Response of rice variety to fertility level and split application of nitrogen fertiliser under medium land condition

A

Thesis submitted to the
Orissa University of Agriculture and Technology Bhubaneswar
in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture
(Agronomy)

By

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10Agro/16

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ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR, ODISHA
2018

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CERTIFICATE –I

This is to certify that the thesis entitled "**Response of rice variety to fertility level and split application of nitrogen fertiliser under medium land condition**" submitted in partial fulfilment of the requirement for the award of degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)** to the Orissa University of Agriculture and Technology is a faithful record of bonafide and original research work carried out by **Rasmirekha Pattnaik** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

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

Dr. MANORANJAN SATAPATHY
CHAIRMAN
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CERTIFICATE –II

This is to certify that the thesis entitled "**Response of rice variety to fertility level and split application of nitrogen fertiliser under medium land condition**" submitted by **Rasmirekha Pattnaik** to the Orissa University of Agriculture and Technology, Bhubaneswar in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)** has been approved/disapproved by the students' advisory committee and the external examiner.

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ACKNOWLEDGEMENT

Gratitude takes three forms, "A feeling from the heart, an expression in words and a giving in return….."

I bow my head before Almighty

"Lord Jagannath"

Whose blessings have helped me to reach at this point

At last, the moment has come to look into the deeper layers of my heart which is filled with the feeling of togetherness and loveliness; consolation, gratitude and satisfaction. Some are permanent and some are momentary but both involve a number of persons to whom I acknowledge my warm regards.

First and foremost I humbly bow my head before the Almighty for the un-merited blessings through various hands. I submit this small venture before God with full satisfaction and pleasure from my heart.

I wish to express my deep sense of reverence to, **Dr. M. R. SATAPATHY,** Associate Professor, Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar and the esteemed chairman of my advisory committee. I am profoundly thankful to him for his constant encouragement, keen interest, constructive criticism and everlasting patience throughout the endeavor and devoting his time amidst his busy schedule and ill health.

It is with great respect and devotion I place on record, my deep sense of gratitude and indebtedness to my advisory committee members **Dr. B. Behera,** Professor & Head, Dept.of Agronomy, OUAT, Bhubaneswar, **Dr. R.K. Paikaray,** Professor, Dept. of Agronomy, OUAT, Bhubaneswar and **Dr. K.K. Rout**, Professor & OIC, AICRP on LTFE for their sustained and valuable guidance, constructive suggestions, unfailing patience, friendly approach, constant support and encouragement throughout the period of my research work.

I am extremely delighted to place on record my profound sense of gratitude to Dr. B. Behera, Professor and Head, Department of Agronomy, Dr. L. M. Garnayak., Dr. R. K. Paikaray, Dr. S. N. Jena, Dr. P. K. Mohanty, Dr. S. Biswal, Dr. B. S. Rath, Dr. A.K. Behera and Miss A. Mohapatra for their unstinted support, critical comments and valuable suggestions during the study and research work.

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I am indebted to all the non-teaching staff of the department and all the field workers who have facilitated me in the research plot. Without them, this piece of work would not have been possible.

With much love and affection, I record my respectful indebtedness and gratitude to my father Mr. Dhananjaya Pattnaik and my mother Mrs. Puspashree Pattnaik, whose love and affection have always been a source of inspiration and encouragement to me in all walks of my life. I feel inadequacy of diction to express my deep sense of gratitude and heartfelt thanks to my brothers Rudra, Bibhu, Prabhu and my sisters Jyotirmayee and Bhumika for their boundless love and unshakeable confidence which inspired me in pursuing the study and responsible for what I am Today. I dedicate this piece of work for their love and sacrifice.

I express my heartfelt thanks to my most beloved friends Amruta, Pradyot, Debasis, Pooja, Krishna, Debasmita and all who have been with me in my endeavor, for their constant help during work helped me to pursue my research work with precision.

I am grateful to my seniors Tapas bhai, Sabyasachi bhai and Satya Bhai for their valuable advises during the degree programme. I express my heartfelt thanks to my batch mates Barshita, Ananyaa, Divya, Kusuma, Santosh, Jitendra, Hemanand, Sourav, Krishna Ananya who were with me in my endeavor and helped me to pursue my research work with precision.

Lastly, I offer my regard to all of those who supported me in any respect during the completion of the project. But for the lapse of my memory, I would place them to the same heights of regards as others have been in the above paragraphs.

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LIST OF SYMBOLS AND ABBREVIATIONS

% : Per cent

Rs. : Rupees

@ : At the rate

C.D.: Critical Difference

cm : Centimeter

DAP : Diammonium Phosphate

DAT : Days After Transplanting

dSm^{-1}: Decisiemen per meter

e.g. : For example

et al. ; Co-workers

F : Fertiliser levels

g : Gram

ha^{-1} : Per hectare

HI : Harvest Index

hrs : Hours

K : Potassium

Kg : Kilogram

L : Litre

LAI : Leaf Area Index

M : Meter

Max.: Maximum

Min. : Minimum

MOP: Muriate of Potash

N : Nitrogen

^{o}C : Degree centigrade

P : Phosphorus

pH : Puissance he hydrogen

PI : Panicle Initiation

S : Split application of nitrogen

SEm(±): Standard error of mean

t : Tonn

V : Variety

ABSTRACT

A field experiment was conducted during *kharif* season of 2017 to study the "Response of rice variety to fertility level and split application of nitrogen fertiliser under medium land condition" at Agronomy Main Research Station, Orissa University of Agriculture and Technology, Bhubaneswar. The experiment was laid out in Split-plot design with sixteen treatment combinations and three replications. Two fertility levels (100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}) each with two different splitting schedules of nitrogen (¼ basal + ½ tillering + ¼ PI) and (¼ basal + ½ tillering + 1/8 PI+ 1/8 flowering) were assigned to four different varieties (Hasanta, Mrunalini, Asutosh and Swarna). The soil of the experimental site was sandy loam, acidic in reaction (pH 5.6), medium in organic carbon (0.71 %), low in available nitrogen (223 kg ha^{-1}), medium in available phosphorus (20 kg ha^{-1}) and medium in potassium (211 kg ha^{-1}). The investigation revealed that application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} with four splits of nitrogen recorded maximum grain yield (4.87 t ha^{-1}), straw yield (7.2 t ha^{-1}), panicle length (26.18 cm), number of panicles m^{-2} (336), total number of grains $panicle^{-1}$ (198), number of fertile grains $panicle^{-1}$ (155), fertility per cent (77.49) and the highest 1000 grain weight (20.03 g). Maximum plant height (60.34 cm) and highest dry matter accumulation (459.08 g m^{-2}) at harvest was also observed under the same fertility level which accounted for the highest total nutrient (NPK) uptake (236.72 kg ha^{-1}). On the other hand application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} with three splits of nitrogen produced the highest grain: straw ratio (0.77) and harvest index (43.77%). Among the varieties, Mrunalini recorded maximum grain yield (5.06 t ha^{-1}), straw yield (7.41 t ha^{-1}), number of panicles m^{-2} (489), total number of grains $panicle^{-1}$ (222), number of fertile grains $panicle^{-1}$ (189) and 1000 grain weight (22.08 g). The highest total nutrient (NPK) uptake (237.26 kg ha^{-1}) was also observed in the same variety which was attributed to highest dry matter accumulation (1481.4 g m^{-2}). However, Hasanta variety recorded maximum harvest index (43%) and grain: straw ratio (0.75). Mrunalini variety with 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits of nitrogen resulted in maximum net return (Rs. 42765 ha^{-1}) and benefit: cost ratio (2.66).

INTRODUCTION

Rice (O*ryza sativa* L.) is a pioneer food crop in Asia that has high plasticity as it can be cultivated in various ecosystems. The green revolution enabled the rice production to meet the demands of increasing population and helped many countries to escape starvation. Presently it is a major staple food providing more than 65% of calorie intake in many developing countries (Sharma *et al*., 2013)

The population of rice consuming countries is increasing at a faster rate. By the year 2025, about 785 million tonnes of rice which is 70 per cent more than the current production will be needed to meet the growing demand (Manomani & Khan, 2003). Presently, rice ranks second with respect to total area and production. It is the principal source of food for more than half of the world population (Nguyen 2002). Rice covers about 42% of total cropped area and provides 21% of global human per capita energy as well as 15% of per capita protein. Among the rice growing countries, India covers the largest area and is the second largest producer next to china. Rice contributes more than 40% of country's total food grain production. In India, rice is cultivated in an area of 43.9 million hectares with the production of 104.32 million tonnes and average productivity of 2404 kg ha^{-1}. The production is lowered by 1.17 million tonnes than the production of 105.48 million tonnes during the previous year (GOI 2016-17).

