasanthi *et al.* (1995) reported that in rice-rice system, application of vermicompost at 5 t ha^{-1} in both seasons increased the available N and organic carbon status of soil by 42.9 per cent and 87.7 per cent respectively. According to George (1996), vermicompost application resulted in higher available N and P in soil. This might be because, vermicompost applied to soil harboured rich amount of microbes that degrade and mobilize nutrients to available form (Gunthilagaraj and Ravignanam, 1996).

2.3.2.3 Effect of vermicompost on plant nutrient content

Shuxin *et al.* (1991) obtained 30 to 50 per cent increase in N uptake in vermicompost applied cereals. Anina (1995) reported that nutrient uptake by plants increased upon application of Eudrillus compost. Nitrogen content in plants applied with earthworm casts was found higher by Alfred and Gunthilagaraj (1996). Kale *et al.* (1992) reported that an increase in the colonization of total microbes and nitrogen fixers in vermicompost applied plots.

2.3.3 Green manure

Organic farming relies on soil health and cycling of nutrients through the soil using natural processes. Green manures perform the vital function of fertilization, in concert with the addition of animal manures if those are used. Application of green manure has been found quite promising in enhancing crop yield and fertilizer saving (Dixit, 2007).

2.3.3.1 Effect of green manure on crop growth and yield of rice

Green manuring of rice with *Crotalaria juncea* and *Sesbania aculeata*, improved growth and yield of transplanted rice (Sharma and Mishra, 1988). Green manuring with either *Crotalaria juncea* or *Sesbania rostrata* significantly increased rice grain yield over the control and was statistically on par with fertilizer application (Choudhary and Thakuria, 1996).

Vaiyapuri *et al.* (1998) reported that application of 12.75 t ha^{-1} sesbania green manure in rice recorded the highest plant height, LAI, number of tillers hill^{-1} and dry matter accumulation. Application of green manure promotes growth of rice by increasing plant height (Bayan, 2000). Hemalatha *et al.* (2000) observed that *in situ* incorporation of dhaincha at 12.0 t ha^{-1} recorded the best values for plant height (97.61 cm), number of tillers hill^{-1} (19.55), leaf area index (6.85), dry matter production (13,848 kg ha^{-1}) and days to 50 per cent flowering (101 days). Mukherjee and Singh (2001) revealed a significant effect of sesbania green manuring on plant height at 50 and 70 days after transplanting and at harvest. Vaiyapuri and Sriramachandrasekharan (2002) revealed that incorporation of 12.5 t ha^{-1} of *Sesbania aculeata* recorded the highest plant height (87.3 cm), number of tillers hill^{-1} (15.4) and LAI (7.9).

2.3.3.2 Effect of green manure on soil properties

Incorporation of green manure crops into the soil had shown to increase soil organic carbon (Swarup, 1987; Sharma and Mishra, 1988 and Cassman *et al.,* 1996). Maurya and Ghosh (1972) and Chatterjee *et al.* (1979) observed an increased cation exchange capacity with green manuring. Setty and Gowda (1997) reported that the inclusion of green manure or grain legumes in the cropping system increased the soil organic carbon. Green manuring not only improves the fertility of soils but also improves air-water relationship (Dalvinderjit Singh *et al.*, 1999). Chaphale *et al.* (2000) also reported that the addition of green manure (*Gliricidia*) over a period of 5 years led to increase in organic carbon, total N, available N, P, K and water holding capacity, but bulk density of soil decreased as compared to control. Ramesh and Chandrasekaran (2004) reported a gradual buildup of organic carbon content when

Sesbania rostrata was incorporated in situ at flowering stage in rice-rice cropping system.

2.3.3.3 Effect of green manure on plant nutrient content

Tiwari *et al.* (1980) observed that sesbania green manure increased the N, P, and K contents in plants and their availability in soil. Nitrogen uptake of rice grain and straw were found to be increased with green manuring (Rekhi and Bajwa, 1992; Panda *et al.* 1994 and Tripathi *et al.*, 1994). Bindra and Thakur (1996) reported an increased NPK uptake in rice grain due to green manuring. While studying the effect of various organics on soil fertility and nutrient uptake in rice, Sriramachandrasekharan *et al.* (1996) observed that N, P, and K uptake of rice grain and straw were higher with sunhemp green manuring than FYM application or control. Apparent N recovery was also higher with sunhemp green manuring than that of FYM application.

Medhi *et al.* (1997) and Sarmah (1997) recorded improvement in P-uptake with green manuring. Chandra and Pareek (1998) reported that N uptake by rice plant from green manure treated plots was more than the untreated plots but significant differences were obtained only at 51 DAT. Saha *et al.* (2000) observed that green manuring registered significantly higher P uptake, which was 8.4 per cent higher over fallow. Duhan *et al.* (2001) observed that application of green manure, in general, increased the K uptake from 2.9 kg ha^{-1} to 4.6 kg ha^{-1} in rice grain, and from 2.4 kg ha^{-1} to 3.9 kg ha^{-1} in straw..

2.3.4 Biofertilizers

Microbial inoculants or biofertilizers is important component of organic farming, which helps to nourish the crops through required nutrients. These microbes help to fix atmospheric nitrogen, solubilize and mobilize phosphorus, translocate minor elements like zinc, copper, etc., to the plants, produce plant growth promoting hormones, vitamins and amino acids and control plant pathogenic fungi, thus helping to improve the soil health and increase crop production. Biofertilizers like

Rhizobium, Azotobacter, Azospirillum and Blue green algae (BGA) are in use since long. These organisms fix atmospheric nitrogen and supply it to plants.

2.3.4.1 Effect of biofertilizers on crop growth and yield of rice

Kulasooriya and de silva (1977) reported higher grain yield by culturing of azolla than applying 80 kg ha^{-1} of urea. Talley *et al.* (1977) obtained 23 per cent increase in grain yield by dual culture of azolla in rice. According to Tien *et al.* (1979), in addition to high N fixation, Azospirillum is known to synthesize growth substances such as IAA and other auxins and vitamin B which might have also helped in increasing the plant height. Sanoria *et al.* (1982) obtained significant increase in the plant height of paddy by Azospirillum inoculation and reported that use of inoculation alone with no application of fertilizer nitrogen was more desirable. The yield responses caused by Azospirillum inoculation may be due to biological nitrogen fixation (Hartmann *et al.,* 1983). Balasubramanian and Kuamr, 1987; Wani, 1990; Bashan and Holgain, 1995 investigated that Azospirillum treatment showed remarkable increase in the grain and the straw yield in sorghum, wheat, maize, paddy and other food and fodder crops.

Split application of biofertilizer inoculation through seed, seeding and soil gave the highest grain, straw yield, plant height and number of productive tillers in rice (Gopalswamy and Vidhyasekaran, 1988). Subba Roa, (1988) reported that approximately 50-70 per cent of crops inoculated with inoculum phosphobacteria increased yield up to 70 -80 per cent. Trials with PSB indicated yield increases in rice (Tiwari *et al.*, 1989), maize (Pal, 1999) and other cereals (Afzal *et al.*, 2005; Ozturk *et al.,* 2003).

Plant growth promoting (PGP) micro-organisms enhance the capacity of plants to absorb nutrients like nitrogen (N) and P efficiently, resulting in stronger growth and higher crop yields (Biswas *et al.*, 2000; Choudhury and Kennedy, 2004; Kennedy *et al.*, 2004; Yanni *et al.*, 1997). Inoculation of plants with Azospirillum could result in significant changes in various growth parameters, such as increase in plant biomass, plant height, leaf size and root length of cereals (Bashan *et al.*, 2004).

Majumdar *et al.* (2006) reported that there was 9.1 per cent increase in the yield of upland rice when inoculated with Azospirillum. N_2 fixing activity has been confirmed in PGPR in many other cases. Azospirillum species have, for instance, been implicated in the enhancement of rice (Pedraza *et al.*, 2009), maize (Montanez *et al.*, 2009) and wheat (Sala *et al.*, 2007) yields, through BNF mechanisms.

2.3.4.2 Effect of biofertilizers on soil properties

Pattanayak *et al.* (2001) reported that incorporation of azolla resulted in significantly high organic carbon content of soil (9.2 g kg^{-1}) than dhaincha (7.9 g kg^{-1}) and sunhemp (7.5 g kg^{-1}) compared to the initial value (5.1 g kg^{-1}). Kannaiyan (1990) reported that azolla incorporation increased the availability of phosphorus, potassium, zinc and iron in rice crop. Application of *Azolla microphylla* could contribute 40-60 kg nitrogen ha^{-1} when inoculated with 500 kg ha^{-1} as dual crop (Kannaiyan, 1995). Gevrek (1999) opined that azolla totally decomposed after 2-3 weeks, increased soil nitrogen by 38-56 per cent. Sundara *et al.* (2002) found that the application of PSB, *Bacillus megatherium* var. phosphaticum, increased the PSB population in the rhizosphere and P availability in the soil.

2.3.4.3 Effect of biofertilizers on plant nutrient content

Azospirillum enhanced the uptake of NO_3, P_2O_5 and K in plants (Sarig *et al.*, 1984). Pacovsky *et al.* (1985) observed an increase in P and other nutrient concentration in the foliage of Azospirillium inoculated sorghum plants. Parvatham *et al.* (1989) noted better N and P uptake in bhindi due to Azospirillum inoculation. Inoculation of plants with Azospirillum could result in significant changes in nutrient uptake and tissue N content (Bashan *et al.*, 2004).

2.3.5 Effect of combined use of different nutrient sources

2.3.5.1 Effect of combined use of different nutrient sources on growth and yield of rice

Subramanian and Rangarajan (1990) reported that combined application of green leaf manure (*Azadirachta indica*), FYM, cow dung slurry and Azospirillum *brasilense* gave the higher grain yield on previous organically than on inorganically fertilized plots. Jeyabal *et al.* (1999) observed that application of either FYM or enriched FYM combined with Azospirillum plus phosphobacteria (biofertilizer) gave 17.2 to 23.4 per cent higher grain yield of rice than application of nutrients through inorganic fertilizers. Dixit and Gupta (2000) observed that application of FYM @ 10 t ha^{-1} and blue green algae (BGA) (Cyanobacteria) inoculation either alone or in combination, increased the economic yield. The average increase in the grain yield due to BGA was 0.24 t ha^{-1}, while combined use of FYM and BGA showed an increase of 0.60 t ha^{-1}. Shanmugam and Veeraputhran (2001) revealed that application of either green manure *(Sesbania aculeata* at 6.25 t ha^{-1}) or FYM (12.5 t ha^{-1}) combined with Azospirillum (2 kg ha^{-1}) significantly increased the growth attributes of rice.

2.3.5.2 Effect of combined use of different nutrient sources on soil properties

Sharma (2006) reported that FYM and biofertilizers improved all the parameters of soil fertility over FYM alone as well over green manuring alone.

2.3.5.3 Effect of combined use of different nutrient sources on plant nutrient content

Dixit and Gupta (2000) pointed out that content and uptake of N, P and K showed increasing trends as a result of application of FYM, and blue green algae inoculation either alone or in combination. Tiwari *et al.* (2001) reported that the concentration of N, P, and K in grain and straw increased significantly with the application of FYM and BGA @ 5 t ha^{-1} and 10 kg ha^{-1} respectively. Quyen and Sharma (2003) reported that combined application of FYM, green manue, BGA and PSB resulted in more N, P and K uptake in rice.

From the above literature, it can be observed that all organic nutrient sources are equally effective in increasing the yield in rice. But, before going for an organic recommendation, the economics as well as the availability of organic source has to be ensured.

Materials and Methods

3. MATERIALS AND METHODS

The research project entitled "Standardisation of nutrient and weed management techniques for organic rice" was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, during the first crop season of 2012. The main objective of the experiment was to standardise the nutrient schedule, spacing and weed management techniques for organic rice and to assess the economic feasibility of the organic package. The details regarding the materials used and methods employed for the study are presented in this chapter.

3.1 MATERIALS

3.1.1 Experimental site

The experiment was undertaken in the "Organic Farm" of the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala. The farm is geographically located at 8.5^0 N latitude and 76.9^0 E longitude and at an altitude of 29 m above mean sea level. The experimental field had fairly levelled topography and good drainage.

3.1.2 Soil

The soil of experimental field is sandy clay which belongs to the order oxisol. The data on the mechanical composition and chemical nature of the soil of the experimental site are presented in Table 1.

3.1.3 Cropping history of the field

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

3.1.4 Cropping season

The experiment was conducted during the first crop season (May to September) of 2012.

Table 1. Physio-chemical characteristics of the soil in the experimental site

SI.No. Parameters	Content (%)	Method used
A. Mechanical composition		
1. Coarse sand	47.76	
2. Fine sand	10.64	Bouyoucos hydrometer method (Bouyoucos ,1962)
3. Silt	8.60	
4. Clay	33.00	
B. Chemical composition		
1. Available N (kg ha^{-1})	356.60 (Medium)	Alkaline permanganate method (Subbiah and Asija, 1956)
2. Available P_2O_5 (kg ha^{-1})	84.20 (High)	Bray colorimetric method (Jackson,1973)
3. Available K_2O (kg ha^{-1})	90.00 (Low)	Ammonium acetate method (Jackson,1973)
4. Organic carbon (%)	1.24 (Medium)	Walkley and Black rapid titration method (Jackson,1973)
5. Soil pH	5.9 (Acidic)	1:2.5 soil solution ratio using pH meter with glass electrode (Jackson,1973)

3.1.5 Weather conditions

The experimental site enjoys a humid tropical climate. Data on weather parameters like temperature, rainfall and relative humidity were obtained from the Class B Agromet Observatory at the College of Agriculture, Vellayani. The average values of weather parameters recorded during the cropping period are given in Appendix-I and graphically presented in Fig 1. The mean maximum and minimum temperature ranged between 28.9°C to 31.5°C and 23.5°C to 26.1°C respectively. The mean maximum and minimum relative humidity ranged from 87.0 per cent to 95.1 per cent and 70.6 per cent to 85.3 per cent respectively. A total rainfall of 111.1 mm was recorded during the cropping period.

3.1.6 Crop variety

The variety used was Uma (Mo-16), which was released from Rice Research Station, Moncompu. Uma is medium duration (115-120 days), dwarf, medium tillering, non-lodging and resistant to BPH. The seeds of this variety were obtained from Rice Research Station, Moncompu.

3.1.7 Manures and fertilizers

FYM (0.70 per cent N, 0.31 per cent P_2O_5, and 0.5 per cent K_2O), neem cake (2.4 per cent N, 0.60 per cent P_2O_5, and 0.80 per cent K_2O), groundnut cake (3.2 per cent N, 0.7 per cent P_2O_5, and 0.7 per cent K_2O), vermicompost (0.9 per cent N, 0.3 per cent P_2O_5, and 0.8 per cent K_2O), urea (46 per cent N), rock phosphate (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used to supply the major nutrients required for the crop.

3.2 METHODS

3.2.1 Design and Layout

The field experiment was laid out in split plot design with four replications. The layout plan of the experiment is given in Fig 2.

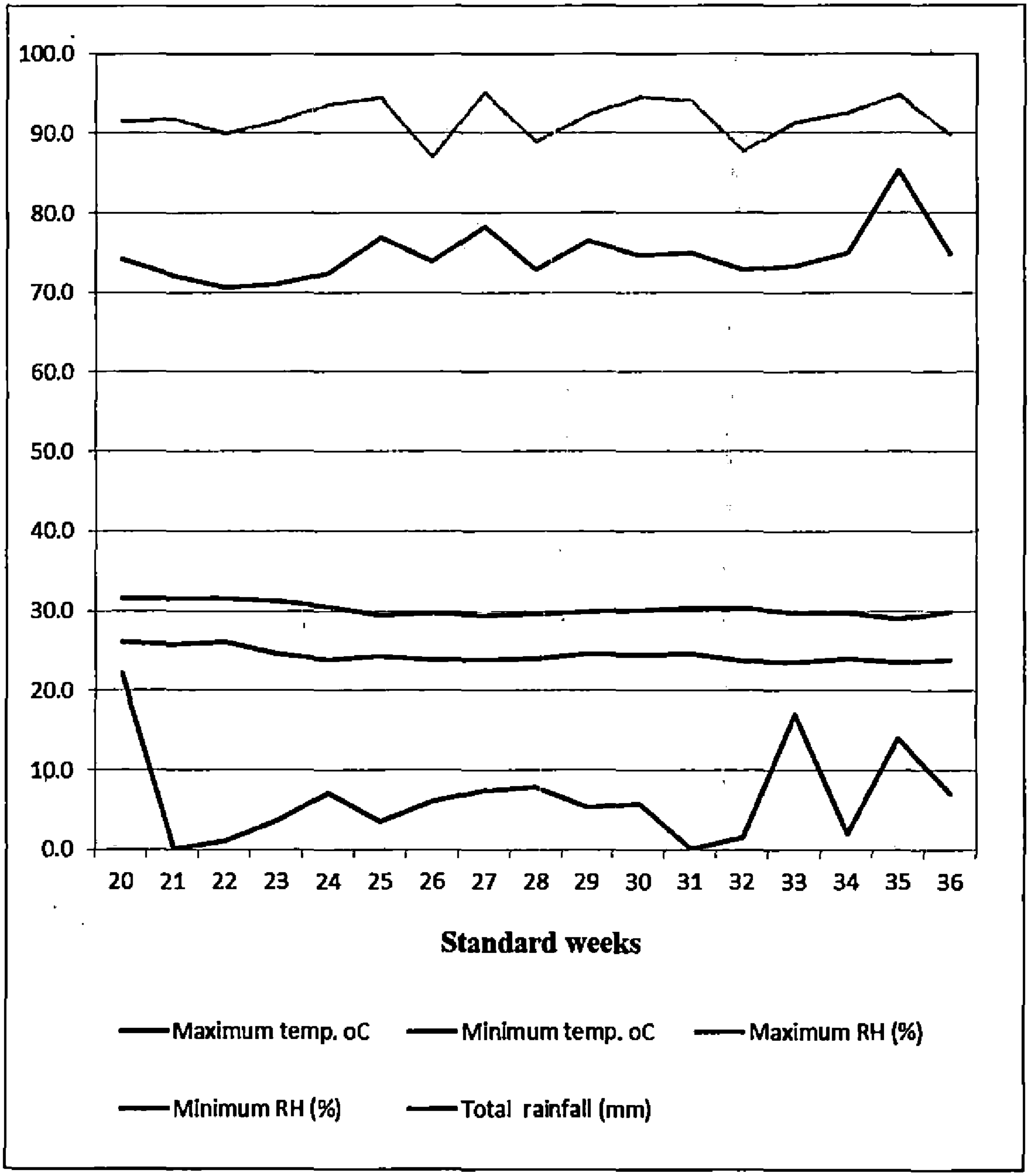
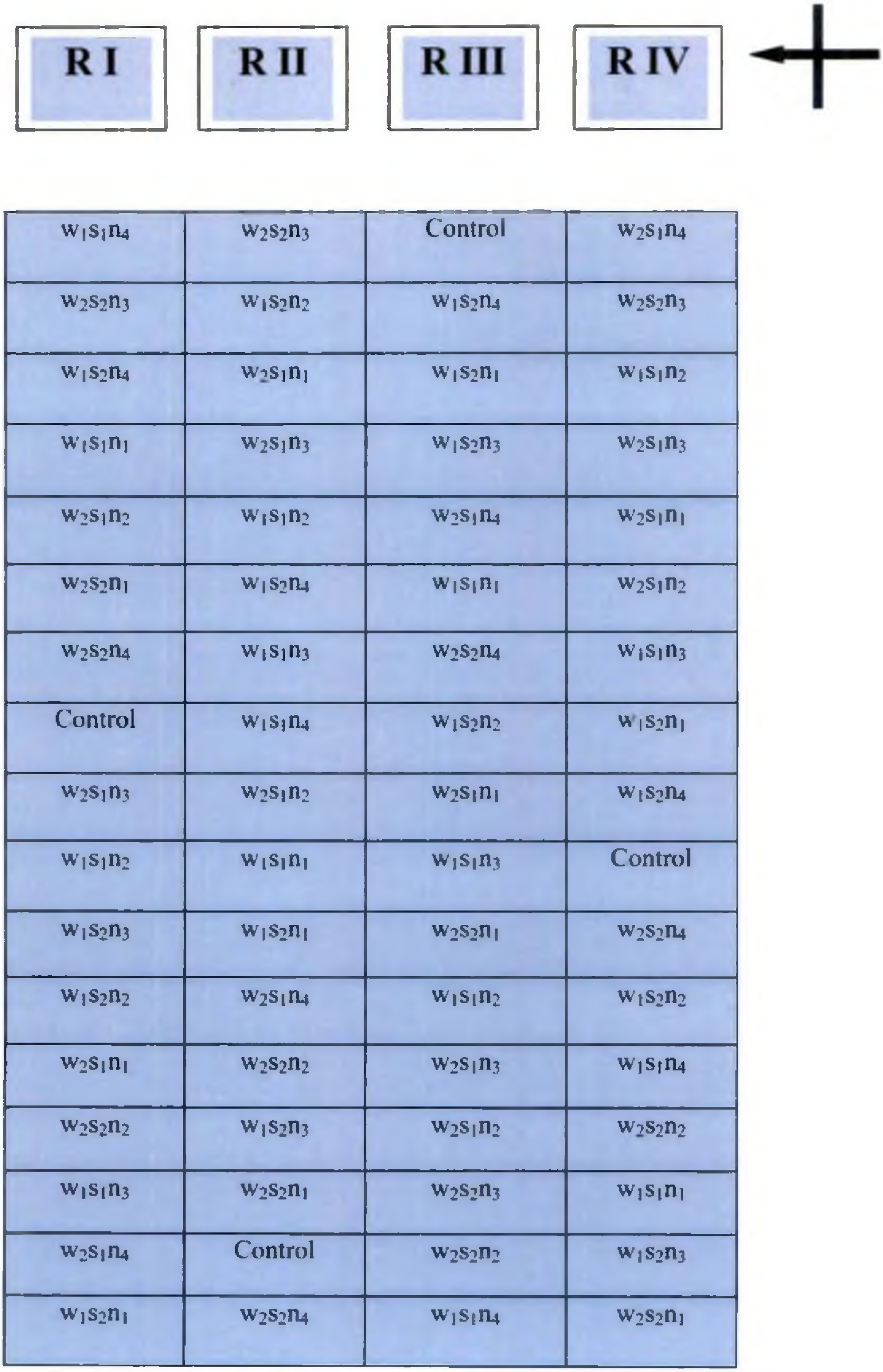


Fig 1. Weather parameters during the cropping period

(May 2012 to September 2012)



R I	R II	R III	R IV
$w_1s_1n_4$	$w_2s_2n_3$	Control	$w_2s_1n_4$
$w_2s_2n_3$	$w_1s_2n_2$	$w_1s_2n_4$	$w_2s_2n_3$
$w_1s_2n_4$	$w_2s_1n_1$	$w_1s_2n_1$	$w_1s_1n_2$
$w_1s_1n_1$	$w_2s_1n_3$	$w_1s_2n_3$	$w_2s_1n_3$
$w_2s_1n_2$	$w_1s_1n_2$	$w_2s_1n_4$	$w_2s_1n_1$
$w_2s_2n_1$	$w_1s_2n_4$	$w_1s_1n_1$	$w_2s_1n_2$
$w_2s_2n_4$	$w_1s_1n_3$	$w_2s_2n_4$	$w_1s_1n_3$
Control	$w_1s_1n_4$	$w_1s_2n_2$	$w_1s_2n_1$
$w_2s_1n_3$	$w_2s_1n_2$	$w_2s_1n_1$	$w_1s_2n_4$
$w_1s_1n_2$	$w_1s_1n_1$	$w_1s_1n_3$	Control
$w_1s_2n_3$	$w_1s_2n_1$	$w_2s_2n_1$	$w_2s_2n_4$
$w_1s_2n_2$	$w_2s_1n_4$	$w_1s_1n_2$	$w_1s_2n_2$
$w_2s_1n_1$	$w_2s_2n_2$	$w_2s_1n_3$	$w_1s_1n_4$
$w_2s_2n_2$	$w_1s_2n_3$	$w_2s_1n_2$	$w_2s_2n_2$
$w_1s_1n_3$	$w_2s_2n_1$	$w_2s_2n_3$	$w_1s_1n_1$
$w_2s_1n_4$	Control	$w_2s_2n_2$	$w_1s_2n_3$
$w_1s_2n_1$	$w_2s_2n_4$	$w_1s_1n_4$	$w_2s_2n_1$

Fig 2. Layout plan of the field experiment

3.2.2 Treatments

A. Main plot treatments

1. Spacing (S)

S_1 - 20 cm x 15 cm
S_2 - 15 cm x 15 cm

2. Weed management practices (W)

W_1-Stale seedbed

W_2-Hand weeding

B. Sub plot treatments

Nutrient schedule (N)

N_1-option-1 of the *ad hoc* recommendation of KAU: FYM 5 t + 800 kg oil cakes ha^{-1} (1/2 basal + 1/2 top dressing at active tillering stage).

