Productivity and economic feasibility of Rainfed Rice (*Oryza sativa* L.) as influenced by crop geometry and cultural practices in Satna District of Madhya Pradesh in the context of climate change

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CERTIFICATE OF ORIGINAL WORK

This is to certify that the study conducted by **Miss D. Saveipune Id. No. 12MSAGRO005,** during **2012-2014** as reported in the present thesis was under my guidance and supervision. The results reported by her are genuine and the candidate herself has written the script of the thesis. Her thesis entitled, **"Productivity and economic feasibility of Rainfed Rice (*Oryza sativa* L.) as influenced by crop geometry and cultural practices in Satna District of Madhya Pradesh in the context of climate change"**, is therefore, being forwarded for the acceptance in partial fulfillment of the requirements for the award of the degree of **Master of Science (Agriculture) in Agronomy**, of the Allahabad School of Agriculture, Faculty of Agriculture, Sam Higginbottom Institute of Agriculture, Technology and Sciences, (Deemed-to-be-University), Allahabad – 211007 (U.P).

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CERTIFICATE OF ACCEPTANCE OF EVALUATION COMMITTEE

This thesis entitled **"Productivity and economic feasibility of Rainfed Rice (*Oryza sativa* L.) as influenced by crop geometry and cultural practices in Satna District of Madhya Pradesh in the context of climate change"**, has been prepared and submitted by **Miss, D. Saveipune Id. No.12MSAGRO005** in partial fulfillment of the requirement for the award of degree of **Master of Science (Agriculture) in Agronomy,** of the Allahabad School of Agriculture, Faculty of Agriculture, Sam Higginbottom Institute of Agriculture, Technology and Sciences, (Deemed-to-be-University), Allahabad - 211007 (U.P.).

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Allahabad.

Date : ***D. Saveipune***

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LIST OF ABBREVIATIONS

%	:	Percentage
&	:	and

/	:	per
@	:	at the rate of
˚C	:	Degree Centigrade or Celsius
ANOVA	:	Analysis of Variance
AES	:	Agro Ecosystems
ARD	:	Agriculture Research for Development
Avg.	:	Average
CD	:	Critical Difference
CGR	:	Crop Growth Rate
cm	:	Centimeter(s)
CTR	:	Conventional transplanted rice
DAP	:	Diammonium phosphate
DAS	:	Days after sowing
DAT	:	Days after transplanting
DPO	:	District Project Officer
DSR	:	Direct seeded rice
d.f.	:	Degrees of freedom
e.g.	:	For example
EC	:	Electrical Conductivity
ESST	:	Error Sum of Squares due to treatment
ESSR	:	Error Sum of Squares due to replication
et al.	:	And others
FAA	:	Fish amino acid
F Cal	:	F calculated
FPDC	:	Food production Distribution Consumption System
F Tab	:	F table
Fig.	:	Figure
FYM	:	Farmyard Manure
GM	:	Green manuring
GMI	:	Green manure incorporation
GLM	:	Green Leaf Manuring
G	:	gram
ha	:	Hectare
i.e.	:	That is
Int.	:	Interaction

kg	:	Kilogram
LAI	:	Leaf area index
m	:	Meter(s)
m ha	:	Million hectares
m^2	:	Square meter(s)
max.	:	Maximum
MESS	:	Error Mean Sum of Squares
mg	:	Milligram
min.	:	Minimum
mm	:	Millimeter
MTSS	:	Treatment Mean Sum of Squares
MRSS	:	Replication Mean Sum of Squares
MSS	:	Mean Sum of Squares
mt	:	Million tonnes
nm	:	nanometer
NABARD	:	National Bank for Agriculture and Rural Development
NAR	:	Net assimilation rate
No.	:	Number
NPK	:	Nitrogen, Phosphorus, Potassium
NRAA	:	National Rainfed Agriculture Authority
NS	:	Non-significant
OM	:	Organic matter
ONM	:	Organic nutrient management
OFARM	:	On-Farm Adaptive Research
pp	:	Pages
PAR	:	*Photosynthetically Active Radiation*(*PAR)*
r	:	Number of replications
Ref	:	References
RF	:	Rainfall
RGR	:	Relative Growth Rate
RH	:	Relative Humidity
rpm	:	Round per minute
RSS	:	Replication Sum of Squares
₹	:	Rupee(s)
S	:	Significant

SHF	:	Small Holder Farmers’
SHFC	:	*Small Holder Farmers' Collective (s)*
SRI	:	System of Rice Intensification
SS	:	Sum of Squares
SV	:	Source of Variation
T	:	Treatment
TCA	:	Tri chloroacetic acid
Temp.	:	Temperature
t ha^{-1}	:	Tonnes per hectare
TSS	:	Total Sum of Squares
VC	:	Vermicompost
Viz.	:	Namely
VRA	:	Village Research Assistant

Chapter 1
Introduction

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of Asia. Rice production constitutes the major economic activity and a key source of livelihood for the rural household of India. It is the world's most important food crop of Asian origin. India has 42.56 m ha area under rice and production 95.33 m tonnes (GOI, 2011). Rice is staple food of more than 60% of Indian population. It accounts for about 43% of total food grain production and 46% of total cereal production in the country. In order to meet the domestic demand of the increasing population the present day production of 95.32 million tonnes (2010) of milled rice has to be increased to 130 million tonnes by the year 2025. This projected demand can only be met by maintaining steady increase in production over the years. Thus, rice is a strategic commodity and sustained growth in its productivity is important for improved food security and income growth of the poor. Increase in food production in the country does not necessarily ensure food security, if the poor do not have the buying power. Therefore, participation of small farmers in food production is essential to achieve food security in the country. Most of them being illiterate and having failed earlier either in adapting new technologies or repaying the loan provided under various development schemes sponsored by the government, they have lost confidence both in themselves and the Extension Agencies. They need support not only to procure inputs but also to gain confidence (Hegde, 2000).

During the Green Revolution era, the growth rate of rice (2.3%) was higher than population growth and thus there was surplus production. But now, with the onset of second-generation problems, such as soil fatigue, declining water table, and most important, climate change, production and productivity gains of rice are a big question mark (Chauhan and Mahajan, 2013). Extreme temperatures – whether low or high – cause injury to the rice plant. In tropical regions, high temperatures are a constraint to rice production. The most damaging effect is on grain sterility; just 1 or 2 hours of high temperature at anthesis (about 9 days before heading and at heading) result in a large percentage of grain sterility. Studies on rice productivity under global warming also suggest that the productivity of rice and other tropical crops will decrease as global temperature increases. Climate change variability and change can immensely affect the agriculture productivity of India. More vulnerable in view of high population depending on agriculture, excessive pressure on natural resources and poor coping mechanism. A large area of land under Dryland agriculture is expected to undergo changes in rainfall patterns, temperature and extreme event over the next several decades due to climate change thus making rainfed agriculture more risk prone (Nguyen, 2006).

Rainfed crops are likely to be worse hit by climate change because of the limited mechanisms for coping with variability of precipitation. Thus, adaptation in rainfed rice production can be seen as a promising entry point to buffer the consequences of climate change amongst the poorest of the poor (Wassmann and Dobermann, 2007). Rainfed areas currently constitute 55 per cent of the net sown area of the country. Even after realizing full irrigation potential, about 50 per cent of the cultivated area will continue to remain rainfed. Moreover, two thirds of livestock and 40 per cent of human population of the country live in rainfed regions. In order to achieve overall development of agriculture in the country, it is essential to bridge the yield gaps, enhance the productivity and profitability, minimize risk and improve the livelihoods of millions of people dependent on rainfed agriculture (NRAA, 2012).

SAF-BIN is an action research programme under the European Union Global Programme on Agriculture Research for Development (ASD). It is multi-dimentional research that address the agricultural development challenges of developing an emerging countries. It is an initiative to promote local food and nutritional security through adaptive small scale farming in four rainfed Agro Ecosystems (ASE) in south Asia. SAF-BIN project dealing with building resilience to climate change through strengthening adaptive small scale farming in Bangladesh, India and Nepal. The OFAR trial was conducted in Satna district of Madhya Pradesh. M.P is the second largest Indian state in terms of geographical size (3.08 lakh sq.km) accounting for 9% of the total geographical area of the country. As per agriculture census 2010-11, total land holding declined from 2.22 ha (2000-01) to 1.78 ha (2010-11). The marginal and small farmers account for 71% and hold 34% of the total area. Fragmentation of land is very challenging issue as evidenced by the increasing number of small land holding in state. Agriculture in the state, especially for small and marginal farmers in rainfed areas is perceived to be increasingly unviable owing to yield and price risk and lack of risk countering mechanism and affect production and productivity (NABARD, 2014). In MP, total area under rice production is 1.7 million ha in which only 223 thousands ha comes under irrigated situation. Total rice production is 1710 thousand tonnes in which 1313 thousands tonnes is from rainfed and 397 thousand tonnes is from irrigated area. The productivity of total rice area in MP is 1103 kg ha^{-1} while irrigated area has 1273 kg ha^{-1} (Rao, 2011). In all probability the productivity of rainfed rice may not be above 940 kg ha^{-1}.

On-Farm Adaptive Research is an important component of rural research that attempts to adapt technology to suits farmers' condition. An On-farm adaptive research

(OFAR) is a link between the laboratory or on-station research and the actual acceptance of proven technologies by farmers, which relate to farmers of various economic strata. OFAR is like the research carried out by an industrial concern to successfully get its product accepted by customers or consumers (Nene, 1993). On-farm research is in fact that "look" in combination with a scientific approach. An on farm trial aims at testing a technology or a new idea in farmer's fields, under farmer's conditions and management, by using farmer's own practice as control (Jakar, RNR-RC. 2001). According to (Mahapatra and Behera., 2011), the strategy for "On Farm Adaptive Research" has to be a "bottom-up" approach, which was certainly implemented and evident during the course of trial in Satna Disrict of Madhya Pradesh.The primary objective of OFAR is to improve the well being of individual farming families by increasing the overall productivity of the farming system in the context of both private and social goal. Adaptive research is designed to adjust technology to the specific needs of a particular set of environmental conditions by taking into account the different bio-physical and socio-economic circumstances of the farmers. The concept of OFAR entails full farmers' participation, direct contact between researchers and farmers and concerted multi- disciplinary investigation of farmers' situations (Adeola *et al*., 2014).

During the process of base line and secondary review of SHF collective through interective sessions, most of the farmers' revealed that they raised rice crop without any consistent spacing and mostly prefered closer spacing. However, according to Hasanuzzama *et al*., 2009, closer plant spacing reduce the number of effective tillers and increases the tiller mortality. Wider spacing coupled with higher number of seedlings hill^{-1} accumulate maximum amount of dry matter and productivity of tillers as well as dry matter yield will be lower with closer spacing. According to Gautam *et al*., 2008, proper planting geometry have more advantages such as, maximize light utilization efficiency, improves aeration within crop canopy, enhances soil respiration and provides better weed control thereby higher crop yields.

Use of natural products to produce crops traces back to early recorded history. According to Pathak and Ram, 2013, use of organic liquid preparations has been an age old practice in India**,** use of these formulations can resolve many problems associated with soil fertility. According to Abraham and Lal, 2002 and Chadha *et al*., 2012 the application of biological and organic manures not only supply a balanced amount of micronutrients but also improve the physico-chemical and biological properties of soil. According to FFTC, 1995, the farmers in recent years are not adopting the cultural practices as they want to ensure good yields, and apply so much fertilizer that much of it is wasted, which is also due to its availability and relatively cheaper. However, there are some problems in their efficient use and also the extremely the fact that the negative balance has serious implications of a long-term loss of productivity.

A major reason for the recent interest in organic input is the widely held view that thereby is safe to humans, environment, and natural enemies of pests (Soon and Bottrell, 1994). It is eco-friendly, enhances crop fertility, helps in soil and water conservation, cost effectiveness, simple and easy method, makes use of material which otherwise goes waste, technically feasible, no risk is involved, and widely accepted (Lal and Verma, 2006). Therfore, the use of organic liquid formulation of bio-products can confer significant economic advantage and service to rural areas.

The rice ear head bug *gundhi bug* (*Leptocoriza acuta* Th.) is one of the major sap sucking pest of paddy. Both the nymphs and adult suck the sap from developing grains during milk growth stage and thus make them partial or completely chaffy. Therefore, the use of bio-pesticides as an eco-friendly and cost effective component in integrated pest management is imperative. Neem, *Azadirachta indica* has come under close scientific scrunity as a source of pest control material imparting no ecological adversity (Chakraborty, 2011) and natural pest management to prevent pest and diseases (Lokanadhan *et al*., 2012).

Agronomic management is the most important input for getting potential yield and high net returns in any crop. Therefore, the present study was undertaken to find out the effect of different agronomic management practices (proper plant spacing, organic component, reduce insect pest attack and agronomic analysis) on productivity and economics of rice in the farmers' fields with the following;

Objectives:

1. To find out the effect of crop geometry on rainfed rice
2. To find out the effect of cultural practices on growth and yield of rice
3. Efficacy of organic formulation against insect infestation in rainfed rice
4. Economics analysis of rainfed rice.

CHAPTER 2
REVIEW OF LITERATURE

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REVIEW OF LITERATURE

In this chapter, attempt has been made to review the important and relevant On Farm Adaptive Research (OFAR) from researchers related to the present thesis entitled "Productivity and economic feasibility of Rainfed Rice (*Oryza sativa* L.) as influenced by crop geometry and cultural practices in Satna District of Madhya Pradesh in the context of climate change''.

On-Farm Adaptive Research is an important component of rural research that attempts to adapt technology to suit farmers' condition. An On-farm adaptive research (OFAR) is a link between the laboratory or on-station research and the actual acceptance of proven technologies by farmers (Nene, 1993). According to Mahapatra and Behera, 2009, the primary objective of OFAR is to improve the well being of individual farming families by increasing the overall productivity of the farming system in the context of both private and social goal.

The work done by researchers have been classified as per the following headings.

2.1 On Farm Adaptive Research (OFAR) approaches

2.2 Effect of Climate change on rice productivity

2.3 Influence of crop geometry on rainfed rice

2.4 Effect of cultural practices on growth and yield of rice

2.5 Efficacy of organic formulation against insect infestation in rainfed rice

2.6 Economic analysis of rainfed rice.

2.1.2 On Farm Adaptive Research Approaches

On-Farm Adaptive Research is an important component of rural research that attempts to adapt technology to suit farmers' condition. An On-farm adaptive research (OFAR) is a link between the laboratory or on-station research and the actual acceptance of proven technologies by farmers. OFAR is like the research carried out by an industrial concern to successfully get its product accepted by customers or consumers. Farmers' participation in OFAR will provide an interactive mode so that both the researcher and farmer can decide on the conduct of trials, and technology to be tested. Active participation of farmers in the conduct of OFAR improves the chances of its success. In most cases, the economic level of farmers determine their capacity to adopt technologies. The aim is to make sure that technology will be well adapted to specific local conditions (Nene, 1993).

Mahapatra and Behera (2011) reported that the strategy for "On Farm Adaptive Research" has to be a "bottom-up" approach. On Farm Adaptive Research target is the small farmers who are extremely variable in socio-economic parameters, and are subjected to enormous bio-physical contraints. It is for this reason that the objective selection of farmers and fields should be done so as to be representative of the most realistic situation in which a crop variety or a production technology should be tested and evaluated and conclusion drawn on the basis of stratification with reference to agro-climatic zone, soil, and fertility levels and socio-economic parameters of farmers. For this reason not only the data on the test varieties and production technology should be collected but the description of the climate, soil, farm, farmers and his management should be made (of the target trial sites and farmers) to be analysed and correlate the information for working out the appropriate recommendations.

Murithi (2000) and Adeola *et al*. (2014) stated that adaptive research is designed to adjust technology to the specific needs of a particular set of environmental conditions by taking into account the different bio-physical and socio-economic circumstances of the farmers. The concept of OFAR entails full farmers' participation, direct contact between researchers and farmers and concerted multi- disciplinary investigation of farmers' situations.

Nielsen (2010) opined that the purpose of conducting field crop research is to come up with fact-based answers to farming's challenging questions for which no previous answers exist. Effects of experimental treatments or variables on crop yield or other important outcomes are evaluated under controlled conditions and then those results are used to predict their future performance across the broader extent of agricultural production. On-farm research (OFR) not only seeks to identify answers to important questions but may also serve to validate previously discovered answers or convince growers that an alternative crop management practice is profitable for their own situations.

RNR-RC Jakar (2001) in its OFAR Mannual states that On-Farm Research is in fact that look in combination with a scientific approach. An on-farm trial aims at testing a technology or a new idea in farmer.s fields, under farmers' conditions and management, by using farmer's own practice as control. It should help to develop innovations consistent with farmer's circumstances, compatible with the actual farming system and corresponding to farmer's goals and preferences. An on-farm-trial is not identical to a demonstration field, which aims at showing farmers a technology of which researchers and extension agents are sure that it works in the area.

Murithi (2000) observed it entails the involvement of a wide range of participants in the identification of farming systems constraints, development of interventions and dissemination of the technologies. The process involves a partnership of multidisciplinary teams of research scientists, extension workers, farmers, farmer organisations, non-governmental organisations, community-based organisations and other stakeholders. Most of the adaptive research activities are conducted on-farm, with varying degrees of researcher and farmer involvement in the design and management of on-farm trials. Farmer participatory research implies the involvement of farmers as equal partners in the diagnosis of constraints, designing of interventions, monitoring and evaluation, dissemination, assessing adoption and impact, and providing feedback. The reason behind the farmers' participatory approaches is that it increases the probability of adoption of the technologies since it creates a sense of ownership and credibility of the process among the farmers and other partners. According to him Kanya Agriculture Research Institute has made great strides in utilising the farmer participatory research approaches in generating appropriate technologies for smallholder farmers.

Veseth *et al*. (1999) reported that farmers have often evaluated a new practice by applying it to a small field and comparing the results with nearby fields, or by splitting a field and applying the new practice on one side and their normal practice on the other. This allows for a local comparison of how a practice "looks." It can be an important first step. The problem comes when you want more than a "look." It is simply not possible to make reliable comparisons of yields and other "quantitative" data without a scientific approach.

2.1.1 Effect of Climate change on rice productivity

Any permanent change in weather phenomena from the normal of a long period average is referred as climate change *e.g.*, the global temperature has increased by 2.0–3.0°C and increase in CO_2 from 180 ppm to 350 ppm. Vast fires in Siberia burned over three million acres of forests. Human and crop losses are the worst phenomena in such weather disasters, affecting

global economy to a considerable extent. In 2004, nobody can forget the Tsunami problem inIndonesia, India, Sri Lanka and other Asian countries. Crop production is weather dependant and any change will have major effects on crop production and productivity. Elevated CO_2 and temperature affects the biological process like respiration, photosynthesis, plant growth, reproduction, water use etc (Chandrasekaran *et al.*, 2010).

Wassmann and Dobermann (2007) reported that rainfed crops are likely to be worse hit by climate change because of the limited mechanisms for coping with variability of precipitation.

Thus, adaptation in rainfed rice production can be seen as a promising entry point to buffer the consequences of climate change amongst the poorest of the poor.

Hegde (2000) opined that capability of the farmers to manage their own farms is another important factor influencing the crop yields. While the rich and elite farmers have been able to adapt improved agronomic practices to earn good returns, poor and uneducated farmers who receive incomplete information or cannot raise money on time to procure critical inputs, generally end up with lower crop yields and huge losses. Hence the strategy to enhance the food production should address the problems of such unsuccessful farmers, who represent over 75% of the total holders in the country. Therefore, participation of small farmers in food production is essential to achieve food security in the country.

Prasad and Bambawale (2010) reported that increased temperatures can alter both plant and herbivore phenology with likely impact on synchronization between the two again indirectly influencing the activity of natural enemies and the effectiveness of their natural control. Higher minimum temperatures in temperate regions can lead to expansion of geographical range of insect pests which are currently intolerant to low temperatures. This may result in pest outbreaks in the newer areas if natural enemies fail to track and follow their hosts. Variability in rainfall reportedly has an adverse influence on parasitism levels of several caterpillar pests. Sucking pests like cereal aphids are less susceptible to climate change effects.

Nguyen (2006) through his studies suggested that the temperature increases, rising seas and changes in rainfall patterns and distribution expected as a result of global climate change could lead to substantial modifications in land and water resources for rice production as well as in the productivity of rice crops grown in different parts of the world.

Chauhan and Mahajan (2013) observed that during the Green Revolution era, the growth rate of rice (2.3%) was higher than population growth and thus there was surplus production. But now, with the onset of second-generation problems, such as soil fatigue, declining water table, and most important, climate change, production and productivity gains of rice are a big question mark.

Nagai and Makino (2009) reported that biomass production and relative growth rate (RGR) were greatest in rice at 30/24 ºC and wheat grown at 25/19ºC. Although there was no difference between the species in the optimal temperature at the leaf area ratio (LARs), the net assimilation rate (NAR) in rice decreased at low temperature 19/16ºC while (NAR) in wheat decreased at high temperature 37/31ºC.

Shah *et al.* (2011) stated that the impact of high temperatures at night is more devastating than day-time or mean daily temperatures. Booting and flowering are the stages most sensitive to high temperature, which may sometimes lead to complete sterility. Humidity also plays a vital role in increasing the spikelet sterility at increased temperature. Significant variation exists among rice germplasms in response to temperature stress. Flowering at cooler times of day, more pollen viability, larger anthers, longer basal dehiscence and presence of long basal pores are some of the phenotypic markers for high temperature tolerance.

NRAA (2012) in its study observed that rainfed areas currently constitute 55 per cent of the net sown area of the country. Even after realizing full irrigation potential, about 50 per cent of the cultivated area will continue to remain rainfed. Moreover, two thirds of livestock and 40 per cent of human population of the country live in rainfed regions. In order to achieve overall development of agriculture in the country, it is essential to bridge the yield gaps, enhance the productivity and profitability, minimize risk and improve the livelihoods of millions of people dependent on rainfed agriculture.

2.3 Effect of crop geometry on rainfed rice

Crop geo**e**metry is the pattern of distribution of plant over the ground or the shape of the area available to the individual plant, in a crop field. It influences crop yield through its influence on light interception, rooting pattern and moisture extraction pattern. Crop geometry is altered by changing inter and intra-row spacing (*Planting pattern*). Wider spaced crops have a advantage, Plants which requires no restriction in all directions are given square geometry. (Chandrasekaran *et al*., 2010).

Rashid and Khan (2006) reported that the wider spacing produced higher number of tillers at maximum tillering stage which was not realized in number of ear bearing tiller m^{-2}. A similar grain yield of BRRI Dhan 44 at a wider spacing of 25 cm × 25 cm indicated its suitability where wider spacing is practiced. Significantly higher filled grains $panicle^{-1}$ was found at the wider spacing, 25 cm × 25 cm (109.6) which was comparable to 20 cm × 20 cm (104.1). The filled grains $panicle^{-1}$ decreased at closer spacing.

Gautam *et al*. (2008) observed that the percentage increase in grain yield of aromatic rice varieties due to plant spacing of 20 cm × 20 cm was in the tune of 16.1 and 16.4% over 20 cm × 10 cm spacing and 6.5 and 5.7% more over 20 cm × 15 cm during 2002 and 2003, respectively. While, a spacing of 20 cm × 15 cm resulted in 9 and 10.2% more grain yield than 20 cm x 10 cm spacing. Higher straw yield was recorded with the adoption of 20 cm × 10 cm spacing. Transplanting of rice at a wider spacing of 20 cm × 20 cm produced a significantly higher number of tillers per hill as compared to closer spacings of 20 cm × 10 cm and 20 cm × 15 cm. Successive increase in nitrogen levels significantly increased the number of tillers at all the growth stages of the crop.