In Odisha, rice is synonymous with food; agriculture in Odisha to a notable extent means growing rice. Odisha occupies 8^{th} position among the highest rice producing states, and produces about 4.47 % rice of the country (Farmer's portal, Ministry of Agriculture, 2016-17). Rice is grown in more than 69% of total cultivated area and covers about 63% of the total area under food grains. Total rice production in Odisha in 2009-10 was recorded as 6.94 million t with productivity of 1,572 kg/ha. During 2012-13, Odisha contributed to about 9% of acerage and 7.4% of production of rice in India. Presently rice in Orissa is grown over an area of 4.4 million hectares, with production of 9.50 million tonnes ha^{-1} which covers about 91 per cent of the area under cereals and contributes about 94 per cent of total cereal production in the state. Major districts of odisha cultivating paddy are Bargarh, Balangir, Kalahandi, Mayurbhanj, Nabarangpur, Subarnapur, Sundargarh, Sambalpur which cover about

40% of rice area and contribute to more than 50% of rice production of the state (Directorate Of Agriculture and Food production, odisha, 2015).

Farmers in odisha generally grow traditional varieties rather than the improved varieties. The newly improved rice varieties supposed to possess higher grain yield as compared to the existing traditional varieties. However, this requires a systematic evaluation of their response to added nutrients in terms of grain yield at higher rates of fertiliser application in order to exploit their yield potential.

Among the agricultural inputs, nitrogen ranked first to give maximum output in agriculture. It is an essential constituent of proteins, chlorophyll and metabolites such as nucleotides, phosphatides, alkaloids, enzymes, hormones, vitamins etc. and hence have a great physiological importance in plant metabolism. Apart from promoting vegetative growth, it also enhances crop yield and protein content in grains. It is an important nutrient element for rice plants, as 75 per cent of leaf nitrogen is associated with chloroplast which physiologically helps in dry matter production through photosynthesis.

Nitrogen fertilization plays a vital in plant physiological processes as it influences the sink size thereby increasing the grain yield of rice (Somasundaram *et al.,* 2002). It is also important for spikelet production during the early phase of panicle formation and contributes to sink size by reducing the number of degenerated spikelet and increasing hull size during the later panicle formation stage (Stanley *et al.,* 2006).

The demand of Nitrogen is increasing at the rate nearly equivalent to the rate of increase in population that is about 2 per cent per annum. It acts as a key nutrient in determining the level of crop productivity. The efficiency of applied nitrogen is very low and varies from 20 to 25% in rice crop that consumes about 40 per cent of the total nitrogen used in India. This lower efficiency is due to the oxidized condition prevailing in uplands and unavoidable heavy nitrogen loss through percolating water. Although, nitrogen fertilizers have played an important role in increasing agricultural production over the past many years, improper use of these fertilizers, instead of giving yield advantage, may reduce the same.

During ripening stage, about 70% of the nitrogen absorbed by the straw is translocated to the grain. Nitrogen content of the grain tends to be maintained at a certain percentage. When a large number of grains relative to the size of vegetative parts is produced, more nitrogen will be needed to support grain growth and there will be a sharper drain in leaf nitrogen content. Under such situation some grains may suffer from nitrogen shortage (Yoshida, 1981).

Split application of nitrogen is a well proven and accepted method of increasing nitrogen use efficiency in most irrigated crops (Prasad, 2007). Generally split application in 2-3 equal or graded doses is recommended. Split application of nitrogen is highly desirable since crops take up only 1-1.2 kg Nitrogen h^{-1} day^{-1} and excess nitrogen not used by crop is subject to various nitrogen losses (Prasad, 2006). The split application of nitrogen is one of the most important strategy for efficient use of nitrogenous fertilisers throughout the growing season by synchronizing the plant demand, reducing denitrification loss and improved nitrogen uptake with high grain yield in direct seeded rice (Frageria, 2010 ; Lampayan *et al*., 2010 and Rehman *et al*., 2013).

Crop varieties are also considered as an important yield determinants on account of their morphological and physiological characteristics. Different varieties may have varying responses to N-fertilizer depending on their agronomic traits. Many workers have reported a significant response of rice to nitrogen indifferent soils in Bangladesh (Bhuiyan *et al*., 2008). The imbalanced fertilizer application and use of traditional variety are the main constraints in the rice production. Hence, fractional application of nitrogen in right amount and proportion, and when it is needed the most seems to be a practical preposition.

Keeping above facts in view, the present investigation entitled, **"Response of rice variety to fertility level and split application of nitrogen fertiliser under medium land condition"** was undertaken with following objectives:

1. To study the effect of treatments on phenology, growth and yield of rice.

2. To optimise the time of nitrogen application for medium land rice.

3. To assess the soil fertility and estimate the nutrient uptake by crop.

4. To find out the comparative economics.

REVIEW OF LITERATURE

A number of literatures are available on response of rice varieties to fertility level and split application of nitrogen fertiliser. In this chapter an attempt has been made to collect some information on reviews of literature on relative performance of rice varieties grown under different fertility levels and different splits of nitrogen with respect to growth, yield and yield attributing characters, nutrient uptake and economics. The available literature pertaining to these aspects from inside and outside of the country is briefly reviewed below under different heads.

Effect of fertiliser doses and split application of nitrogen on:

2.1 Growth and growth parameters

Singh and Jain (2000) reported that higher dose of NPK fertilization (200-100-80 kg ha^{-1}) significantly increased plant height, tillers $hill^{-1}$, leaf area index, leaf area ratio and crop growth rate but specific leaf weight and foliage efficiency were reduced drastically. Physiological characters during pre and post anthesis like dry matter accumulation, relative growth rate and net assimilation rate were not affected by high (200-100-80 kg NPK ha^{-1}) and moderate (100-50-40 kg NPK ha^{-1}) levels of nutrient application.

Rammohan *et al.* (2000) revealed that increasing levels of nitrogen from 0-150 kg N ha^{-1} resulted in taller plants with greater leaf area index and more number of productive tillers $hill^{-1}$. Application of 150 kg N ha^{-1} resulted in highest number of productive tillers (8.69 to 11.05) as well as maximum dry matter production (923.8 to 32.3 g $hill^{-1}$).

The highest plant height, number of tillers, leaf area index and dry weight were recorded with 100 per cent recommended NPK @ 80-40-20 kg ha^{-1} over 50 and 75 per cent of recommended NPK (Prasad *et al.*, 2001). Higher plant height and leaf area index were obtained with application of 150-100-60 kg NPK than 100-60-40 kg NPK ha^{-1} (Pandey *et al*., 2001).

Lawal and Lawal (2002) recorded that application of fertilizer up to 80 kg N ha^{-1} significantly enhanced crop growth rate, number of ear bearing tillers m^{-2} and per cent filled grains of rice.

Kundu and Kundu (2002) noticed maximum plant height, number of tillers and dry-matter accumulation under application of 180-90-90 kg NPK ha^{-1}. Plant height, tillers hill^{-1} and leaf-area index increased with application of 150-50-50 kg NPK ha^{-1} (Lenin and Rangaswamy, 2002). Prasad *et al.* (2003) found that the level of N had significant effect on the plant height, number of tiller m^{-2}, leaf area index and dry matter accumulation.

Singh *et al.* (2005) found that fresh weight, dry weight and growth of seedlings increased significantly with increasing NPK levels up to 200-100-50 kg ha^{-1}**.** It was found that chlorophyll content increased with the increasing level of nitrogen up to 120 kg N ha^{-1} (Sharma and Agrawal, 2006). Singh *et al.* (2007) reported that tiller density and panicle length increased significantly with N application up to 120 kg N ha^{-1}. Plant height increased significantly with increasing levels of nitrogen up to 120 kg N ha^{-1} (Sharma *et al.*, 2007).