N_2-option-2 of the *ad hoc* recommendation of KAU: FYM 1 t + green leaf manure 1t + dual culture of azolla + 2 kg Azospirillum + 2 kg P solubilizing bacteria + 1kg PGPR (mix 1) ha^{-1}.

N_3-option-3 of the *ad hoc* recommendation of KAU: 1/3rd RDN as FYM, 1/3rd as vermicompost and 1/3rd as neem cake + 2 kg Azospirillum + 2 kg P solubilizing bacteria ha^{-1}.

N_4-Soil test based application–half as vermicompost and half as neem cake.

Control-KAU POP (FYM 5 t + 90:45:45 kg NPK ha^{-1}).

Treatment combinations

$T_1 - w_1s_1n_1$

$T_2 - w_1s_1n_2$

$T_3 - w_1s_1n_3$

$T_4 - w_1s_1n_4$

$T_5 - w_1s_2n_1$

$T_6 - w_1s_2n_2$

$T_7 - w_1s_2n_3$

$T_8 - w_1s_2n_4$

$T_9 - w_2s_1n_1$

$T_{10} - w_2s_1n_2$

$T_{11} - w_2s_1n_3$

$T_{12} - w_2s_1n_4$

$T_{13} - w_2s_2n_1$

$T_{14} - w_2s_2n_2$

$T_{15} - w_2s_2n_3$

$T_{16} - w_2s_2n_4$

Treatments	:	16 + 1
Number of replications	:	4
Total number of plots	:	68
Gross plot size	:	5 m x 4 m

3.3 CULTURAL OPERATIONS

3.3.1 Nursery

The land was digged, leveled and weeds were removed and nursery bed was prepared. Pre germinated seeds of Uma @ 60 kg ha^{-1} were broadcasted in nursery beds of size 1.2 m width, 15 cm height and 4 m length on April 2012.

3.3.2 Main field

The experimental area was ploughed, puddled and levelled. Weeds and

Plate 1. Layout of the experimental plot

Plate 2. Field during transplanting

stubbles were removed. Individual plots of size 5 m x 4 m were laid out before transplanting.

3.3.3 Transplanting

Twenty five days old seedlings were gently pulled out from the nursery beds and planted in the main field maintaining the spacing and seedling density as per the treatments.

3.3.4 Weed management

Weed management practices as per treatments were done.

3.3.5 Plant protection

None of the diseases were observed above the economic threshold levels warranting control measures. Biological pesticides were used for rice bug control after scoring for the pest.

3.3.6 Plant sampling

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

3.3.7 Harvest

The crop was harvested when the straw just turned yellow. The net plots were harvested separately, threshed, winnowed and the weight of straw and grain were recorded separately from the individual plots. The border and sampling rows were harvested separately.

3.4 OBSERVATIONS

Growth characters and weed observations were taken at active tillering (20 DAT), maximum tillering (40 DAT), panicle initiation stage (60 DAT) and at harvest stage.

3.4.1 Growth characters

3.4.1.1 Height of the plant (20, 40, 60 DAT and at harvest)

The mean value of the height of six randomly selected observational plants from the net plot area was computed at 20, 40 60 DAT and at harvest and expressed in cm. The height was measured from the base of the plant to the tip of top most leaf. At harvest, height was recorded from the base of the plant to the tip of the longest panicle and mean height was computed and expressed in cm.

3.4.1.2 Number of tillers m^{-2} (20, 40, 60 DAT and at harvest)

Tiller numbers from one sq.m area were counted at 20, 40, 60 DAT and at harvest.

3.4.1.3 Leaf Area Index (LAI)

Leaf area index was calculated at 20, 40, 60 DAT and at harvest stages as per the method suggested by Gomez (1972).

Leaf area = L x W x K where 'L' is the length of leaf, 'W' is maximum width of leaf and 'K' is crop factor (0.75 at maximum tillering, panicle initiation and flowering and 0.67 at harvest stage).

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Land area}}$$

3.4.1.4 Dry matter production

Dry matter production (DMP) was recorded at harvest stage. The sample plants were uprooted, washed, dried under shade and later oven dried at $80 \pm 5\ ^{0}$C to constant weight and dry matter production expressed in kg ha^{-1}.

3.4.2 Yield and yield attributes

3.4.2.1 Number of productive tillers m^{-2}

Productive tiller number from one sq. m area was counted at harvest.

Plate 3. General view of the experimental field

Plate 4. Crop at harvest stage

3.4.2.2 Weight of panicle

Twelve panicles collected at random from each net plot at harvest were weighed and the mean weight per panicle was expressed in g.

3.4.2.3 Number of spikelets panicle^{-1}

The spikelets present in the twelve randomly selected panicles were counted and the mean was expressed as the number of spikelets panicle^{-1}.

3.4.2.4 No of filled grains panicle^{-1}

The filled grains obtained from the twelve randomly selected panicles were counted and the mean was expressed as the number of filled grains panicle^{-1}.

3.4.2.5 Thousand grain weight

One thousand grains were counted from the cleaned and dried produce from each plot and the weight was recorded in g.

3.4.2.6 Grain yield

The net plot area was harvested individually, threshed, winnowed, dried and the dry weight was recorded in kg ha$^{-1.}$

3.4.2.7 Straw yield

The straw harvested from each individual net plot was dried and the weight was recorded and expressed in kg ha^{-1}.

3.4.2.8 Harvest Index

The harvest index was calculated from the grain yield and straw yield using the formula,

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.4.3 Observations on weeds

3.4.3.1 Weedflora

Major weed species that infested the experimental site during the period of experimentation were identified and grouped into grasses, sedges, and broad leaved weeds.

3.4.3.2 Weed biomass

Weed samples were pulled out along with roots from the experimental site. The samples were washed, dried under shade and later oven dried at 80 ± 5 ^{0} C to constant weight. The dry weight of weeds was recorded and expressed as g m^{-2}.

3.4.4 Pest and disease scoring

None of the diseases were observed beyond the economic threshold levels. But there was severe incidence of rice bug. The rice bug was counted from six randomly selected observational plants from the net plot area and expressed as number hill^{-1}.

3.4.5 Plant Analysis

The sample plants collected from each plot at harvest stage was sun dried, oven dried to constant weight, ground, digested and nutrient content estimated. The N content (modified microkjeldhal method), P content (vanado-molybdo phosphoric yellow colour method) and K content (Flame photometer method) were estimated for plant samples from each plot separately (Jackson, 1973). Plant nutrient uptake was calculated by multiplying the nutrient content of the sample with the respective dry weight at harvest stage and expressed in kg ha^{-1}.

3.4.6 Soil analysis

Soil was analyzed for chemical properties before and after the experiment by obtaining composite samples from the top 15 cm layer of soil. The samples obtained were air dried in shade, sieved through 2 mm sieve for N, P and K analysis and sieved through 0.5 mm sieve for determining organic carbon content.

3.4.6.1 Organic carbon content

The soil organic carbon content after the experiment was estimated using the Walkley and Black's rapid titration method (Jackson, 1973) and expressed in percentage.

3.4.6.2 Available nitrogen content

The available N content of soil after the experiment was estimated using alkaline permanganate method (Subbiah and Asija, 1956) and expressed in kg ha^{-1}.

3.4.6.3 Available phosphorus content

The available P_2O_5 content of the soil after the experiment was estimated using Dickman and Bray's molybdenum blue method with Bray No.1 reagent as extractant (Jackson, 1973) and expressed in kg ha^{-1}.

3.4.6.4 Available potassium content

The available K_2O content of the soil after the experiment was determined using neutral ammonium acetate extract and estimated using EEL Flame photometer (Jackson, 1973) and expressed in kg ha^{-1}.

3.4.7 Economics of cultivation

Economics of cultivation was calculated based on the total income and total expenditure.

3.4.7.1 Net Income

Net income was computed using the formula

$$\text{Net income (Rs ha}^{-1}\text{)} = \text{Gross income - Total expenditure}$$

3.4.7.2 Benefit Cost Ratio

Benefit cost ratio was calculated using the formula

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

3.4.8 Statistical analysis

The data relating to different characters were analysed statistically by applying the technique of analysis of variance for split plot design and the significance was tested by F test. Wherever the F value was found significant, critical difference was worked out at five per cent and one per cent probability level. The results and discussions are based on levels of significance.

Results

4. RESULTS

A field experiment was conducted at the 'Organic Farm' of the Instructional Farm attached to the College of Agriculture, Vellayani during the first crop season of 2012 to standardize the weed management techniques (W), spacing (S) and nutrient schedule (N) for organic rice production with its economic feasibility for production.

The results of the experiment are presented here with their main as well as interaction effects.

4.1. GROWTH CHARACTERS

4.1.1. Height of plant (Tables 2, 3 and 4)

Weed management techniques significantly influenced plant height only at 40 DAT with W_2 (35.32 cm) recording the highest height than W_1 (35.04 cm). Spacing had significant effect at 60 DAT and at harvest stage with S_2 recorded the higher height (80.86 cm) than S_1 (79.49 cm). However, the effect of nutrient schedule was significant throughout the growth stages with N_3 recording the highest at all stages (36.94, 53.62, 81.89 and 93.38 cm respectively), but was on par with N_4 at 20 and 60 DAT (36.38 and 81.28 cm respectively).

The interaction effects were also significant. The W x S interaction effect was significant at 20 DAT with w_2s_1 recording the maximum height (35.76 cm) and was on par with all other treatments except w_1s_1 which recorded the lowest height (34.81 cm).

The W x N interaction effect was significant at 40 and 60 DAT and at harvest stage. At 40 DAT, w_2n_3 recorded maximum plant height (54.19 cm) and on par with w_1n_3 (53.05 cm) and plant height was the lowest in w_1n_2 (50.21 cm). At 60 DAT, w_1n_4 (82.63 cm) recorded maximum height and was on par with w_2n_3 (82.25 cm) and w_1n_3 (81.54 cm) respectively and plant height was the lowest in w_2n_2 (77.80 cm). At harvest stage w_1n_3 recorded the highest plant height (94.34 cm) which was significantly superior to all other treatments and the lowest in w_2n_2 (85.81 cm).

Table 2. Effect of weed management techniques, spacing and nutrient schedule on plant height

Treatments	Height of plant (cm)			
	20 DAT	40 DAT	60 DAT	Harvest
Weed management (W)				
W_1	35.04	51.66	80.52	90.13
W_2	35.32	52.55	79.84	89.51
S E m (±)	0.20	0.23	0.31	0.22
C D (0.05)	NS	0.74	NS	NS
Spacing (S)				
S_1	35.28	52.23	79.49	89.24
S_2	35.07	51.97	80.86	90.40
S E m (±)	0.20	0.23	0.31	0.22
C D (0.05)	NS	NS	1.01	0.70
Nutrient schedule (N)				
N_1	33.85	51.09	79.12	87.88
N_2	33.53	51.49	78.42	86.79
N_3	36.94	53.62	81.89	93.30
N_4	36.38	52.21	81.28	91.31
S E m (±)	0.26	0.33	0.43	0.35
C D (0.05)	0.74	0.94	1.25	1.02

Table 3. Interaction effect of weed management techniques, spacing and nutrient schedule on plant height (2 factor)

Treatments	Height of plant (cm)			
	20 DAT	40 DAT	60 DAT	Harvest
W x S				
w_1s_1	34.81	51.73	79.63	89.54
w_1s_2	35.26	51.59	81.41	90.72
w_2s_1	35.76	52.74	79.36	88.93
w_2s_2	34.87	52.36	80.31	90.08
S E m (±)	0.28	0.33	0.44	0.31
C D (0.05)	0.90	NS	NS	NS
W x N				
w_1n_1	33.79	51.15	78.86	87.42
w_1n_2	33.86	50.21	79.04	87.76
w_1n_3	36.58	53.05	81.54	94.34
w_1n_4	35.92	52.21	82.63	91.01
w_2n_1	33.92	51.03	79.38	88.33
w_2n_2	33.20	52.77	77.80	85.81
w_2n_3	37.31	54.19	82.25	92.27
w_2n_4	36.84	52.21	79.92	91.62
S E m (±)	0.36	0.46	0.61	0.50
C D (0.05)	NS	1.34	1.77	1.45
S x N				
s_1n_1	33.14	50.96	78.50	88.14
s_1n_2	34.15	50.42	78.18	85.65
s_1n_3	38.33	55.66	81.40	91.72
s_1n_4	35.52	51.89	79.89	91.44
s_2n_1	34.57	51.23	79.73	87.61
s_2n_2	32.91	52.56	78.66	87.92
s_2n_3	35.56	51.58	82.38	94.88
s_2n_4	37.24	52.53	82.66	91.19
S E m (±)	0.36	0.46	0.61	0.50
C D (0.05)	1.05	1.34	NS	1.45

Table 4. Interaction effect of weed management techniques, spacing and nutrient schedule on plant height (3 factor)

Treatments	Height of plant (cm)			
	20 DAT	40 DAT	60 DAT	Harvest
W x S x N				
$w_1s_1n_1$	32.95	51.01	78.31	88.25
$w_1s_1n_2$	34.01	50.57	79.10	85.98
$w_1s_1n_3$	36.93	53.67	80.92	93.39
$w_1s_1n_4$	35.35	51.67	80.17	90.55
$w_1s_2n_1$	34.64	51.30	79.41	86.58
$w_1s_2n_2$	33.71	49.86	78.97	89.54
$w_1s_2n_3$	36.23	52.43	82.15	95.29
$w_1s_2n_4$	36.48	52.76	85.09	91.47
$w_2s_1n_1$	33.34	50.91	78.70	88.04
$w_2s_1n_2$	34.30	50.28	77.25	85.32
$w_2s_1n_3$	39.72	57.64	81.89	90.05
$w_2s_1n_4$	35.68	52.11	79.61	92.33
$w_2s_2n_1$	34.50	51.16	80.06	88.63
$w_2s_2n_2$	32.10	55.25	78.36	86.31
$w_2s_2n_3$	34.90	50.73	82.61	94.48
$w_2s_2n_4$	38.01	52.31	80.24	90.91
S Em (±)	0.52	0.66	0.87	0.71
C D (0.05)	1.49	1.89	N S	2.05
Treatment mean	35.18	52.10	80.18	89.82
Control mean	39.73	57.93	82.03	90.96
Control vs. Treatment	S	S	S	NS

The S x N interaction effect was significant at 20 and 40 DAT and at harvest stage. At 20 and 40 DAT, the plant height was the highest in s_1n_3 (38.33 cm and 55.66 cm respectively) which were significantly superior to all other treatments. The plant height was the lowest in s_2n_2 (32.91 cm) at 20 DAT and in s_1n_2 (50.42 cm) at 40 DAT. At harvest stage s_2n_3 (94.88 cm) was found significantly superior to all others and s_1n_2 significantly inferior to all (85.65 cm).

The W x S x N interaction effect was significant at 20 and 40 DAT and at harvest stage with $w_2s_1n_3$ recording the highest plant height at 20 and 40 DAT (39.72 cm and 57.64 cm respectively) and were significantly superior to others. The plant height was the lowest in $w_2s_2n_2$ at 20 DAT (32.10 cm) and in $w_1s_2n_2$ at 40 DAT (49.86 cm). At harvest stage $w_1s_2n_3$ recorded maximum plant height (95.29 cm), but was on par with $w_2s_2n_3$ (94.48 cm) and $w_1s_1n_3$ (93.39 cm) and the lowest in $w_2s_1n_2$ (85.32 cm).

The comparison between organic (treatments mean) and conventional (control mean) revealed that there was significant difference at 20, 40 and 60 DAT. At all these stages conventional (control mean) recorded the highest plant height of 39.73, 57.93 and 82.03 cm respectively than organic (treatments mean).

4.1.2. Tiller number m^{-2} (Tables 5, 6 and 7)

The weed management techniques had no effect on tiller number. The spacing had significant effect with S_2 recording the highest tiller number (306.90, 513.45, 591.151 and 465.98 respectively) at all stages than S_1 (236.27, 390.01, 446.822 and 465.98 respectively). The effect of nutrient schedule was also significant with N_3 recording the highest tiller number (301.35, 490.99, 598.95 and 480.62 respectively) and N_2, the lowest (238.42, 423.93, 467.33 and 383.62 respectively) at all stages.

Among the different interactions, only W x N interaction was found significant and that too only at harvest stage of the crop, with w_1n_3 recording the highest number of tillers (512.52) and the lowest in w_1n_2 (375.74).

Table 5. Effect of weed management techniques, spacing and nutrient schedule on tillers m^{-2}

Treatments	Tillers m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
Weed management (W)				
W_1	270.77	456.13	521.78	430.11
W_2	272.40	447.33	516.18	416.19
S E m (±)	6.78	8.16	5.72	7.56
C D (0.05)	NS	NS	NS	NS
Spacing (S)				
S_1	236.27	390.01	446.822	380.32
S_2	306.90	513.45	591.151	465.98
S E m (±)	6.78	8.16	5.72	7.56
C D (0.05)	21.69	26.11	18.32	24.19
Nutrient schedule (N)				
N_1	261.28	435.02	492.12	386.20
N_2	238.42	423.93	467.33	383.62
N_3	301.35	490.99	598.95	480.62
N_4	285.29	456.99	517.55	442.18
S E m (±)	5.41	8.01	11.25	8.85
C D (0.05)	15.52	22.97	32.27	25.39

Table 6. Interaction effect of weed management techniques, spacing and nutrient schedule on tillers m^{-2} (2 factor)

Treatments	Tillers m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
W x S				
w_1s_1	240.16	392.79	451.47	384.44
w_1s_2	301.37	519.47	592.10	475.78
w_2s_1	232.37	387.23	442.17	376.20
w_2s_2	312.44	507.43	590.20	456.18
S E m (±)	9.59	11.54	8.09	10.69
C D (0.05)	NS	NS	NS	NS
W x N				
w_1n_1	260.46	437.06	481.98	380.89
w_1n_2	233.84	427.59	472.53	375.74
w_1n_3	304.47	505.31	604.60	512.52
w_1n_4	284.29	454.55	528.02	451.27
w_2n_1	262.10	432.97	502.24	391.49
w_2n_2	243.01	420.27	462.13	391.48
w_2n_3	298.22	476.67	593.29	448.71
w_2n_4	286.28	459.41	507.06	433.08
S E m (±)	7.65	11.32	15.91	12.51
C D (0.05)	NS	NS	NS	35.94
S x N				
s_1n_1	228.45	371.41	415.11	344.12
s_1n_2	207.87	371.31	398.56	335.72
s_1n_3	257.41	421.17	509.53	440.25
s_1n_4	251.33	396.14	464.07	401.19
s_2n_1	294.12	498.62	569.12	428.27
s_2n_2	268.98	476.55	536.10	431.50
s_2n_3	345.28	560.80	688.36	520.98
s_2n_4	319.24	517.82	571.01	483.16
S E m (±)	7.65	11.32	15.91	12.51
C D (0.05)	NS	NS	NS	NS

Table 7. Interaction effect of weed management techniques, spacing and nutrient schedule on tillers m^{-2} (3 factor)

Treatments	Tillers m^{-2}			
	20 DAT	40 DAT	60 DAT	Harvest
W x S x N				
$w_1s_1n_1$	232.68	367.31	406.84	350.38
$w_1s_1n_2$	215.61	383.74	419.65	334.27
$w_1s_1n_3$	262.09	417.37	493.41	450.90
$w_1s_1n_4$	250.27	402.73	485.98	402.20
$w_1s_2n_1$	288.25	506.81	557.13	411.41
$w_1s_2n_2$	252.07	471.44	525.40	417.22
$w_1s_2n_3$	346.86	593.25	715.80	574.14
$w_1s_2n_4$	318.32	506.37	570.06	500.35
$w_2s_1n_1$	224.22	375.52	423.38	337.86
$w_2s_1n_2$	200.14	358.88	377.47	337.17
$w_2s_1n_3$	252.74	424.98	525.65	429.60
$w_2s_1n_4$	252.40	389.55	442.17	400.18
$w_2s_2n_1$	299.99	490.42	581.11	445.13
$w_2s_2n_2$	285.88	481.66	546.79	445.79
$w_2s_2n_3$	343.70	528.36	660.93	467.82
$w_2s_2n_4$	320.16	529.28	571.95	465.98
S E m (±)	10.82	16.02	22.5	17.70
C D (0.05)	NS	NS	NS	NS
Treatment mean	271.59	451.73	518.98	423.15
Control mean	279.15	452.76	516.46	426.27
Control vs. Treatment	NS	NS	NS	NS

There was no significant difference between organic (treatments mean) and conventional (control mean).

4.1.3. Leaf area index (LAI) (Tables 8, 9 and 10)

LAI was not found influenced by weed management techniques. Spacing significantly influenced LAI at 20 DAT with S_2 recording the highest LAI (1.91). Nutrient schedule had significantly influenced LAI at all stages with N_3 recording the highest LAI at all stages (2.11, 3.37, 3.81 and 3.76 respectively), but on par with N_4 at 20 and 40 DAT (1.93 and 3.16 respectively).

None of the interactions were significant

The comparison made between organic (treatments mean) and conventional (control mean) showed that there was no significant difference between them.

4.1.4. Dry matter production (DMP) (Tables 11, 12 and 13)

The DMP of the plant was significantly influenced by weed management techniques with W_1 recording the highest DMP of 5,580 kg ha^{-1} than W_2 (5,385 kg ha^{-1}). Spacing significantly influenced DMP with S_2 recording the highest DMP of 5,764 kg ha^{-1} than S_1 (5,200 kg ha^{-1}). Nutrient schedule also had significant influence with N_3 recording the maximum DMP which was on par with N_4 (5,957 kg ha^{-1} and 5,714 kg ha^{-1} respectively) and the lowest in N_2 (5,067 kg ha^{-1}), but was on par with N_1 (5,192 kg ha^{-1}).

The interaction effects did not have any significant influence on DMP.

The comparison made between organic (treatments mean) and conventional (control mean) showed that there was no significant difference between them.

