EVALUATION OF BIOZYME FORMULATIONS IN ORGANICALLY GROWN RICE-RICE SEQUENCE

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**MASTER OF SCIENCE IN AGRICULTURE
(AGRONOMY)**

By

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DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
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CERTIFICATE- I

This is to certify that the thesis entitled **"EVALUATION OF BIOZYME FORMULATIONS IN ORGANICALLY GROWN RICE-RICE SEQUENCE"** submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)** to the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of bona fide research work carried out by **CHOUDHURY SUNMARG KAR** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma or published in any other form.

It is further certified that the assistance and help availed by him from various sources during the course of investigation has been duly acknowledged.

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CERTIFICATE – II

This is to certify that the thesis entitled **"EVALUATION OF BIOZYME FORMULATIONS IN ORGANICALLY GROWN RICE-RICE SEQUENCE"** submitted by **CHOUDHURY SUNMARG KAR** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY),** has been approved by the Student's Advisory Committee after an oral examination on the same in collaboration with an External Examiner.

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ABSTRACT

The field experiment was conducted on "Evaluation of Biozyme formulations in organically grown rice-rice sequence" during 2012-2013 in Organic Block of Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar. The experiment was laid out in a randomized block design with twelve treatments viz., *Dhanicha* @ 25 kg seed/ha (T_1), *Dhanicha* + FYM @ 5t/ha (basal) (T_2), *Dhanicha* + FYM + Vermicompost @ 2t/ha (20DAT) (T_3) , T_1 + BSP@ 2.5 ml kg^{-1} seed (Seed Treatment) + BG @ 15 kg ha^{-1}(Basal) (T_4), T_1 + BSP (Seed Treatment) + BPPL @ 750 ml ha^{-1} (Tillering + P.I. stage) (T_5), T_1 + BSP + BG + BPPL (T_6), T_2 + BSP (Seed Treatment) + BG (Basal) (T_7), T_2 + BSP (Seed Treatment) + BPPL (Tillering + P.I. stage) (T_8), T_2 + BSP + BG + BPPL (T_9), T_3 + BSP (Seed Treatment) + BG (Basal) (T_{10}), T_3 + BSP (Seed Treatment) + BPPL (Tillering + P.I. stage) (T_{11}), T_3 + BSP + BG + BPPL (T_{12}) in *kharif* season, and in summer season, all the corresponding treatments were the same except *Dhanicha*. The soil of the experimental site was sandy loam with pH 6.35, BD 1.58 t m^{-3}, PD 2.65 t m^{-3}, high in organic carbon (9.7 g kg^{-1}) and medium in available N-P_2O_5-K_2O (375.0, 34.49 and 221.25 kg ha^{-1}, respectively). Rice variety "Lalat" was grown as the test crop. Pot manure was used intermittently as a prophylactic measure against disease and insect pest infestation.

Organic nutrient management and Biozyme formulations expressed significant effect on all growth parameters of rice. Number of tiller per hill at 45 DAT were maximum (29.70 and 28.60 in *kharif* and summer seasons, respectively) for treatment receiving *Dhanicha* + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) which was at par with those of T_7 to T_{11} in both the seasons. Number of effective tillers per hill also observed similar trend. At 75 DAT, the root volume per hill was found to be maximum in T_{12} i.e. 83.23 and 81.91 cc, respectively which were at par with those of treatments T_{10} and T_{11} in *kharif* and T_9 to T_{11} in summer,

respectively. Dry matter production per hill at maturity was significantly more for T_{12} (75.08 and 73.50 g per hill in respective seasons). Yield attributes and yield were also significantly affected by organic nutrient management and Biozyme formulations. Number of panicle per m^2 was significantly maximum for T_{12} (379.20 and 361.60 in *kharif* and summer seasons, respectively) at harvest. However, these were at par with those of T_7 to T_{11} in both the seasons. As regards to spikelet per panicle, T_{12} registered the maximum (152.33 and 148.33 in *kharif* and summer seasons, respectively) which were at par with those of treatments T_6 to T_{11} in both the seasons. Number of filled grains per panicle also observed similar trend. Test weight was not affected by organic nutrient management and Biozyme formulations treatments. Grain yield and straw yield were significantly higher for T_{12} (5087 and 5647; 4951 and 5444 kg ha^{-1} in *kharif* and summer seasons, respectively) which was at par with those of T_9 to T_{11} in *kharif* and T_8 to T_{11} in summer seasons for grain yield and T_8 to T_{11} in both seasons for straw yield. On the other hand, the minimum values were observed for T_1 for all these parameters. Microbial population was highly influenced by organic nutrient management and Biozyme formulations during the crop growing period. Maximum microbial population at 90 DAT (Bacteria 1.1 x 10^7 and 1.08 x 10^7, Actinomycetes 1.14 x 10^7 and 1.11 x 10^7, Fungi 1.05 x 10^5 and 1.07 x 10^5 cfu g^{-1} of soil) was observed for T_{12} in both seasons. The N-P-K content was not radically influenced by organic nutrient management and Biozyme formulations. Nutrient content was found maximum in T_1 whereas nutrient uptake was found higher in T_{12} (55.88 and 22.38; 12.42 and 4.57; 9.94 and 90.44 in *kharif;* 52.94 and 20.66; 11.15 and 3.96; 8.36 and 80.43 kg ha^{-1}in summer seasons, respectively). Soil physical and chemical properties had improved due to organic nutrient management and Biozyme formulations. Soil fertility status after system yield (N-P-K 358, 36, 229 kg ha^{-1} ; OC 12.0 g kg^{-1}; pH 6.6; EC 0.115 dSm^{-1}; BD and PD 1.54 and 2.63 t m^{-3}) was very close to or improved from those of initial status of soil. Gross return, net return and return per rupee invested were affected by organic nutrient management and Biozyme formulations. Net return was the highest for T_{12} (₹ 26, 663 and 26,059 ha^{-1} in *kharif* and summer seasons, respectively) with return per rupee invest of ₹ 1.79 and 1.80 as compared to T_1 which accounted for lowest net return (₹ 11,126 and 10,386 ha^{-1}) with return per rupee invest of ₹ 1.37 and 1.35, in *kharif* and summer seasons, respectively. Keeping the grain yield, net monetary return and soil status in view, organic nutrient management with Biozyme formulation option like *Dhanicha* + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and FYM + Vermicompost + BSP + BG + BPPL in summer can be advocated in organically grown rice-rice sequence.

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CHAPTER-I

Introduction

INTRODUCTION

Conventional agriculture has resulted in declining factor productivity and hence, is no more sustainable. Furthermore, it has propped up many environmental problems including soil, air and water pollution and finally human health hazards (Singh *et al*., 2011). With an effort to minimize these threats in conjunction with sustainability of agriculture, many systems such as integrated arable farming systems, low external input system and organic farming system have been tried and tested in many parts of our country and the world , as well.

However, organic farming system is adjudged to be the most viable option to sustain agricultural growth (Kalra *et al*., 2012). Moreover, this system is associated with soil health, clean environment, promotion and enhancement of agro-ecosystem services, biodiversity, biological cycles and soil biological activities.

It is widely recognized that organic matter in soils plays an essential role in a range of soil physical, chemical and biological processes and that soil organic carbon (SOC) is one of the most important indicators of soil quality and health. Maintaining or increasing SOM is critical to achieve optimum soil functions and therefore fertility and crop production.

Organic residues including green manure, animal waste and farmyard manure (FYM) are traditionally applied to rice soils in order to maintain the soil organic matter (SOM) status, to increase the levels of plant nutrients and to improve the physical, chemical and biological soil properties that directly or indirectly affect soil fertility and productivity.

Application of compost/manure and biofertilizers are two major components of organic farming, which offers an economically attractive and ecologically sound means of reducing external inputs and improving internal resources (Singh, 1989; Saxena and Tilak, 1994; Pathak *et al.* 1997; Ramesh, 2008).

An ideal agricultural system is sustainable, maintains and improves human health, benefits producers and consumers both economically and spiritually, protects the environment, and produces enough food for an increasing world population (Higa, 1991). Rice-rice sequence is a predominant system in coastal agro-ecology of Odisha. The productivity of this system has to be sustainable to stabilize the economic condition of bulk of the farming community in this zone.

Biozyme is a bio-extract from a sea weed *Ascophyllum nodosum* . It is large, common brown algae in the family Fucaceae. It is used as alginates, fertilizers and for the manufacture of seaweed meal for animal and human consumption. It can be used as an organic manure due to presence of both macronutrient (N, P, K, Ca, Mg, S) and micronutrient (Mn, Cu, Fe, Zn, etc). It also contains plant growth hormones, organic acids, polysaccharides, amino acids, and proteins which are all very beneficial and widely used in agriculture. It is a formulation of sea-weed extract, which is said to be a soil conditioner and enhance the inherent plant capacity to express itself with full potential (Wallace, 1998). It provides plant growth hormones which promote plant growth (Cassan *et al*., 1992) and accelerate soil biological activities (Stephenson, 2008)

Formation and remineralization of SOM depend on biogeochemical pathways of C and N that are governed by soil microbial biomass and soil enzymes. Mainly prokaryotic biomass constitutes the major fraction of the soil biota in flooded soils that accounts for the most labile fraction of SOM and functions simultaneously as a sink and as a source of plant nutrients. Under this circumstance, an area that appears to hold the greatest promise for technological advance in crop production, crop rotation and natural resource conservation is that of beneficial and effective microorganism, applied as soil, plant and environmental inoculants (Higa and Parr, 2004). On this account, soil microbial study needs to be emphasized. Keeping in view the importance of this research, which mostly remains unattended, it has been rightly adjudged to the “Century of microbes”.

With these considerations, this experiment on “Evaluation of Biozyme formulations in organically grown rice-rice sequence” has been proposed to be laid out with the following objectives

1) To augment yield of the system.
2) To study maintenance and enhancement of soil ecosystem health.
3) To study the microbial population shift of soil.
4) To study economics of the system.

CHAPTER-II

Review of Literature

REVIEW OF LITERATURE

Global agricultural expansion threatens to impact worldwide biodiversity on an unprecedented scale that may rival climate change in its significance for the persistence of panoply of species, during the next 50 years (Tilman *et al.,* 2001). Use of chemicals in agriculture has increased the crop yield, yet caused many environmental problems including soil, air and water pollution and finally human health hazards and making the crop productivity unsustainable (Eid *et al.,* 2006). According to Park *et al.,* (2008) and Oenema *et al.,* (2009), use of herbicides and nitrogen fertilization in agriculture is becoming limited in Korea due to their expense and environmental impact, which has recently caused great concern. Therefore, environment-friendly approaches to the cultivation of rice are necessary to ensure adequate crop yield while protecting the environment.

Since the beginning of 21st century, development of organic farming has shown a strong growth worldwide. Organic agriculture is practised in almost all countries of the world, and its share of agricultural land and farms are growing (FA0 2002). It is again reported that in 2002, about 23 million hectares of cropped area were managed organically worldwide and it is 31.4 % more than that of 2000. This suggests the aptitude of the farmers and the demand of the consumers to produce and consume organic food, respectively. The total world retail sales of organic products reached US$25 billion in 2002, which increased by 42.9% compared to 2000 (Yussefi and Willer 2003). The demand for safe food, parallelly in consonance with increased environmental awareness, has resulted in an increasing demand for organic products. Organic agriculture has been found to enhance soil fertility and increase biodiversity (Mäder *et al.*, 2002). For example, one meta-analytical study, comparing conventional and organic farms, showed that the latter tend to have higher soil organic matter content and lower nutrient losses (Tuomisto *et al.*, 2012). After conversion to organic farming, simulation models predict an increase in soil carbon sequestration in the form of soil organic matter during the first 50 years, which becomes stabilized after about 100 years (Foereid and Hogh-Jensen, 2004). Therefore, it is expected that organic farming systems should be able to combat climate change, allowing food supplies to be secured (Jordan *et al.*, 2009). Furthermore, Schmid and Sinabell (2006) reaffirm that organic food is not only free of chemical residues, but is also free of genetically modified organisms, with consumers receiving this second attribute for free. Hence, organic agriculture might be considered a powerful "tool" within the framework of natural resource management, territorial development, and viable food production, which represent the three broad objectives proposed for Common Agricultural Policy (CAP) reforms after 2013 by the European Commission (2011).

2.1 ORGANIC FARMING - DEFINITION

Organic agriculture is a unique production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity, and this is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion of all synthetic off-farm inputs (FAO).

Organic farming is a method of farming system which primarily aims at cultivating the land and raising crops in such a way so as to keep the soil alive and in good health. Organic management stresses on optimization of resource use and productivity, rather than maximization of productivity and over exploitation of resources at the cost of resources meant for future generations. Organic farming envisages a comprehensive management approach to improve soil health, the ecosystem of the region and the quality of produce. It includes all agricultural systems that promote environmentally sound production of food and fibers. These systems take inherent soil fertility as a key to successful production, by respecting the natural capacity of plants, animals and the landscape; they aim to optimize quality in all aspects of agriculture and environment.

2.2 ORGANIC FARMING - ECOLOGICAL IMPLICATIONS

Organic farming is a safe, sustainable, economical and eco-friendly system of agriculture. It is being practiced in more than 100 countries in the world covering an area of 24 million hectare and in India, it has a spread and extent of 2.5 million hectare (Bhattacharya and Chakraborthy, 2005). Organic farming improves and maintains the soil fertility for longer period, increases soil biological activity and water holding capacity, and reduces the disease and insect pest incidence in crops (Dasappa 2000 and Ingram, 2007).

Preservation and improvement of soil fertility is an inherent principle of organic farming technology. Studies show that organic farming conserves soil fertility and improves system stability better than conventional farming (Stolze *et al.,* 2000; Shepherd *et al.,* 2003). A study of cotton production under organic conditions in India found yield levels similar to a modern cultivation technique, but soil quality, as indicated by soil organic matter, water stable aggregates and mean weight diameter, showed advantages for the organic system (Blaise, 2006).

The growing concern about environmental degradation, dwindling natural resources and urgency to meet the food needs of the increasing population are compelling farm scientist and policy makers to seriously examine alternative to chemical agriculture. Nemecek *et al.,* (2005) found green house warming potential in organic systems 29 to 32 percent lower on per ha basis than in a mineral fertilizer system and 35 to 37 percent lower than in the conventional manure-based system. Various studies have confirmed that organic agriculture is productive and sustainable (Madar *et al.,* 2002).

Conversion to organic farming contributes to mitigate the share of agriculture to global warming. It, therefore, stands for stability of food supply which is threatened by climate change (Aubert, 2007).

The use of organic amendments for the management of plant pathogens has often been considered as best variable but more often biological agents has attained importance in modern agriculture to curtail the hazardous effect of intensive use of chemicals for disease control (Tuber and Baker, 1998).

2.3 ORGANIC NUTRIENT MANAGEMENT

Organic manuring play a pivotal role in minimizing the ill effects of intensive agriculture that has resulted in many adverse effect on natural resources i.e., decline in soil health, deficiency of major and micro nutrients and stagnation in yield (Viridi *et al.,* 2006). Boosting yield, reducing production cost and improving soil health are three inter-linked components of the sustainability triangle (Singh *et al.,* 2008). Application of organic manures and biofertilizers increased nitrogen uptake by rice and also increased the fertility of the soil as shown by an increase in organic carbon content and total nitrogen after the rice harvest. Increase in soil fertility as a result of green manuring and *Azolla* has been reported by Singh and Singh, (1989). Other workers have also found enhanced soil organic carbon due to manuring (Hartwig and Ammon, 2002). Organic manure and biofertilizers also release their nutrients slowly and thus help the plant in providing nutrients throughout the growth period (Saha *et al.*, 1982). Increase in the soil organic carbon also enriches the microbial flora of the soil. Interestingly, there occurs no serious incidence of insect pests and diseases in organically grown rice crop.

Application of compost/manure and biofertilizers are two major components of organic farming, which offers an economically attractive and ecologically sound means of reducing external inputs and improving internal resources (Singh, 1989; Saxena and Tilak, 1994; Pathak *et al.*, 1997; Ramesh, 2008). Organic manuring of rice with farm yard manure (FYM) and vermicompost is practiced by Asian farmers and regarded as an important source of nutrient for rice (Singh, 1985; Watanabe, 1984). FYM and vermicompost are generally low in nutrient content, so their high application rates are needed to meet crop nutrient requirement. Under these limitations, organic manures may be used in combination with other inputs for organic productions. Such as green manuring is a practice of ploughing or turning undecomposed green plant materials into the soil for improving the physical condition of soil or for addition at nitrogen where the green manure crop is legume (Cheema, 1997).

Use of green manure in agriculture was recognised as early as 500 BC in India. Vacchani and Murthy (1964) extensively surveyed about 100 leguminous green manure plants in India and recommended several suitable ones for rice ecosystem. Sunhemp and *Dhanicha* were more acceptable to farmers in India and widely grown in other countries of tropics. Researchers, while consolidating the research work carried out on biomass production and N accumulation of green manure and grain legumes indicated the biomass production of leguminous green manure ranging from 0.6 t to 37 t ha^{-1} fresh weight while N accumulation varied from 9 kg to 302 kg N ha^{-1}. Organic manures, particularly green manures and FYM, not only supply macronutrients but also meet the requirement of micronutrient besides improving soil health.

Incorporation of *Sesbania*, a leguminous crop in the soil adds 60-80 kg of nitrogen per hectare and also has buffering action (Abhrol, 1985). On decomposition, it increases the humus and available nitrogen contents along with low C: N ratio. Green manuring may also enhance the boron and iron availability in soil (Anonymous, 2004).

The green manure legumes produce significant yield increase in a succeeding rice crop. Yield responses were higher from soil amended with green manure relative to control without green manure. As expected, higher grain yields are often accompanied by increases in plant height, tiller number, productive tillers and straw yield (Sreenivasulu Reddy, 1998; Siddeswara, 1992 and Mridha, 1987). In low fertility soils, rice yield increased by 78 % while on high fertility soils yield increase was 22 % due to green manure (Gu and Wen, 1981 and Siddeswaran and Palaniappan, 1995). Generally the NFE values obtained with green manured rice ranged from 34 kg to 220 kg N ha^{-1} but averaged at 50 to 100 kg N ha^{-1} (Meelu and Morris, 1988 and Siddeswaran and Palaniappan, 1995).

A number of organic waste materials are available, which can supply a good amount of plant nutrients to produce comparable yield (Ghosh, 2005), as organic manures are natural, eco-friendly, less expensive and supply useful amount of Ca, Mg, S and micronutrients like Zn, Mn, Fe, Cu and help in conditioning the soil and promoting the activity of useful microorganisms

(Subbaswamy *et al.,* 1994 and Krishna and Bongale, 2001). Organic sources offer more balanced nutrition to the plants especially secondary and micro nutrients (Rakshit *et al.,* 2008). Proper selection of a variety and appropriate nutrient management are important in organic rice production (Manjunath *et al.,* 2009).

2.3.1 Plant characters

It has been reported that due to green manure decomposition, high concentration of organic acids, phenolic substances and other organic compounds are released which could influence the growth and establishment of rice seedlings (Diekmann and De Dutta, 1992). Green manuring had positive correlation with plant height and dry biomass as reported by Virdi *et al.,* (2006).

Similarly, application of FYM in increasing dose up to 15 t ha^{-1} increased the growth and yield attributes of Basmati rice. The tillers m^{-2} increased from 260 to 300, grains per panicle were 115 to 122 and test weight was 21 to 24 g, and application of 20 t FYM ha^{-1} recorded significantly higher plant height and dry matter accumulation in both the years observed by Shekara *et al.,* (2010).

In organic rice cultivation, vermicompost also plays a key role in growth and development. Reddy (1988) found that application of vermicompost increased the plant height (81.5 cm) about 30 % more than that of control treatment.

2.2.2 Yield attributes and yield

Application of 20 t FYM ha^{-1} recorded significantly more productive tillers per hill filled spikelets, 1000 grain weight which cumulatively leads to higher grain yield of rice (6.01 and 6.44 t ha^{-1}) in both years, respectively as reported by Shekara *et al.,* (2010). The number of panicle/m^2 significantly increased with FYM at 5.54 t ha^{-1} (Sharma and Sharma, 1994). Use of green manure or vermicompost 5 t ha^{-1} or 10 t ha^{-1} FYM increased grain yield (4.44 to 4.48 t ha^{-1}) than NPK application alone (4.15 t ha^{-1}) as reported by Singh *et al.,* 2008.

In a medium duration rice variety Mahsoori, Bhuvaneshwari *et al.*,2012 observed that grain yield of rice increased significantly over control due to application of all the amendments(farm yard manure, vermicompost and fresh bioinoculants as *Azolla*, Blue – green algae (BGA)), although maximum yield increase of 28% was recorded when all the four amendments were used together. Singh *et al.*, (2007) also reported that rice grain yield increased by 114 to 116.8 % with application of BGA 15 kg/ha, *Azolla* 1.0 t ha^{-1}, vermicompost and FYM 5 t ha^{-1} each than recommended dose of fertilizer.

Yield of rice was greater when manure rather than fertilizer was applied (Sherchan *et al.*, 1999). Urkurkar *et al.*, (2010) reported rice yield of 3.66 t ha^{-1} when 100 % N was applied through cowdung manure, neem cake and composted crop residue. This was very close to that of 100 % N through chemical fertilizer whereas, Surekha and Rao (2009) in their 3 years experimentation observed that all the organic manuring treatments produced rice grain yield in the range of 4.76 to 5.51 t ha^{-1} as against 4.18 t ha^{-1} produced with 120-60-40 kg N, P and K ha^{-1}. Lee *et al.*, (2008) reported that application of rice straw, hairy vetch and compost increased the rice yield for 3.02 t ha^{-1} to a range of 4.38 to 5.29 t ha^{-1}.

Organic farming not only increased the grain yield but also increased the micronutrient concentrations and ultimately their uptake in grain. Increase in uptake of micronutrients may be due to the availability of these nutrients in organic source of nutrients and increased grain yield due to these sources nutrients (Bhattacharya and Chakraborty, 2005). It is evident that due to application of FYM and vermicompost, wheat yield is increased (Singh and Singh, 2007) whereas Kumar *et al.*, (2007) recorded higher yield of rice and wheat with the use of organic manures.

Kumar *et al.,* (2011) found that due to integrated organic nutrient management practices for quality and economics of groundnut under rainfed condition, quality parameters like protein content (22.4%), oil and protein yield (685.1 kg ha $^{-1}$ and 377.7 kg ha^{-1}, respectively) were significantly higher with application of FYM (7.5 t ha $^{-1}$ + *Rhizobium* + PSB + Panchagavya spray (3% at 30, 60 and 75 DAS) as compared with other treatments.

Ghosh *et al.,* (2012) assessed the effects of a range of commonly applied organic and inorganic amendments on soil quality in a rice–wheat cropping system in the Indo-Gangetic plains of eastern India, showed that there were significant increases in soil nutrient availability with the application of farm yard manure (FYM @ 7.5 t ha^{-1}), paddy straw (PS @ 10 t ha^{-1}) and green manure (GM @ 8 t ha^{-1}) along with inorganic fertilizer. Both microbial biomass C and mineralizable C increased following the addition of the organic inputs and also it was observed a significant increase in yield of *kharif* rice due to the addition of these organic amendments.

Prakash *et al.,* (2002) observed that organic manure treatment on balancing with RDF led to higher production dry matter and grain yield than application of only chemical fertilizer. Barik *et al.,* (2006) reported higher number of effective tiller m^{-2}, and grain and straw yields were significantly higher in case of 50 % RDF + 10 t ha^{-1} vermicompost when compare with 100 % RDF. Mishra and Adhikari (2004) found that Basmati 370 and Pusa Sugandha-3 gave the highest yield with a meagre use of 60 kg of vermicompost along with 23 kg N ha^{-1}. In a field experiment on rice during *kharif* season conducted by Sudha and Chandini (2002) found that effect of 5 t vermicompost was equal to 10 t ha^{-1} FYM with respect to increase in grain yield of rice.

Prakash and Bhadoria (2002) conducted a field experiment to study the effect of vermicompost, FYM and water hyacinth compost in comparison to inorganic fertilizer and zero fertilizer. They reported that vermicompost provided more resistance to disease and pest than FYM and water hyacinth and produced higher grain yield. Chakravorti and Samantaray (2006) reported from CRRI Cuttack that maximum grain yield was obtained where 25 % of applied N was substituted with vermicompost.

2.4 SOIL HEALTH

Improvement in inherent nutrient supplying capacity of the soil and improved soil physical properties due to the application of organic manures has been well documented (Hati *et al.,* 2006), which promote better rooting, higher nutrient and water uptake and transpiration efficiency of crops (Zhang *et al.,* 1998). High organic matter content in soil with humic substances and growth hormones make it suitable in improving the soil quality (Cavender *et al.,* 2003).

The soil properties like organic carbon (%), pH and EC were improved from organic treatments than inorganic treatment and the initial values (Yadav *et al.,* 2009). Kharub and Chander (2008) reported improvement in soil fertility status after 3 years of organic farming, organic carbon improved from 0.36 to 0.39, available N, P and K improved from 139, 16.5 and 154 kg ha^{-1} to 148, 17.4 and 158 kg ha^{-1}. In organic agriculture, organic carbon (6.3 g kg^{-1}), bulk density 1.35 Mg m^{-3}, available N, P and K (256, 19.8 and 275 kg ha^{-1}) improved from initial status of 5.8 g kg^{-1}, 1.66 Mg m^{-3} and N, P and K from 169, 17.4 and 274 kg ha^{-1} as reported by Urkurkar *et al.,* (2010).

Surekha and Rao (2009) reported that all the organic manuring treatments improved soil quality than N, P and K application of 120-60-40 kg ha^{-1}. The bulk density was in the range of 1.17 to 1.20 as against 1.31 Mg m^{-3}. Organic carbon (%) improved from 0.63 to a range of 0.76 to 0.87. Available N, P and K was in the range of 228 to 240, 92.0 to 99.3 and 59.8 to 649 kg ha^{-1} as against 222, 89.7 and 567 kg ha^{-1}, respectively.

Aswal *et al.,* 2012 observed that the regular addition of organic composts (vermin, NADEP, biodynamic & EM) increase certain beneficial soil inhabiting fauna such as earthworm and collembolan, helpful in regeneration of soil quality. The earthworm population varied from 6.85-8.35 and collembolan from 102.91-132.53 in 25 cm^{-2}.

Singh *et al.,* (2011) reported that different sources of nutrients such as *multani mitti* based blue green algae (BGA) @ 2.0 kg ha^{-1}, *Azolla* @ 1.0 tonne ha^{-1}, vermicompost (VC) @ 5.0 tonne ha^{-1} and farm yard manure (FYM) @ 5.0 tonne ha^{-1} were tested alone or in combinations to find out suitable organic sources of nutrient supply for sustaining the productivity of Basmati rice-wheat-green gram cropping systems. They also found that total uptake of Fe, Zn, Mn and Cu in rice-wheat-greengram cropping system ranged between 177.1 to 414.7, 175.0 to 381.0, 177.3 to 420.2 and 71.2 to 181.0 g kg^{-1}, respectively.

Incorporation of FYM significantly increased the N, P and K contents in grain and straw. FYM was found superior in increasing the N, P and K uptake by rice (Alok and Yadav, 1995). Singh (1984) observed that legumes grown in rotation with lowland rice could increase the availability of mineral N. Vermicompost was slightly acidic and it contains high organic matter and essential macro and micro-nutrients. Vermicompost prepared from other sources of solid waste materials had high manurial value, indicating its suitability for use in agricultural field (Zaller, 2007).

Saravana Pandian and Rani Perumal (2000) studied the effect of integrated nitrogen management on fertility status of rice soil and found that there was a depletion of all the major nutrients with the application of fertilizer N alone. Increased in N uptake correspondingly increased the P and K uptake as reported by Shivraj (1981) and Singh and Singh (2000).

Green manures, when buried just before transplanting rice, create reducing condition, which help in mobilizing several other nutrient elements (Singh, 1984). Application of green manure resulted in better aggregation, which may be the possible reason for decreased bulk density due to the application of green manure (Mishra and Sharma, 1997). Soil recovery of green manure N ranged from 15 to 35 per cent of the added amount, which is found to be higher than the recovery of fertilizer N (West Cott and Mikkelson, 1987). Sanyasi Raju (1952) reported that green manure crops such as *S. aculeate*, *Crotolaria juncea* and cowpea, when incorporated after 60 days growth contributed N ranging from 74 to 134 kg ha^{-1}).

Meelu and Morris (1986) obtained N substitution of 60 kg N ha^{-1} by green manuring to rice. Abrol and Palaniappan (1988) reported a substitution of 60 to 100 kg N ha^{-1} by green manure crops, under rice-based cropping systems. Sharma and Mitra (1988) from their findings reported that mineral N to the extent of 45 to 60 kg ha^{-1} could be replaced by growing green manures.

Green manures, unlike inorganic fertilizers, must undergo decomposition and mineralization, before its N becomes available to the rice crop (Nagarajan, 1988). Models of organic matter decomposition in flooded soil have two distinct components. One decomposing within a few months and having less residual effect and other decomposing slowly over several year (Bouldin, 1988). Ponnamperuma (1965) reported that the NH_4^+-N released from green manure is rapidly adsorbed on to the cation exchange complex of the soil leaving the balance of NH_4^+-N in the soil solution.

Singh and Rai (1973) studied the effect of green manure on availability of organic P and concluded that maximum increase in organic P in the soil occurred on the 30th day of decomposition of a 60 day old crop. Ranjan and Kothandaraman (1986) reported increased availability of P from rock phosphate applied to rice with green manure. Enhanced availability of some micronutrient (e.g. Fe) due to green manure incorporation was reported by (Takkar and Nayyar, 1986).

Wen Qixiao and Yu Tiarren (1988) reported that in addition to supplying nutrients like N, P and K, green manure is an important source of organic matter and can improve soil physical properties such as porosity and strength. Use of green manures increases the nutrient retention capacity, improves soil structure and microbial activity (Arunin *et al.,* 1988).

2.4.1 Soil organic carbon

For sustainable crop production, many diverse organic materials, e.g. crop residues, manures, peat and composts, are used, but they each have specific effects on SOM stocks, soil functioning and the soil microbial community. Positive effects of organic matter application on microbial biomass, compared to mineral fertilization, have extensively been documented (e.g. Kandeler *et al.,* 1999; Peacock *et al.,* 2001).

Organic amendments, especially composts, have repeatedly been reported to control soil borne pathogens, but amendments that are suppressive to some pathogens may well be conducive to others (Bonanomi *et al.,* 2010). To offset deterioration of soil structure, different organic amendments such as manure (farmyard manure, green manure), compost, and crop residues (particularly rice straw) are commonly recommended and when applied, they are distributed in different SOC pools (Majumder *et al.,* 2008).

In Western Europe, the transition towards modern agriculture with adoption of short crop rotations or monoculture, deep tillage operations, and declining use of manure or other organic fertilizers, has resulted in drastic reductions of soil organic matter (SOM) levels (Gardi and Sconosciuto 2007). SOM is, however, a key attribute of soil quality (Gregorich *et al.*, 1994). SOM is crucial to soil fertility (Rhoton *et al.,* 1993; Riffaldi *et al.,* 1994) and physical soil quality (Reeves 1997), and it serves as a nutrient and energy source for a diverse population of bacteria, fungi (Bünemann *et al.,* 2004; Birkhofer *et al.,* 2008) and invertebrates such as earthworms (Hendrix *et al.,* 1992; Leroy 2008).

In the other hand, growing crops in sequence has an impact on SOC. Prasad and Mishra (2001) and Sharma and Prasad (2002) reported a significant increase in soil organic C in rice-wheat cropping system due to addition of FYM and crop reisdues. Growing rice especially in double cropped areas results in relatively stable soil organic carbon (SOC) levels (Cassman *et al.*, 1995).

2.4.2 Soil microbial property

The role of soil organisms, found abundantly in organic systems is central to soil processes and fertility since they catalyse availability of the elements in plant residues and organic debris entering the soil (Alfoldi *et al.,* 2002). Microbial biomass has been assigned important roles in paddy soils as a nutrient pool, driving force of nutrient turnover and early indicator of soil for crop management (Shibahara and Inubushi, 1997). Soils with a high functional diversity of micro-organism, which occur very often under organic agriculture practice, develop disease and insect suppressive properties and can help to induce resistance in plants (Flieβbach *et al.,* 2007).

Soil microbial biomass constitutes a small portion (1–4%) of SOM (Smith and Paul, 1990), but it is more dynamic and fluctuates more over time than the total SOM. Therefore, measurement of soil microbial biomass may show the effect of soil management on potential changes in SOM long before such effect can be detected by measuring total SOC (Powlson *et al.,* 1987).

Microbial population was enhanced due to the application of four sources of organic nutrients as compared to absolute control that resulted in a notable enhancement in dehydrogenase enzyme activity. Generally, microbial biomass increases with increasing C_{org} content of the soil (Dhillion, 1997), and in a number of short-term studies it has been shown that organic amendments increase microbial biomass (Hu *et al.,* 1999).

Dasappa *et al.,* 2011 found that application of organic manure enhanced the soil fertility and microbial status in the soil. The results revealed that soil pH decreased considerably whereas, OC, macronutrients (P and K), micronutrients (Mn, Fe, Cu and Zn) and microbial population increased significantly in organic treated plot (Sericompost-10tons + Vermicompost-10tons + Vesicular arbuscular mycorrhiza (*Glomus mosseae*)-1000kg + *Azotobacter chrococcum*-23kg + Phosphorus solubilizing bacteria (PSB)-5kg + Green manure (*Dhanicha*) seeds-40kg + Neem Oil cake (Azadirachtin) 1000kg $ha^{-1}yr^{-1}$ + Farm Yard Manure-@20tons $ha^{-1}yr^{-1}$) than that of inorganic treated plot (100% chemical fertilizers (350:140:140 kg NPK $ha^{-1}yr^{-1}$) + Farm Yard Manure-@20tons $ha^{-1}yr^{-1}$).

Nayak *et al.,* 2007 reported in a field study that long-term application of compost to a tropical Aeric Endoaquept under continuous rice growing in a rice–rice–fallow sequence resulted in the stimulation of microbial biomass and select soil enzyme activities. Mean seasonal soil microbial biomass-C (C_{mic})

increased by 42%, 39% and 89% in inorganic fertilizer, compost and compost + inorganic fertilizer treatments, respectively, over the unamended control and demonstrated that microbial biomass and soil enzyme activity is sensitive in discriminating between long-term organic residue amendment practices.

Change in composition of microbial communities due to fertilizer treatment (Jha *et al.,* 2004), soil water content and application of organic matter (Jha *et al.,* 2004; Asari *et al.,* 2008) has been reported. Flieβbach *et al.,* (2007) also reported that organic farming systems enhance microbial biomass and activities. According to Kenchaiah (1997), the microbial population was increased by FYM + poultry manure and *Sesbania rostrata* + poultry manure in a rice crop.