Kumar and Shivay (2009) noticed that nitrogen application significantly increased the plant height, tillers hill^{-1}, dry matter accumulation and leaf area index with each successive increase in the N level up to 150 kg N ha^{-1} during all the growth stages of rice.

Sathiya and Ramesh (2009) reported that application of 150 kg N ha^{-1} in four splits – 1/6 at 15 DAS, 1/3 at tillering, 1/3 at panicle initiation and 1/6 at flowering obtained higher number of tillers, plant height, dry matter at flowering and grain yield over four equal splits. Plant height, number of tillers hill^{-1}, number of leaves hill^{-1}, leaf area hill^{-1}, dry matter of root, stem and leaves hill^{-1}, total dry matter hill^{-1} and chlorophyll content in leaves, were increased with the split application of N (Shaiful *et al*., 2009).

Baba *et al*. (2010) observed that growth characters *viz.* plant height, leaf area index and dry matter responded significantly to N levels up to 120 kg N ha^{-1}. Murthy *et al*. (2012) recorded that plant height, leaf area index and dry matter production increased with the increasing level of nitrogen up to 120 kg ha^{-1}.

Devi *et al.* (2012) documented that, highest values of all growth parameters were recorded with application of nitrogen 175 kg ha^{-1} which was comparable with 150 kg ha^{-1}. Application of nitrogen in four splits i.e. at 1/4 basal, 1/4 at active tillering, 1/4 at panicle initiation and 1/2 at heading was the most suitable.

Rehman *et al.* (2013) observed that total dry matter, leaf area index (LAI) and crop growth rate (CGR) increased with application of nitrogen in two splits as 1/2 at sowing and 1/2 at anthesis. Yoseftabar *et. al.* (2013) concluded that maximum number of tillers was observed under application of 300 kg ha^{-1} nitrogen in three splits (1/3basal, 1/3 mid tillering and 1/3panicle initiation).

Singh *et al.* (2014) revealed that application of N 1/3 as basal, 1/3 at tillering, 1/3 at panicle initiation and 1/4 as basal, 1/2 at tillering and 1/4 at panicle Initiation stage recorded significantly higher crop growth rate (CGR) and relative growth rate (RGR) than 1/2 as basal, 1/4 at tillering and 1/4 at panicle initiation stage.

Singh *et al*. (2014) recorded that increase in N level increased plant height. Maximum plant height (104.6 cm) was observed in plots supplemented with 60 kg N ha^{-1}, which was at par with plant height at 40 kg N ha^{-1}. The minimum plant height (94.4 cm) was observed in the unfertilized plots.

Prakash *et al.* (2014) noticed highest plant height, number of tillers m^{-2}, number of panicles m^{-2}, panicle weight, number of filled spikelets panicles and test weight with the application of 125 kg N^{-1}, which was statistically at par with the application of 100 kg N ha^{-1}.

Kyi Moe *et al.* (2016) observed maximum plant height under application of 120 kg N ha^{-1} in two splits, at the basal and active tillering stages.

2.2 Yield and yield attributes

Application of recommended NPK at optimum level (100-60-40 kg NPK ha^{-1}) resulted in significantly higher panicles m^{-2}, panicle weight, grain and straw yields as compared to the lower rates of application (Dwivedi and Thakur, 2000).

Singh and Sharma (2000) noticed a significant increase in grain and straw yields of rice with increase in rate of N application from 0 to 120 kg N ha^{-1}. However, further increase in N application from 120 to 180 kg N ha^{-1} had no significant effect on grain and straw yields of rice. Nair *et al.* (2000) recorded that the maximum grain yield, straw yield and harvest index were obtained under application of 80 kg N ha^{-1} with four splits of nitrogen over other nitrogen scheduling treatments.

Supply of major nutrients (NPK) mainly through recommended doses of chemical fertilizers has helped to double the productivity of rice (Raju and Reddy, 2000).

Singh and Jain (2000) concluded that high level of NPK fertilization (200-100-80 kg NPK ha^{-1}) in all rice cultivars gave significantly higher economic and biological productivity ha^{-1} day^{-1}, panicles m^{-2}, grain and straw yields. However, grains $panicle^{-1}$ were reduced drastically under high level of NPK. Prasad *et al*. (2001) observed the highest panicles m^{-2}, filled grains $panicle^{-1}$, 1000-grain weight, grain and straw yield with recommended NPK application (80-40-40 kg NPK ha^{-1}) in transplanted rice over 50 and 75 per cent of recommended NPK. Sharma *et al.*, (2001) also noticed significant increase in the grain yield with increase in NPK levels up to 150-33-41.5 kg ha^{-1}.

Ehsnullah *et al.* (2001) documented that application of 125 kg N ha^{-1} produced significantly higher number of grains $panicle^{-1}$, 1000-grain weight and grain yield than 100 kg N ha^{-1}. However, panicles m^{-2} and straw yield were statistically at par with 125 and 100 kg N ha^{-1} in rice.

Kundu and Kundu (2002) noticed higher panicles per unit area as well as a higher percentage of filled grains $panicle^{-1}$ and yield under application of 180-90-90 kg NPK ha^{-1}.

Similarly, significant increase in the panicle number, panicle weight and grain as well as straw yield was obtained with application of 120-60-40 kg N-P_2O_5-K_2O ha^{-1} (Singh *et al.*, 2002).

Lawal and Lawal (2002) recorded that plant height, test weight (1000-grain weight) and grain weight per panicle responded to fertilizer dose up to 120 kg N ha^{-1}. Meena *et al*. (2002) concluded that number of effective tillers, length and weight of panicle, number of grains, filled grains $panicle^{-1}$, 1000 grain weight, grain yield, and NPK uptake by hybrid rice was optimal up to 200 kg N ha^{-1}.

Prasad *et al.* (2003) reported that all yield attributing characters increased significantly with the increase in levels of N from 40 to 100 kg ha^{-1} in rice. However, application of 100 kg N ha^{-1} significantly increased the plant height, total number of tillers $hill^{-1}$, dry matter production, grain and straw yield of rice. The response between of rice varieties in terms of grain and straw yield increased gradually with increasing levels of N application from 40 to 120 kg ha^{-1} (Mhaskar and Thorat, 2005; Kadiyala *et al.*, 2012).

Singh and Singh (2006) recorded that application of 120 kg N ha^{-1} increased the yield of transplanted rice than 80 and 100 kg N ha^{-1}. Khan *et al* (2006) observed significant increase in the grain yield of transplanted rice up to 180 kg N ha^{-1}. The rice grain and straw yield declined at higher nitrogen dose i.e. 240 kg N ha^{-1}.

All the yield attributing parameters *viz*. panicle length, panicle weight, spikelets per panicle, filled grains $panicle^{-1}$ and 1000 grain weight of rice increased significantly with increasing levels of N from 0 to 120 kg ha^{-1} (Singh *et al*., 2006). Manzoor *et al.* (2006) stated that number of productive tillers $plant^{-1}$, panicle length, number of grains panicle^{-1}, 1000 grain weight and yield increased from 0 kg N ha^{-1} up to 175 kg N ha^{-1}.

Singh and Thakur (2007) reported that grain yield of rice was superior with the application of nitrogen in four splits (1/4 as basal, 1/4 at active tillering, 1/4 at panicle initiation and 1/4 at boot stage) or three splits (1/4 as basal, 1/4 at active tillering and 1/4 at panicle initiation) splits as compared to other split applications.

Sharma *et al* (2007) reported that the successive increase in N application significantly increased the grain and straw yield up to 120 kg N ha^{-1}. The application of 120 kg N ha^{-1} gave significantly higher grain and straw yield over 40 kg N ha^{-1}. The highest grain and straw yields were found when N was applied as ½ N at 20 DAS + ¼ N at tillering + ¼ N at panicle initiation (PI) than the application of ½ N as basal+.½ N during tillering stage.

Skipping the nitrogen dose at sowing and applying the same at 20 DAS was more favourable for higher grain and straw yield, owing to higher N, P and K uptake and resulting in better yield and yield attributes (Sharma *et al.*, 2007).