4.2. YIELD AND YIELD ATTRIBUTES

4.2.1. Productive tillers m^{-2} (Tables 11, 12 and 13)

The weed management techniques significantly influenced productive tiller number with W_1 recording the highest number of productive tillers (319) than W_2 (299.32). Spacing also had significant influence, with S_2 recording the highest number of productive tillers (351.03) than S_1 (267.30). Nutrient schedule had also

Table 8. Effect of weed management techniques, spacing and nutrient schedule on leaf area index (LAI)

Treatments	Leaf Area Index			
	20 DAT	40 DAT	60 DAT	Harvest
Weed management (W)				
W_1	1.86	3.06	3.53	3.27
W_2	1.81	3.00	3.43	3.36
S E m (±)	0.02	0.07	0.07	0.04
C D (0.05)	NS	NS	NS	NS
Spacing (S)				
S_1	1.77	2.96	3.41	3.27
S_2	1.91	3.09	3.56	3.37
S E m (±)	0.02	0.07	0.07	0.04
C D (0.05)	0.09	NS	NS	NS
Nutrient schedule (N)				
N_1	1.81	2.91	3.41	3.13
N_2	1.49	2.67	3.19	2.95
N_3	2.11	3.37	3.81	3.76
N_4	1.93	3.16	3.52	3.43
S E m (±)	0.08	0.09	0.08	0.07
C D (0.05)	0.24	0.27	0.24	0.21

Table 9. Interaction effect of weed management techniques, spacing and nutrient schedule on leaf area index (LAI) (2 factor)

Treatments	Leaf Area Index			
	20 DAT	40 DAT	60 DAT	Harvest
W x S				
w_1s_1	1.75	2.96	3.52	3.21
w_1s_2	1.96	3.15	3.55	3.33
w_2s_1	1.78	2.97	3.30	3.32
w_2s_2	1.856	3.03	3.57	3.40
S E m (±)	0.04	0.11	0.10	0.05
C D (0.05)	NS	NS	NS	NS
W x N				
w_1n_1	1.84	3.00	3.48	3.10
w_1n_2	1.47	2.65	3.26	2.96
w_1n_3	2.12	3.36	3.82	3.64
w_1n_4	2.00	3.21	3.57	3.39
w_2n_1	1.79	2.82	3.35	3.16
w_2n_2	1.51	2.68	3.13	2.95
w_2n_3	2.10	3.38	3.79	3.88
w_2n_4	1.86	3.10	3.47	3.46
S E m (±)	0.12	0.13	0.12	0.10
C D (0.05)	NS	NS	NS	NS
S x N				
s_1n_1	1.80	2.88	3.38	3.13
s_1n_2	1.37	2.57	3.07	2.93
s_1n_3	2.03	3.31	3.73	3.68
s_1n_4	1.87	3.09	3.45	3.33
s_2n_1	1.83	2.94	3.44	3.13
s_2n_2	1.62	2.76	3.32	2.98
s_2n_3	2.19	3.43	3.88	3.84
s_2n_4	1.99	3.23	3.60	3.53
S E m (±)	0.12	0.13	0.12	0.10
C D (0.05)	NS	NS	NS	NS

Table 10. Interaction effect of weed management techniques, spacing and nutrient schedule on leaf area index (LAI) (3 factor)

Treatments	Leaf Area Index			
	20 DAT	40 DAT	60 DAT	Harvest
W x S x N				
$w_1s_1n_1$	1.82	2.95	3.48	3.08
$w_1s_1n_2$	1.29	2.49	3.14	2.95
$w_1s_1n_3$	2.01	3.29	3.90	3.54
$w_1s_1n_4$	1.88	3.10	3.54	3.29
$w_1s_2n_1$	1.85	3.05	3.47	3.12
$w_1s_2n_2$	1.66	2.80	3.37	2.97
$w_1s_2n_3$	2.23	3.43	3.75	3.74
$w_1s_2n_4$	2.13	3.32	3.60	3.50
$w_2s_1n_1$	1.77	2.81	3.29	3.18
$w_2s_1n_2$	1.44	2.66	2.99	2.91
$w_2s_1n_3$	2.04	3.33	3.56	3.82
$w_2s_1n_4$	1.86	3.07	3.35	3.37
$w_2s_2n_1$	1.81	2.84	3.41	3.14
$w_2s_2n_2$	1.58	2.71	3.27	2.99
$w_2s_2n_3$	2.16	3.43	4.02	3.93
$w_2s_2n_4$	1.86	3.13	3.60	3.55
S E m (±)	0.17	0.18	0.17	0.15
C D (0.05)	NS	NS	NS	NS
Treatment mean	1.84	3.03	3.48	3.32
Control mean	1.85	3.17	3.57	3.23
Control vs. Treatment	NS	NS	NS	NS

significant effect with N_3 recording the highest number of productive tillers (365.00) and was significantly superior to all other treatments and the lowest in N_2 (264.84), which was significantly inferior to others.

Among the different interactions, the S x N interaction effect was significant with s_1n_3 recording the highest number of productive tillers (300.92) and was significantly superior to all others and the lowest in s_1n_2 (237.12), which was on par with s_1n_1 (249.74).

There was no significant difference between the organic (treatments mean) and conventional (control mean).

4.2.2. Grain weight panicle^{-1} (Tables 11, 12 and 13)

Grain weight panicle^{-1} was significantly influenced by weed management techniques with W_1'recording the highest grain weight (1.62 g) than W_2'(1.47 g). Spacing did not have any significant effect on grain weight panicle^{-1}. Nutrient schedule had significant effect with N_3 recording maximum grain weight panicle^{-1} which was on par with N_4 (1.72 and 1.65 g respectively) and the lowest in N_2 (1.36 g) which was on par with N_1 (1.45 g).

Interaction effects did not have any significant effect on grain weight panicle^{-1}.

The comparison between organic (treatments mean) and conventional (control mean) showed that there was no significant difference between them.

4.2.3. Spikelets panicle^{-1} (Tables 14, 15 and 16)

The effect of weed management techniques was significant on number of spikelets panicle^{-1} with W_1 recording the highest number of spikelets panicle^{-1} than W_2 (90.43 and 88.47 respectively), but spacing didn't have any significant effect on spikelets panicle^{-1}. Nutrient schedule had significant effect on number of spikelets panicle^{-1} with N_3 recording the highest number of spikelets panicle^{-1} (93.12) than all other treatments and the lowest in N_2 (86.63) which was on par with N_1 (88.34).

The interaction effects were not significant at all.

Table 11. Effect of weed management techniques, spacing and nutrient schedule on dry matter production, productive tillers m^{-2} and grain weight panicle^{-1}

Treatments	DMP (kg ha^{-1})	Productive tillers m^{-2}	Grain weight panicle^{-1} (g)
Weed management (W)			
W_1	5,580	319.00	1.62
W_2	5,385	299.32	1.47
S E m (±)	51.64	4.10	0.01
C D (0.05)	165.21	13.11	0.05
Spacing (S)			
S_1	5,200	267.30	1.56
S_2	5,764	351.03	1.53
S E m (±)	51.64	4.10	0.01
C D (0.05)	165.21	13.11	NS
Nutrient schedule (N)			
N_1	5,192	283.69	1.45
N_2	5,067	264.84	1.36
N_3	5,957	365.00	1.72
N_4	5,714	323.12	1.65
S E m (±)	114.28	6.11	0.05
C D (0.05)	327.79	17.55	0.14

Table 12. Interaction effect of weed management techniques, spacing and nutrient schedule on dry matter production, productive tillers m^{-2} and grain weight panicle^{-1}(2 factor)

Treatments	DMP (kg ha^{-1})	Productive tillers m^{-2}	Grain weight panicle^{-1} (g)
W x S			
w_1s_1	5,311	279.40	1.64
w_1s_2	5,848	358.61	1.60
w_2s_1	5,090	255.20	1.48
w_2s_2	5,681	343.45	1.46
S E m (±)	73.03	5.79	0.02
C D (0.05)	NS	NS	NS
W x N			
w_1n_1	5,309	297.06	1.49
w_1n_2	5,206	273.00	1.44
w_1n_3	6,048	364.68	1.81
w_1n_4	5,756	341.28	1.74
w_2n_1	5,076	270.32	1.40
w_2n_2	4,928	256.68	1.29
w_2n_3	5,865	365.33	1.63
w_2n_4	5,671	304.96	1.56
S E m (±)	161.62	8.65	0.07
C D (0.05)	NS	NS	NS
S x N			
s_1n_1	4,831	249.74	1.46
s_1n_2	4,860	237.12	1.40
s_1n_3	5,658	300.92	1.74
s_1n_4	5,452	281.41	1.64
s_2n_1	5,553	317.64	1.43
s_2n_2	5,274	292.56	1.33
s_2n_3	6,255	429.09	1.70
s_2n_4	5,975	364.83	1.65
S E m (±)	161.62	8.65	0.07
C D (0.05)	NS	24.84	NS

Table 13. Interaction effect of weed management techniques, spacing and nutrient schedule on dry matter production, productive tillers m^{-2}, and grain weight panicle^{-1}(3 factor)

Treatments	DMP (kg ha^{-1})	Productive tillers m^{-2}	Grain weight panicle^{-1} (g)
W x S x N			
$w_1s_1n_1$	4,993	268.71	1.50
$w_1s_1n_2$	4,984	248.94	1.45
$w_1s_1n_3$	5,779	295.49	1.86
$w_1s_1n_4$	5,489	304.45	1.75
$w_1s_2n_1$	5,625	325.41	1.48
$w_1s_2n_2$	5,427	297.07	1.43
$w_1s_2n_3$	6,317	433.86	1.76
$w_1s_2n_4$	6,024	378.11	1.72
$w_2s_1n_1$	4,670	230.77	1.42
$w_2s_1n_2$	4,736	225.31	1.35
$w_2s_1n_3$	5,536	306.34	1.63
$w_2s_1n_4$	5,416	258.36	1.54
$w_2s_2n_1$	5,482	309.87	1.38
$w_2s_2n_2$	5,120	288.05	1.23
$w_2s_2n_3$	6,193	424.33	1.64
$w_2s_2n_4$	5,927	351.55	1.59
S E m (±)	228.57	12.23	0.10
C D (0.05)	NS	NS	NS
Treatment mean	5,482	309.16	1.54
Control mean	5,502	289.54	1.60
Control vs. Treatment	NS	NS	NS

Organic (treatments mean) vs. conventional (control mean) was also non-significant.

4.2.4. Filled grains panicle^{-1} (Tables 14, 15 and 16)

Weed management techniques and spacing did not have any significant effect on number of filled grains panicle^{-1}. But nutrient schedule significantly affected filled grains panicle^{-1} with N_3 recording the highest number of filled grains panicle^{-1} (75.35) and the lowest in N_2 (69.10) which was on par with N_1 (79.59).

The interaction effects were not significant.

Comparison of organic (treatments mean) and conventional (control mean) revealed that there was no significant difference between them.

4.2.5. Thousand grain weight (Tables 14, 15 and 16)

Weed management techniques and spacing had no significant effect on thousand grain weight. The nutrient schedule had significant effect on thousand grain weight with N_3 recording the maximum (17.91 g) followed by N_4 (17.12 g), which were on par and the lowest in N_2 (15.84g) which was on par with N_1 (16.65 g).

The interaction effects were not significant.

The comparison between organic (treatments mean) and conventional (control mean) showed that there was no significant difference.

4.2.6. Grain yield (kg ha^{-1}) (Tables 17, 18 and 19)

Weed management techniques had no significant effect on grain yield. Spacing significantly influenced grain yield with S_2 recording the highest grain yield of 1,978 kg ha^{-1} than S_1 (1,781 kg ha^{-1}). Nutrient schedule also significantly influenced grain yield with N_3 recording the maximum grain yield (2,067 kg ha^{-1}), which was on par with N_4 (1,960 kg ha^{-1}) and the lowest in N_2 (1,694 kg ha^{-1}) which was on par with N_1 (1,798 kg ha^{-1}).

The interaction effects were not significant.

Table 14. Effect of weed management techniques, spacing and nutrient schedule on spikelets panicle^{-1}, filled grains panicle^{-1} and thousand grain weight

Treatments	Spikelets panicle^{-1}	Filled grains panicle^{-1}	Thousand grain weight (g)
Weed management (W)			
W_1	90.43	72.97	17.13
W_2	88.47	71.63	16.63
S E m (±)	0.56	0.77	0.23
C D (0.05)	1.82	NS	NS
Spacing (S)			
S_1	88.92	71.44	16.75
S_2	89.98	73.15	17.01
S E m (±)	0.56	0.77	0.23
C D (0.05)	NS	NS	NS
Nutrient schedule (N)			
N_1	88.34	71.59	16.65
N_2	86.63	69.10	15.84
N_3	93.12	75.35	17.91
N_4	89.71	73.16	17.12
S E m (±)	0.67	0.95	0.29
C D (0.05)	1.93	2.72	0.84

Table 15. Interaction effect of weed management techniques, spacing and nutrient schedule on spikelets panicle^{-1}, filled grains panicle^{-1} and thousand grain weight (2 factor)

Treatments	Spikelets panicle^{-1}	Filled grains panicle^{-1}	Thousand grain weight (g)
W x S			
w_1s_1	89.88	72.08	17.20
w_1s_2	90.99	73.85	17.06
w_2s_1	87.96	70.80	16.30
w_2s_2	88.98	72.45	16.95
S E m (±)	0.80	1.09	0.32
C D (0.05)	NS	NS	NS
W x N			
w_1n_1	88.66	72.02	16.78
w_1n_2	87.43	69.58	16.00
w_1n_3	93.87	76.10	18.30
w_1n_4	91.77	74.17	17.44
w_2n_1	88.02	71.16	16.51
w_2n_2	85.83	68.61	15.69
w_2n_3	92.37	74.60	17.52
w_2n_4	87.65	72.15	16.80
S E m (±)	0.95	1.33	0.41
C D (0.05)	NS	NS	NS
S x N			
s_1n_1	88.90	71.48	16.68
s_1n_2	85.98	68.37	15.83
s_1n_3	91.66	73.63	17.67
s_1n_4	89.13	72.28	16.82
s_2n_1	87.78	71.70	16.61
s_2n_2	87.28	69.82	15.86
s_2n_3	94.58	77.06	18.15
s_2n_4	90.28	74.03	17.41
S E m (±)	0.95	1.34	0.41
C D (0.05)	NS	NS	NS

Table 16. Interaction effect of weed management techniques, spacing and nutrient schedule on spikelets panicle^{-1}, filled grains panicle^{-1} and thousand grain weight (3 factor)

Treatments	Spikelets panicle^{-1}	Filled grains panicle^{-1}	Thousand grain weight (g)
W x S x N			
$w_1s_1n_1$	89.70	71.97	16.96
$w_1s_1n_2$	86.17	68.80	16.22
$w_1s_1n_3$	93.00	74.20	18.24
$w_1s_1n_4$	90.65	73.37	17.38
$w_1s_2n_1$	87.62	72.07	16.61
$w_1s_2n_2$	88.70	70.37	15.78
$w_1s_2n_3$	94.75	78.00	18.37
$w_1s_2n_4$	92.90	74.97	17.50
$w_2s_1n_1$	88.10	71.00	16.41
$w_2s_1n_2$	85.80	67.95	15.43
$w_2s_1n_3$	90.32	73.07	17.11
$w_2s_1n_4$	87.62	71.20	16.27
$w_2s_2n_1$	87.95	71.32	16.62
$w_2s_2n_2$	85.87	69.27	15.95
$w_2s_2n_3$	94.42	76.12	17.93
$w_2s_2n_4$	87.67	73.10	17.33
S E m (±)	1.35	1.90	0.59
C D (0.05)	NS	NS	NS
Treatment mean	89.45	72.30	16.88
Control mean	89.80	73.15	17.07
Control vs. Treatment	NS	NS	NS

Table 17. Effect of weed management techniques, spacing and nutrient schedule on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Weed management (W)			
W_1	1,912	3,667	0.34
W_2	1,847	3,537	0.34
S E m (±)	41.38	10.03	7.68
C D (0.05)	NS	NS	NS
Spacing (S)			
S_1	1,781	3,419	0.34
S_2	1,978	3,786	0.34
S E m (±)	41.38	10.03	7.68
C D (0.05)	132.38	181.65	NS
Nutrient schedule (N)			
N_1	1,798	3,394	0.34
N_2	1,694	3,373	0.33
N_3	2,067	3,889	0.34
N_4	1,960	3,753	0.34
S E m (±)	75.04	81.42	9.75
C D (0.05)	215.25	233.55	NS

Table 18. Interaction effect of weed management techniques, spacing and nutrient schedule on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index (2 factor)

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
W x S			
w_1s_1	1,817	3,494	0.34
w_1s_2	2,008	3,840	0.34
w_2s_1	1,746	3,343	0.34
w_2s_2	1,948	3,732	0.34
S E m (±)	58.52	80.29	0.01
C D (0.05)	NS	NS	NS
W x N			
w_1n_1	1,831	3,477	0.34
w_1n_2	1,720	3,485	0.33
w_1n_3	2,121	3,927	0.35
w_1n_4	1,977	3,778	0.34
w_2n_1	1,764	3,311	0.34
w_2n_2	1,667	3,260	0.33
w_2n_3	2,014	3,851	0.34
w_2n_4	1,943	3,727	0.34
S E m (±)	106.13	115.15	0.01
C D (0.05)	NS	NS	NS
S x N			
s_1n_1	1,664	3,167	0.34
s_1n_2	1,659	3,201	0.33
s_1n_3	1,959	3,698	0.34
s_1n_4	1,843	3,609	0.33
s_2n_1	1,931	3,621	0.34
s_2n_2	1,728	3,545	0.32
s_2n_3	2,175	4,080	0.34
s_2n_4	2,077	3,897	0.34
S E m (±)	106.13	115.15	0.01
C D (0.05)	NS	NS	NS

Table 19. Interaction effect of weed management techniques, spacing and nutrient schedule on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index (3 factor)

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
W x S x N			
$w_1s_1n_1$	1,681	3,311	0.33
$w_1s_1n_2$	1,706	3,277	0.34
$w_1s_1n_3$	2,017	3,761	0.35
$w_1s_1n_4$	1,863	3,626	0.33
$w_1s_2n_1$	1,981	3,643	0.35
$w_1s_2n_2$	1,734	3,693	0.31
$w_1s_2n_3$	2,224	4,093	0.35
$w_1s_2n_4$	2,092	3,931	0.34
$w_2s_1n_1$	1,647	3,023	0.35
$w_2s_1n_2$	1,611	3,125	0.33
$w_2s_1n_3$	1,902	3,634	0.34
$w_2s_1n_4$	1,824	3,592	0.33
$w_2s_2n_1$	1,881	3,600	0.34
$w_2s_2n_2$	1,723	3,396	0.33
$w_2s_2n_3$	2,126	4,067	0.34
$w_2s_2n_4$	2,063	3,863	0.34
S E m (±)	150.09	162.85	0.01
C D (0.05)	NS	NS	NS
Treatment mean	1,880	3,602	0.34
Control mean	1,791	3,710	0.32
Control vs. Treatment	NS	NS	NS

The difference between organic (treatments mean) and conventional (control mean) showed that there was no significant difference.

4.2.7. Straw yield (kg ha^{-1}) (Tables 17, 18 and 19)

Weed management techniques had no significant effect on straw yield. Spacing had significant effect with S_2 recording the highest straw yield (3,786 kg ha^{-1}) than S_1 (3,419 kg ha^{-1}). Nutrient schedule also had significant influence on straw yield with N_3 recording the maximum (3,889 kg ha^{-1}), which was on par with N_4 (3,753 kg ha$^{-1)}$ and the lowest in N_2 (3,373 kg ha^{-1}) which was on par with N_1 (3,394 kg ha^{-1}).

The interaction effects were not significant.

There was no significant difference between organic (treatments mean) and conventional (control mean).

4.2.8. Harvest index (Tables 17, 18 and 19)

Main effects as well as interaction effects were not significant. There was no significant difference between organic (treatments mean) and conventional (control mean).

4.3. OBSERVATION ON WEEDS

4.3.1 Major weed flora in experimental field

The different weed species observed in the experimental field were identified and categorized into grasses, sedges and broadleaved weeds.

Detailed list of the entire weed species observed is given in Table 20.

4.3.2 Weed biomass (Tables 21, 22 and 23)

Weed management techniques had significant effect on weed biomass at 20, 40, 60 DAT and at harvest. At, all these stages W_1 recorded the lowest weed biomass (47.60 g m^{-2}, 54.92 g m^{-2}, 67.03 g m^{-2}, and 106.13 g m^{-2} respectively) than W_2 (50.44 g m^{-2}, 59.59 g m^{-2}, 71.20 g m^{-2}, and 111.98 g m^{-2} respectively). Spacing also had significant influence on weed biomass at all the crop growth stages with S_2

Table 20. Weed species observed in the experimental site

Grasses	**Sedges**	**Broadleaved weeds**
Echinochloa crus-galli *Cynodon dactylon* *Panicum repens* *Dactyloctenium aegyptium*	*Cyperus iria* *Cyperus difformis* *Cyperus rotundus*	*Mimosa pudica* *Synedrella nodiflora* *Phyllanthus niruri* *Cleome viscosa* *Cleome rutidospermum* *Commelina benghalensis* *Commelina jacobi*

Table 21. Effect of weed management techniques, spacing and nutrient schedule on weed biomass

Treatments	Weed biomass (g m^{-2})			
	20 DAT	40 DAT	60 DAT	Harvest
Weed management (W)				
W_1	47.60	54.92	67.03	106.13
W_2	50.44	59.59	71.20	111.98
S E m (±)	0.44	0.73	1.32	1.68
C D (0.05)	2.14	3.18	3.52	5.12
Spacing (S)				
S_1	50.75	61.33	71.07	113.26
S_2	47.29	53.18	67.17	104.85
S E m (±)	0.44	0.73	1.32	1.68
C D (0.05)	2.14	3.18	3.52	5.12
Nutrient schedule				
N_1	47.60	54.50	67.09	107.73
N_2	46.36	55.06	65.60	106.18
N_3	52.29	59.76	72.05	112.31
N_4	49.83	59.70	71.73	110.01
S E m (±)	0.94	1.40	1.55	2.26
C D (0.05)	1.82	2.98	5.38	NS

Table 22. Interaction effect of weed management techniques, spacing and nutrient schedule on weed biomass (2 factor)

Treatments	Weed biomass (g m^{-2})			
	20 DAT	40 DAT	60 DAT	Harvest
W x S				
w_1s_1	49.19	57.88	69.18	110.17
w_1s_2	46.01	51.96	64.89	102.09
w_2s_1	52.30	64.78	72.96	116.35
w_2s_2	48.58	54.40	69.45	107.61
S E m (±)	0.63	1.04	1.87	2.38
C D (0.05)	NS	NS	NS	NS
W x N				
w_1n_1	46.54	52.52	65.68	104.77
w_1n_2	44.62	53.94	63.69	103.31
w_1n_3	50.76	58.00	69.62	109.77
w_1n_4	48.49	55.21	69.15	106.69
w_2n_1	48.66	56.48	68.51	110.70
w_2n_2	48.09	56.19	67.52	109.04
w_2n_3	53.82	61.39	74.47	114.85
w_2n_4	51.18	64.32	74.31	113.34
S E m (±)	1.34	1.99	2.20	3.20
C D (0.05)	NS	NS	NS	NS
S x N				
s_1n_1	49.64	60.27	69.19	111.19
s_1n_2	48.21	58.72	65.11	110.78
s_1n_3	53.73	63.44	74.45	117.07
s_1n_4	51.40	62.88	75.53	113.99
s_2n_1	45.57	48.73	65.00	104.27
s_2n_2	44.50	51.41	66.10	101.57
s_2n_3	50.84	55.95	69.64	107.55
s_2n_4	48.27	56.64	67.94	106.03
S E m (±)	1.34	1.99	2.20	3.20
C D (0.05)	NS	NS	NS	NS

Table 23. Interaction effect of weed management techniques, spacing and nutrient schedule on weed biomass (3 factor)

Treatments	Weed biomass (g m^{-2})			
	20 DAT	40 DAT	60 DAT	Harvest
W x S x N				
$w_1s_1n_1$	47.94	57.86	69.11	108.29
$w_1s_1n_2$	45.66	55.89	59.65	105.87
$w_1s_1n_3$	52.99	60.94	73.24	115.49
$w_1s_1n_4$	50.18	56.82	74.72	111.04
$w_1s_2n_1$	45.14	47.18	62.24	101.25
$w_1s_2n_2$	43.59	52.00	67.73	100.75
$w_1s_2n_3$	48.53	55.07	66.00	104.05
$w_1s_2n_4$	46.80	53.60	63.58	102.34
$w_2s_1n_1$	51.33	62.67	69.27	114.10
$w_2s_1n_2$	50.77	61.55	70.57	115.70
$w_2s_1n_3$	54.47	65.95	75.66	118.66
$w_2s_1n_4$	52.63	68.95	76.33	116.95
$w_2s_2n_1$	46.00	50.29	67.75	107.30
$w_2s_2n_2$	45.41	50.83	64.47	102.39
$w_2s_2n_3$	53.16	56.83	73.28	111.05
$w_2s_2n_4$	49.74	59.68	72.29	109.73
S E m (±)	1.89	2.817	3.11	4.52
C D (0.05)	NS	NS	NS	NS
Treatment mean	49.02	57.25	69.12	109.06
Control mean	54.44	67.23	77.99	119.16
Control vs. Treatment	S	S	S	S

recording the lowest weed biomass (47.29 g m^{-2}, 53.18 g m^{-2}, 67.17 g m^{-2} and 104.85 g m^{-2} respectively) than S_1 (50.75 g m^{-2}, 61.33 g m^{-2}, 71.07 g m^{-2} and 113.26 g m^{-2} respectively).

Nutrient schedule also significantly influenced weed biomass at 20, 40 and 60 DAT, with N_2 recording the lowest weed biomass at 20 DAT (46.36 g m^{-2}) and 60 DAT (65.60 g m^{-2}) which was on par with N_1 (47.60 g m^{-2} and 67.09 g m^{-2}). At 40 DAT, N_1 recorded the lowest weed biomass (54.50 g m^{-2}) which was on par with N_2 (55.06 g m^{-2})

Interaction effects did not have any significant effect.