2.5 BIOZYME APPLICATION

Biozyme is an eco-friendly non-toxic commercial growth stimulant which influences the plants physiological system at low concentrations and known to be rich in cytokinin and auxin precursor, enzymes and hydrolyzed protein and is a storehouse of naturally occurring nutrients derived from Norwegian seaweed *Ascophyllum nodosum* (Kumar *et al.,* 2000).

Biozyme is a soil conditioner and contains some biological compounds identified as growth regulators (Wallace, 1998). The biotechnological product of *Ascophyllum nodosum* is a plant growth regulator that enables the plants to develop biomorphological and physiological behaviour in such a way that they can have best use of existing as well as applied input (Humphries, 1968).

Sea weed is one of the most important resources of the world. Liquid fertilizers were extracted from the brown algae *Turbinaria decurrens* collected from Rameshwaram coast. The liquid extract of *Turbinaria decurrens* used as a foliar spray and observed the growth: yield and biochemical constitutes on *Vigna radiate*. The low concentration of sea weed liquid fertilizer enhanced the productivity of greengram (Gurusaravanan *et al.*, 2011).

The percentage of germination, growth and yield was found to be increased with an increase in the concentration of the sea weed extract up to 1.5% when compared with control due to the presence of some growth promoting substances, like IAA, IBA, Gibberellins (A & B), cytokinins and microelements, (Fe, Cu, Zn, Co, Mo, Mn, Ni, etc.,) vitamins and amino acids (Challen and Hemingway, 1964).

Manna *et al.*, (2012) reported that different treatment combinations of fertilizer and different formulation of Biozyme, soil application of recommended dose of fertilizer (100:60:60 kg ha^{-1} NPK) + seeding treatment with Biozyme seed plus (10ml l^{-1} water) + Biozyme vegetable granules as soil application (20kg ha^{-1}) + Biozyme mirchi liquid as foliar spraying (500ml ha^{-1}) was found to be the best in terms of growth, yield (9.77t ha^{-1}) and quality (121.28 mg $100g^{-1}$ ascorbic acid) of chilli with higher benefit : cost ratio (2:19). Total chlorophyll content of green chilli was maximum (0.1643 mg g^{-1}) in recommended dose of fertilizer (100:60:60 kg ha-1 NPK) + seedling treatment with Biozyme seed plus (10ml l^{-1} water) + Biozyme mirchi liquid as foliar spraying (500ml ha^{-1}).

A field experiment was conducted by Singh *et al.,* during 1997-98 and 1998-99 and the experimental results indicated that 30 kg/ha dose of Biozyme granules applied as basal at the time of planting proved beneficial and produced significantly higher cane yield (11.30%) and C:B ratio (11.10%) as compared to control treatment (without Biozyme granule + recommended doses of N and

P). Further, treatments consisting the application of Biozyme granules @ 20 kg ha^{-1} as basal coupled with each liquid doses of foliar sprayings (300, 400 and 500 ml ha^{-1} at 120 DAP) or 500 ml Biozyme liquid (without granules) sprayed half at 120 DAP and remaining half at 150 DAP proved more effective and gave higher cane yield (mean) and C:B ratio to the tune of 4.06% and 5.24%, respectively as compared to different doses of Biozyme granules applied as basal without spraying.

Sen and Sontosh (1996) reported increase in grain yield due to application of Biozyme. Swain and Sen (1996) reported that the grain yield was increased by the application of Biozyme. Biozyme application significantly increased the yield of chilli and bell pepper (Gore *et al.,* 2007 and Kumar *et al.,* 2000). Singh and Chandel (2005) reported the biometric characters like spikes m^{-2}, grain per spike, 1000-grain weight also increased due to the application of Biozyme.

Bastia *et al*., (2013) reported that the pooled grain, straw and total biomass yields of rice-rice system were the highest (8.1, 9.9 and 18.0 t ha^{-1}, respectively) with application of GM + FYM + vermicompost in split dose + Biozyme granule and power plus in *kharif* and FYM + vermicompost in split dose + Biozyme granule and power plus in summer and were at par with those of all other Biozyme applied treatments.

2.6 ECONOMICS

Yadav *et al.,* (2009) conducted one organic experiment with treatments comprising of green manure, straw, pressmud, FYM and biofertilizers in different combinations for 5 years. They observed higher plant character and yield attributes for all organic treatments than inorganic treatment (N, P and K, 120:26.4:33.4 kg ha^{-1}) in rice. The yield of rice ranged from 5.20 to 5.86 t ha^{-1}

for organic treatments and the same was 3.64 for the inorganic treatment. Net income was also in the range of ₹ 41,570 to ₹ 57,650 in 5 organic treatments, whereas it was ₹ 23,840 for inorganic treatment. Net B:C ratio also followed similar trend.

Kharub and Chandra (2008) reported yield increase of basmati rice from 4.26 to 5.13 t ha^{-1} with increase of FYM up to 15 t ha^{-1}. The net return from Basmati rice with application of 15 t ha^{-1} FYM was ₹ 58,700 ha^{-1}. The benefit:cost ratio was 1.52 with the same treatment whereas by application of vermicompost in paddy, the cost of production was reduced by 8 % without reduction of grain yields (Ansari and Ismail (2006)

Singh *et al.,* (1999) suggested that sugarcane variety CoS 91269 produced 15.84% higher cane yield (18.84 tonnes) when treated with Biozyme (20 kg ha^{-1} granules as soil application + 500 ml liquid sprayed on crop plants; 1/2 at 120th day and remaining 1/2 at 150th day of planting). Biozyme application also yields a higher net profit of Indian ₹ 14873 (approx. US$ 355) and C:B (cost : benefit) ratio of 16.99% per hectare.

CHAPTER-III

Materials & Methods

MATERIALS AND METHODS

The materials used and methods employed during the course of investigation have been elaborated in this chapter.

3.1 LOCATION

A field experiment was conducted during 2012-2013 at the Organic Block of Central Research Station of Orissa University of Agriculture and Technology, Bhubaneswar located at 20º 15’ N latitude and 85º 52’ E longitude and at an altitude of 25.9 m above mean sea level. The station comes under the East and South Eastern Coastal Plain Agro-climatic Zone of Orissa.

3.2 EXPERIMENTAL SITE

The experiment was carried out during *kharif* and summer season of the year 2012-2013 in medium land situation where the ground water table fluctuated between 30-60 cm below the surface during the crop growing period.

3.3 SOIL CHARACTERISTICS

Soil samples were collected from each plot with a post-hole auger at depth of 0-15 cm at random from several locations before and after the of crop growing seasons. After thorough mixing, the composite soil samples collected before the seasons were taken to characterize its physico-chemical properties. Data on these aspects are presented in Table 3.1a, 3.1b and 3.1c. The soil samples collected before, after and in intermittent period of crop growing seasons were analyzed for microbial population by serial dilution method.

Table 3.1a. Mechanical composition of the soil (0-15 cm)

Mechanical constituent	Percentage composition (air dry basis)	Method adopted
Sand	71.1	Bouyoucos Hydrometer Method (Piper, 1950)
Silt	10.3	
Clay	18.6	
Textural class	Sandy loam	

Table 3.1b. Physical properties of the soil (0-15 cm)

Particulars	Value	Method adopted
Bulk density (t m^{-3})	1.58	Core method
Particle density (t m^{-3})	2.65	Pycnometer method
Porosity (%)	41	

Table 3.1c. Chemical composition of the soil (0-15 cm)

Chemical composition	Value	Method adopted
Organic carbon (g kg^{-1})	9.7	Walkley and Black's rapid titration method (Jackson, 1973)
Available nitrogen (kg ha^{-1})	375	Alkaline $KMnO_4$ method (Jackson 1973)
Available P_2O_5 (kg ha^{-1})	34.49	Bray's method (Jackson, 1973)
Available K_2O (kg ha^{-1})	221.25	Flame photometer method (Jackson, 1973)
pH	6.35	Digital pH meter with 1:2.5 Soil: Water (Jackson, 1973)
EC (dSm^{-1})	0.177	Conductivity meter

3.4 CROPPING HISTORY OF THE EXPERIMENTAL PLOT

Year	*Kharif*	Summer
2007-2008	Rice	Rice
2008-2009	Rice	Rice
2009-2010	Rice	Rice
2010-2011	Rice	Rice
2011-2012	Rice	Rice

3.5 CLIMATE AND WEATHER

The region is characterized by a sub-tropical climate with a hot and humid summer (March-June), hot and wet monsoon (late June –mid October) and a mild and dry winter (November- February). Broadly, the climate falls in the group of moist hot type (Lenka, 1976). Meteorological data (Mean of 10 years) for the period 2002-2011 presented in Table 3.2 and Fig.3.1 revealed that the mean annual rainfall at the centre is 1571.6 mm received in 100 days. Nearly, 76.71 % of the annual rainfall is received between June to September. The rainfall is monsoonal and unimodal. The South-West monsoon, in Orissa, usually sets in around mid-June and recedes by mid-October. August and September are rainiest months with 363.5 and 339.5 mm rainfall, respectively while; December is the driest month with mean rainfall of 6.4 mm. The rainfall code of Bhubaneswar has been coded as D_1E_3 ($B_1A_2B_1$) $C_1D_1E_2$ (Lenka, 1976).

May is the hottest (37.8°C) and January is the coldest (14.8°C) months. Highest per day evaporation of 9.0 mm occurs in May and lowest per day evaporation of 3.1 mm occurs in July. Mean relative humidity varies from the minimum of 65.5 % in December to the maximum of 85.5 % in the months of

August and September. Maximum bright sunshine hour (8.5 hr) is recorded in the month of April and May and minimum of 3.9 hr in July and August. Wind velocity is maximum in the month of May (12.8 km hr^{-1}) and minimum in the month of December (2.8 km hr^{-1}).

Table 3.2 Mean monthly meteorological data from 2002-2011

Month	Rainfall (mm)	No. of rainy days	Evaporation (mm d^{-1})	Atm. temp. (^{0}C)		Relative humidity (%)		BSH (hrd^{-1})	Wind Velocity (km hr^{-1})
				Max.	Min.	FN	AN		
January	10.0	1	3.5	29.0	14.8	90	43	7.9	3.5
February	14.1	1	4.0	32.1	18.2	93	42	8.4	4.2
March	22.3	2	5.6	35.2	22.4	92	46	8.3	7.2
April	27.0	3	7.3	36.6	25.3	90	51	8.5	10.7
May	98.8	7	9.0	37.8	26.5	88	54	8.5	12.8
June	198.2	13	6.3	35.8	26.5	90	64	5.5	9.3
July	304.4	21	3.1	32.6	25.8	93	77	3.9	6.4
August	363.5	21	3.2	31.9	25.6	93	78	3.9	5.8
September	339.5	18	3.3	32.1	25.3	94	77	5.3	4.9
October	166.2	10	3.5	32.0	23.3	92	65	6.7	3.5
November	21.2	2	3.4	31.1	18.7	90	49	7.8	2.8
December	6.4	1	3.8	28.9	15.2	89	42	7.4	3.0

Weather during crop growing seasons

Kharif season

Meteorological conditions during the *kharif* crop growing season are presented in Table 3.3 and Fig. 3.2. Crop received a total of 943.1 mm rainfall in 71 rainy days. All the meteorological weeks of the crop growing season were wet weeks (received > 25 mm rainfall) except 38, 39, 41, 42, 43 and 45. Mean weekly temperature during the season ranged from 29.6°C in 28 week to 25.3°C in 45 week.

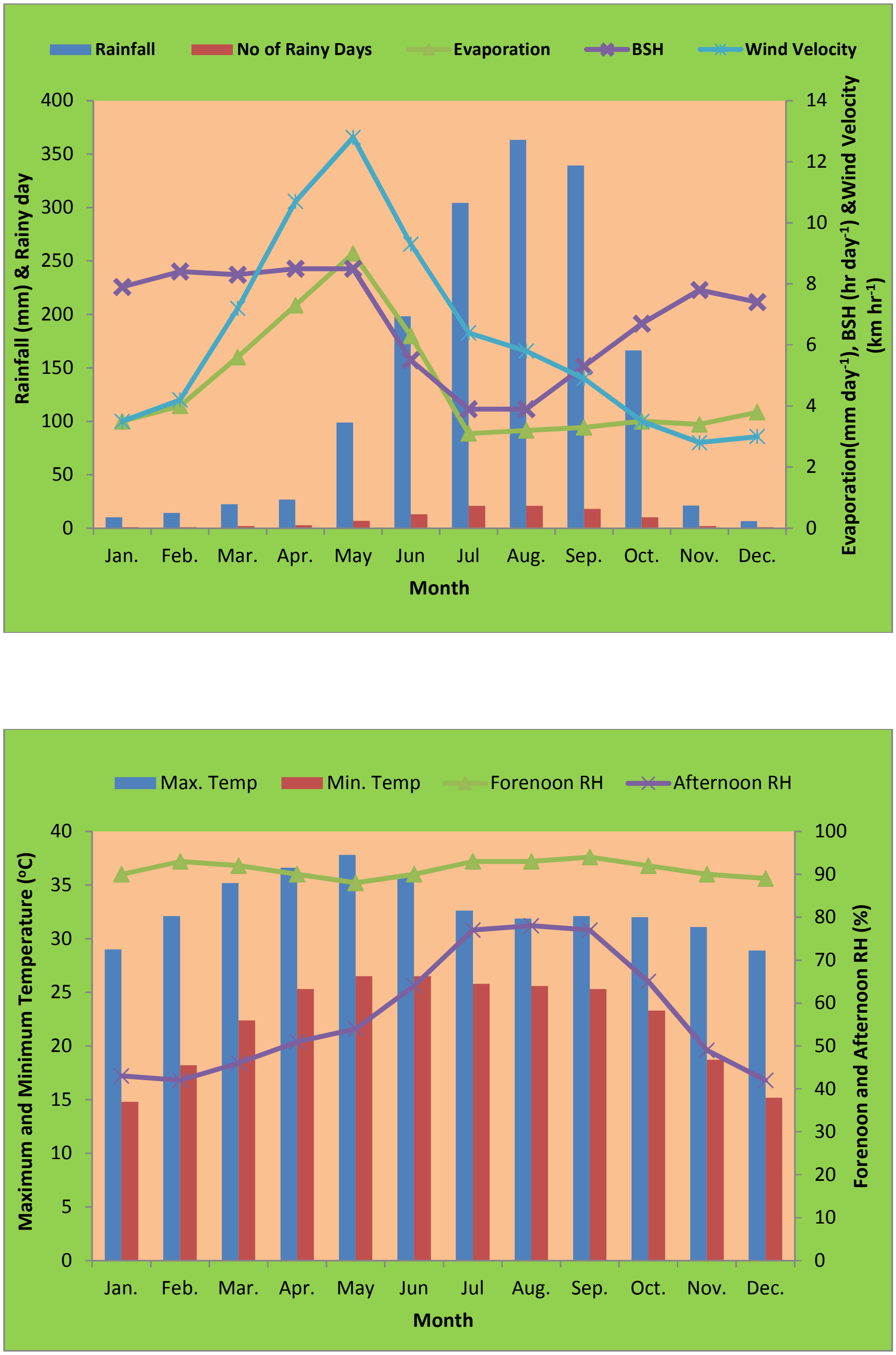


Fig. 3.2 Mean monthly meteorological data from 2002-2011

Table 3.3 Mean weekly weather data during crop growing season (*kharif*, 2012)

Std. Met. week	Date	Rainfall (mm)	No. of rainy days	Evaporation (mm d^{-1})	Atm. temp. (^{0}C)		Relative humidity (%)		BSH (hr d^{-1})	Wind Velocity (km hr^{-1})
					Max.	Min.	FN	AN		
23	04-10 June	0.0	0	9.2	44.0	28.7	79	30	6.5	9.2
24	11-17 June	40.4	3	6.9	40.6	27.7	89	55	2.8	11.7
25	18-25 June	50.7	4	4.4	30.4	24.5	92	84	0.8	7.1
26	25-1 July	39.0	3	4.2	34.2	25.3	92	77	1.5	8.1
27	2-8 July	103.4	6	2.9	32.9	25.1	95	81	0.5	5.2
28	9-15 July	39.0	4	3.7	33.2	25.9	95	81	4.4	5.2
29	16-22 July	162.8	4	2.4	31.8	25.2	93	83	2.2	5.8
30	23-29 July	56.0	5	3.1	31.5	25.3	94	80	2.9	6.2
31	30-5 Aug	38.3	5	3.1	28.9	24.4	94	88	0.2	5.5
32	6-12 Aug	70.9	6	3.2	32.1	24.8	96	81	4.0	5.9
33	13-19 Aug	106.0	4	3.0	32.4	25.2	93	80	2.7	6.0
34	20-26 Aug	26.9	4	3.5	32.9	25.3	94	82	5.3	7.4
35	27-2 Sept	49.7	4	3.4	33.0	25.7	93	79	6.1	4.1
36	3-9 Sept	37.8	7	3.0	30.6	25.5	96	88	1.8	4.9
37	10-16 Sept	27.6	4	3.3	31.6	25.4	94	84	2.0	3.3
38	17-23 Sept	23.8	3	3.4	33.3	25.6	95	75	4.7	2.4
39	24-30 Sept	4.4	2	3.5	33.6	24.9	90	67	6.9	3.4
40	1-7 Oct	45.2	3	3.4	32.4	24.5	93	82	5.5	5.2
41	8-14 Oct	16.4	4	3.3	31.2	24.4	84	84	3.9	4.3
42	15-21 Oct	0.0	0	3.6	32.0	22.0	90	54	8.6	2.8
43	22-28 Oct	0.0	0	3.7	33.1	20.9	92	59	8.1	2.5
44	29-4 Nov	110.5	3	2.9	30.7	20.5	90	72	6.3	3.5
45	5-11 Nov	24.4	3	3.3	29.6	21.0	96	72	4.4	2.5

Evaporation recorded from the USWB Class-A open pan evaporimeter showed that Epan ranged from 2.4 to 3.7 mm per day during the season. Similarly, mean relative humidity varied from 92.0 % in 36 week to 72.0 % in 42 week. Record on bright sunshine hours showed that it ranged between 0.2 hour to 8.6 hours in different weeks where as wind velocity ranged between 2.4 km hr^{-1} to 7.4 km hr^{-1}.

Fig. 3.3 Mean weekly weather data during crop growing season (*kharif*, 2012)

Summer season

Meteorological information on the *summer* crop growing season is presented in Table 3.4 and Fig. 3.3. Crop received a total of 83.9 mm rainfall in 4 rainy days. Mean weekly temperature during the season ranged from 33.6^{o}C in 18 week to 21.6^{o}C in 4 week.

Table 3.4 Mean weekly weather data during crop growing season (summer, 2013)

Std. Met. week	Date	Rainfall (mm)	No. of rainy days	Evaporation (mm d^{-1})	Atm. temp. (^{0}C)		Relative humidity %		BSH (hr d^{-1})	Wind Velocity (km hr^{-1})
					Max.	Min.	FN	AN		
1	01-07 Jan	0.0	-	3.8	29.6	18.2	96	63	3.5	3.8
2	08-14 Jan	0.0	-	3.7	28.2	12.6	86	34	6.5	3.7
3	15-21 Jan	0.0	-	3.6	31.9	16.5	95	43	7.1	3.6
4	22-28 Jan	0.0	-	3.6	29.3	13.9	88	36	6.6	3.6
5	29-04 Feb	0.0	-	3.6	29.9	14.4	94	41	6.6	3.6
6	05-11 Feb	0.0	-	4.3	32.5	16.8	88	36	7.3	2.5
7	12-18 Feb	0.0	-	4.2	31.6	17.4	90	40	5.3	2.9
8	19-25 Feb	0.0	-	4.3	32.3	16.3	88	34	8.8	2.7
9*	26-04 Mar	0.0	-	4.4	35.7	16.9	88	28	9.2	2.9
10	05-11 Mar	0.0	-	5.6	37.3	19.8	91	26	8.7	3.7
11	12-18 Mar	0.0	-	6.2	37.5	22.6	90	34	6.2	4.5
12	19-25 Mar	0.0	-	6.2	38.3	23.1	92	32	7.6	5.7
13	26-01 April	0.0	-	6.5	39.0	24.5	89	40	6.7	5.9
14	02-08 April	0.0	-	7.4	40.5	24.2	90	31	7.8	5.4
15	09-15 April	1.0	0	8.2	40.0	24.7	59	36	7.1	8.5
16	16-22 April	41.2	2	7.5	37.1	23.5	87	58	6.0	7.7
17	23-29 April	0.0	-	7.7	37.8	25.3	92	57	8.6	6.6
18	30-06 May	0.0	-	9.0	39.8	27.3	88	52	7.1	12.1
19	07-13 May	41.7	2	8.3	39.1	26.5	91	57	7.8	13.9
20	14-20 May	0.0	-	8.3	37.3	27.5	87	56	4.3	8.7

Evaporation recorded from the USWB Class-A open pan evaporimeter showed that Epan ranged from 3.6 to 9.0 mm per day during the season. Similarly, mean relative humidity varied from 74.5 % in 17 week to 47.5 % in 15 week. Record on bright sunshine hours showed that it ranged between 4.3 hour to 9.2 hours in different weeks where as wind velocity ranged between 2.5 km hr^{-1} to 13.9 km hr^{-1}.

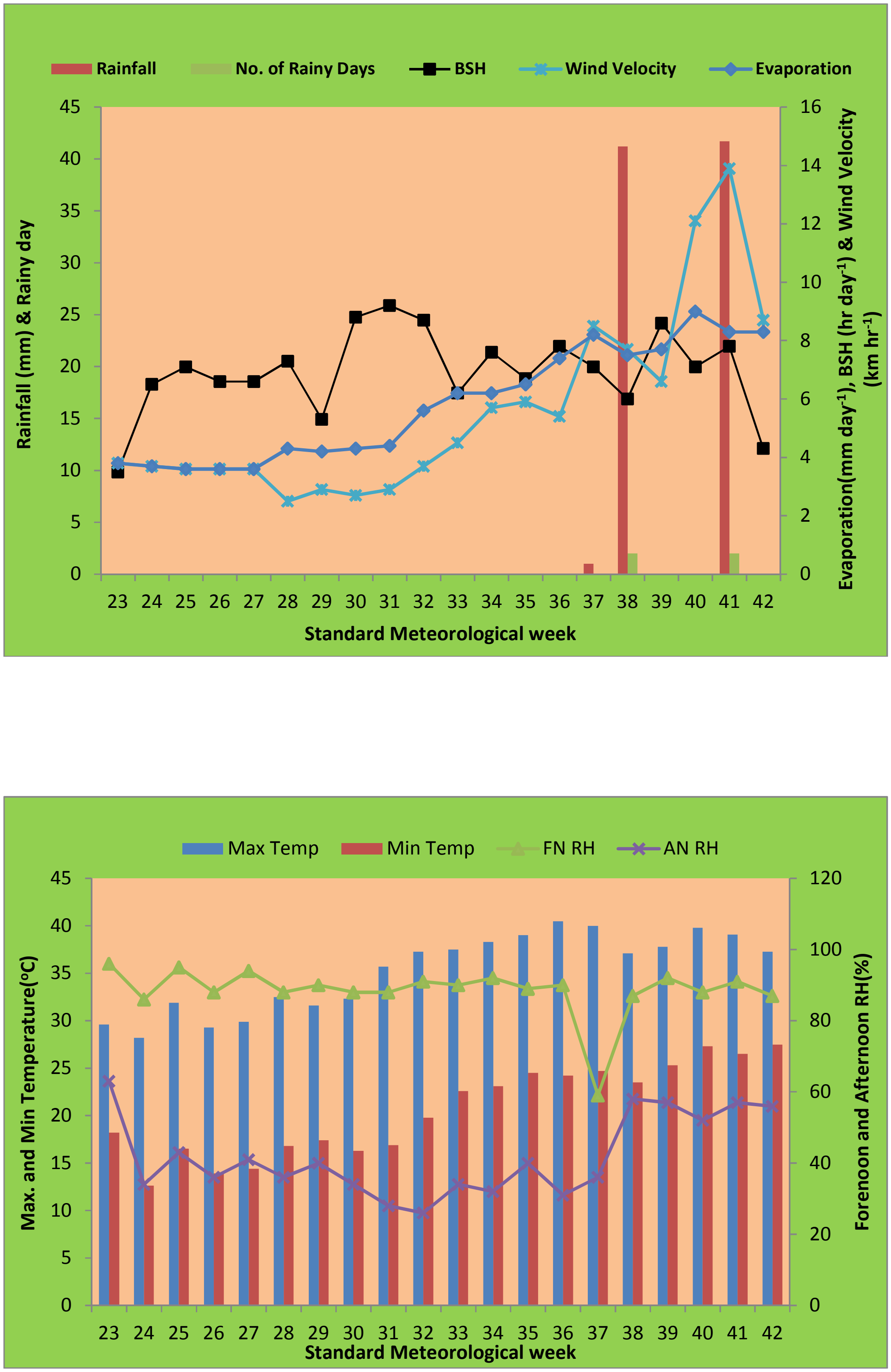


Fig. 3.4 Mean weekly weather data during crop growing season (Summer, 2013)

3.6 Experimental details

The experiment was laid out in a randomized block design with three replications. *Kharif* rice followed by summer rice was cultivated with twelve treatment combinations (Table 3.5). The size of individual bed was 1.5m width x 11.25m length. The lay out plan has been presented in Fig.3.5.

Table 3.5 Treatment Details

Kharif			**Summer**		
T_1	:	Dhanicha 25 kg seed/ha	T_1	:	Control
T_2	:	Dhanicha + FYM 5t/ha (basal)	T_2	:	FYM 5t/ha (basal)
T_3	:	Dhanicha + FYM + Vermicompost 2t/ha (20DAT)	T_3	:	FYM + Vermicompost 2t/ha (20DAT)
T_4	:	T_1 + BSP (Seed Treatment) + BG (Basal)	T_4	:	T_1 + BSP (Seed Treatment) + BG (Basal)
T_5	:	T_1 + BSP (Seed Treatment) + BPPL (Tillering + P.I. stage)	T_5	:	T_1 + BSP (Seed Treatment) + BPPL (Tillering + P.I. stage)
T_6	:	T_1 + BSP + BG + BPPL	T_6	:	T_1 + BSP + BG + BPPL
T_7	:	T_2 + BSP (Seed Treatment) + BG (Basal)	T_7	:	T_2 + BSP (Seed Treatment) + BG (Basal)
T_8	:	T_2 + BSP (Seed Treatment) + BPPL (Tillering + P.I. stage)	T_8	:	T_2 + BSP (Seed Treatment) + BPPL (Tillering + P.I. stage)
T_9	:	T_2 + BSP + BG + BPPL	T_9	:	T_2 + BSP + BG + BPPL
T_{10}	:	T_3 + BSP (Seed Treatment) + BG (Basal)	T_{10}	:	T_3 + BSP (Seed Treatment) + BG (Basal)
T_{11}	:	T_3 + BSP (Seed Treatment) + BPPL (Tillering + P.I. stage)	T_{11}	:	T_3 + BSP (Seed Treatment) + BPPL (Tillering + P.I. stage)
T_{12}	:	T_3 + BSP + BG + BPPL	T_{12}	:	T_3 + BSP + BG + BPPL

BSP-Biozyme Seed Plus, BG-Biozyme Granule, BPPL-Biozyme Power Plus Liquid

- Seed treatment with Biozyme seed plus @ 2.5ml with 25ml of water for 1kg seed
- Biozyme granule broadcasted @15kg/ha with Vermicompost
- Biozyme power plus liquid sprayed as foliar application @750ml/ha with 400 litre of water.

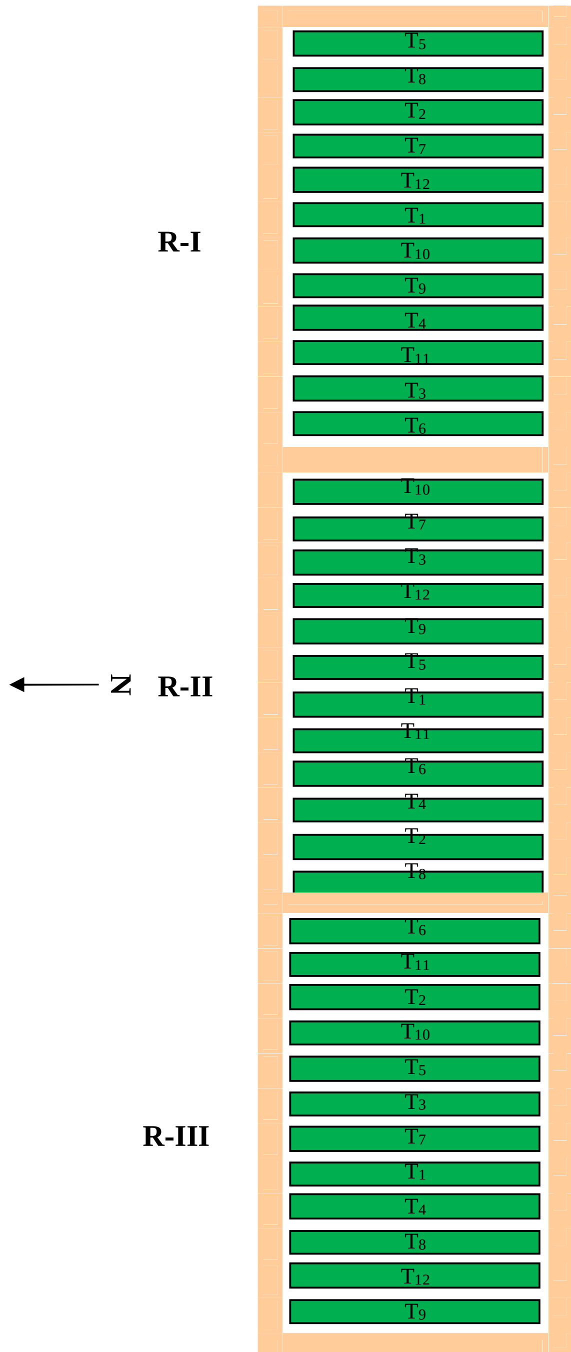


Fig. 3.5 Layout plan of the experiment

Design	: (Randomized Block Design) RBD
No. of treatments	: 12
Total no. of beds	: 36
Individual bed size	: 1.5m x 11.25m = 16.83 m^2
Gross experimental area	: 67.3 m x 12.65 m = 851.35 m^2

3.7 Details of test cultivar

Cultivar	Parentage	Days to 50% flowering	Potential yield (kg/ha)
Lalat	Obs 677/ IR 2071/ Vikram / WI 263	95	6870

3.8 N, P_2O_5 and K_2O content (%) of various organic nutrients used

Various organic inputs like FYM, Dhanicha and Vermicompost are used in this experiment and the percentages of nutrients found in those inputs are presented in Table 3.6.

Table 3.6 N, P_2O_5 and K_2O content (%) of various organic nutrients used (oven dry basis)

Material	Content (%)		
	N	P_2O_5	K_2O
FYM	0.53	0.40	0.28
Dhanicha	3.82	0.38	1.60
Vermicompost	1.56	1.20	0.75

3.9 Details of cultural operations

(i) Raising of seedlings

Seedlings were raised in wet nursery bed. Prior to sowing in nursery beds, the seeds were soaked for 24 hours in water. Then it was treated with BSP as per treatment. After draining out the water, seeds were incubated for sprouting. The sprouted seeds were sown in raised beds. Saturation water was maintained all through in the nursery bed by allowing standing water in the bed channels.

(ii) Preparation of main field

Dhanicha seeds were sown on 04.06.12 @ 25 kg ha^{-1} and the plants were incorporated into the soil on 10.07.12 by ploughing with tractor drawn cultivator and puddler for green manuring purpose. Standing water was maintained for proper decomposition. After decomposition of *Dhanicha* in soil, the field was puddled twice and levelled. The field was laid out as per the design of layout.

(iii) Transplanting

The seedlings were uprooted from the nursery bed on the day of transplanting. Twelve days old seedlings were transplanted in the main field at a spacing of 25 cm x 25 cm in both the seasons.

(iv) Manure application

The manures were applied as per allocation of the treatments. Farm yard manure @ 5 t ha^{-1} and Biozyme Granule @ 15 kg ha^{-1} were applied basally at the time of final land preparation. Vermicompost @ 2 t ha^{-1} and mustard oil cake @ 2 q ha^{-1} were applied at 20 days after transplanting in both the seasons.

(v) Weed management

Crop was weeded thrice and weeds were incorporated through criss-cross run of cono weeder at 20, 30 and 40 days after transplanting.

(vi) Water management

The rainfall in the cropping season was well distributed and most of the meteorological weeks were wet during *kharif* season. Hence, irrigation was not applied to any treatment. Only drainage of excess rain water was done and a saturation water condition was managed in the field. In summer season, irrigation was frequently applied to keep standing water in the channels.

(vii) Plant protection

No major incidence of disease and insect pest was noticed. However, as a prophylactic measure, pot manure (5 kg cowdung + 5 litre urine + 250 g gur

+ 1.0 kg each of *Azadirachta indica*, *Pongamia pinnata* and *Calotropis gigantia* leaves, fermented for 15 days) was sprayed four times at 15 days interval starting from 15 DAT in both the seasons.

(viii) Harvesting and threshing

The crop was harvested when more than 80 per cent grains were ripened and turned yellow. The harvest was sun dried in the field for 3-4 days and threshed. The grain and straw yields were recorded after 3 days of thorough sun drying.

Table 3.7 Calendar of operation

***Kharif* Date**	**Operations**	**Summer Date**
04.06.12	Dhanicha sowing	-
06.07.12	BSP treatment, Nursery sowing	20.01.13
10.07.12	Dhanicha incorporation	-
15.07.12	Bed preparation, BG application	-
17.07.12	Transplanting	31.01.13
05.08.12	Vermicompost application (T_3, T_{10},T_{11},T_{12})	20.02.13
05.08.12	1st weeding (cono)	20.02.13
12.08.12	1st BPPL application (T_5,T_6,T_8,T_9,T_{11},T_{12})	26.02.13
15.08.12	2nd weeding (cono)	03.03.13
25.09.12	3rd weeding (cono)	13.03.13
12.09.12	2nd BPPL application (T_5,T_6,T_8,T_9,T_{11},T_{12})	28.03.13
10.11.12	Harvesting	20.05.13
11-13.11.12	Field drying	21-23.05.13
15.11.12	Threshing	25.05.13

3.10 STUDIES CONDUCTED

3.10.1 Studies on microbial population

The soil bacteria, actinomycetes and fungi population count were done before, after and intermittently and the data have been presented in Table 4.12a, b; 4.13a, b and 4.14a, b for both the seasons (Plate 3).

Microbial enumeration by spread plate technique

Media:

1. **For bacteria:** Nutrient agar.
2. **For actinomycetes:** Actinomycetes isolation agar.
3. **For fungi:** Rose bengal chloramphenicol agar.