Sathiya and Ramesh (2009) documented that various N management practices showed significant difference on yield attributes and yield of aerobic rice. Zhang *et al.* (2009) observed that less N application before anthesis and more N application at or after anthesis increased post anthesis dry matter accumulation, grain filling and grain yield of rice.

Application of 100 kg N ha^{-1} increased the number of fertile tillers hill^{-1} by 50.3%, filled grains panicle^{-1} by 16.9%, panicle weight by 51.2% and panicle length by 14.8% over the control (Kumar *et al.*, 2010). Reddy *et al.* (2010) noted that grain yield of rice increased with the increasing level of nitrogen from 0 to 150 kg ha^{-1}.

Prabhakar *et al.* (2010) recorded that application of 160 kg N ha^{-1} found superior over the other nitrogen levels for yield attributes and yield of aerobic rice. Reddy (2010) noticed that application of nitrogen in three splits (sowing, active tillering and panicle initiation) was found to be superior over basal application of nitrogen.

Kaushal *et al.* (2010) inferred that the grain yield of rice was highest with application of 120 kg N ha^{-1} (47.82 q ha^{-1}), which was statistically at par with 150 kg N ha^{-1} (49.71 quintal ha^{-1}) and among different methods of nitrogen application, 1/2 basal, 1/4 at tillering and 1/4 at panicle initiation obtained yield of 49.76 q ha^{-1}.

Latheef *et al.* (2011) observed that panicle number, length, weight and filled spikelets panicle^{-1} were significantly higher at 180 kg N ha^{-1} as compared to 150 and 120 kg N ha^{-1}. Sumreen *et. al* (2011) recorded that the maximum paddy yield (4.550 t ha^{-1}) under application of 135-135-60 kg ha^{-1} NPK.

Algeson and Rajababu (2011) concluded that application of nitrogen in four equal splits (seedling, active tillering, panicle initiation and flowering) obtained the higher yield attributes and yield of rice as compared to three equal splits (seedling, active tillering, and panicle initiation). Mahajan *et al.* (2011) noted that increase in grain yield in response to 60 kg ha^{-1} of N in 3 splits was attributed to higher panicle m^{-2} and grain panicle^{-1} as compared to 40 kg ha^{-1} of N applied in either 2 or 3 splits.

Dastan *et al*. (2012) documented that the maximum grain yield was observed with 150 kg ha^{-1} nitrogen application and varied with soil types. Murthy *et al*. (2012) also revealed that increasing level of nitrogen progressively increased panicles m^{-2}, filled grains panicle^{-1}, grain and straw yield only up to 120 kg N ha^{-1}.

Application of nitrogen in two splits i.e. ½ at active tillering + ½ at panicle initiation, with no basal application recorded the lowest grain and straw yields of rice.Likewise, Yoseftabar (2013) noticed that higher grain yield was with 4 spilts of nitrogen as ¼ basal, ¼ mid tillering, ¼ panicle initiation and ¼ flowering than the 2 split application, ½ basal and ½ mid tillering and it also resulted in increasing leaf area plant^{-1}, number of grains panicle^{-1} and 1000-grain weight and likewise, decreased the spikelet sterility.

Zayed *et al.* (2013) reported that application of nitrogen at 165 kg ha^{-1} significantly increased the number of panicles tiller^{-1} and panicle length compared to lower level of N application (110 kg ha^{-1}).

Jhansi and Ramana murthy (2013) revealed that application of 120 kg N ha^{-1} with four splits of 1/4 each at basal, tillering, panicle initiation and flowering gave highest grain and straw yield as well as the monetary returns was found significantly superior than other nitrogen levels.

The most appropriate time of N application to rice plant is panicle initiation, which produced maximum grains panicle^{-1}, grain yield and straw yield (Singh *et al.,* 2014).

2.3 Nutrient uptake

Nutrient (NPK) uptake by rice increased significantly with each successive increase of 60 kg N ha^{-1} from 0-180 kg N ha^{-1}. This effect of N application was attributed not only to increase grain and straw yield but also to increase nutrient concentration in grain and straw (Singh and Sharma, 2000).

Dwivedi and Thakur (2000) recorded significant increase in NPK uptake by rice with the application of 100-60-40 kg NPK ha^{-1} compared to its lower rates of application (75% and 50% NPK). Application of N at 120 kg N ha^{-1} increased the nitrogen uptake by 41.9 and 34.8% over 60 kg N ha^{-1} in grain and straw, respectively (Meena *et al*., 2002).

Yaduvanshi (2001) noticed that application of N, P_2O_5 and K_2O increased the uptake of these nutrients by rice crop. The total nutrient (NPK) uptake by rice increased with corresponding increase in NPK levels up to 150-33-41.4 kg ha^{-1} (Sharma *et al*., 2001). The higher N uptake attributed to better root growth, shoot growth and yield with high doses of Nitrogenous fertiliser (Jaiswal and Singh, 2001).

Kundu and Kundu (2002) reported the highest N, P and K uptake at 150 per cent of the recommended fertilizer rate i.e. 180-90-90 kg NPK ha^{-1}. The increasing levels of N increased the N uptake significantly with each successive increment there was significant increase in N uptake over the preceding levels of N. Further, there was significant increase in N uptake with 3 split doses of 120 kg N ha^{-1} (Shivay and Singh, 2003). Gunri *et al.* (2004) recorded significant increase in N uptake with increase in nitrogen dose.

Singh *et al*. (2005) revealed that application of NPK up to the level of 200-100- 50 kg ha^{-1} increased the N content and their uptake in wet season rice. Likewise, split application of nitrogen as 17% basal, 20% at 18 DAT, 27% at 30 DAT and 36% at panicle initiation obtained the highest apparent N recovery (Belder *et al.,* 2005).

Nitrogen uptake was increased with increase in nitrogen level from 100 to 175 kg ha^{-1} due to more absorption of nitrogen from soil (Devi *et al*., 2012). These results were also corroborated with findings of Saradeep *et al.* (2005). Similarly, with each successive dose of fertiliser up to 160 kg N ha^{-1}, uptake increased and the highest uptake was obtained at 160 kg N ha^{-1}.However, the agronomic and physiological efficiencies of applied N were highest in the 120 kg N ha^{-1} treatment (Singh *et al*., 2007). N efficiency in rice can be improved through N efficient varieties, split application of N and incorporation of basal fertilizer without standing water (Ali *et al.,* 2007).

The split application of N reduced the N losses and gave higher N uptake and recovery which accounted to higher grain yield (El-Refaee *et al.,* 2007).

Laroo *et al* (2007) observed that N uptake was significantly influenced by different levels of N. Based on the total N uptake (grain + straw), there was 49.9, 63.9 and 70.4 per cent increase in N uptake over the control with application of 50, 100 and 150 kg N ha^{-1} respectively.

Kumar *et al.* (2007) reported that N, P and K uptake by grain and straw and total nutrient uptake increased significantly with increase in N level from 50 to 150 kg ha^{-1}.Application of N without basal nitrogen resulted in significantly higher grain yields and nutrient uptake in rice in comparison to application of nitrogen in splits where part of nitrogen was applied at sowing (Sharma *et al.*, 2007).

Zaidi *et al.* (2007) recorded that the application of N resulted significant increase in total N uptake with an increase in the dose of nitrogen up to 150 kg N ha-1. The total N uptake and N concentration in plant increased with increasing level of nitrogen up to 120 kg N ha^{-1} (Prudente *et al*., 2008).

Kaushal *et al.* (2010) noticed that nitrogen removal by grain and total uptake increased significantly with increase in nitrogen levels from 90 to 150 kg N ha^{-1} where as in case of straw significant increase of nitrogen uptake was observed up to 120 kg N ha^{-1} only.

Chaudhary *et al.* (2011) inferred that application of N at four splits *viz.* 1/4th N each at early tillering, active tillering, panicles initiation and panicle emergence recorded maximum N, P and K (kg ha^{-1}) uptake which was significantly superior over other practices.

The application of nitrogen in splits as per the requirement of the crop reduced the nitrogen loss, which gave high nitrogen absorption and utilization leading to higher nutrient uptake and dry matter accumulation (Devi *et al.,* 2012).

Murthy *et al.* (2012) recorded that application of nitrogen up to 120 kg ha^{-1} was found to be superior over other doses of nitrogen and increased the nitrogen uptake by grain and straw.