The comparison between organic (treatments mean) and conventional (control mean) showed that there was significant difference between them at all the crop stages with organic (treatments mean) recording the lowest weed biomass than conventional (control mean).

4.4 PEST AND DISEASE SCORING (Tables 24, 25 and 26)

Neither weed management techniques nor spacing or nutrient schedule had any significant effect on rice bug attack.

The interaction effects were not significant.

There was no significant difference between organic (treatments mean) and conventional (control mean).

4.5 SOIL ANALYSIS

4.5.1 Organic carbon (Tables 27, 28 and 29)

Main effects as well as interaction effects were not significant.

There was no significant difference between organic (treatments mean) and conventional (control mean).

4.5.2 Available nitrogen (Tables 27, 28 and 29)

Weed management techniques did not have any significant effect on available nitrogen status of soil after the experiment. Spacing significantly influenced available

Table 24. Effect of weed management techniques, spacing and nutrient schedule on rice bug

Treatments	Rice bug (numbers hill^{-1})
Weed management (W)	
W_1	7.59
W_2	7.62
S E m (±)	0.18
C D (0.05)	NS
Spacing (S)	
S_1	7.59
S_2	7.62
S E m (±)	0.18
C D (0.05)	NS
Nutrient schedule (N)	
N_1	7.68
N_2	7.43
N_3	7.68
N_4	7.62
S E m (±)	0.32
C D (0.05)	NS

Table 25. Interaction effect of weed management techniques, spacing and nutrient schedule on rice bug (2 factor)

Treatments	Rice bug (numbers hill^{-1})
W x S	
w_1s_1	7.56
w_1s_2	7.62
w_2s_1	7.62
w_2s_2	7.62
S E m (±)	0.04
C D (0.05)	NS
W x N	
w_1n_1	7.75
w_1n_2	7.25
w_1n_3	7.62
w_1n_4	7.75
w_2n_1	7.62
w_2n_2	7.62
w_2n_3	7.75
w_2n_4	7.50
S E m (±)	0.46
C D (0.05)	NS
S x N	
s_1n_1	7.75
s_1n_2	7.37
s_1n_3	7.75
s_1n_4	7.50
s_2n_1	7.62
s_2n_2	7.50
s_2n_3	7.62
s_2n_4	7.75
S E m (±)	0.46
C D (0.05)	NS

Table 26. Interaction effect of weed management techniques, spacing and nutrient schedule on rice bug (3 factor)

Treatments	Rice bug (numbers hill^{-1})
W x S x N	
$w_1s_1n_1$	7.75
$w_1s_1n_2$	7.25
$w_1s_1n_3$	7.75
$w_1s_1n_4$	7.50
$w_1s_2n_1$	7.75
$w_1s_2n_2$	7.25
$w_1s_2n_3$	7.50
$w_1s_2n_4$	8.00
$w_2s_1n_1$	7.75
$w_2s_1n_2$	7.50
$w_2s_1n_3$	7.75
$w_2s_1n_4$	7.50
$w_2s_2n_1$	7.50
$w_2s_2n_2$	7.75
$w_2s_2n_3$	7.75
$w_2s_2n_4$	7.50
S E m (±)	0.65
C D (0.05)	NS
Treatment mean	7.60
Control mean	8.00
Control vs. Treatment	NS

nitrogen content of the soil with S_1 recording the highest content (267.47 kg ha^{-1}) than S_2 (262.65 kg ha^{-1}). Nutrient schedule significantly influenced available nitrogen content in soil with N_3 recording the highest content (278.42 kg ha^{-1}) and N_2 the lowest (253.58 kg ha^{-1}).

Interaction effects did not have any significant effect.

The comparison between organic (treatments mean) and conventional (control mean) mean revealed that there was no significant difference.

4.5.3 Available phosphorus (Tables 27, 28 and 29)

The available phosphorus content of the soil after the experiment was not significantly influenced by weed management techniques and spacing. Nutrient schedule had significant effect with N_3 recording the highest content (63.77 kg ha^{-1}) and N_2 the lowest (50.20 kg ha^{-1}).

Interaction effects were not significant.

Between the organic (treatments mean) and conventional (control mean) there was no significant difference.

4.5.4 Available potash (Tables 27, 28 and 29)

Weed management techniques and spacing did not have any significant effect on available potash status of the soil after the experiment. Nutrient schedule significantly influenced available potash content in soil with N_3 recording the maximum content (55.92 kg ha^{-1}) which was on par with N_4 (54.33 kg ha^{-1}) and N_2 the lowest (41.78 kg ha^{-1}).

The interaction effects were not significant at all.

There was no significant difference between organic (treatments mean) and conventional (control mean).

Table 27. Effect of weed management techniques, spacing and nutrient schedule on organic carbon, available nitrogen, phosphorus and potassium status of the soil after the experiment

Treatments	Organic carbon (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
Weed management (W)				
W_1	1.38	263.58	58.32	49.45
W_2	1.37	266.53	58.33	50.18
S E m (±)	0.01	1.62	0.53	0.66
C D (0.05)	NS	NS	NS	NS
Spacing (S)				
S_1	1.38	267.47	58.48	50.23
S_2	1.36	262.65	58.16	49.40
S E m (±)	0.01	1.62	0.53	0.66
C D (0.05)	NS	4.78	NS	NS
Nutrient schedule (N)				
N_1	1.36	262.54	58.44	47.23
N_2	1.36	253.58	50.20	41.78
N_3	1.42	278.42	63.77	55.92
N_4	1.35	265.69	60.87	54.33
S E m (±)	0.03	2.11	0.57	0.67
C D (0.05)	NS	6.59	2.16	2.68

Table 28. Interaction effect of weed management techniques, spacing and nutrient schedule on organic carbon, available nitrogen, phosphorus and potassium status of the soil after the experiment (2 factor)

Treatments	Organic carbon (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
W X S				
w_1s_1	1.38	266.30	58.55	49.74
w_1s_2	1.37	260.86	58.08	49.16
w_2s_1	1.38	268.63	58.41	50.72
w_2s_2	1.35	264.43	58.24	49.64
S E m (±)	0.02	2.30	0.75	0.93
C D (0.05)	NS	NS	NS	NS
W X N				
w_1n_1	1.35	261.35	58.68	46.92
w_1n_2	1.39	252.44	50.65	41.01
w_1n_3	1.42	276.88	63.91	56.01
w_1n_4	1.36	263.66	60.02	53.86
w_2n_1	1.36	263.73	58.20	47.55
w_2n_2	1.34	254.73	49.75	42.55
w_2n_3	1.42	279.97	63.64	55.82
w_2n_4	1.35	267.71	61.72	54.80
S E m (±)	0.04	2.99	0.81	0.95
C D (0.05)	NS	NS	NS	NS
S X N				
s_1n_1	1.37	265.08	59.17	47.80
s_1n_2	1.38	255.58	49.27	41.94
s_1n_3	1.42	280.93	64.44	56.37
s_1n_4	1.37	268.28	61.06	54.80
s_2n_1	1.35	260.00	57.71	46.66
s_2n_2	1.35	251.58	51.13	41.62
s_2n_3	1.42	275.92	63.11	55.47
s_2n_4	1.34	263.09	60.68	53.86
S E m (±)	0.04	2.99	0.81	0.95
C D (0.05)	NS	NS	NS	NS

Table 29. Interaction effect of weed management techniques, spacing and nutrient schedule on organic carbon, available nitrogen, phosphorus and potassium status of the soil after the experiment (3 factor)

Treatments	Organic carbon (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
W X S X N				
$w_1s_1n_1$	1.36	264.14	58.62	47.21
$w_1s_1n_2$	1.39	253.21	51.31	41.31
$w_1s_1n_3$	1.44	280.48	64.04	56.27
$w_1s_1n_4$	1.35	267.38	60.24	54.17
$w_1s_2n_1$	1.35	258.56	58.75	46.62
$w_1s_2n_2$	1.38	251.66	49.98	40.71
$w_1s_2n_3$	1.40	273.28	63.78	55.76
$w_1s_2n_4$	1.37	259.95	59.80	53.56
$w_2s_1n_1$	1.37	266.02	59.73	48.39
$w_2s_1n_2$	1.36	257.95	47.22	42.58
$w_2s_1n_3$	1.41	281.38	64.84	56.47
$w_2s_1n_4$	1.39	269.18	61.87	55.44
$w_2s_1n_1$	1.35	261.44	56.67	46.71
$w_2s_2n_2$	1.32	251.51	52.28	42.53
$w_2s_2n_3$	1.44	278.56	62.45	55.18
$w_2s_2n_4$	1.31	266.23	61.56	54.16
S E m (±)	0.06	4.22	1.14	1.34
C D (0.05)	NS	NS	NS	NS
Treatment mean	1.37	265.06	58.32	49.81
Control mean	1.42	260.26	55.96	47.54
Control vs. Treatment	NS	NS	NS	NS

4.6 UPTAKE OF NUTRIENTS

4.6.1 Nitrogen uptake (Tables 30, 31 and 32)

Weed management techniques and spacing did not have any significant effect on nitrogen uptake. Nutrient schedule had significant effect on nitrogen uptake with N_3 recording the highest uptake (61.85 kg ha^{-1}) and N_2 the lowest (45.84 kg ha^{-1}).

Interaction effects did not have any significant effect.

The organic (treatments mean) and conventional (control mean) had significant difference between them with the conventional (control mean) recording the highest uptake (63.26 kg ha^{-1}) than organic (treatments mean) (54.45 kg ha^{-1}).

4.6.2 Phosphorus uptake (Tables 30, 31 and 32)

Neither weed management techniques nor spacing had any significant effect on phosphorus uptake. But nutrient schedule had significant effect on phosphorus uptake with N_3 recording maximum uptake (19.09 kg ha^{-1}) which was on par with N_4 (17.20 kg ha^{-1}) and N_2 the lowest uptake (12.81 kg ha^{-1}) which was on par with N_1 (15.44 kg ha^{-1}).

The interaction effects were not significant.

There was significant difference between organic (treatments mean) and conventional (control mean) with the conventional (control mean) recording the highest uptake (21.14 kg ha^{-1}) than organic (treatments mean) (16.13 kg ha^{-1}).

4.6.3 Potash uptake (Tables 30, 31 and 32)

Weed management techniques and spacing did not have any significant effect on potash uptake. Nutrient schedule had significant effect on potash uptake with N_3 recording the highest uptake (58.55 kg ha^{-1}) and N_2 the lowest (45.76 kg ha^{-1}).

The interaction effects were not significant at all.

The comparision between organic (treatments mean) and conventional (control mean) revealed that there was significant difference between them with the

Table 30. Effect of weed management techniques, spacing and nutrient schedule on nutrient uptake at harvest

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
Weed management (W)			
W_1	54.16	15.90	54.17
W_2	54.75	16.37	52.37
S E m (±)	0.85	0.74	0.48
C D (0.05)	NS	NS	NS
Spacing (S)			
S_1	53.02	15.66	53.07
S_2	55.89	16.61	53.48
S E m (±)	0.85	0.74	0.48
C D (0.05)	NS	NS	NS
Nutrient schedule (N)			
N_1	52.13	15.44	53.28
N_2	45.84	12.81	45.76
N_3	61.85	19.09	58.55
N_4	57.99	17.20	55.50
S E m (±)	1.31	0.85	0.89
C D (0.05)	3.46	3.02	1.95

Table 31. Interaction effect of weed management techniques, spacing and nutrient schedule on nutrient uptake at harvest (2 factor)

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
W X S			
w_1s_1	52.67	15.39	54.76
w_1s_2	55.64	16.41	53.59
w_2s_1	53.36	15.93	51.38
w_2s_2	56.14	16.81	53.37
S E m (±)	1.20	1.05	0.60
C D (0.05)	NS	NS	NS
W X N			
w_1n_1	52.11	15.86	53.92
w_1n_2	45.26	12.18	47.93
w_1n_3	62.16	18.93	59.41
w_1n_4	57.10	16.62	55.44
w_2n_1	52.15	15.02	52.64
w_2n_2	46.43	13.45	43.60
w_2n_3	61.53	19.24	57.68
w_2n_4	58.89	17.78	55.56
S E m (±)	1.86	1.20	1.26
C D (0.05)	NS	NS	NS
S X N			
s_1n_1	50.56	14.55	52.87
s_1n_2	42.72	12.95	45.88
s_1n_3	61.50	18.03	58.30
s_1n_4	57.28	17.11	55.22
s_2n_1	53.70	16.33	53.68
s_2n_2	48.96	12.67	45.65
s_2n_3	62.19	20.15	58.80
s_2n_4	58.71	17.29	55.78
S E m (±)	1.86	1.20	1.26
C D (0.05)	NS	NS	NS

Table 32. Interaction effect of weed management techniques, spacing and nutrient schedule on nutrient uptake at harvest (3 factor)

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
W x S x N			
$w_1s_1n_1$	50.52	15.04	54.08
$w_1s_1n_2$	40.99	12.89	49.54
$w_1s_1n_3$	61.61	17.26	59.78
$w_1s_1n_4$	57.58	16.37	55.64
$w_1s_2n_1$	53.71	16.69	53.75
$w_1s_2n_2$	49.52	11.46	46.31
$w_1s_2n_3$	62.72	20.61	59.04
$w_1s_2n_4$	56.63	16.87	55.24
$w_2s_1n_1$	50.61	14.06	51.67
$w_2s_1n_2$	44.45	13.01	42.22
$w_2s_1n_3$	61.40	18.80	56.83
$w_2s_1n_4$	56.98	17.85	54.80
$w_2s_2n_1$	53.70	15.98	53.62
$w_2s_2n_2$	48.40	13.88	44.98
$w_2s_2n_3$	61.67	19.69	58.56
$w_2s_2n_4$	60.80	17.71	56.32
S E m (±)	2.63	1.70	1.79
C D (0.05)	NS	NS	NS
Treatment mean	54.45	16.13	53.27
Control mean	63.26	21.14	60.00
Control vs. Treatment	S	S	S

conventional (control mean) recording the highest uptake (60 kg ha^{-1}) than organic (treatments mean) (53.27 kg ha^{-1}).

4.6 ECONOMIC ANALYSIS

4.6.1 Net returns (Tables 33, 34 and 35)

Weed management practices did not have any significant influence on net returns. Spacing had significant effect on net returns with S_2 recording the highest net returns (32,589 Rs ha^{-1}) than S_1 (24,035 Rs ha^{-1}). Nutrient schedule did not have any significant effect on net returns.

The interaction effects were not significant at all.

There was significant difference between organic (treatments mean) and conventional (control mean) with organic (treatments mean) recording the highest net returns (28,312 Rs ha^{-1}) than conventional (control mean) (16,283 Rs ha^{-1}).

4.6.2 Benefit cost ratio (Tables 33, 34 and 35)

Weed management practices did not have any significant influence on B:C ratio. Spacing had significant effect on B:C ratio with S_2 recording the highest B:C ratio (1.60) than S_1 (1.45). Nutrient schedule did not have any significant effect on B:C ratio.

The interaction effects were not significant at all.

There was significant difference between organic (treatments mean) and conventional (control mean) with organic (treatments mean) recording the highest B:C ratio (1.52) than conventional (control mean) (1.36).

Table 33. Effect of weed management techniques, spacing and nutrient schedule on net returns and BCR

Treatments	Net return (Rs ha^{-1})	BCR
Weed management (W)		
W_1	29,745	1.55
W_2	26,880	1.50
S E m (±)	1,394	0.02
C D (0.05)	NS	NS
Spacing (S)		
S_1	24,035	1.45
S_2	32,589	1.60
S E m (±)	1394	0.02
C D (0.05)	4,460	0.08
Nutrient schedule (N)		
N_1	24,261	1.44
N_2	27,892	1.59
N_3	34,046	1.60
N_4	27,051	1.46
S E m (±)	2,914	0.05
C D (0.05)	NS	NS

Table 34. Interaction effect of weed management techniques, spacing and nutrient schedule on net returns and BCR (2 factor)

Treatments	Net return (Rs ha^{-1})	BCR
W x S		
w_1s_1	25,613	1.48
w_1s_2	33,876	1.63
w_2s_1	22,458	1.42
w_2s_2	31,303	1.58
S E m (±)	1,971	0.03
C D (0.05)	NS	NS
W x N		
w_1n_1	25,800	1.47
w_1n_2	29,289	1.62
w_1n_3	36,125	1.64
w_1n_4	27,764	1.47
w_2n_1	22,723	1.42
w_2n_2	26,494	1.56
w_2n_3	31,967	1.57
w_2n_4	26,337	1.44
S E m (±)	4,121	0.07
C D (0.05)	NS	NS
S x N		
s_1n_1	18,538	1.34
s_1n_2	25,950	1.55
s_1n_3	29,399	1.52
s_1n_4	22,255	1.38
s_2n_1	29,985	1.55
s_2n_2	29,833	1.64
s_2n_3	38,693	1.69
s_2n_4	31,847	1.54
S E m (±)	4,121	0.07
C D (0.05)	NS	NS

Table 35. Interaction effect of weed management techniques, spacing and nutrient schedule on net returns and BCR (3 factor)

Treatments	Net return (Rs ha^{-1})	BCR
W x S x N		
$w_1s_1n_1$	19,727	1.36
$w_1s_1n_2$	27,968	1.60
$w_1s_1n_3$	31,733	1.56
$w_1s_1n_4$	23,026	1.39
$w_1s_2n_1$	31,873	1.58
$w_1s_2n_2$	30,611	1.65
$w_1s_2n_3$	40,517	1.72
$w_1s_2n_4$	32,502	1.55
$w_2s_1n_1$	17,349	1.32
$w_2s_1n_2$	23,933	1.51
$w_2s_1n_3$	27,066	1.48
$w_2s_1n_4$	21,483	1.36
$w_2s_2n_1$	28,096	1.51
$w_2s_2n_2$	29,055	1.62
$w_2s_2n_3$	36,869	1.65
$w_2s_2n_4$	31,191	1.53
S E m (±)	5,828	0.11
C D (0.05)	NS	NS
Treatment mean	28,312	1.52
Control mean	16,283	1.36
Control vs. Treatment	S	S

Discussion

5. DISCUSSION

The results of the study conducted to standardize the weed management techniques (W), spacing (S) and nutrient schedule (N) for organic rice production with its economic feasibility of production are briefly discussed in this chapter.

Interpretation of results of this investigation demand a better understanding of weather prevailed during the crop growth period. The experiment was conducted in the kharif season of 2012, which was typically a drought year, agriculturally, hydrologically and meteorologically. The total rainfall obtained was only 111.1 mm from the date of transplanting upto harvest as against a normal rainfall of 171.58 mm in the previous years. But the water requirement of rice is 900-2,500 mm. Due to low rainfall/water availability, the grain and straw yield of the crop which was mainly raised as rainfed crop was very low. The results were discussed with this contingency in mind.

5.1 Effect of weed management techniques on crop growth and yield

The results showed that both stale seedbed technique and hand weeding at critical stages were equally effective in crop growth characters. The reduction in weed biomass under both techniques might have enabled the rice plant to put forth better growth resulting in higher plant height (Fig. 3), tiller count and LAI. This was in accordance with Saikia and Pathak (1993) who reported that stale seedbed suppressed the weeds better than the conventional seedbed method and allowed better crop growth. The plant DMP was also significantly influenced by weed management techniques with stale seedbed technique recording the highest DMP. The better growth characters of rice plant evident from higher plant height, tiller number and LAI in turn contributed to high dry matter production.

The stale seedbed technique and hand weeding were on par with respect to grain yield (Fig. 7). The influence of stale seedbed technique and hand weeding was same on filled grains panicle^{-1} and thousand grain weight. These two parameters being the two main yield contributing characters, no significant effect on these two

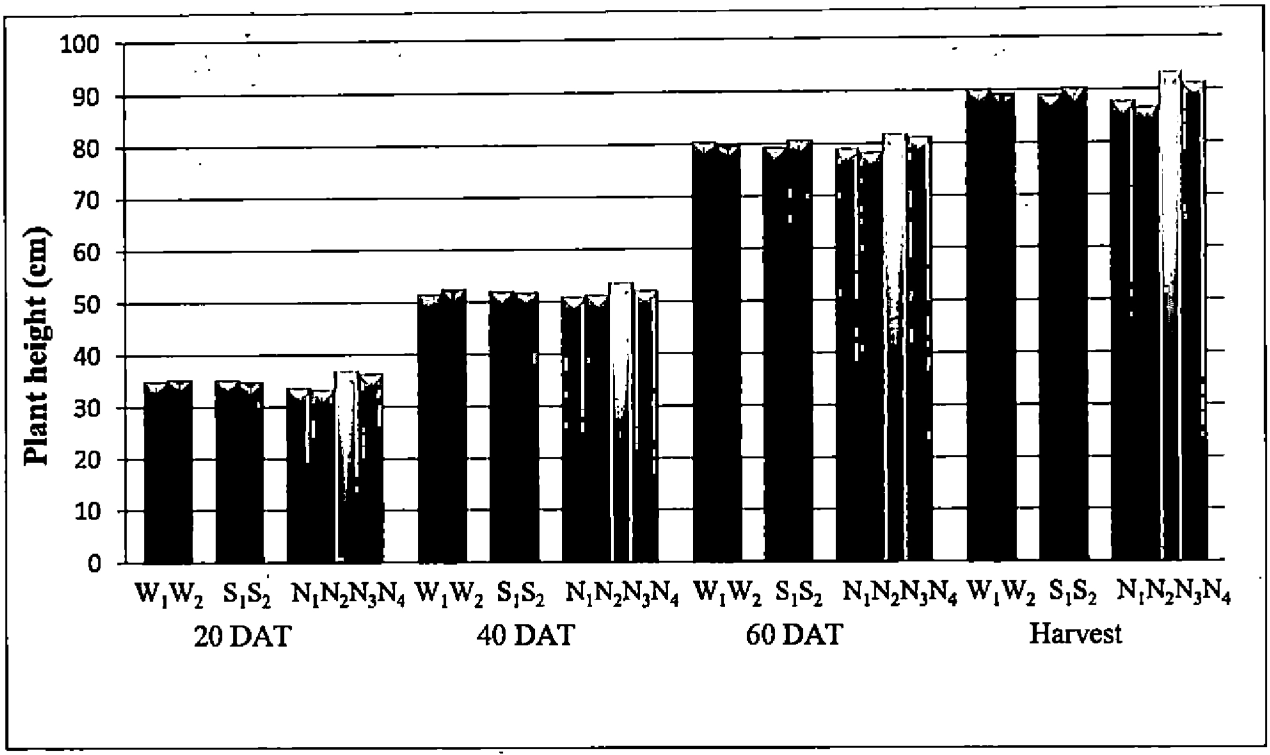


Fig 3. Mean height of plant as affected by weed management techniques, spacing and nutrient schedule

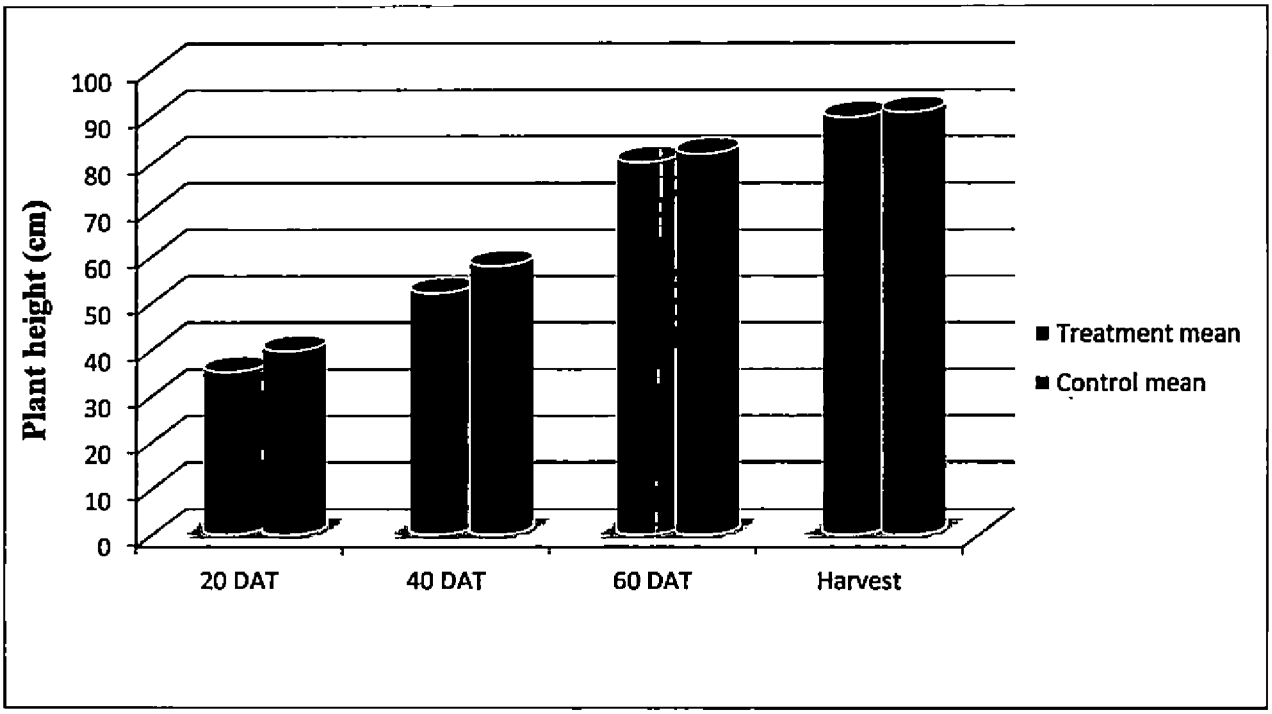


Fig 4. Mean height of plant as affected by treatments as against control

parameters by the two weed management techniques might have resulted in same grain yield under both stale seedbed technique and hand weeding. Similar results were reported by Sindhu *et al.* (2010).