Hasanuzzama *et al*. (2009) conducted a study and their results revealed that both the plant spacing and number of seedlings $hill^{-1}$ showed a significant effect on the tillering and dry matter yield of transplanted rice. At initial stages the treatments did not show any significant effect. At all the growth stages wider row spacings (25 cm × 20 cm) and higher number of seedlings hill^{-1} (3 and 4) showed maximum tillering. Closer plant spacing reduced the number of effective tillers and increased the tiller mortality.

Shekhar *et al*. (2009) ascertained significantly higher grain yield in ICM (Integrated crop management) (6.67 t ha^{-1}) which was transplanted 20 cm × 20 cm spacing as compared to conventional transplanting (5.81 t ha^{-1}) with the spacing 20 cm × 10 cm spacing.

Bezbaruha *et al.* (2011) also reported that higher grain yield was registered when the cultivars were grown in 20 cm × 20 cm planting geometry and also produced maximum biomass. Maximum N, P, and K uptake values were recorded in 20 cm × 20 cm crop geometry and inorganic fertilizers treatment.

Mohaddesi *et al*. (2011) observed that grain yield was significantly affected by plant spacing with sets of management practices. Greater plant spacing contributed to higher yield as cultivar yields rose from 7280.4 kg yield ha^{-1} with 25 × 25 plant spacing to 8619.9 kg yields ha^{-1} with
20 cm × 20 cm spacing.

Damodaran *et al.* (2012) reported that time of planting, spacing and nitrogen management practices significantly influenced the growth and yield attributes while number of seedlings/ hill did not exert any influence on these parameters**.** Planting in second fortnight of June with 20 × 20 cm spacing recorded higher number of tillers (18.3), DMP (17.6 g), panicles m^{-2} (9.2) and filled grains panicle m^{-1} (9.1) and also reported that the yield attributes *viz*, panicles m^{-2}, panicle length and filled grains panicle^{-1} was significantly influenced by the time of planting, spacing and N management practices while number of seedlings hill^{-1} did not show much variations on the yield attributes.

Ogbodo *et al*. (2010) conducted elaborate study and reported that wider spacing showed superior influence in crop growth attributes measured, tillering and plant height increased linearly with increases in plant spacing. The wider spacing produced plants with more vigorous growth and larger plant size which normally increases photosynthetic efficiency. The wider feeding area provided by transplanting at 30 cm × 30 cm and 20 cm × 20 cm provided opportunity for greater root growth, increased availability of nutrients and greater accessibility of nutrients to plant. Grain yield increased significantly with every increase in plant spacing. The rice crops transplanted at 30 cm × 30 cm produced 2.62 and 1.43 t ha^{-1} and 2.11 and 1.21 t ha^{-1} which were significantly ($p<0.05$) higher grain yield in the first and second years than the ones transplanted at 10 cm × 10 cm and 20 cm × 20 cm respectively. The rice transplanted at 20 cm x 20 cm also yielded 1.80 and 0.90 t ha^{-1}, significantly

($p<0.05$) more grains than those transplanted at 10 cm x 10 cm in the first and second years respectively.

Roshan *et al*. (2011) observed that the effect of plant spacings on traits grain yield, plant height, number of grains per panicle and number of bearer and non-bearer tillers per square meter had a significant difference in 1% probability level. The spacing of 20 cm × 20 cm with 5582kg ha^{-1} grain yield was recorded highest amount this traits.

Rasool *et al*. (2013) reported that the plant spacing of 20 cm × 20 cm significantly recorded higher panicle length, panicle weight more spikelets panicle^{-1}, grain panicle^{-1} as compared to 15 × 20 cm and 15 × 15 cm spacings. The wider spacing adopted appears to be an advantageous factor for better development of panicles, hence more panicle length, panicle weight, spikelets number and filled grains panicle^{-1}.

Gorgy (2010) conducted a research in Egypt and reported that regarding planting spacing, the closer spacing (20 cm × 15 cm) gave higher dry weight, plant height, sterility percentage, straw yield than wider spacings (20 × 20 and 20 cm × 25 cm). Seedlings planted at 20 cm × 20 cm produced the highest value of LAI, chlorophyll content, number of panicles m^{-2}, number of filled grains panicle^{-1}, grain yield and nitrogen use efficiency (NUE). Both wider spacings (20 cm × 20 cm and 20 cm × 25 cm) gave the heaviest panicles and maximum filled grains panicle^{-1} without any significant differences between them. The wider spacings of 20 cm × 20 cm (25 hills m^{-2}) and 20 × 25 cm (20 hills m^{-2}) gave the heaviest panicle weight, maximum number of filled grains panicle^{-1} and lowest sterility%. The inferiority of 20 cm × 15 cm hill spacing may be due to reduced rate of photosynthesis because of the competition among plants for light within the dense plants. These results were in agreement with those obtained by Shivay and Singh (2003) and Gorgy (2007).

Tyeb *et al*. (2013) reported that plant height, number of effective tillers hill^{-1}, non-effective tillers hill^{-1}, grains panicle^{-1}, unfilled grains panicle^{-1}, grain yield, straw yield, biological yield and harvest index were significantly influenced by spacing. The highest plant height (112.57cm) was recorded in 25 cm × 15 cm which was identical to 25 cm × 20 cm (117.75cm) followed by 20 cm × 20 cm (110.81cm) while the lowest plant height (105.27 cm) was obtained in 20 cm × 10 cm.

2.2 Effect of cultural practices on growth and yield of rice

Abraham and Lal (2002) reported that the application of biological and organic manures not only supply a balanced amount of micronutrients but also improve the physico-chemical and biological properties of soil, thus creating a conducive rhizosheric environment for crop production. It is pertinent that for sustainability in cropping systems, combining manure application with crop rotation involving legumes could be an effective crop management practice.

Soon and Bottrell (1994) reported that major reason for the recent interest in organic inputs is the widely held view that these are safe to humans, the environment, and natural enemies of pests. The farmers derive many of these materials from plants. Some traditional botanical pest control methods are still used, especially by rice farmers not yet heavily influenced by modern technology.

Gupta and Dikshit (2010) reported that the rich traditional knowledge base available with the highly diverse indigenous communities in India may provide valuable clues for developing newer and effective biopesticide. The stress on organic farming and on residue free commodities would certainly warrant increased adoption of biopesticides by the farmers, which increased adoption of biopesticides by the farmers. Increased adoption further depends on-1.Concrete evidences of efficacy of biopesticides in controlling crop damage and the resultant increase in crop yield, 2. Availability of high quality products at affordable prices, 3.Strengthning of supply chain management in order to increase the usage of biopesticides. In this regard, an efficient delivery system from the place of production (factory) to place of utilization (farm) of biopesticides is quite essential.

Ahmed and Koppel (1987) conducted a survey of post-harvest control practices of 145 farmers in 11 districts of six provinces in India. They found that 30-60% of the farmers who stored wheat, rice, sorghum, and millet, used 4-10% neem leaves for protection which was found to be effective.

Chadha *et al.* (2012) reported that nutritional and microbial analysis of these organic liquid manures shows the presence of macro and micro nutrients and large population of essential microbes, *Azotobacter* sp., *actinomycetes* sp. and phosphate solubilizer. According to them, all the *Vedic inputs* are found to be quite effective in enhancing the productivity of different crops and supressing the growth of various plant pathogens by producing anti bacterial and anti fungal compounds, hormones and siderorphores. Compost tea, *Matka khad* and jeevamrit as foliar spray were also prooved quite effective in enhancing the productivity of different crops and effective against various plant pathogens.

In organic production systems, there is always a challenge of how to improve soil fertility, crop productivity and management of pests by organic techniques**.** Pathak and Ram (2013) opined that concentrated manures, bio products in powder or in liquid form, henceforth termed as Bio-enhancers are organic preparations, obtained by active fermentation of animal & plant residues over specific duration. These are rich source of microbial consortia, macro, micronutrients and plant growth promoting substances including im- munity enhancers. Review of available literature with bio enhancer indicates that there is immense scope for its promotion in agriculture, as it could be a cheap and alternative tool to resolve issues like fertigation using resources, their own products and utilize them as per requirement.

Branca *et al*. (2013) opined that the sustainable land management practices considered in the review are found to increase the yield of cereals. They further, opined that adopting organic fertilization (compost, animal, and green manure) is widely found to have positive effects on the yields. However, agronomy, integrated nutrients, and water management practices are more effective at increasing crop yields in humid than in dry areas.

Azarpour *et al.*, 2014 observed that crop growth rate is as long as its represents total dry weight increment. So, the curve of crop rate cannot match with the curve of total dry weight. It mean that at the end of the growth total dry weight reaches each maximum while crop growth rate at flowering stage reaches to its maximum. When CGR is negative total dry weight is reduce. When CGR reaches to its highest level the gradient of plant growth is maximum and when CGR is fixed the gradient of dry matter accumulation is fixed. After flowering stage due to senensecence and abscission active photosynthesis tissues are reduce and stuctural tissues are increased or may be LAI is so increased which lower leaves cannot absorb sufficient light for having positive CGR. When RGR in the treatments was observed at early growth stage and over the time it is decreased linearly.

Kumar *et al*. (2007) also recorded higher yield of rice-wheat cropping system with the use of organic manures. They also reported that bio-fertilizers have added advantage in wheat production.

Surekha *et al*. (2008) reported that the grain yield increased significantly with organics (4.06–6.05 tonnes ha^{-1}) over inorganic fertilizers alone (3.94–4.33 tonnes ha^{-1}).

Sangheeta *et al*. (2014) stated that yield attributing characters, *viz*., productive tillers m^{-2}, filled spikelets $panicle^{-1}$ and grain and straw yield of rice were influenced significantly by the application of organic manures.

Satyanarayana *et al*. (2002) results showed that application of farmyard manure at 10 t ha^{-1} increased grain yield of rice by 25% compared to control. Similar observations were also made on straw yield 12%, tiller number 12%, filled grains per panicle 6%, and 1000-grain weight 9%. Application of farmyard manure significantly improved number of tillers, number of filled grains, 1000-grain weight, grain yield and straw yield of rice.

Munda *et al*. (2008) reported that utilization of indigenous sources of organics, *viz.*, FYM, obnoxious weeds and green leaf manures may serve as alternatives to chemical fertilizers and helped in increasing the productivity of rice-based cropping system.

Kharub and Chander (2008) reported that FYM application for three years significantly improved the values of soil organic carbon (14.3%), available N (10.7%), P (5.4%) and K (2.6%).

Shekhar *et al*. (2009) stated that more tillering at hill level compensated and thus effective tillers m^{-2} in integrated crop management (247) were at par with conventional transplanting (244) but were less in system of rice intensification (203). Panicle weight (g) was significantly more in system of rice intensification (3.75 g) followed by integrated crop management (3.01 g) and conventional transplanting (2.85 g). On an average integrated crop management (6.67 t ha^{-1}, 14.5%) and system of rice intensification (6.43 t ha^{-1}, 10.6%) produced significantly more grain yield compared to conventional transplanting (5.81 t ha^{-1}).

Kumari *et al*. (2013) in the experiment observed that the productivity of rice was similar after wheat (2.28 t ha^{-1}) or lentil (2.25 t ha^{-1}) as heavy application of organic manure in wheat compared to lentil compensated the residual N gain of soil after lentil. All combinations of organic manuring were almost equally effective in increasing productivity of rice.

Kumar *et al*. (2013) opined that the benefit of using organic manure like FYM was due to release of aliphatic and aromatic hydroxy acids and humates that leads to higher availability of nutrients.

Paul *et al.* (2013) reported that soil organic matter content (2.1%) was found maintained in FYM containing treatments (2.15–2.17%), while declining with inorganic treatments. The uptake of N, P and K was found to be associated with production of total dry matter resulted by the addition of NPK fertilizer and FYM application.

Yadav *et al*. (2013) reported that rice productivity was increased by 28% due to application of RDN through organic manure along with biofertilizers over control. Similarly, 100% RDN through organic manure alone enhanced the productivity of rice by 25.6% over the control.

2.3 Efficacy of organic formulation against insect infestation in rainfed rice

Prakash *et al*. (2008) reported that against *Leptocoriza. acuta*, a number of botanicals, *viz*., 5 per cent aqueous leaf extract of king of bitters *A.paniculata,* 3 per cent oil emulsion spray of neem *A.indica*, seed extract of orange *C.reticulate* and leaf extract of lemon grass *C.citrate* are found to protect developing rice grains (Gupta *et al*., 1990).

Khan *et al.* (2009) from their trial of botanicals showed that the Neem (300 g Neem leaf biomass) treatment gave the highest grain yield and that of Arjun was the lowest. There was no significant effect on 1000 grain weight. The highest grain yield (5.66 t ha^{1}) was recorded in the treatment T_6 (300 g Neem leaf biomass) followed by mahogany (second highest) treatment. Among the tree leaf biomass, Neem and Mahogany treatments were found the best. Thus it appears that tree leaf biomass could successfully be used as an alternative to chemical fertilizers. The highest plant height (104.19 cm), panicle length (24.33 cm) and total number of effective tillers $hill^{-1}$ (12.12) was observed in the treatment T_6 (300 g Neem leaf biomass) which was statistically identical with T_{12} (300g mahogany leaf biomass) treatment. The highest plant height (104.19 cm), panicle length (24.33 cm) and total number of effective tillers $hill^{-1}$ (12.12) was observed in the treatment T_6 (300g Neem leaf biomass) which was statistically identical with T_{12} (300g mahogany leaf biomass) treatment.

Chakraborty (2011) reported that for the suppression of *gundhi bug* (*Leptocoriza acuta* Th.) population, all the neem formulations were found prudent in reducing the number of adult and nymphal population of EHB in field condition. Significant variation in EHB population suppression by different pesticides were also noted.

Ram *et al*. (2011) opined that pests are generally not a significant problem in organic system, since healthy plants living in good soil with balanced nutrition are better able to resist pest and disease attack. Futher, in rice-wheat cropping system, they assumed that those farmers who adopted organic management practices, found a way to improve the quality of their soil, or at least stemmed the deterioration ensuring productive capacity for future generations.
Lokanadhan *et al*. (2012) stated that several workers have studied and reported that the properties of neem as insecticide, antifeedant, hormonal, antifungal, antiviral and nematicide properties is well known.These activities are brought out with neem use in the form of leaves, leaf extracts, seeds, cakes, oil and fruit extracts. The neem and its products are used in seed treatment, manurial application, increasing nutrient efficiency by which the grain yield in rice crop is enhanced and its sustainability is seen in rice based cropping system.

Katti (2013) stated reported that the efficacy of plant products (neem and its products) against rice pests with more potential have been better investigated than other products. Neem oil and neem cake have been extensively tested for their efficacy against various pests of rice. There are several reports on their utilization in rice pest management. However, their performance has been moderate and also inconsistent in comparison to chemical insecticides which have also been found superior in terms of their curative effect, easy application and availability. According to them, botanicals products can be alternated with synthetic pesticides to hinder the development of insecticide resistance. Futher, they emphasized that more focused research efforts in production, formulation are needed to effectively harness their potential and convince the farmers about their role as equally efficient and eco-friendly alternatives to conventional chemical pesticides.

Zong and Wang, 2004 stated that nicotine is most effective on soft-bodied insects and mites, including aphids, thrips, leafhoppers, and spider mites. Many caterpillars are resistant to nicotine. Further, Sohial *et al*. (2012) reported that botanical pesticides showed high efficacy against aphid and spray with tobacco extract effectively control aphid population followed by neem extract and garlic extract remained least effective against aphid on tea cutting.

2.4 Economic analysis of rainfed rice

Adhikari (2011) reported that their study revealed that organic farming is more cost effective than conventional one and, can yield higher than the average. The average productivity of organic rice production was found 3.15 t ha^{-1} which is consistent higher than national average. Among the factor cost, labor cost was found to contribute highest in total cost of production while poultry manure cost and oil cake cost were found to be significant factors at (P value < 0.05) to contribute in total revenue. The B:C ratio of organic rice production was found to be 1.15. The higher productivity of organic rice than the national and regional average proved that the organic rice production is a viable option for the sustainable food production and food security.

Surekha *et al*. (2013) opined that organic rice farming is more profitable and cost effective with higher productivity than conventional rice farming. Organic rice production can be sustainable and economical/remunerative over a period of time, once the soil fertility is built up due to continuous use of organic nutrient sources that release the nutrients to the plant in a balanced way, for a longer period. Hence, using easily available local natural resources, organic farming can be practiced with a view to protect/preserve/safe guard the natural resources and environment for a fertile soil, healthy crop and quality food, and let our future generations enjoy the benefits of non-chemical agriculture. According to their study, the total cost of production was high with organics in all the 5 years, though gross returns, net returns and benefit/cost (B:C) ratio were higher in inorganic production system in the first year (with 1.37 and 1.09 B:C ratio in inorganic and organic systems, respectively), organic system showed its superiority in the fifth year by fetching higher returns (with 1.75 and 1.99 B:C ratio in inorganic and organic systems, respectively).

Debashri and Tamal (2012) stated thatin recent pesticides from *A. indica* have become very much popular because of their biodegradability, least persistence and least toxic to non-target organisms, economic and easy availability, biologically active one which has a repellent, antifeedent and insecticidal activity against a number of insect pests. In India, neem products are effective against various pests of both crop fields as well as stored grains like rice, wheat, corn, legumes, potato, tomato, etc.

Tesfaye and Gautam (2003) reported that a revalidation study on the effectiveness of fermented cattle urine and natural pest against barley aphids *D. noxia* Mordov and Welo bush cricket *D. Brevipennis* Raggea in Ethiopia revealed that cow urine was toxic to these insects, provided more than double increase in yield and the toxicity was at par with tobacco, neem, chilli and garlic. The fact that synthetic pesticides are costly and often beyond the reach of the poor marginal farmers, calls upon taking a different approach based on research on the farmers indigenous technical knowledge which could ultimately lead to the development of bio-intensive IPM (integrated pest management), which will be economically feasible, socially acceptable and effective crop pest management strategies for the developing countries.

Yadav *et al*. (2009) reported that the higher returns under organic farming when compared with chemical fertilizers was mainly due to better soil health, leading to better plant growth, yield components, yield and higher prices of organic produce.

Deshpande and Devasenapathy (2010) stated that the application of organic manures for increasing soil fertility has gained importance in recent years due to high cost and adverse impact of fertilizers. Incorporation of organic manures has given a hope to reduce the cost of cultivation and minimize adverse effects of chemical fertilizers.

Upadhyay *et al.* (2011) concluded from the study that Organic nutrient management (ONM) may be followed in rice-based cropping systems, where the input costs are low and market prices for the produce are higher, which results in higher B:C ratio.

CHAPTER 3
MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The materials, methodology and techniques adopted during the course of OFAR investigation entitled, "Productivity and economic feasibility of rainfed rice (*Oryza sativa* L.) as influenced by crop geometry and cultural practices in Satna District of Madhya Pradesh in the context of climate change," of SAF-BIN Research Development Programme are described in this chapter has being classified appropriately after a brief overview of OFAR under the following heads:

The strategy for "On Farm Adaptive Research" has to be a "bottom-up" approach (Mahapatra and Behera., 2011), which was certainly implemented and evident during the course of trial in Satna Disrict of Madhya Pradesh. The adaptive research takes into account the different bio-physical and socio-economic circumstances of the clients. It entails the involvement of a wide range of participants in the identification of farming systems constraints, development and dissemination of the technologies (Murithi, 2000).

SAF-BIN is an action research programme under the European Union Global programme on Agriculture Research for Development (ARD). It is a multi-dimensional research that addresses the agricultural development challenges of developing and emerging countries. It is an initiative to promote local food and nutritional security through adaptive small scale farming in four rainfed Agro Ecosystems (AES) in South Asia. The research is being carried out under the project dealing with building resilience to climate change through strengthening adaptive small scale farming in Bangladesh, India and Nepal, to improve productivity, diversification, and adaptation in small farms and enhanced food and nutritional security of SHF in vulnerable and fragile background.

The selection of DPO, farmers (SHFCs) VRAs in each village, student researcher and trial plot in farmers' field, etc under OFAR was carried out to represent the most realistic situation in which a crop production technology was tested and evaluated and conclusions drawn on the basis of stratification with reference to agro-climatic zone, soil, and fertility levels. The participative contribution evaluation of the farmers also taken into consideration during the current experiment.

3.1 Experimental site

The field experiment was carried out during *kharif* season 2013 at in 9 villages of Satna district, Madhya Pradesh . The physiographic details of Satna is: latitude (23° 58' to 25° 12' N), longitude (80° 21' to 81° 23' E) and altitude 313 m above mean sea level.

3.2 Soil of the experimental field

The soil samples were collected randomly from 0 to 15 cm depth from each cluster of villages. Cluster I (Shivrampur, Akahi, Birpur, Itmakala, Gawraunkala) and cluster II (Akaha, Dadari, Matripataura, Dhaneh). A representative homogenous composite sample was drawn by mixing all these soil samples for the respective cluster, which was analyzed to determine the physico-chemical properties of the soil. The result of analysis along with the methods used for determination is presented under the following heads:

3.2.1 Mechanical analysis of the soil

The mechanical analysis of soil (0 to 15 cm depth) is presented in Table 3.1 and 3.2.

Table 3.2.1 Mechanical analysis of the soil of farmers' field of cluster I (Vertisols)

Mineral fraction	Value (unit)	Method (references)
Sand	33.63%	
Silt	32.04%	Bouyoucos hydrometer method (Bouyoucos, 1927)
Clay	34.33%	
Textural class	clay loam	

Table 3.2.2 Mechanical analysis of the soil of farmers' field of cluster II (Alfisols)

Mineral fraction	Value (unit)	Method (references)
Sand	28.45%	
Silt	46.55%	Bouyoucos hydrometer method (Bouyoucos, 1927)
Clay	25.00%	
Textural class	Silty clay loam	

3.2.2 Chemical analysis of soil

Chemical analysis of the soil (0 to 15 cm depth) is presented in Table 3.3 and 3.4.

Table 3.2.1 Chemical analysis of soil at pre experiment stage of cluster I

Parameter	Value (unit)	Method (references)
Available nitrogen	195.00 kg ha^{-1}	Alkaline permanganate method (Subbiah and Asija, 1956)

Available phosphorus	9.42 kg ha^{-1}	Olsen method (Olsen *et al.*, 1954)
Available potassium	299.00 kg ha^{-1}	Flame Photometer method (Toth and Prince, 1949)
Organic carbon	0.38%	Walkley and Black method (Jackson, 1973)
pH	7.51	Glass electrode pH meter (Jackson, 1973)
EC	1.28 (dS m^{-1})	Method No.4 USDA Hand Book No.16 (Richards, 1954)

Table 3.2.2 Chemical analysis of soil at pre experiment stage of cluster II

Parameter	Value (unit)	Method (references)
Available nitrogen	185.00 kg ha^{-1}	Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus	9.43 kg ha^{-1}	Olsen method (Olsen *et al.*, 1954)
Available potassium	300.00 kg ha^{-1}	Flame Photometer method (Toth and Prince, 1949)
Organic carbon	0.39%	Walkley and Black method (Jackson, 1973)
pH	7.53	Glass electrode pH meter (Jackson, 1973)
EC	1.27 (dS m^{-1})	Method No.4 USDA Hand Book No.16 (Richards, 1954)

3.3 Cropping history

Different crops grown in successive years and seasons in the plots used for trial were recorded for the last 5 years to get an idea about the different species grown. Cropping history of the experimental fields of the 2 clusters for the last five years is presented in Table 3.3.1 and 3.3.2.