Devi *et al.* (2012) found that application of N at 175 kg ha $^{-1}$ with four equal splits at 1/4 basal, 1/4 active tillering, 1/4 panicle initiation and 1/4 harvesting resulted in the highest N uptake over other treatments.

The split application of nitrogen is one of the most important strategy for efficient use of nitrogenous fertilisers throughout the growing season by synchronizing the plant demand, reducing denitrification loss and improved nitrogen uptake with high grain yield in Direct Seeded Rice (Frageria, 2010 ; Lampayan et al., 2010 and Rehman et al., 2013). Similarly, supply of nitrogen in three splits gave the highest NPK uptake in rice at harvest stage followed four splits (Jogi Naidu *et al*., 2013).

Rao *et al.* (2013) observed that N uptake increased with increasing level of nitrogen up to 240 kg ha^{-1}. Jhansi and Ramana murthy (2013) revealed that at crop harvest, application of nitrogen at 120 kg ha^{-1} with four splits 1/4 each at basal, tillering, panicle initiation and flowering produced highest uptake of phosphorous, potassium and nitrogen by grain as well as straw.

The uptake of NPK was high when 150 kg N ha$^{- 1}$ was applied in 4 splits as basal + at active tillering + panicle initiation + at flowering (Singh *et al*., 2015).

Singh *et al.* (2015) recorded that the total nutrient (NPK) uptake was higher under application of 150 kg N ha^{-1} in 4 splits (basal, at active tillering, panicle initiation and at flowering).

2.5 Effect of varieties on growth, yield attributes and yield of rice

Triphati and Jaiswal (2002) noticed that rice variety HRI 120, HRI 126, and HRI 160 produced highest yield at 120 kg N ha^{-1} while HRI 122, EXPH 204, NDRH 2 and NDR 359 produced highest grain yield at 180 kg N ha^{-1}. Chandra Prakash (2002) reported that Pusa 615, HRK 228 and RP 2144 were higher yielder over Taraori Basamati and economic optimum grain yield can be achieved by using these varieties with 90 kg N ha^{-1}.

Mhaskar *et al.* (2005) recorded that rice variety *Indrayan* produced significant increase in grain yield (49.74 q ha^{-1}) and straw yield (72.75 q ha^{-1}) with 120 kg N ha^{-1}. Sabir *et al.* (2007) observed that the rice variety ADTRHI with 150 kg N ha^{-1} produced more number of productive tillers plant^{-1}, number of spikelets panicle^{-1}, test weight and seed yield as compared to variety CORH2.

Chaudhary *et al.* (2008) observed the response of rice cultivars (IR 36 130d, Kanak 145d, Mahsuri 160d and Rajshree 150d) of varying maturity groups to rates of nitrogen (0, 40, 80 and 120 kg ha^{-1}) under rainfed ecosystem. The highest grain (4.83 tonnes ha^{-1}) and straw (7.10 tonnes ha^{-1}) yields were obtained with 120 kg N ha^{-1}. Similar trend was recorded for root and shoot dry weight, number of panicles m^{-2}, fertile spikelet panicle^{-1} and 1000-grain weight. N, P and K uptake was also maximum at the highest level of N. Among the cultivars, Rajshree proved to be the best for most of the growth, development and yield characters.

Singh and Srivastava (2008) noticed that performance of NDR 359 (local check) was rated to be the best, particularly at lower and higher levels of nitrogen. Rice variety CSAR 515-1 at 150 kg N/ha and CSAR 442 at 100 kg N/ha performed equally well. Similar trend was noticed for yield, net income and total nitrogen uptake by rice crop.

Mahto *et al.* (2001) observed a negative correlation among the doses of nitrogen fertilizer and leaf injury with grain yield in rice. Yadav *et al.* (2002) noticed that the long duration varieties i.e. Mahsuri (142 days) and Swarna (135 days) produced significantly higher dry matter than medium duration Sarjoo-52 (129 days) and mid early (121 days) IR-36. The former and later group of varieties remained at par with Swarna and produced significantly higher grain yield of 5.86 t/ha, which showed an increase of 1.11, 1.69, and 1.70 t/ha over Sarjoo-52, Mahsuri and IR-36 respectively. Nitrogen application up to 120 kg N ha^{-1} significantly increased the growth and yield attributing characters viz. Plant height, panicles m^{-2}, panicle length, panicle weight total dry matter and grain yield with every increase in the dose. Application of 120 kg N ha^{-1}produced highest grain yield of 5.54 t ha^{-1}, which was higher by 2.24, 0.70 and 0.30 t ha^{-1} over 0, 40 and 80 kg N ha^{-1} respectively.

Prakash (2002) reported that Pusa-615, HKR-228 and RP-2144 are high yielder over Taraori basmati and it is possible to achieve economic optimum grain yield using these varieties with 90 kg N ha^{-1}in the humid south eastern plants of Rajasthan.

Rani (2006) observed that local variety Dihula grown with 80 kg N ha^{-1} proved the most remuneration giving net income up to Rs. 26141 ha^{-1}. The existing best variety of this region JR 3-45 with 80 kg N ha^{-1} also gave equally higher net income (Rs. 2571 ha^{-1}). Vandana and Heera were found to be less remunerative.

Mittoliya (2006) noticed that the variety IET 18458 grown with 150 kg N ha^{-1} proved the most remuneration giving net income up to Rs. 20690 ha^{-1}. Lar *et al*. (2007) reported that the grain and straw yield of rice variety Pusa Sugandh-5 increased significantly at different N levels up to 100 kg ha^{-1}. The maximum biological yield (20.63 t ha^{-1}) was recorded with 150 kg N ha^{-1}, respectively.

Nawlakhe and Mankar (2009) concluded that rice variety Pusa Basmati recorded maximum and significantly higher yield over Kasturi and Haryana Basmati during all the three years of experimentation and also in the pooled analysis (2721 kg ha^{-1}) which showed 17.69% increase in grain yield over Kasturi (2312 kg ha^{-1}) and

30.38% increase in grain yield over Haryana Basmati (2082 kg ha^{-1}). Among the different nitrogen levels tested, 100 kg N ha^{-1} recorded maximum and significantly higher yield over all other levels.

Mahajan *et al.* (2010) noticed that rice variety 'Punjab Mehak 1' responded significantly up to 60 kg N ha^{-1} due to more NUE and higher N uptake as compared to 'Pusa 1121' and 'Punjab Basmati 2'. Results from this study indicate that genotype differences in NUE existed in aromatic rice cultivars. Therefore, NUE of different cultivars could be a useful tool to adopt the appropriate cultural practices for achieving high yield and N response exploration.

Sumreen *et. al.* (2011) recorded that rice variety B-super gave significantly higher yield followed by, B-385, B-kernel, B-2000 and B-2002 respectively.

2.4 Economics

Chaudhary *et al.* (2007) reported that net income increased with increasing the levels of nitrogen up to 120 kg N ha^{-1} .

Kumawat *et al*. (2017) observed that split application of N as ¼ basal, ¼ 2 wk stage, ¼ at 5 wk stage, ¼ at 9 wk stage gave highest gross and net return as well as B:C ratio followed by ½ at basal, ¼ at 2 wk stage, ¼ at 5 wk stage application.

Maheswari *et al.* (2008) concluded that among different doses of nitrogen 150 kg N ha^{-1} is an economic optimum to realize maximum yield under aerobic rice cultivation.

Shekhara *et al.* (2011) reported that application of 125 kg N ha^{-1} fetched the maximum net monetary returns and benefit: cost ratio but found comparable with 100 kg N ha^{-1}.

Murthy *et al.* (2012) recorded higher economic return at 120 kg N ha^{-1} and it was found to be optimum for aerobic rice. Pasha *et al.* (2012) noticed that gross return, net return and benefit: cost ratio of aerobic rice was higher with application of 180 kg N ha^{-1} as compared to 120 and 150 kg N ha^{-1}.

Pradhan *et al.* (2013) reported that the highest gross and net returns as well as benefit: cost ratio were found highest with 'Tulsi' at a nitrogen level of 90 kg ha^{-1}.