Straw yield being a plant character contributed mainly by number of tillers and leaves, no significant influence by both weed management techniques on tiller production and leaf area might have resulted in same straw yield (Fig. 7) under both the weed management techniques.

5.2 Effect of spacing on crop growth and yield

Spacing significantly influenced plant height at 60 DAT and at harvest stage with closer spacing (15 cm x 15 cm) recording the highest height than wider spacing (20 cm x 15 cm) (Fig. 3). The similar result was reported by Shah *et al.* (1991) and Maske *et al.* (1997). It is because of light intensity and the plant population, which are responsible for the elongation of the internodes of the plant. The increase in plant height with decreasing spacing has been reported by Panda and Leewrik (1971) who attributed it to the enhancement in the internode length induced by lower light intensity. According to Tanaka *et al.* (1964) increase in height is related to receipt of radiant energy. Because of higher density of plants in the closely spaced plots, sunlight cannot reach the base of the plants which lead to acceleration of internodal elongation in the early stages. Spacing had significant effect with closer spacing recording the highest tiller number m^{-2} than in the wider spacing. The same results had also been reported by DRR (1991) and Shah *et al.* (1991). The high yielding varieties permit high functional assimilation system and high light transmission ratio as described by Tsunodo and Matsuo (1965) and hence tillering was not adversely affected by closer spacing. Spacing also had significant effect on leaf area index and DMP with closer spacing recording the highest LAI and DMP. This might be mainly due to more leaves which occupied the same land area and consequently trapped more light and CO_2 resulting in high photosynthetic capacity and producing more dry matter production. Similar results were reported by Maske *et al.* (1997).

Spacing also had significant influence on productive tillers m^{-2} with closer spacing recording the highest number of productive tillers than wider spacing

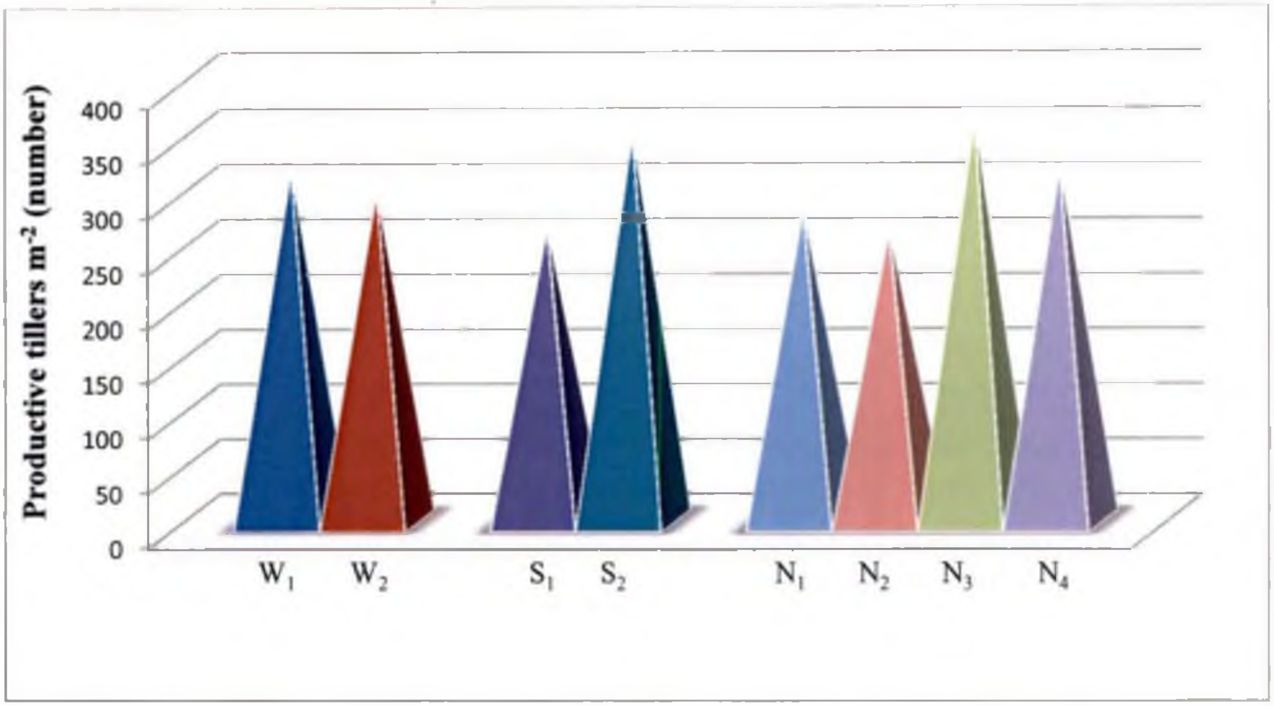


Fig 5. Productive tiller number as affected by weed management techniques, spacing and nutrient schedule

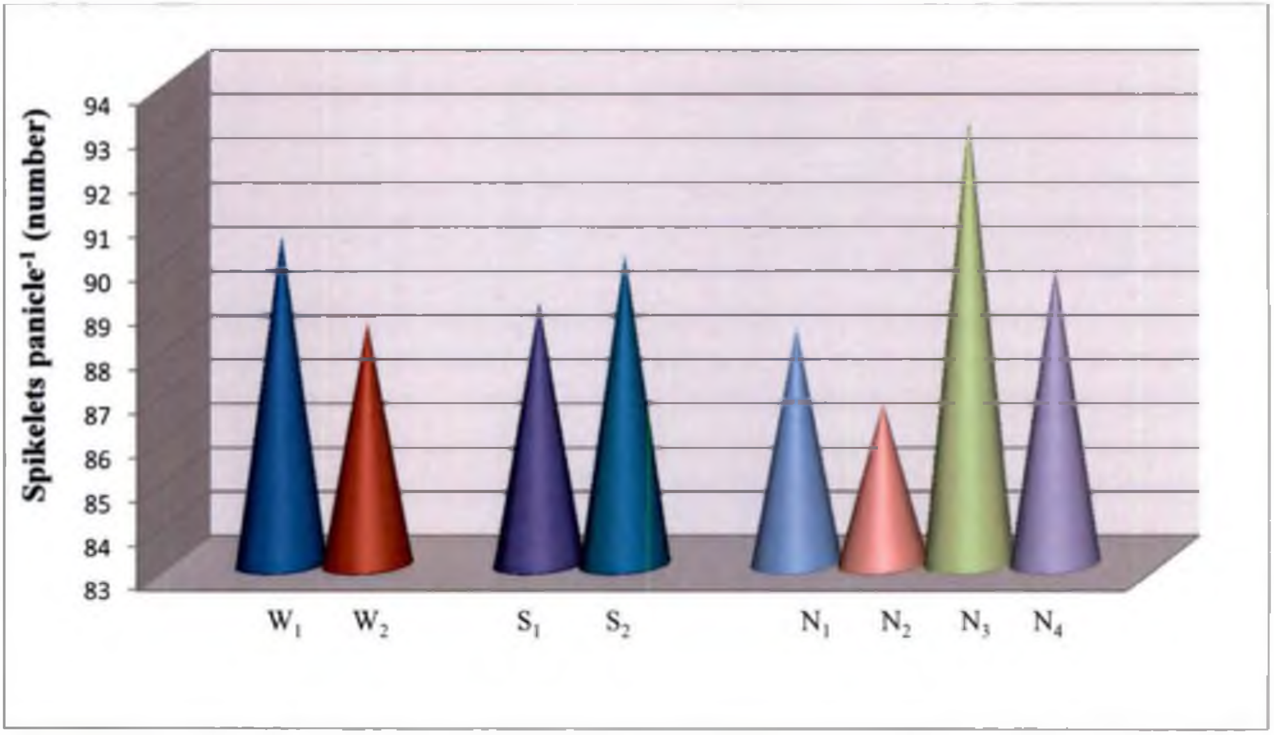


Fig 6. Spikelets panicle^{-1} as affected by weed management techniques, spacing and nutrient schedule

(Fig. 5). The similar results were reported by Srinivasan (1990), Maske *et al.* (1997) and Omina, EL-Shayieb (2003).

Spacing significantly influenced grain and straw yield with closer spacing recording the highest grain and straw yield (Fig. 7). The higher grain yield in closer spacing might be due to more productive tillers m^{-2} produced by an increased plant population in closer spacing. This was reported by Pandey and Tripathi (1995), Maske *et al.* (1997) and Omina, EL-Shayieb (2003). The higher straw yield could be attributed to the higher tiller number, height and LAI contributed by closer spacing. The closer spacing also accounted for shading of leaves of one plant to another which in turn accounted for more vegetative growth, contributing to high straw yield. This was also reported by Maske *et al.* (1997).

5.3 Effect of nutrient schedule on crop growth and yield

The effect of nutrient schedule was significant on plant height, tiller production and leaf area index (LAI) throughout the growth stages with N_3 (option-3 of the *ad hoc* recommendation of KAU *i.e.*, substitution of recommended dose of nutrients by 1/3rd as FYM, 1/3rd as vermicompost and 1/3rd as neem cake along with azospirillum and P solubilising bacteria @ 2 kg ha^{-1}) recorded the highest at all stages (Fig. 3). The similar results were reported by Sanoria *et al.* (1982), Sharma (1994), Babu (1996), Shanmugam and Veeraputhran (2001) and Singh and Sharma (2005). The DMP of the plant was also found significant in N_3. The yield and yield attributing characters like productive tillers m^{-2} (Fig. 5), grain weight panicle^{-1}, number of spikelets panicle^{-1} (Fig. 6), filled grains panicle^{-1}, thousand grain weight, grain and straw yield (Fig. 7), were also significantly influenced by nutrient schedule with N_3 recording the highest for all these. The same results were reported by Thakur and Patel (1998), Shanmugam and Veeraputhran (2001), Majumdar *et al.* (2006), and Mirza Hasanuzzaman *et al.* (2010). N_3 was followed by N_4 (Soil test based nutrient application, where nitrogen was given half as vermicompost and half as neem cake) in grain and straw yield.

The increased availability of nutrients through FYM, vermicompost, neem cake and biofertilizers in N_3 might have resulted in increased nitrogen uptake. The

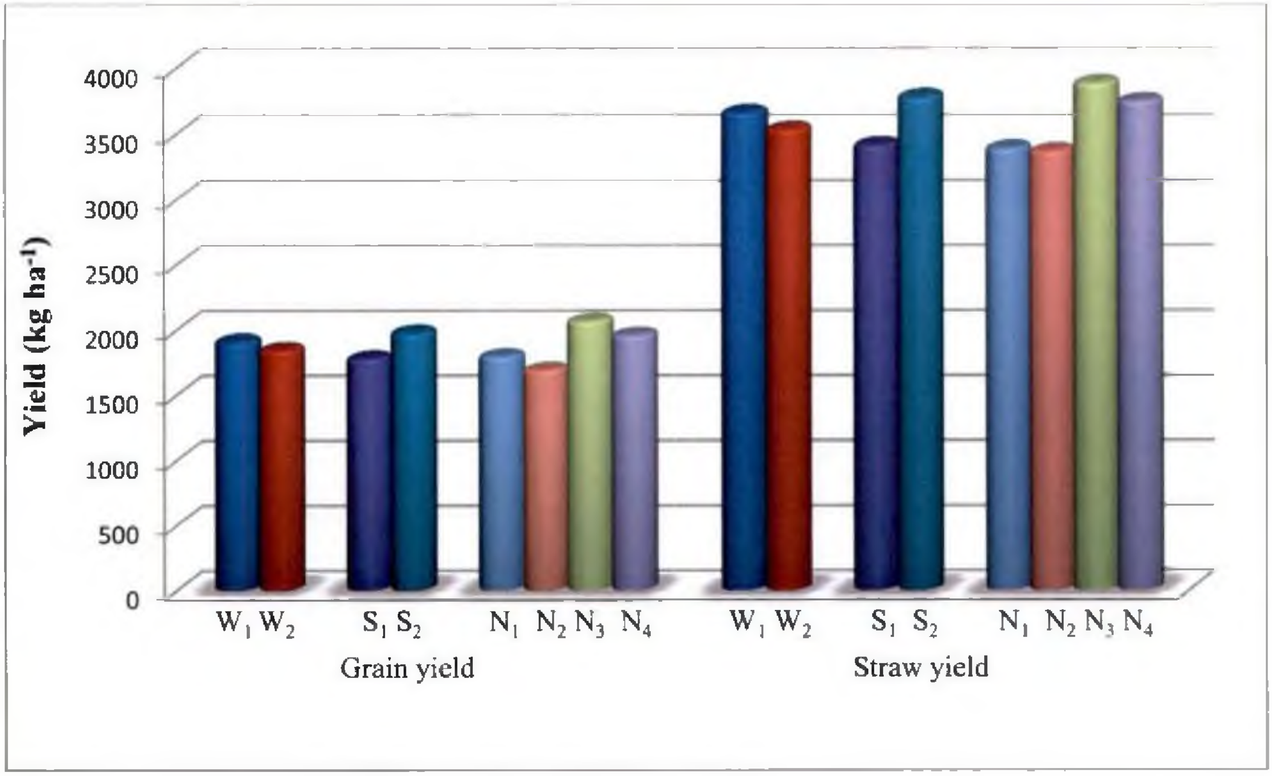


Fig 7. Grain and straw yield as affected by weed management techniques, spacing and nutrient schedule

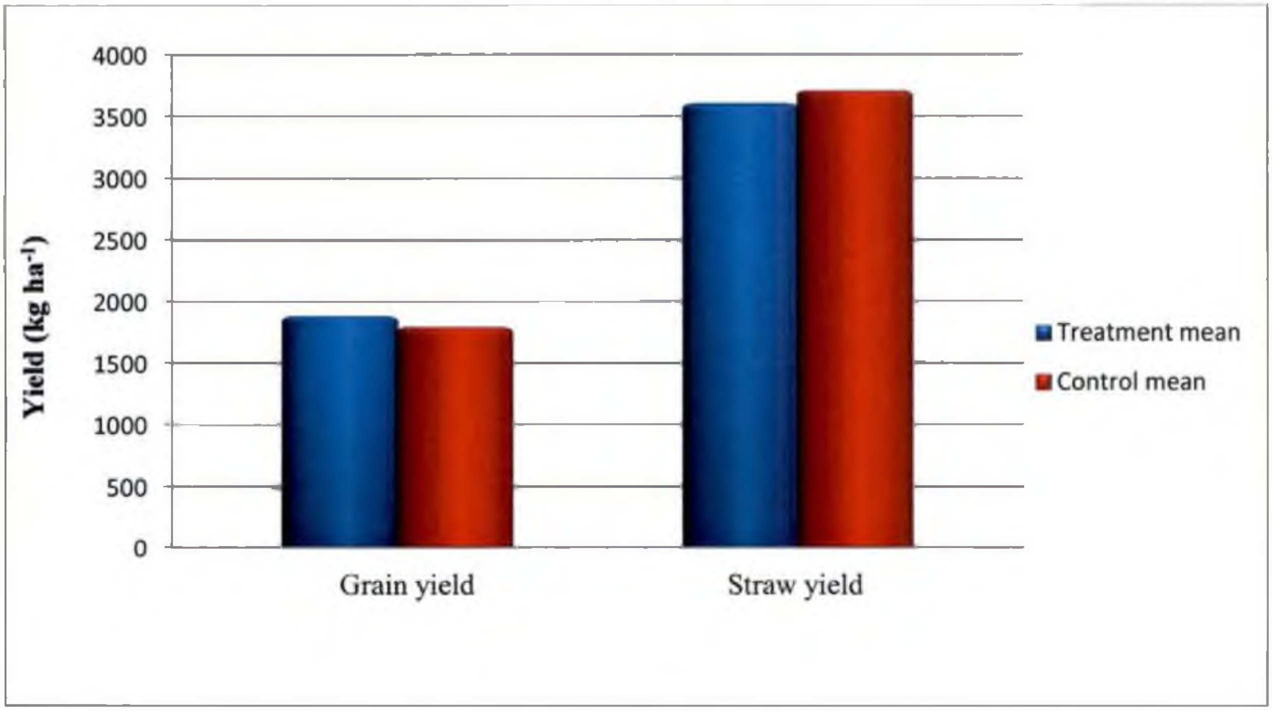


Fig 8. Grain and straw yield as affected by treatments as against control

increased uptake of nitrogen might have contributed to increase the meristematic activity (Crowther, 1935), coupled with rapid cell division brought about by phosphorous (Bear, 1965) and by increased growth of meristematic tissue (Tisdale & Nelson, 1985). These might have led to increase the plant height.

Increased nitrogen availability and its uptake might have increased the production, translocation and assimilation of photosynthates to growing points there by stimulating the plants to produce more number of tillers. According to Russel (1973), as the nutrient availability especially nitrogen increases, the extra protein produced allows the plant leaves to grow larger and with more surface area available for photosynthesis. The favourable effect of vermicompost on growth could be attributed to the readily available N (NH_4–N) from the assimilable products of excretion, mucoprotein, vermicast and rapid mineralization of body tissues of the earthworms which lead to greater availability of nutrients in the initial stages of crop growth. This could be the reason for taller plants and production of higher number of tillers in the vermicompost-applied treatments. The presence of nitrates and available forms of phosphorus, calcium and magnesium in vermicasts might have favourably influenced LAI. With the higher leaf area index, plants may become photosynthetically more active, which would contribute to improvement in yield attributes. The physical condition brought about by organic manure addition, higher microbial population and dehydrogenase activity might have influenced the nutrient uptake, chlorophyll synthesis, plant growth and finally dry matter.

The beneficial effect of organic manure on the yield attributes like number of productive tillers could be attributed to the supply of plant nutrients in an available form through the proper decomposition and mineralization of organic manure and also on the solubilising effects of organic manure on the fixed forms of nutrients (Sinha *et al.*, 1981). Choudhary and Thakuria (1996) observed more number of productive tillers under integrated nutrient management due to the greater survival of tillers with organic manures owing to continuous and controlled supply of nutrients throughout the crop growth period.

Organic manures, in general have been reported to maintain a better nutrient status in the soil. This in turn might have improved the photosynthetic efficiency of the plant and thereby increased the number of filled grains as observed by Nehra *et al.* (2001). Application of FYM improved the physical and chemical properties of soil and copious time to its decomposition and increased the availability of different nutrients which was reflected in growth of plants and increased yield and its components. The plant growth promoting (PGP) micro-organisms enhance the capacity of plants to absorb nutrients like nitrogen (N) and phosphorus (P) efficiently, resulting in stronger growth and higher crop yields. Increase in thousand grain weight might be due to continuous supply of nutrients through organic manure which resulted in more number of normal and filled grains. The enhanced grain weight due to higher organic manure, previously reported by Babu (1996).

Application of neem cake as fertilizer and pesticide is a traditional practice. Apart from the major nutrients neem cake also contains calcium, magnesium and sulphur compounds which favour the crop growth and yield. Further neem cake, which has been shown to inhibit nitrification, might have resulted in a desirable slow release of nitrogen to the plants. Thus, it might have helped in spreading the effect of fertilizer over a longer period of time by reducing losses through denitrification and leaching. The increased yield in N_3 and N_4 is mainly due to better mineralization, increased nutrient uptake and the enhanced microbial population.

Organic manures might have also increased the adsorptive power of the soil for cations and anions, phosphates and nitrates and released them slowly for the benefit of the crop during the entire crop growth period and leading to higher yield as reported by Sinha *et al.* (1981). Application of FYM and vermicompost had favourable effect on grain yield. Increase in grain yield might be due to increase in ammonical and nitrate nitrogen and enhanced availability of major and micro nutrients due to FYM addition (Mondal and Chettri, 1998). All the growth parameters were found to be responding well to vermicompost. This might be due to increased availability of nutrients to plants. Worm casts were rich in available nutrients for plant growth (Tomati *et al.*, 1990) and had all the qualities of a fertilizer

(Bano *et al.,* 1987). The combination of FYM, vermicompost and neem cake was better in improving the grain yield.

5.4 Interaction effect of weed management techniques and nutrient schedule on crop growth and yield

The results indicated that only plant height and tiller production were significantly influenced by the interaction between weed management techniques and nutrient schedule. The W x N interaction effect was significant on plant height at 40 and 60 DAT and at harvest stage. At 40 DAT, the combination of N_3 with W_2 and W_1 recorded the maximum plant height showing the effectiveness of both weed management techniques along with the individual effect of N_3 in producing taller plants. At harvest stage also, the combination of N_3 with W_1 recorded the highest height. At 60 DAT, the same combinations were found good even though the combination involving N_4 (soil test based application of nutrients) and W_2 had given the maximum height, but on par with the other two combinations.

The tiller production was found affected only at harvest stage with w_1n_3 producing the highest number of tillers showing the cumulative effect of option-3 and stale seedbed in tiller production.