Procedure:

A suspension was prepared by using 1 g of freshly collected soil sample and added with 10 ml of distilled water. This establishes 1:10 or 10^{-1} dilution. The above stock was mixed gently by vortexing for uniform soil suspension. Aseptically 1 ml of the stock was transferred to a set of test tubes (5 nos.) containing 9 ml of diluents for making a ten-fold serial dilution. 0.1ml of the soil suspension from each dilution was transferred to pre-sterilized culture media plate with the help of a micropipette. From each dilution minimum three replicates were used for accuracy of colony counts. With the help of sterile L-spreader the soil suspension was spread over the culture media till complete spreading. Then the plates were incubated at $30^{o}C \pm 2^{o}C$ for fungi (2-3 days), for bacteria (1-5 days) and actinomycetes (1 week). The nature of colonies developed on agar plates were examined after the required incubation period. The numbers of colonies developed in the media were counted with the help of a digital colony counter or by manually. Then the CFU/g of soil was calculated by using the standard formula given below. Care was taken to record the number of colonies within a range of 30 to 300 colonies per plate for valid count (Chhonkar *et al.*, 2007).

Calculation:

$$\text{CFU g}^{-1} \text{ of soil} = \frac{\text{Number of colonies (Mean of 3 replicates)}}{\text{Quantity taken x Dilution factor}}$$

3.10.2 Studies on growth parameters

Observations on different growth parameters were recorded at fortnightly interval commencing from 15 days after transplanting (DAT) up to the harvest on randomly selected and pegged 5 hills from every treatment plots. Fourth row was selected for destructive sampling. Observation on dry matter accumulation was also recorded at 15 days interval by uprooting and thoroughly washing of samples. The weight of shoot and root was recorded after drying in oven at 70^{o}C till a constant weight was recorded (Plate 1).

Sampling technique

Random sampling technique was adopted in selecting five hills from each plot for recording biometric observations. Plant height, tiller number, leaf number were recorded from the five hills in each plot.

Plant height

Plant height was measured from ground level up to the tip of the top most leaf of each sampling hill. Then the average figure was worked out. The height at maturity was recorded from ground level up to the tip of the topmost panicle. The observations were recorded from all the replications and put into statistical analysis.

Plate 1: Biometric observations taken at field and laboratory

Plate 2: Rice crop at grain filling stage in *kharif* (lower) and summer (upper) seasons

Tiller number

Total number of tillers in 5 sample hills from each plot were counted periodically and averaged to find out the mean number of tillers per hill and then analyzed statistically.

Number of leaves per hill

Total number of leaves of five sample hill from each plot were counted periodically and averaged out to find out the mean number of leaves per hill.

Leaf area index (LAI)

Third leaf from the top of five hills from one replication at each sampling date was taken afresh and actual leaf area was recorded with the help of a leaf area meter. The actual leaf area of a leaf was multiplied by the number of leaves/ hill to obtain the leaf area/hill.

Leaf area index is expressed as total leaf area of a hill (only one side) per unit ground area occupied by the hill. (25cm x 25cm.)

Formula adopted for determining leaf area index is furnished below:

$$\text{LAI} = \frac{\text{Total leaf area } (\text{m}^2)}{\text{Unit land area } (\text{m}^2)}$$

Dry matter accumulation

Studies on dry matter accumulation were carried out following the destructive sampling technique. One hill from each plot was uprooted and its roots were clearly washed in water. The root and shoot portions were separated. The samples were air dried and subsequently oven dried at 70°C to a constant weight and the dry weights of plant samples were converted to g m^{-2}. Dry matter accumulation study was carried out at 15 days interval up to maturity of the crop and the following growth studies were made using the prescribed formulae:

(i) Crop growth rate (CGR)

It represents the increase of plant dry matter per unit area per unit time and it was calculated according to the formula given by Gregory (1962).

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \text{ (g m}^{-2}\text{ day}^{-1}\text{)}$$

Where, W_1 and W_2 were the whole plant dry weight m^{-2} at time t_1 and t_2, respectively.

(ii) Relative growth rate (RGR)

It is defined as the increase in dry weight of the plant per unit of original weight per unit of time. It is calculated by the formula

$$RGR = \frac{(\ln W_2 - \ln W_1)}{t_2 - t_1} \text{ (g g}^{-1}\text{day}^{-1}\text{)}$$

Where W_1 and W_2 are the whole plant dry weight on two successive occasions at the time t_1 and t_2, respectively.

(iii) Net Assimilation Rate (NAR)

The net assimilation rate was calculated according to the formula suggested by Gregory (1962).

$$NAR = \left(\frac{W_2 - W_1}{t_2 - t_1}\right) \times \left(\frac{\ln A_2 - \ln A_2}{A_2 - A_1}\right) \text{ (g m}^{-2}\text{ leaf area day}^{-1}\text{)}$$

Where, W_1 and W_2 are the total dry weight of plant m^{-2} on two successive occasions t_1 and t_2 and A_1 and A_2 are the corresponding leaf area index.

Phenological studies

The important phenophases of rice viz., number of days taken from nursery sowing to panicle initiation, 50 % flowering and physiological maturity were recorded as per the guidelines by Reddy and Reddi (1992) and presented in Table 3.8 (Plate 6).

Table 3.8. Phenophases of Rice crop in *kharif* and summer season

Growth Stages	No. of days taken from seeding	
	(*kharif*)	**(Summer)**
Seedling emergence	3	5
Initiation of 5th leaf/1st tiller	18	20
Tillering (up to)	62	60
Panicle initiation stage	70	67
Panicle emergence stage	86	82
50% flowering	92	87
Maturity	125	120

3.10.3 Studies on yield parameters

Effective tillers per hill

Effective tillers in 5 samples hills from each plot were counted at harvest and reported on per hill basis.

Length of panicle

Length of 5 panicles collected from 5 sample hills from each plot was measured in cm from the neck node to the tip of the topmost grain and averaged to get the mean length of the panicle.

Number of grains per panicle

The total number of grains of each sampled panicle used for determining panicle length were counted separately and the average was estimated to obtain the total grains, fertile and sterile grains per panicle.

1000 grain-weight

The weight of 1000 well filled grains, counted at random from the sample panicles of each plot, was weighed to find out test weight of grain.

Per cent sterile grain

The total number of grains and fertile and sterile grains of each sampled panicle used for determining panicle length were counted separately and the average was estimated to obtain the total grains, fertile and sterile grains per panicle. Sterility percentage was worked out from the number of sterile and total grains per panicle by using the formula.

$$\text{Sterility (\%)} = \frac{\text{No.of sterile grains in the panicle}}{\text{Total no.of grains in the panicle}} \times 100$$

3.10.4 Grain, straw yield and harvest index

The harvested produce from the net plot area was sun-dried plot-wise upto constant weight and then weighed. The grain and straw yields were presented separately in kg ha^{-1}.

The harvest index was estimated using the formula given by Nichiporovic (1960) and expressed in percentage

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

Where economic yield is the grain yield and biological yield is the total biomass (grain + straw) yield.

3.10.5 Chemical Analysis

Plant analysis

Plant samples were collected from each treatment at the time of harvest to determine the uptake of different nutrients (N, P and K). The grain and straw samples of each treatment from three replications were taken for this purpose. The samples were oven dried, finely ground, passed through 2 mm sieve and were analyzed to determine N, P and K content following standard methods (Table 3.9). The N, P and K uptake by grain and straw were calculated separately by multiplying the respective yields with the corresponding nutrient contents and were expressed in kg ha^{-1}. The moisture content in grain and straw were taken into account to be 10 and 14%, respectively, while calculating the nutrient uptake.

Table 3.9 Method employed for plant analysis

Nutrient	Method employed
Total Nitrogen	Modified Micro-Kjeldahl method
Total Phosphorus	Di-acid digestion method and colorimetric estimation (Piper, 1966)
Total Potassium	Flame photometer method (Jackson, 1973)

Soil analysis

Composite soil samples from 0 to 15 cm soil depth were collected from each treatment after harvest. The pH, organic carbon, available N, P and K and the total bacterial population were determined as per the methods mentioned previously in this chapter. Microbial population was determined by serial dilution plate count method (Schmidt and Paul, 1982).

3.10.6 Economics of production

Studies on economics of production was made by keeping a record on operation carried out, number of labourers engaged, power and inputs utilized. The standard cost of cultivation was calculated as per government fixed rates. FYM and vermicompost are farm recycled products and there costs are not included in the cost of cultivation. Only labour cost for FYM and vermicompost preparation is taken into consideration. Gross return was calculated using prevailing price of produce. Net return per hectare and return per rupee invested were also worked out as per the following formula

i) Net return = Gross return – cost of cultivation

ii) Return per rupee invested = $\frac{\text{Gross return}}{\text{Total cost of cultivation}}$

3.10.7 Statistical analysis

The biometric data and yield of grain and straw recorded during pre-harvest and post harvest stages were compiled in appropriate tables and analyzed statistically as per the procedure prescribed for randomized block design (Gomez and Gomez, 1984). To obtain the analysis of variance table, standard error of means i.e., SE(m)± were determined in all the cases, while critical difference (CD) at 5 % level of significance was estimated only in cases where ‘F’ test was found significant.

CHAPTER-IV

Experimental Findings

EXPERIMENTAL FINDINGS

Observations on different growth parameters, yield attributes microbial study and yield of rice as influenced by organic nutrient management and Biozyme formulations were recorded. Soil and plant analysis data and economics were computed. The data collected replication wise were analysed statistically. The results so obtained are presented in this chapter.

4.1 STUDIES ON GROWTH PARAMETERS

The plant characters considered for study of growth parameters of rice were plant height, tiller number per hill, leaf area index, dry matter accumulation, crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR).

4.1.1 Plant height

Data on plant height of rice recorded at different days after transplanting (DAT) i.e., from 30 DAT to harvest at an interval of 15 days are presented in Table 4.1a and 4.1b ; depicted in Fig 4.1a and 4.1b for *kharif* and summer seasons, respectively. The data reveal that plant height followed similar trend in both the seasons. It increased with the advancement of crop age and reached the maximum at 90 DAT. Treatment receiving Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) produced the tallest plants at harvest (125.8 and 124.1 cm, respectively). However, these were at par with those of all other treatments except T_1 and T_2 in both the seasons. On the other hand, treatments with only Dhanicha @ 25 kg seed ha^{-1} in *kharif* and no manure application in summer (T_1) expressed the shortest plants at harvest (101.8 and 99.9 cm, respectively) which were at par with those of T_2 to T_5 in both the seasons.

Table 4.1a Effect of organic nutrient management and Biozyme formulations on plant height (cm) of *kharif* rice

Treatment	Days After Transplanting					
	30	45	60	75	90	At harvest
T_1	59.7	85.6	95.1	100.3	102.2	101.8
T_2	63.2	87.7	97.4	104.0	104.6	104.2
T_3	66.9	88.1	101.9	114.6	116.0	116.5
T_4	64.8	88.4	99.4	113.4	115.2	113.6
T_5	66.2	91.3	102.0	115.1	115.4	115.1
T_6	68.3	92.8	106.2	118.4	117.6	117.6
T_7	67.8	94.0	106.3	120.2	121.0	120.7
T_8	68.1	94.5	104.8	121.2	121.6	121.8
T_9	69.0	95.4	108.4	124.4	124.3	124.8
T_{10}	69.3	95.9	108.4	122.7	122.6	122.1
T_{11}	70.4	96.9	109.1	123.3	123.5	123.1
T_{12}	72.9	97.1	110.4	126.2	126.2	125.8
SE(m)±	**2.29**	**2.51**	**2.72**	**3.57**	**2.93**	**5.09**
CD(0.05)	**6.7**	**7.4**	**8.0**	**10.5**	**8.6**	**14.9**
CV (%)	**5.91**	**4.70**	**4.52**	**5.29**	**4.32**	**7.52**

Table 4.1b Effect of organic nutrient management and Biozyme formulations on plant height (cm) of summer rice

Treatment	Days After Transplanting					
	30	45	60	75	90	At harvest
T_1	58.3	84.2	93.8	99.0	100.9	99.9
T_2	62.0	85.8	96.3	102.8	103.4	102.4
T_3	65.7	85.5	100.9	113.8	115.0	115.1
T_4	63.7	88.1	98.9	112.3	114.1	112.0
T_5	65.1	90.1	100.8	113.9	115.6	113.4
T_6	67.5	91.9	105.3	117.5	116.7	116.2
T_7	66.7	92.2	105.2	119.1	119.9	119.1
T_8	67.1	93.4	106.1	120.1	120.4	120.1
T_9	68.0	94.6	106.6	123.3	123.2	123.1
T_{10}	68.5	95.1	107.7	121.9	121.8	120.9
T_{11}	69.1	95.7	107.9	122.1	122.3	121.2
T_{12}	71.7	95.9	109.4	125.1	125.2	124.1
SE(m) ±	**2.32**	**2.73**	**2.99**	**3.71**	**3.39**	**5.16**
CD(0.05)	**6.8**	**8.0**	**8.8**	**10.9**	**10.0**	**15.1**
CV (%)	**6.09**	**5.20**	**5.01**	**5.55**	**5.05**	**7.73**

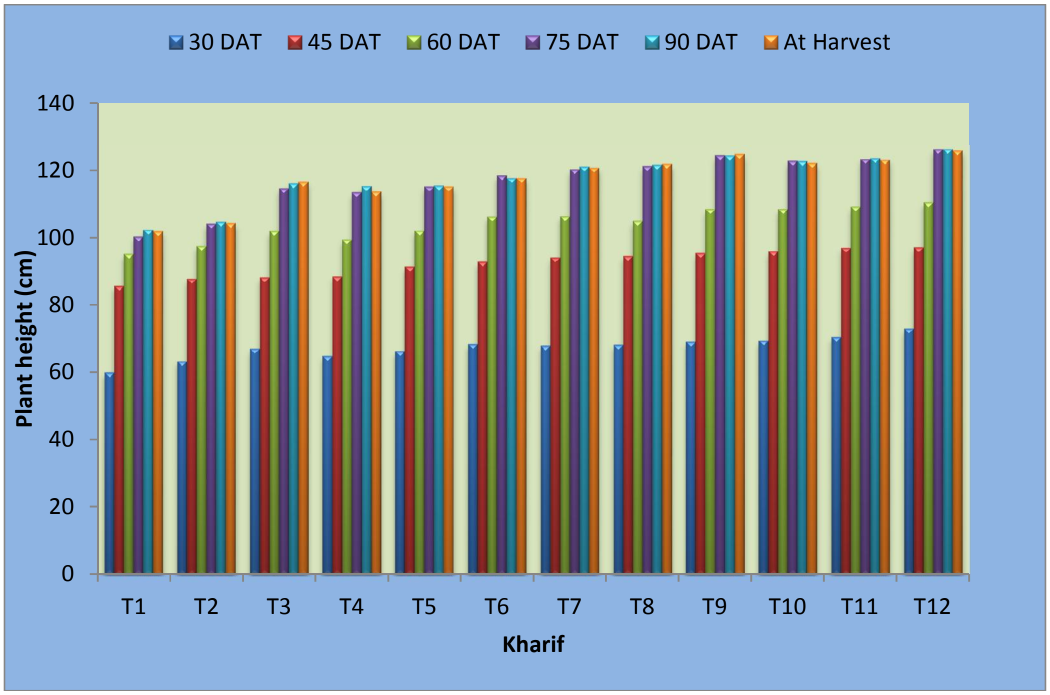


Fig. 4.1a Effect of organic nutrient management and Biozyme formulations on plant height (cm) of *kharif* rice

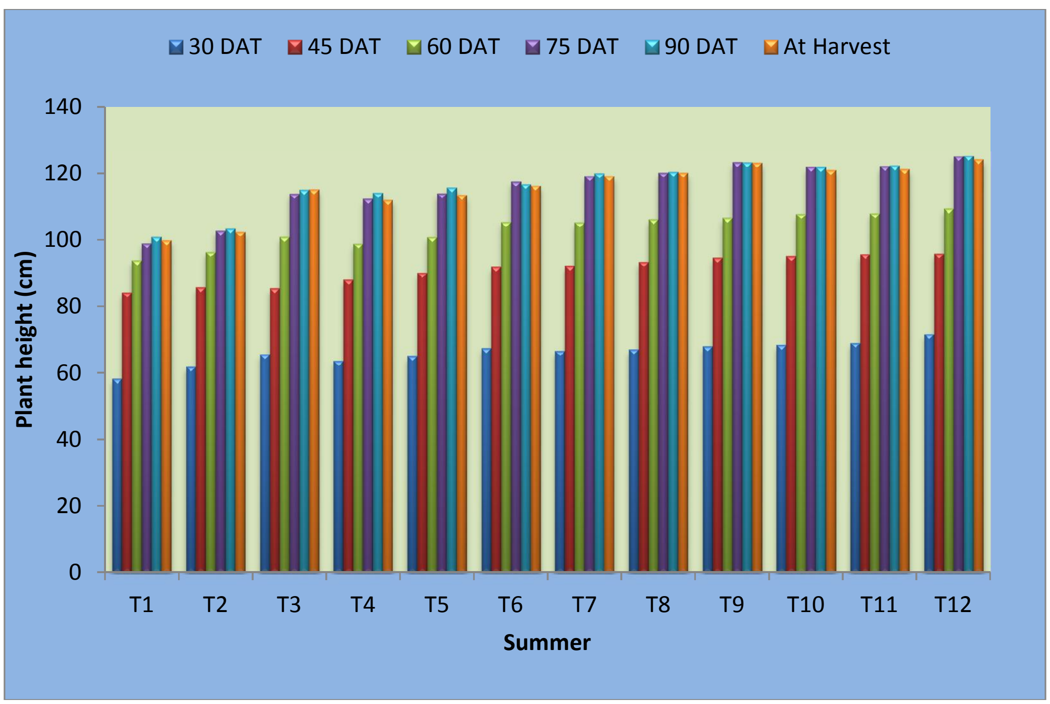


Fig. 4.1b Effect of organic nutrient management and Biozyme formulations on plant height (cm) of summer rice

Table 4.2a Effect of organic nutrient management and Biozyme formulations on tiller number of *kharif* rice

Treatment	Days After Transplanting					
	30	45	60	75	90	At Harvest
T_1	12.18	20.13	19.10	16.87	14.51	14.07
T_2	12.37	20.50	19.20	17.37	15.21	15.00
T_3	13.50	23.03	20.07	19.00	17.64	17.07
T_4	13.83	21.63	19.40	17.63	15.93	15.07
T_5	13.67	22.53	20.37	18.30	16.88	15.97
T_6	14.07	23.40	22.90	20.30	18.90	17.20
T_7	14.60	25.27	23.17	22.93	20.67	20.37
T_8	14.30	25.53	24.70	22.57	20.77	20.60
T_9	14.80	27.23	26.00	24.60	22.90	22.27
T_{10}	15.33	28.50	26.67	24.80	22.80	22.77
T_{11}	16.23	28.10	26.90	25.40	23.23	23.20
T_{12}	16.93	29.70	28.30	26.87	23.80	23.70
SE(m)±	**0.931**	**1.612**	**1.706**	**1.741**	**1.445**	**1.397**
CD(0.05)	**2.73**	**4.73**	**5.00**	**5.11**	**4.24**	**4.10**
CV (%)	**11.27**	**11.34**	**12.81**	**14.10**	**12.88**	**12.78**

Table 4.2b Effect of organic nutrient management and Biozyme formulations on tiller number of summer rice

Treatment	Days After Transplanting					
	30	45	60	75	90	At Harvest
T_1	10.86	18.83	17.80	15.57	13.21	12.77
T_2	11.20	19.30	17.97	16.10	14.01	13.80
T_3	12.57	22.13	19.20	18.17	16.74	16.17
T_4	12.77	20.53	18.27	16.53	14.83	13.97
T_5	12.50	21.33	19.10	17.03	15.68	14.77
T_6	13.17	22.50	22.03	19.40	18.00	16.30
T_7	13.57	24.17	22.07	21.87	19.57	19.27
T_8	13.20	24.43	23.60	22.47	20.60	20.37
T_9	13.63	26.13	24.93	23.37	21.80	21.17
T_{10}	14.53	27.70	25.83	24.07	22.00	21.97
T_{11}	15.07	26.90	25.70	24.20	22.03	22.00
T_{12}	15.80	28.60	27.13	25.80	22.70	22.60
SE(m)±	**0.927**	**1.612**	**1.711**	**1.769**	**1.480**	**1.356**
CD(0.05)	**2.72**	**4.73**	**5.02**	**5.19**	**4.34**	**3.98**
CV (%)	**12.13**	**11.86**	**13.49**	**15.03**	**13.91**	**13.11**

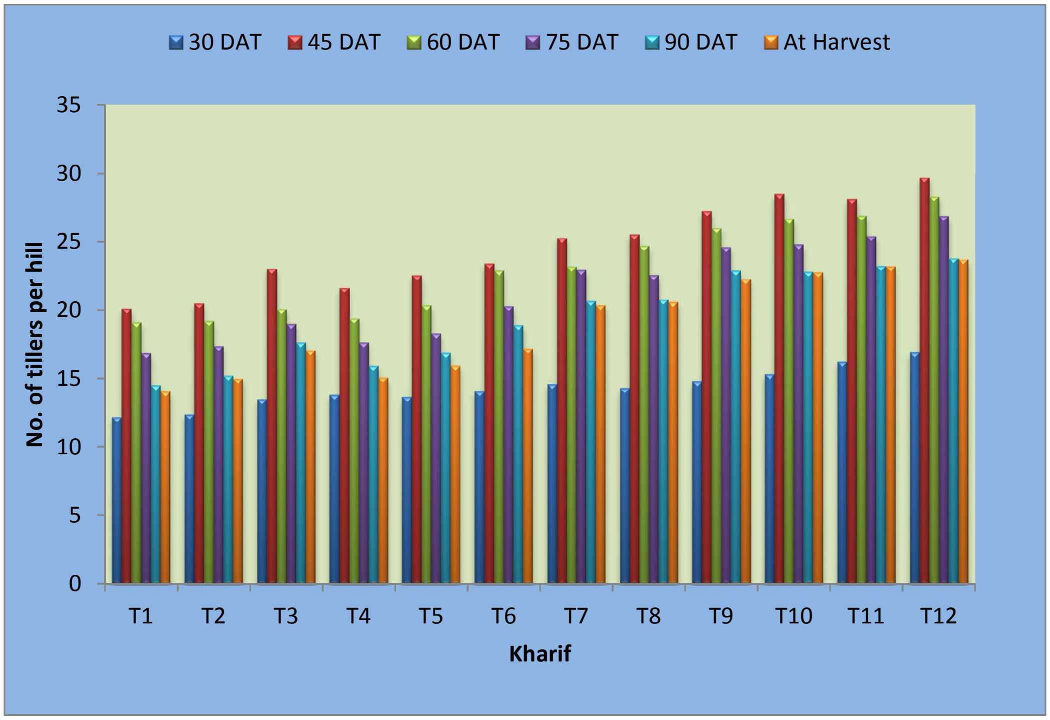


Fig. 4.2a Effect of organic nutrient management and Biozyme formulations on tiller number of *kharif* rice

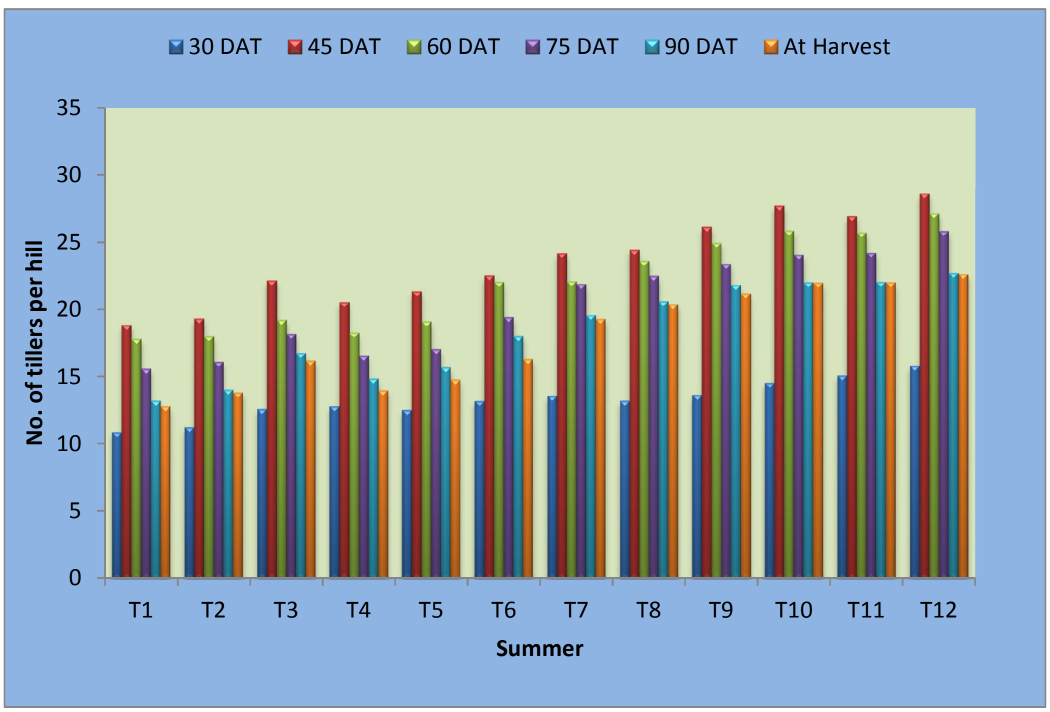


Fig. 4.2b Effect of organic nutrient management and Biozyme formulations on tiller number of summer rice

4.1.2 Number of tillers per hill

The number of total tillers per hill was recorded at 30, 45, 60, 75, 90 DAT and at harvest and the results reveal that tiller number showed similar response to ONM options in both the seasons and the rate of appearance of tillers was faster up to 45 DAT, where it attained the maximum number and declined thereafter (Table 4.2a and 4.2b; Fig. 4.2a and 4.2b). Treatment receiving Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) resulted the maximum number of tillers per hill at 45 DAT i.e. 29.70 and 28.60 in *kharif* and summer, respectively. However, these were at par with those of treatments T_7 to T_{11}. On the otherhand, treatments with only Dhanicha @ 25 kg seed ha^{-1} in *kharif* and no manure application in summer (T_1) produced minimum number of tillers per hill (20.13 and 18.83, respectively) at 45 DAT which were at par with those of treatments T_2 to T_6. Thereafter tiller number declined gradually up to harvest and attained effective tillers of 23.70 and 22.60 in *kharif* and summer season, respectively (T_{12}) which were at par with those of treatments T_7 to T_{11}.

4.1.3 Effective tillers per hill

Effective tiller count per hill was recorded as ear bearing tiller per hill and are presented in Table 4.3 and depicted in Fig. 4.3. Organic nutrient management options and Biozyme formulations influenced the effective tiller per hill significantly. The number of effective tiller per hill was recorded to be the maximum for T_{12} in both the seasons (23.70 and 22.60 in *kharif* and summer, respectively) where as treatment T_1 registered the minimum (14.07 and 12.77) in both the season. The conversion percentage was the maximum for T_{11} in *kharif* (82.56 %) and T_8 in summer season (83.38%). But the conversion percentage was very close to one another for treatments T_7 to T_{12}. A strong positive linear relationship (R^2 = 0.963 and 0.965 in *kharif* and summer seasons, respectively) was observed between effective tillers and grain yield (Fig. 4.20).

Table 4.3 Effect of organic nutrient management and Biozyme formulations on effective tillers per hill of *kharif* and summer rice

Treatment	***Kharif* season**			**Summer season**		
	Maximum tillers	**Effective tillers**	**Conversion (%)**	**Maximum tillers**	**Effective tillers**	**Conversion (%)**
T_1	20.13	14.07	**69.90**	18.83	12.77	**67.82**
T_2	20.50	15.00	**73.17**	19.30	13.80	**71.50**
T_3	23.03	17.07	**74.12**	22.13	16.17	**73.07**
T_4	21.63	15.07	**69.67**	20.53	13.97	**68.05**
T_5	22.53	15.97	**70.88**	21.33	14.77	**69.25**
T_6	23.40	17.20	**73.50**	22.50	16.30	**72.44**
T_7	25.27	20.37	**80.61**	24.17	19.27	**79.73**
T_8	25.53	20.60	**81.51**	24.43	20.37	**83.38**
T_9	27.23	22.27	**81.78**	26.13	21.17	**81.02**
T_{10}	28.50	22.77	**79.89**	27.70	21.97	**79.31**
T_{11}	28.10	23.20	**82.56**	26.90	22.00	**81.78**
T_{12}	29.70	23.70	**79.80**	28.60	22.60	**79.02**

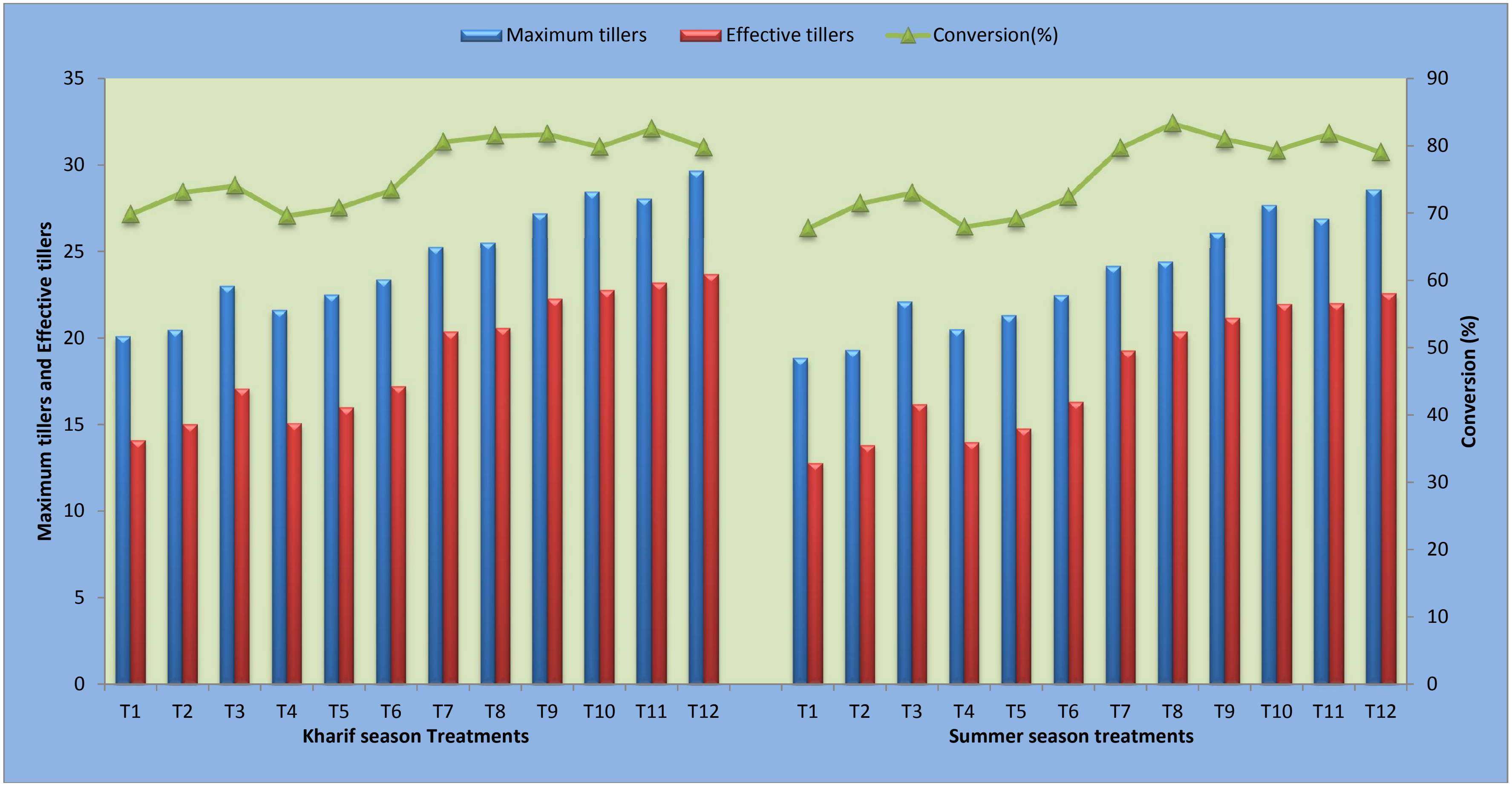


Fig. 4.3 Effect of organic nutrient management and Biozyme formulations on effective tillers per hill of *kharif* and summer rice

Table 4.4a Effect of organic nutrient management and Biozyme formulations on root volume (cc) per hill of *kharif* rice

Treatment	Days After Transplanting					
	30	45	60	75	90	At harvest
T_1	14.93	24.23	38.47	39.10	34.50	29.30
T_2	16.20	27.43	39.57	39.90	34.23	29.53
T_3	19.97	40.53	48.07	56.70	55.97	51.73
T_4	17.37	31.63	45.77	49.00	43.63	38.50
T_5	18.13	35.60	55.67	55.13	48.97	41.37
T_6	20.63	37.37	61.00	59.90	52.53	46.03
T_7	22.70	43.37	71.13	65.70	57.60	47.70
T_8	22.70	46.20	72.03	68.40	57.93	48.67
T_9	25.37	46.30	74.87	73.97	63.50	52.43
T_{10}	24.80	46.87	75.90	77.33	67.63	60.70
T_{11}	25.30	47.83	76.97	81.40	74.00	66.37
T_{12}	26.30	50.87	78.63	83.23	75.67	67.20
SE(m)±	**1.661**	**2.343**	**1.635**	**2.852**	**3.214**	**2.119**
CD(0.05)	**4.87**	**6.87**	**4.79**	**8.36**	**9.43**	**6.21**
CV (%)	**13.57**	**10.18**	**4.60**	**7.91**	**10.03**	**7.60**

Table 4.4b Effect of organic nutrient management and Biozyme formulations on root volume (cc) per hill of summer rice

Treatment	Days After Transplanting					
	30	45	60	75	90	At harvest
T_1	10.87	22.67	36.91	37.54	32.94	27.74
T_2	12.26	25.99	38.13	38.46	32.79	28.09
T_3	16.39	39.45	46.99	56.95	54.89	50.65
T_4	13.55	30.31	44.45	47.68	42.31	37.18
T_5	14.19	34.16	54.23	53.69	47.53	39.93
T_6	17.05	36.29	59.92	58.82	51.45	44.95
T_7	18.88	42.05	69.81	64.38	56.28	46.38
T_8	18.88	44.88	70.71	67.08	56.61	47.35
T_9	21.55	44.98	73.55	72.65	62.18	51.11
T_{10}	21.34	45.91	74.94	76.37	66.67	59.74
T_{11}	21.36	46.39	75.53	79.96	72.56	64.93
T_{12}	22.48	49.55	77.31	81.91	74.35	65.88
SE(m)±	**1.486**	**2.343**	**3.066**	**3.587**	**3.214**	**2.509**
CD(0.05)	**4.36**	**6.87**	**8.99**	**10.52**	**9.43**	**7.36**
CV (%)	**14.79**	**10.53**	**8.82**	**10.14**	**10.27**	**9.25**