3.3.1 Cropping history of the experimental fields in cluster I

Years	Cropping season		
	Kharif	***Rabi***	***Zaid***
2008-09	Fallow	Wheat	Fallow
2009-10	Rice	Wheat	Fallow
2010-11	Rice	Wheat	Fallow
2011-12	Rice	Wheat	Fallow
2012-13	Rice	Wheat	Fallow

3.3.2 Cropping history of the experimental fields in cluster II

Years	Cropping season		
	Kharif	***Rabi***	***Zaid***
2008-09	Fallow	Wheat	Fallow

2009-10	Soybean	Wheat	Fallow
2010-11	Soybean	Wheat	Fallow
2011-12	Rice	Wheat	Fallow
2012-13	Rice	Wheat	Fallow

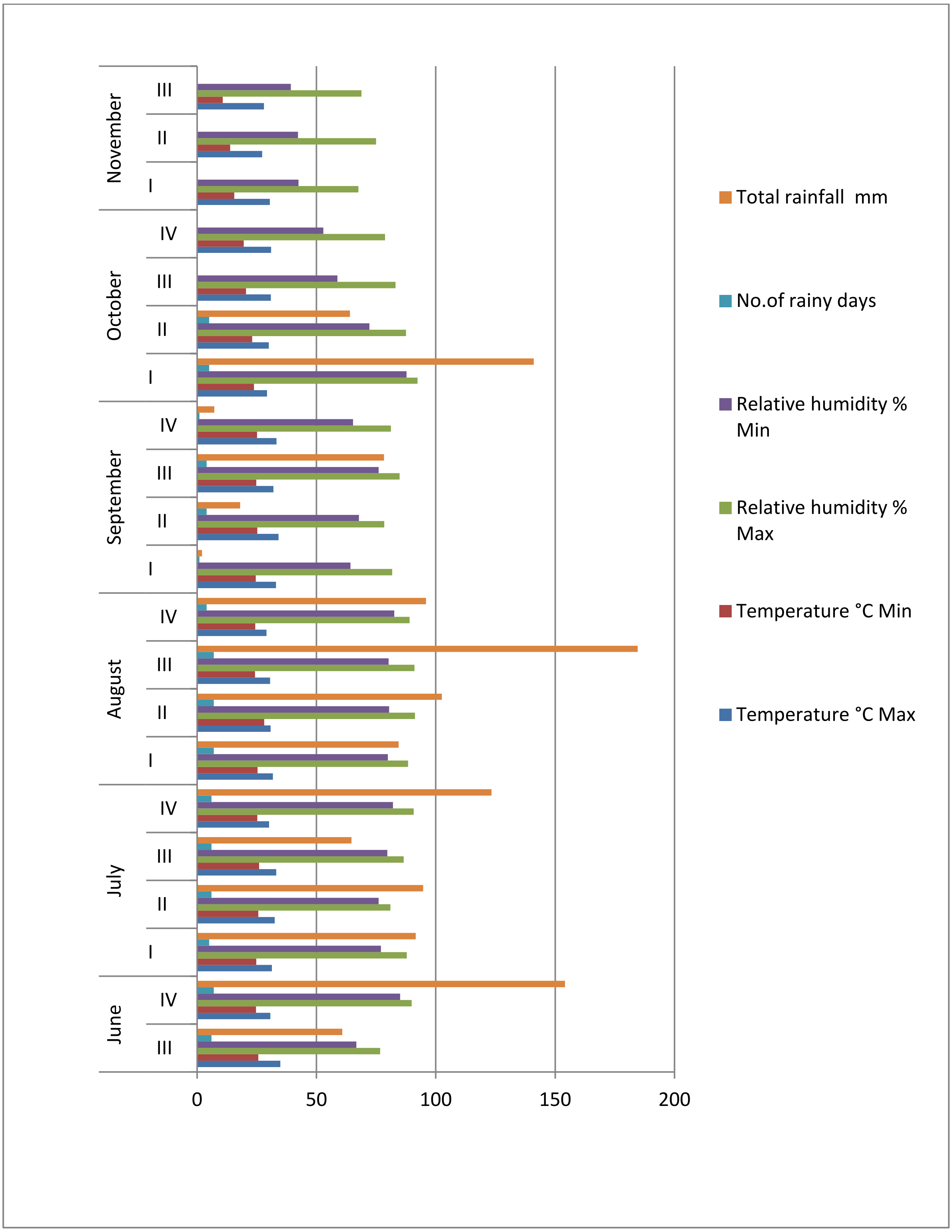
3.4 Climate and Weather condition

Satna has a sub-tropical climate with the monsoon commencing from July and withdrawing by second week of October. The rainfall is evenly distributed and most of it is received between July and September. Apart from this, a few winter and summer showers are also received. The average maximum and minimum temperature during the experimentation was recorded in June (34.90 ^{o}C) and November (10.74 ^{o}C) respectively. The highest maximum relative humidity was 92.29% in October and the minimum relative humidity remained 39.25% in November and total rainfall of 1367.1 mm was obtained in 80 rainy days. The meteorological data including the weekly average of maximum and minimum temperature, relative humidity, no.of rainy days and total rainfall recorded at Satna during the period of experiment is presented in table 3.4 and figure 3.1

Table 3.4 Mean weekly weather parameters and total rainfall during the cropping season (*Kharif*, 2013)

Months	Week	Temperature °C		Relative humidity %		No. of rainy days	Total Rainfall Mm
		Max	**Min**	**Max**	**Min**		
June	III	34.90	25.61	76.71	66.71	6	60.80
	IV	30.66	24.70	89.86	85.00	7	154.10
July	I	31.33	24.79	87.88	77.00	5	91.60
	II	32.49	25.63	81.00	76.00	6	94.70
	III	33.18	25.98	86.50	79.63	6	64.70
	IV	30.13	25.16	90.71	82.00	6	123.30
August	I	31.71	25.29	88.38	79.89	7	84.40
	II	30.75	28.08	91.25	80.38	7	102.50
	III	30.54	24.19	91.00	80.25	7	184.60
	IV	29.10	24.31	89.00	82.57	4	95.90
September	I	33.04	24.59	81.75	64.25	1	2.00
	II	34.10	25.24	78.37	67.75	4	18.00
	III	31.94	24.74	84.86	76.00	4	78.30
	IV	33.26	25.04	81.14	65.29	1	7.20
October	I	29.26	23.83	92.29	87.71	5	141.00
	II	30.04	23.04	87.50	72.13	5	64.00
	III	30.84	20.44	83.13	58.75	-	0.00
	IV	30.99	19.51	78.75	52.88	-	0.00
November	I	30.49	15.56	67.57	42.43	-	0.00
	II	27.27	13.79	75.00	42.29	-	0.00
	III	27.95	10.74	68.86	39.25	-	0.00
				Grand Total :		**80**	**1367.10**

Source: IMD, Pune (2013)



Source: IMD, Pune (2013)

Fig 3.1 Mean weekly weather parameters and total rainfall during the cropping season (*Kharif*, 2013)

3.5 Experimental details of OFAR

The experimental details are given below under following headings:

3.5.1 Experimental design

The experiment was conducted in randomized block design consisting of 3 treatment combinations with 9 replications and was laid out with the different treatments allocated randomly in each replication.

3.5.2 Details of layout

Experimental design	: RBD
Number of treatments	: 3
Number of replications	: 9 (for T_1 and T_2), 18 for T_3
Total number of plots	: 36
Net plot size	: 10 m x 10 m (100 m^2)
Width of bunds	: 0.3 m
Length of the field	: 93 m
Width of the field	: 41.5 m
Net cultivated area	: 3600 m^2
Gross cultivated area	: 3859.50 m^2

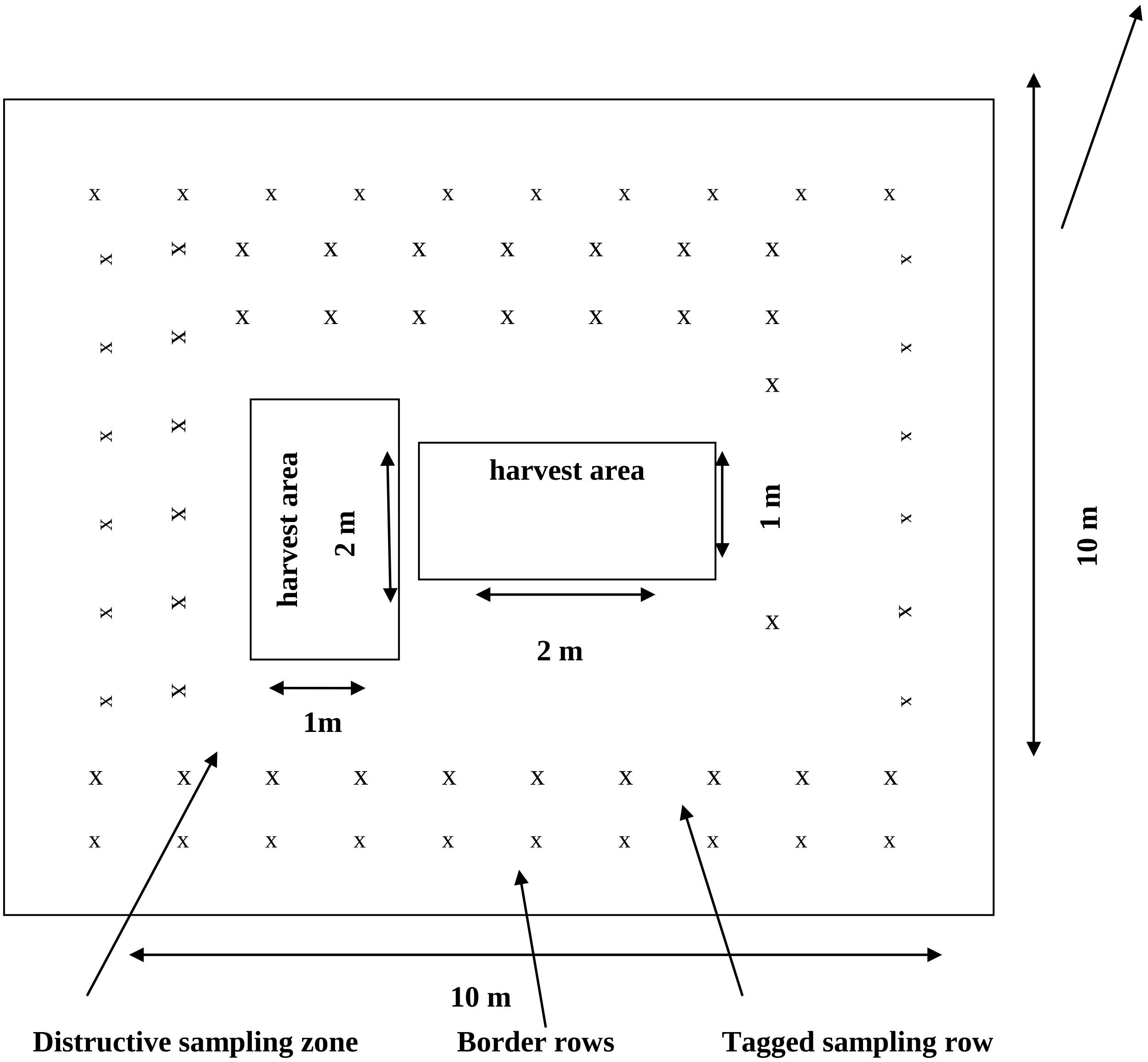


Fig. 3.2 Layout of a plot (representative layout) in farmers' field under the OFAR which included total of 36 plots in 9 villages in Satna District

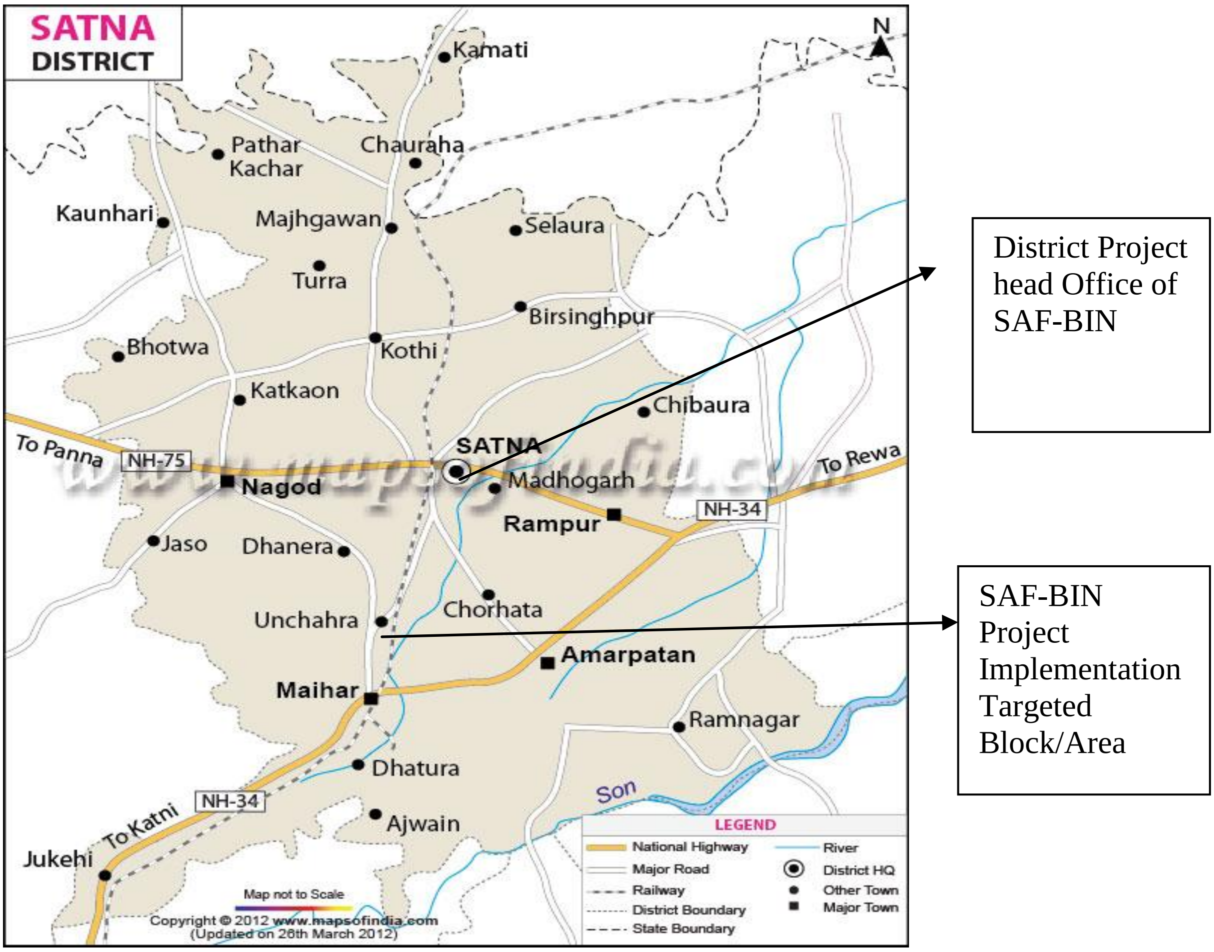


Fig 3.3 Map of Satna District indicating the target block/area

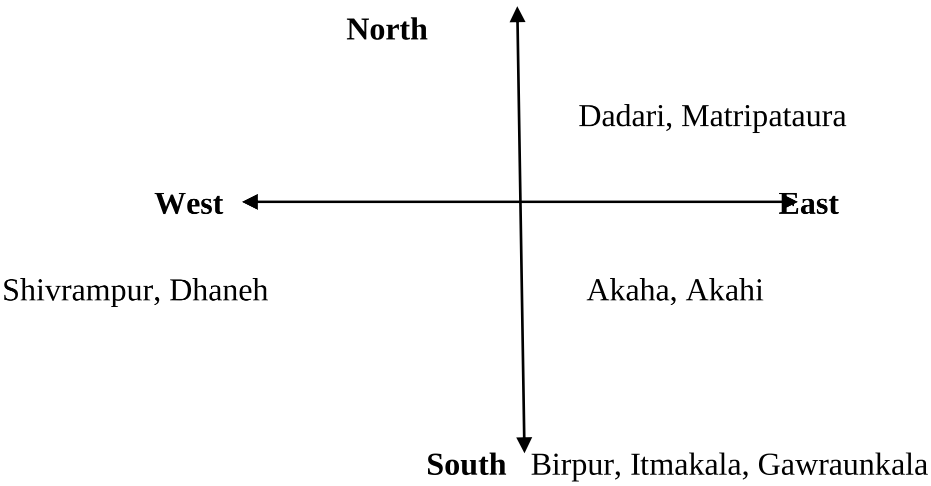


Fig 3.4 Indication of OFAR villages' location of Unchahra block

3.5.3 Details of crop cultivation

Crop : Rice

Variety : IR 36

Duration : 90-100 days

3.5.4 Experimental factor

Factor I: Crop geometry

I. Transplanting : 20 cm × 20 cm

II. Transplanting (conventional practice) : 20 cm × 15 cm

Factor II: Organic liquid formulation

I. *Matka khad* [2 kg Neem (*Azadirachta indica*) leaves + 2 kg akaua (*Calotropis gigantea*) + 1 litre cow urine + 2 kg cow dung + 250 gm jaggery]

II. Neem and Tobacco extract [1 kg neem (*Azadirachta indica*)] leaves and 1 kg tobacco (*Nicotiana tabacum*) leaves]

3.5.5 Treatment combinations:

T_1 : 20 cm × 20 cm + 5% *Matka khad*

T_2 : 20 cm × 20 cm + 5% neem + tobacco extract

T_3 : 20 cm × 15 cm + inorganic fertilizer, conventional practice [(*i.e.*, 108.69 kg DAP ha^{-1} and 175.00 kg urea ha^{-1}, a recommended dose of 100 kg N ha^{-1} and 50 kg P ha^{-1}, nitrogen admistration took place through two sources, *viz*., urea 80.56 kg N and DAP 19.56 kg N)]

- Under the On Farm Adaptive Research (OFAR) based on the 2 major factors 3 treatment combinations were worked out and T_1 and T_2 replicated 9 times and T_3 replicated 18 times.

3.6 Details of raising the test crop

The schedule of different pre and post planting operations carried out in the plots where experiment was conducted in farmers' field has been given in Table 3.5.

Table 3.5 Chronological record of agro-techniques (Calender of operations) during experiment conducted at 9 locations.

S.No.	Operations	Date	DAT
1	**2**	**3**	**4**
1.1	Seed bed preparation & seed sowing	24.06.2013 to 10.07.2013	
1.2	Field preparation (ploughing + harrowing +	13.07.2013 to	

	planking)	21.07.2013	
1.3	Basal application of organic manuring (FYM 10 t ha^{-1})	17.07.2013 to 27.07.2013	
1.4	Transplanting	22.07.2013 to 02.08.2013	23 to 29
1.5	Gap filling	27.07.2013 to 09.08.2013	5 to 7
1.6	Hand weeding	25.08.2013 to 03.09.2013	33 to 42
1.7	Organic liquid formulation application of T_1 : *Matka khaad* foliar spray T_2 : neem and tobacco extract foliar spray		
	(i) 1st application	06.08.2013 to 17.08.2013	15
	(ii) 2nd application	22.08.2013 to 01.09.2013	30
	(iii) 3rd application	05.09.2013 to 16.09.2013	45
1.8	Fertilizer application		
	(i) Basal application of inorganic fertilizers	06.08.2013 to 17.08.2013	3-5
	(ii) 1st application	21.08.2013 to 01.09.2013	30
	(iii) 2nd application	05.09.2013 to 16.09.2013	45
1.9	Harvesting	25.10.2013 to 14.11.2013	95 to 109
1.10	Threshing	29.10.2013 to 17.11.2013	99 to 117

3.6.1 Land preparation

The farmers' field (experimental field) was ploughed with the help of bullock drawn desi plough followed by two harrowing and planking. However, in some fields tractor drawn plough was used. Thereafter, flooding and puddling operations were done manually in experimental blocks. The layout of the field was prepared with the help of wooden pegs, ropes, measuring tape, etc.

3.6.2 Transplanting

For T_1 and T_2 treatments, transplanting was done at 20 cm x 20 cm spacing, but for treatment T_3 transplanting was done at 20 cm x 15 cm spacing. In all the treatments transplanting was done with 23-29 days old rice seedling. One to two rice seedlings per hill was transplanted.

3.6.3 FYM application

FYM was applied at the rate of 10 tonnes ha^{-1} 7 days before transplanting.

3.6.4 Gap filling

Gaps caused by mortality were filled by re-transplanting after 5-7 days of transplanting. This operation was done for maintaining a proper hill to hill distance and standard plant population.

3.6.5 Hand weeding

Hand weeding was done in some trial plots. However, most of the farmers did not practice hand weeding as there was less weed infestation in the field.

3.6.6 Organic liquid formulation application

During the process of finalizing the experimental details the organic formulations which are inherently ITKs, with some refinement were included. According to the participating farmer of the SHFCs, these possess properties of improving germination after soil health and productivity and also prevents or lessens infestation of pest like *gundhi bug.*

3.6.6.1 *Matka khaad*

The treatment *Matka khaad* was prepared with [2 kg neem leaves (*Azadirachta indica*) + 2 kg akaua (*Calotropis gigantea*) + 1 litre cow urine + 2 kg cow dung + 250 g jaggery]. The leaves were ground or chopped and added to the mixture of cow dung and urine. After adding jaggery the whole mixture was stirred thoroughly. The mouth of the container (plastic drum or mud pot) was covered with muslin clot and kept under shade. The mixture was stirred at an interval of 2-3 days. After 15-20 days the above mixture was ready for use. *Matka khaad* 5% was prepared by adding 500 ml prepared and filtered solution in 10 liters of water, and applied as foliar spray 3 times at fortnightly intervals.

3.6.6.2 Neem and tobacco extract

The leaves and young twigs of neem leaves and tobacco leaves [(1kg neem leaves (*Azadirachta indica*) and 1 kg tobacco (*Nicotiana tabacum*) leaves] were ground or chopped mixture was stirred thoroughly. The mouth of the container (plastic drum or mud pot) was covered with muslin clot and kept under shade. The mixture was stirred at an interval of 2-3 days. After 15-20 days the above mixture was ready for use. The treatment neem and tobacco extract 5% was prepared by adding 500 ml prepared and filtered solution in 10 liters of water, and applied as foliar spray 3 times at fortnightly intervals.

3.6.7 Basal fertilizer application

3.6.7.1 Phosphorus application

A dose of 50 kg P ha^{-1} was applied through DAP 108.69 kg ha^{-1}. Half of the phosphorus (25 kg P) was applied as basal along with supplement of nitrogen (9.76 kg N) and broadcast at the time of transplanting or within 3-5 days after transplanting. The remaining amount of phosphorus and supplement of nitrogen through 54.34 kg ha^{-1} was applied in two equal splits at fortnightly intervals (30-45 DAT and 45-60 DAT), as per the prevailing practice of the farmers of the region.

3.6.7.2 Nitrogen application

A dose of 100 kg N ha^{-1} was applied through urea (175 kg ha^{-1}). The nitrogen administration took place through two sources namely urea (80.44 kg N) and DAP (19.56 kg N). Half of the nitrogen was applied as basal and broadcast at the time of transplanting or within 3-5 days after transplanting. The remaining amount of nitrogen was applied as top dressing fortnightly intervals (30-45 DAT and 45-60 DAT), as per the prevailing practice of the farmers of the region.