5.5 Interaction effect of spacing and nutrient schedule on crop growth and yield

The interaction effect was significant only for height of the plant. The S x N interaction effect was significant on plant height at 20 and 40 DAT and at harvest stage. At 20 and 40 DAT, the plant height was the highest in s_1n_3 which was significantly superior to all other treatments. In the initial stages of crop growth, the growth of the plant in terms of height was favoured by the wider spacing (20 cm x 15 cm). The nutrient schedule of N_3 (option-3 of *ad hoc* recommendation of KAU) also contributed to the higher height through its supply of nutrients where the full recommended dose of nutrients were given through organic sources. The plant height was the lowest in s_2n_2 at 20 DAT. This might be due to the closer spacing (15 cm x 15 cm) and low quantity of nutrients supplied in this treatment. The plant height was the lowest in s_1n_2 at 40 DAT. This might also be due to the low nutrient

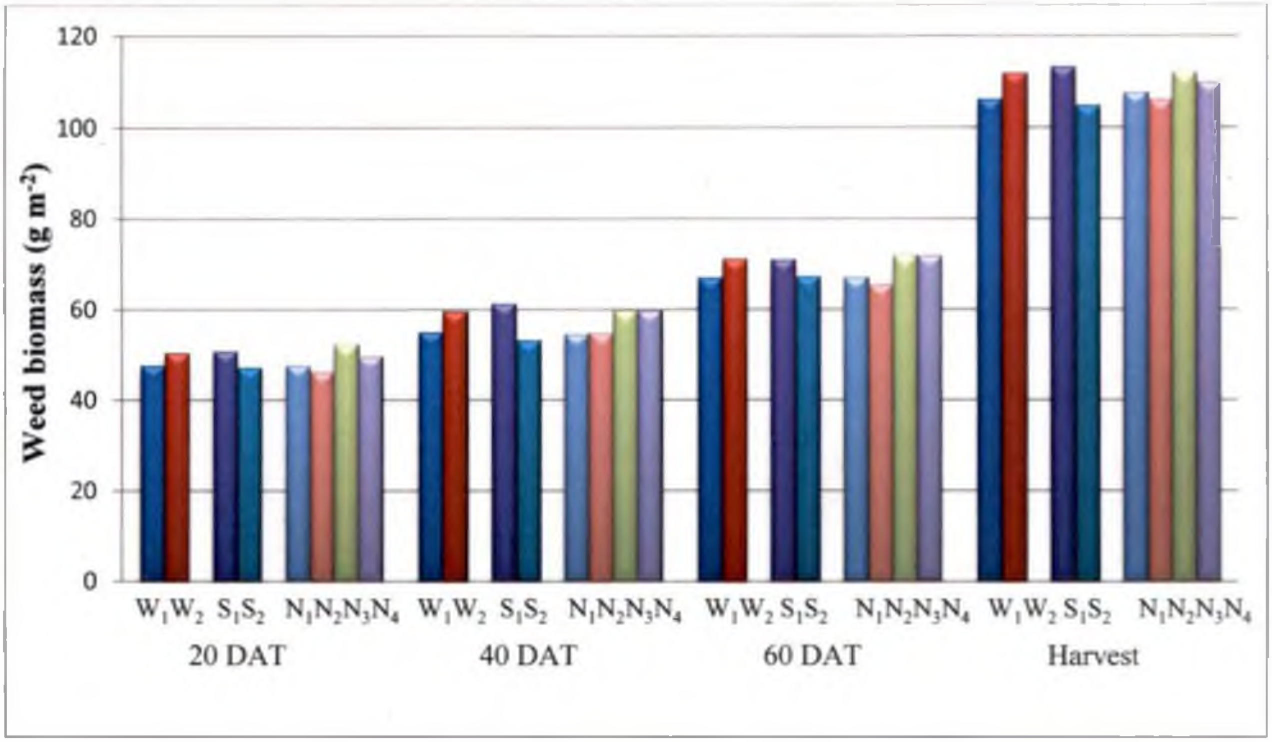


Fig 9. Weed biomass as affected by weed management techniques, spacing and nutrient schedule

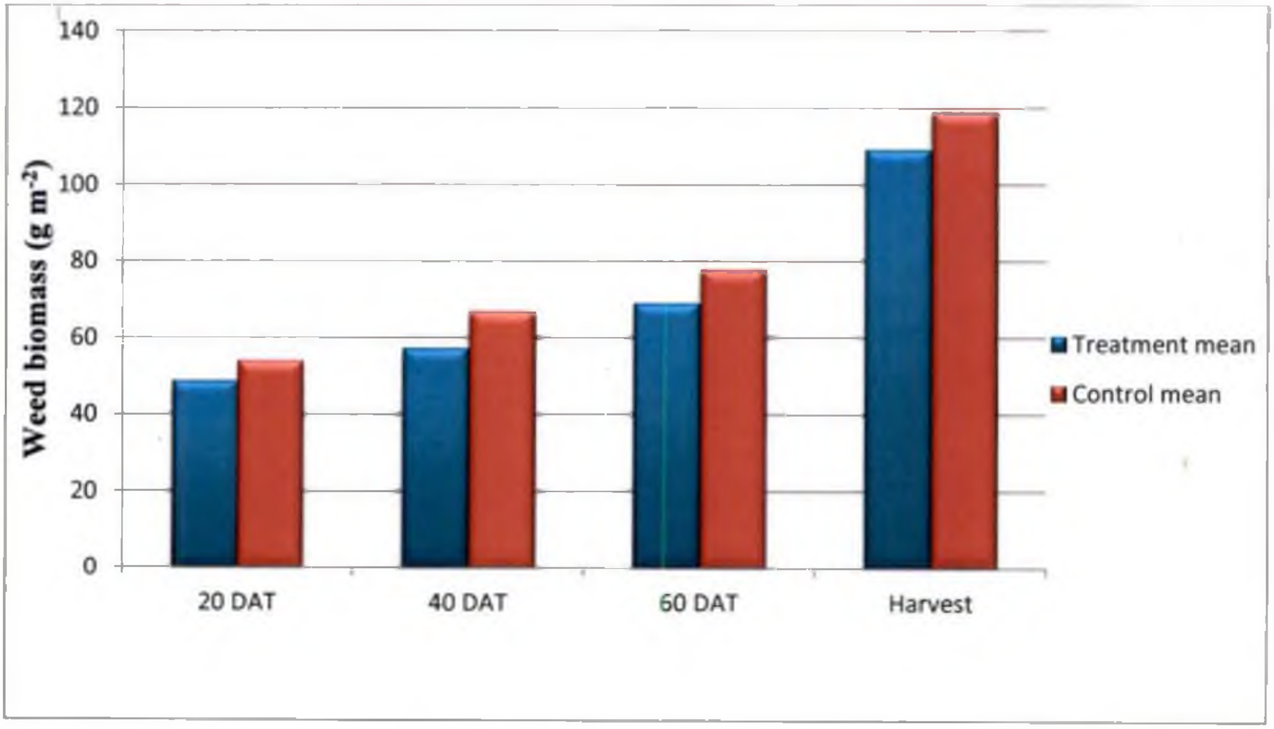


Fig 10. Weed biomass as affected by treatments as against control

supply in this treatment and the wider spacing permitted enough sunlight, so that the plants need not elongate to capture the light. At harvest stage, s_2n_3 was found significantly superior to all others and s_1n_2 significantly inferior to all. The superiority of s_2n_3 was due to the closer spacing which enabled the plants to grow taller to capture sunlight to make the best nutrient use efficiency of the recommended quantity of nutrients supplied through organic sources in N_3.

5.6 Effect of weed management techniques on weed biomass

Weed management techniques significantly influenced weed biomass with stale seedbed technique recording the lowest weed biomass (Fig. 9). In this technique, seeds were not sown immediately after land preparation. Instead, weeds were encouraged to germinate by giving one irrigation, killed by tillage prior to sowing of crop. The positive effect of stale seedbed in draining the weed seed bank in soil and there by drastically reducing further weed emergence caused reduction in weed biomass. The same results were obtained to All *et al.* (1979) and Sumner *et al.* (1981). Hosmani and Meti (1983) observed that stale seedbed encouraged a flush of new weed seedlings, which can be controlled very easily prior to planting and reduced the crop-weed competition in succeeding crops.

5.7 Effect of spacing on weed biomass

Closer spacing recorded the lowest weed biomass (Fig. 9). Closer spacing prevented sprouted weed seedlings from harvesting adequate sunlight and other resources thus causing reduced dry matter accumulation of weeds. Same results were obtained to Estornios and Moody (1983), Gogoi (1998) and Lourduraj *et al.* (2000).

5.8 Effect of nutrient schedule on weed biomass

The lowest weed biomass was recorded in N_2 (option-2 of *ad hoc* recommendation, FYM 1t + green leaf manure 1t + dual culture of azolla, 2 kg Azospirillum + 2 kg P solubilizing bacteria + 1kg PGPR (mix 1) ha^{-1}), where the quantity of nutrients supplied were low and through organic sources, whereas the highest weed biomass was in N_3 (option-3 of *ad hoc* recommendation) where the full recommended quantity of nutrients were supplied. Similar to the favourable effect of

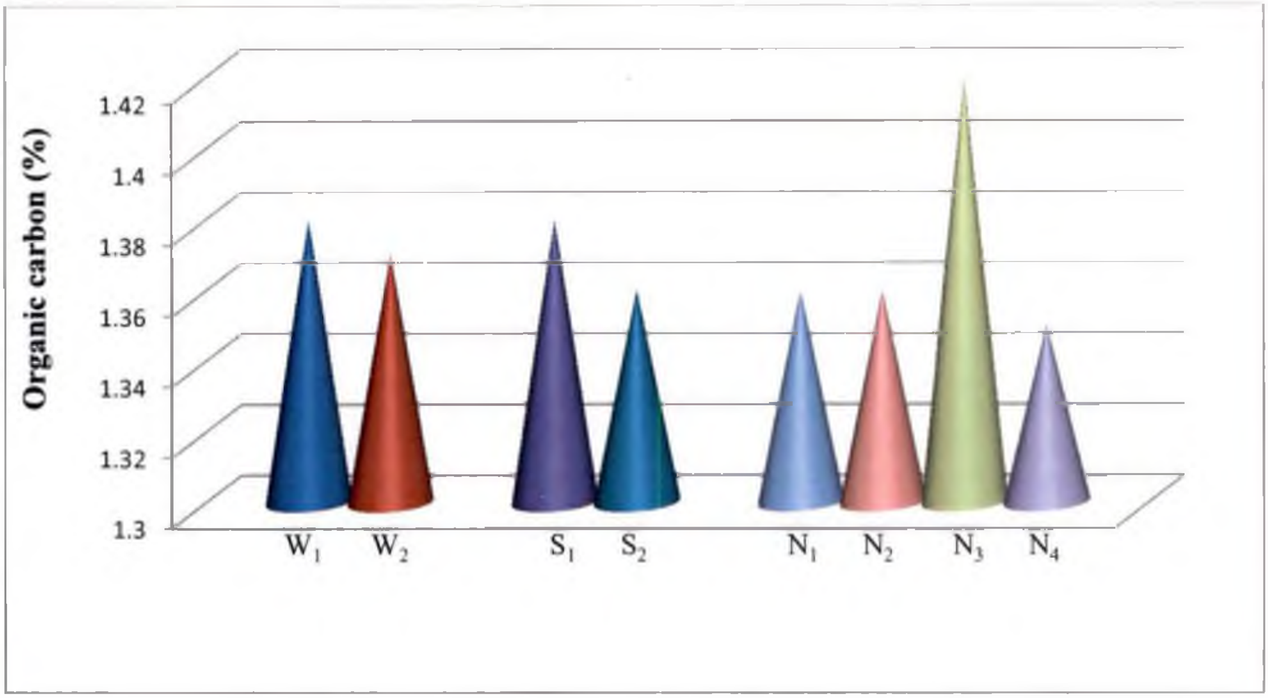


Fig 11. Organic carbon content as affected by weed management techniques, spacing and nutrient schedule

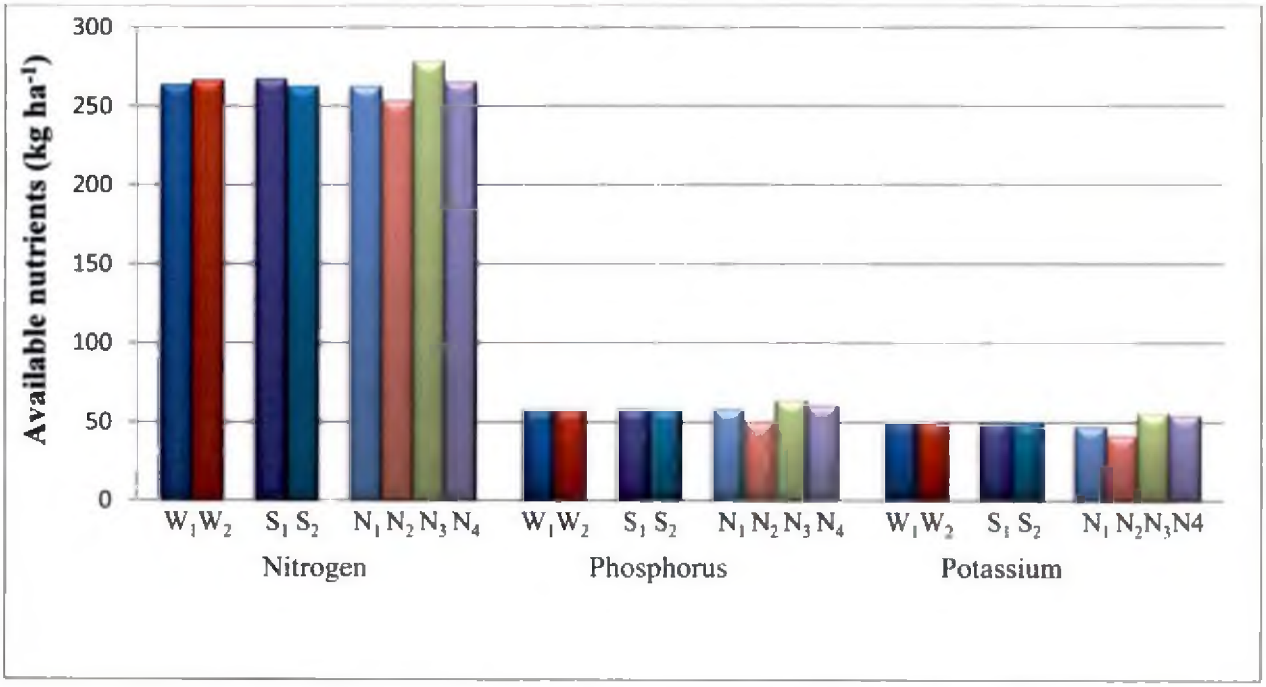


Fig 12. Available nutrient status after the experiment as affected by weed management techniques, spacing and nutrient schedule

nutrients on crop growth, the sufficient quantity of nutrients in this treatment compared to others might have contributed favourable condition for weed growth also. However, there was no detrimental effect on grain yield due to the increased weed growth in N_3.

The comparison between organic and conventional showed that there was significant difference between them at all the crop stages with conventional recording the lowest weed control efficiency through its highest weed biomass. This result emphasizes the weed control efficiency of organic nutrition of crops, thus reducing the cost of weed control, which accounts a major part of the cost of cultivation in rice production.

5.9 Effect of weed management techniques, spacing and nutrient schedule on soil fertility status

Weed management techniques did not have any significant effect on soil organic carbon content (Fig. 11), available nitrogen, phosphorous and potassium content. Spacing had significant effect only on available nitrogen content of soil with wider spacing recorded the higher available nitrogen (Fig. 12). This might be due to the lower plant population and low uptake in the widest spacing.

Nutrient schedule significantly influenced soil fertility status except organic carbon. N_3 recorded the highest available nitrogen and phosphorus content in soil and recorded maximum available potash which was on par with N_4 (Fig. 12). The favourable influence of organic manures on the content of nutrients and organic carbon in soil is well established. Sharma and Sharma (1994) reported that application of organic manure increased the available N content of soil. Application of organic manure increased P availability in soil. Sharma *et al.* (1988) found that incorporation of organic wastes improved the available P content by 20 per cent due to the release of P during decomposition and solubilisation of P compounds by organic acids released during decomposition. Increase in the available K status of soil by application of organic manure was reported by Sharma and Sharma (1994). Mahapatra and Jee (1993) opined that the increased availability of K in soil may be due to the decomposition of mineral constituents, and their effect in dislodging the exchangeable K into the soil solution.

It has been proved that vermicompost has high degree of urease activity than soil and other organic materials. The high degree of decomposition and mineralization in vermicompost may be one of the reasons for high N content in worm casts and this might have finally contributed to the available N status of soil. Nitrogen fixing organisms present in vermicompost might fix atmospheric N in significant quantities which also increased the available N content in soil (Lee, 1992).

The higher P content in vermicompost might have reflected in higher P status of soil. Organic acids formed during the decomposition of organic matter might have accelerated the mineralization of native soil P which in turn increased the P status of soil. Vermicompost contains the beneficial microorganisms like P solubilizing bacteria. The solubilisation of P by microorganisms was attributed to the secretion of organic acids like citric, glutamic, succinic, lactic, oxalic, glyoxalic, maleic, fumaric and tartaric acid (Rao, 1998). Higher the phosphatase activity in the presence of vermicompost also increases the solubility of P.

Increased availability of K in vermicompost treated plots may be due to high K content in vermicompost and increased concentration of available and exchangeable K content in worm casts compared to surrounding soil. Earth worms increase the availability of K by shifting the equilibrium among the forms of K from relatively unavailable to more available forms (Baskar *et al.*, 1992).

Even though there was no significant difference between organic and conventional on the available nutrient status of the soil, the data from the table (Table 29) revealed that the available nutrient status of the soil after the experiment was low in conventional compared to organic. This could be attributed to the high nutrient uptake by crop in conventional system, where nutrients are present in the readily available form to crop, when compared to organic where the nutrients are made available to the crop slowly. It indicates the residual effect of organic nutrition in maintaining the soil fertile even after cropping for sustainable crop production.

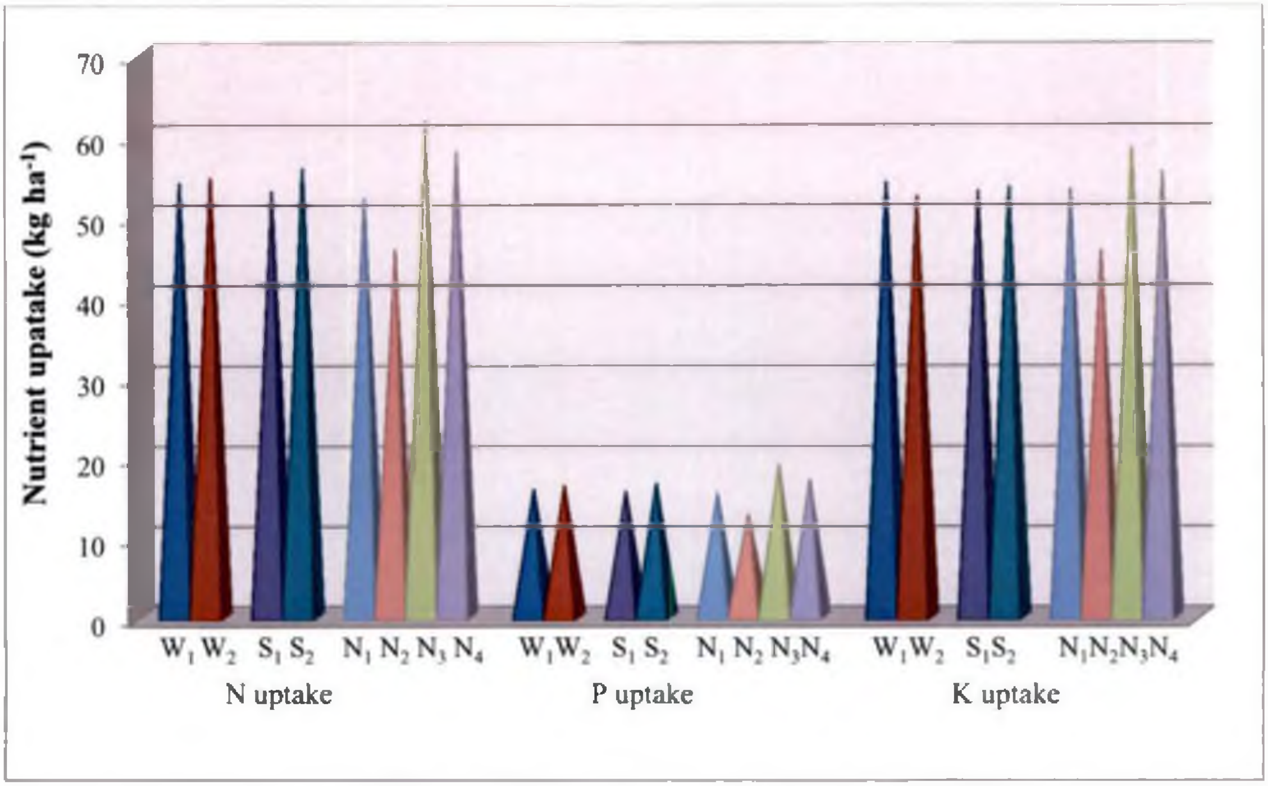


Fig 13. Nutrient uptake as affected by weed management techniques, spacing and nutrient schedule

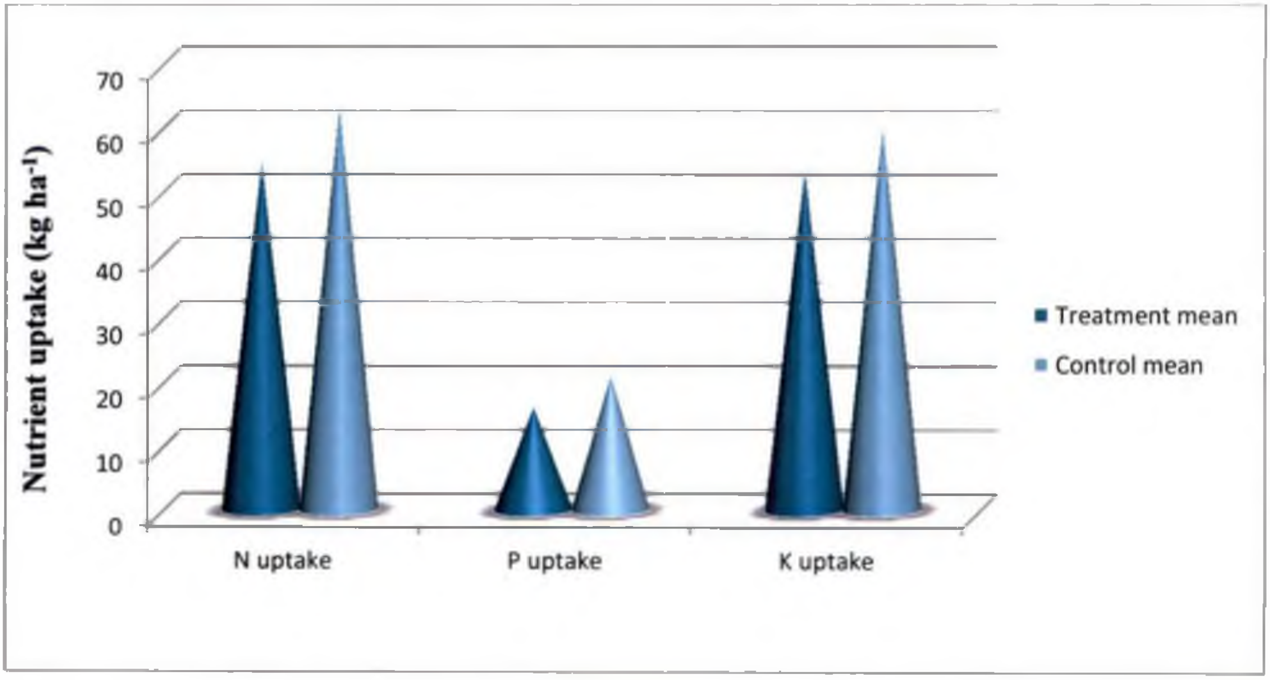


Fig 14. Nutrient uptake as affected by treatments as against control

5.10 Effect of weed management techniques, spacing and nutrient schedule on nutrient uptake

Weed management techniques and spacing did not have any significant effect on nutrient uptake. But nutrient schedule significantly influenced nutrient uptake with N_3 recording the highest N and K uptake and maximum P uptake which was on par with N_4 (Fig. 13). On N and K uptake N_2 recorded the lowest but on P uptake it was minimum which was on par with N_1.

Organic manures must have exerted profound influence on the uptake of nutrients. Deepa (1998) found that treatments receiving FYM showed better uptake values throughout the growth period of crop. The similar results were obtained by Lal and Mathur (1989). The better dry matter yield, grain and straw yields noticed in the organic manure applied plots had resulted in higher uptake values. Minhas and Sood (1994) had reported the beneficial effect of FYM in enhancing the uptake of P by crop plants. Maximum K uptake in rice at harvest stage was obtained due to organic manure application (Sharma and Mitra, 1991).

Vermicompost can act not only as a growth determinant, but also as a yield determinant. Increased nutrient uptake upon vermicompost application may be due to better nutrient content and soil improving properties of vermicompost. Application of vermicompost might have significantly contributed plant nutrients and growth promoting substances, which in turn have increased uptake of nutrients and metabolic activities of plants as reported by Nielson (1965). Syres and Springett (1984) reported the beneficial influence of vermicompost through the activity of microorganisms like phosphorous solubilizing bacteria. The phosphorous solubilizing microorganisms increase the available P content of vermicompost which might have increased P uptake of plants.