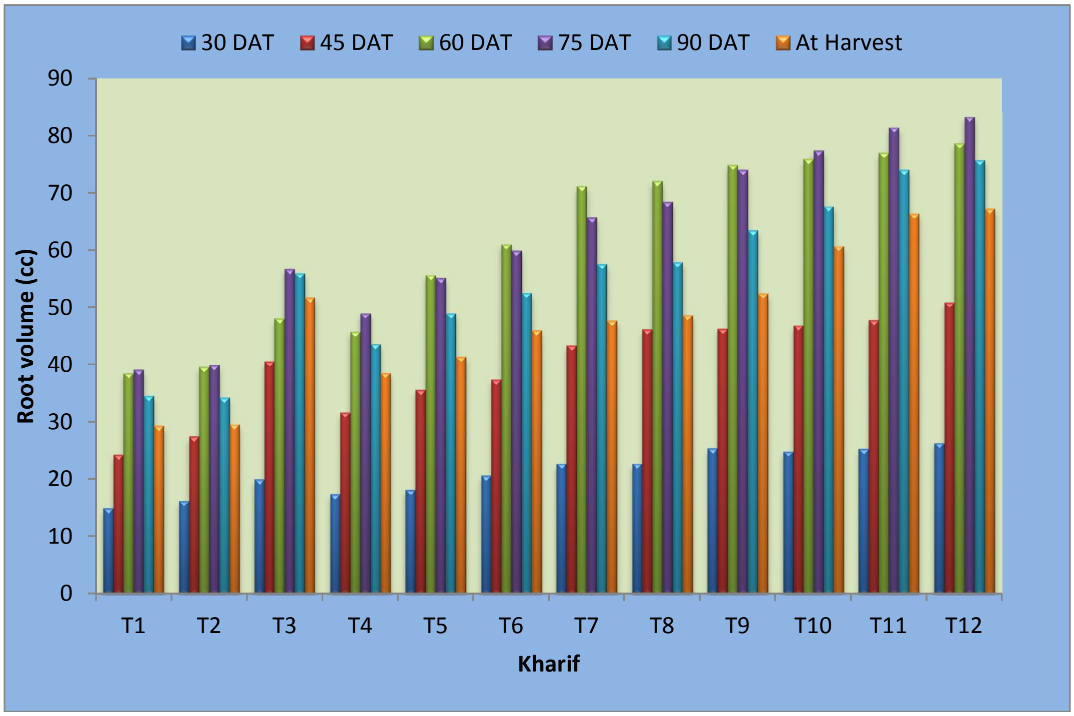


Fig. 4.4a Effect of organic nutrient management and Biozyme formulations on root volume (cc) of *kharif* rice

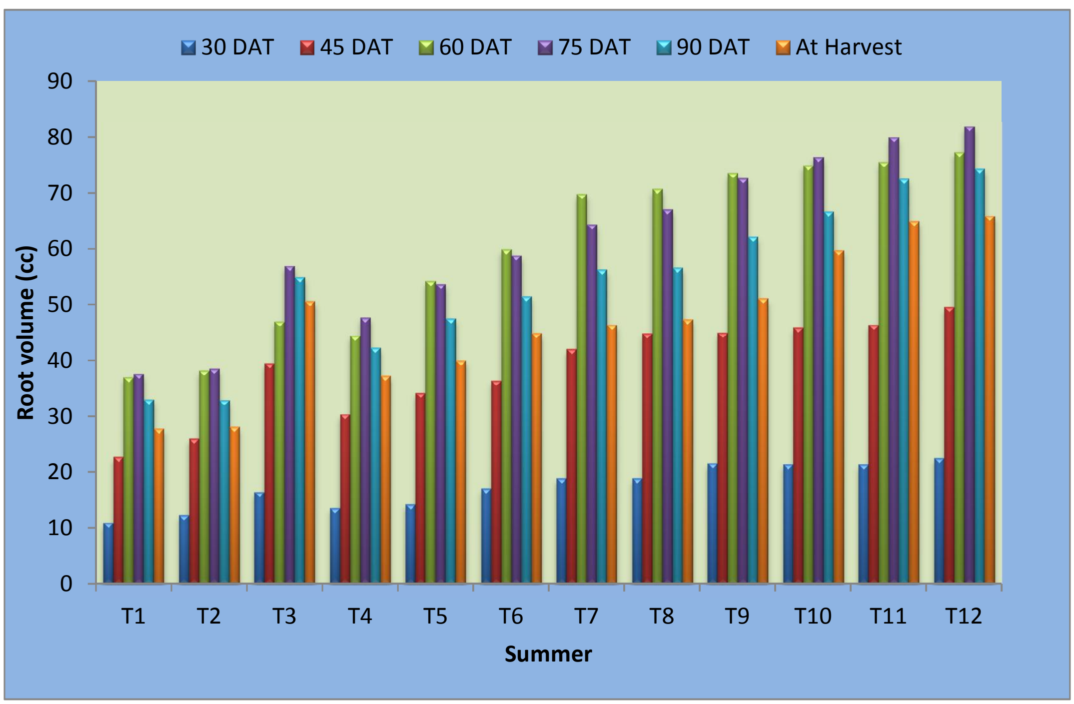


Fig. 4.4b Effect of organic nutrient management and Biozyme formulations on root volume (cc) of summer rice

4.1.4 Root volume per hill

The root volume per hill was recorded at 30, 45, 60, 75, 90 DAT and at harvest (Table 4.4a and 4.4b; Fig. 4.4a and 4.4b). The results reveal that observation on root volume followed similar trend in both the seasons, more or less increase up to 75 DAT, and declined thereafter. At 75 DAT, the root volume per hill was found highest in the treatment receiving Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) i.e. 83.23 and 81.91 cc, respectively which were at par with those treatments T_{10} and T_{11} in *kharif* and T_9 to T_{11} in summer. On the otherhand, treatments with only Dhanicha @ 25 kg seed ha^{-1} in *kharif* and no manure application in summer (T_1) resulted in lowest production of root volume per hill (39.10 and 37.54, respectively) at 75 DAT which were at par with that of treatment T_2 in both the seasons. A strong positive linear relationship (R^2 = 0.819 and 0.821 in *kharif* and summer seasons, respectively) was observed between root volume at harvest and grain yield (Fig. 4.21).

4.1.5 Leaf Area Index

Leaf area index of both *kharif* and summer rice recorded at 30, 45, 60, 75, 90 DAT and at harvest are presented in Table 4.5a and 4.5b; depicted in Fig.4.5a and 4.5b. It is observed that the leaf area index due to organic nutrient management and Biozyme formulations followed similar trend in both the seasons. It almost increased linearly up to 60 and 75 DAT in respective seasons and decreased thereafter. The average leaf area index at 30, 45, 60, 75, 90 DAT and at harvest were 0.96 and 0.82, 3.32 and 3.20, 4.38 and 4.25, 4.42 and 4.30, 4.22 and 4.08, 3.91 and 3.77 in *kharif* and summer season, respectively. Highest leaf area index was recorded in the treatment receiving Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) at 60 DAT (5.32) in *kharif* and at 75 DAT (5.22) in summer season, respectively, which were at par with those of T_9 to T_{11} in both the seasons. However, treatment T_1 registered the lowest LAI all along the growth stages in both the seasons.

Table 4.5a Effect of organic nutrient management and Biozyme formulations on Leaf Area Index of *kharif* rice

Treatment	Days After Transplanting					
	30	45	60	75	90	At Harvest
T_1	0.81	2.13	3.24	3.23	3.22	2.56
T_2	0.84	2.16	3.38	3.42	3.33	2.75
T_3	0.90	3.60	4.76	4.75	4.43	3.79
T_4	0.87	2.31	3.76	3.74	3.61	3.39
T_5	0.90	2.67	4.04	4.19	4.18	4.06
T_6	0.96	3.35	4.12	4.25	4.28	4.13
T_7	0.93	3.61	4.35	4.44	4.33	4.26
T_8	0.98	3.83	4.63	4.60	4.54	4.21
T_9	1.07	3.92	5.04	4.85	4.68	4.48
T_{10}	1.05	4.03	4.79	5.13	4.48	4.12
T_{11}	1.07	4.07	5.14	5.22	4.64	4.38
T_{12}	1.09	4.21	5.32	5.29	4.84	4.73
SE(m)±	**0.057**	**0.207**	**0.233**	**0.210**	**0.254**	**0.194**
CD(0.05)	**0.17**	**0.61**	**0.68**	**0.61**	**0.75**	**0.57**
CV (%)	**10.27**	**10.80**	**9.22**	**8.21**	**10.44**	**8.61**

Table 4.5b Effect of organic nutrient management and Biozyme formulations on Leaf Area Index of summer rice

Treatment	Days After Transplanting					
	30	45	60	75	90	At harvest
T_1	0.65	1.97	3.07	3.11	3.10	2.40
T_2	0.69	2.08	3.23	3.27	3.18	2.60
T_3	0.79	3.52	4.68	4.64	4.32	3.68
T_4	0.74	2.17	3.63	3.60	3.48	3.26
T_5	0.75	2.52	3.89	4.05	4.03	3.91
T_6	0.85	3.27	4.01	4.13	4.17	4.02
T_7	0.80	3.48	4.25	4.28	4.19	4.12
T_8	0.84	3.70	4.50	4.49	4.41	4.07
T_9	0.94	3.78	4.91	4.72	4.55	4.34
T_{10}	0.95	3.93	4.69	5.03	4.38	4.02
T_{11}	0.92	3.92	4.99	5.06	4.49	4.23
T_{12}	0.95	4.11	5.18	5.22	4.71	4.60
SE(m)±	**0.057**	**0.210**	**0.232**	**0.213**	**0.255**	**0.194**
CD(0.05p)	**0.17**	**0.62**	**0.68**	**0.63**	**0.75**	**0.57**
CV (%)	**12.12**	**11.36**	**9.46**	**8.60**	**10.84**	**8.91**

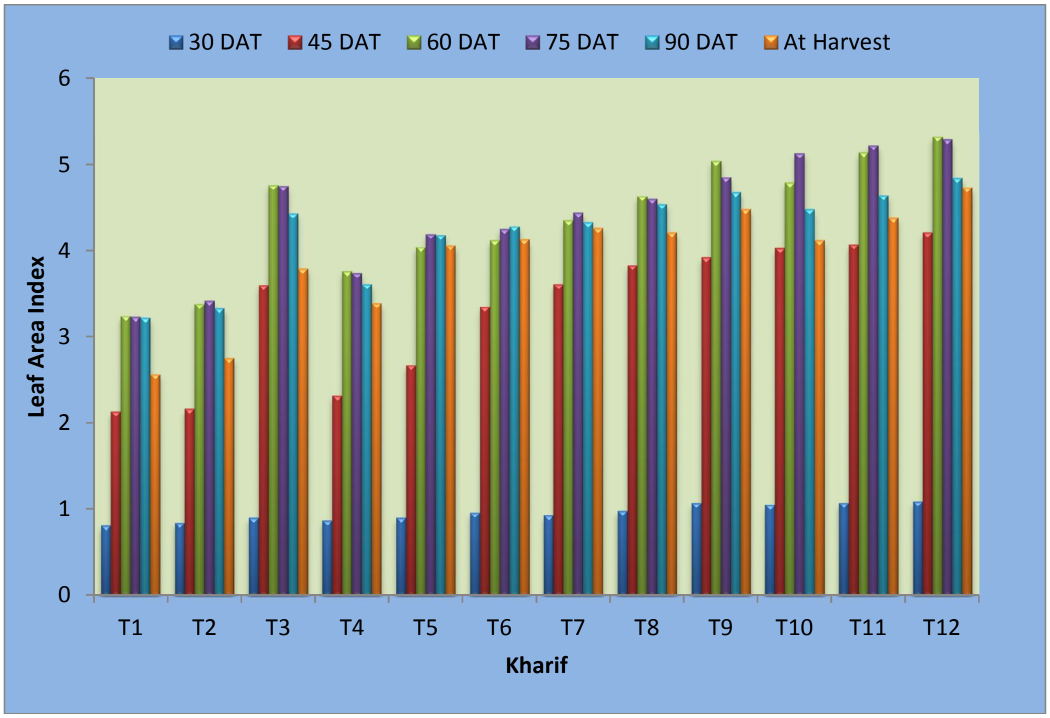


Fig. 4.5a Effect of organic nutrient management and Biozyme formulations on Leaf Area Index of *kharif* rice

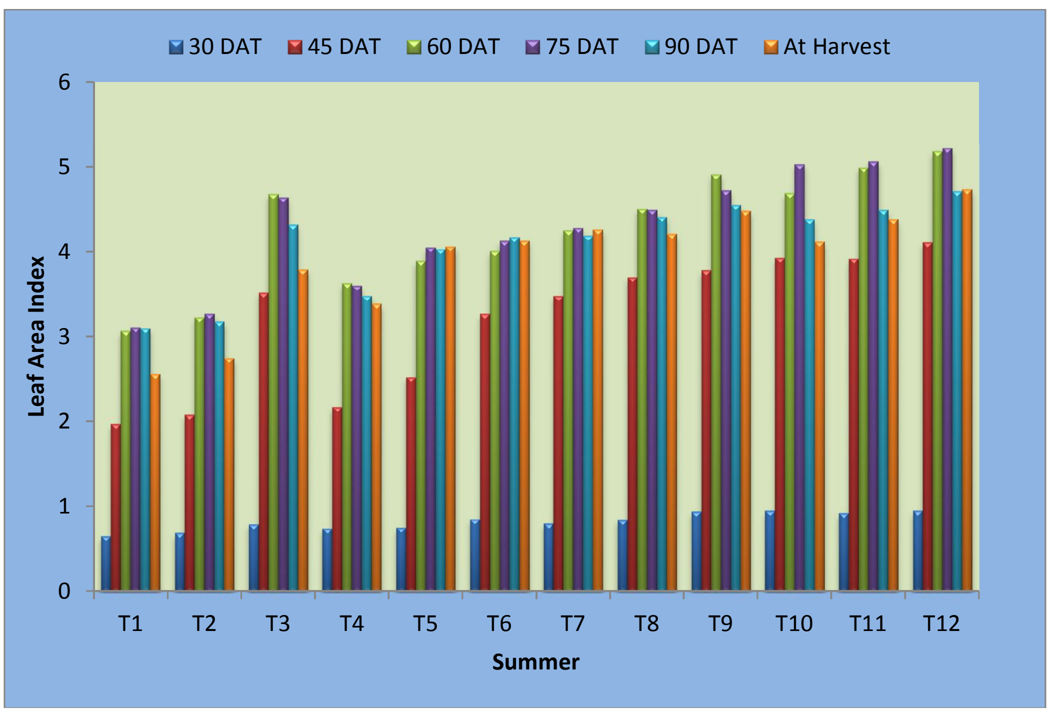


Fig. 4.5b Effect of organic nutrient management and Biozyme formulations on Leaf Area Index of summer rice

Table 4.6a Effect of organic nutrient management and Biozyme formulations on dry matter accumulation (g hill^{-1}) of *kharif* rice

Treatment	Days After Transplanting					
	30	45	60	75	90	At Harvest
T_1	7.17	17.71	25.73	35.44	40.21	42.44
T_2	8.62	19.81	27.03	39.04	43.37	45.80
T_3	11.46	25.38	32.15	45.44	52.74	60.76
T_4	9.97	27.51	29.35	41.98	47.44	50.86
T_5	9.98	27.85	31.16	46.74	49.44	56.69
T_6	10.69	29.00	34.35	49.44	52.43	60.07
T_7	10.52	30.61	34.85	51.51	57.09	62.32
T_8	11.06	33.34	37.19	53.87	59.74	64.29
T_9	12.63	30.39	42.46	55.63	62.61	66.28
T_{10}	11.63	32.41	43.61	58.29	66.76	70.59
T_{11}	12.27	33.38	46.46	59.33	68.76	73.81
T_{12}	12.77	34.97	50.55	62.58	71.17	75.08
SE(m)±	**0.453**	**0.807**	**1.143**	**1.600**	**1.903**	**1.905**
CD(0.05)	**1.33**	**2.37**	**3.35**	**4.69**	**5.58**	**5.59**
CV (%)	**7.31**	**4.90**	**5.46**	**5.55**	**5.89**	**5.43**

Table 4.6b Effect of organic nutrient management and Biozyme formulations on dry matter accumulation (g hill^{-1}) of summer rice

Treatment	Days After Transplanting					
	30	45	60	75	90	At harvest
T_1	6.18	16.23	24.54	35.11	39.03	40.70
T_2	7.26	18.55	25.61	38.76	41.67	44.16
T_3	10.64	23.89	30.79	43.63	48.25	59.36
T_4	8.76	25.93	28.38	40.73	46.44	49.73
T_5	8.65	26.22	29.56	43.21	48.40	55.21
T_6	9.51	27.51	33.01	48.67	51.63	58.93
T_7	9.25	29.69	33.80	50.05	56.51	60.70
T_8	10.05	31.76	36.31	53.43	58.78	62.60
T_9	11.04	29.03	40.85	54.19	60.69	65.02
T_{10}	10.46	31.13	42.19	56.97	65.17	69.26
T_{11}	10.87	31.83	44.61	58.20	67.29	72.35
T_{12}	11.55	33.89	49.19	61.09	69.45	73.50
SE(m)±	**0.526**	**1.669**	**1.984**	**3.077**	**2.936**	**3.543**
CD(0.05p)	**1.54**	**4.89**	**5.82**	**9.02**	**8.61**	**10.39**
CV (%)	**9.58**	**10.65**	**9.85**	**10.95**	**9.34**	**10.35**

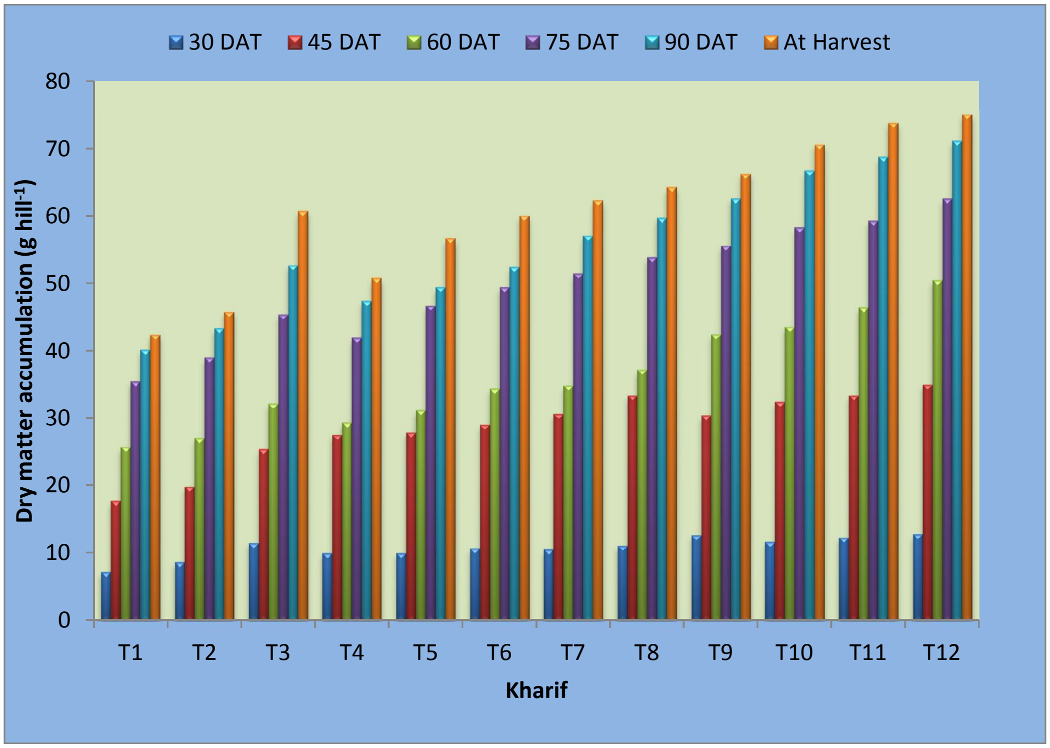


Fig. 4.6a Effect of organic nutrient management and Biozyme formulations on dry matter accumulation (g hill^{-1}) of *kharif* rice

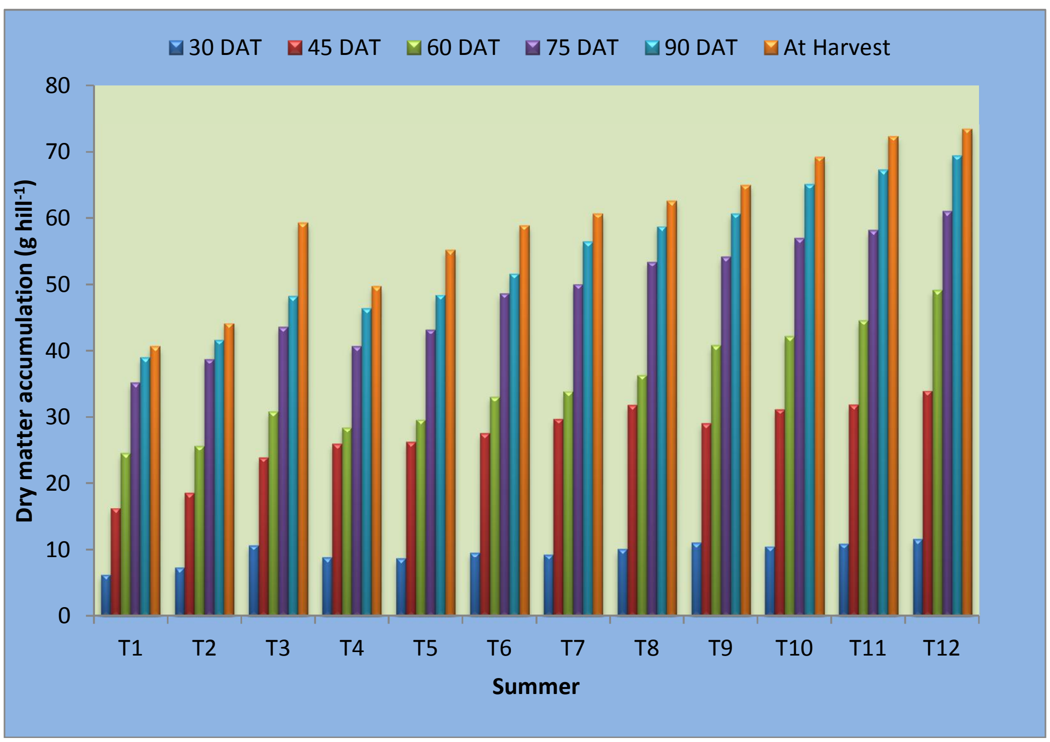


Fig. 4.6b Effect of organic nutrient management and Biozyme formulations on dry matter accumulation (g hill^{-1}) of summer rice

Table 4.7a Effect of organic nutrient management and Biozyme formulations on crop growth rate (g day $^{-1}$hill $^{-1}$) of *kharif* rice

Treatment	Days After Transplanting				
	30-45	45-60	60-75	75-90	90-Harvest
T_1	0.703	0.535	0.647	0.318	0.149
T_2	0.746	0.481	0.801	0.289	0.162
T_3	0.928	0.451	0.886	0.487	0.535
T_4	1.169	0.123	0.842	0.364	0.228
T_5	1.191	0.221	1.039	0.180	0.483
T_6	1.221	0.357	1.006	0.199	0.509
T_7	1.339	0.283	1.111	0.372	0.349
T_8	1.485	0.257	1.112	0.391	0.303
T_9	1.184	0.805	0.878	0.465	0.245
T_{10}	1.385	0.747	0.979	0.565	0.255
T_{11}	1.407	0.872	0.858	0.629	0.337
T_{12}	1.480	1.039	0.802	0.573	0.261

Table 4.7b Effect of organic nutrient management and Biozyme formulations on crop growth rate (g day $^{-1}$hill $^{-1}$) of summer rice

Treatment	Days After Transplanting				
	30-45	45-60	60-75	75-90	90-Harvest
T_1	0.670	0.554	0.705	0.261	0.111
T_2	0.753	0.471	0.877	0.194	0.166
T_3	0.883	0.460	0.856	0.308	0.741
T_4	1.145	0.163	0.823	0.381	0.219
T_5	1.171	0.223	0.910	0.346	0.454
T_6	1.200	0.367	1.044	0.197	0.487
T_7	1.363	0.274	1.083	0.431	0.279
T_8	1.447	0.303	1.141	0.357	0.255
T_9	1.199	0.788	0.889	0.433	0.289
T_{10}	1.378	0.737	0.985	0.547	0.273
T_{11}	1.397	0.852	0.906	0.606	0.337
T_{12}	1.489	1.020	0.793	0.557	0.270

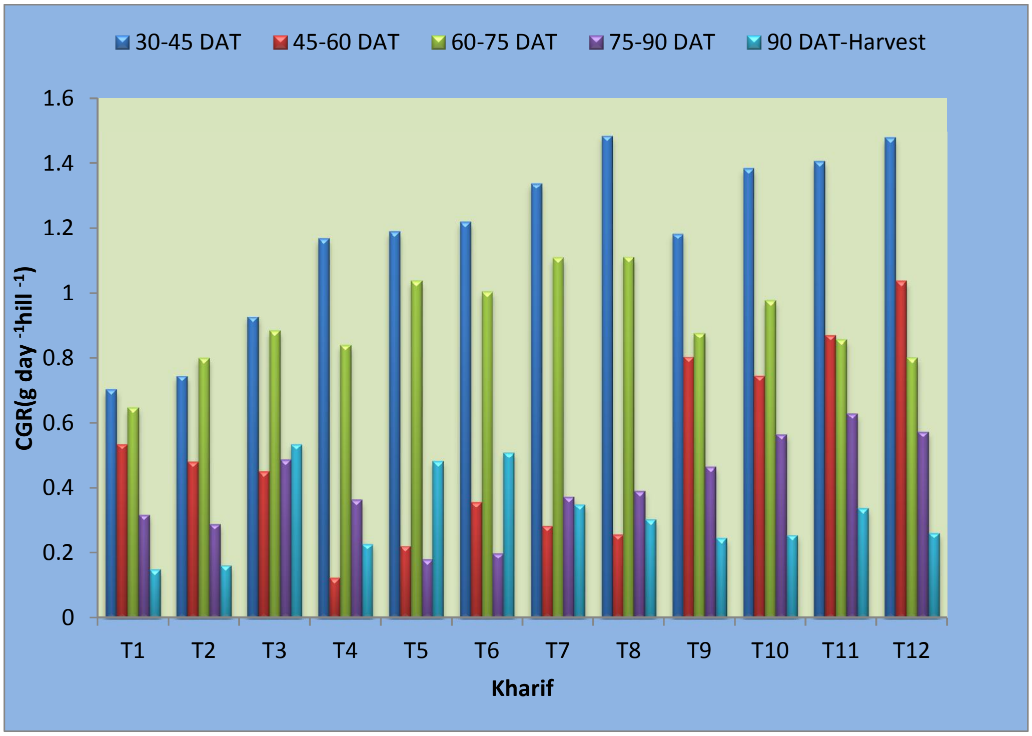


Fig. 4.7a Effect of organic nutrient management and Biozyme formulations on crop growth rate (g day $^{-1}$hill $^{-1}$) of *kharif* rice

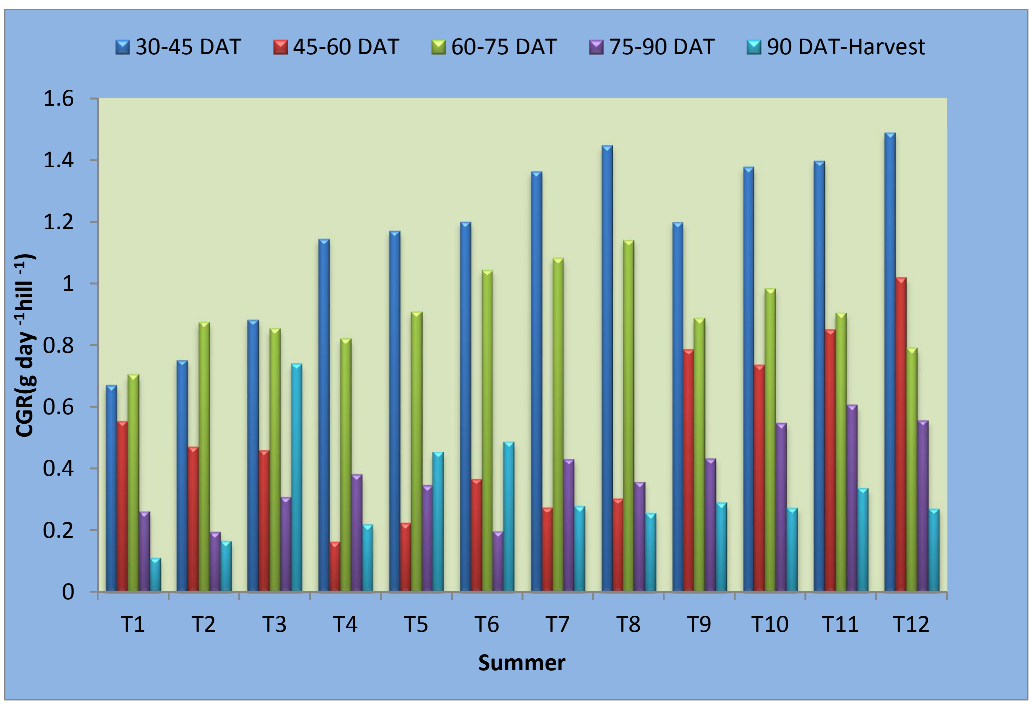


Fig. 4.7b Effect of organic nutrient management and Biozyme formulations on crop growth rate (g day $^{-1}$hill $^{-1}$) of summer rice

Table 4.8a Effect of organic nutrient management and Biozyme formulations on relative growth rate (g g $^{-1}$day $^{-1}$) of *kharif* rice

Treatment	Days After Transplanting				
	30-45	45-60	60-75	75-90	90-Harvest
T_1	0.060	0.025	0.021	0.008	0.004
T_2	0.055	0.021	0.025	0.007	0.004
T_3	0.053	0.016	0.023	0.010	0.009
T_4	0.068	0.004	0.024	0.008	0.005
T_5	0.068	0.007	0.027	0.004	0.009
T_6	0.067	0.011	0.024	0.004	0.009
T_7	0.071	0.009	0.026	0.007	0.006
T_8	0.074	0.007	0.025	0.007	0.005
T_9	0.059	0.022	0.018	0.008	0.004
T_{10}	0.068	0.020	0.019	0.009	0.004
T_{11}	0.067	0.022	0.016	0.010	0.005
T_{12}	0.067	0.025	0.014	0.009	0.004

Table 4.8b Effect of organic nutrient management and Biozyme formulations on relative growth rate (g g $^{-1}$day $^{-1}$) of summer rice

Treatment	Days After Transplanting				
	30-45	45-60	60-75	75-90	90-Harvest
T_1	0.064	0.028	0.024	0.007	0.003
T_2	0.063	0.022	0.028	0.005	0.004
T_3	0.054	0.017	0.023	0.007	0.014
T_4	0.072	0.006	0.024	0.009	0.005
T_5	0.074	0.008	0.025	0.008	0.009
T_6	0.071	0.012	0.026	0.004	0.009
T_7	0.078	0.009	0.026	0.008	0.005
T_8	0.077	0.009	0.026	0.006	0.004
T_9	0.064	0.023	0.019	0.008	0.005
T_{10}	0.073	0.020	0.020	0.009	0.004
T_{11}	0.072	0.023	0.018	0.010	0.005
T_{12}	0.072	0.025	0.014	0.009	0.004

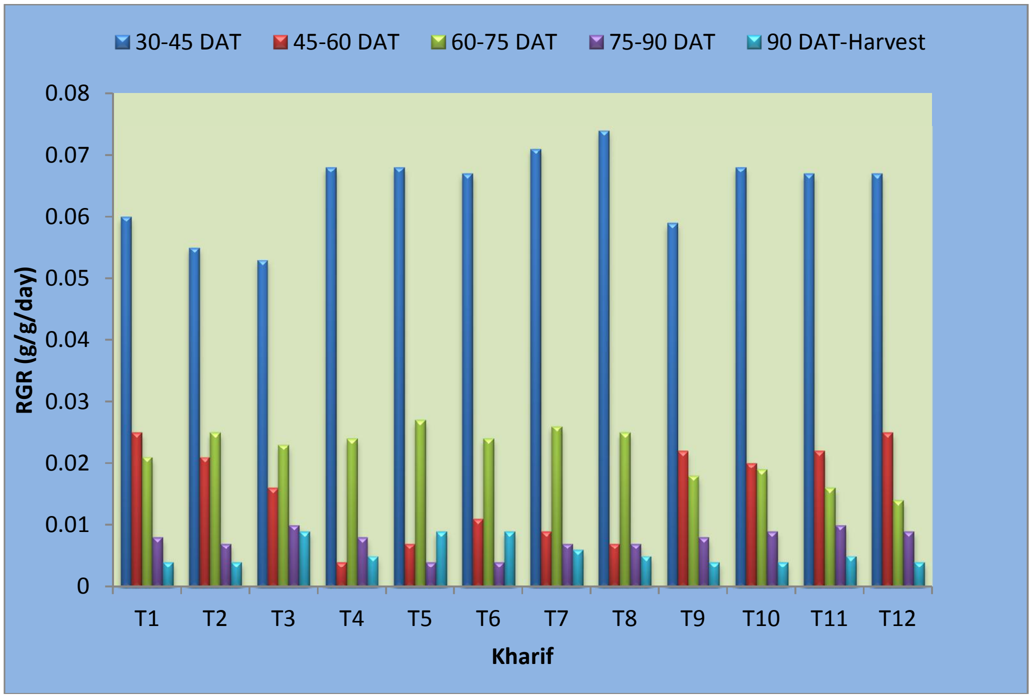


Fig. 4.8a Effect of organic nutrient management and Biozyme formulations on relative growth rate (g g $^{-1}$day $^{-1}$) of *kharif* rice

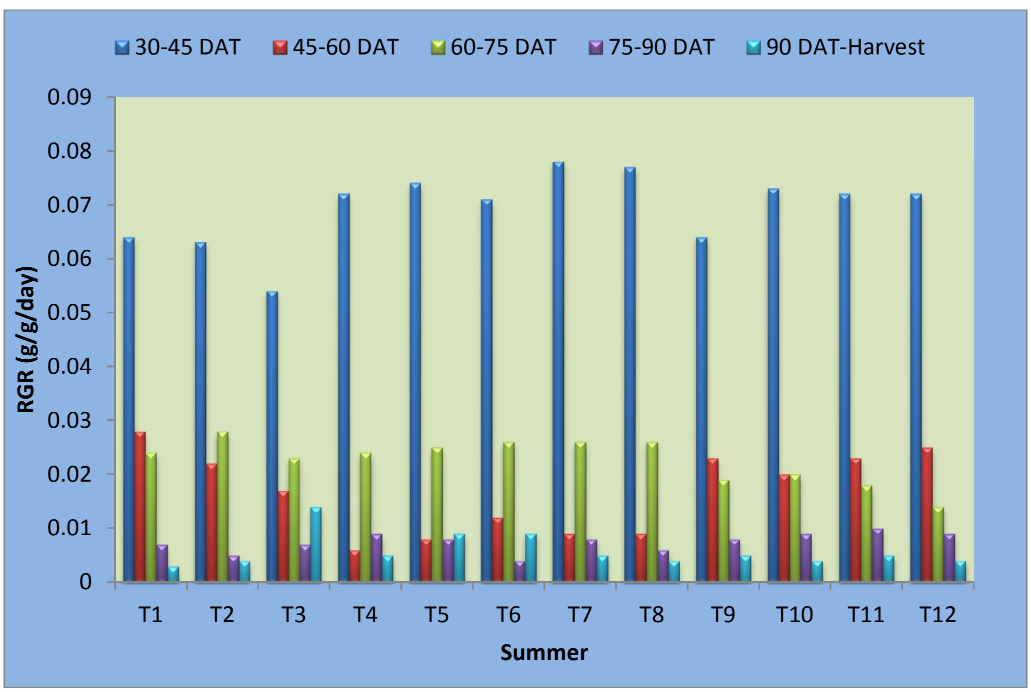


Fig. 4.8b Effect of organic nutrient management and Biozyme formulations on relative growth rate (g g $^{-1}$day $^{-1}$) of summer rice