3.6.8 Irrigation

Irrigation was not provided as it was rainfed crop. Rainfall was evenly distributed and sufficient precipitation of 1367.10 mm was received for the crop growth during the crop season 1367.10 mm through 80 no.of rainy days).

3.6.9 Harvesting

The crop was harvested separately from two random quadratic area of 2.0 m^2 in each plot ensuring exclude the border rows and sampling rows. Thereafter, the produce from net plot was tied in bundles separately and then tagged. The tagged bundles were allowed for sun drying in field and after drying on the threshing floor, the weight of bundles was recorded for obtaining biological yield.

3.6.10 Threshing

Threshing of rice was done manually by beating panicles on the sheaf with wooden baton and then seeds were separated by winnowing. This was done in temporary (*Kachha*) threshing floor.

Observations Recorded

The observations were recorded as per the schedule of the synopsis along with the VRAs and farmers' of the respective trial plots. All the observations were taken from the four tagged hills which was tagged randomly in each plot.

3.7. Growth parameters

3.7.1 Plant height (cm)

From the four hills which were randomly tagged, the height of these plants were measured from the ground level up to the tip of the growing point. The plant height was recorded at 15, 30, 45, 60, 75 and 90 DAT. The samples for DMP etc., was obtained from the distructive sampling zone.

3.7.2 Plant dry weight (g)

Rice plants from 3 hills were randomly uprooted from the distructive sampling zone without damaging the root, from each plot at 15, 30, 45, 60, 75 and 90 DAT. The samples were air dried and then kept in oven for 2-3 days at 70^0 C, thereafter, dry weight was determined and the average dry weight per hill was calculated.

3.7.3 Crop growth rate (CGR)

It represents dry weight gained by a unit area of crop in a unit time expressed as g m^{-2} day^{-1} (Fisher, 1921). The values of plant dry weight at 0 to 15, 15 to 30, 30 to 45, 45 to 60, 60 to 75 and 75 to 90 DAT intervals were used for calculating the CGR.

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

Where,

W_1 = Initial dry weight of plant (g)

W_2 = Final dry weight of plant (g)

t_1 = Initial time period

t_2 = Final time period

3.7.4 Relative growth rate (RGR)

It was described by Fisher (1921) which indicates the increase in dry weight per unit dry matter over any specific time interval and it was calculated by the following equation:

$$\text{Relative growth rate (RGR) (g g}^{-1}\text{ day}^{-1}) = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where,

W_1 = Initial dry weight of plant (g)

W_2 = Final dry weight of plant (g)

t_1 = Initial time period

t_2 = Final time period

It is also called efficiency index (y) and can be expressed in g g^{-1} day^{-1}
This parameter was calculated for the time intervals, *i.e* 15 to 30, 30 to 45, 45 to 60, 60 to 75 and 75 to 90 DAT intervals using the data obtained from dry weight of plants.

3.7.5 No. of tillers $hill^{-1}$

Number of tillers $hill^{-1}$ was recorded at 15, 30, 45, 60, 75 and 90 DAT. These were counted from four tagged hills in each plot.

3.8 Yield and Yield attributes

With the active participation of the stake holders besides VRAs the harvestings of crops was done.

3.8.1 Panicle length (cm)

Panicle length (cm) was observed at the time of harvest randomly from four tagged hills and their averages were recorded.

3.8.2 Number of grains $panicle^{-1}$

Grains from the four panicles were counted separately which were obtained randomly from four tagged hills and their averages were recorded**.**

3.8.3 Test weight (g)

One thousand grains were randomly counted from the threshed cleaned and dried grains obtained from each plot and weighed and recorded as test weight (g) at 12% moisture approximately. The moisture of the grain was tested by bitting the grains before taking test weight which was done after 4 weeks after harvesting the crop.

3.8.4 Grain yield (t ha^{-1})

Grains from harvest area (2 m^2) were dried in sun, cleaned and weighed separately from each plot for calculating the grain yield per hectare.

3.8.5 Straw yield (t ha^{-1})

Straw from harvest area ($2m^2$) after drying in sun, bundled, tagged and weighed separately from each plot for calculating the straw yield per hectare.

3.8.6 Biological yield (t ha^{-1})

Biological yield from harvest area was obtained before threshing the sieves, which were (2 m^2) after dried in sun, bundled, tagged and weighed separately from each plot. These was further calculated on per hactare basis.

3.8.7 Harvest index (%)

Harvest index was obtained by dividing the economic yield (grain) by the biological yield (grain + straw). It was calculated for each of the plots and was represented in percentage. The following formula was used (Donald, 1962).

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

3.9 Post harvest qualitative studies

Approximately 50 g seed samples were collected at the time of threshing from each plot, and thereafter, ground into powder with the help of pestle and mortar. The qualitative parameter, *viz*., protein (%), carbohydrate (%), fat (%), moisture (%) and ash in grains were evaluated. The methodology which was adopted are described below.

3.9.1 Protein (%) in grain

It is calculated by the formula, Protein (%) = N (%) x 6.25. The nitrogen content of grains was analyzed by Micro-Kjeldahl's method (AOAC, 1965).The Micro-Kjeldahl's method for total nitrogen content (%) essentially involves digestion of the sample to convert N compounds in the sample to NH_4 form. The grain sample was digested with sulphuric acid and catalyst mixture (K_2SO_4 + $CuSO_4$) was added to each digestion tube to raise the temperature of digestion and thereafter, cooled to room temperature. The digest was transferred to distillation flask with granulated zinc added to it (which acts as anti bumping agent). Thirty to 50 ml NaOH was poured into the distillation flask where NH_4 was captured in the flask containing boric acid and the ethylene blue indicator was mixed in receiving flask. Titration of the sample was done by using 0.05N HCl. Similar procedure for blank sample was followed. The N (%) content was calculated using the formula:

$$\text{Nitrogen (\%)} = \frac{\text{(Sample titre – Blank titre) x 0.05 N HCl x 14 x100}}{\text{Weight of sample x 1000}}$$

3.9.2 Carbohydrate (%) in the rice grain

The following formula was used for calculation (Ranganna, 2003).

Carbohydrate (%) = 100 - [Moisture (%) + Fat (%) + Ash (%) + Protein (%)]

3.9.3 Fat (%) in the rice grain

The extractor and extract flask were cleaned and dried. The extract flask was weighed on chemical balance up to 2 decimal. Two gram of prepared sample was placed on what man paper number 42 which was folded in to a shape as thimble and it was placed inside the extractor. Two hundred fifty ml of ether solvent was added in the extractor flask and to avoid over heating, the intensity of heat from electric coil was lowered with the help of regulator and 1000 ml of ether solvent were used in four cycles of siphoning, which was needed for complete removal of fat of grain sample. The solvent was kept in flask and only the fat content was heated gently till the smell of ether was not there. It was taken out and kept for cooling and the weight was taken. It was represented in percentage. The following formula was used for calculation (Ranganna, 2003).

$$\text{Fat percentage} = \frac{(X - Y)}{\text{Weight of sample}} \times 100$$

Where,

X is initial weight of flask

Y is final weight of flask

3.9.4 Moisture (%) in the rice grain

This method consists in measuring the weight lost by prepared sample. The moisture content was determined by the air oven method and the methodology was used as follows. The temperature of the oven was set at 80 ˚C and samples were placed inside the oven and the final weight of samples were measured after the 8 hours (Ranganna, 2003).

$$\text{Moisture percentage (\%)} = \frac{(X - Y)}{X} \times 100$$

Where,

X = initial weight of grain sample (g)

Y = final weight of grain sample (g)

3.9.5 Ash (%) in the rice grain

The ash content in rice was determined by the Bunsen burner and muffle furnace. The methodology was used as follows. Two g sample was prepared and put in the crucible and the initial weight was taken. The sample was kept over the Bunsen burner for 5 to 6 minutes. Samples were put inside the muffle furnace at 525 ˚C for 4 hours samples and thereafter it was cooled and the final weight recorded. The difference in weights gave the total ash content and was expressed as percent (Ranganna, 2003).

$$\text{Ash percentage} = \frac{(X - Y)}{X} \times 100$$

Where,

X = initial weight of grain sample

Y = final weight of grain sample

3.10 Economic Analysis

Cost of cultivation, gross return, net return and benefit cost ratio were worked out to evaluate the economics of each treatment, based on the existing market price of inputs and output.

3.10.1 Cost of cultivation (₹ ha^{-1})

The cost of cultivation for each treatment was worked out seperately, taking into consideration all the cultural practices followed in the cultivation.

3.10.2 Gross return (₹ ha^{-1})

The gross return from each treatment was calculated by

Gross return (₹ ha^{-1}) = Income of grain + Income of straw

3.10.3 Net Return (₹ ha^{-1})

The net profit from each treatment was calculated seperately, by using the following formula

Net return = Gross return (₹ ha^{-1}) – cost of cultivation (₹ ha^{-1})

3.10.4 Benefit cost ratio

Benefit cost ratio was calculated using the formula

$$\text{Benefit cost ratio} = \frac{\text{Gross return (₹ } ha^{-1})}{\text{Total cost of cultivation (₹ } ha^{-1})}$$

3.11 Statistical analysis

Data recorded on different aspects of crop, *viz.*, growth, yield attributes and yield were tabulated and subjected to statistical analysis as per Gomez and Gomez, 1976. Significance of difference between treatment means was tested through 'F' test and the critical difference (CD) was worked out wherever 'F' value was found to be significant for treatment effect. The analysis of variance for the data have been given in appendix at the end. Table 3.9 depicts the skelton of ANOVA

3.9 Table Skelton of ANOVA

Source of Variation	df	SS	MSS	F Cal	F Tab%
Due to Replication	(r-1)	RSS	MSSR	MSSR/MESS	
Due to Treatment	(t-1)	TSS	MSST	MSST/MESS	
Due to Error	(r-1)(t-1)	ESS	MESS		
Total	rt-1	TSS			

Standard Error Deviation (SEd)

Standard error was calculated by the following formula

$$SE(d) \pm = \sqrt{\frac{2 \times MESS}{r}}$$

Critical difference

CD (P= 0.05) = SE (d) x‘t’ error df at 5%

Coefficient of variation

$$CV\% = \sqrt{\frac{MESS}{Mean}}$$

Where,

(CD)	=	Critical difference
CV	=	Coefficient of variation
df	=	Degrees of freedom
ESS	=	Error Sum of Squares due to treatment
MESS	=	Error Mean Sum of Squares due to treatment
MTSS	=	treatment Mean Sum of Squares
MRSS	=	Replication Mean Sum of Squares
MSS	=	Mean Sum of Squares
R	=	Number of replications
RSS	=	Replication Sum of Squares
SS	=	Sum of Squares
TSS	=	Total Sum of Squares

CHAPTER 4
RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The selection of DPO, farmers (SHFCs) VRAs in each village,student researcherand trial plot in farmers' field, OFAR is being carried out in 9 villages to represent the most realistic situation in which a crop production technology was tested and evaluated and conclusions drawn on the basis of stratification with reference to agro-climatic zone, soil, and fertility levels and socio-economic parameters of farmers.

The findings of the present experiment On Farm Adaptive Research entitled, "Productivity and economic feasibility of rainfed rice (*Oryza sativa* L.) as influenced by crop geometry and cultural practices in Satna District of Madhya Pradesh in the context of climate change'', are being presented and discussed in the following pages under appropriate headings. Data on pre-harvest and post harvest observations were analyzed and discussion on experimental findings in the light of scientific reasoning has been stated.

OBSERVATIONS RECORDED

A. Pre-harvestobservations (at 15, 30, 45, 60, 75 and 90 DAT)

4.1 Plant height (cm)

4.2 Plant dry weight (g)

4.3CGR (g m^{-2} day^{-1})at15 to 30, 30 to 45, 45 to 60, 60 to 75 and 75 to 90 DAT Intervals

4.4 RGR (g g^{-1} day^{-1}) at 15 to 30, 30 to 45, 45 to 60, 60 to 75 and 75 to 90 DAT Intervals

4.5 Number of tillers $hill^{-1}$

B. Post harvest observations

4.6 Panicle length (cm)

4.7 Number of grains $panicle^{-1}$

4.8 Test weight (g)

4.9Grain yield (t ha^{-1})

4.10 Straw yield (t ha^{-1})

4.11 Biological yield ((t ha^{-1})

4.12 Harvest Index (%)

C. Participatory farmers' perception on *gundhi bug* (*Leptocoriza acuta*Th.) infestation and damage in rainfed rice

D. Quality parameter

4.13 Carbohydrate (%)

4.14 Protein (%)

E. Economics

4.15 Cost of cultivation (`ha^{-1})

4.16 Gross return (ha^{-1})

4.17 Net return (ha^{-1})

4.18 Benefit cost ratio

F. Soil fertility status

4.19 Availableorganic carbon%

4.20 Available N (kg ha^{-1})

4.21 Available P_2O_5 (kg ha^{-1})

4.22 Available K_2O(kg ha^{-1})

4.23 Available EC(d Sm^{-1})

4.24 pH

GROWTH PARAMETERS OF RICE

A. Pre-harvest observations

4.1 Plant height (cm)

Observations regarding the plant height (cm) isgiven in table 4.1. and fig.4.1.

The data showed that plant height increased continuously during vegetative growth and attained a maximum value at 90 DAT. At 15, 30, 45 and 60 DAT treatment T_2(20 cm × 20 cm + neem and tobacco extract) (28.49, 41.86, 55.12 and 88.06 cm) recorded highestvalue of plant height.However, plant height at 75 DAT and 90 DAT of treatment T_2(20 cm x 20 cm + neem and tobacco extract) (96.24 cm and 101.21 cm) recorded significantly higher over T_1(20 cm × 20 cm + *Matka khaad*) (82.64 cm and 90.09 cm) and T_3(20 cm × 15 cm + inorganic fertilizers conventional practice) (83.97 cm and 89.75 cm) respectively.T_2(20 cm × 20 cm + neem and tobacco extract) was 16.45% and 12.34% higher in value than T_1(20 cm × 20 cm + *Matka khaad*) and T_3(20 cm × 15 cm + inorganic fertilizers conventional practice).

The higher plant height could have contributed to optimum condition for light reception, water and nutrient consumption and less competition leading to enhanced photosynthesis could have been higher(Roshan*et al*., 2011) and thereby expressingmore vigorous growth.Further, Larger plant size normally increases photosynthetic efficiency, increased availability of nutrients and greater accessibility of nutrients to plant(Ogbodo *et al*., 2010), which was evident in maximum plant spacing.

4.2 Plant dry weight (g)

Observations regarding the plant dry weight (g) is given in table 4.2 and fig. 4.2.

Throughout the growth stage treatment T_2 (20 cm × 20 cm + neem and tobacco extract) registered higher value in plant dry weight, though in the initial stage of 15, 30 and 45 DAT there was no significant difference. At 60, 75 and 90 DAT treatment T_2 (20 cm × 20 cm + neem and tobacco extract) recorded significantly higher in plant dry weight (35.70, 49.17 and 51.02 g hill^{-1}) over treatment T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice)(25.84, 35.27 and 37.24 g hill^{-1}) respectively. Plant dry weight of T_2 (20 cm × 20 cm + neem and tobacco extract) was found to be 38.15%, 39.41% and 37% higher in value than T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice)(25.84, 35.27 and 37.24 g hill^{-1}) respectively. However, treatment T_1 (20 cm × 20 cm + *Matka khaad*) at 60, 75 and 90 DAT (33.32, 47.94 and 50.24 g hill^{-1}) was found statistically at par with T_2 (20 cm × 20 cm + neem and tobacco extract). Further, plant dry weight of T_1 (20 cm × 20 cm + *Matka khaad*) at 60, 75 and 90 DAT (33.32, 47.94 and 50.24g hill^{-1}) recorded significantly higher 28.94%, 35.92% and 34.90% respectively over T_3 (25.84, 35.27 and 37.24 g hill^{-1}).

The higher dry matter with wider spacing may be due to increased amount of photosynthate accumulation, which was provided by more availability of PAR, nutrient and soil moisture compared to closely spaced plants (Hasanuzzama *et al.*, 2009).

4.3Crop Growth Rate (g m^{-2}day^{-1})

Observations regarding the crop growth rate is given in the table 4.3 and fig.4.3.

The data showed that there was a fluctuation in CGR at all the growth stages, it was found to be non-significant. At 15-30 DAT intervals highest CGR was observed in treatment T_2 (20 cm × 20 cm + neem and tobacco extract) (9.09 g m^{-2} day^{-1}). However, at 45-60 and 60-75 DAT intervals highest CGR was observed in T_1 (20 cm × 20 cm + *Matka khaad*) (35.90 and 24.37 g m^{-2} day^{-1}). And at 30-45 and 75-90 DAT intervals T_3 (20 cm × 20 cm + inorganic fertilizers conventional practice) (12.52 and 7.88 g m^{-2} day^{-1}) was observed highest, but at all growth stages

Biomass production in a plant community is positively correlated with crop growth rate and wider spacing recorded more CGR as observed by Rao *et al*., 1998 in sorghum. When CGR reaches to its highest level the gradient of plant growth is maximum and after flowering stage due to the senescence and abscission, active photosynthesis tissues are reduced and structural tissues are increased or may be LAI is so increased which lower leaves cannot absorb sufficient light for having positive CGR (Azarpour *et al*., 2014). This phenomenon was observed in the current rice experiment.

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4 Relative Growth Rate (g g^{-1}day^{-1})

Observation regarding the relative growth rate is given in table.4.4 and fig.4.4.

A steady but marginal increase in the RGR was observed till peak vegetative growth stage (45-60 DAT) however, during the successive growth intervals there was a decline in the value. At 15-30 and 30-45 DAT intervals highest RGR (0.100 and 0.111 g g^{-1} day^{-1}) was observed in treatment T_2 (20 cm × 20 cm + neem and tobacco extract) At 45-60, 60-75 and 75-90 DAT intervals highest RGR (0.195, 0.159 and 0.046 g g^{-1} day^{-1}) was observed in T_1 (20 cm × 20 cm + *Matka khad*) respectively. And throuhgout the growth stages lowest was observerd in T_3 (20 cm× 15 cm + inorganic fertilizer conventional practice).However, it was found to be non significant in all the treatment and in all the growth stages. This growth curve pattern in rice was reported by Azarpour *et al*., 2014. Further, the increase in LAR in the rice grown at 30/24°C as reported by Nagai and Makino, 2009 may have led to an increase in RGR.

4.5 Number of tillers hill^{-1}

Observations regarding the tillering pattern hill^{-1} is given in table. 4.5 and fig. 4.5.

The data showed that there was a steady increase in number of tillers hill^{-1} from 15 to 45 DAT with the advancement of crop growth. Therafter, the declining trend was observed. At 15, 30 and 60 DAT treatment T_2 (20 cm × 20 cm + neem and tobacco extract) recorded highest in number of tillers hill^{-1} (6.78, 15.83, and 18.19 hill^{-1}) but found to be non significant. Further, at 45 DAT treatment T_2 (20 cm × 20 cm + neem and tobacco extract) (19.58 hill^{-1}) recorded significantly higher (29.49%) number of tillers hill^{-1} over T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) (15.12 hill^{-1}). However, T_1 (20 cm × 20 cm + *Matka khaad*)(18.42 hill^{-1}) was statistically at par with T_2 (20 cm × 20 cm + neem and tobacco extract). Further, number of tillers hill^{-1} of treatment T_1 (20 cm × 20 cm + *Matka khaad*)(18.42 hill^{-1}) recorded significantly higher (21.82%) number of tillers hill^{-1} over T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice)(15.12 hill^{-1}). At 75 DAT treatment T_1 (20 cm x 20 cm + *Matka khaad*)(17.94 hill^{-1}) recorded highest in number of tillers hill^{-1} but was found to be non significant. At 90 DAT treatment T_1 (20 cm × 20 cm + *Matka khaad*) with 17.89 tillers hill^{-1} recorded significantly higher 34.71% value over T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) (13.28 hill^{-1}). However, T_2 (20 cm × 20 cm + neem and tobacco extract) (17.06 hill^{-1})was found statistically at par with T_1 (20 cm × 20 cm + *Matka khaad*). Further, T_2 (20 cm × 20 cm + neem and tobacco extract) (17.06 hill^{-1})recorded significant and 28.46% higher number of tillers hill^{-1} over T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) (13.28 hill^{-1}). The decrease in tiller number on ageing (post peak growth stage) resulted from death of the last tillers due to their failure to compete for light, nutrients and tiller mortality (Hasanuzzama *et al.,* 2009).

The more vigorous plants with particularly higher tillering ability produce more photosynthate than less vigorous plants of the closer spacing (Ogbodo *et al.*, 2010). Transplanting of rice at a wider spacing produced a significantly higher number of tillers hill^{-1} as compared to closer spacings which may be due to increase in available nitrogen levels (Gautam *et al.*, 2008). Similar results were also reported by Bezbaruha*et al*., 2011 and Mohaddesi *etal*., 2011. Further, the liquid formulation may have contained sufficient level of nutrients and pesticidal properties for better growth and development of plants (Ram *et al*., 2008).

Yield parameters of rice

B. **Post-harvest observations**

4.6 Panicle length (cm)

Observations regarding the panicle length (cm) is given in tables 4.6 and fig.4.6.

The panicle length of treatment T_2 (20 cm × 20 cm + neem and tobacco extract) (21.12 cm) recorded significant and 17.66% higher over T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) (17.97cm)**.** However, T_1 (20 cm × 20 cm + *Matka khaad*) (20.54 cm) to be was found statistically at par with T_2 (20 cm × 20 cm + neem and tobacco extract). The wider spacing adopted appears to be an advantageous factor for better development of panicles, hence more panicle length and maybe due to filled grains panicle^{-1} (Rasool *et al.,* 2013 and Bezbaruha*et al.,* 2011).The yield attributes *viz*., panicles m^{-2}, panicle length and filled grains panicle^{-1} was significantly influenced by spacing and nutrient management practices (Damodaran *et al.,* 2012).

4.7 Number of grains panicle^{-1}

Observations regarding number of grains per panicle is given in table 4.6 and fig.4.7.

The treatmentT_2 (20 cm × 20 cm + neem and tobacco extract) (136.67 panicle^{-1}) recorded maximum number of grains panicle^{-1} followed by T_1 (20 cm × 20 cm + *Matka khaad*) and lowest was recorded in T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) (125.70 panicle^{-1}). However, the number of grains per panicle was found to be non-significant.

Fertility of grains and development of grains depend on environmental factors such as nutrition, moisture and light. Wider spacing possibly facilitated the supply of more food materials, moisture and light for the plant and ultimately for development of grain as compared to closer spacing (Tyeb *et al*., 2013), leading to maximum number of filled grains panicle^{-1} and lowest sterilit percent (Gorgy, 2010). Similar result was reported by Rashid and Khan, 2006.

4.8 Test weight (g)

Observations regarding test weight is given in table 4.6 and fig.4.8.

Treatment T_2 (20 cm × 20 cm + neem and tobacco extract) was registered significant and 2.96% higher test weight over T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice). However, T_1 (20 cm × 20 cm + *Matka khaad*) was statistically at par with T_2 (20 cm × 20 cm + neem and tobacco extract).

Adoption of wider spacing for rice transplanting may have resulted in higher grain weight than at closer spacing (Gautam *et al.*, 2008), and due to nutrient management practices

(Bezbaruha*etal*., 2011). The tendency of increasing 1000 grain weight with increased spacing was also observed by Rashid and Khan, 2011.