Oil cake is concentrated organic manure and comparatively richer in NPK. Neem cake is a non-edible oil cake. In addition to nutrients, it contains the alkaloids, nimbin and nimbicidin and certain sulphur components, which effectively inhibit, the nitrification procedure and improve nitrogen use effectively in crops (Reddy and Prasad, 1985). The neem, mahua, karanj and castor cakes have great value as means

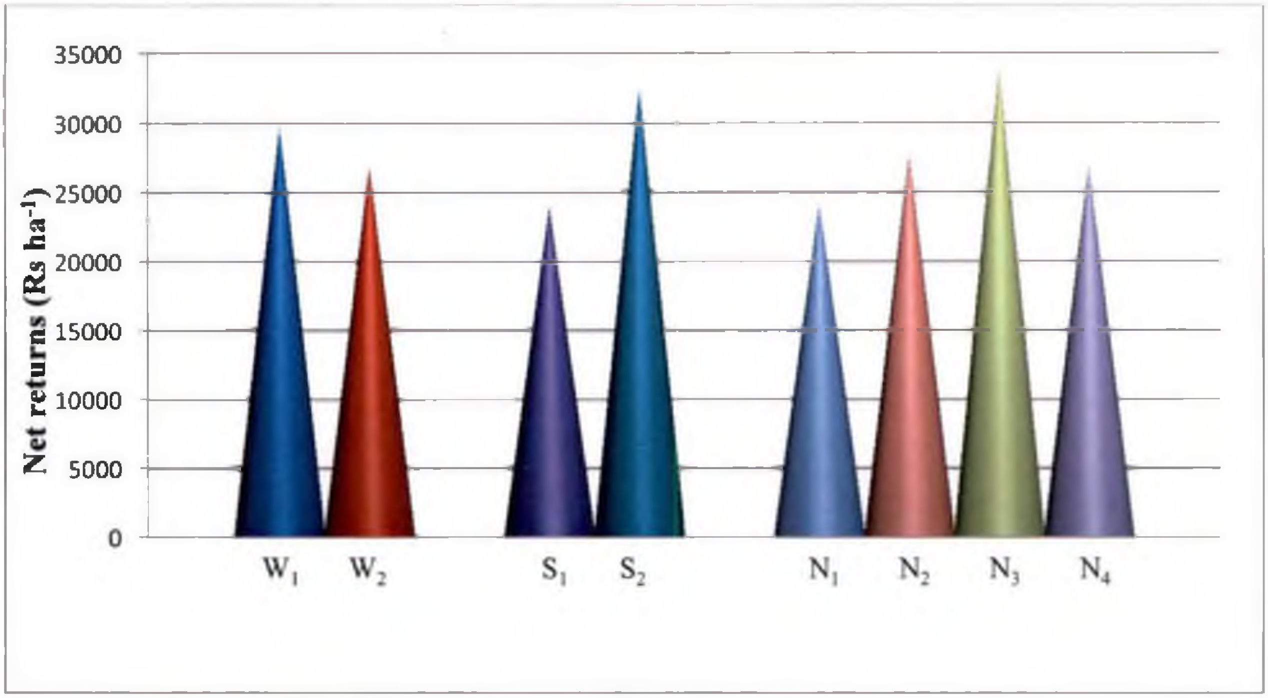


Fig 15. Net returns as affected by weed management techniques, spacing and nutrient schedule

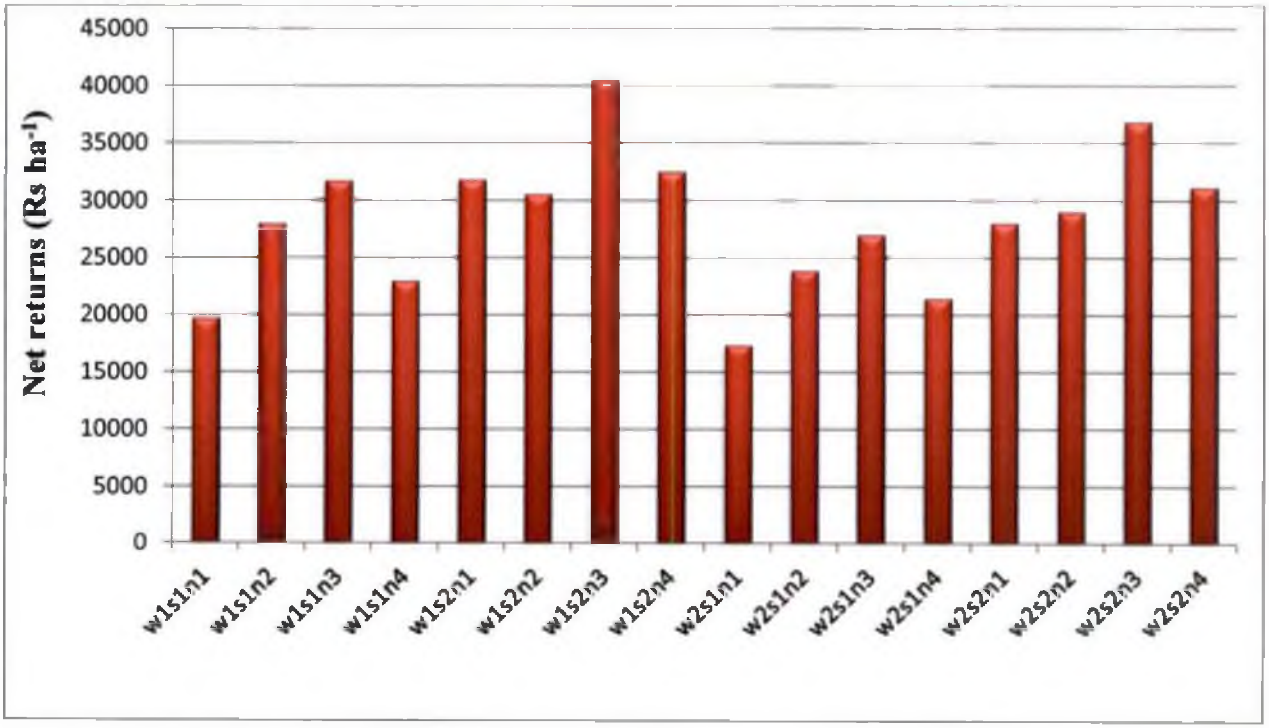


Fig 16. Net returns as affected by interaction effects of treatments

of immobilizers, thus, conserving the applied and soil nitrogen and mineralizing steadily over a longer period. They could aid in metered supply of nitrogen over a stipulating period of crop growth (Hulagur, 1996).

The increase in nitrogen uptake due to application of organic manures in N_3 and N_4 might be due to the fact that organic manures when applied to soil results in the breakdown of complex nitrogenous compounds by the action of microorganisms (slow mineralization) and its availability to the soil in the form of nitrate nitrogen (Rajeswari and Shakila, 2009).

Increase in available P content of soil due to organic manure application may be due to the solubility of native P through release of various organic acids (Sharma *et al.*, 2009) which might be the reason for increased uptake. According to Bhawalkar (1992), vermicompost also contains more number of N-fixing, phosphate solubilizing and other benefical microbes, antibiotics, vitamins, hormones, enzymes etc. which have better effects on growth and yield of plants. Because of this, vermicompost is easily mineralizable and N is readily available to plants.

The lowest uptake in N_2 (option-2 of the *ad hoc* recommendation of KAU) might be due to the low quantity of nutrients supplied in the treatment, *i.e.*, only 61 kg nitrogen, 10.1 kg phosphorous and 39 kg of potash from FYM, glyricidia leaf incorporation and azolla applied together as against the recommended dose of 90:45:45 NPK kg ha^{-1} supplied through various organic sources in N_3 and N_4.

5.11 Effect of weed management techniques, spacing and nutrient schedule on net returns and B:C ratio

Better grain and straw yield in closely spaced plants have resulted in the highest net returns and B:C ratio with closer spacing (Fig. 15 and 17). Though productivity of organic and conventional rice was same, organic rice production registered higher net returns and B:C ratio (Fig. 19) mainly due to the premium price fetched by organic rice.

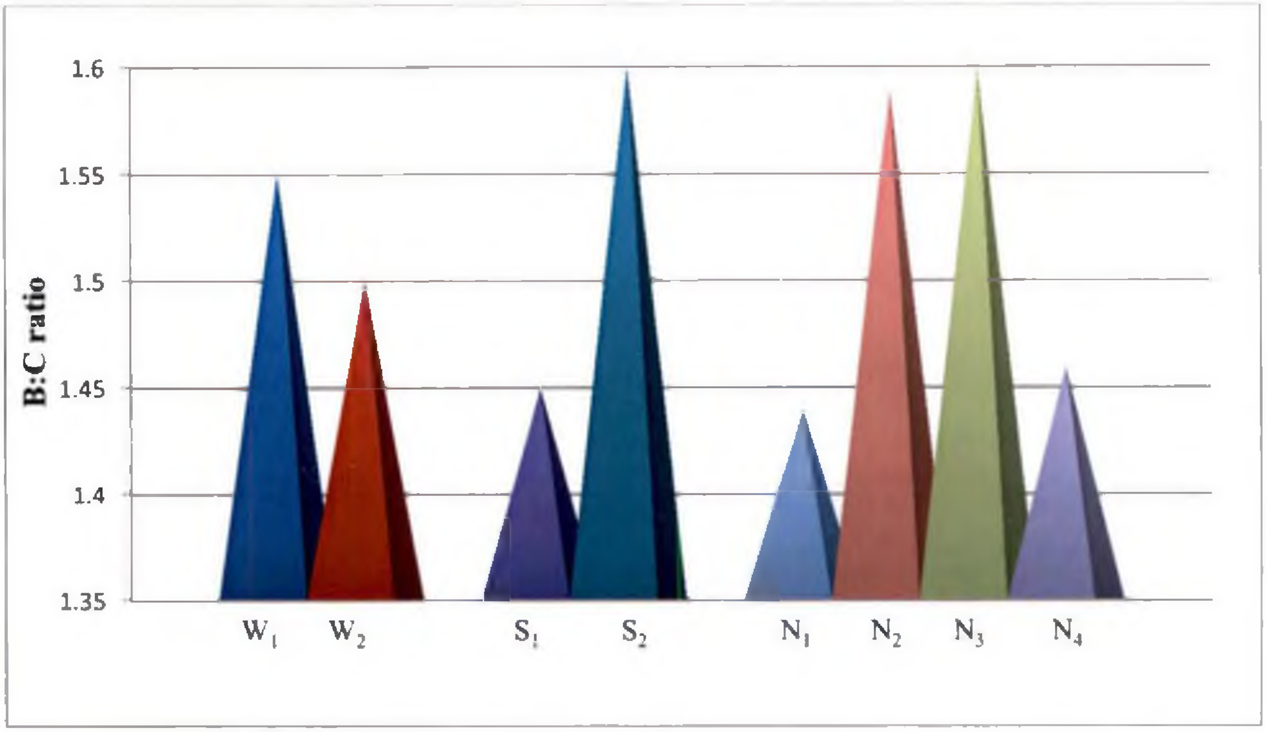


Fig 17. B:C ratio as affected by weed management techniques, spacing and nutrient schedule

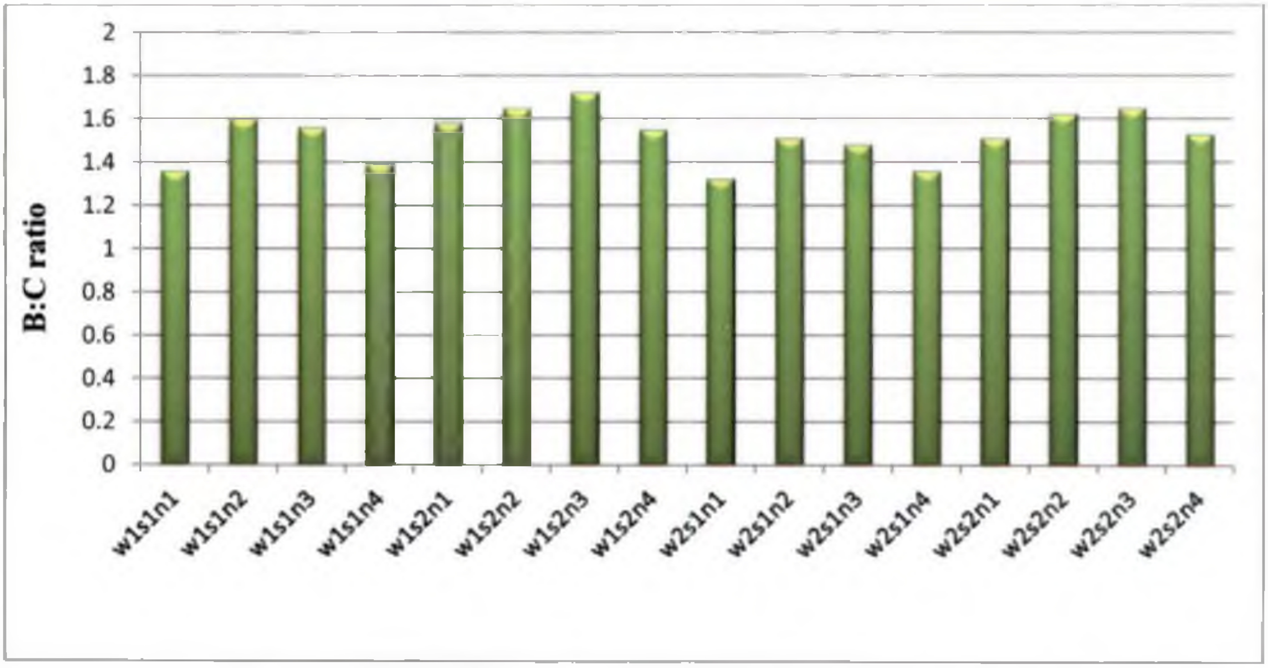


Fig 18. B:C ratio as affected by interaction effects of treatments

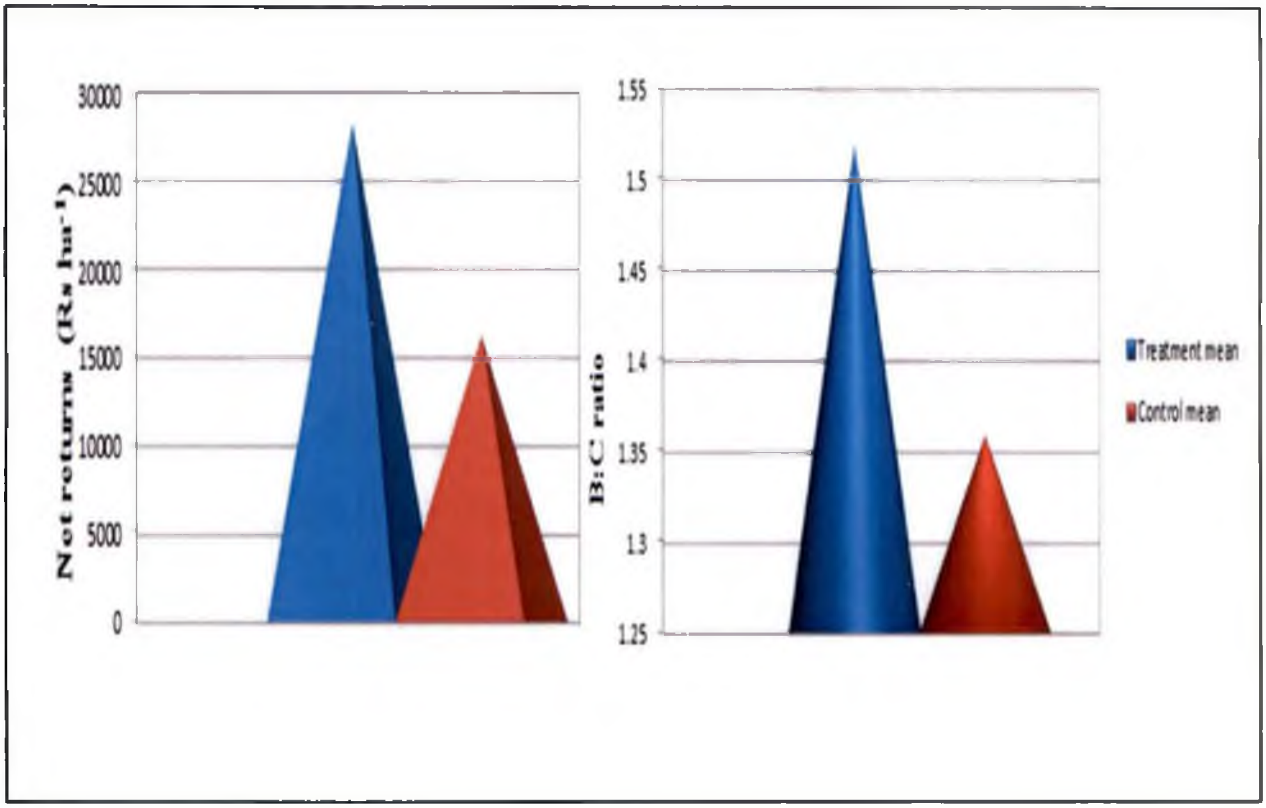


Fig 19. Net returns and B:C ratio as affected by treatments as against control

Summary

6. SUMMARY

An experiment entitled "Standardisation of nutrient and weed management techniques for organic rice" was undertaken at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, during the first crop season of 2012. The major objectives of the study were to standardise the nutrient schedule, spacing and weed management techniques for organic rice and to assess the economic feasibility of the organic package.

The experiment was laid out in split plot design with four replications. The treatments comprised of two main plot treatments - two spacings (S_1-20 cm x 15 cm, S_2-15 cm x 15 cm), two weed management practices (W_1-stale seedbed, W_2-hand weeding) and one sub plot treatment - four nutrient schedule (N_1-option-1 of the *ad hoc* recommendation of KAU: FYM 5 t + 800 kg oil cakes ha^{-1} (1/2 basal + 1/2 top dressing at active tillering stage), N_2-option-2 of the *ad hoc* recommendation of KAU: FYM 1 t + green leaf manure 1t + dual culture of azolla + 2 kg Azospirillum + 2 kg P solubilizing bacteria + 1kg PGPR (mix 1) ha^{-1}, N_3-option-3 of the *ad hoc* recommendation of KAU: 1/3rd RDN as FYM, 1/3rd as vermicompost and 1/3rd as neem cake + 2 kg Azospirillum + 2 kg P solubilizing bacteria ha^{-1}, N_4-soil test based application–half as vermicompost and half as neem cake) and one control - Package of Practices Recommendations of KAU for medium duration rice variety (FYM 5 t + 90:45:45 kg NPK ha^{-1}). There were a total of 17 (16+1) treatment combinations. The variety used for the experiment was, Uma (Mo-16). Observations were recorded at 20 DAT (active tillering), 40 DAT (maximum tillering), and 60 DAT (panicle initiation) and at harvest.

Weed management techniques had significant influence on plant height only at 40 DAT with W_2 (hand weeding) recording higher height. Spacing had significant effect at 60 DAT and at harvest stage with S_2 (15 cm x 15 cm) recording higher height. Among the nutrient schedule N_3 (option-3 of the *ad hoc* recommendation of KAU) recorded higher plant height at all stages, but was on par with N_4 (soil test based application) at 20 and 60 DAT. The W x S interaction effect was significant at

20 DAT with w_2s_1 (hand weeding with 20 cm x 15 cm spacing) recording the maximum height and was on par with all other treatments except w_1s_1 (stale seedbed with 20 cm x 15 cm spacing), which recorded the lower height. The W x N interaction effect was significant at 40 and 60 DAT and at harvest stage. At 40 DAT, w_2n_3 (hand weeding with option-3 of the *ad hoc* recommendation of KAU) recorded maximum plant height and was on par with w_1n_3 (stale seedbed with option-3 of the *ad hoc* recommendation of KAU). At 60 DAT, w_1n_4 (stale seedbed with soil test based application) recorded maximum height and was on par with w_2n_3 (hand weeding with option-3 of the *ad hoc* recommendation of KAU) and w_1n_3 (stale seedbed with option-3 of the *ad hoc* recommendation of KAU) and at harvest stage w_1n_3 (stale seedbed with option-3 of the *ad hoc* recommendation of KAU) recorded higher plant height.

The S x N interaction effect was significant at 20 and 40 DAT and at harvest stage. At 20 and 40 DAT, the plant height was higher in s_1n_3 (20 cm x 15 cm spacing with option-3 of the *ad hoc* recommendation of KAU). At harvest stage s_2n_3 (15 cm x 15 cm spacing with option-3 of the *ad hoc* recommendation of KAU) recorded higher plant height.

The W x S x N interaction effect was significant at 20 and 40 DAT and at harvest stage with $w_2s_1n_3$ (hand weeding with wider spacing of 20 cm x 15 cm and option-3 of the *ad hoc* recommendation of KAU) recorded the highest plant height at 20 and 40 DAT. At harvest stage $w_1s_2n_3$ (stale seedbed with 15 cm x 15 cm spacing and option-3 of the *ad hoc* recommendation of KAU) recorded maximum plant height, but was on par with $w_2s_2n_3$ (hand weeding with 15 cm x 15 cm spacing and option-3 of the *ad hoc* recommendation of KAU) and $w_1s_1n_3$ (stale seedbed with 20 cm x 15 cm spacing and option-3 of the *ad hoc* recommendation of KAU). Conventionally grown crop produced the tallest plants at all stages.

The weed management techniques had no influence on tiller number. Spacing had significant influence with S_2 (15 cm x 15 cm) recording the higher tiller number at all stages. The effect of nutrient schedule was also significant with N_3 (option-3 of the *ad hoc* recommendation of KAU) recording the higher tiller number. Among the interactions, only W x N interaction was found significant and that too only at harvest stage of the crop, with w_1n_3 (stale seedbed with option-3 of the *ad hoc* recommendation of KAU) recording the higher number of tillers.

LAI was not found influenced by weed management techniques. Spacing significantly influenced LAI at 20 DAT with S_2 (15 cm x 15 cm) recording higher LAI. Nutrient schedule had significantly influenced LAI at all stages with N_3 (option-3 of the *ad hoc* recommendation of KAU) recording higher LAI at all stages, but on par with N_4 (soil test based application) at 20 and 40 DAT.

The DMP of the plant was significantly influenced by weed management techniques with W_1 (stale seedbed) recording higher DMP. Spacing significantly influenced DMP with S_2 (15 cm x 15 cm) recording the highest DMP. Nutrient schedule also had significant influence with N_3 (option-3 of the *ad hoc* recommendation of KAU) recording the maximum DMP which was on par with N_4 (soil test based application).

The interaction effects failed to produce any significant influence on LAI and DMP.

The weed management techniques significantly influenced productive tiller number with W_1 (stale seedbed) recording higher number of productive tillers. Spacing also had significant influence, with S_2 (15 cm x 15 cm) recording higher number of productive tillers. N_3 (option-3 of the *ad hoc* recommendation of KAU) recorded the higher number of productive tillers. Among the interactions, the S x N interaction effect was significant with s_1n_3 (20 cm x 15 cm spacing with option-3 of the *ad hoc* recommendation of KAU) recording the higher number of productive tillers.

Grain weight panicle^{-1} was significantly influenced by weed management techniques with W_1 (stale seedbed) recording the higher grain weight. Spacing did not have any significant effect on grain weight panicle^{-1}. N_3 (option-3 of the *ad hoc* recommendation of KAU) recorded maximum grain weight panicle^{-1} which was on par with N_4 (soil test based application).

Weed management techniques had significant influence on number of spikelets panicle^{-1} with W_1 (stale seedbed) recording the higher number of spikelets panicle^{-1}, but spacing didn't have any significant effect on spikelets panicle^{-1}. N_3 (option-3 of the *ad hoc* recommendation of KAU) recorded the higher number of spikelets panicle^{-1}.

Weed management techniques and spacing did not have any significant effect on number of filled grains panicle^{-1}. But nutrient schedule had significant effect with N_3 (option-3 of the *ad hoc* recommendation of KAU) recording the higher number of filled grains panicle^{-1}.

Weed management techniques and spacing had no significant effect on thousand grain weight. The nutrient schedule had significant effect on thousand grain weight with N_3 (option-3 of the *ad hoc* recommendation of KAU) recording the maximum grain weight which was on par with N_4 (soil test based application).

Weed management techniques had no significant effect on grain yield. Spacing significantly influenced grain yield with S_2 (15 cm x 15 cm) recording the higher grain yield. Nutrient schedule also significantly influenced grain yield with N_3 (option-3 of the *ad hoc* recommendation of KAU) recording the maximum grain yield, which was on par with N_4 (soil test based application).

Weed management techniques had no significant effect on straw yield. Spacing had significant effect with S_2 (15 cm x 15 cm) recording the higher straw yield. N_3 (option-3 of the *ad hoc* recommendation of KAU) recorded maximum straw yield, and was on par with N_4 (soil test based application).

Harvest index was not significantly influenced by any of the treatments.

None of the interaction effects was significant for the above characters.

Except height, the organic and conventional crops showed no significant difference.