Table 4.9a Effect of organic nutrient management and Biozyme formulations on net assimilation rate (g m^{-2} leaf area day^{-1}) of *kharif* rice

Treatment	Days After Transplanting				
	30-45	45-60	60-75	75-90	90-Harvest
T_1	0.515	0.202	0.200	0.099	0.052
T_2	0.534	0.177	0.235	0.086	0.053
T_3	0.476	0.109	0.186	0.106	0.130
T_4	0.793	0.041	0.225	0.099	0.065
T_5	0.732	0.067	0.252	0.043	0.117
T_6	0.638	0.096	0.240	0.047	0.121
T_7	0.678	0.071	0.253	0.085	0.081
T_8	0.710	0.061	0.241	0.086	0.069
T_9	0.539	0.181	0.178	0.098	0.053
T_{10}	0.625	0.170	0.197	0.118	0.059
T_{11}	0.627	0.190	0.166	0.128	0.075
T_{12}	0.641	0.219	0.151	0.113	0.054

Table 4.9b Effect of organic nutrient management and Biozyme formulations on net assimilation rate (g m^{-2} leaf area day^{-1}) of summer rice

Treatment	Days After Transplanting				
	30-45	45-60	60-75	75-90	90-Harvest
T_1	0.563	0.223	0.228	0.084	0.041
T_2	0.597	0.180	0.270	0.060	0.058
T_3	0.483	0.113	0.184	0.069	0.186
T_4	0.861	0.058	0.228	0.108	0.065
T_5	0.802	0.071	0.229	0.086	0.114
T_6	0.668	0.101	0.257	0.048	0.119
T_7	0.748	0.071	0.254	0.102	0.067
T_8	0.750	0.074	0.254	0.080	0.060
T_9	0.588	0.182	0.185	0.094	0.065
T_{10}	0.657	0.172	0.203	0.116	0.065
T_{11}	0.675	0.192	0.180	0.127	0.077
T_{12}	0.690	0.221	0.153	0.112	0.058

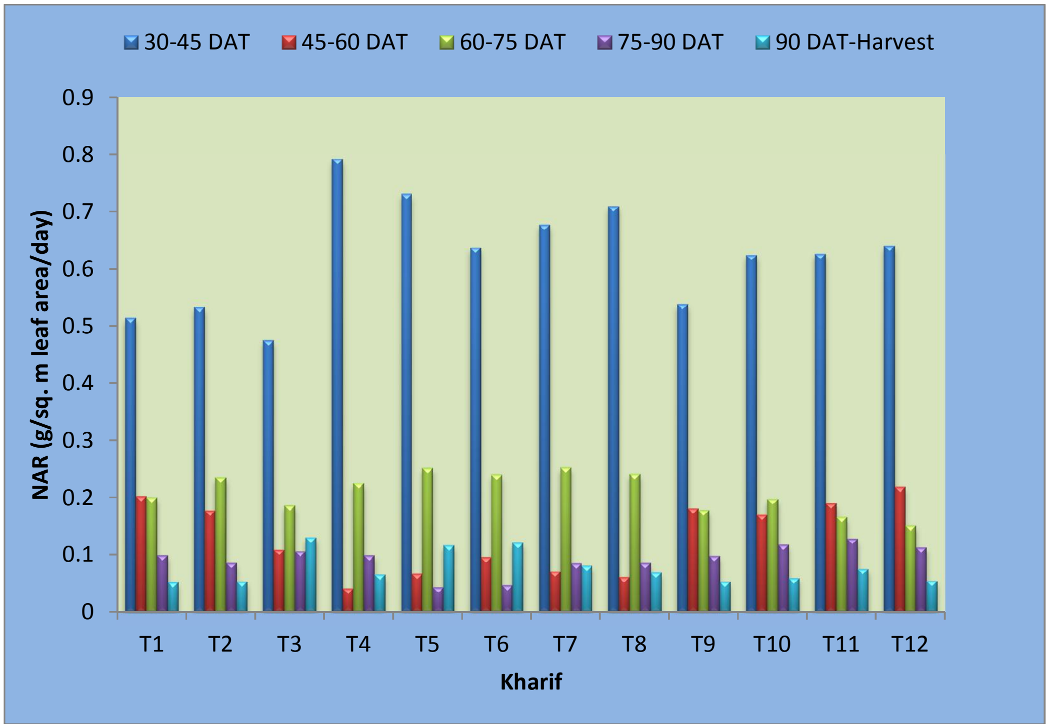


Fig. 4.9a Effect of organic nutrient management and Biozyme formulations on net assimilation rate (g m^{-2} leaf area day^{-1}) of *kharif* rice

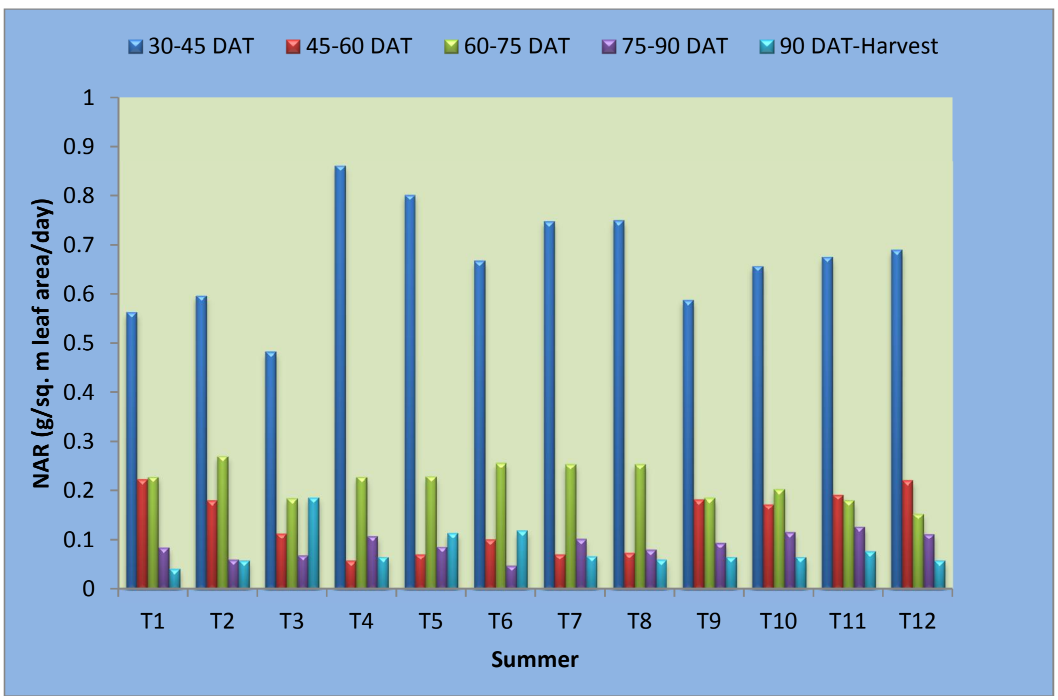


Fig. 4.9b Effect of organic nutrient management and Biozyme formulations on net assimilation rate (g m^{-2} leaf area day^{-1}) of summer rice

4.1.6 Dry matter accumulation

Dry matter production (g $hill^{-1}$) of rice recorded at 30, 45, 60, 75, 90 DAT and at harvest are presented in Table 4.6a and 4.6b; depicted in Fig.4.6a and 4.6b. It is observed that the dry matter production due to organic nutrient management and Biozyme formulations increased linearly up to maturity and followed similar trend in both the seasons. The average dry matter production were (10.73 and 9.52, 28.53 and 27.14, 36.24 and 34.90, 49.94 and 48.67, 55.98 and 54.44, 60.75 and 59.29 g $hill^{-1}$ in *kharif* and summer, respectively) recorded at 30, 45, 60, 75, 90 DAT and at harvest. Dry matter production was found more in the treatment T_{12} (75.08 and 73.50 g $hill^{-1}$ in *kharif* and summer, respectively) at harvest which was at par with those of T10 and T11 in *kharif* and T9 to T11 in summer respectively. On the other hand dry matter accumulation occurred less in T_1 (42.44 and 40.70 g $hill^{-1}$ in *kharif* and summer seasons, respectively) at harvest which was at par with that of T_2 in both the seasons.

4.1.7 Crop Growth Rate

Crop growth rate of rice recorded from 30 DAT till harvest are presented in Table 4.7a and 4.7b; depicted in Fig.4.7a and 4.7b. The average CGR (g $day^{-1}hill^{-1}$) were (1.187 and 1.175, 0.514 and 0.518, 0.913 and 0.918, 0.403 and 0.385, 0.318 and 0.323 g $day^{-1}hill^{-1}$ in *kharif* and summer, respectively) recorded during the period of 30-45, 45-60, 60-75, 75-90 DAT and at 90 DAT-harvest. Crop growth rate due to organic sources and Biozyme formulations were found maximum in all growth stages than the organic sources applied alone. Highest crop growth rate was recorded in the treatment T_{12} (1.480 and 1.489, 1.039 and 1.020, 0.802 and 0.793, 0.573 and 0.557, 0.261 and 0.270 g $day^{-1}hill^{-1}$ in *kharif* and summer, respectively) during 30-45, 45-

60, 60-75, 75-90 DAT and 90 DAT- harvest, whereas, treatment T1 resulted in minimum crop growth rate (0.703 and 0.670, 0.535 and 0.554, 0.647 and 0.705, 0.318 and 0.261, 0.149 and 0.111in *kharif* and summer seasons, respectively) during 30-45, 45-60, 60-75, 75-90 DAT and 90 DAT- harvest.

4.1.8 Relative Growth Rate

Relative growth rate of rice plant recorded from 30-45 DAT till 90 DAT-harvest are presented in Table 4.8a and 4.8b; depicted in Fig.4.8a and 4.8b. The relative growth rate (g $g^{-1}day^{-1}$) varied from 0.053-0.078, 0.004-0.028, 0.014-0.028, 0.004-0.010 and 0.003-0.014 during 30-45, 45-60, 60-75, 75-90 and 90-harvest, respectively in both crop sequence. The average RGR at 30-45, 45-60, 60-75, 75-90 DAT and 90 DAT-harvest were 0.065 and 0.069, 0.017 and 0.017, 0.023 and 0.023, 0.007 and 0.007, 0.006 and 0.006 g $g^{-1}day^{-1}$ in *kharif* and summer seasons, respectively.

4.1.9 Net Assimilation Rate

Data on net assimilation rate of rice estimated from 30 DAT to harvest at an interval of 15 days are presented in Table 4.9a and 4.9b; depicted in Fig. 4.9a and 4.9b. The net assimilation rate (g m^{-2} leaf area day^{-1}) varied from 0.476-0.861, 0.058-0.221, 0.151-0.221, 0. 043-0.128 and 0.041-0.186 during 30-45, 45-60, 60-75, 75-90 and 90-harvest, respectively in both crop seasons. The average NAR at 30-45, 45-60, 60-75, 75-90 DAT and 90 DAT-harvest were 0.626 and 0.674, 0.132 and 0.138, 0.210 and 0.219, 0.092 and 0.090, 0.078 and 0.081 g m^{-2} leaf area day^{-1} in *kharif* and summer seasons, respectively.

4.2 STUDIES ON YIELD ATTRIBUTING CHARACTERS

The yield attributing characters like number of panicle m^{-2}, length of panicle, number of grain per panicle and 1000-grain weight were studied at harvest of the rice crop. The mean data of these characters were collected replication wise, statistically analysed and has been presented in Table 4.10a and 4.10b; depicted in Fig.4.10a and 4.10b which followed similar trend in both the seasons.

4.2.1 Number of panicle m^{-2}

Data on number of panicle m^{-2} presented in Table 4.10a and 4.10b; depicted in Fig. 4.10a and 4.10b reveal that it followed similar trend in both the seasons. The treatment receiving Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) produced the highest number of panicle per m^2 (379.20 and 361.60 in *kharif* and summer seasons, respectively) at harvest. However, these were at par with those of T_7 to T_{11} in both the seasons. On the otherhand, treatments with only Dhanicha @ 25 kg seed ha^{-1} in *kharif* and no manure application in summer(T_1) resulted in less number of panicle per m^2 at harvest (225.07 and 204.27, respectively) which were at par with those of T_2 to T_6 in both the seasons.

4.2.2 Length of panicle

Data on panicle length presented in Table 4.10a and 4.10b; depicted in Fig. 4.10a and 4.10b indicate that rice crop supplied with Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) produced the highest length of panicle at harvest (31.8 and 30.6 in *kharif* and summer seasons, respectively) which was at par with those of T_9 to $T_{11.}$ The treatment T_1 recorded the smallest panicle (25.5 and 24.3 in *kharif* and summer seasons, respectively) at harvest in both the seasons.

Table 4.10a Effect of organic nutrient management and Biozyme formulations on panicle m^{-2}, length of panicle, number of grains per panicle of *kharif* rice

Treatment	Panicle m^{-2}	Length of panicle (cm)	No. of spikelet per panicle	No. of filled grain per panicle	Sterility (%)	1000 grain weight (g)
T_1	225.07	25.5	110.67	97.87	14.00	24.53
T_2	240.00	27.1	113.00	100.91	13.60	24.87
T_3	273.07	28.4	118.00	108.35	11.30	25.13
T_4	241.07	28.6	122.33	111.01	13.80	24.70
T_5	255.47	29.1	128.33	118.12	12.80	24.90
T_6	275.20	28.7	136.33	127.24	12.30	25.33
T_7	325.87	29.2	139.33	129.58	13.50	25.57
T_8	329.60	28.4	144.33	135.51	12.70	25.67
T_9	356.27	29.6	145.00	136.63	12.10	25.90
T_{10}	364.27	30.0	148.67	140.99	11.40	25.50
T_{11}	371.20	29.9	150.33	143.38	10.40	25.93
T_{12}	379.20	31.8	152.33	145.84	9.80	26.07
SE(m)±	**22.354**	**1.01**	**7.374**	**7.978**	**-**	**0.768**
CD(0.05)	**65.56**	**3.0**	**21.63**	**23.40**	**-**	**NS**
CV (%)	**12.78**	**6.07**	**9.53**	**11.09**	**-**	**5.25**

Table 4.10b Effect of organic nutrient management and Biozyme formulations on panicle m^{-2}, length of panicle, number of grains per panicle of summer rice

Treatment	Panicle m^{-2}	Length of panicle (cm)	No. of spikelet per panicle	No. of filled grain per panicle	Sterility (%)	1000 grain weight (g)
T_1	204.27	24.3	110.00	95.37	15.99	24.36
T_2	220.80	25.9	112.33	98.81	15.17	24.72
T_3	258.67	27.2	116.67	104.67	13.92	25.06
T_4	223.47	27.4	121.00	108.04	15.70	24.58
T_5	236.27	27.9	126.67	114.59	15.14	24.75
T_6	260.80	27.5	134.67	123.41	14.96	25.26
T_7	308.27	28.0	136.67	125.40	15.17	25.44
T_8	325.87	27.2	142.00	131.72	14.49	25.54
T_9	338.67	28.1	143.33	132.81	15.05	25.78
T_{10}	351.47	28.5	146.00	136.57	13.84	25.45
T_{11}	352.00	29.1	148.00	138.78	13.61	25.78
T_{12}	361.60	30.6	149.67	140.83	13.21	25.94
SE(m)±	**22.311**	**0.99**	**7.124**	**7.680**	**-**	**0.768**
CD(0.05p)	**65.43**	**2.9**	**20.89**	**22.52**	**-**	**NS**
CV (%)	**13.47**	**6.18**	**9.33**	**11.00**	**-**	**5.28**

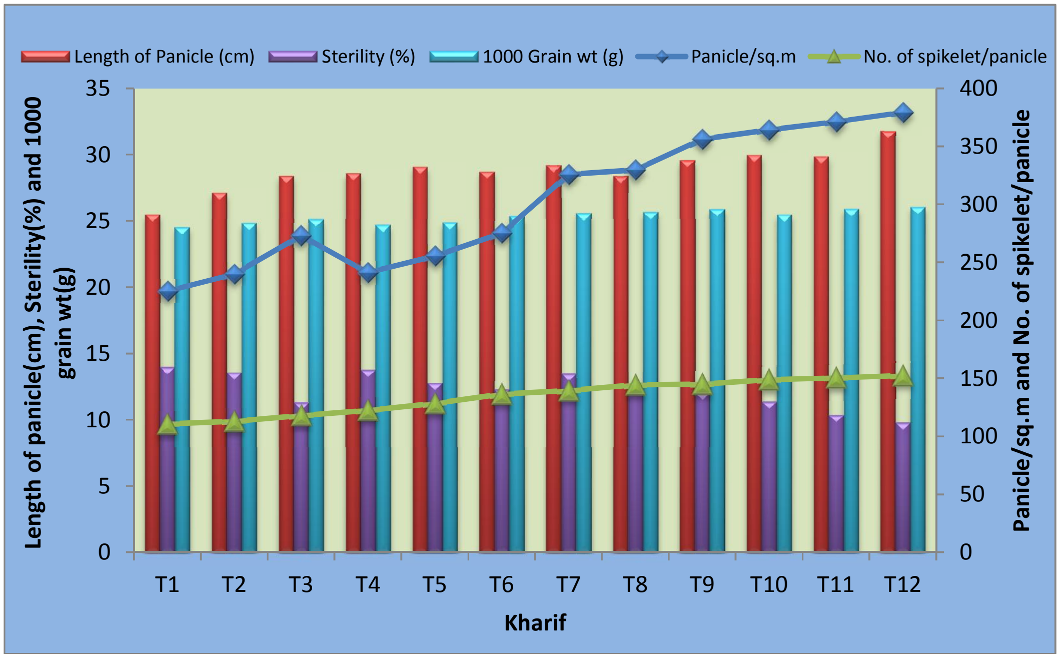


Fig. 4.10a **Effect of organic nutrient management and Biozyme formulations on panicle m^{-2}, length of panicle, number of grains per panicle of *kharif* rice**

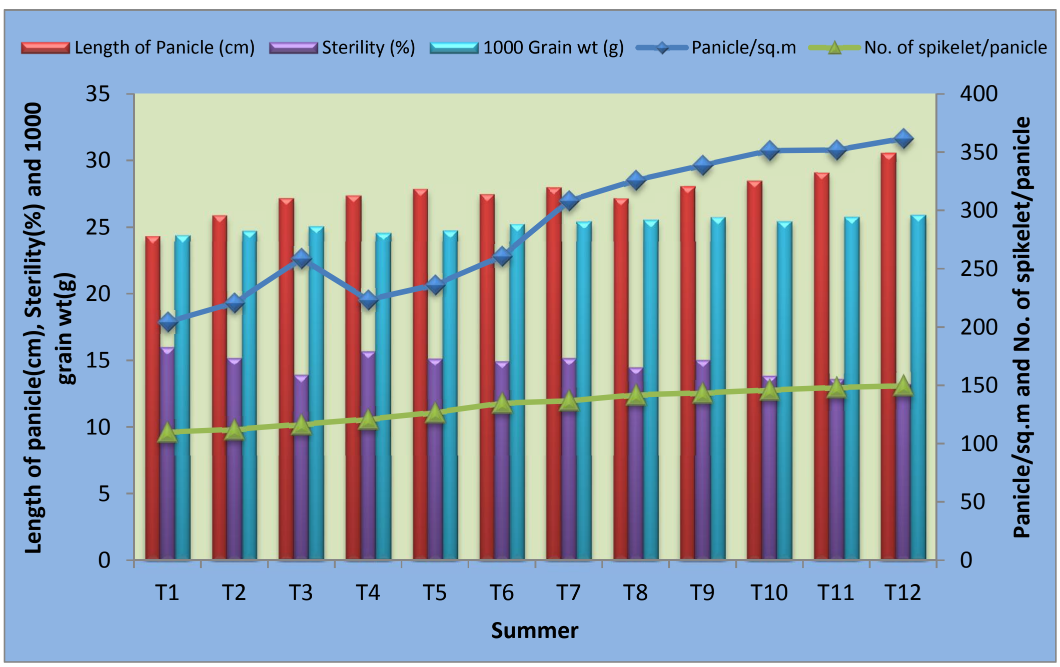


Fig. 4.10b **Effect of organic nutrient management and Biozyme formulations on panicle m^{-2}, length of panicle, number of grains per panicle of summer rice**

4.2.3 Number of Spikelet per panicle

Number of spikelet per panicle was found to be maximum (152.33 and 148.33 in *kharif* and summer seasons, respectively) for the treatment T_{12}, which was at par with those of treatments T_6 to T_{11} in both the seasons. However, the treatment T_1 resulted the lowest number of spikelet per panicle (110.67 and 109.67 in *kharif* and summer seasons, respectively) which was at par with those of T_2 to T_5 in both the seasons.

4.2.4 1000- grain weight

Various combinations of organic sources and Biozyme formulations did not influence the 1000- grain weight of rice cv. 'Lalat', which varied within a narrow range of 24.36 to 26.07 g including both the seasons with the average of 25.34 and 25.22 g in *kharif* and summer seasons, respectively. (Table 4.10a and 4.10b; Fig. 4.10a and 4.10b).

4.2.5 Number of filled grain per panicle

The average number of filled grains per panicle was recorded to be 124.62 and 122.37 in *kharif* and summer seasons, respectively. It was significantly affected by organic nutrient management and Biozyme formulations (Table 4.10a and 4.10b; Fig. 4.10a and 4.10b). Significantly more number of filled grains per panicle (145.84 and 142.09 in *kharif* and summer seasons, respectively) was observed in T_{12} and was at par with those of T_6 to T_{11} in both the seasons.

4.2.6 Sterility percentage

Application of Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) resulted lowest sterility percentage of 9.80 and 9.18 % (Table 4.10a and 4.10b; Fig. 4.10a and 4.10b) being at par with T_{11} in both *kharif* and summer seasons. Maximum sterility percentage was observed in T_1 (14.00% and 13.33% in *kharif* and summer seasons, respectively) which was at par with those of T_2, T_4 and T_7 in kahrif and T_2, T_4, T_5, T_7 and T_8 in summer seasons, respectively.

4.3 STUDIES ON YIELD

Grain yield, straw yield, and harvest index were studied after the harvest of rice crop. The mean data of these characters were collected replication wise, statistically analysed and has been presented in Table 4.11a and 4.11b; depicted in Fig. 4.11a and 4.11b.

4.3.1 Grain yield

Perusal of data on grain yield presented in Table 4.11a and 4.11b; depicted in Fig. 4.11a and 4.11b reveal that on an average, rice cv. 'Lalat' produced 4243 and 4108 kg grains ha^{-1} in *kharif* and summer seasons, respectively. Various combinations of organic and Biozyme formulations to supply plant nutrients significantly influenced the grain yield. Application of Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) resulted in the highest grain yield (5087 and 4951 kg ha^{-1} in *kharif* and summer seasons, respectively) which was at par with those of T_9 to T_{11} in *kharif* and T_8 to T_{11} in summer seasons, respectively. However, the treatment T_1 was the lowest yielder (3480 and 3332 kg ha^{-1} in *kharif* and summer seasons, respectively), which was at par with those of T_2 and T_3 in *kharif* and T_2 to T_5 in summer seasons, respectively.

4.3.2 Straw yield

Different combinations of organic sources and Biozyme formulations significantly influenced the straw yield of rice cv 'Lalat' and followed similar trend in both the seasons (Table 4.11a and 4.11b; Fig. 4.11a and 4.11b). On an average the crop produced 4817 and 4629 kg straw ha^{-1} in *kharif* and summer season, respectively. Like grain yield, T_{12} produced the highest straw yield (5647 and 5444 kg ha^{-1} in *kharif* and summer seasons, respectively) which was on a par with those of T_8 to T_{11} in both the seasons. The treatment T_1 was recorded as the lowest straw yielder (4073 and 3859 kg ha^{-1} in *kharif* and summer seasons, respectively) and was at par with those of T_2 to T_5 in *kharif* and T_2 to T_6 in summer seasons, respectively.

4.3.3 Harvest Index

Various combinations of organic sources and Biozyme formulations of plant nutrients could not influence the harvest index of rice cv. 'Lalat' (Table 4.11 and Fig. 4.11), which varied within a narrow range of 0.46-0.48 in both the seasons. However, the value was numerically the highest under T_{11}

and T_{12} for summer season (0.48). In general, application of organic sources alone showed lesser values of harvest index than those due to combination of organic sources and Biozyme formulations.

Table 4.11 Effect of organic nutrient management and Biozyme formulations on grain yield (q ha^{-1}) and straw yield (q ha^{-1}) of *kharif* and summer rice

Treatment	*Kharif*			Summer		
	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest Index	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest Index
T_1	34.80	40.73	0.46	33.32	38.59	0.47
T_2	35.90	41.53	0.46	34.48	39.45	0.47
T_3	39.57	45.07	0.47	38.33	43.83	0.47
T_4	37.31	43.27	0.46	35.95	41.24	0.47
T_5	38.30	44.13	0.46	36.88	42.05	0.47
T_6	40.60	47.03	0.46	39.36	44.79	0.47
T_7	42.87	48.97	0.47	41.51	47.27	0.47
T_8	45.80	51.13	0.47	44.44	49.44	0.47
T_9	48.63	53.93	0.47	47.27	52.24	0.47
T_{10}	46.50	52.37	0.47	45.32	50.85	0.47
T_{11}	48.03	53.43	0.47	46.61	51.35	0.48
T_{12}	50.87	56.47	0.47	49.51	54.44	0.48
SE(m)±	**1.651**	**2.062**	**-**	**1.831**	**2.286**	**-**
CD(0.05p)	**4.84**	**6.05**	**-**	**5.37**	**6.70**	**-**
CV (%)	**6.74**	**7.41**	**-**	**7.72**	**8.55**	**-**

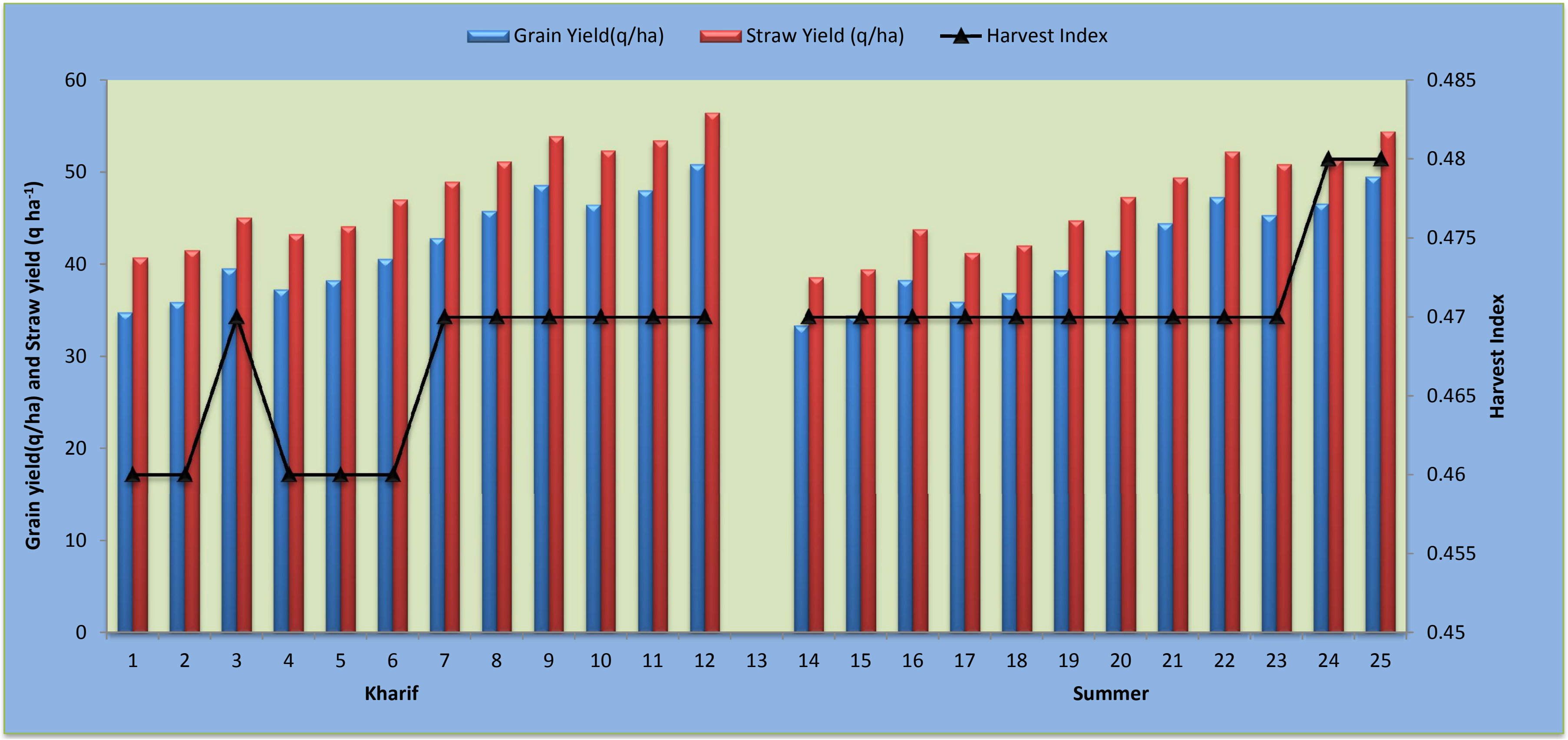


Fig. 4.11 **Effect of organic nutrient management and Biozyme formulations on grain yield (q ha^{-1}) and straw yield (q ha^{-1}) of *kharif* and summer rice**

4.4 STUDIES ON MICROBIAL POPULATION

Data on microbial population was recorded for both the seasons before transplanting, at 30 days interval during crop growing season and after harvest and presented in the Table. 4.12a and 4.12b; 4.13a and 4.13b; 4.14a and 4.14b (Plate 4 and 5)

4.4.1 Bacterial population

Data on bacterial population have least variation between before transplanting and after harvest observations (Table 4.12a and 4.12b; Fig. 4.12a and 4.12b). But, during crop growing seasons, it was highly influenced by organic nutrients and Biozyme formulations. The treatment receiving Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) produced the highest bacterial population (1.1×10^7 and 1.08×10^7 cfu g^{-1} of soil in *kharif* and summer seasons, respectively) at 90 DAT. On the otherhand, treatments with only Dhanicha @ 25 kg seed ha^{-1} in *kharif* and no manure application in summer(T_1) resulted in lowest bacterial population at 90 DAT (6.03×10^6 and 5.8×10^6 cfu g^{-1} of soil in *kharif* and summer seasons, respectively). A positive linear relationship (R^2 = 0.706 and 0.707 in *kharif* and summer seasons, respectively) was observed between bacterial population at 90 DAT and grain yield (Fig. 4.23).

4.4.2 Actinomycetes population

Actinomycetes population reveal conspicuous variation during crop growing season influenced by organic nutrient management and Biozyme formulations whereas initial and after harvest shows least variation among treatments (Table 4.13a and 4.13b; Fig. 4.13a and 4.13b). The treatment T_{12} registered the highest population in both the season (1.14×10^7 and 1.11×10^7 cfu g^{-1} of soil in *kharif* and summer seasons, respectively) at 90 DAT whereas the treatment T_1 resulted in the lowest population (6.9×10^6 and 6.6×10^6 cfu g^{-1} of soil in *kharif* and summer seasons, respectively) at 90 DAT. A positive linear relationship (R^2 = 0.566 and 0.574 in *kharif* and summer seasons, respectively) was observed between actinomycetes population at 90 DAT and grain yield (Fig. 4.24).