4.9 Grain yield (t ha^{-1})

Observations regarding grain yield is given in table 4.6 and fig.4.9.

Treatment T_2 (20 cm × 20 cm + neem and tobacco extract) (7.78 t ha^{-1}) recorded significantly higher grain yield over T_1 (20 cm × 20 cm + *Matka khaad*) (6.93 t ha^{-1}) and T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) (6.69 t ha^{-1}) and T_2 (20 cm x 20 cm + neem and tobacco extract) was 16.29 % higher in value than T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) in grain yield. However, T_1 (20 cm × 20 cm + *Matka khaad*) recorded significantly higher in grain yield over T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) and 3.58% higher in value than T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice). The higher value in grain yield in T_1 ((20 cm × 20 cm + *Matka khaad*) andT_2 (20 cm × 20 cm + neem and tobacco extract) may be due to the wider spacing. Wider spacing facilitates maximum light interception and better soil aeration (Bezbaruha*et al*., 2011) and more area of land around them to draw the nutrition and more solar radiation to absorb for better photosynthetic process and hence performed better as individual plant (Mohaddesi *etal*., 2011) and leading to more dry matter production (Chandrasekaran *et al*., 2010), ultimately resulting in yield enhancement.

Infestation of *gundhi bug* in rice was less in both the treatments with neem component over the conventional practice. The neem formulations were found prudent in reducing the number of adult and nymphal population of EHB (Ear head bug), thereby leading to reduced incidence of chaffy grains (Chakraborty, 2011) and higher yield **(**Khan *et al*., 2009).

4.10 Biological yield and Straw yield (t ha^{-1})

Observations regarding biological yield and straw yield (t ha^{-1}) are given in table 4.6 and fig.4.10 & 4.11.

The biological yield and straw yield of treatment T_2 (20 cm × 20 cm + neem and tobacco extract) (24.76 t ha^{-1})and (17.06 t ha^{-1}) were significantly higher over treatment T_1 (20 cm × 20 cm + *Matka khaad*) (22.04 t ha^{-1}) and (19.57 t ha^{-1}) and treatment T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) (19.57 t ha^{-1} and 12.86 t ha^{-1}). T_2 (20 cm × 20 cm + neem and tobacco extract) was 12.90% and 32.66% higher in value than T_1 (20 cm × 20 cm + *Matka khaad*) and T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) in straw yield and T_2 (20 cm × 20 cm + neem and tobacco extract) was 12.34% and 26.52% higher in value than T_1 (20 cm × 20 cm + *Matka khaad*) and T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) in biological yield. Further, biological and straw yield of T_1 (20 cm × 20 cm + *Matka khaad*) (22.04 and 15.11t ha^{-1}) were significanly higher over T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) (19.57 and 12.86 t ha^{-1}).And T_1 (20 cm × 20 cm + *Matka khaad*)was 12.62% and 17.49% higher in value in biological and straw yield.

The increases in biological yield with the decrease of hill density might be due to the increase in plant height and number of tillers and panicle m^{-1} (Mohaddesi *et al.,* 2011). Dry matter production is the product of the influence of growth characters like plant height, number of tillers, LAI and efficiencies of the crop to capture available resources (Damodaran *et al.,* 2012).

4.11 Harvest index

Observations regarding harvest index is given in table 4.6.

The harvest index of treatment T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) (34.18%) was recorded highest, followed by T_2 (20 cm × 20 cm + neem and tobacco extract) (31.42%) and T_1 (20 cm x 20 cm + *Matka khaad*) (30.35%). However, it was found non-significant in all the treatments.

C. Participatory farmers' perception on *gundhi bug* (*Leptocoriza acuta* Th.) infestation and damage in rainfed rice

Observations regarding farmers' perceptionon *gundhi bug* (*Leptocoriza acuta* Th.)infestation and damage is given in table 4.7.

As per the farmers perception during the trial, the farmers of the SHFCs as well as other stakeholders observed that the treatment T_1 (*Matka khaad*) and T_2 (neem and tobacco extract) were found prophylactic in reducing *sucking*pest *gundhi bug* incidence (10% and 8% infestation, 6% and 5% damage in cluster I and cluster II repectively under treatment T_1, 6% and 5% infestation, 4% and 3% damage in cluster I and cluster II respectively under treatment $T_{2;}$ However, treatment T_3 (inorganic fertilizers conventional practice) recorded14% and 12% infestation, 8% and 7% damage in cluster I and cluster II respectively. This pest incident was observed in the nearby areas of farmers' field and non participating farmers also. Further, a reduction of damage by 25% and 28.57% under treatment T_1, 50% and 57% under treatment T_2 respectively in cluster I and cluster II over T_3 was observed. *Matka khaad* as foliar spray also proved quite effective against various insect pests. The current experiment corroborates the findings reported by Chakraborty, 2011 and Chadha *et* *al*., 2012. Similarly, Prakash et al., 2008 also reported the effectiveness of botanical products againts *Leptocoriza acuta*. Nicotine, an active compound of *Nicotiana tobaccum* is considered to be a strong organic poison, which acts as a contact poison with insecticidal properties (Rohman, 1990). Futher, the active compound of *Azadirachta indica* also possess characteristics of being contact poison. Formulation of *Azadirachtaindica* is biologically active, one which has a repellent, antifeedent and insecticidal activity against a number of insect pests of both crop fields as well as stored grains like rice, wheat, corn, legumes, potato, tomato, etc (Debashri and Tamal, 2012 and Lal and Verma, 2006), yet non-toxic to benificial insects and mites (Isman, 2006 and Rambold, 1989).The main advantages of botanical pesticides are ecofriendly, easily biodegradable, produced from locally available raw materials (Rajashekar*et al*., 2012).

Ponnusamy (2003) from Tamil Nadu had reported a quantum jump of yield generation when the paddy field was treated with neem formulations. The positive impact of neem products on paddy yield have been also noted by Kaul *et al*., 1999 and Singh *et al.*, 1999. Similar phenomenon was observed in the present OFAR trial.

D. Quality parameter

Observation regarding the quality parameter namely protein content (%) in grain is given in the table 4.8.

4.12 Carbohydrate (%)

Observations regarding carbohydrate content is given in table 4.8.

There was negligible variation between treatments with regard to carbohydrate content in grain. The highest carbohydrate (74.55%) was observed in treatment T_1 (20 cm x 20 cm + *Matka khaad*), which was 0.34% higher compared to lowest value (74.29%) in treatment T_3(20 cm × 15 cm + inorganic fertilizers conventional practice)

The grain quality parameters of organic nutrient sources can perform comparatively well as regards chemical and physico-chemical properties (Quyen *et al*., 2002).

4.13 Protein content (%)

Observations regarding protein content is given in table 4.8.

Similarly, with regard to protein, there was no remarkable difference between treatments. The highest protein content was observed in T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice) (8.91) followed by T_2 (20 cm x 20 cm + neem and tobacco extract) (8.72%) and T_1 (20 cm x 20 cm + *Matka khaad*) (8.65%). The phenomenon of inverse relationship of protein and carbohydate was evident as the value increase with high protein analysed with lower value of carbohydrate and vise versa was observed in the current experiment by Saveipune *et al.,* 2013.

E. Economics

Observations regarding the economics is given in the Table 4.9.

Highest gross return (₹ 122090.00), net return (₹ 97690.00) and benefit-cost ratio (5.00) were observed in treatment T_2 (20 cm x 20 cm + neem and tobacco extract) which was 18.33%, 28.01% and 30.89% respectively as to be higher as compared with the lowest value (₹ 103175.00), net return (₹ 76189.30) and benefit-cost ratio (3.82) registered with treatment T_3(20 cm × 15 cm + inorganic fertilizers conventional practice). Further, gross return (₹ 108665.00), net return (₹ 85165.00), benefit-cost ratio (4.62) of T_1 (20 cm x 20 cm + *Matka khaad*) which were also observed to be higher by 5.32%, 11.78%, 20.94% compared with the lowest value in T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice). The economic analysis shows the potential promise of rice transplanted in 20 cm × 20 cm spacing and economically feasible as compared to conventional practices.

The products of *Azadirachta indica* are cheap, easy to prepare, ecofriendly and low-cost alternatives to agrochemicals. The extracts of *A. indica* have been compared with commercial pesticides on various crop pests where they have been found to be efficacious, and equally or more cost effective (Shukla *et al*., 1996).

The higher returns under organic farming practices when compared with inorganic sources may be accrued to tha fact that better soil health results in better plant growth, yield components, and yield (Yadav *et al*., 2009). Futher, the input costs are lower (Upadhyay *et al.*, 2011) as observed in the reduction of cost of cultivation (Deshpande and Devasenapathy, 2010) in the current experiment also.

F. Soil fertility status of soil after harvesting

Nutrients status of soil was influenced by crop geometry and cultural practices is given in the table 4.10 and 4.11.

Based on the data pertaining to the in soil fertility after harvesting, the status of soil varied marginally under different treatment. Organic carbon increased by 5.26%, 13.15% and 7.89% in cluster I and 5.12%, 7.69% and 5.12% in cluster II from the initial value with treatment T_1 (20 cm × 20 cm + *Matka khaad*), T_2 (20 cm × 20 cm + neem and tobacco extract) and T_3 (20 cm x 15 cm conventional practice) respectively. Available nitrogen increased by 12.82%, 15.38% and 2.56% in cluster I and18.91%, 20.54% and 8.10% in cluster II from the initial value with T_1 (20 cm × 20 cm + *Matka khaad*), T_2 (20 cm × 20 cm + neem and tobacco extract) and T_3 (20 cm x 15 cm conventional practice) respectively. Phosphorous increased by 38%, 30.99% and 46.60% in cluster I and 27.25%, 27.25% and 37.85% in cluster II from the initial value under T_1 (20 cm × 20 cm + *Matka khaad*), T_2 (20 cm × 20 cm + neem and tobacco extract) and T_3 (20 cm x 15 cm conventional practice) respectively. Available potassium slightly decreased by 2.82%, 3.22% and 8.51% in cluster I and 2.49%, 3.44%and 9.10% in cluster II respectively from the initial value with T_1 (20 cm × 20 cm + *Matka khaad*), T_2 (20 cm × 20 cm + neem and tobacco extract) and T_3 (20 cm x 15 cm conventional practice) respectively. Further, the pH favourably reduce by 1.35%, 1.07% and 1.35 % in cluster I and 1.61%, 1.48% and 1.61% in cluster II from the initial value with T_1 (20 cm × 20 cm + *Matka khaad*), T_2 (20 cm × 20 cm + neem and tobacco extract) and T_3 (20 cm x 15 cm conventional practice) respectively. Similarly, the EC fractional decreased due to the treatments by 0.17%, 2.38% cluster I and 0.80% in cluster II from the initial value with treatment T_1 (20 cm × 20 cm + *Matka khaad*), T_2 (20 cm × 20 cm + neem and tobacco extract). However the value increased by 4.65% in cluster I and 3.17% in cluster II from the initial value under treatment T_3 (20 cm x 15 cm + inorganic fertilizers conventional practice) respectively.

Organic liquid manures have varying response, which have the important role in quick decomposition of organic wastes, improve humus content of the soil which is essential to maintain the activity of microorganisms and other life forms in the soil (Pathak and Ram, 2013).

Increase in available N and P might be due to the direct addition of N through FYM and improved microbial activities, which might have converted organically bound N to inorganic forms. This phenomenon may be due to the release of aliphatic and aromatichydroxy acids and humates that leads to higher availabilityof nutrients (Kumar *et al*., 2013).

Neem is a natural soil conditioner that helps improve the quality of soil, thereby enhancing the fertility as well as in preventing biotic stress (distruction attacked by pest and insects) (Lokanadhan *et al*., 2012).

CHAPTER 5
SUMMARY AN CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

The present investigation entitled, "Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices in Satna district of Madhya Pradesh in the context of climate change", was conducted in Satna district of Madhya Pradesh in 9 villages, during *Kharif* season of 2013. The experiment was laid out in Randomized block design consisting of 3 treatments replicated 9 times. The different treatments were allocated randomly in each replication and the results of the investigation are summarized below with the following heads

5.1. Effect of crop geometry on rainfed rice

Transplanting of rice at 20 cm × 20 cm spacing registered significant and highest in plant height (101.21 cm), dry weight (51.02 g hill^{-1}), number of tillers hill^{-1} (17.89 hill^{-1}), panicle length (21.12 cm), test weight (24.99 g), grain yield (7.78 t ha^{-1}), straw yield (17.06 t ha^{-1}) and biological yield (24.76 t ha^{-1}) respectively. At 45-60 DAT intervals both CGR (35.39 g m^{-2} day^{-1}) and RGR (0.195 g g^{-1}day^{-1}) recorded highest at 20 cm × 20 cm spacing. Further, highest number of grains panicle^{-1} (136.67 panicle^{-1}) was registered with wider spacing.

5.2. Effect of cultural practices on growth and yield of rice

With regard to same growth parameters and yield attributes, *viz.*, plant height (101.21cm), plant dry weight (51.02 hill^{-1}), number of tillers hill^{-1} (17.89 hill^{-1}) panicle length (21.12 cm), test weight (24.99 g), grain yield (7.78 t ha^{-1}), straw yield (17.06 t ha^{-1}), biological yield (24.76 t ha^{-1}) were registered significant and higher in value under treatment *Matka khaad*, neem and tobacco extract. Further, maximum number of grains panicle^{-1} (136.67 panicle^{-1}) was registered under treatment neem and tobbacco extract. The highest carbohydrate (74.55%) was observed in *Matka khaad*, which was 0.34% higher compared to lowest value (74.29%) inorganic fertilizer, conventional practice.

5.3. Efficacy of organic formulation against insect infestation in rainfed rice

Organic liquid formulation *Matka khaad*, neem and tobacco extract were found prophylactic in reducing *sucking* pest [*gundhi bug* (*Leptocoriza acuta* Th.)] incidence (10% and 8% infestation, 6% and 5% damage in cluster I and cluster II respectively under treatment T_1, 6%

and 5% infestation, 4% and 3% damage in cluster I and cluster II respectively under treatment T_2) *compared to* T_3.

5.4. Economic analysis of rainfed rice

The highest gross return (₹ 122090.00), net return (₹ 97690.00) and benefit-cost ratio (5.00) was registered in treatment T_2 (20 cm × 20 cm + neem and tobacco extract) which was 18.33%, 28.01% and 30.89% respectively higher compared to the lowest value (₹ 103175.00), net return (₹ 76189.30) and benefit-cost ratio (3.82) of treatment T_3 (20 cm × 15 cm + inorganic fertilizers conventional practice).

Conclusion

It may be concluded that among the treatments, treatment T_2 (20 cm × 20 cm + neem and tobacco extract) was regarded as best in growth parameters, yield attributes. However, treatment T_1 (20 cm × 20 cm + *Matka khaad*) was found to be at par with T_2. Further, the organic liquid formulations were found prophylactic in reducing infestation of *gundhi bug* incidence. According to the participating farmers of SHFCs as well as other stakeholders, the findings of OFAR have manifest that this possess better soil health and productivity and also lessens infestation of pests, which is feasible and acceptable. Therefore, this combination enables appropriate agronomic expression and most economic yield. Since the findings are based on the research done in one season and it may be repeated for confirmation.

APPENDICES

APPENDIX I

Plate 1. VRAs and Farmers assissting to the student researcher to the nursery field in Dhaneh

Plate 2. Picture indicating transplanting at 20 cm x 20 cm spacing

e 3. T_2 at 30-45 DAT in Akaha village

Plate 4. T_2 at 30-40 DAT in Dhaneh village

Plate 5. T_3 at 30-45 DAT field in Dhaneh village

Plate 6. T_2 at 30-45 DAT in Dadari village

Plate 7. Infestation of insect pest during milk stage

Plate 8. DPO assissting field visit with the VRAs of Satna and Mandla District in Birpur

Plate 9. T_2 at 45-60 DAT in Shivrampur village

Plate 10. T_2 at 60-75 DAT in Akaha village

Plate 11. DPO and VRAs with the farmers taking 2 m^2 plot area for harvesting

Plate 12. preparation neem and tobacco extract in mud pot

APPENDIX II

ANOVA TABLES

ANOVA Table 1. Plant height (cm) of rice at 15 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	3994.93	499.366	30.9565	2.56	
due to treatment	2	43.11	21.555	1.33623	3.63	NS
due to error	16	258.1	16.1313			
Total		26	4296.14			

ANOVA Table 2. Plant height (cm) of rice at 30 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result

due to replication	8	3192.59	399.074	8.25087	2.56	
due to treatment	2	205.96	102.98	2.12912	3.63	NS
due to error	16	773.88	48.3675			
Total	26	4172.43				

ANOVA Table 3. Plant height (cm) of rice at 45 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	3157.24	394.655	10.8949	2.56	
due to treatment	2	138.69	69.345	1.91435	3.63	NS
due to error	16	579.58	36.2238			
Total	26	3875.52				

ANOVA Table 4. Plant height (cm) of rice at 60 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	9627.2	1203.4	12.1323	2.56	
due to treatment	2	413	206.5	2.08188	3.63	NS
due to error	16	1587.03	99.1894			
Total	26	11627.2				

ANOVA Table 5. Plant height (cm) of rice at 75 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	5615.26	701.908	8.21936	2.56	
due to treatment	2	1886.85	943.425	3.66325	3.63	S
due to error	16	1105.17	69.0731			
Total	26	7607.28				

ANOVA Table 6. Plant height (cm) of rice at 90 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	5703.46	712.933	10.070	2.56	
due to treatment	2	765.90	382.950	5.409	3.63	S
due to error	16	1132.71	70.7944			
Total	26	7602.07				

ANOVA Table 7. Dry weight of rice at 15 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	17.58	2.1975	83.7143	2.56	

due to treatment	2	0.03	0.015	0.60889	3.63	NS
due to error	16	0.42	0.02625			
Total	26	18.03				

ANOVA Table 8. Dry weight of rice at 30DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	1287.31	160.914	5.2141	2.56	
due to treatment	2	51.3	25.65	0.83114	3.63	NS
due to error	16	493.78	30.8613			
Total	26	1832.38				

ANOVA Table 9. Dry weight of rice at 45 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	2977.3	372.163	7.17984	2.56	
due to treatment	2	110.84	55.42	1.06917	3.63	NS
due to error	16	829.35	51.8344			
Total	26	3197.5				

ANOVA Table 10. Dry weight of rice at 60 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	1369.4	171.175	5.18114	2.56	
due to treatment	2	476.69	238.345	7.21424	3.63	S
due to error	16	528.61	33.0381			
Total	26	2374.69				

ANOVA Table 11. Dry weight of rice at 75 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	4192.06	524.008	4.93326	2.56	
due to treatment	2	1066.29	533.145	5.01928	3.63	s
due to error	16	1699.51	106.219			
Total	26	6957.86				

ANOVA Table 12. Dry weight of rice at 90 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	4727.13	590.891	5.66619	2.56	
due to treatment	2	1079.19	539.595	5.1743	3.63	s
due to error	16	1668.54	104.284			
Total	26	7474.86				

ANOVA Table 13. CGR of rice at 15 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	59.88	7.485	54.6849	2.56	
due to treatment	2	0.92	0.46	3.36073	3.63	NS
due to error	16	2.19	0.13688			
Total	26	62.99				

ANOVA Table 14. CGR of rice at 30 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	4104.48	513.06	6.07064	2.56	
due to treatment	2	115.46	57.73	0.68307	3.63	NS
due to error	16	1352.24	84.515			
Total	26	5572.18				

ANOVA Table 15. CGR of rice at 45 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	1364.8	170.6	15.2355	2.56	
due to treatment	2	59.8	29.9	2.67024	3.63	NS
due to error	16	179.16	11.1975			
Total	26	1603.76				

ANOVA Table 16. CGR of rice at 60 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	5862.05	732.756	15.7968	2.56	
due to treatment	2	143.17	71.585	1.54324	3.63	NS
due to error	16	742.18	46.3863			

Total	26	6747.4

ANOVA Table 17.CGR of rice at 75 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	8087.13	1010.89	4.87256	2.56	
due to treatment	2	34.41	17.205	0.08293	3.63	NS
due to error	16	3319.46	207.466			
Total	26	11441				

ANOVA Table 18. CGR of rice at 90 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	93.56	11.695	2.51303	2.56	
due to treatment	2	14.6	7.3	1.56863	3.63	NS
due to error	16	74.46	4.65375			
Total	26	182.61				

ANOVA Table 19. RGR of rice at 15 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	0.12807	0.01601	45.9032	2.56	
due to treatment	2	0.00084	0.00042	1.2043	3.63	NS
due to error	16	0.00558	0.00035			
Total	26	0.13449				

ANOVA Table 20. RGR of rice at 30DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	0.16975	0.02122	33.3829	2.56	
due to treatment	2	0.00087	0.00044	0.68751	3.63	NS
due to error	16	0.01017	0.00064			
Total	26	0.1808				

ANOVA Table 21. RGR of rice at 45 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	0.00799	0.001	19.7284	2.56	
due to treatment	2	3.47E-05	1.7E-05	0.34272	3.63	NS
due to error	16	0.00081	5.1E-05			
Total	26	0.00883				

ANOVA Table 22. RGR of rice at 60 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	0.03932	0.00491	20.53	2.56	
due to treatment	2	1.48E-03	0.00074	3.09347	3.63	NS
due to error	16	0.00383	0.00024			
Total	26	0.00883				

ANOVA Table 23. RGR of rice at 75 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	0.00495	0.00062	5.8869	2.56	
due to treatment	2	2.64E-05	1.3E-05	0.12571	3.63	NS
due to error	16	0.00168	0.00011			
Total	26	0.00665				

ANOVA Table 24. RGR of rice at 90 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	3.31E-05	4.1E-06	1.45815	2.56	
due to treatment	2	3.49E-06	1.7E-06	0.61498	3.63	NS
due to error	16	4.54E-05	2.8E-06			
Total	26	8.20E-05				

ANOVA Table 25. Number of tillers of rice at 15 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	491.35	61.419	10.381	2.56	
due to treatment	2	9.77	4.885	0.825	3.63	NS
due to error	16	94.66	5.916			
Total	26	595.77				

ANOVA Table 26. Number of tillers of rice at 30 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	726.56	90.82	5.38133	2.56	
due to treatment	2	25.97	12.985	0.7694	3.63	NS
due to error	16	270.03	16.8769			
Total	26	1022.56				

ANOVA Table 27. Number of tillers of rice at 45 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	614.12	76.765	8.16052	2.56	
due to treatment	2	90.28	45.14	4.79862	3.63	S
due to error	16	150.51	9.40688			
Total	26	854.91				

ANOVA Table 28. Number of tillers of rice at 60 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	652.43	81.5538	5.17186	2.56	
due to treatment	2	24.18	12.09	0.76671	3.63	NS
due to error	16	252.3	15.7688			
Total	26	928.91				

ANOVA Table 29. Number of tillers of rice at 75 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	478.95	59.8688	4.91609	2.56	
due to treatment	2	60.19	30.095	2.47123	3.63	NS
due to error	16	194.85	12.1781			
Total	26	733.99				

ANOVA Table 30. Number of tillers of rice at 90 DAT

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	450.6	56.325	4.73121	2.56	
due to treatment	2	108.63	54.315	4.56237	3.63	S
due to error	16	190.48	11.905			
Total	26	749.71				

ANOVA Table 31 Panicle length of rice

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	848	106	11.09	2.56	
due to treatment	2	607.42	303.71	31.7751	3.63	S
due to error	16	152.93	9.55813			
Total	26	1609.33				