Weed management techniques had significant effect on weed biomass at 20, 40, 60 DAT and at harvest. At all these stages W_1 (stale seedbed) recorded the lower weed biomass. Spacing also had significant influence on weed biomass at all the crop growth stages with S_2 (15 cm x 15 cm) recording the lower weed biomass. Nutrient schedule also significantly influenced weed biomass at 20, 40 and 60 DAT, with N_2 (option-2 of the *ad hoc* recommendation of KAU) recording the lower weed biomass at 20 DAT and 60 DAT which was on par with N_1 (option-1 of the *ad hoc* recommendation of KAU). At 40 DAT, N_1 (option-1 of the *ad hoc* recommendation of KAU) recorded the lower weed biomass which was on par with N_2 (option-2 of the *ad hoc* recommendation of KAU).

Interaction effects failed to produce any significant influence.

The weed control efficiency of conventional crop was significantly poor.

Neither weed management techniques nor spacing or nutrient schedule had any significant effect on rice bug attack. The rice bug attack was uniform in all treatments above threshold level. Between the organic and conventional crop also there was no significant difference.

None of the treatments had significant effect on organic carbon content of soil after the experiment.

Weed management techniques did not have any significant effect on available nitrogen, phosphorus and potassium status of soil after the experiment. Spacing significantly influenced available nitrogen content only with S_1 (20 cm x 15 cm) recording higher available nitrogen content in the soil after the experiment. N_3 (option-3 of the *ad hoc* recommendation of KAU) left the soil with the higher available NPK status.

None of the interaction effects were significant with respect to the available nutrient status of the soil after the experiment. Though the organic crop left the soil with a slightly higher quantity of nutrients, there was no significant difference between organic and conventional crops.

Weed management techniques and spacing did not have any significant effect on nitrogen, phosphorus and potassium uptake. Nutrient schedule had significant effect on nutrient uptake with N_3 (option-3 of the *ad hoc* recommendation of KAU) recording higher N and K uptake. The phosphorus uptake was also higher in N_3, but was on par with N_4(soil test based application).

None of the interaction effects were significant in nutrient uptake. However the uptake of nutrients was the highest in conventional crop compared to organic showing the easiness in nutrient availability from inorganic sources compared to organic.

Weed management techniques and nutrient schedule did not have any significant influence on net returns and B:C ratio. Spacing had significant effect on net returns and B:C ratio with S_2 (15 cm x 15 cm) recording higher net returns and B:C ratio. The interaction effects were not significant at all. Between organic and conventional rice, the organic rice had given higher net returns with higher B:C ratio of 1.52.

To sum up, for realising maximum yield from organic rice, a closer spacing of 15 cm x 15 cm (S_2) is ideal. Any of the weed management techniques, *i.e.*, either stale seedbed (W_1) or hand weeding (W_2) can be practiced. Option-3 of the *ad hoc* recommendation of KAU (N_3 - 1/3rd RDN as FYM, 1/3rd as vermicompost and 1/3rd as neem cake + 2 kg Azospirillum + 2 kg P solubilizing bacteria ha^{-1}) is the best nutrient schedule for realizing maximum yield from organic rice.

The most economic package for organic rice production is the combination of closer spacing of 15 cm x 15 cm (S_2), with stale seedbed technique (W_1) of weed control and option-3 of the *ad hoc* recommendation of KAU (N_3 - 1/3rd RDN as FYM, 1/3rd as vermicompost and1/3rd as neem cake + 2 Kg Azospirillum + 2 Kg P solubilizing bacteria ha^{-1}) as nutrient schedule. The organic package was economically significantly superior to conventional package due to the premium price fetched by organic rice.

Future line of work

- Residual effect of organic nutrition should be studied by taking succeeding crops.
- Alternate and other weed control techniques in organic farming should be studied.
- Organic plant protection measures to be studied in a scientific way.
- Varietal variation in responding to organic sources and population effect on pests and diseases incidence should also be studied.
- Quality improvements if any, need to be studied.

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7. REFERENCES

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Appendices

APPENDIX- 1

Standard week wise mean weather parameters during the cropping period (May 2012 - September 2012)

Standard week	Temperature (°C)		Relative Humidity (%)		Total rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
20	31.5	26.1	91.4	74.3	22.0
21	31.5	25.8	91.7	72.1	0.0
22	31.5	26.1	90.0	70.6	1.0
23	31.3	24.7	91.4	71.1	3.6
24	30.4	23.9	93.6	72.4	7.0
25	29.4	24.3	94.4	77.0	3.5
26	29.8	23.8	87.0	74.0	6.0
27	29.5	23.9	95.1	78.3	7.4
28	29.6	24.0	88.9	72.9	7.9
29	29.9	24.6	92.3	76.4	5.3
30	30.0	24.5	94.4	74.7	5.8
31	30.2	24.6	94.0	75.0	0.0
32	30.3	23.7	87.7	72.9	1.5
33	29.7	23.5	91.3	73.3	17.0
34	29.8	23.9	92.6	75.0	2.0
35	28.9	23.5	94.7	85.3	14.0
36	29.8	23.8	89.9	74.9	7.1

APPENDIX II

Cost of cultivation and market price of produce

Option-1 of the *ad hoc* recommendation of KAU

	Particulars	**Cost (Rs)**
1	Seeds	1,800-00
2	Labour	31,250-00
3	Plant protection	3,000-00
4	Neem cake (400 kg ha^{-1} @ Rs 15 kg^{-1})	6,000-00
5	Ground nut cake (400 kg ha^{-1} @ Rs 30 kg^{-1})	12,000-00
	Total	**54,050-00**

Option-2 of the *ad hoc* recommendation of KAU

	Particulars	**Cost (Rs)**
1	Seeds	1,800-00
2	Labour	31,250-00
3	Plant protection	3,000-00
4	Azolla (200 kg ha^{-1} @ Rs 50 kg^{-1})	10,000-00
5	Biofertilizers	540-00
	Total	**46,590-00**

Option-3 of the *ad hoc* recommendation of KAU

	Particulars	**Cost (Rs)**
1	Seeds	1,800-00
2	Labour	31,250-00
3	Plant protection	3,000-00
4	Neem cake (1,300 kg ha^{-1} @ Rs 15 kg^{-1})	19,500-00
5	Biofertilizers	400-00
	Total	**55,950-00**

Option-4 (Soil test based application)

	Particulars	Cost (Rs)
1	Seeds	1,800-00
2	Labour	31,250-00
3	Plant protection	3,000-00
4	Neem cake (1,500 kg ha^{-1} @ Rs 15 kg^{-1})	22,500-00
	Total	**58,550-00**

Control-KAU Package of Practices Recommendation (FYM 5 t +90:45:45 kg NPK ha^{-1})

	Particulars	Cost (Rs)
1	Seeds	1,800-00
2	Labour	31,250-00
3	Plant protection	3,000-00
4	FYM (5 t ha^{-1} @ Rs 400 t^{-1})	2,000-00
5	Urea (196 kg ha^{-1} @ Rs 8 kg^{-1})	1,568-00
6	Rock phosphate (225 kg ha^{-1}@ Rs 10 kg^{-1})	2,250-00
7	MOP (75 kg ha^{-1} @ Rs 17 kg^{-1})	1,275-00
	Total	**43,143-00**

Market price of produce

Organically grown rice – Rs 36 kg^{-1}

Conventionally grown rice – Rs 25 kg^{-1}

Straw – Rs 4 kg^{-1}

STANDARDISATION OF NUTRIENT AND WEED MANAGEMENT TECHNIQUES FOR ORGANIC RICE

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ABSTRACT

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ABSTRACT

The present investigation on "Standardisation of nutrient and weed management techniques for organic rice" was conducted at the Department of Agronomy, College of Agriculture, Vellayani, during 2012-2013. The objectives were to standardise the nutrient schedule, spacing and weed management techniques for organic rice and to assess the economic feasibility of the organic package.

The experiment was laid out in the field in split plot design with combination of spacing, S (S_1-20 cm x 15 cm and S_2-15 cm x 15 cm) and weed management techniques, W (W_1-stale seedbed and W_2-hand weeding) as main plot treatments and nutrient schedule, N (N_1-option-1 of the *ad hoc* recommendation of KAU: FYM 5 t + 800 kg oil cakes ha^{-1} (1/2 basal + 1/2 top dressing at active tillering stage), N_2-option-2 of the *ad hoc* recommendation of KAU: FYM 1 t + green leaf manure 1t + dual culture of azolla + 2 kg Azospirillum + 2 kg P solubilizing bacteria + 1kg PGPR (mix 1) ha^{-1}, N_3-option-3 of the *ad hoc* recommendation of KAU: 1/3rd RDN as FYM, 1/3rd as vermicompost and 1/3rd as neem cake + 2 kg Azospirillum + 2 kg P solubilizing bacteria ha^{-1}, N_4-soil test based application–half as vermicompost and half as neem cake). The KAU Package of Practices Recommendation (FYM 5 t + 90:45:45 kg NPK ha^{-1}) was taken as control.

Closer spacing (S_2-15cm x 15 cm), hand weeding (W_2) and option-3 of the *ad hoc* recommendation of KAU (N_3) significantly influenced plant height and DMP, while closer spacing (S_2-15cm x 15 cm) and option-3 of the *ad hoc* recommendation of KAU (N_3) only had significant influence on tiller production and LAI.

Stale seedbed (W_1) and closer spacing (S_2-15 cm x 15 cm) had significant influence on most of the yield attributing characters, while, among nutrient schedule, N_3 (option-3 of the *ad hoc* recommendation of KAU) attributed the maximum for yield contributing characters, but was on par with N_4 (soil test based application) and also with N_1 (option-1 of the *ad hoc* recommendation of KAU) for grain yield.

The results on weed control revealed the superiority of closer spacing (S_2-15 cm x 15 cm) and stale seedbed technique (W_1) over others in controlling the weeds throughout the growth stages. However the weed control efficiency was the lowest in conventional (Control-KAU Package of Practices Recommendation) compared to the organic throughout the growth stages.

The nutrient uptake was the highest in N_3 (option-3 of the *ad hoc* recommendation of KAU) and the lowest in N_2 (option-2 of the *ad hoc* recommendation of KAU). However, uptake study had also revealed the superiority of conventional (Control-KAU Package of Practices Recommendation) over organic in the uptake of nutrients.

The net returns and B:C ratio were the highest in closely spaced plants (S_2-15 cm x 15 cm) and in N_3 (option-3 of the *ad hoc* recommendation of KAU).

From the study it can be concluded that for realising higher grain yield in organic rice, a closer spacing of 15 cm x 15 cm (S_2) is ideal. Any of the two weed management techniques, *i.e.,* either stale seedbed (W_1) or hand weeding (W_2) can be practiced for controlling weeds. Option-3 of the *ad hoc* recommendation of KAU (N_3-1/3rd RDN as FYM, 1/3rd as vermicompost and 1/3rd as neem cake + 2 kg Azospirillum + 2 kg P solubilizing bacteria ha^{-1}) is the best nutrient schedule for realizing maximum yield from organic rice.

The most economic package for organic rice production is the combination of closer spacing of 15 cm x 15 cm (S_2), with stale seedbed technique (W_1) of weed control and option-3 of the *ad hoc* recommendation of KAU (N_3-1/3rd RDN as FYM, 1/3rd as vermicompost and1/3rd as neem cake + 2 Kg Azospirillum + 2 Kg P solubilizing bacteria ha^{-1}) as nutrient schedule. The organic package was economically significantly superior to conventional package due to the premium price fetched by organic rice.

സംഗ്രഹം

വെള്ളായണി കാർഷിക കോളേജിലെ അഗ്രോണമി വിഭാഗത്തിൽ 2012-13 അദ്ധ്യായന വർഷം ശ്രീ. മുരുഗേഷ്. എം. എസ്. (അഡ്മിഷൻ നമ്പർ-2011-11-151) എന്ന ബിരുദാനന്തരബിരുദ വിദ്യാർത്ഥി **'ജൈവ നെൽകൃഷിയിൽ പോഷകമൂലകങ്ങളുടെ അളവ്, തരം, കളനിയന്ത്രണ മാർഗങ്ങൾ എന്നിവയുടെ ക്രമീകരണം'** എന്ന പഠന വിഷയത്തിൽ നടത്തിയ ഗവേഷണത്തിന്റെ വിശദാംശങ്ങളും നിരീക്ഷണ ഫലങ്ങളും ചുവടെ സംക്ഷിപ്തമായിസംഗ്രഹിച്ചിരിക്കുന്നു.

ജൈവ നെൽകൃഷിയിൽ നടീൽ അകലം, പോഷകമൂലകങ്ങളുടെ അളവ്, തരം, കളനിയന്ത്രണ മാർഗ്ഗങ്ങൾ എന്നിവ എങ്ങിനെ ക്രമീകരിക്കണം എന്നുള്ളതായിരുന്നു പഠനത്തിന്റെ പ്രധാന നിർദ്ദേശങ്ങൾ, കൂടാതെ ജൈവ നെല്ലുൽപാദനം ആദായകരമാണോ അല്ലയോ എന്നു തെളിയിക്കേണ്ട മറ്റൊരുദ്ദേശവും കൂടെ പഠനത്തിന് ഉണ്ടായിരുന്നു.

ശാസ്ത്രീയ രീതിയിലുള്ള പരീക്ഷണ നിരീക്ഷണ മാർഗ്ഗങ്ങൾ ഉപയോഗിച്ച് 'സ്പ്ലിറ്റ് പ്ലോട്ട് ഡിസൈൻ' എന്ന സാംഖ്യകീയ രീതിയിലാണ് പഠനം നടത്തിയത്. ചെടികൾ തമ്മിലുള്ള അകലം നിശ്ചയിക്കുന്നതിന് രണ്ട് നടീൽ അകലങ്ങളും (20 സെ.മീ x 15 സെ.മീറ്ററും, 15 സെ.മീ x 15 സെ. മീറ്ററും), കളനിയന്ത്രണ മാർഗ്ഗമറിയാൻ രണ്ടു കള നിയന്ത്രണ മാർഗ്ഗങ്ങളും (കളയ്ക്ക് കിളിർപ്പിക്കുക എന്ന രീതിയും, കള പറിച്ചു മാറ്റുക എന്ന രീതിയും), പോഷക മൂലകങ്ങളുടെ അളവും തരവും നിശ്ചയിക്കുന്നതിന് നാലു തരത്തിലും അളവിലും പോഷക മൂലകങ്ങൾ നൽകിയും (1. കാർഷിക സർവ്വകലാശാലയുടെ ഓപ്ഷൻ-1 എന്ന അഡ് ഹോക്ക് നിർദ്ദേശം - ഹെക്ടറിന് 5 ടൺ കാലിവളവും, 800 കിലോഗ്രാം പിണ്ണാക്ക് വളവും (ഇതിൽ പകുതി അടി വളമായും, ബാക്കി പകുതി അടിക്കണ പരുവത്തിൽ മേൽ വളമായും), 2. കാർഷിക സർവ്വകലാശാലയുടെ ഓപ്ഷൻ-2 എന്ന അഡ് ഹോക്ക് നിർദ്ദേശം -ഹെക്ടറിന് 1 ടൺ കാലിവളവും, 1 ടൺ പച്ചില വളവും, ആസോള ജീവാണു വളം സംയുക്തമായും, 2 കിലോഗ്രാം അസോസ്പൈറില്ലവും, 2 കിലോഗ്രാം ഭാവഹലായക ബാക്ടീരിയ വളവും, 1 കിലോഗ്രാം പി.ജി.പി.ആർ മിശ്രിതവും ഒരുമിച്ച്, 3. കാർഷിക സർവ്വകലാശാലയുടെ ഓപ്ഷൻ-3 എന്ന അഡ് ഹോക്ക് നിർദ്ദേശം -ഹെക്ടറിന് മൊത്തം വളത്തിന്റെ മൂന്നിലൊന്ന് ഭാഗം കാലിവളമായും, മറ്റൊരു മൂന്നിലൊന്ന് ഭാഗം മണ്ണിര കമ്പോസ്റ്റായും, ഇനിയുള്ള മൂന്നിലൊന്നു ഭാഗം വേപ്പിൻ പിണ്ണാക്കായും, കുടാതെ 2 കിലോഗ്രാം അസോസ്പൈറില്ലവും, 2 കിലോഗ്രാം ഭാവഹലായക ബാക്ടീരിയ വളവും ഒരുമിച്ച്, 4 മണ്ണിലെ പോഷകമൂലകങ്ങളുടെ കണക്കനുരിച്ച് പകുതി

വളം മണ്ണിര കമ്പോസ്റ്റായും, പകുതി വളം വേപ്പിൻ പിണ്ണാക്കായും) ആണ് പഠനം നടത്തിയത്. ഇവയിൽ ആദ്യത്തെ രണ്ടു പരീക്ഷണ പ്രയോഗങ്ങൾ മുഖ്യ പ്ലോട്ടുകളിലും, മൂന്നാമത്തേത് സബ് പ്ലോട്ടുകളിലുമാണ് പരീക്ഷണ വിധേയമാക്കിയത്. കൂടാതെ ജൈവകൃഷിയും സാധാരണകൃഷിയും തമ്മിലുള്ള താരതമ്യപഠനത്തിനായി സാധാരണ രീതിയിൽ കൃഷി ചെയ്യുന്ന ഒരു അധിക (നിയന്ത്രണ) പ്ലോട്ടും പഠനത്തിൽ ഉൾപ്പെടുത്തി.

പഠന ഫലങ്ങൾ സംക്ഷിപ്ത രൂപത്തിൽ ഇനിപറയും പ്രകാരമാണ്. അടുപ്പിച്ച് നടുന്നതും (15 സെ.മീ X 15 സെ.മീ), കൈ കൊണ്ട് കളപറിച്ചു മാറ്റുന്നതും, ഓപ്ഷൻ - 3 (കാർഷിക സർവ്വകലാശാലയുടെ ഓപ്ഷൻ - 3 എന്ന അഡ്ഹോക്ക് നിർദ്ദേശം - ഹെക്ടറിന് മൊത്തം വളത്തിന്റെ മൂന്നിലൊന്ന് കാലിവളമായും, മറ്റൊരു മൂന്നിലൊന്ന് ഭാഗം മണ്ണിര കമ്പോസ്റ്റായും, ഇനിയുള്ള മൂന്നിലൊന്ന് ഭാഗം വേപ്പിൻ പിണ്ണാക്കായും, കൂടാതെ 2 കിലോഗ്രാം അസോസ്പൈറില്ലവും, 2 കിലോഗ്രാം ഭാവഹലായക ബാക്ടീരിയ വളവും ഒരുമിച്ച്) വഴി വളപ്രയോഗം നടത്തുന്നതും ചെടിയുടെ പൊക്കവും, തൂക്കവും കൂട്ടുമെന്നും, എന്നാൽ ചിനപ്പുകളുടെ എണ്ണത്തിലും, ഇലകളുടെ കഴിവ് നിശ്ചയിക്കുന്ന പ്രതല വിസ്തീർണ്ണത്തിലും കളനിയന്ത്രണ മാർഗ്ഗങ്ങൾക്ക് വലിയ പങ്കില്ലെന്നും കണ്ടു. അന്തിമ വിളവ് നിശ്ചയിക്കുന്ന ഘടകങ്ങൾ കളയ്ക്ക് കിളിർപ്പിക്കൽ, ഓപ്ഷൻ - 3 വഴിയുള്ള വളപ്രയോഗം എന്നിവ വഴി കൂട്ടാമെന്നും, അന്തിമ വിളവ് അഥവാ നെല്ലുല്പാദനം ഓപ്ഷൻ - 3 വഴിയുള്ള വളപ്രയോഗത്തിനും, മണ്ണ്പരിശോധന നടത്തി വളം നൽകുന്നതിനും, ഓപ്ഷൻ - 1 വഴി നൽകുന്ന വളപ്രയോഗത്തിനും ഒരേ പങ്കാണുള്ളതെന്നും കണ്ടു.

അടുപ്പിച്ച് നടുന്നത് ഉല്പാദനം കൂട്ടുമെന്നു മാത്രമല്ല കള നിയന്ത്രണത്തിനും ഉത്തമമാണെന്നും ബോധ്യപ്പെട്ടു. എന്നാൽ രണ്ടു കള നിയന്ത്രണ മാർഗങ്ങൾ പഠിച്ചതിൽ, കളയ്ക്ക് കിളിർപ്പിക്കുക എന്ന രീതിയാണ് മെച്ചമെന്ന് ബോധ്യപ്പെട്ടു. സാധാരണകൃഷിയിൽ നിന്നും ജൈവകൃഷി കൂടുതൽ മെച്ചമെണെന്നും പഠനഫലങ്ങൾ സൂചിപ്പിക്കുന്നു.

പോഷകമൂലകങ്ങളുടെ ആഗിരണവും ലഭ്യതയും ഓപ്ഷൻ - 3 വഴി നൽകുന്നതിലാണ് കൂടുതലെന്നും, ഓപ്ഷൻ - 2 വഴിയുള്ളതിൽ കുറവാണെന്നും കണ്ടു. അതേ സമയം, സാധാരണ രീതിയിൽ രാസവളം ഉപയോഗിച്ചുള്ള കൃഷിയിൽ പോഷകമൂലകങ്ങളുടെ ആഗിരണം വളരെ കൂടുതലാണെന്നും കാണപ്പെട്ടു.

അടുപ്പിച്ച് നടുന്നതും, ഓപ്ഷൻ - 3 വഴി വളം നൽകുന്നതും വരവ്- ചെലവ് അനുപാതവും, അറ്റാദായവും കൂട്ടുമെന്നും തെളിയിച്ചു.

പഠനഫലങ്ങളിൽ നിന്നുള്ള നിർദ്ദേശങ്ങൾ

1. ജൈവകൃഷിക്ക് ഞാറ് അടുപ്പിച്ച് നടുകയാണെങ്കിൽ (15 സെ.മീ x 15 സെ.മീ) വിളവ് കൂട്ടാം, അതുപോലെ കളകളെയും നിയന്ത്രിക്കാം.

2 "രണ്ടു കളനിയന്ത്രണ മാർഗ്ഗങ്ങളും,അതായത് കളയ്ക്ക് കിളിർപ്പിക്കലും,കൈ കൊണ്ട് കള പറിച്ചു മാറ്റുന്നതും ജൈവകൃഷിക്ക് ഉത്തമം.

3. ഓപ്ഷൻ - 3 വഴിയുള്ള വളപ്രയോഗം (കാർഷിക സർവ്വകലാശാലയുടെ ഓപ്ഷൻ - 3 എന്ന അഡ്ഹോക്ക് നിർദ്ദേശം - ഹെക്ടറിന് മൊത്തം വളത്തിന്റെ മൂന്നിലൊന്ന് കാലിവളമായും, മറ്റൊരു മൂന്നിലൊന്ന് ഭാഗം മണ്ണിര കമ്പോസ്റ്റായും, ഇനിയുള്ള മൂന്നിലൊന്ന് ഭാഗം വേപ്പിൻ പിണ്ണാക്കായും, കൂടാതെ 2 കിലോഗ്രാം അസോസൈപറില്ലവും, 2 കിലോഗ്രാം ഭാവഹലായക ബാക്ടീരിയ വളവും ഒരുമിച്ച്) അഭികാമ്യം.

മറ്റൊരു സംക്ഷിപ്തം ഇപ്രകാരം നല്കാം - അതായതു ഞാറുകൾ തമ്മിലുള്ള അകലം കുറച്ച്, കളയ്ക്ക് കിളിർപ്പിക്കൽ വഴിയിലൂടെ കള നിയന്ത്രണം നടത്തി, ഓപ്ഷൻ - 3 വഴിയുള്ള വളപ്രയോഗവും (കാർഷിക സർവ്വകലാശാലയുടെ ഓപ്ഷൻ - 3 എന്ന അഡ്ഹോക്ക് നിർദ്ദേശം - ഹെക്ടറിന് മൊത്തം വളത്തിന്റെ മൂന്നിലൊന്ന് കാലിവളമായും, മറ്റൊരു മൂന്നിലൊന്ന് ഭാഗം മണ്ണിര കമ്പോസ്റ്റായും, ഇനിയുള്ള മൂന്നിലൊന്ന് ഭാഗം വേപ്പിൻ പിണ്ണാക്കായും, കുടാതെ 2 കിലോഗ്രാം അസോസൈപറില്ലവും, 2 കിലോഗ്രാം ഭാവഹലായക ബാക്ടീരിയ വളവും ഒരുമിച്ച്) സംയുക്തമായി പ്രാവർത്തികമാക്കാമെങ്കിൽ ജൈവ നെൽ കൃഷി ആദായകരവും, ഗുണകരവുമാക്കി മാറ്റാവുന്നതാണ്.