Table 4.12a Effect of organic nutrient management and Biozyme formulations on bacterial population (cfu g^{-1} of soil) of *kharif* rice

Treatment	Days After Transplanting				
	Initial ($x\ 10^4$)	30 ($x\ 10^5$)	60 ($x\ 10^5$)	90 ($x\ 10^5$)	After Harvest ($x\ 10^5$)
T_1	53.00	56.00	58.33	60.33	36.67
T_2	52.00	59.00	68.67	73.33	38.67
T_3	53.67	65.00	87.67	99.33	45.00
T_4	53.33	61.00	81.33	83.00	42.33
T_5	54.33	62.00	83.00	83.33	42.67
T_6	52.00	67.00	90.00	91.00	44.67
T_7	53.00	65.00	91.00	93.33	50.67
T_8	54.33	80.00	92.00	99.00	52.67
T_9	54.67	75.00	99.00	98.33	54.33
T_{10}	51.33	72.00	95.00	92.00	56.67
T_{11}	53.00	89.00	97.00	97.00	60.67
T_{12}	53.33	93.00	101.00	110.00	62.33

Table 4.12b Effect of organic nutrient management and Biozyme formulations on bacterial population (cfu g^{-1} of soil) of summer rice

Treatments	Days After Transplanting				
	Initial ($x\ 10^4$)	30 ($x\ 10^5$)	60 ($x\ 10^5$)	90 ($x\ 10^5$)	After Harvest ($x\ 10^5$)
T_1	33.00	54.00	56.33	58.33	39.33
T_2	36.33	56.00	65.67	70.33	37.33
T_3	43.00	63.00	85.67	97.33	42.00
T_4	42.00	57.00	77.33	79.00	40.33
T_5	42.67	59.00	80.00	80.33	43.33
T_6	43.00	65.00	88.00	89.00	39.67
T_7	46.00	62.00	88.00	90.33	44.00
T_8	46.67	76.00	88.00	95.00	46.67
T_9	47.33	73.00	97.00	96.33	48.67
T_{10}	48.00	69.00	92.00	89.00	49.33
T_{11}	49.33	85.00	93.00	93.00	53.00
T_{12}	50.67	91.00	99.00	108.00	53.67

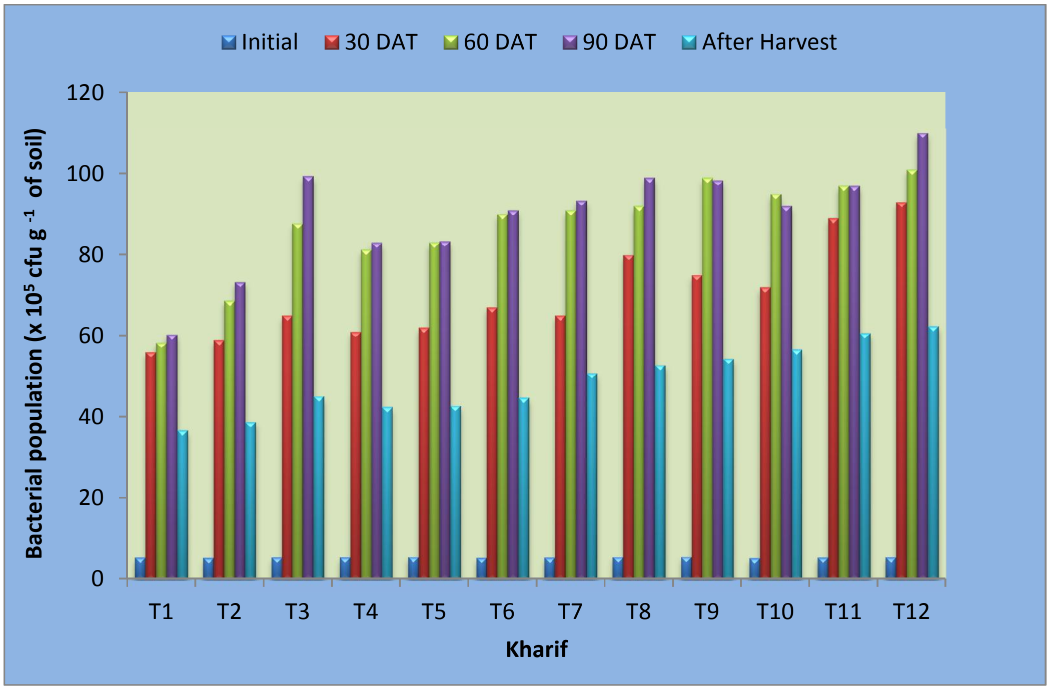


Fig. 4.12a Effect of organic nutrient management and Biozyme formulations on bacterial population (cfu g $^{-1}$ of soil) of *kharif* rice

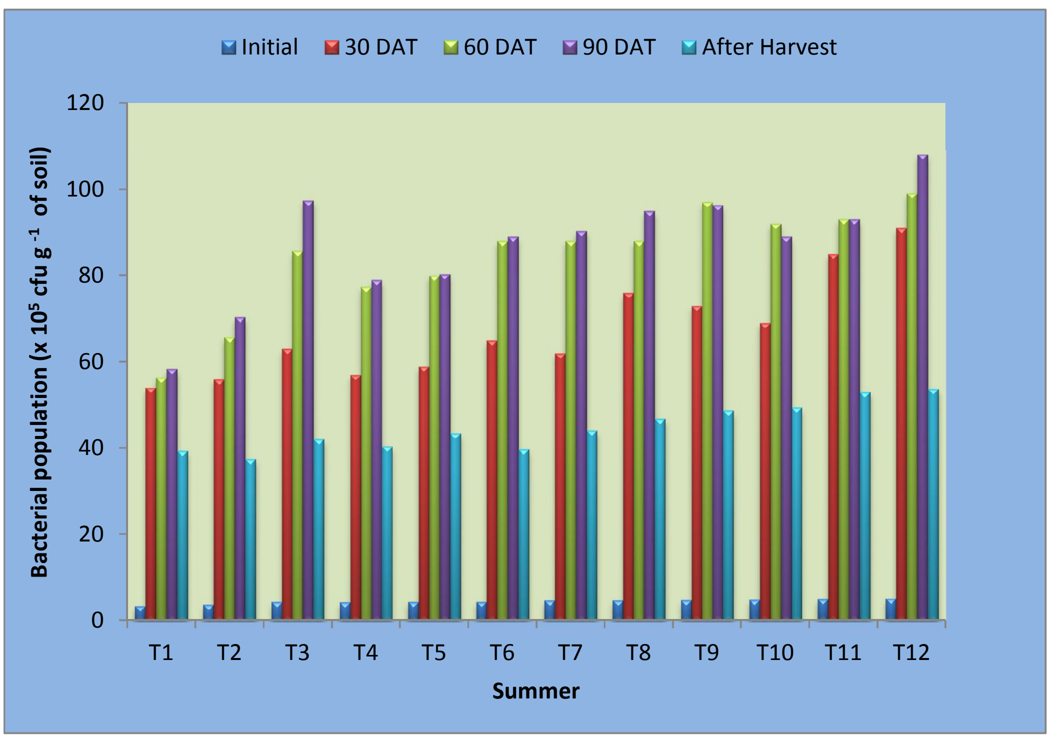


Fig. 4.12b Effect of organic nutrient management and Biozyme formulations on bacterial population (cfu g $^{-1}$ of soil) of summer rice

Table 4.13a Effect of organic nutrient management and Biozyme formulations on actinomycetes population (cfu g^{-1} of soil) of *kharif* rice

Treatments	Days After Transplanting				
	Initial (x 10^4)	30 (x 10^5)	60 (x 10^5)	90 (x 10^5)	After Harvest (x 10^4)
T_1	44.67	57.67	65.67	69.67	65.33
T_2	46.00	62.00	72.00	73.00	70.00
T_3	44.00	85.00	91.67	99.00	93.00
T_4	44.67	67.00	69.00	75.33	72.33
T_5	43.00	69.00	71.00	75.67	71.67
T_6	46.00	71.00	75.00	79.00	79.33
T_7	45.00	76.33	83.00	82.67	78.33
T_8	49.67	78.00	88.00	85.33	84.33
T_9	49.67	84.33	92.67	88.33	87.00
T_{10}	48.00	83.00	89.33	90.67	86.00
T_{11}	48.33	92.00	97.00	90.67	87.67
T_{12}	46.00	83.67	114.00	96.33	94.33

Table 4.13b Effect of organic nutrient management and Biozyme formulations on actinomycetes population (cfu g^{-1} of soil) of summer rice

Treatment	Days After Transplanting				
	Initial (x 10^4)	30 (x 10^5)	60 (x 10^5)	90 (x 10^5)	After Harvest (x 10^4)
T_1	40.00	54.67	62.67	66.67	38.33
T_2	38.67	59.00	69.00	70.00	42.67
T_3	45.00	82.00	88.67	96.00	46.67
T_4	41.67	64.00	66.00	72.33	42.67
T_5	41.33	66.00	68.00	72.67	45.67
T_6	42.00	68.00	72.00	76.00	46.00
T_7	42.67	73.33	80.00	79.67	51.33
T_8	43.33	75.00	85.00	82.33	54.67
T_9	44.67	81.33	89.67	85.33	50.33
T_{10}	45.00	80.00	86.33	87.67	54.33
T_{11}	48.67	89.00	94.00	87.67	53.33
T_{12}	43.00	80.67	111.00	93.33	54.00

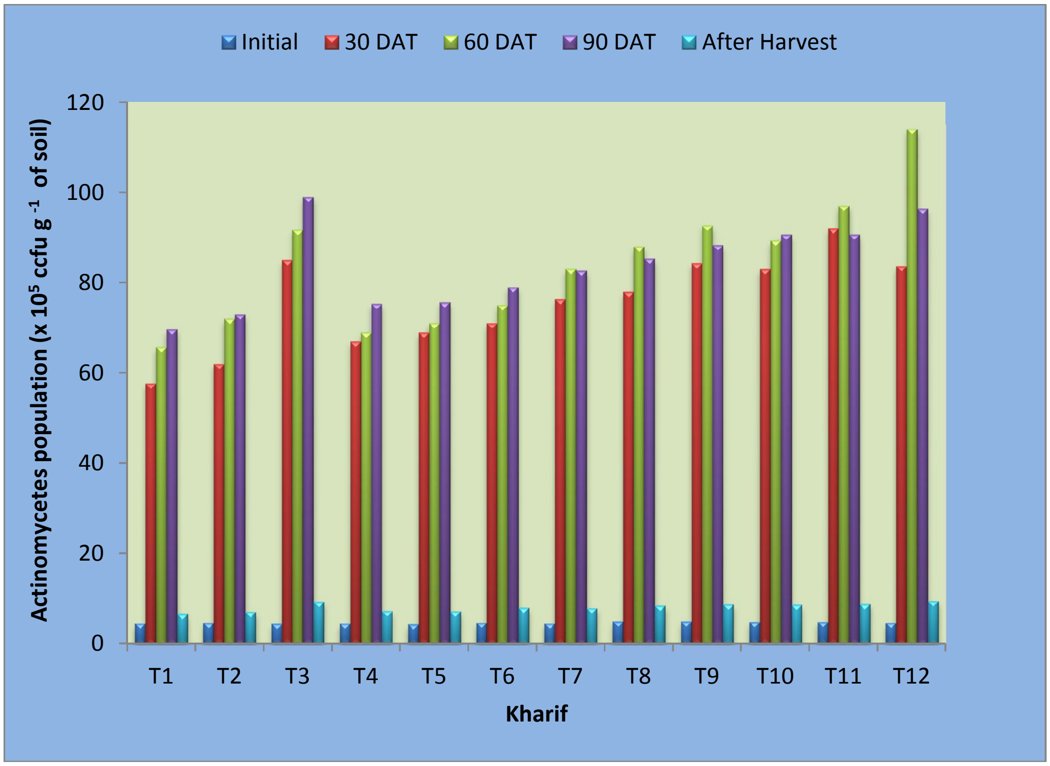


Fig. 4.13a Effect of organic nutrient management and Biozyme formulations on actinomycetes population (cfu g $^{-1}$ of soil) of *kharif* rice

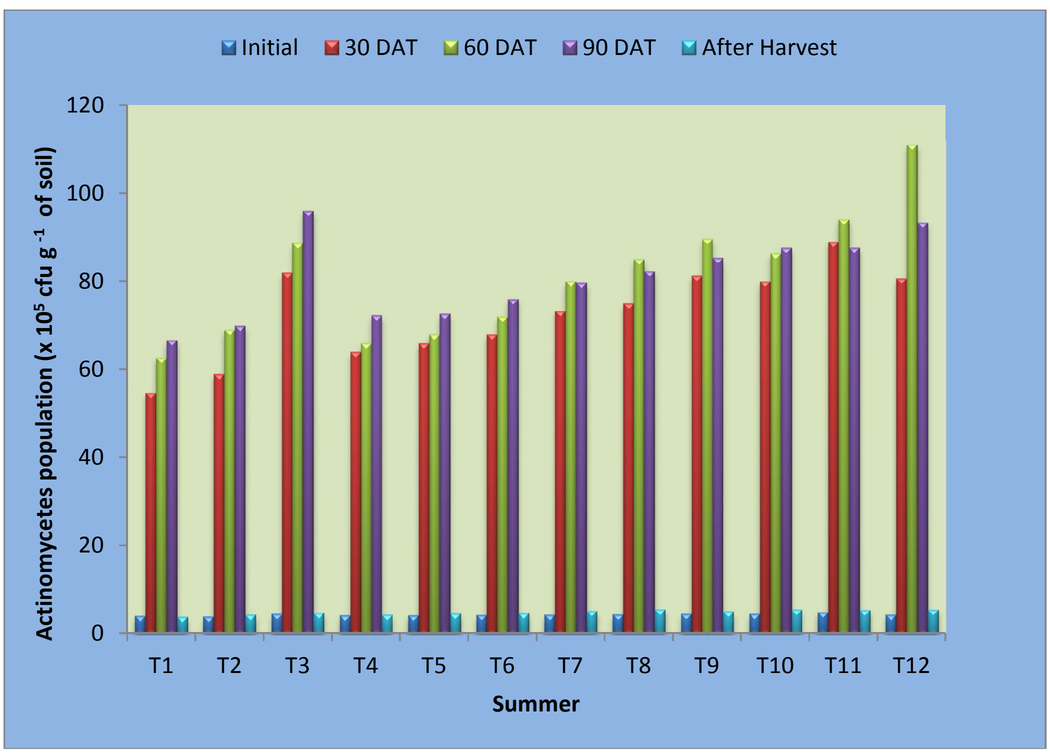


Fig. 4.13b Effect of organic nutrient management and Biozyme formulations on actinomycetes population (cfu g $^{-1}$ of soil) of summer rice

Table 4.14a Effect of organic nutrient management and Biozyme formulations on fungal population (cfu g^{-1} of soil) of *kharif* rice

Treatment	Days After Transplanting				
	Initial ($x 10^3$)	30 ($x 10^3$)	60 ($x 10^3$)	90 ($x 10^3$)	After Harvest ($x 10^3$)
T_1	42.33	63.00	63.00	61.00	36.00
T_2	44.00	64.33	71.00	71.00	38.33
T_3	44.00	72.00	73.00	73.00	47.33
T_4	46.67	66.00	67.67	68.00	42.67
T_5	46.00	66.00	71.00	71.33	44.67
T_6	42.67	69.00	69.00	69.00	45.00
T_7	43.00	83.00	81.67	81.00	49.33
T_8	47.67	85.00	81.33	82.00	50.67
T_9	45.67	99.33	96.00	92.33	52.67
T_{10}	45.00	91.00	91.00	91.67	53.67
T_{11}	46.00	92.00	89.00	91.00	55.00
T_{12}	46.00	98.67	105.67	96.33	56.33

Table 4.14b Effect of organic nutrient management and Biozyme formulations on fungal population (cfu g^{-1} of soil) of summer rice

Treatment	Days After Transplanting				
	Initial ($x 10^3$)	30 ($x 10^3$)	60 ($x 10^3$)	90 ($x 10^3$)	After harvest ($x 10^3$)
T_1	38.00	60.00	60.00	58.00	36.67
T_2	38.67	62.33	69.00	69.00	38.67
T_3	41.00	69.00	70.00	70.00	42.00
T_4	44.67	62.00	63.67	64.00	39.33
T_5	41.67	62.00	67.00	67.33	41.67
T_6	39.67	66.00	66.00	66.00	40.33
T_7	41.00	81.00	79.67	79.00	41.00
T_8	44.00	80.00	76.33	77.00	40.33
T_9	46.00	97.33	94.00	90.33	43.33
T_{10}	41.00	87.00	87.00	87.67	40.67
T_{11}	44.00	90.00	87.00	89.00	46.67
T_{12}	43.00	107.00	96.00	93.33	45.33

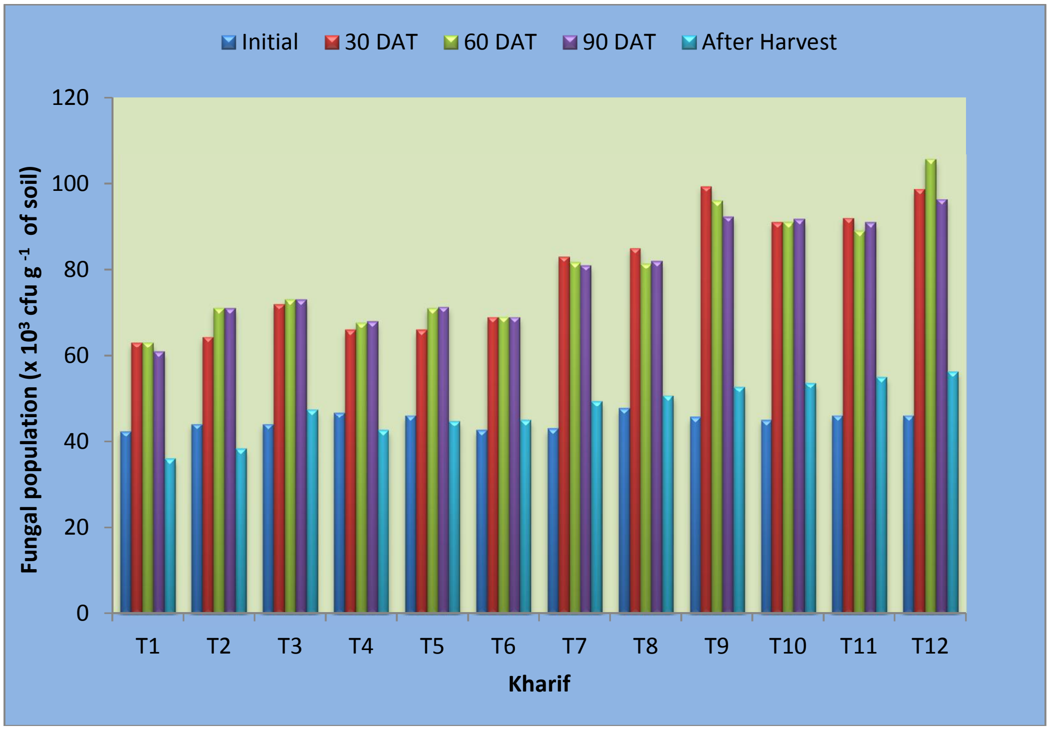


Fig. 4.14a Effect of organic nutrient management and Biozyme formulations on fungal population (cfu g $^{-1}$ of soil) of *kharif* rice

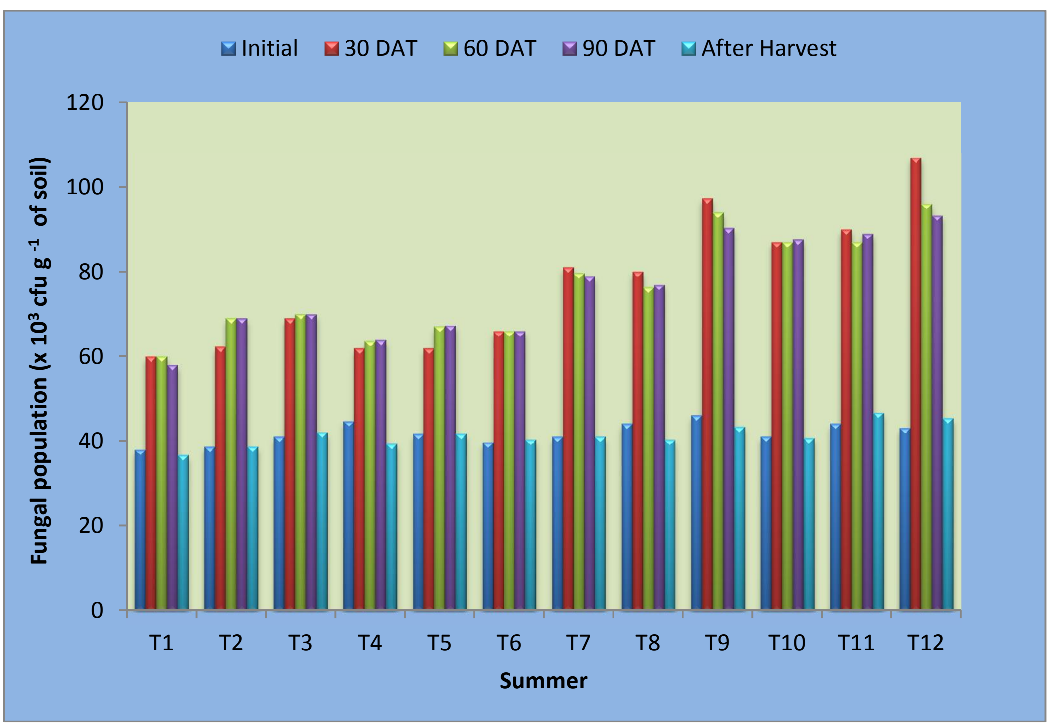
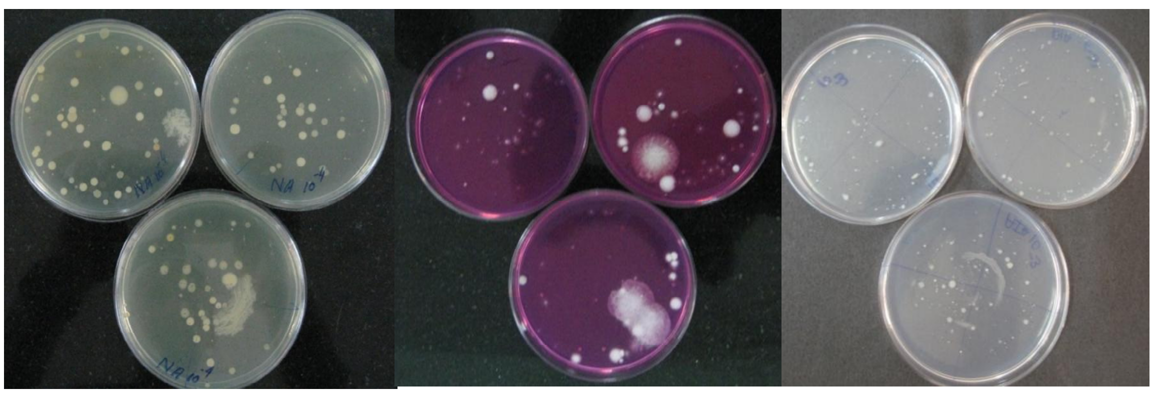


Fig. 4.14b Effect of organic nutrient management and Biozyme formulations on fungal population (cfu g $^{-1}$ of soil) of summer rice

Plate 3: Soil microbial study in the laboratory



Bacterial load (10^{-4} dilution)	Fungal load (10^{-2} dilution)	Actinomycetes load (10^{-4} dilution)

Plate 4: Microbial population count

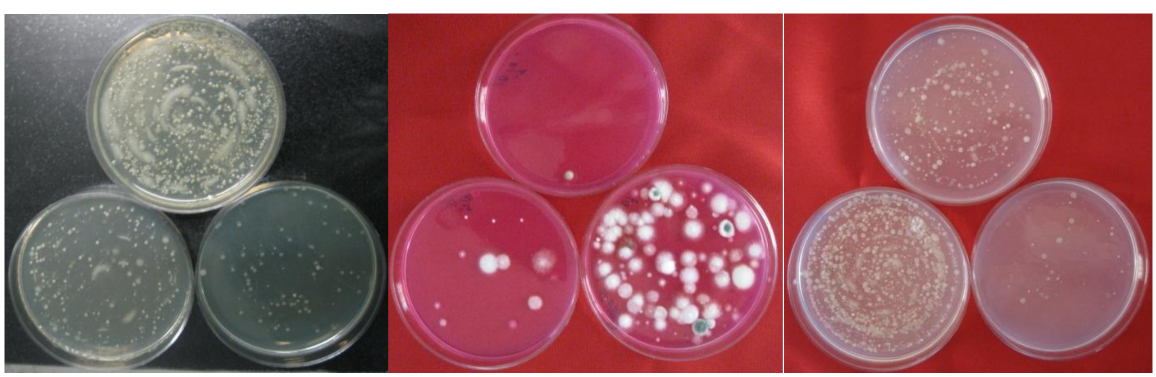


Plate 5: Bacteria, Fungi and Actinomycetes Population with 10^{-2}, 10^{-3} and 10^{-4} dilution

4.4.3 Fungal population

Fungal population showed least significant variation under the influence of organic nutrient management and Biozyme formulations but the population of fungi increased to some extent than the initial status during crop growing seasons and then reduced after the crop was harvested (Table 4.14a and 4.14b; Fig 4.14a and 4.14b). The treatment T_{12} resulted in highest fungal population (1.05×10^5 and 1.07×10^5 cfu g^{-1} of soil in *kharif* and summer seasons) at 60 and 30 DAT, respectively. A strong positive linear relationship (R^2 = 0.926 and 0.906 in *kharif* and summer seasons, respectively) was observed between fungal population at 90 DAT and grain yield (Fig. 4.25).

4.5 STUDIES ON NITROGEN, PHOSPHOROUS AND POTASSIUM CONTENT (%) OF RICE

The nitrogen, phosphorus and potassium content of rice crop was estimated and presented in Table 4.15a and 4.15b; depicted in Fig. 4.15a and 4.15b. The average percentage of nitrogen, phosphorus and potassium both in grain and straw were 1.27 and 0.46 %; 0.27 and 0.08 %; 0.21 and 1.73 % respectively in *kharif* whereas, the average percentage of nitrogen, phosphorus and potassium both in grain and straw were 1.26 and 0.44 %; 0.26 and 0.08 %; 0.18 and 1.62 % respectively in summer season. The N-P-K content of rice was not radically influenced by organic nutrient management and Biozyme formulations. The treatment T_1 registered higher percentage of nitrogen, phosphorus and potassium content both in grain and straw (1.35 and 0.49; 0.30 and 0.10; 0.24 and 1.98 per cent in *kharif* ; 1.33 and 0.47; 0.28 and 0.09; 0.21 and 1.83 percent in summer seasons, respectively). Lower percentage of N-P-K content was found in T_{12} in both the seasons.

Table 4.15a Effect of organic nutrient management and Biozyme formulations on nutrient content of *kharif* rice

Treatment	Nitrogen (%)		Phosphorous (%)		Potassium (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1	1.35	0.49	0.30	0.10	0.24	1.98
T_2	1.33	0.49	0.29	0.10	0.23	1.88
T_3	1.30	0.47	0.29	0.09	0.23	1.75
T_4	1.32	0.48	0.27	0.07	0.24	1.89
T_5	1.27	0.45	0.27	0.07	0.22	1.74
T_6	1.26	0.46	0.28	0.08	0.21	1.76
T_7	1.26	0.45	0.27	0.07	0.21	1.73
T_8	1.24	0.46	0.26	0.07	0.20	1.64
T_9	1.24	0.44	0.26	0.08	0.19	1.59
T_{10}	1.26	0.44	0.27	0.09	0.19	1.60
T_{11}	1.24	0.44	0.26	0.06	0.17	1.58
T_{12}	1.22	0.42	0.26	0.06	0.17	1.56

Table 4.15b Effect of organic nutrient management and Biozyme formulations on nutrient content of summer rice

Treatments	Nitrogen (%)		Phosphorous (%)		Potassium (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1	1.33	0.47	0.28	0.09	0.21	1.83
T_2	1.31	0.47	0.27	0.09	0.21	1.79
T_3	1.29	0.46	0.28	0.08	0.20	1.72
T_4	1.29	0.46	0.26	0.07	0.20	1.72
T_5	1.26	0.45	0.26	0.08	0.20	1.66
T_6	1.25	0.44	0.26	0.09	0.19	1.60
T_7	1.25	0.43	0.25	0.08	0.19	1.55
T_8	1.25	0.44	0.25	0.08	0.18	1.57
T_9	1.24	0.41	0.25	0.07	0.17	1.52
T_{10}	1.24	0.42	0.24	0.07	0.16	1.50
T_{11}	1.23	0.39	0.24	0.07	0.14	1.48
T_{12}	1.20	0.38	0.23	0.06	0.14	1.47

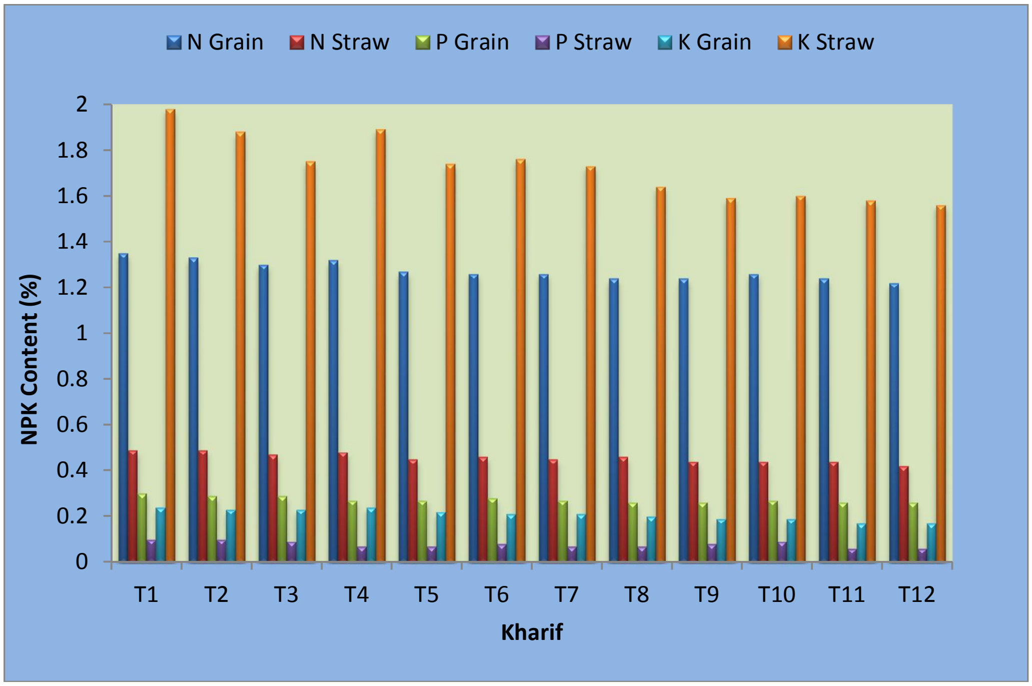


Fig. 4.15a Effect of organic nutrient management and Biozyme formulations on nutrient content of *kharif* rice

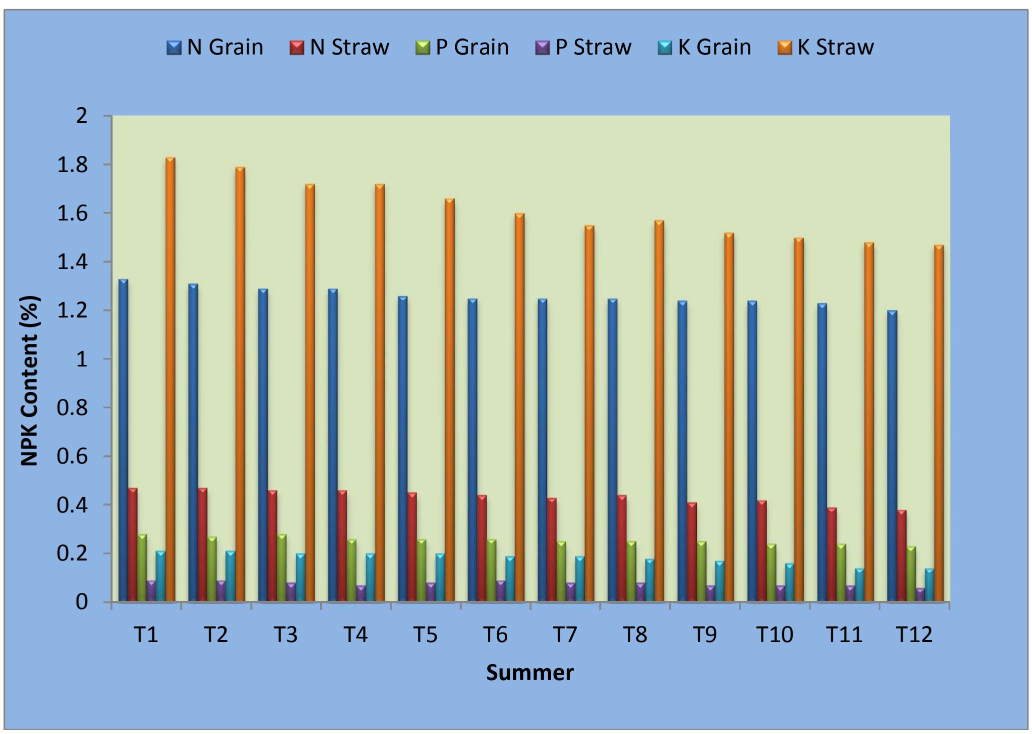


Fig. 4.15b Effect of organic nutrient management and Biozyme formulations on nutrient content of summer rice

Table 4.16a Effect of organic nutrient management and Biozyme formulations on nutrient uptake (kg ha^{-1}) of *kharif* rice

Treatment	Nitrogen (kg ha^{-1})		Phosphorous (kg ha^{-1})		Potassium (kg ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1	33.96	14.11	7.24	2.02	4.73	52.39
T_2	34.37	15.06	7.21	2.05	4.71	54.07
T_3	41.15	16.30	8.82	3.34	6.20	59.29
T_4	37.14	15.32	7.79	2.79	5.69	55.36
T_5	39.23	16.70	8.23	2.54	6.33	59.54
T_6	42.18	17.38	9.04	2.70	7.03	66.82
T_7	44.09	18.34	9.80	3.19	7.35	70.18
T_8	46.79	18.86	9.95	2.93	8.10	72.91
T_9	52.67	21.09	10.77	3.08	9.58	83.05
T_{10}	49.14	19.97	10.96	3.82	8.69	74.37
T_{11}	51.77	21.19	11.29	4.32	8.95	81.30
T_{12}	55.88	22.38	12.42	4.57	9.94	90.44

Table 4.16b Effect of organic nutrient management and Biozyme formulations on nutrient uptake (kg ha^{-1}) of summer rice

Treatment	Nitrogen (kg ha^{-1})		Phosphorous (kg ha^{-1})		Potassium (kg ha^{-1})	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T_1	32.23	11.77	6.18	1.86	3.76	45.53
T_2	34.17	12.46	6.67	2.24	3.89	47.30
T_3	39.02	14.94	7.55	2.49	5.03	53.35
T_4	35.91	13.65	7.24	2.33	4.92	50.60
T_5	37.13	14.93	7.43	2.72	5.35	53.29
T_6	39.86	15.67	7.97	2.91	6.06	56.47
T_7	42.26	16.99	8.79	3.48	6.42	61.79
T_8	45.30	17.98	9.35	3.20	7.19	66.32
T_9	49.56	19.18	9.99	2.92	7.68	71.71
T_{10}	46.64	18.57	10.12	3.23	7.23	69.45
T_{11}	49.50	19.54	10.20	3.74	7.94	74.43
T_{12}	52.94	20.66	11.15	3.96	8.36	80.43

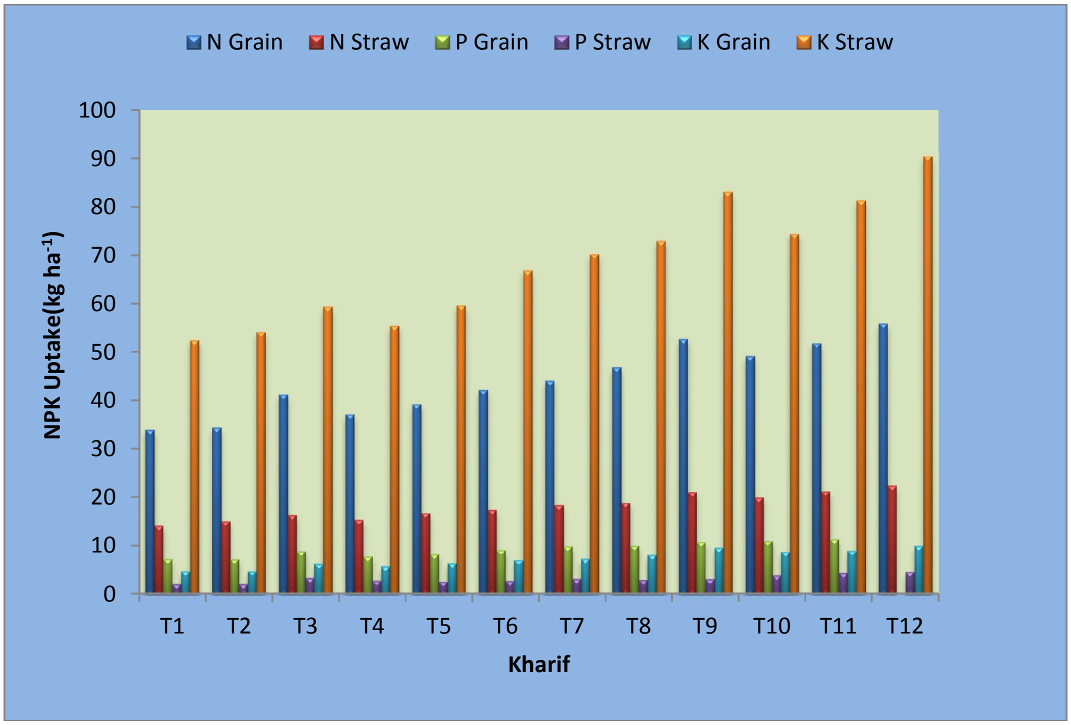


Fig. 4.16a Effect of organic nutrient management and Biozyme formulations on nutrient uptake (kg ha^{-1}) of *kharif* rice

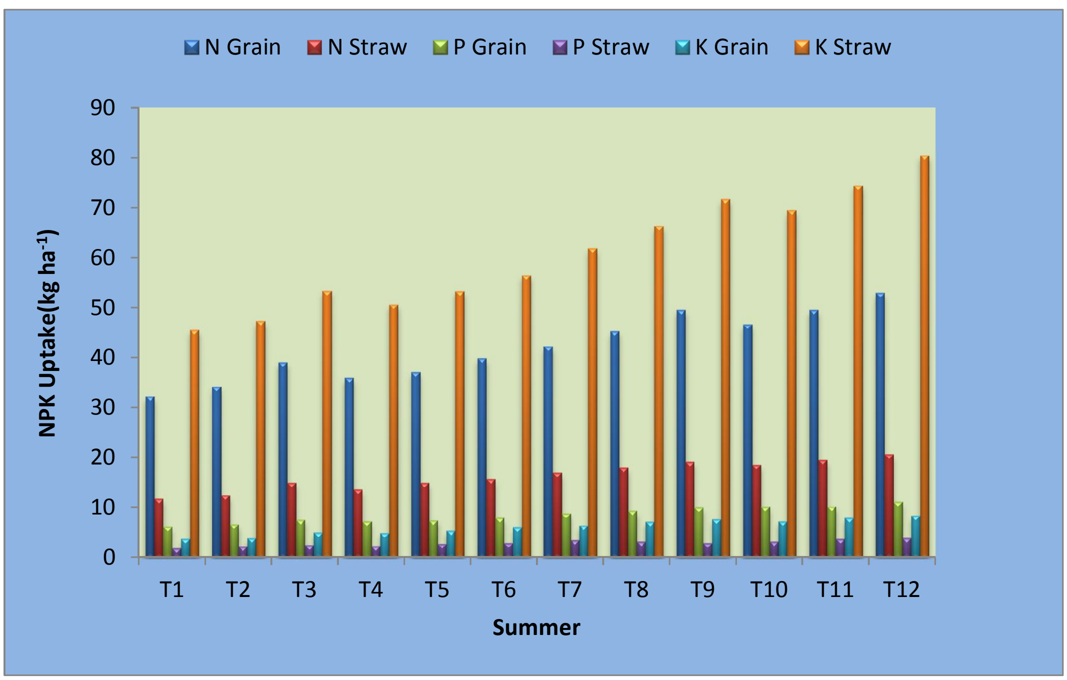


Fig. 4.16b Effect of organic nutrient management and Biozyme formulations on nutrient uptake (kg ha^{-1}) of summer rice

4.6 STUDIES ON NITROGEN, PHOSPHOROUS AND POTASSIUM UPTAKE OF RICE

The average uptake of nitrogen, phosphorus and potassium by rice crop both in grain and straw were 44.03 and 18.06 kg ha^{-1}; 9.46 and 3.11 kg ha^{-1} ; 7.28 and 68.31 kg ha^{-1} in *kharif* where as 42.04 and 16.36 kg ha^{-1}; 8.55 and 2.92 kg ha^{-1} ; 6.15 and 60.89 kg ha^{-1} in summer, respectively (Table 4.16a and 4.16b; Figure 4.16a and 4.16b). The N-P-K uptake was slightly influenced by organic nutrient management and Biozyme formulations. The maximum N-P-K uptake values was observed at T_{12} (55.88 and 22.38; 12.42 and 4.57; 9.94 and 90.44 in *kharif;* 52.94 and 20.66; 11.15 and 3.96; 8.36 and 80.43 kg ha^{-1}in summer seasons, respectively) whereas the lowest value was observed at T_1 in both the seasons.