Riste *et al.* (2017) observed that highest gross return per ha as well as benefit: cost ratio was recorded by a cultivar (Muntse) with application of recommended fertiliser dose of 60:30:30 kg NPK ha^{-1} compared to the control.

MATERIALS AND METHODS

A field experiment was conducted to study the "Response of rice variety to fertility level and split application of nitrogen fertiliser under medium land condition" during *Kharif* season of 2017, using the materials and methods as described in this chapter.

3.1 Experimental site

The experiment was conducted in Agronomy Main Research Station, Orissa University of Agriculture and Technology, Bhubaneswar. The latitude and the longitude of the research station are $21^0$15' N and $85^0$52'E, respectively, with an altitude of 25.9 m above the mean sea level. It is situated at about 64 km away from the Bay of Bengal. The station falls under the East and South Eastern Coastal Plain Agro-climatic Zone of Odisha. The land is a medium land.

3.2 Soil characteristics

Soil samples were collected from the experimental site. Before the layout of the field samples were collected up to a depth of 15 cm at random from several locations. After thorough mixing, a composite soil sample of 0-15 cm depth was taken for mechanical and chemical analysis. After careful mixing, the samples were dried and sieved through 2 mm sieve and analysed for different properties.

The particulars of physicochemical properties and the methods employed for analysis are present in Table 3.2. The result of the physicochemical analysis reveals that the soil is sandy loam in texture, acidic in reaction, medium in organic carbon, low in nitrogen, medium in available phosphorus and medium in available potassium.

Table 3.1 Mechanical composition of the soil of the experimental plot (0-15 cm depth)

Constituent	**Percentage composition (air dry basis)**	**Method employed**
Sand	72.4	Bouyoucos hydrometer method (Piper,1950)
Silt	10.2	
Clay	16.5	
Textural class	Sandy loam	

Table 3.2 Chemical composition of the soil of the experimental plot (0-15 cm depth)

Composition	Value	Method employed
Bulk density (g cc^{-1})	1.64	Core sampler method (Dastane, 1972)
Particle density (g cc^{1})	2.67	Pycnometer method (Dastane, 1972)
Electrical conductivity (dSm^{-1})	0.050	Conductivity Bridge method (Jackson,1973)
pH	5.6	Glass electrode Beckman's electronic pH meter (Jackson 1967)
Organic carbon(%)	0.71	Walkley and Black method (Jackson 1967)
Available N (kg ha^{-1})	223	Alkaline permanganate method (Jackson 1967)
Available P (kg ha^{-1})	20	Bray's method (Jackson 1967)
Available K (kg ha^{-1})	211	Ammonium acetate extraction method by Flame Photometer (Jackson 1967)

Table 3.3 Cropping history of the experimental site

Year	***Kharif***	***Rabi***
2013-2014	Rice	Fallow
2014-2015	Rice	Fallow
2015-2016	Rice	Fallow
2016-2017	Rice	Fallow
2017-2018	Experiment	Black gram

3.3 Climate and weather conditions

The climate of the experimental site is warm and moist, distinguished by hot humid summer and mild winter. Broadly the climate falls in the group of moist hot type (Lenka, 1976). The weekly and monthly weather data during the cropping season (kharif, 2017) recorded at the meteorological observatory of Central Research Station, OUAT are presented in Table no. 3.4 and table no. 3.6, respectively.

Table 3.4 Mean weekly meteorological data during the cropping season (*kharif*, 2017-18)

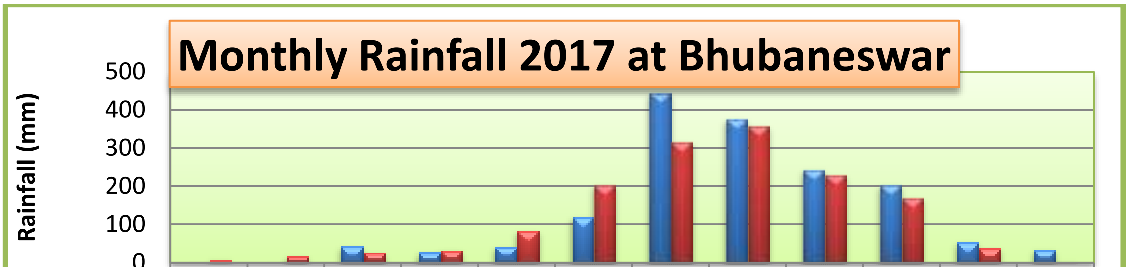
Week (No.)	Temperature (◦C)		Rainfall	Relative Humidity (%)		Wind Velocity	BSH	Evaporation
	Max	Min	Daily (mm)	7hr	14hr	Km/hr	hrs/day	mm/day
29	31.7	26.1	164.3	93	85	5.8	2.8	3.1
30	31.8	26.3	34.3	92	78	3.4	2.7	3.4
31	33.8	26.1	56.0	91	71	2.6	3.7	3.5
32	33.1	25.6	85.1	90	76	3.9	6.1	3.4
33	32.4	25.8	76.9	93	84	2.7	3.5	3.4
34	33.6	26.0	63.2	87	71	2.4	7.3	3.4
35	32.1	25.3	161.4	96	78	2.9	3.3	3.2
36	33.6	26.0	24.9	92	74	2.5	5.7	3.4
37	34.4	25.7	77.9	90	65	3.2	6.6	3.5
38	32.6	25.8	44.9	92	71	1.7	3.1	3.3
39	33.7	25.5	33.7	92	69	2.1	3.4	3.4
40	30.7	25.1	77.7	94	80	1.8	2.3	3.1
41	33.3	25.4	24.6	94	64	2.3	6.1	3.4
42	31.5	24.8	102.2	93	72	4.8	5.3	3.3
43	33.5	23.2	0.0	92	63	1.7	8.8	3.5
44	31.1	20.6	0.0	90	62	1.9	8.2	3.5
45	31.4	19.5	0.0	86	52	2.3	9.3	3.5
46	27.3	20.7	55.2	87	66	5.9	3.5	3.0
47	29.6	18.7	0.0	91	56	1.9	6.5	3.3
48	29.4	13.9	0.0	92	40	1.3	8.4	3.5
49	27.1	14.0	36.3	88	49	3.1	5.6	3.3
50	29.5	18.3	0.0	94	59	1.7	6.3	3.5
51	28.0	13.6	0.0	92	43	1.3	7.8	3.5
52	28.0	12.5	0.0	93	43	1.8	7.8	3.5

Table 3.5 Mean monthly meteorological data (2006-2016)

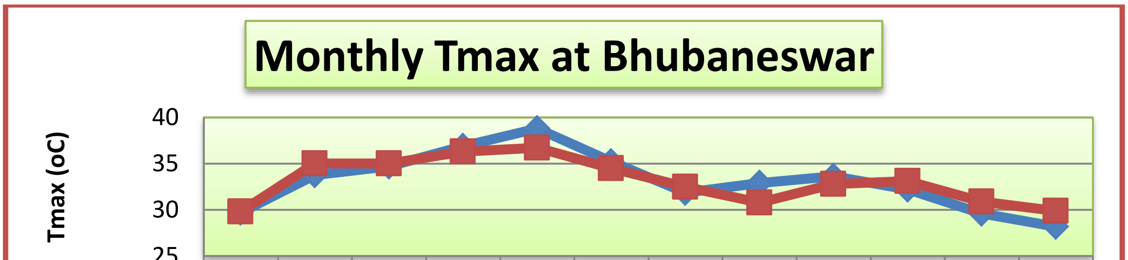
Month	Rainfall (mm)	Evaporation (mm/day)	Atmospheric temperature (◦C)		Relative humidity (%)		BSH (hrs/day)
			Max.	Min.	7hr	14hr	
January	10.2	3.4	29.8	14.0	90	43	8.7
February	19.3	3.5	35.0	17.6	92	44	9
March	27.5	5.4	35.0	21.9	91	44	8.8
April	32.7	6.5	36.3	25.6	88	50	8.8
May	84.2	7.8	36.7	26.0	85	53	8.9
June	204.6	5.7	34.5	26.2	87	65	5.6
July	317.6	3.2	32.5	26.1	91	76	4.2
August	359.3	3.5	30.8	25.3	92	79	4.6
September	231.6	3.3	32.8	25.8	93	76	5.9
October	170.4	3.6	33.1	23.6	92	66	7.5
November	40.0	3.4	30.9	19.7	89	50	8.1
December	5.0	3.5	29.9	15.7	88	42	8.7