ANOVA Table 32 Number of grains per panicle of rice

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	81053.30	10131.70	12.46	2.56	
due to treatment	2	583.03	291.52	0.35	3.63	NS
due to error	16	13004.00	812.75			
Total	26	94640.40				

ANOVA Table 33 Test weight of rice

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	5.12907	0.64113	2.77219	2.56	
due to treatment	2	2.55796	1.27898	5.53017	3.63	s
due to error	16	3.70037	0.23127			
Total	26	11.3874				

ANOVA Table 34 Grain yield kg ha^{-1}

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	1.648	0.206	39.3036	2.56	
due to treatment	2	0.04956	0.02478	4.72788	3.63	S
due to error	16	0.08386	0.00524			
Total	26	1.78133				

ANOVA Table 35 Straw yield kg ha^{-1}

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	1.92867	0.24108	0.60975	2.56	
due to treatment	2	0.79076	0.39538	10.544	3.63	S
due to error	16	0.59997	0.0375			
Total	26					

ANOVA Table 36 Biological yield kg ha^{-1}

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	5.40	0.67464	1.11148	2.56	
due to treatment	2	1.21	0.60698	13.4678	3.63	
due to error	16	0.72	0.04507			
Total	26					

ANOVA Table 37 harvest index of rice

Source of variance	df	SS	MSS	F Cal	F Tab %	Result
due to replication	8	1195.75	149.469	7.90019	2.56	
due to treatment	2	37.8393	18.9197	1.09974	3.63	NS
due to error	16	275.261	17.2038			
Total	26					

APPENDIX III

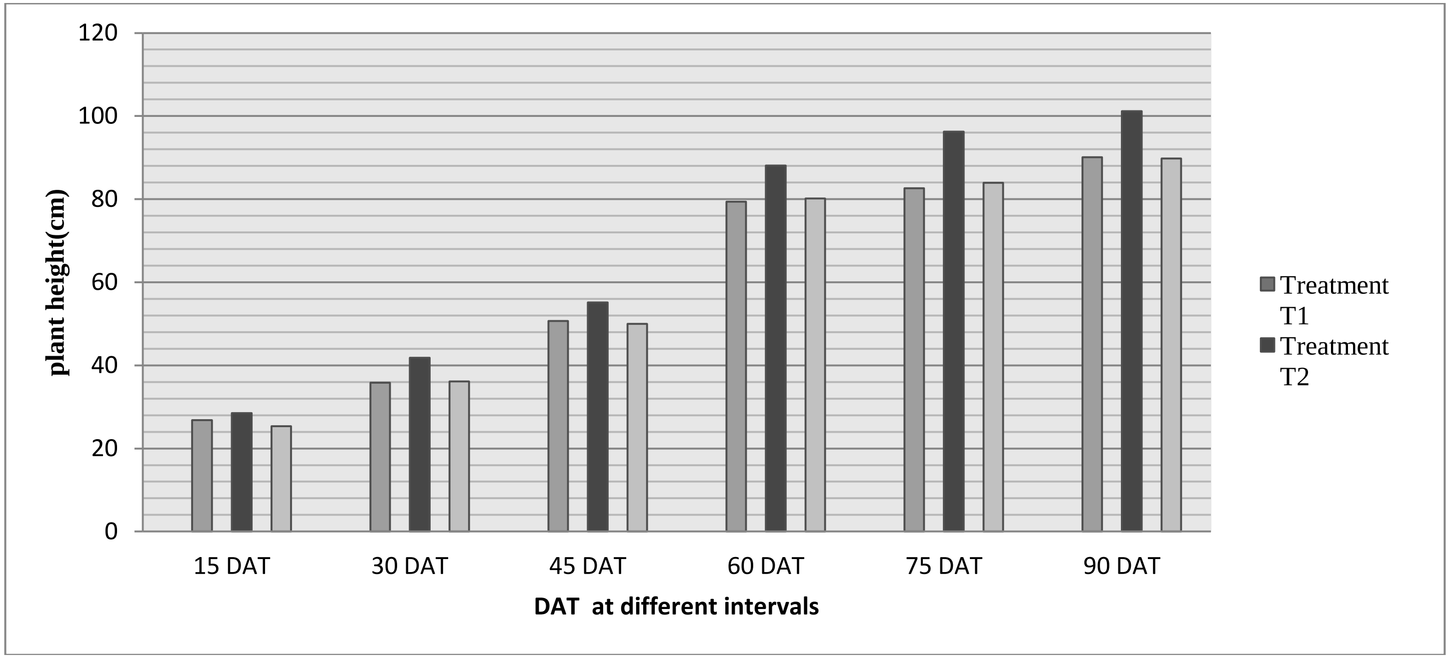
Table I. Cost of cultivation of different forms of organic source for rainfed rice (cost for all treatments)

S. No.		Particulars	Unit	Qty.	Rate unit^{-1} (₹)	Cost (₹ ha^{-1})
A		Land preparation				
	1	Ploughing and puddling	Hours	10	300	3000
	2	Layout	Labour	10	130	1300
B		Seed	Kg	100	30	3000
C		Transplanting	Labour	12	130	1560
D		Nutrient application				
	1	FYM	Tonne	10	1000	10000
E		Interculture operation				
	1	Gap filling	Labour	3	130	390
	2	Hand weeding	Labour	5	130	650
F		Harvesting and threshing	Labour	20	130	2600
						Total=22500

Table II. Cost of cultivation for treatments

Treatment	Matka khad 5% @ ₹ 2/L total 500L (3 times)	Neem and tobacco extract 5% @ ₹ 20/L total 95L (3 times)	DAP 108.69 kg/ha @ ₹ 30 kg^{-1}	Urea175.00 kg/ha @ ₹ 7/kg	Total cost
T_1	1000				1000.00
T_2		1900			1900.00
T_3			3260.70	1225.00	4485.70

Matka khad @ ₹ 2 kg^{-1}, DAP @ ₹ 30 kg^{-1}
Urea @ ₹ 7/kg



Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on plant height at different intervals

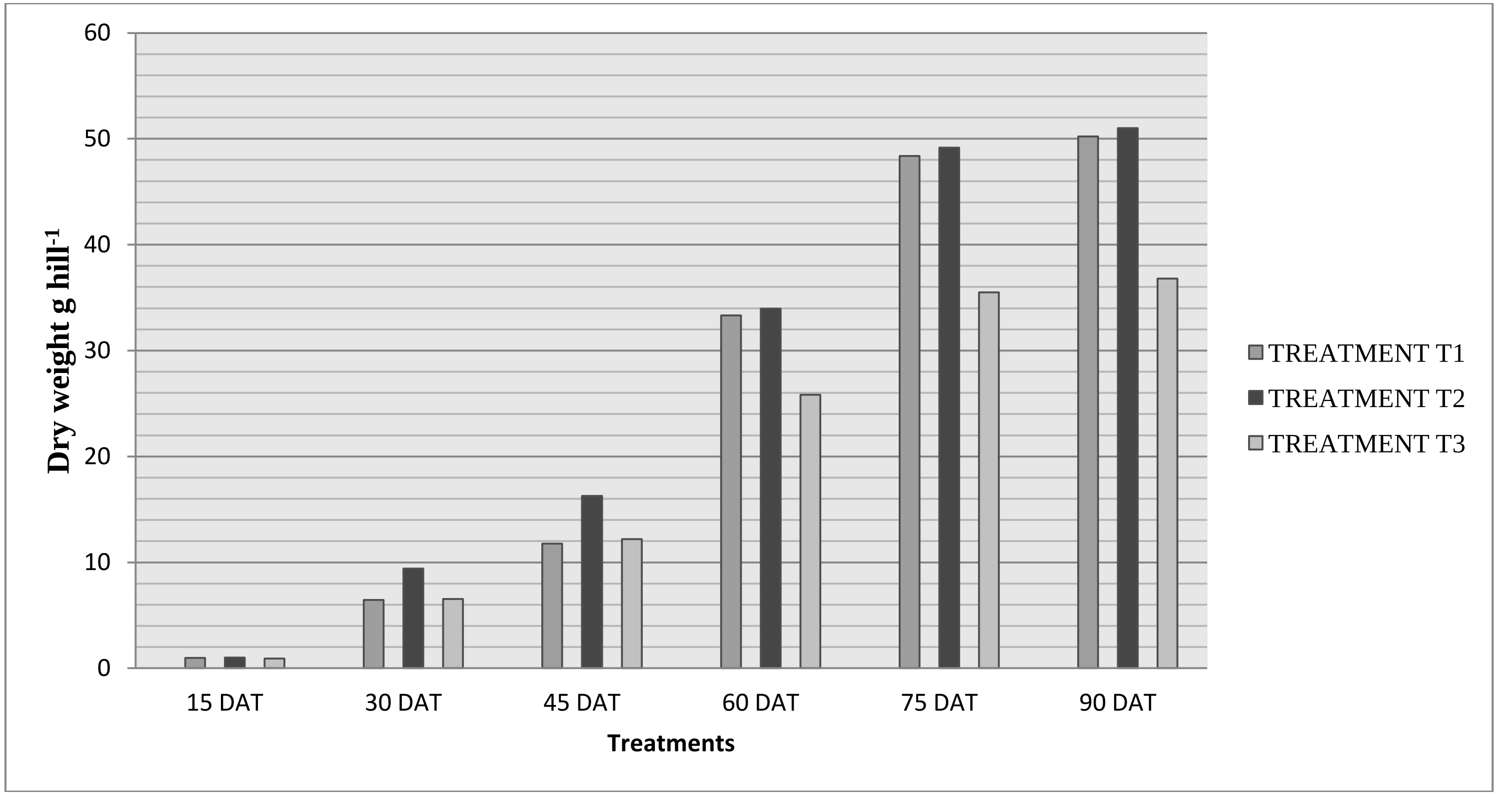


Fig.4.2 Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on plant dry weight hill^{-1}

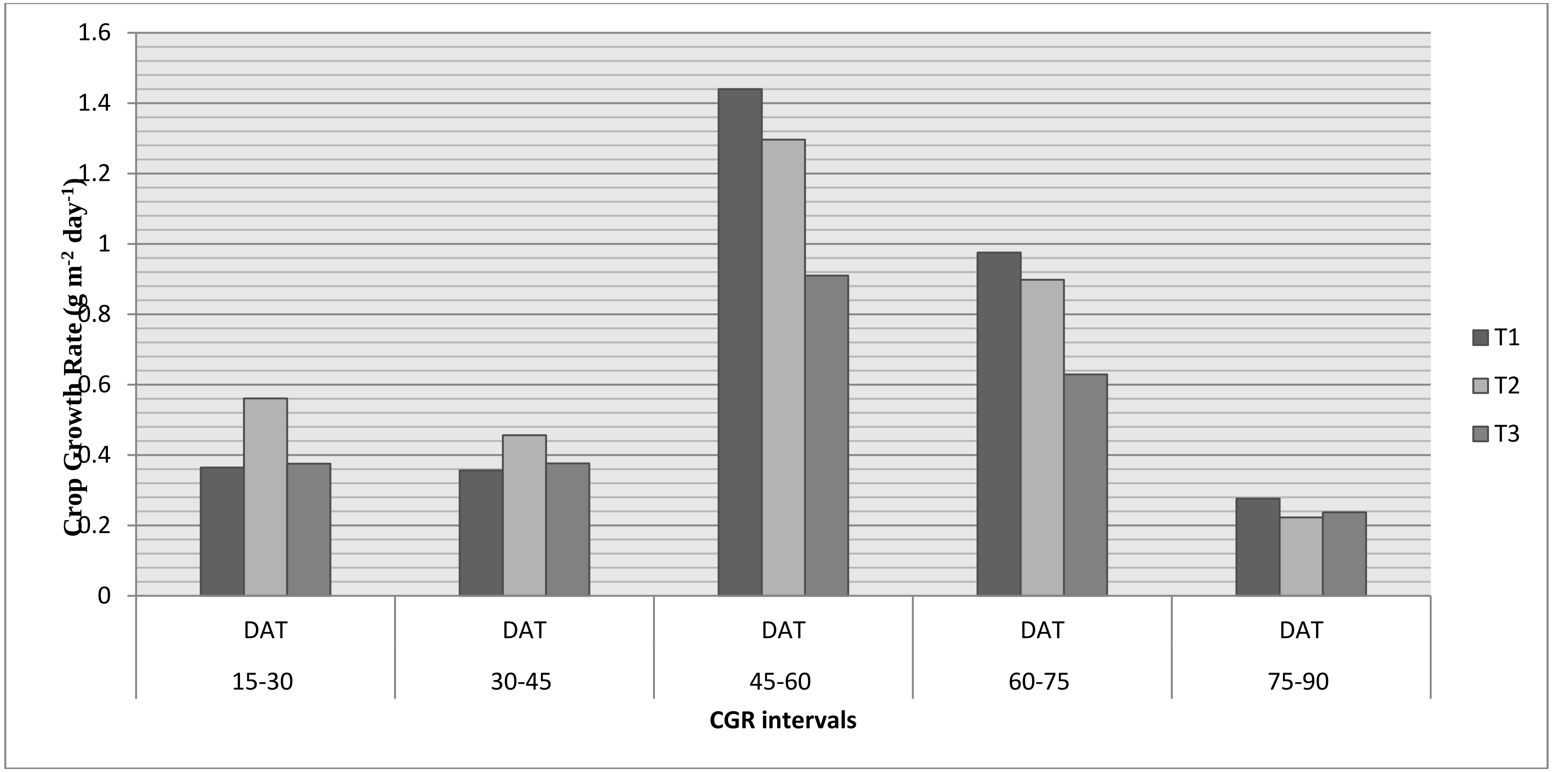


Fig.4.3. Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on Crop Growth Rate

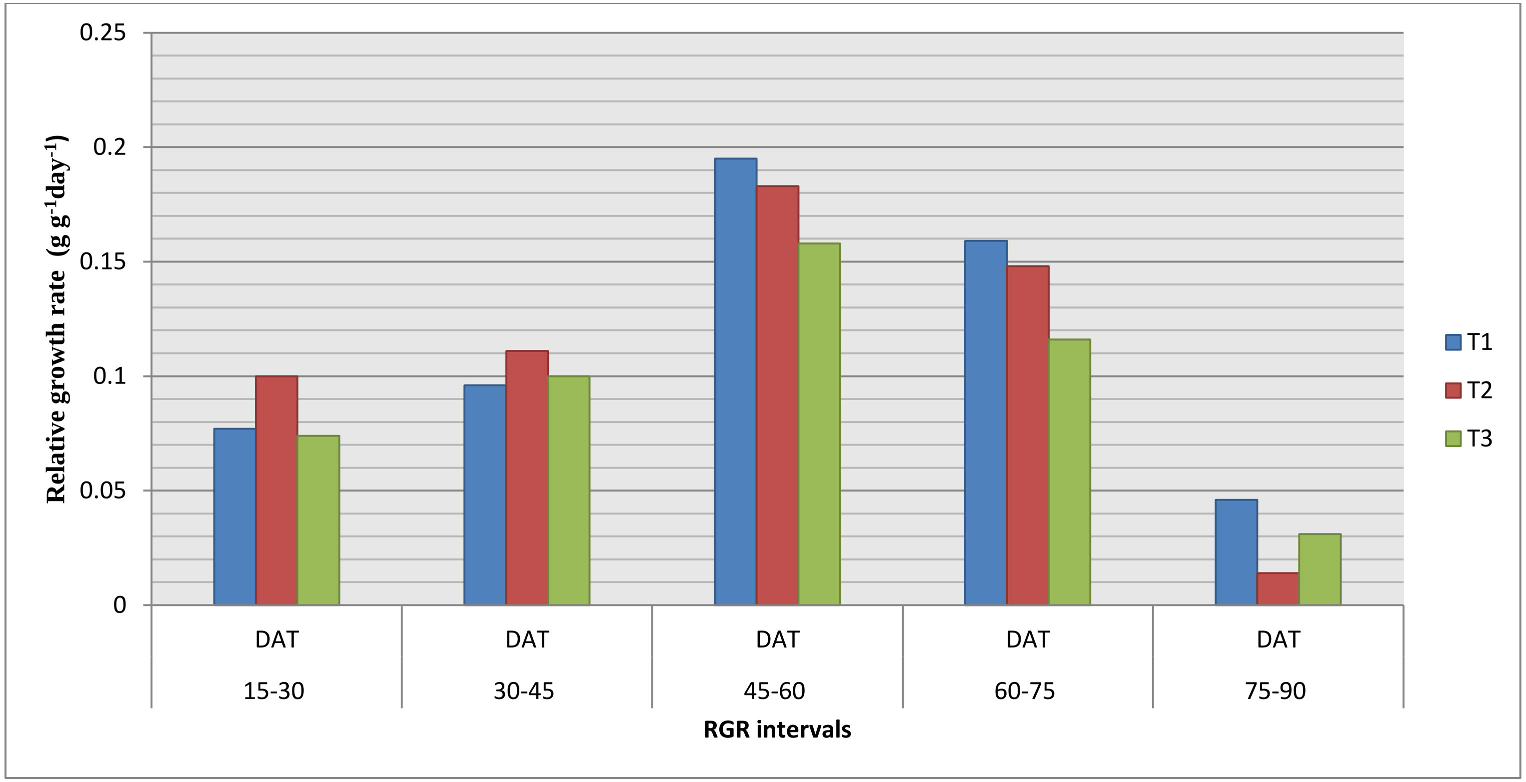


Fig.4.4. Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on Relative Growth Rate

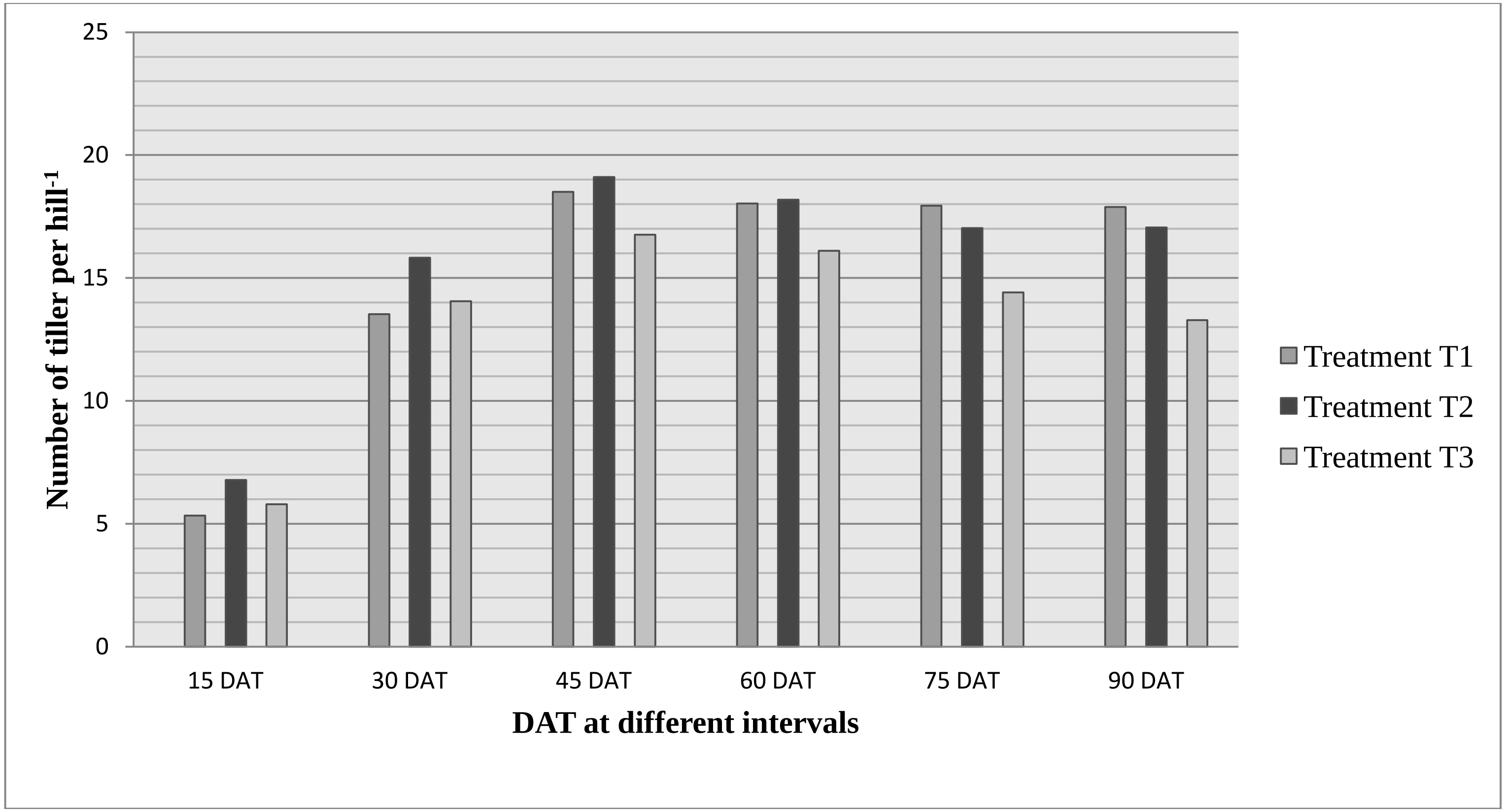


Fig.4.5. Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on number of tillers panicle^{-1}

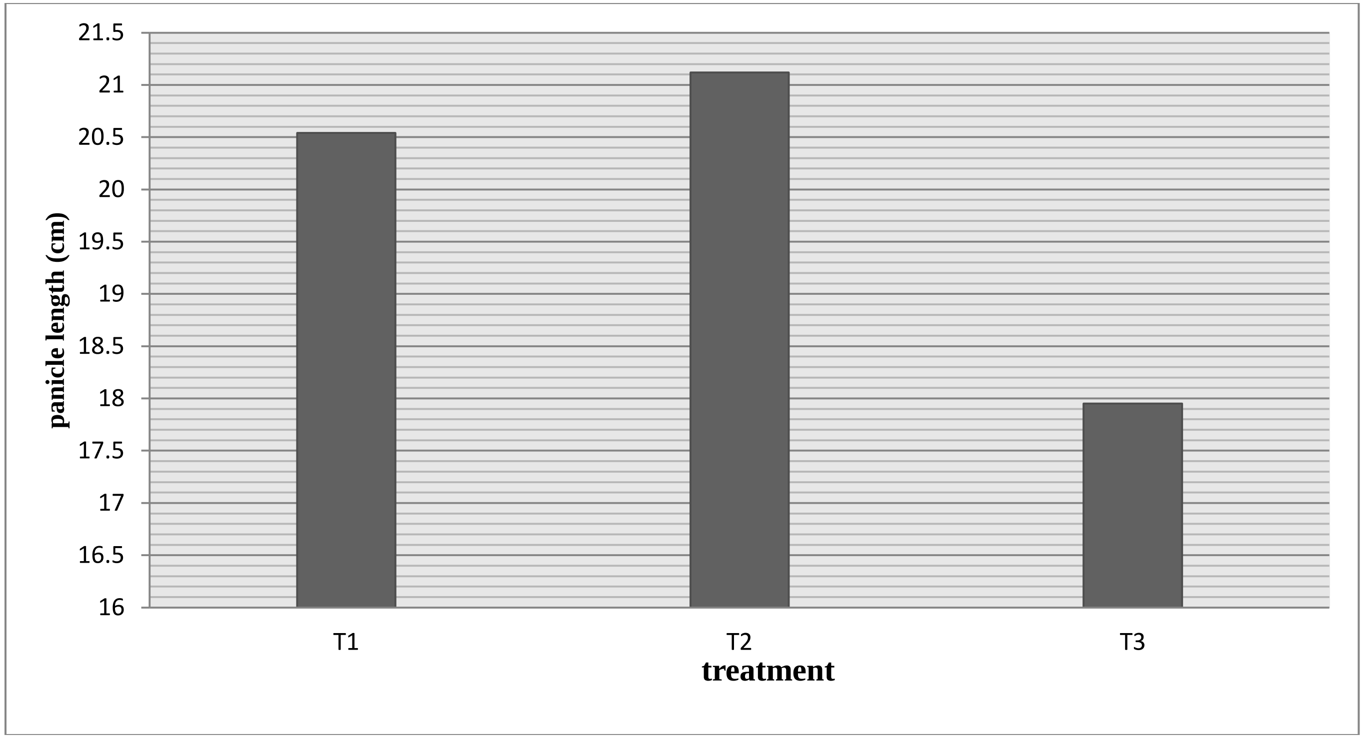


Fig.4.6 Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on panicle length (cm)