4.7 STUDIES ON SOIL FERTILITY STATUS

The fertility status of the soil was analysed after harvest of both seasons' rice crop and presented in Table 4.17a and 4.17b; depicted in Fig. 4.17a and 4.17b. The available nutrient status of N-P-K was in the range of 314 to 397; 34.43 to 43.46 and 220.2 to 242.56 kg ha^{-1} in both the seasons. The average N-P-K status was 372 and 358; 39 and 36; 240 and 229 kg ha^{-1} in *kharif* and summer seasons, respectively which was very close to the initial values. The bulk density and particle density were in the range of 1.52 to 1.56 and 2.62 to 2.64 t m^{-3}, respectively due to organic nutrient management options and Biozyme formulations which were slightly less than the initial values. The pH was in the range of 6.4 to 6.9 as against initial value of 6.3. Organic carbon increased marginally due to all organic nutrient management and Biozyme formulations (10.2 to 15.7, as against 9.7 g kg^{-1}). Overall, the soil fertility status improved for all treatments of organic nutrient management and Biozyme formulations. Soil fertility status after system yield (N-P-K @ 358, 36, 229 kg ha^{-1} ; OC @ 12 g kg^{-1}; pH@ 6.6; EC@0.115 dSm^{-1}; BD and PD@ 1.54 and 2.63 t m^{-3}) was very close to those of initial status of soil. A strong positive linear relationship (R^2 = 0.825 and 0.938 in *kharif* and summer seasons, respectively) was observed between OC and grain yield (Fig. 4.22).

Table 4.17a Effect of organic nutrient management and Biozyme formulations on soil fertility status after *kharif* rice harvest

Treatment	Available nutrients (kg ha^{-1})			Organic Carbon (g kg^{-1})	pH (1:2.5)	EC (dS m^{-1})	Bulk density (t m^{-3})	Particle density (t m^{-3})
	N	P_2O_5	K_2O					
Initial	375	34.49	221.3	9.7	6.3	0.177	1.58	2.65
T_1	355	35.23	234.4	11.2	6.4	0.123	1.55	2.64
T_2	340	37.31	241.2	12.5	6.4	0.165	1.55	2.63
T_3	356	35.78	241.6	13.4	6.6	0.124	1.54	2.63
T_4	368	37.87	236.3	12.9	6.4	0.127	1.54	2.62
T_5	367	39.65	242.5	12.8	6.5	0.179	1.53	2.63
T_6	345	40.32	238.9	14.1	6.4	0.165	1.54	2.63
T_7	376	35.57	242.3	13.5	6.6	0.145	1.53	2.62
T_8	390	42.79	238.0	14.4	6.7	0.193	1.52	2.62
T_9	397	39.46	240.4	14.2	6.6	0.123	1.53	2.63
T_{10}	388	40.65	241.8	14.6	6.9	0.156	1.52	2.62
T_{11}	382	41.76	240.8	15.7	6.8	0.183	1.52	2.63
T_{12}	395	43.46	240.3	15.3	6.7	0.156	1.52	2.62

Table 4.17b Effect of organic nutrient management and Biozyme formulations on soil fertility status after summer rice harvest

Treatment	Available nutrients (kg ha^{-1})			Organic Carbon (g kg^{-1})	pH (1:2.5)	EC (dS m^{-1})	Bulk density (t m^{-3})	Particle density (t m^{-3})
	N	P_2O_5	K_2O					
T_1	314	34.43	220.2	10.2	6.5	0.110	1.55	2.64
T_2	333	34.67	222.4	10.4	6.6	0.113	1.56	2.64
T_3	342	36.54	234.5	11.6	6.5	0.098	1.55	2.63
T_4	333	37.32	225.6	11.1	6.4	0.127	1.54	2.62
T_5	357	37.21	227.8	11.3	6.5	0.137	1.52	2.62
T_6	345	35.40	224.4	12.1	6.6	0.117	1.53	2.63
T_7	365	37.36	228.7	12.5	6.4	0.132	1.54	2.63
T_8	368	36.68	236.9	12.6	6.5	0.097	1.53	2.63
T_9	379	36.46	231.3	12.9	6.6	0.142	1.53	2.63
T_{10}	384	37.35	228.6	13.6	6.7	0.111	1.53	2.63
T_{11}	389	37.67	233.4	13.4	6.8	0.101	1.52	2.62
T_{12}	392	36.89	235.2	14.2	6.7	0.091	1.52	2.62

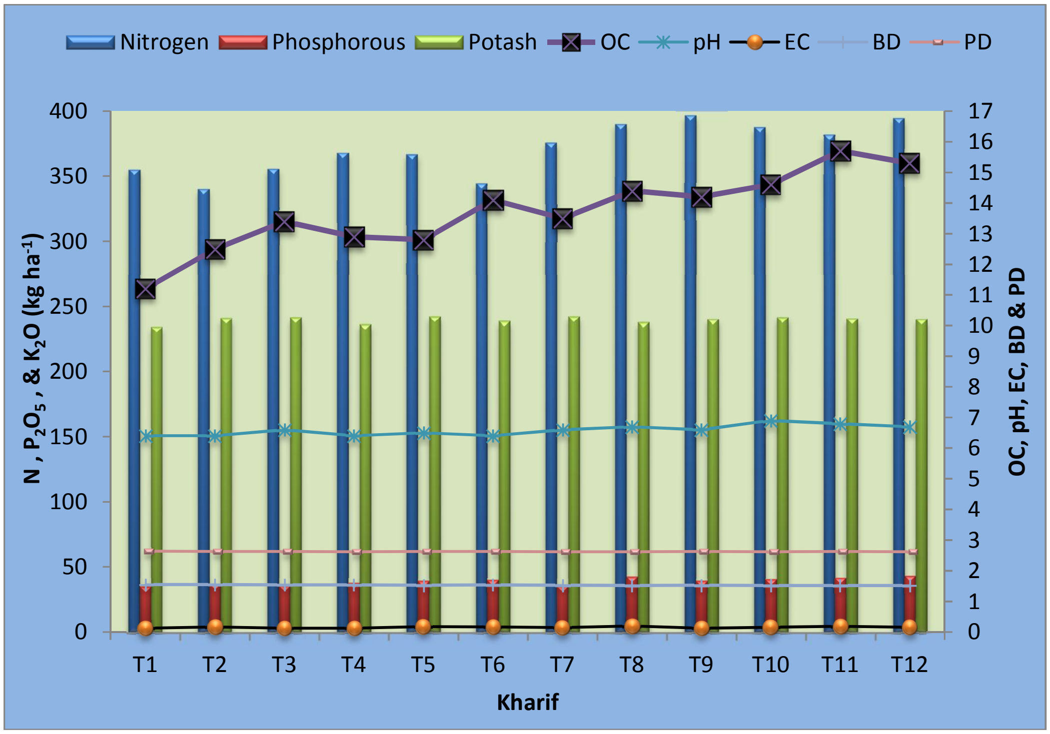


Fig. 4.17a Effect of organic nutrient management and Biozyme formulations on soil fertility status after *kharif* rice harvest

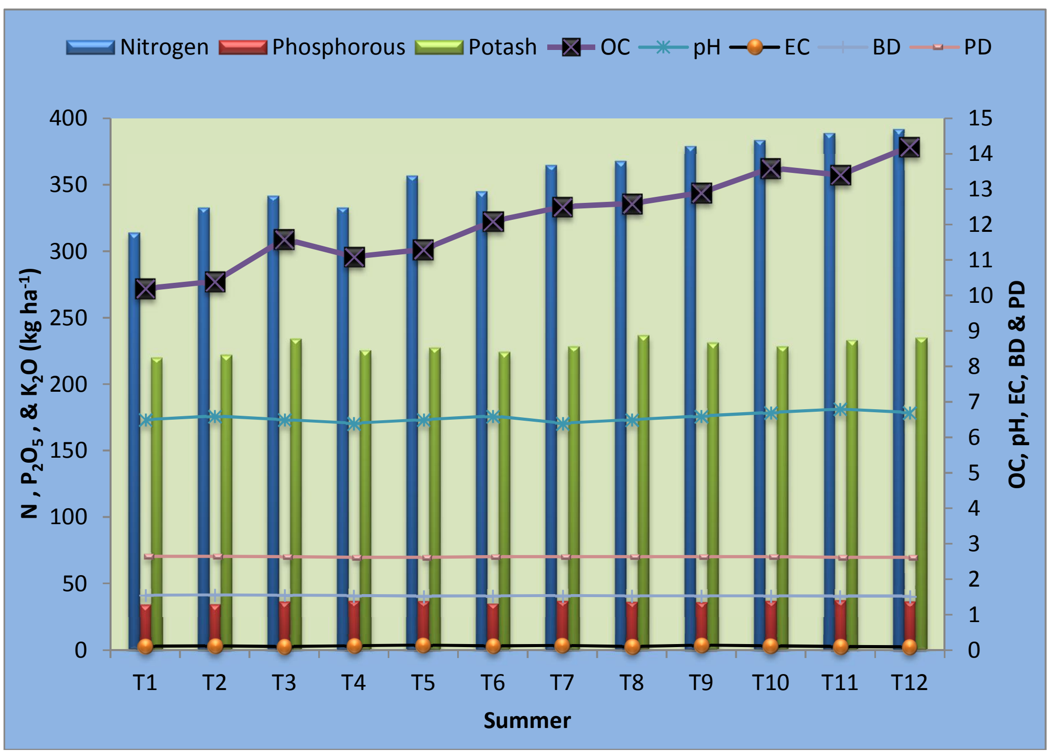


Fig. 4.17b Effect of organic nutrient management and Biozyme formulations on soil fertility status after summer rice harvest

4.8 STUDIES ON ECONOMICS OF RICE PRODUCTION

Data on cost of cultivation, gross returns, net returns and return per rupee invest of both season rice cultivation under organic nutrient management and Biozyme formulations are presented in Table 4.18a and 4.18b; depicted in Fig.4.18a and 4.18b. The treatment receiving Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) incurred the highest cost of cultivation of ₹ 33, 812 and 32,757 ha^{-1} but fetched the maximum gross returns (₹ 60, 475 and 58, 816 ha^{-1}) with net monetary returns of ₹ 26, 663 and 26,059 ha^{-1} and return per rupee invest of ₹1.79 and 1.80 in *kharif* and summer seasons, respectively. In both the seasons, the similar pattern of net return and return per rupee invest were fetched according to the use of organic sources and Biozyme formulations. Treatments with only Dhanicha @ 25 kg seed ha^{-1} in *kharif* and no manure application in summer (T_1) fetched the minimum net monetary returns of ₹ 11,126 and 10,386 and return per rupee invest of ₹ 1.37 and 1.35, in *kharif* and summer seasons, respectively.

After summer rice harvested, the average system grain yield, straw yield, gross return, net return and return per rupee invested were found to be 8351 kg ha^{-1}, 9447 kg ha^{-1}, ₹ 64080.0, ₹ 99422.0, ₹ 35342.0 and ₹ 1.55, respectively (Table 4.19 and Fig. 4.19) and grain yield, straw yield, gross return, net return and return per rupee invested were found to be maximum for T_{12} (10038 kg ha^{-1}, 11091 kg ha^{-1}, ₹ 66569.2, ₹119290.8, ₹52721.6 and ₹ 1.79, respectively).

Table 4.18a Effect of organic nutrient management and Biozyme formulations on economics of *kharif* rice

Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Cost of cultivation (₹)	Gross return (₹)	Net return (₹)	Return per rupee invested (₹)
T_1	34.80	40.07	30412.0	41538.4	11126.4	1.37
T_2	35.90	40.87	30834.0	42812.4	11978.4	1.39
T_3	39.57	45.07	31232.8	47132.6	15899.8	1.51
T_4	37.31	42.60	32644.4	44502.6	11858.2	1.36
T_5	38.30	43.47	32684.0	45660.4	12976.4	1.40
T_6	40.60	46.03	33527.0	48422.4	14895.4	1.44
T_7	42.87	48.63	32866.8	51074.6	18207.8	1.55
T_8	45.80	50.80	32984.0	54470.4	21486.4	1.65
T_9	48.63	53.60	33722.2	57807.4	24085.2	1.71
T_{10}	46.50	52.03	33012.0	55339.6	22327.6	1.68
T_{11}	48.03	52.77	33073.2	57107.4	24034.2	1.73
T_{12}	50.87	55.80	33811.8	60474.6	26662.8	1.79

Table 4.18b Effect of organic nutrient management and Biozyme formulations on economics of summer rice

Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Cost of cultivation (₹)	Gross return (₹)	Net return (₹)	Return per rupee invested (₹)
T_1	33.32	38.59	29352.8	39739.2	10386.4	1.35
T_2	34.48	39.45	29777.2	41084.0	11306.8	1.38
T_3	38.33	43.83	30183.2	45669.4	15486.2	1.51
T_4	35.95	41.24	31590.0	42844.2	11254.2	1.36
T_5	36.88	42.05	31627.2	43932.0	12304.8	1.39
T_6	39.36	44.79	32477.4	46879.2	14401.8	1.44
T_7	41.51	47.27	31812.4	49442.6	17630.2	1.55
T_8	44.44	49.44	31929.6	52839.2	20909.6	1.65
T_9	47.27	52.24	32667.8	56176.2	23508.4	1.72
T_{10}	45.32	50.85	31964.8	53920.0	21955.2	1.69
T_{11}	46.61	51.35	32016.4	55379.0	23362.6	1.73
T_{12}	49.51	54.44	32757.4	58816.2	26058.8	1.80

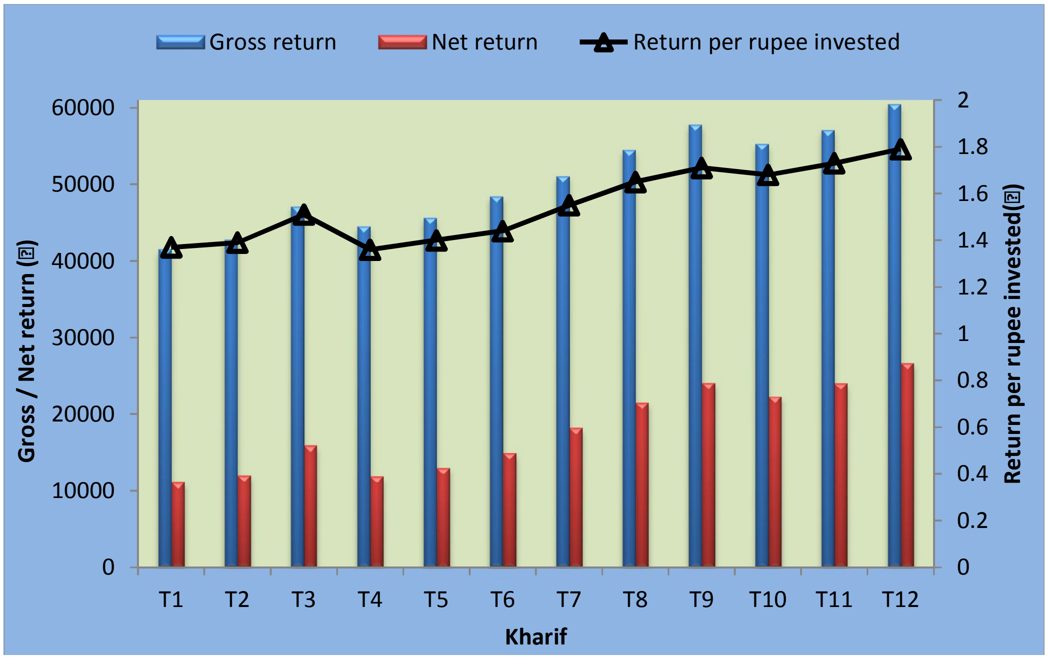


Fig. 4.18b Effect of organic nutrient management and Biozyme formulations on economics of *kharif* rice

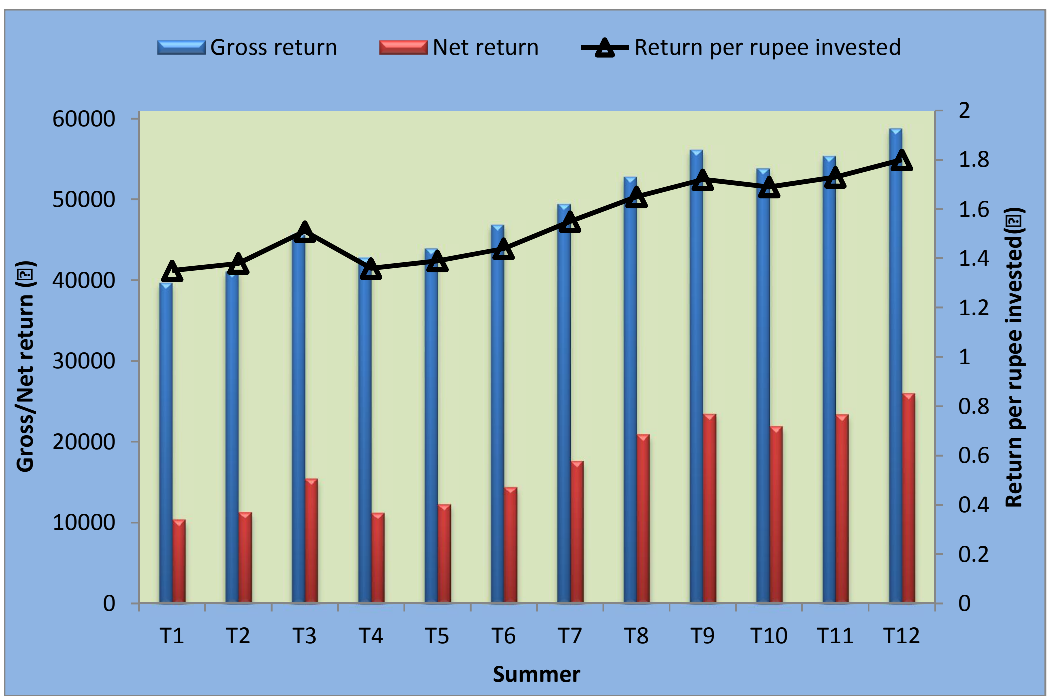


Fig. 4.18b Effect of organic nutrient management and Biozyme formulations on economics of summer rice

Table 4.19 Effect of organic nutrient management and Biozyme formulations on system yield after summer harvest

Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Cost of cultivation (₹)	Gross return (₹)	Net return (₹)	Return per rupee invested (₹)
T_1	68.12	79.32	59764.8	81277.6	21512.8	1.36
T_2	70.38	80.98	60611.2	83896.4	23285.2	1.38
T_3	77.9	88.9	61416.0	92802.0	31386	1.51
T_4	73.26	84.51	64234.4	87346.8	23112.4	1.36
T_5	75.18	86.18	64311.2	89592.4	25281.2	1.39
T_6	79.96	91.82	66004.4	95301.6	29297.2	1.44
T_7	84.38	96.24	64679.2	100517.2	35838	1.55
T_8	90.24	100.57	64913.6	107309.6	42396	1.65
T_9	95.9	106.17	66390.0	113983.6	47593.6	1.72
T_{10}	91.82	103.22	64976.8	109259.6	44282.8	1.68
T_{11}	94.64	104.78	65089.6	112486.4	47396.8	1.73
T_{12}	100.38	110.91	66569.2	119290.8	52721.6	1.79

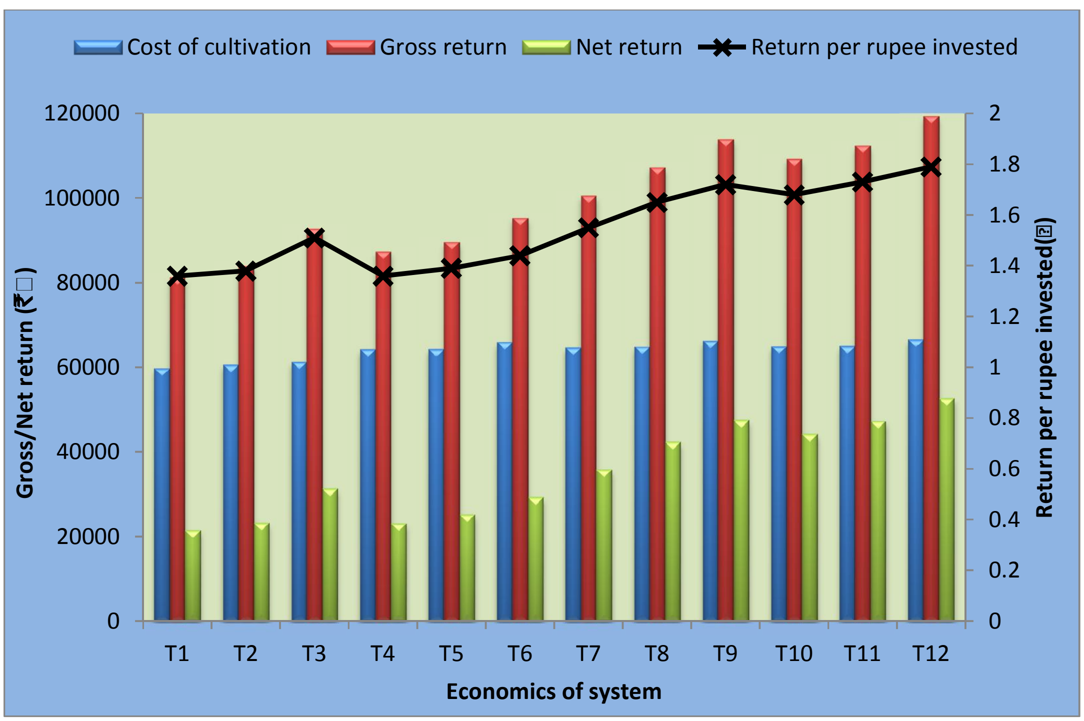


Fig. 4.19 Effect of organic nutrient management and Biozyme formulations on system yield after summer harvest

Co-relation studies

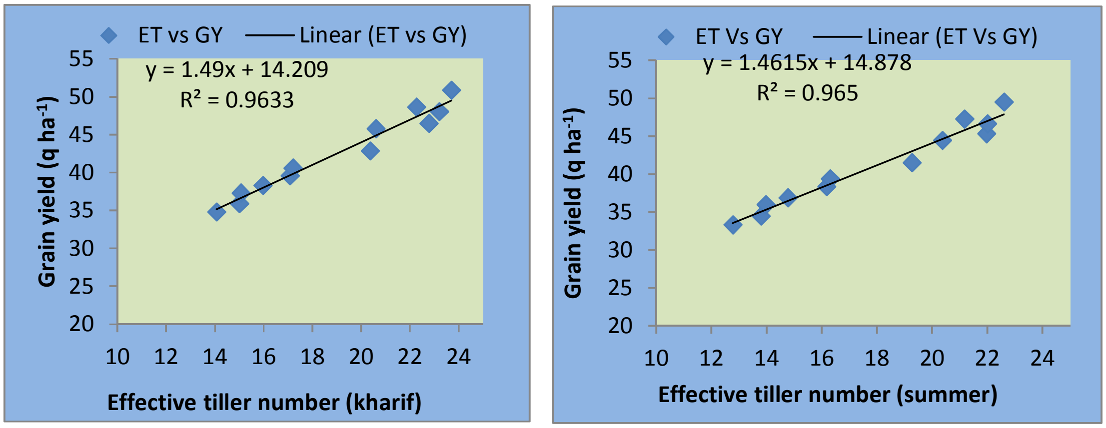


Fig. 4.20 Correlation of effective tillers to grain yield of *kharif* and summer rice as affected by ONM and Biozyme formulations

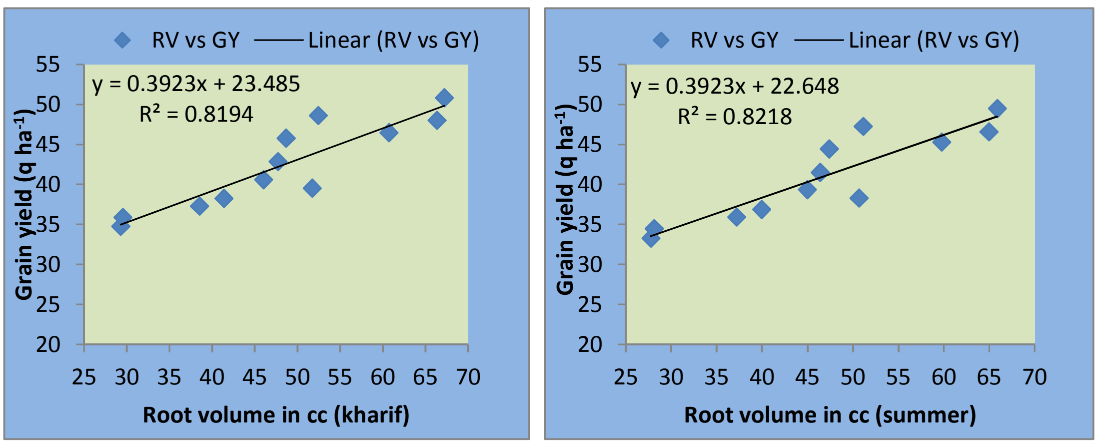


Fig. 4.21 Correlation of root volume to grain yield of *kharif* and summer rice as affected by ONM and Biozyme formulations

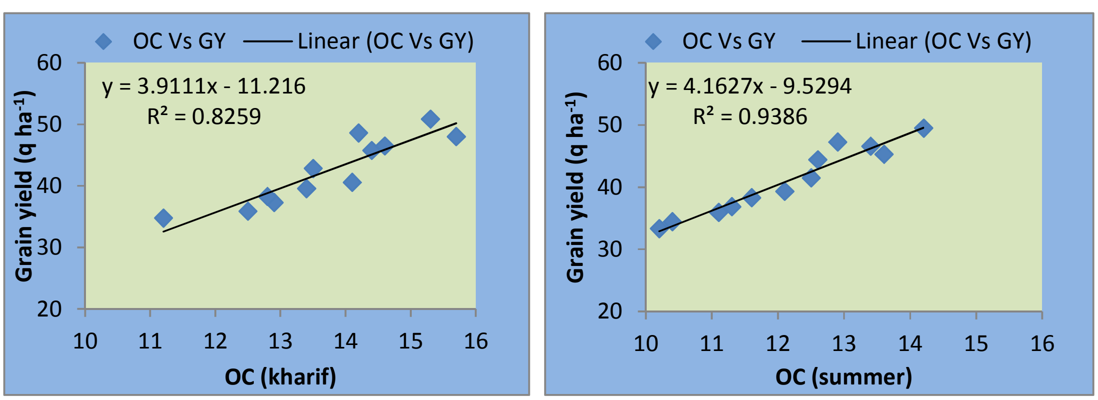


Fig. 4.22 Correlation of organic carbon to grain yield of *kharif* and summer rice as affected by ONM and Biozyme formulations

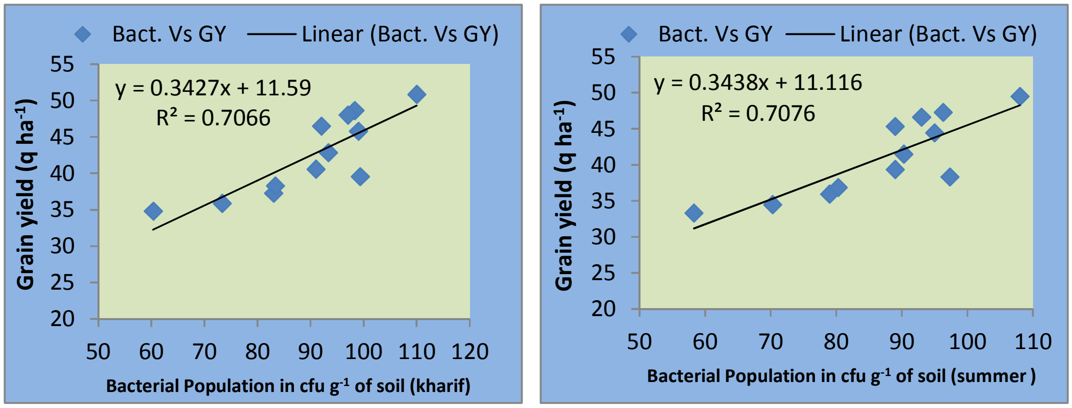


Fig. 4.23 Correlation of bacterial population to grain yield of *kharif* and summer rice as affected by ONM and Biozyme formulations

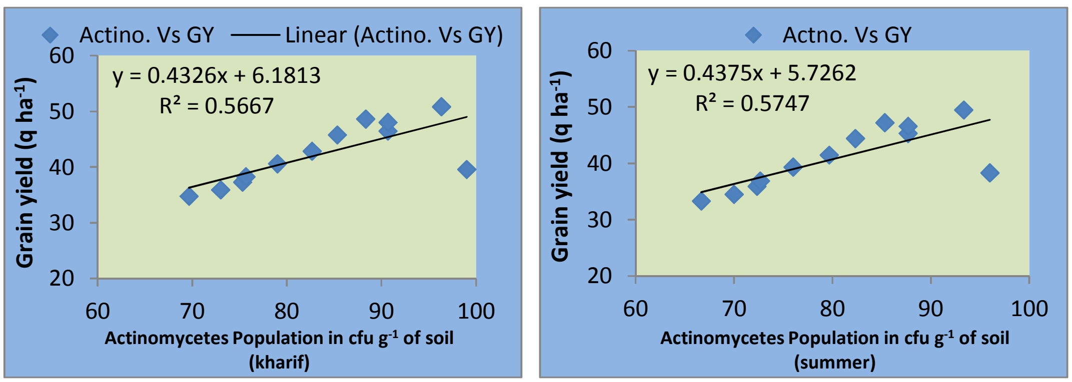


Fig. 4.24 Correlation of actinomycetes population to grain yield of *kharif* and summer rice as affected by ONM and Biozyme formulations

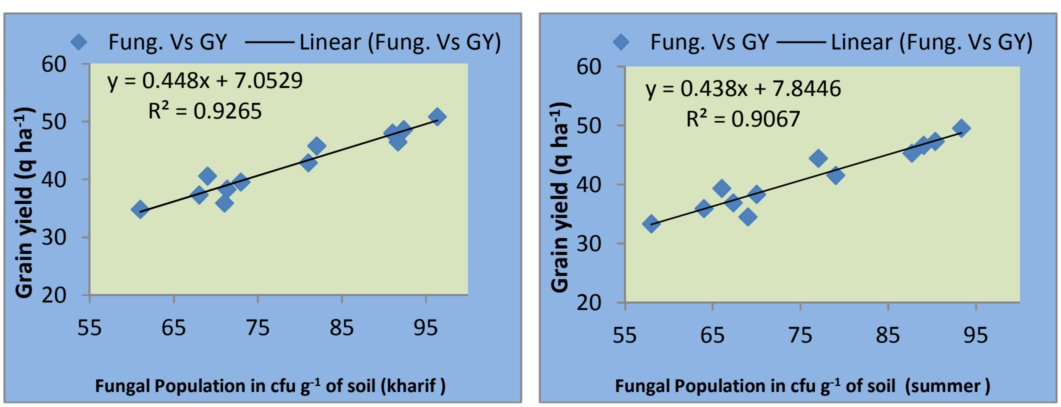


Fig. 4.25 Correlation of fungal population to grain yield of *kharif* and summer rice as affected by ONM and Biozyme formulations

CHAPTER-V

Discussion

DISCUSSION

The results of the experiment on "Evaluation of Biozyme formulations in organically grown rice-rice sequence" have been presented in the previous chapter. In this chapter, an attempt has been made to establish the cause and effect relationship for the variations induced by different factors corroborated with the scientific findings of various researchers.