Table 3.6 Mean monthly meteorological data during the cropping season (*kharif*, 2017-18)

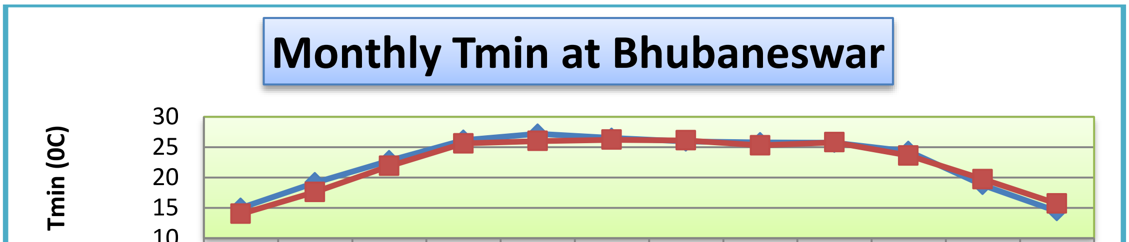
Month	Rainfall (mm)	Wind Velocity (km/hr)	Evaporation (mm/d)	Atmospheric temperature (◦C)		Relative humidity (%)		BSH (hrs/day)
				Max.	Min.	7hr	14hr	
July	445.9	3.7	3.3	31.9	25.9	92	78	2.0
August	377.0	2.9	3.4	32.9	25.8	91	76	4.9
September	245.2	2.4	3.4	33.6	25.7	92	70	4.7
October	204.5	2.5	3.3	32.2	24.3	93	69	6.0
November	55.2	3.0	3.3	29.6	18.7	89	56	7.1
December	36.3	1.9	3.4	28.2	14.4	91.8	47.6	7.0



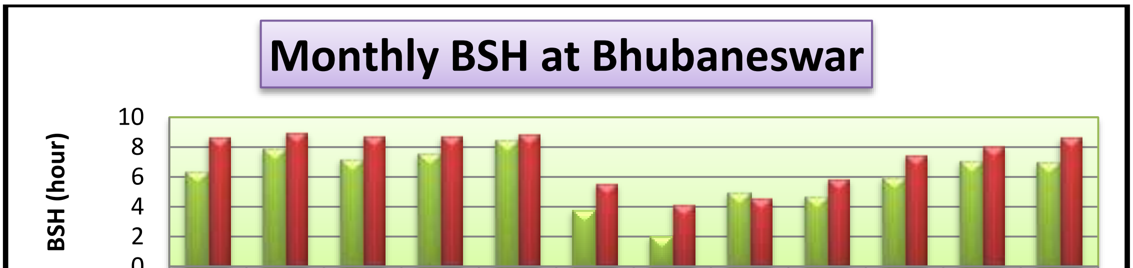
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Actual	0	0	45.4	29.2	43.1	122	445.9	377	245.2	204.5	55.2	36.3
Normal	10.2	19.3	27.5	32.7	84.2	204.6	317.6	359.3	231.6	170.4	40	5



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2017	29.73	33.77	34.7	36.9	38.78	35.23	31.86	32.88	33.61	32.22	29.62	28.17
Normal	29.8	35	35	36.3	36.7	34.5	32.5	30.8	32.8	33.1	30.9	29.9



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2017	14.97	19.16	22.8	26.15	27.18	26.5	25.91	25.75	25.71	24.31	18.74	14.44
Normal	14	17.6	21.9	25.6	26	26.2	26.1	25.3	25.8	23.6	19.7	15.7



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2017	6.348	7.896	7.167	7.54	8.455	3.773	2.029	4.944	4.66	5.957	7.057	6.971
Normal	8.7	9	8.8	8.8	8.9	5.6	4.2	4.6	5.9	7.5	8.1	8.7

Fig 3.1 Mean Monthly meteorological data with normal in the cropping year 2017

3.3.1 Rainfall

The mean annual precipitation is 1603.8 mm out of which 1190.1 mm (74.20%) was received from June to September (Monsoon season). The rainfall is monsoonic and unimodal. The South-west monsoon usually sets on around mid June and recedes by the mid October. The month of July received the highest rainfall of 445.9 mm and considered as the rainiest month whereas the month of December has received the lowest rainfall of 36.3mm and considered as the driest month of the cropping season. The average rainfall code of Bhubaneswar is D1F3 (B1A2B1) C1D1E2 (Lenka, 1976).

The total rainfall received during the period of cropping season *i.e.* July to December of 2017 was 1364.1 mm. The rainfall received during the cropping season was about 21.37% more than normal. All the months of the cropping season (July to December) received more than normal rainfall.29th week which falls under month of July received highest daily rainfall of about 164.3 mm whereas maximum weeks in the month of November and December were without rain.

3.3.2 Temperature

The mean monthly temperature varied from 29.65^{0}C in September to 21.3^{0}C in December. The monthly maximum temperature remained above 30^{0}C in all the months except November and December, when it came down to 29.6^{0}C and 28.2^{0}C, respectively. September was the hottest month with maximum temperature of 33.6^{0}C, while December was the coolest month with minimum temperature of 14.4^{0}C in the period of cropping season.

37th week of the year recorded the maximum temperature of 34.4^{0}C and 52nd week was the coolest with minimum temperature of 12.5^{0}C.

3.3.3 Relative Humidity

Morning Relative Humidity (RH) varied between 89% in November to 93% in October but the afternoon RH showed wide variation ranging from 48% in December to 78% in July. Weekly relative humidity variation ranged from 96% in 35th week to 86% in 45th week in morning hours whereas in afternoon a wide variation ranging from 85% in 29th week to 43% in 52nd week was found in the cropping season.

3.3.4 Evaporation

The monthly evaporation from the USDA pan evaporimeter varied from 3.3mm/day to 3.4mm/day. The variation in evaporation was negligible in between the months during the period of the cropping season. The weekly evaporation varied between 3.1mm/day to 3.5mm/day and the lowest evaporation was found in 29^{th} and 40^{th} week.

3.3.5 Bright Sunshine Hour

The daily bright sunshine hours (BSH) during the cropping season ranged from 2 hr/day in July to 7 hr/day in December. The highest Sunshine hour recorded in month of November that is 7.1 hr/day. On weekly basis the lowest sunshine hour recorded in 40^{th} week that is 2.3hr/day and the highest value was recorded in 45^{th} week that is 9.3 hr/day.

3.4 Experimental Details

The experiment comprised of 16 treatments; the combination of four (4) varieties and two (2) fertility levels (NPK) and two (2) splitting schedules evaluated during the *Kharif* season of 2017.

Season	: Kharif
Design	: split plot
Replication	: Three
Treatment combination	: 16
Main plot size	: 8m×6.4m
Sub plot size	: 4m×3.2m
Spacing	: 20cm×10cm
Location	: Agronomy Main Research Station, OUAT

3.4.1 Treatment combinations:

(a) main plot :

Fertiliser schedule :

F_1 : 80:40:40 N: P_2O_5 :K_20/ha

F_2 : 100:50:50 N:P_2O_5:K_2O /ha

Splitting schedule :