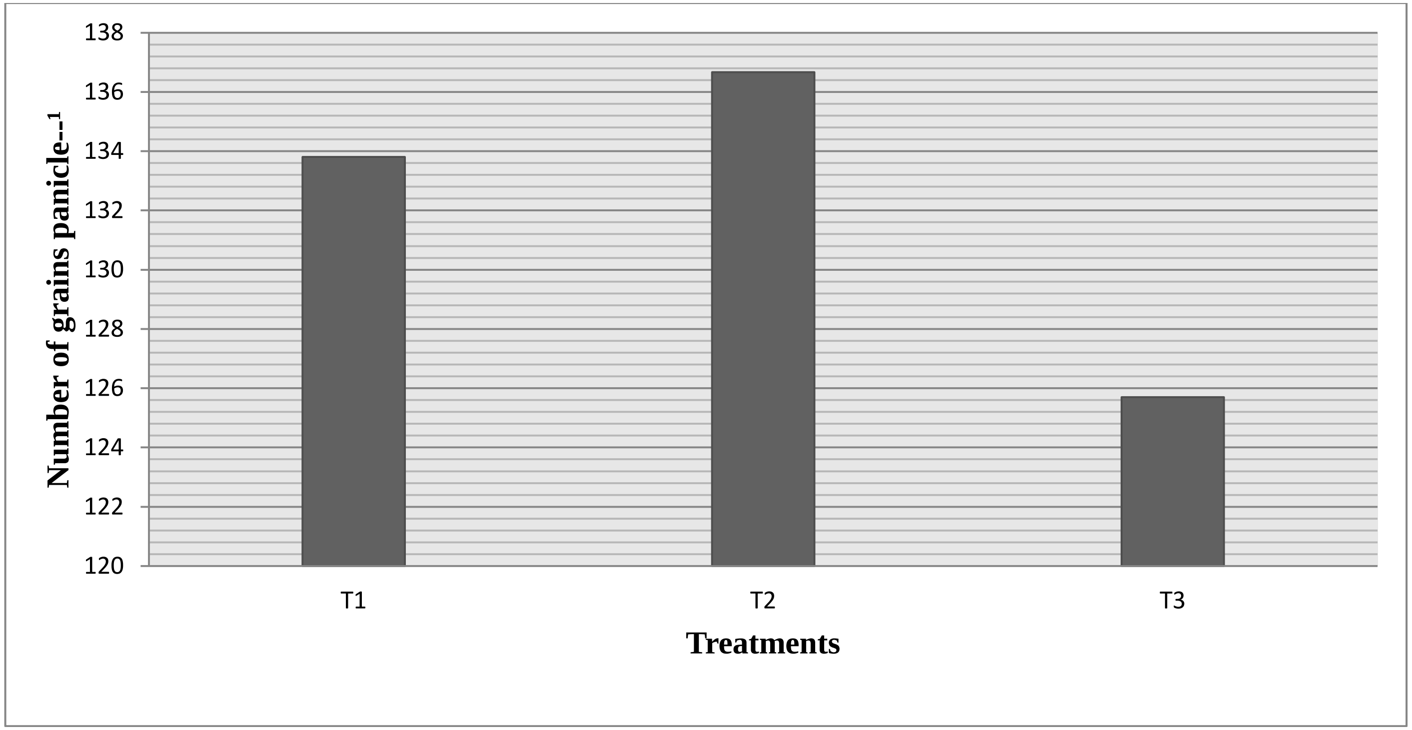


Fig 4.7 Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on number of grains panicle^{-1}

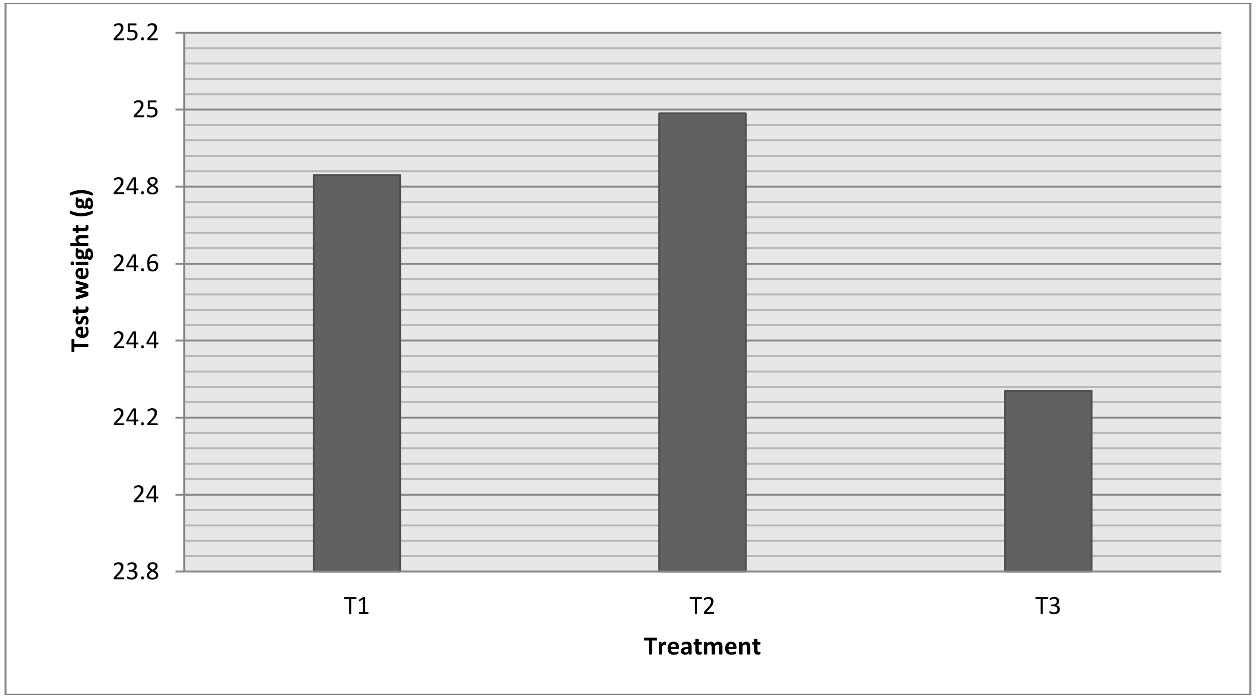


Fig.4.8.Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on test weight (g)

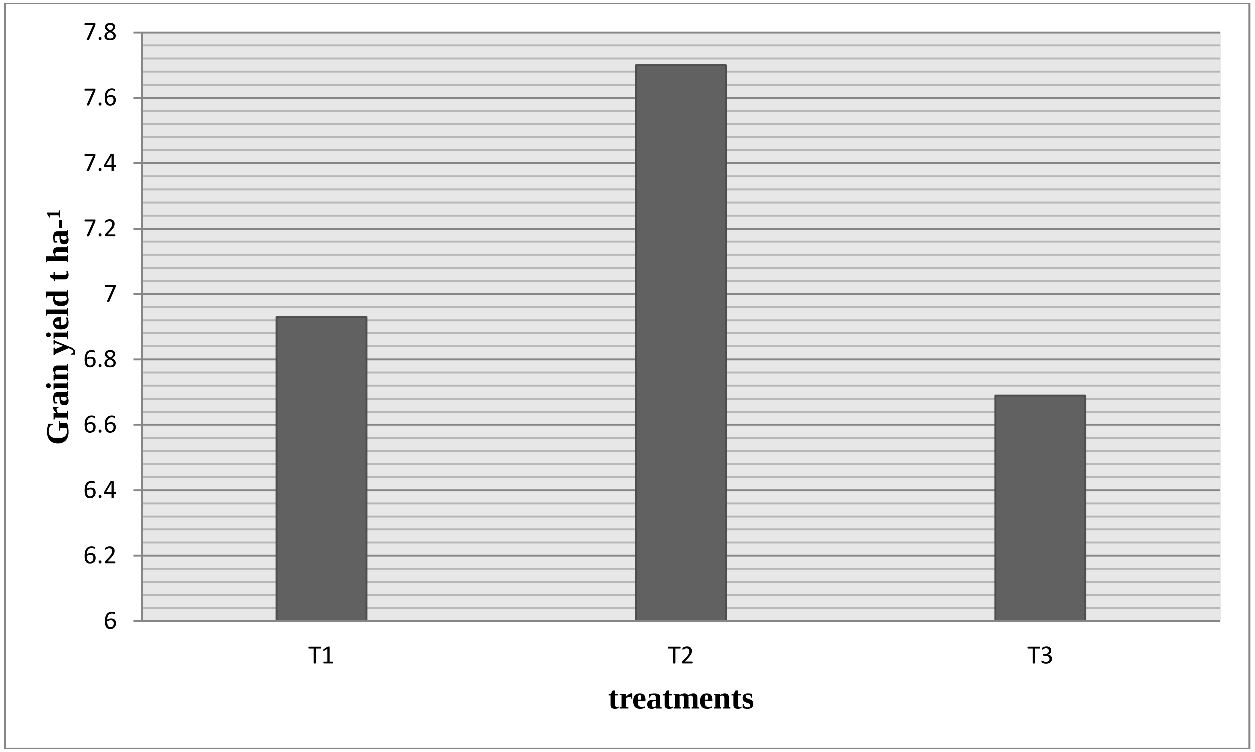


Fig.4.9. Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices grain yield t ha^{-1}

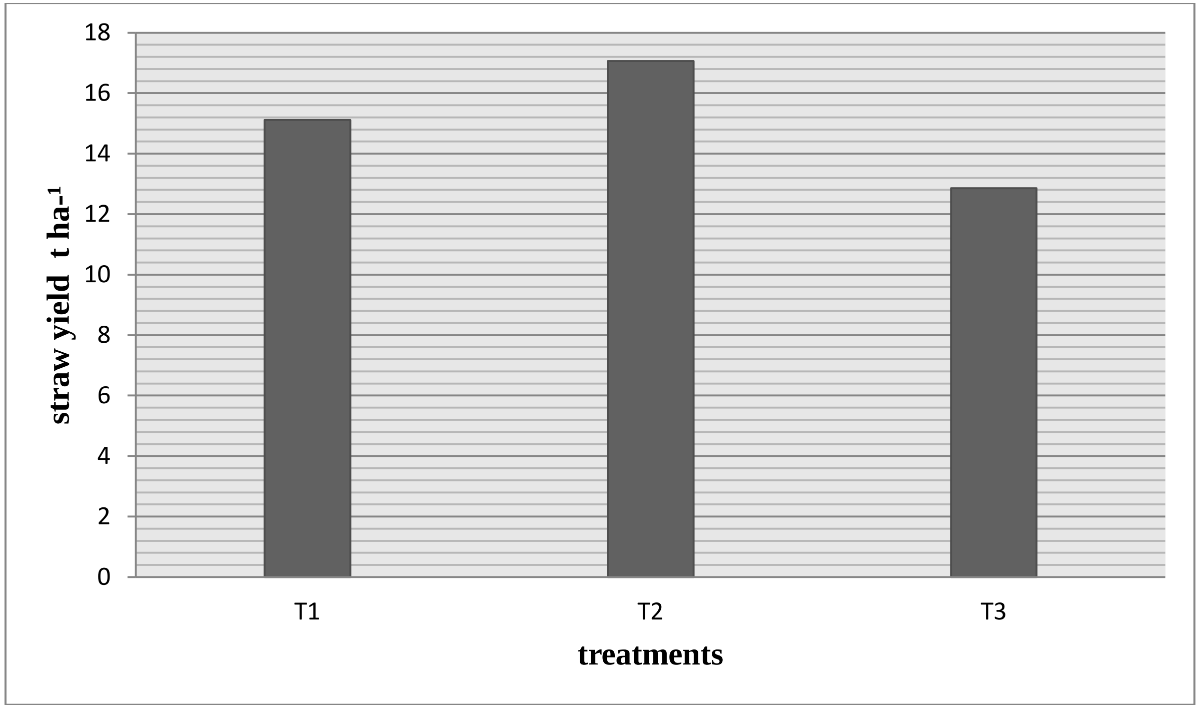


Fig.4.10. Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on straw yield t ha^{-1}

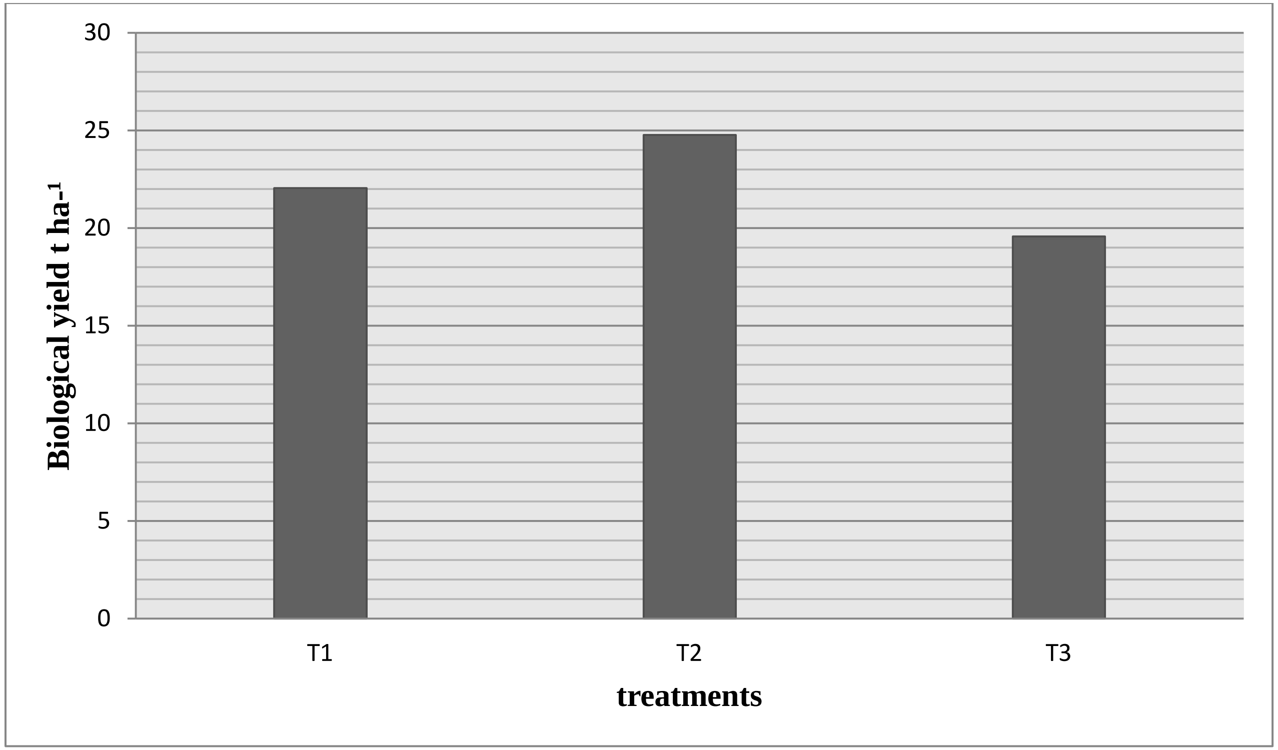


Fig.4.11. Yield parameter of rainfed rice as influenced by crop geometry and cultural practices on Biological yield t ha^{-1}

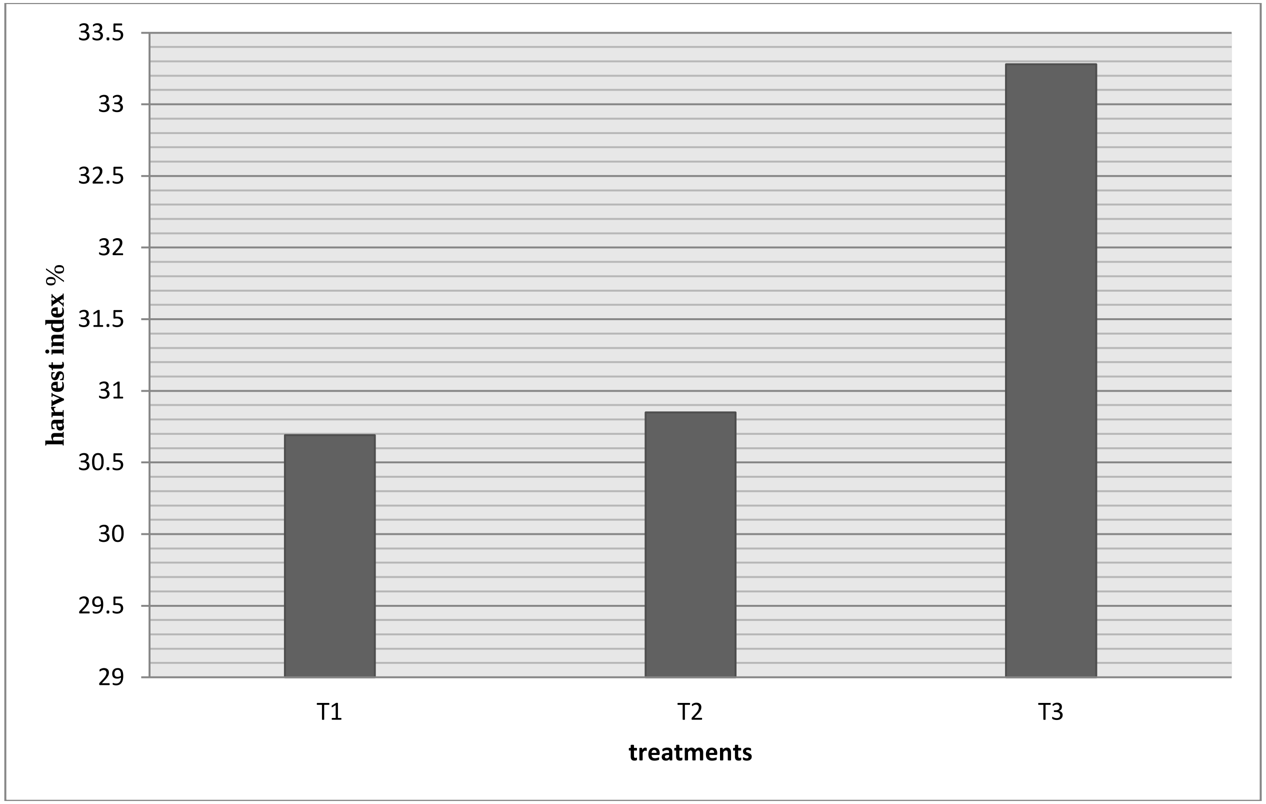


Fig.4.12. Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on Harvest Index (%)

Table 4.1 Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on plant height at different intervals.

Treatment	Plant height (cm)					
	15 DAT	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
T_1	26.85	35.85	50.69	79.38	82.64	90.09
T_2	28.49	41.86	55.12	88.06	96.24	101.21
T_3	25.39	36.17	49.99	80.17	83.97	89.75
F-test	NS	NS	NS	NS	S	S
SEd±	1.89	3.28	2.84	4.69	3.92	3.97
CD(P=0.05)	-	-	-	-	8.31	8.42
CV(%)	14.93	18.32	11.59	12.07	9.51	8.91

T_1 :20 cm x 20 cm + *Matka khaad*,T_2: 20 cm x 20 cm + neem and tobacco extract, T_3:20 cm x 15 cm + inorganic fertilizersconventional practice, CV(%)=Cofficient of variation

Table 4.2 Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on plant dryweight

Treatment	Dry weight (g $hill^{-1}$)					
	15 DAT	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
T_1	0.98	6.44	11.78	33.32	47.94	50.24
T_2	1.00	9.42	16.27	35.70	49.17	51.02
T_3	0.92	6.55	12.19	25.84	35.27	37.24
F-test	NS	NS	NS	S	S	S
SE(d)±	0.08	2.62	3.39	2.71	4.86	4.81
CD (P=0.05)	-	-	-	5.75	10.3	10.19
CV (%)	16.66	74.33	53.68	18.18	23.36	22.12

T_1 :20 cm x 20 cm + *Matka khaad* , T_2 : 20 cm x 20 cm + neem and tobacco extract, T_3 : 20 cm x 15 cm + inorganic fertilizers conventional practice, CV(%) = Cofficient of variation

Table 4.3 Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on crop growth rate

Treatment	Crop Growth Rate (g m^{-2} day^{-1})				
	15-30 DAT	**30-45 DAT**	**45-60 DAT**	**60-75 DAT**	**75-90 DAT**
T_1	9.09	8.89	35.90	24.37	6.90
T_2	14.04	11.41	32.39	22.44	5.57
T_3	12.52	12.517	30.33	20.94	7.88
F-test	NS	NS	NS	NS	NS
SE(d)±	3.59	2.52	7.02	5.96	0.85
CV(%)	192.71	149.24	135	167.86	144.32

T_1 :20 cm x 20 cm + *Matka khaad* , T_2 : 20 cm x 20 cm + neem and tobacco extract, T_3 : 20 cm x 15 cm + inorganic fertilizers conventional practice, CV(%) = Cofficient of variation

Table4.4Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on Relative growth rate (g g-^{1}day^{-1})

Treatment	Relative growth rate (g g-^{1}day^{-1})				
	15-30 DAT	**30-45 DAT**	**45- 60 DAT**	**60-75 DAT**	**75-90 DAT**
T_1	0.077	0.096	0.195	0.159	0.046
T_2	0.100	0.111	0.183	0.148	0.014
T_3	0.074	0.100	0.158	0.116	0.031
F-test	NS	NS	NS	NS	NS
SE (d)±	0.022	0.022	0.036	0.029	0.011
CV (%)	169.13	135.00	127.09	133.84	248.88

T_1 :20 cm x 20 cm + *Matka khaad* , T_2 : 20 cm x 20 cm + neem and tobacco extract, T_3 : 20 cm x 15 cm + inorganic fertilizers conventional practice, CV(%) = Cofficient of variation

Table 4.5 Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practices on number of tillers per hill.