5.1 WEATHER AND CROP

Weather is the most important environmental factor that affects crop growth, development and the ultimate economic yield. When no other environmental factor is limiting, weather can contribute 50% to yield realization of a cultivar (Ramkrishna *et al*., 2000). Especially, weather elements like rainfall, temperature, relative humidity, solar radiation etc. have strong bearing on the performance of a crop under a certain farming situation

The physiological processes involved in the events of growth and yield of rice plant is directly affected by temperature, solar radiation and rainfall. In general, the temperature regime recorded in the tropics is suitable for rice growth throughout the year.

The rice crop under the experiment received 943.1 and 83.9 mm rainfall in 72 and 4 rainy days in *kharif* and summer seasons, respectively. The SW monsoon was well distributed and all the meteorological weeks of the *kharif* crop growing season were wet weeks (received > 25 mm rainfall) except 38 (23.8mm), 39 (4.4mm), 41 (16.4mm), 42 (0.0mm), 43 (0.0mm) and 45 (24.4mm) week. There was a little less rainfall at the time of panicle emergence stage and flowering. But water stress was not encountered due to application of irrigation. The rainfall stress at grain filling to maturity was also taken care of by irrigation and adverse effect due to dry spell was observed. The rainfall was adequate and well distributed up to the panicle emergence stage. The crop received deficient rainfall in summer season, but the effect was not visualized as the crop was irrigated as and when required and the beds were kept saturated all through.

The mean atmospheric temperature during crop growing period ranged from 25.3 to 29.6^{o}C in *kharif* and 21.6 to 33.6^{o}C in summer season. Yoshida (1978) studied the response of rice plant to temperature variations at different growth stages and reported ranges of 25-30, 25-28, 25-31 and 20-29^{o}C as the optimum for crop establishment, rooting, tillering and ripening stages, respectively. The rice crop under the experiment experienced the mean temperature of 28.9 and 23.2, 28.3 and 25.9 , 28.8 and 31.4, 26.5 and 32.1^{o}C in the respective growth stages in the respective seasons of *kharif* and summer, which were all most within the optimum range excepting rooting and ripening in summer. As the mean temperature was below normal at the time of rooting initiation in summer, a suppressed rooting volume was observed at this period. However, due to optimal temperature regime in subsequent period, the root growth compensated later on. The summer crop encountered a very high temperature trend at the time of ripening. There occurred visible response to this aberration and sterility percentage of grains increased. High temperature at this stage dries up the stigmatic surface and pollens from the anthers do not fertilize the ovules. This may be the reason for higher sterility of rice grains.

Bright sunshine hours provide the solar energy for photosynthesis. Average bright sunshine hour per day fluctuated from 0.2 hour to 7.6 hours and 4.3 hours to 9.2 hours in *kharif* and summer, respectively. For almost all the crop growing period, it was dismally low i.e., below 5.5 hours in *kharif* whereas it was higher than 5.5 hours in almost all the crop growing period of summer crop. Accumulation of bright sunshine hours is a basis for crop growth and development. Phenophases of crops are responsive to accumulation of heliothermal units. This may be the reason for which the Phenophases were delayed and finally the maturity was extended by 5-7 days in *kharif* season.

The mean relative humidity was 87.8, 88.5, 86.1 and 79.8 per cent in the months of July, August, September and October, respectively in *kharif* season whereas it was 65.5, 63.9, 60.1 and 63.9 per cent in the month of January, February, March and April, respectively in summer season. Angladette (1966) reported that 70 to 80 per cent relative humidity is the most favourable condition for rice crop. Relative humidity modifies the plant physiological processes like transpiration and nutrient translocation. High relative humidity decreased transpiration and hence nutrient uptake by the plant. On the otherhand, low relative humidity increases energy use due to accelerated transpiration. These were the conditions in both the crop growing season, respectively. This might be one of the reasons for lower dry matter accumulation and yield in both the seasons.

5.2 GROWTH OF RICE

Growth of a plant is the permanent and irreversible increase in its size and form. It is affected by its environment like availability of plant nutrients, water, energy, space, etc. Therefore, the growth of a plant in a community differs in many ways from the individual plant because of inter plant interaction in the field. Full production potential of individual plants can only be realized when the growth and development conditions during the early phases are optimal. The dry matter accumulation showed a typical sigmoidal curve. The pattern indicates that early vegetative growth in rice tends to be exponential but because of mutual interactions within the individuals that impose limitation on growth, the actual growth curve falls away in sigmoidal manner which is more characteristic of its entire life span. Since growth is not exponential, NAR is not a constant value and it always declines and ascends later in the life curve (Evans, 1972). In the present investigation almost all the growth parameters of the rice such as plant height, number of tillers, dry matter accumulation and physiological growth parameters like LAI, CGR and NAR were influenced by organic nutrient management practices and Biozyme formulations.

Plant height increased progressively upto maturity irrespective of organic nutrient management and Biozyme formulations and followed same trend in both the seasons. The average plant height at maturity (117.26 and 115.62 cm in *kharif* and summer, respectively) and there was significant difference due to treatments after 45 DAT. Treatment receiving *Dhanicha* + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) produced the tallest plants at harvest, those were 23.5 and 24.2 per cent higher than the treatment expressed the shortest plant height i.e. only *Dhanicha* @ 25 kg seed ha^{-1} in *kharif* and no manure application in summer (T_1), respectively. The mean of treatments receiving organic nutrient and Biozyme formulations (T_4 to T_{12}) resulted in 12.10 and 12.38 per cent higher than those of treatments receiving organic sources alone (T_1 to T_3). The average tiller number of 18.94 and 17.93 and leaf area index of 3.91 and 3.77 were found at harvest in *kharif* and summer seasons, respectively. T_{12} resulted 68.4 and 76.9 per cent higher tiller number and 84.8 and 91.6 per cent higher LAI than T_1 in respective seasons. The mean of treatments receiving organic nutrient and

Biozyme formulations (T_4 to T_{12}) resulted in 30.87 and 34.47, and 38.32 and 40.44 per cent higher tiller number and leaf area index in *kharif* and summer seasons, respectively than those of treatments receiving organic sources alone (T_1 to T_3). The average root volume was found to be 48.29 and 46.99 cc in respective seasons. T_{12} expressed 129.3 and 137.5 per cent higher root volume than T_1 in *kharif* and summer, respectively, whereas T_4 to T_{12} resulted in 52.1 and 43.20 per cent higher root volume than T_1 to T_3 in respective seasons (Plate 8). In case of dry matter, the average dry matter production for the respective seasons was found to be 60.75 and 59.29 g per hill. T_{12} found 76.9 and 80.6 per cent higher dry matter in respective seasons whereas T_4 to T_{12} resulted in 29.75 and 31.12 per cent higher than T_1 to T_3 in respective seasons of *kharif* and summer.

Application of FYM improves physical properties of soil, availability of plant nutrients and encourages enzymatic activities that encourage root development and growth of crop (Rao *et al*., 2004; Kumari *et al*., 2010; Shekara *et al*., 2010). *Sesbania* green manure slowly but continuously maintains nitrogen supply during most of the rice growing season thereby enhancing dry matter production, LAI, NAR, CGR and LAD (Vennila *et al.*, 2007; Surekha *et al*., 2008). The organic carbon supplied through manure load must have offered a favourable ecological niche to the microorganisms to proliferate and act effectively (Kenchaiah, 1997), which was well visualized through increased microbial population in treatments receiving organic inputs.

The factors influencing organic manure decomposition in the soil can be broadly categorized as manure factors which include chemical composition (N concentration, C:N ratio, lignin concentration, polyphenol concentration etc.), particle size of the manures and indigenous microflora on the manures; soil factors which include soil water, temperature, pH, aeration and available nutrients and management factors like rate of manure loading and method of application. Nutrient release from manures can be regulated by altering or manipulating these factors. In the present investigation organic manures were applied in additive series, increasing the manure load every time. Furthermore, they were applied in splits in different phases of crop growth. The indigenous microorganisms were abundant (Table. 4.12a and 4.12b; 4.13a and 4.13b; 4.14a and 4.14b) as it was an organic plot. Application of FYM improves physical properties of soil, especially, the structure, water holding capacity, bulk density, porosity, CEC etc., apart from these, enzymatic activities are enhanced that encourage root development and growth of crop (Shekara *et al*., 2010). Rao *et al*. (2004) also reported that increase in plant height and dry matter production due to FYM application might be due to the fact that application of FYM increases the soil organic carbon, which holds more moisture in soil and creation of suitable condition for better root growth and proliferation and also opportunity to extract nutrients from larger profile area. Beneficial effects of FYM with increased plant height, LAI and higher DMP over other organics were observed by Ramasamy (1998). Vennila *et al*. (2007) reported significant increase in growth factors due to application of FYM. They, again, reported that *sesbania* green manure slowly but continuously maintained nitrogen supply during most of the rice growing season. Matiwade and Sheelavantar (1994) reported that green manuring enhanced the values of dry matter production, LAI, NAR, CGR, LAD and there by increased rice growth. Application of external product like Biozyme which is based on sea weed (*Ascophyllum nodosum*) extract enhance the ability of plants to increase its uptake capacity to a substantial level (Cassan *et al*., 1992). This sea weed contains some biological compounds identified as growth regulators (Wallace, 1998). These might be the cause of higher plant growth in additive treatments up to Biozyme.

5.3 YIELD ATTRIBUTES AND YIELD

Yield attributes are mostly manifested from the growth parameters if the environmental factors remain conducive. Yield is an integration of yield attributes. Yield attributes and yield followed similar trend in both the seasons. The average length of panicle was found 28.86 and 27.67 cm in *kharif* and summer, respectively. Treatment receiving *Dhanicha* + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) revealed highest length of panicle at harvest, those were 24.7 and 25.9 per cent higher than the treatment producing shortest length of panicle i.e. only *Dhanicha* @ 25 kg seed ha^{-1} in *kharif* and no manure application in summer (T_1), respectively. The mean of treatments receiving organic nutrient and Biozyme formulations (T_4 to T_{12}) resulted 9.18 and 9.52 per cent longer panicle than those of treatments receiving organic sources alone (T_1 to T_3). The average spikelet per panicle was 134.06 and 132.25 in *kharif* and summer, respectively. T_{12} produced maximum spikelet per panicle at harvest; those were 37.6 and 36.0 per cent higher than T_1, respectively. The mean of treatments receiving organic nutrient and Biozyme formulations (T_4 to T_{12}) resulted 23.61 and 22.71 per cent higher spikelet per panicle than those of treatments receiving organic sources alone (T_1 to T_3) in respective seasons. The average sterility per cent was 12.31 and 14.69 in *kharif* and summer, respectively. Lower sterility per cent was observed in T_{12} which were 30.0 and 17.0 per cent lower than T_1, respectively. The mean of treatments receiving organic nutrient and Biozyme formulations (T_4 to T_{12}) resulted 7.26 and 3.10 per cent lower sterility than those of treatments receiving organic sources alone (T_1 to T_3) in respective seasons. The 1000 grain weight were non-significant with the application of organic nutrient management and Biozyme formulations. The average grain yield and straw yield were 42.43 and 48.17; 41.08 and 46.29 q ha^{-1} in *kharif* and summer, respectively. Higher grain and straw yield were recorded in T_{12} in both the seasons, and those were 46.2 and 38.6; 48.5 and 41.1 per cent higher than T_1, respectively. The mean of treatments receiving organic nutrient and Biozyme formulations (T_4 to T_{12}) resulted in 20.6 and 18.0; 21.5 and 18.6 per cent higher grain and straw yield than those of treatments receiving organic sources alone (T_1 to T_3) in respective seasons. Treatments were unable to influence harvest index of rice which varied within a narrow range of 0.46-0.48 in both the seasons.

Organic manures when applied in sufficient quantity supplied all the essential nutrients in adequate amount for plant growth and development and ultimately resulted in yield. Besides, they encourage the activity of microbes which, in turn, release enzymes and hormones that promote plant growth. Mankotia (2007) reported higher yield of rice due to *in situ* green manure of *Dhanicha* with application of FYM. Shekara *et al*. (2010) suggested that increase in the growth, yield attributes and yield of rice due to addition of various organic manures could be attributed to adequate supply of nutrients, higher uptake and recovery of applied nutrients, which in turn, must have improved synthesis and translocation of metabolites to various reproductive structures of the plant. Organic manures besides improving the physico-chemical and biological properties of soil might have prevented leaching and volatilization losses and its slow release pattern might have supplied nutrients in optimal congruence with crop demand improving synthesis and translocation of metabolites to various reproductive structures resulting in improvement in its yield and yield attributes (Upadhyaya *et al*., 2000; Shanmugam *et al*., 2001; Bhattacharya *et al*., 2003; Raju and Sreenivas, 2008; Kumari *et al*., 2010).

Integrated use of two or three sources of organic nutrients with biofertilizers has resulted in higher grain yield of rice (Yadav *et al*., 2009; Davari and Sharma, 2010; Singh *et al*., 2011). However, harvest index, which expresses the relationship of economic yield to total biological yield remained unaffected due to different nutrient management practices and varied within a narrow range of 37.24 to 38.67% indicating that under optimal nutrient supply either through inorganic, organic or both sources, the plants were equally efficient in synthesis and translocation of photosynthates from source to sink.

Vennila *et al*. (2007) confirmed that *Sesbania* green manure slowly but continuously maintain nitrogen supply during most of the rice growing season. The rate of decomposition and N mineralization of green manures added to soil depend on a large extent on the chemical composition or quality of the manures. Manures quality is determined largely by the organic constituents and nutrient contents of the material and the ease of mineralization by decomposer organisms. As regards to these aspects *Sesbania* is a very good green manuring crop. Mankotia (2007) also reported higher yield of rice due to in situ green manure of *Dhanicha* with application of FYM. Shekara *et al*. (2010) suggested that increase in the growth, yield attributes and yield of rice due to addition of various organic manures could be attributed to adequate supply of nutrients, higher uptake and recovery of applied nutrients, which in turn must have improved synthesis and translocation of metabolites to various reproductive structures of the plant. Apart from dry matter accumulation, the better translocation of it into reproductive parts resulted in higher grain yield. Barik and Gulati (2009), while reviewing vermicompost, reported that apart from the high nutrient content of vermicompost over FYM, the former contains many plant growth hormones, vitamins and beneficial microorganisms.

The promotive effects of Biozyme on yield and yield attributes might be because of increased root proliferation and establishment, thereby, plants were able to mine more nutrients even from distance places and deeper soil horizons, in balanced proportion. Besides, Biozyme regulate the plant bio-physiological activities (increased chlorophyll content in leaf etc.) also, which collectively resulted in maintaining higher photosynthetic activity even during later period of the plant life-cycle (during grain-filling), thus the higher yield and yield attributes (Wierzbowska and Nowak, 1998).

Plant growth and yield and soil NH^{4+}content were higher in soil treated with vermicompost compared to compost suggesting higher N mineralization and utilization by the plants (Doan *et al*., 2013)

5.4 PLANT NUTRIENT CONTENT AND UPTAKE

N, P and K content of grain and straw decreased from T_1 to T_{12} due to organic nutrient management and Biozyme formulation. It is an established fact that when the economic and biological yields increase the nutrient contents of grain and straw decrease (Choudhary *et al*., 2007). On the other hand, N, P and K uptake exhibited a complete reverse trend. This is because of higher grain and straw yields of the treatments. Dixit and Gupta (2000), Yadav *et al*. (2009), Kumari *et al*. (2010) and Davari and Sharma (2010), who observed that addition of various sources of organic nutrients increased the grain yield, soil available nutrients and N, P and K uptake by rice crop. Higher N, P and K uptake by rice with FYM + poultry manure and *Sesbania rostrata* + poultry manure, and increase in microbial population in the soil, was reported by Kenchaiah (1997).

5.5 SOIL PHYSICO-CHEMICAL STATUS

The experimental site is organically maintained since 2003. Therefore, Bulk density and particle density has almost stabilized. Soil pH was within range of (6.4 to 6.9) due to different treatments that may be due to the buffering property of the organic manures used. The available nutrient status of N-P-K was in the optimum range due to organic nutrient management and Biozyme formulations. Organic carbon increased according to the treatments in the range of 10.2 to 15.7 g kg^{-1}. The increase in organic carbon content in the manurial treatment combinations is attributed to the direct incorporation of organic matter in the soil. Subsequent decomposition of these materials might have resulted in the enhanced organic carbon content of the soil (Singh *et al*., 2008). The increased SOC content with the long-term application of FYM resulted in decreased soil bulk density increased total porosity as well as water holding capacity and improved soil aggregation even in the deeper soil layers (Rasool *et al*., 2008). Data on soil properties as influenced by different treatments showed that organic carbon content increased to a great extent with the addition of different organic manures (Yadav *et al*., 2009). Addition of exogenous OM such like compost results in an enhancement of OC storage in addition to improvement of many other soil functions related to the presence of organic matter (Ngo *et al*., 2012). Humic substances (HS) contained in the vermicompost, are environmental friendly materials that restore the chemical and physical properties of soils and improve plant growth (Garcia *et al*., 2012)

Higher available N content of soil under FYM addition could be due to favourable microbial activity and enhanced biomass addition to the soil probably as a result of improved soil physical properties. Vennila *et al*. (2007) reported that the available N and P of soil after the crop harvest increased considerably as compared to initial level due to FYM application. Singh *et al*., (2008) observed that highest available P was recorded with the application of vermicompost followed by FYM, green manuring and residue incorporation. The increased available P content of soil might be due to release of CO_2 and organic acids during decomposition, which helps in solubilising the native soil P. The organic matter (humus) may also reduce the fixation of phosphate by providing protective cover on sesqueoxides and chelating cations like Ca^{2+} and mg^{2+}, which in turn enhanced availability of P. The beneficial effect of FYM, vermicompost, green manuring on available K may be ascribed to the reduction of K-fixation, solubilization and release of K due to the interaction of organic matter with clay. Sinha (1981) opined that besides supplying nutrients, organic manures have also solubilizing effect on fixed form of other nutrients and therefore, improve the productivity of soil. Kumar *et al*. (2007), Yaduvanshi (2003) and Patil *et al*. (2003) were of similar opinion. As regards to Biozyme application, higher available nutrient content of soil might be due to the fact that application of Biozyme improved the biological productivity of the soil (Mandal *et al*., 2006) and organic carbon concentration, total soil organic carbon stock and soil organic carbon sequestration rates were also significantly influenced by the organic nutrient management and Biozyme application treatments (Bastia *et al*., 2013).

5.6 SOIL BIOLOGICAL PROPERTIES

Soil microbial population curve followed a parabolic trend from start to end of a season. Soil microbial population was found higher and active during crop growing period in both the seasons whereas before transplanting and after harvest the population was low. The treatment T_{12} resulted in maximum microbial population in both the seasons due to organic nutrient management and Biozyme formulations. On the otherhand, microbial population due to T_1 treatment remained low in both the seasons.

It is important to recognize that the best soil and crop management practices to achieve a more sustainable agriculture will also enhance the growth, numbers and activities of beneficial soil microorganism that, in turn, can improve the growth, yield and quality of crops. In essence, soil quality is the very foundation of a more sustainable agriculture (NAS, 1989; Hornick, 1992; Parr *et al*., 1992). Parr and Hornick (1992) promulgated that we must give more attention to soil biological property because of their important relationship to crop production, plant and animal health, environmental quality, and food safety and quality. Moreover, one should adopt the philosophical attitude in applying microbial technologies to agricultural production and conservation systems.

Insam *et al*. (1991) have also reported that the carbon input from both organic amendments and rice biomass return plays a dominant role in promoting paddy soil microbial biomass and activity. The promoting effects of the quantity of organic amendments may intensify through increasing more carbon return from rice biomass (Pan *et al*., 2006). In addition to stimulating microbial development by substrate direct from organic amendments, the great impacts of organic amendments on soil quality possibly also result from indirect effects, such as changes of soil microbial community composition or changes in soil physico-chemical environment (Carter *et al*., 1999). It was found that organic amendments can improve soil physical properties (soil moisture and structural stability), and consequently benefited soil microbial mediated processes (Liu, 2005).

Addition of organic inputs could have favoured microbial activity and enhanced the soil microbial biomass (SMB) including total bacterial population because of supply of organic carbon and improved soil physical properties (Kenchaiah, 1997).

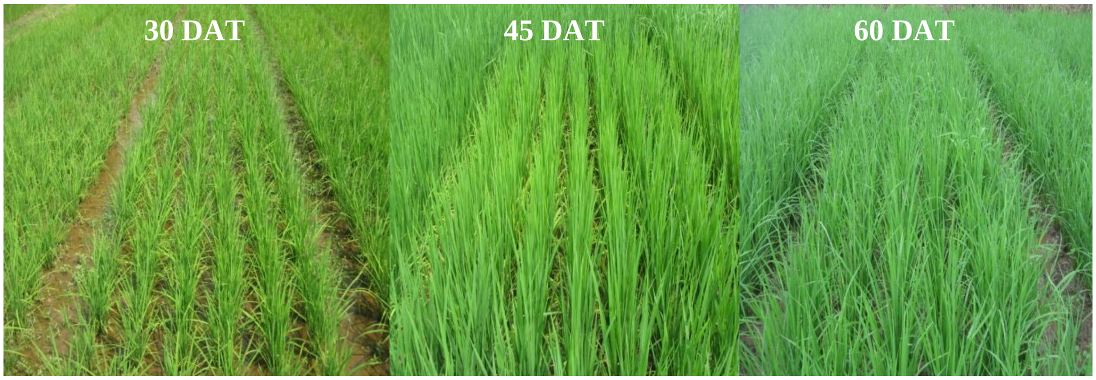


Plate 6: Rice crop at different growth stages

Plate 7: Vermi-cast showing soil health

O + B **Organic + Biozyme** **Organic** **O**

Plate 8: Root studies comparing different treatments

The amendment of organic substrates led to the survival and development of earthworms. (Doan *et al*., 2013) therefore appearance of vermin-cast (Plate 7) found in the field, indicating soil is in good health. Earthworms, as soil engineers, play a key role in soil functioning. They enhance soil aeration, water infiltration, influence microbial activity and diversity and stimulate organic decomposition and facilitate nutrient cycling. (Ngo *et al*., 2012).

The influence of FYM on soil quality is more pronounced than green manure (Yang *et al*., 2005; Tu *et al*., 2006; Birkhofer *et al*., 2008). These trends are due to the lower C: N ratio of FYM (10.4) compared to that of GM (22:4) which can lead to more organic matter decomposition and greater microbial turnover rates (Hao *et al*., 2008). (Liu *et al*., 2009).

5.7 ECONOMICS

Any technology will not be acceptable to the farming community unless it is remunerative. It necessitates calculation of economics of the practice in terms of gross and net returns and benefit to cost ratio. The cost of cultivation and gross returns were maximum for the treatment receiving *Dhanicha* + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and corresponding treatment receiving FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) (₹ 33,811.8 and 32,757.4; 60,474.6 and 58,816.2 in *kharif* and summer seasons, respectively) and fetched the highest net returns (₹ 26662.8 and 26058.8 ha^{-1} in *kharif* and summer seasons, respectively) with ₹ 1.79 and 1.80 return per rupee invest in respective seasons. Economics of cultivation is mostly dependent on cost of cultivation and grain and straw yields. Higher cost of cultivation in organic combinations was due to higher cost of organic inputs per unit of plant nutrients in conformity with the findings of Kumari *et al.* (2010), Davari and Sharma (2010) and Singh *et al.* (2012), who reported increased cost of production due to application of organic inputs alone or in combination as compared to use of inorganic sources. The higher returns under organic farming when compared with chemical fertilizers was mainly due to better soil health resulted in better plant growth, yield components, yield and higher prices of organic produce (Yadav *et al.*, 2009). The FYM and vermicompost used are farm recycled products and there costs are not included in the cost of cultivation, only labour cost for FYM and vermicompost preparation is taken into consideration. Therefore, average return per rupee invest is found to be ₹ 1.5 in both the seasons.

CHAPTER-VI

Summary & Conclusion

SUMMARY AND CONCLUSION

A field experiment was conducted on "Evaluation of Biozyme formulations in organically grown rice-rice sequence" during, 2012-2013 at the Organic Block of Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar in a Randomized Block Design with three replications and twelve treatment combinations. The kharif treatments consisted of T_1=Dhanicha @ 25 kg seed/ha, T_2 =Dhanicha + FYM 5t/ha (basal), T_3=Dhanicha + FYM + Vermicompost 2t/ha (20DAT) , T_4=T_1 + BSP (Seed Treatment) + BG (Basal), T_5=T_1 + BSP (Seed Treatment) + BPPL (Tillering + P.I. stage) , T_6 =T_1 + BSP + BG + BPPL , T_7=T_2 + BSP (Seed Treatment) + BG (Basal) , T_8=T_2 + BSP (Seed Treatment) + BPPL (Tillering + P.I. stage), T_9=T_2 + BSP + BG + BPPL, T_{10}=T_3 + BSP (Seed Treatment) + BG (Basal), T_{11}=T_3 + BSP (Seed Treatment) + BPPL (Tillering + P.I. stage) , T_{12} =T_3 + BSP + BG + BPPL, but in summer seasons, all the treatments were the same except *Dhanicha* as green manure crop. The soil was sandy loam with pH 6.35, BD 1.58 t m^{-3}, PD 2.65 t m^{-3}, high in organic carbon (9.7 g kg^{-1}) and available N-P_2O_5-K_2O was in medium range (375.0, 34.49 and 221.25 kg ha^{-1}, respectively). Rice variety "Lalat" (125 days) was grown as the test crop. Pot manure was used intermittently to avoid disease and insect pest infestation.

Observations on the growth, yield attributing characters and microbial population were recorded at different growth stages of the crop and at harvest. All data so collected were analyzed, computed and salient findings of the present investigation are summarized in this chapter.

6.1 Height of the plant increased with age of the crop. Application of Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) produced the tallest plants at harvest (125.8 and 124.1 cm, respectively). Mean plant height of rice at 30, 45, 60, 75, 90 DAT and at maturity were 67.2 and 66.11, 92.31 and 91.05, 104.11 and 103.23, 116.98 and 115.90, 117.51 and 116.54, 117.26 and 115.62 cm in *kharif* and summer seasons, respectively

6.2 Mean tiller number per hill at 30, 45, 60, 75, 90 DAT and at maturity were 14.32 and 13.24, 24.63 and 23.55, 23.06 and 21.97, 21.39 and 20.38, 19.44 and 18.43, 18.94 and 17.93 in *kharif* and summer seasons, respectively. Number of tillers per hill was found to be maximum for T_{12} at 45 DAT i.e. 29.70 and 28.60 in *kharif* and summer, respectively. However, these were at par with those of treatments T_7 to T_{11}. . The number of effective tiller per hill at harvest was maximum for T_{12} in both the seasons (23.70 and 22.60 in *kharif* and summer, respectively).

6.3 Mean root volume at 30, 45, 60, 75, 90 DAT and at harvest were 21.20 and 17.40, 39.85 and 38.55, 61.51 and 60.21, 62.48 and 61.29, 55.51 and 54.21, 48.29 and 46.99 cc in *kharif* and summer season, respectively. Root volume per hill was found to be highest in T_{12} i.e. 83.23 and 81.91 cc in *kharif* and summer, respectively which were at par with those treatments T_{10} and T_{11} in *kharif* and T_9 to T_{11} in summer.

6.4 Average leaf area index at 30, 45, 60, 75, 90 DAT and at harvest were 0.96 and 0.82, 3.32 and 3.20, 4.38 and 4.25, 4.42 and 4.30, 4.22 and 4.08, 3.91 and 3.77 in *kharif* and summer season, respectively. Highest leaf area index was recorded in T_{12} at 60 DAT (5.32) in *kharif* and at 75 DAT (5.22) in summer season, respectively, which were at par with those of T_9 to T_{11} in both the seasons.

6.5 Average dry matter production at 30, 45, 60, 75, 90 DAT and at harvest were 10.73 and 9.52, 28.53 and 27.14, 36.24 and 34.90, 49.94 and 48.67, 55.98 and 54.44, 60.75 and 59.29 g per hill in *kharif* and summer season, respectively. Dry matter production (75.08 and 73.50 g $hill^{-1}$ in *kharif* and summer, respectively) at harvest were highest for T_{12} which was at par with those of T_{10} and T_{11} in *kharif* and T_9 to T_{11} in summer respectively.

6.6 The average CGR (g $day^{-1}hill^{-1}$) of 1.187 and 1.175, 0.514 and 0.518, 0.913 and 0.918, 0.403 and 0.385, 0.318 and 0.323 g $day^{-1}hill^{-1}$ in *kharif* and summer, respectively were recorded during the period of 30-45, 45-60, 60-75, 75-90 DAT and at 90 DAT-harvest whereas highest CGR found in T_{12} in both the seasons. . The average RGR and NAR at same interval were 0.065 and 0.069, 0.017 and 0.017, 0.023 and 0.023, 0.007 and 0.007, 0.006 and 0.006 g $g^{-1}day^{-1}$ and 0.626 and 0.674, 0.132 and 0.138, 0.210 and 0.219, 0.092 and 0.090, 0.078 and 0.081 g m^{-2} leaf area day^{-1} in *kharif* and summer seasons, respectively.

6.7 The average number of panicles per unit area were 303.02 and 286.84 in *kharif* and summer, respectively. Application of all organic sources and Biozyme formulations (T_{12}) resulted in higher number of panicles per unit area (379.20 and 361.60 in *kharif* and summer, respectively). However, these were at par with those of T_7 to T_{11} in both the seasons.

6.8 The crop matured in 120days in summer and that was five days earlier than the *kharif* season crop (125days).

6.9 The average number of spikelet per panicle and number of filled grains per panicle was 134.06 and 124.62; 132.25 and 120.92 in *kharif* and summer seasons, respectively. Mean Sterility percent was higher in summer (14.69 %) as compared to *kharif* (12.31%). Maximum filled grain was found in T_{12} (145.84 and 140.83 in *kharif* and summer, respectively).

6.10 Grain and straw yields were significantly the maximum for T_{12} treatments (5087 and 5647; 4951 and 5444 kg ha^{-1} in *kharif* and summer seasons respectively) whereas, grain yield was at par with those of T_9 to T_{11} in *kharif* and T_8 to T_{11} in summer seasons, respectively and straw yield was on a par with those of T_8 to T_{11} in both the seasons. However, average grain and straw yields were 4243 and 4817; 4108 and 4629 in respective seasons. The harvest index was in the range of 0.46 to 0.48 for all the treatments in both the seasons.

6.11 Soil microbial population was found higher and active during crop growing period in both the seasons whereas before transplanting and after harvest, the population was quite low. The treatment T_{12} resulted in maximum microbial population at 90 DAT (Bacteria @ 1.1 x 10^7 and 1.08 x 10^7 , Actinimycetes @ 1.14 x 10^7 and 1.11 x 10^7 , Fungi @1.05 x 10^5 and 1.07 x 10^5 cfu g^{-1} of soil) due to organic nutrient management and Biozyme formulations. However, average bacteria, actinomycetes and fungi at 90 DAT were 9.0 x 10^6 and 8.7 x 10^6; 8.3 x 10^6 and 8.0 x 10^6; 7.8 x 10^4 and 7.5 x 10^4 cfu g^{-1} of soil in *kharif* and summer seasons, respectively.

6.12 The N-P-K content of rice showed least variation influenced by organic nutrient management and Biozyme formulations The average percentage of nitrogen, phosphorus and potassium both in grain and straw were 1.27 and 0.46 %; 0.27 and 0.08 %; 0.21 and 1.73 % respectively in *kharif* whereas, the average percentage of nitrogen, phosphorus and potassium both in grain and straw were 1.26 and 0.44 %; 0.26 and 0.08 %; 0.18 and 1.62 % respectively in summer season. The average uptake of nitrogen, phosphorus and potassium by rice crop both in grain and straw were 44.03 and 18.06 kg ha^{-1}; 9.46 and 3.11 kg ha^{-1} ; 7.28 and 68.31 kg ha^{-1} in *kharif* where as 42.04 and 16.36 kg ha^{-1}; 8.55 and 2.92 kg ha^{-1} ; 6.15 and 60.89 kg ha^{-1} in summer, respectively . The nutrient content and uptake followed reverse trend with each other in all the treatments.

6.13 Organic manuring along with Biozyme application improved the physico-chemical and biological properties of the soil like organic carbon, available N, P and K status, microbial population, vermicast and nearly neutral soil pH.

6.14 Crop receiving Dhanicha + FYM + Vermicompost + BSP + BG + BPPL in *kharif* and FYM + Vermicompost + BSP + BG + BPPL in summer (T_{12}) incurred the highest cost of cultivation of ₹ 32, 811.8 and 32, 757.4 ha^{-1} , but fetched the highest gross returns of ₹ 60, 474.6 and 58,816.2 ha^{-1} with net monetary returns of ₹ 26, 662.8 and 26, 058.8 ha^{-1} and return per rupee invested of ₹1.79 and 1.80 in respective seasons in comparison with average cost of cultivation of ₹ 32, 567.0 and 31, 513.0 ha^{-1} , but fetched gross returns of ₹ 50, 528.6 and 48, 893.4 ha^{-1} with net monetary returns of ₹ 17, 961.6 and 17, 380.4 ha^{-1} and return per rupee invested of ₹1.5 in both the seasons.

Plate 9: Field supervisors and workers at their job

Plate 10: Field visit of Biostadtians

Plate 11: Field visit of OUATians

CONCLUSION

As per the experimental findings combination of organic nutrients with Biozyme formulations such as *Dhanicha* + FYM + Vermicompost + BSP + BG + BPPL in kharif and FYM + Vermicompost + BSP + BG + BPPL in summer rice are encouraging as regards to productivity of rice and soil health. For more return per rupee invested and for enhancement of soil health the same treatment can be advocated to be practiced in rice-rice sequence. But, the experiment needs to be repeated for verification and confirmation.

FUTURE THRUST OF WORK

- Detailed study on microbial population and microbial biomass.
- Rate of soil carbon sequestration and their fractionation.
- Quality aspect of the organic product

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