Treatme	Number of tillers hill^{-1}					
	15 DAT	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
T_1	5.33	13.53	18.42	18.03	17.94	17.89
T_2	6.78	15.83	19.58	18.19	17.03	17.06
T_3	5.80	14.06	15.12	16.11	14.42	13.28
F-Test	NS	NS	S	NS	NS	S
SE(d)±	1.15	1.93	1.45	1.87	1.65	1.63
CD (P=0.(	-	-	3.13	-	-	3.46
CV(%)	40.73	28.36	17.55	22.76	21.2	21.47

T_1 :20 cm x 20 cm + *Matka khaad* , T_2 : 20 cm x 20 cm + neem and tobacco extract, T_3 : 20 cm x 15 cm + inorganic fertilizers conventional practice, CV(%) = Cofficient of variation

Table 4.6 Yield parameters of rainfed rice as influenced by crop geometry and cultural practices

Treatme	Panicle Length (cm)	Number of grains Panicle^{-1}	Test weight (g)	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Biologica Yield (t ha^{-1})	Harvest Index (%)
T_1	20.54	133.81	24.83	6.93	15.11	22.04	30.35
T_2	21.12	136.67	24.99	7.78	17.06	24.76	31.42
T_3	17.95	125.70	24.27	6.69	12.86	19.57	34.18
F-Tes	S	NS	S	S	S	S	NS
SE(d):	1.46	13.44	0.23	0.03	0.29	0.10	1.95
CD(P=0.	3.09	-	0.48	0.07	0.19	0.21	-
CV(%	15.98	21.59	1.95	10.19	12.83	11.70	13.12

T_1 :20 cm x 20 cm + *Matka khaad* , T_2 : 20 cm x 20 cm + neem and tobacco extract, T_3 : 20 cm x 15 cm + inorganic fertilizers conventional practice, CV(%) = Cofficient of variation

Table 4.7 Percentage of *gundhi bug*(*Leptocoriza acuta*Th.) infestation and damage in rice crop as percieved by farmers OFAR during the *kharif* trial 2013

cluster I	infestation	damage	cluster II	infestation	damage
T_1	10%	6%	T_1	8%	5%
T_2	6%	4%	T_2	5%	3%
T_3	14%	8%	T_3	12%	7%

Cluster I (Shivrampur, Dhaneh, Birpur, Itmakala, Gawraunkala); Cluster II (Akaha, Akahi, Dadari, Matripataura)

*data was not subjected to statistical analysis

Table 4.8 Productivity and economic feasibility of rainfed rice as influenced by crop geometry and cultural practice on quality parameters* of rice grain

Treatment	Carbohydrate (%)	Protein (%)	Moisture%	Fat (%)	Ash (%)
T_1	74.55	8.65	13.90	1.90	1.00
T_2	74.48	8.72	13.90	1.90	1.00
T_3	74.29	8.91	13.90	1.90	1.00

T_1 :20 cm x 20 cm + *Matka khaad* , T_2 : 20 cm x 20 cm + neem and tobacco extract, T_3 : 20 cm x 15 cm + inorganic fertilizers conventional practice, CV(%) = Cofficient of variation

*Data was not subjected to statistical analysis.

Table 4.9.Economic feasibility* of different treatments of rainfed rice as influenced by crop geometry and cultural practices

Treatment	Gross return ₹	Net return ₹	Cost of cultivation ₹	B:C ratio
T_1	108665.00	85165.00	23500.00	4.62
T_2	122090.00	97690.00	24400.00	5.00
T_3	103175.00	76189.30	26985.70	3.82

sale price of grain₹13500 t^{-1}, sale price of straw₹ 1000 t^{-1}

* Data was not subjected to statistical analysis

Table 4. 10 Fertility status soil forpre-experimental and post- harvest of crop in cluster II (Shivrampur, Dhaneh, Birpur, Itmakala, Gawraunkala) villages in Satna District of Madhya Pradesh

Cluster I Pre-experimental		Cluster I Post-harvest		
Parameter (unit)	**Value**	**T_1**	**T_2**	**T_3**
Availablenitrogen (%)	195.00	220	225	200
Available phosphorus (kg ha^{-1})	9.42	13.00	12.34	13.81
AvailablePotassium (kg ha^{-1})	299.00	290.70	289.67	275.00
Organic carbon (%)	0.38%	0.40%	0.43%	0.40%
pH	7.51	7.41	7.47	7.41
EC (dS m^{-1})	1.25	1.28	1.26	1.35

T_1 :20 cm x 20 cm + *Matka khaad* , T_2 : 20 cm x 20 cm + neem and tobacco extract, T_3 : 20 cm x 15 cm + inorganic fertilizers conventional practice, CV(%) = Cofficient of variation
*Data of nitrogen was not subjected to statistical analysis

Table 4. 11Fertility status soil forpre experimntal and post- harvest of crop in cluster II(Akaha, Akahi, Dadari, Matripataura) villages in Satna District of Madhya Pradesh

Cluster II Pre- experimental		Cluster II Post-harvest		
Parameter	**Value (unit)**	**T_1**	**T_2**	**T_3**
Available nitrogen (%)	185.00	220	223	200
Available phosphorus(kg ha^{-1})	9.43	12.00	12.00	13.00
Available potassium(kg ha^{-1})	300.00	292.70	290.00	275.56

Organic carbon (%)	0.39%		0.41%	0.42%	0.42%
pH	7.53		7.41	7.47	7.41
EC (dS m^{-1})	1.25		1.28	1.26	1.35

T_1 :20 cm x 20 cm + *Matka khaad* , T_2 : 20 cm x 20 cm + neem and tobacco extract, T_3 : 20 cm x 15 cm + inorganic fertilizers conventional practice, CV(%) = Cofficient of variation

*Data of nitrogenwas not subjected to statistical analysis

BIBLIOGRAPHY

Abraham, Thomas and Lal, R.B. 2002. Sustainable enhancement of yield potential of mustard (*Brassica juncea* L. Czern. Coss.) through integrated nutrient NM) in a legume based cropping system for the inceptisols. Cruciferae Newsletter Nr. 24 (July 2002) Eucarpia Ed. INRA Rennes, France. 99 – 100.

Adeola, R.G., Tijani-Eniola, H. and Fakunle1, A.O. 2014. Assessment of farmers' participation in on-farm adaptive research in south-western, Nigeria. *International Journal of Innovation and Applied Studies* **9**(3):1155-1160. ISSN 2028-9324. http://www.ijias.issr-journals.org/.

Ahmed, S. and B. Koppel. 1987. Use of neem and other botanical materials for pest control by farmers in India: summary of findings, pp. 623-626. (In:) (H.Schmutterer and KR.S. Ascher, eds.) Natural Pesticides from the Neem Tree (*Azadirachta indica* A. Juss) and Other Tropical Plants. *Proc. 3rd Int. Neem Conf*., Nairobi, Kenya, 1986.

AOAC, 1965. Official methods of analysis. Association of official analytical chemist, Washington DC.10th ed. pp. 15-16.

Adhikari, Raj. K. 2011.economics of organic rice production. *The Journal of Agriculture and Environment* **12**:97-103.

Azarpour, Ebrahim, Moraditochaee, Maral and Bozorgi, Hamid, Reza. 2014. Effect of nitrogen fertilizer management on growth analysis of rice cultivars *International Journal of Biosciences* **4**(5):35-47.

Bezbaruha, Ranjita, Sharma, Ravi. Chandra. and Banik, Pabitra. 2011. Effect of nutrient management and planting geometry on productivity of hybrid rice (*Oryza sativa* L.) Cultivars. *American Journal of Plant Sciences* **2**: 297-302.

Bouyoucos, G. J. 1927. The hydrometer as a new method for the mechanical analysis of soils. *Soil Sci.* **23**: 343-353.

Branca, Giacomo, Lipper. Leslie, Nancy, Mc. Carthy. and Jolejole, Maria. Christina. 2013. *Food security, climate change, and sustainable land management*. **33**(4):635-650.

Chakraborty, Kaushik. 2011**.** Extent of suppression of rice ear head bug, *Leptocoryza acuta.th* population by different neem formulation in field of paddy cultivar *swarna* *mashuri* (MTU 7029) during *kharif* season. *ARPN Journal of Agricultural and Biological Science* **6**(12):37-41.

Chadha, Sanjay, Ashlesha, Rameshwar, Saini, J.P. and Paul, Y.S. 2012. *Vedic krishi*: Sustainable livelihood option for small and marginal farmers. *Indian Journal of traditional knowledge* **11**(3): 480-486.

Chandrasekaran, B., Annadurai, K. and Somasundaram. E. 2010. A textbook of agronomy. New Age International (P) Ltd., Publishers. 1-835.

Chauhan, Bhagirath. Singh. and Mahajan, Gulshan. 2013. Strategies for boosting rice yield in the face of climate change in India. *International Rice Research Institute* 1:1 http://dx.doi.org/10.4172/jrr.1000105.

Collins, H.P., Rasmussen, P.E. and Douglas, C.L., 1992, Crop rotation and residue management effect on soil carbon and microbial biomass dynamics. *Soil Sci. Soc. America. J.*, 56: 783-788.

Damodaran, V., Saren, B.K., Ravisankar, N. and Bommayasamy, N. 2012. Influence of time of planting, spacing, seedling number and nitrogen management practices on productivity, profitability and energetics of rice (*Oryza sativa*) in Island Ecosystem. *Madras Agricultural Journal* ***99*** (7-9): 538-544.

Debashri, Mondal and Tamal, Mondal. 2012. A review on efficacy of *Azadirachta indica* A. Juss based biopesticides: An Indian perspective. *Research Journal of Recent Sciences* **1**(3) 94-99.

Deshpande, Harish. H. and Devasenapathy, P. 2010. Effect of green manuring and organic manures on yield, quality and economics of rice (*Oryza sativa* L.) under lowland condition. *Karnataka J. Agric. Sci* **23** (2):235-238.

Dhiman, S.D., Nandal, D.P., Hariom. and Mehla. 2000. Productivity and economic feasibility of rice (*Oriza sativa*) based cropping systems in north- western India. *Indian Journal of Agricultural science* **70** (9):571-3.

Donald, C.M. (1962). In search of yield. *Journal of Australian Institute of Agriculture Science* **28**: 171-178.

European union global programe on agricultural research for development. http://www.safbin.org.

FFTC, 1995. The appropriate use of fertilizers.
Co-sponsors**:** Asian Productivity Organization, Council of Agriculture Chinese Society of Soil and Fertilizer Sciences, National Taiwan University, Taiwan Agricultural Research Institute.
http://www.fftc.agnet.org/library

Fisher, R.A. 1921**.** Some remarks on the methods formulated in a recent article in "The quantitative analysis of plant growth" *Annals of Applied Biology* **7**: 367-369.

Gautam, A.K., Kumar, Dinesh, Shivay, Y.S. and Mishra, B.N. 2008 Influence of nitrogen levels and plant spacing on growth, productivity and quality of two inbred varieties and a hybrid of aromatic rice. *Archives of Agronomy and Soil Science* **54** (5) 515–532.

GOI. 2011**.** Agriculture statistic at a glance: publuish by Ministry of Agriculture, Govt. of India.http://agricoop.nic.in.

Gomez, K.A. and Gomez, A.A. 1976**.** Three or more factor expects. In: *Statistical Agricultural Research* 2nd ed., pp.139 -141.

Gorgy, R.N. 2010. Effect of transplanting spacing and nitrogen level on growth, yield and nitrogen used efficiency of some promising rice varieties. *Journal of Agriculture. Research. Kafer El-Shiekh University* **36**(2):123-144.

Gupta, Suman and Dikshit, A. K. 2010. Biopesticides:An eco-friendly approach for pest control Journal of Biopesticides **3**(1) 186 – 188.

Hasanuzzaman, Mirza, Nahar, Kamrun, Roy. T.S., Rahman, M.L., Hozzain, M.Z. and Ahmed, J.U. 2009. Tiller dynamics and dry matter production of transplanted rice as affected by plant spacing and number of seedlings per hill. *Academic journal of plant science* **2**(3) 162-168.

Jackson, K.L. 1973. Soil chemical analysis prentice hall of india. Pvt. Ltd. New Delhi. pp. 38-43.

Jakar, RNR-R. 2001. On-farm trial - Guidelines for extension agents, Renewable Natural Resources Research Centre Jakar, Extension Sector, Bhutan. (In:) Meertens, Bert. 2008. On-Farm Research mannual 1-54.
http://www.adron.sr/files/On-Farm-Research-Manual-Suriname.pdf107,13

Kaul, B. K. and Sharma, P. K. 1999. Efficacy of neem based insecticides against the major insect pests. *Journal of Entomological Research*. 23: 377-379. (In:) Chakraborty, Kaushik. 2011**.** Extent of suppression of rice ear head bug, *Leptocoryza acuta.th* population by different neem formulation in field of paddy cultivar *swarna mashuri* (MTU 7029) during *kharif* season. *ARPN Journal of Agricultural and Biological Science* **6**(12):37-41.

Khan, T.A., Sorwar, S.S.R.M.M.A., Mondol, M.A. and Mazumdar, J.M. 2010. Effect of tree leaf litter on the yield and yield contributing characteristics of T. aman rice cv. BR11. *Journal of Agroforestry Enviroment* **4** (2): 85-88, ISSN 1995-6983.

Kumar, Niru., Singh, C.S., Prasad, j., Singh, M.K. and Kumars, Rajesh. 2013. Influence of organic nutrient sources on productivity of rice (*Oryza sativa*)-based cropping systems in Jharkhand. *Indian Journal of Agronomy* **58** (3): 277-281.

Kumar, Manoj, Das, Anup, G,I. Ramakrushna., Patel, D.P., Munda, G.C., Naropongla. and Buragohan, Juri. 2013. Effect of nutrient sources and transplanting date on aromatic rice (*Oryza sativa*) under mid hills of north eastern India. *Journal of Agronomy* **58** (3): 322-326.

Lal, Chaman and Verma, L.R. 2006. Use of certain bio-products for insect-pest control. *Indian Journal of Traditional Knowledge* **5**(1) 79-82.

Lokanadhan, Subbalakshmi, Muthukrishnan, P. and Jeyaraman, S. 2012**.** Neem products and their agricultural applications. *Journal of Biopest* **5** (Supplementary): 72-76.

Mohaddesi, Ali., Abbasian, Abouzar, Bakhshipour, Saeid. and Aminpanath, Hashem. 2011. Effect of different level of nitrogen and plant spacing on yield, yield components and physiological indices in high-yield Rice. *American-Eurasian Journal of Agriculture and Enviromental science* **10**(5): 893-900.

Nagai, Takeshi and Makino, Amane. 2009. Differences between rice and wheat in temperature responses of photosynthesis and plant growth. *Oxford journal plant and physiology* **50**(4):744-755.

NABARD. 2014. Status focus paper 2014-2015 Madhya Pradesh. http://www.indiaenvironmentportal.org.in/content/387332/nabards-state focus-paper-2014-15-for-madhya-pradesh/

Nene, Y.L. 1993. On-Farm Adaptive Research and Technology Exchange. (In:)

*Approaches to On Farm Research in Asia.*1993. *Interntaional Crops Research Institute for the Semi-Arid Tropics.* Patancheru, Andhra Pradesh 7-12.

Nguyen, N.V. 2006. Global climate changes and rice ***food security***. Retrieved from the article, United Nations FAO Food Price Index ***published*** October 4:24-30. www.fao.org.

NRAA. 2012. Prioritization of Rainfed Areas in India, Study Report 4, NRAA, New Delhi, India 100p.

Ogbodo, E.N., Ekpe, I.I., Utobo , E.B. and Ogah, E.O. 2010. Effect of plant spacing and N rates on the growth and yields of rice at Abakaliki Ebonyi State, Southeast. *Nigeria. Research Journal of Agriculture and Biological Sciences*, **6**(5): 653-658.

Olsen, S.R., Cole, C.V., Watanable, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *U.S. Dept. Agr. Circ*. 939.

Pathak, R.K. and Ram, R.A. 2013. Bio-enhancers: A potential tool to improve soil fertility, plant health in organic production of horticultural crops. *Progressive Horticulture,* **45**(2):237-254.

Ponnusamy, K. 2003. Farmers participatory assessment of neem based insecticide in controlling the ear head bug (*Leptocorisa acuta*) in rice. *Madras Agriculture Journal* **90**(7-9): 564-566. (In:) Chakraborty, Kaushik. 2011**.** Extent of suppression of rice ear head bug, *Leptocoryza acuta.th* population by different neem formulation in field of paddy cultivar *swarna mashuri* (MTU 7029) during *kharif* season. *ARPN Journal of Agricultural and Biological Science* **6**(12):37-41.

Prakash, Anand., Rao, Jagadiswari. and Nandagopal, V. 2008. Future of Botanical Pesticides in rice, wheat, pulses and vegetables pest management. *Journal of Biopesticides* **1**(2):154-169.

Prasad, Y.G. and Bambawale, O.M. 2010. Effects of Climate Change on Natural Control of Insect Pests. *Indian Journal of Dryland Agriculture Research and Develovpment* **25**(2): 1-12.

Quyen, N.V., Sharma, S.N., Gautam, R.C. (2002) Comparative study of organic and traditional farming for sustainable rice production. *Omonrice Journal* 10: 74-78.

Rajashekar, Yallappa, Bakthavatsalam Nandagopal and Shivanandappa, Thimmappa. 2012. Botanicals as Grain Protectants . *Hindawi Publishing Corporation Psyche 1-13* Article ID 646740.

Ram, Moola, Davari, Mohammadreza. and Sharma, S. N. 2011. Organic farming of rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) cropping system: *International journal of Agronomy and Plant Production* **2** (3): 114-134. http:// www.victorquestpub.com.

Ram, R.A. and Bhriguvanshi, S.R. 2008. Annual Report, Central Institute for Subtropical Horticulture, Lucknow, pp. 35-36.

Ranganna, S. 2003. *Handbook of Analysis & Quality Control for Fruit and Vegetable Product*. Tata Mc Graw- Hill Publishing Company Limited New Delhi, pp. 7-12.

Rao, S.S., Rao, M.H., Khrishnan. and Rana, B.S. 1998. Characteristcs of sorghum hybrids and varieties for growth parameters, biomass accumulation and yield potential in rainy season. *Indian journal of plant physiology* (**3**):269-273.

Rashid, Harunur. M.D. and khan, Akhter, Hossain. 2006**.** Tillering Dynamics and productivity of BRRI dhan 44 as influenced by spacing and nitrogen management technique. *Journal of Agriculture & Rural Development* **4**(1&2):47-52, ISSN 1810-1860.

Rasool, Faisul. Ur., Habib, Raihana. and Bhat, M. I. 2013. Agronomic evaluation of rice (*Oryza sativa* L.) for plant spacings and seedlings per hill under temperate conditions. *African Journal of Agricultural Research* **8** (37): 4650-4653.

Roshan, Naser. Mohammadian., Azapour, Ebrahim. and Modadi, Maral. 2011. Study of yield and yield components of rice in different plant spacings and number of seedlings per hill. *Middle- East Journal of Scientific Research* **7**(2):136-140.

Roul, P. K. and Sarawgi, S.K. 2005. Effect of integrated nitrogen nutrition techniques on yield, N content, uptake and use efficiency of rice (*Oryza sativa*). *Indian Journal of Agronomy* **50** (2):129-131.

Satyanarayana, V., Prasad, Vara. P.V., Murthy, V.R.K. and Boote, K.J. 2002. Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield component of irrigated lowlwnd rice. *Journal of Plant Nutrition* **25** (10):2081-2090.

Saxena, Ramesh. C. 2006. Prcatical applications of neem against pests of stored products.

Shah, F., Huang, J., Cui,k., Nie, L., Shah, T. Chen, C. and Wang, k. 2011. Impact of high-temperature stress on rice plant and its traits related to tolerance. *Journal of Agricultural Science*, 1-12.

Sharma, R.P., Pathak, S.K., Haque, M. and Manser. 2008**.** Productivity, profitability and nutrient balance as influenced by diversification of rice (*Oriza sativa*)-wheat (*Triticum aestivum*) croppind system. *Indian Journal of Agronomy* **53**(2):97-101.

Shukla, A., Pathak,S.C. and Agrawal, R.K. 1996. Efficacy andeconomics of some insecticides and plant products againstthe infestation of okra shoot and fruit borer, *Earis vittella* Fab. *Crop Res.*, **12,** 367-373**.** (In:) Debashri, Mondal and Tamal, Mondal. 2012. A review on efficacy of *Azadirachta indica* A. Juss based biopesticides: An Indian perspective. *Research Journal of Recent Sciences* **1**(3) 94-99.

Singh, A.K., Venkateswarlu, B. Director. 2009**.** Climate change and rainfed agriculture. *Indian Journal of dry land Agriculture research and Development* **24**(2):1-9.

Singh, Kumar, Dinesh., Kumar, Purushottam. and Bhardwaj, A. K. 2014. Evaluation of agronomic management practices on farmers' fields under rice-wheat cropping system in northern india. *International Journal of Agronomy.*
Article ID 740656, 5 pages
http://dx.doi.org/10.1155/2014/740656

Singh, S. P. and Singh, A. K. 1999. Efficacy of some neem formulations against rice leaf folder *Cnapholocrocis medinalis* Guenee in North Bihar, agro-climatic condition. Pesticide Research. 11: 51-54.

Soon, Lim. Guan. and Bottrell, Dale. G. 1994. Neem in pesticides rice: potential and limitations 1- 68.

Sohail, A., Hamid, F. S., Waheed, A., Ahmed, N., Aslam, N., Zaman, Q., Ahmed, F. and Islam, S. 2012. Efficacy of different botanical materials against aphid *toxoptera aurantii* on tea (*camellia sinensis* l.) cuttings under high shade nursery. *J. Mater. Environ. Sci.* **3** (6):1065-1070.

Subbiah, B.V. and Asija, C.L. 1956**.** A rapid procedure for the estimation of available Nitrogen in soil. *Soil Sci.* **25**: 328.

Suman, Gupta and Dikshit, A. K. 2010. Biopesticides: An ecofriendly approach for pest control. *Journal of Biopesticides* **3**(1): 186-188.

Surekha, K., Rao, K.V. , Shobha Rani,.N., Latha, P.C. and Kumar, R.M. 2013. Evaluation of organic and conventional rice production systems for their productivity, profitability, grain quality and soil health. *Agrotechnology* Special Issue 11 •1-6.

Tesfaye, Adane. and Gautam, R. D. 2003. Traditional pest management practices and lesser exploited natural products in Ethiopia and India: Appraisal and revalidation. *Indian Journal of Traditional Knowledge* **2** (2)189-201.

Toth, S.J. and Prince, A.L. 1949. Estimation of cation exchange capacity and exchangeable Ca, K and Na content of soil by flame photometer technique. *Soil Sci*. **67**:439-445.

Tyeb, A., Paul, S.K. and Samad, M.A. 2013. Performance of variety and spacing on the yield and yield contributing characters of transplanted *Aman* rice. *Journal of Agrofor. Environ*. 7 (1): 57-60, ISSN 1995-6983.

Upadhyay, V.B., Jain, Vikas, Vishwakarma, S.K. and Kumhar, A.K. 2011. Production potential, soil health, water productivity and economics of rice (*Oryza sativa*)–based cropping systems under different nutrient sources. *Indian Journal of Agronomy* **56** (4): 311-316.

Wassmann, Reiner. and Dobermann, Achim. 2007. Climate change adaptation through rice production in regions with high poverty levels. *SAT* eJournal/ejournal.icrisat.org (**4)**:1-24.

Yadav, D.S., Kumar, Veneet. and Yadav, Vivek. 2009**.** Effect of organic farming on productivity, soil health and economic of rice (*Oriza sativa)*-wheat (*Triticum aestivum)* system. *Indian Journal of Agronomy* **54**(3):267-27.

Yadav, S.K., Babu, Subhash., Singh, Y., Yadav, G.S., Singh, Kalyan, Singh, Raghavendra. and Singh, Harvir. 2013. Effect of organic nitrogen sources and biofertilizers on production potential and energy budgeting of rice (*Oryza sativa*)-based cropping systems. *Indian Journal of Agronomy* **58** (4): 459-464.

Zong, N and Wang, C. 2004. “Induction of nicotine in tobacco by herbivory and its relation to glucose oxidase activity in the labial gland of three noctuid caterpillars,” *Chinese Science Bulletin*, **49** (15):1596–1601.