S_1 : ¼ basal + ½ tillering + ¼ PI

S_2 : ¼ basal + ½ tillering + 1/8 PI + 1/8flowering

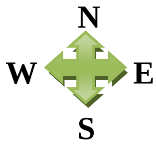
(b) sub plot : variety

V1 : Hasanta

V2 : Mrunalini

V3 : Asutosh

V4 : Swarna



$V_2F_1S_2$	$V_1F_1S_2$	$V_3F_2S_2$	$V_1F_2S_2$	$V_2F_1S_1$	$V_3F_1S_1$
$V_3F_1S_2$	$V_4F_1S_2$	$V_2F_2S_2$	$V_4F_2S_2$	$V_1F_1S_1$	$V_4F_1S_1$
$V_1F_2S_1$	$V_3F_2S_1$	$V_1F_1S_1$	$V_3F_1S_1$	$V_4F_2S_2$	$V_3F_2S_2$
$V_2F_2S_1$	$V_4F_2S_1$	$V_2F_1S_1$	$V_4F_1S_1$	$V_1F_2S_2$	$V_2F_2S_2$
$V_3F_1S_1$	$V_2F_1S_1$	$V_3F_2S_1$	$V_1F_2S_1$	$V_2F_1S_2$	$V_4F_1S_2$
$V_4F_1S_1$	$V_1F_1S_1$	$V_4F_2S_1$	$V_2F_2S_1$	$V_1F_1S_2$	$V_3F_1S_2$
$V_1F_2S_2$	$V_4F_2S_2$	$V_3F_1S_2$	$V_4F_1S_2$	$V_3F_2S_1$	$V_2F_2S_1$
$V_3F_2S_2$	$V_2F_2S_2$	$V_1F_1S_2$	$V_2F_1S_2$	$V_1F_2S_1$	$V_4F_2S_1$
RI		**RII**		**RIII**	

Fig 3.2 Plan of Layout

3.4.2 Details of treatment combinations

T_1	$V_1F_1S_1$	T_9	$V_3F_1S_1$
T_2	$V_1F_1S_2$	T_{10}	$V_3F_1S_2$
T_3	$V_1F_2S_1$	T_{11}	$V_3F_2S_1$
T_4	$V_1F_2S_2$	T_{12}	$V_3F_2S_2$
T_5	$V_2F_1S_1$	T_{13}	$V_4F_1S_1$
T_6	$V_2F_1S_2$	T_{14}	$V_4F_1S_2$
T_7	$V_2F_2S_1$	T_{15}	$V_4F_2S_1$
T_8	$V_2F_2S_2$	T_{16}	$V_4F_2S_2$

3.5 Description of varieties:

3.5.1 Hasanta

Hasanta (OR 2328-5) is a medium duration variety of 140-150 days duration with short and bold type grains. It was developed in OUAT in the year 2011.The parental varieties are OR 1206-26-2 and OR 1534-129. It was developed by pedigree method of selection. This variety is moderately resistant to Leaf blast and WBPH and tolerant to Sheath rot. It is best suited for rainfed and irrigated shallow lowlands. Average yield is about 4 ton ha^{-1} and yield potential is up to 10 ton/ha.

3.5.2 Mrunalini

Mrunalini (OR 1898-18) is a long duration rice variety of 146 days duration. It is generally grown in rainfed and irrigated shallow water low land areas of Orissa, Andhra Pradesh and Gujurat. It was released from odisha in the year 2007.Grain is short and bold type. This variety is resistant to leaf and neck blast. Average yield is about 5-6 ton ha^{-1} but it has the yield potential of 9-10 ton ha^{-1}.

3.5.3 Ashutosh

Ashutosh (OR 2331-14) is a long duration variety which matures in about 145-155 days. It is best suited for rainfed shallow & semi deep lowlands. Parental varieties are OR 1301-32 and IR 52561. It was developed by pedigree method of selection. It is moderately resistant to submergence. It was developed from OUAT in 2013. Average yield is about 4 ton ha^{-1} but the yield potential is 7 ton ha^{-1}.

3.5.4 Swarna

Swarna (MTU 7029) is a long duration variety which matures in about 135 days. It is best suited for rainfed lowlands. It was notified in 1987 and is resistant to Bacterial leaf blight.

3.6 Details of field operations

3.6.1 Raising of seedlings in nursery

Seedlings were raised in the nursery using wet bed method. Seed beds of 5 m x 1.5 m size were prepared to accommodate the seeds. Prior to sowing of seeds in the nursery beds, the seeds were soaked for at least 24 hours in water. After draining out the water, seeds were incubated for sprouting. After the seed bed preparation, the beds were fertilized with the appropriate nutrients. Sprouted seeds were sown on 17^{th}

July. Four days after sowing, 1-2 cm of standing water was maintained in the nursery bed.

3.6.2 Preparation of main field

The field was ploughed and cross ploughed by mould board plough (3 times) in dry condition a week before transplanting. The preparatory tillage, bund preparation of the main and sub plots, bund trimmings, puddling and levelling were undertaken one day before transplanting for wet season rice cultivation.

3.6.3Manuring and fertilizer application

Well decomposed FYM @ 5 t per hectare was applied and spread uniformly to all the plots at the time of final ploughing. NPK was supplied in form of Urea, DAP and MOP at 80:40:40, 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1}. Fertilizer was applied as per treatments. Full dose of P, half of K and ¼ th N were applied as basal. First top dressing with 50% N was done at tillering stage. In some treatments rest ¼ th of nitrogen was applied at PI stage and in rest of the treatments 1/8 th of nitrogen was applied at PI stage and another 1/8 th part was applied at flowering stage.

3.6.4 Transplanting

The seedlings were uprooted from the nursery bed on the day of transplanting. Twenty nine days old seedlings were transplanted in the main field with spacing of 20 cm × 10 cm on 16th august.

3.6.5 Water management

Initially thin film of water was maintained at the time of transplanting. After transplanting of seeding, about 2-3 cm water was maintained in the field till the seeding get fully established. Thereafter, submergence of water of about 5 cm was maintained during the rest of the growth stages up to dough stage, expect at the period of nitrogen top dressing. Then water was drained out completely 10 days before harvesting to ensure uniform ripening and to facilitate harvesting in all the plots. Excess rain water was drained out when required.

3.6.6 Intercultural operations

Hand weeding was done twice, first one was done 3 weeks after transplanting and second was 2 weeks after the first weeding to keep the plot weed free.

3.6.7 Plant protection

Monocrotophos @ 1000 ml/ha was sprayed at 30 DAT and 45 DAT as a prophylactic measure to save the crop from stem borer, leaf roller and mealy bug infestation. In addition to this, Hexaconozole was sprayed two times (1ml per litre of water) to prevent sheath blight and thiomethoxam was applied (1 g per 4 litres of water) two times against brown plant hopper. These were sprayed in alternative weeks after transplanting.

Table 3.7 Calendar of operations

Sl. No.	Cultural operations	Date
1.	Date of nursery sowing	17.7.17
2.	Layout and bunds preparation	15.8.17
3.	Basal fertiliser application	15.8.17
4.	Transplanting	16.8.17
5.	Hand weeding	11.9.17
6.	First top dressing of nitrogen	12.9.17
7.	Pesticide application	16.9.17 and 30.9.17
8.	Second top dressing of nitrogen	7.10.17
9.	Second manual weeding	12.10.17
10.	Third top dressing of nitrogen	6.11.17
12.	Harvesting	21.12.17 and 25.12.17
14.	Threshing	30.12.17

3.6.8 Harvesting and threshing

The crop was harvested when approximately 80 percent of the grains turned straw yellow in colour and free from greenish tint. Harvesting was done manually leaving the border plants (three rows all around). The individual net plot was measured, harvested and left in the field for drying. A day after, the bundles were taken to the threshing floor and threshed separately. The grain and straw yield were recorded after final sun drying for 3-4 days.

3.7 Biometric observation

3.7.1 Pre-harvest study

3.7.1.1 Sampling technique

Five clumps in the middle row of each plot were selected randomly and biometric observation of various agronomic traits at different stages of growth were recorded from all the sample hills in each plot. Destructive sampling was done at 15 days interval commencing from 30 days after transplanting (DAT) till 90DAT and the final observation was taken at harvest. Border rows were not sampled to avoid border effects.

3.7.1.2 Plant height

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

3.7.1.3 Number of tillers m^{-2}

The number of tillers form five tagged plants in each sub-plot were counted and averaged out in the field at different growth stages of the crop, to find out tiller number per hill. The data was then converted and expressed in terms of number of tillers per square meter area. During maturity however, only panicle bearing tillers were counted and recorded.

3.7.1.4 Leaf area index

The leaf area index is the ratio of total leaf area (one side only) to unit ground area covered by the plant. Five clumps were collected from destructive sampling zone for dry matter analysis in the laboratory. These samples were collect from the 3rd border rows from each side at each stage of growth. Three leaves from each hill (small, medium and large) were measured by the help of automatic leaf area meter. Total leaf area was estimated by multiplying average leaf area with number of leaves in a clump.

$$\text{LAI} = \frac{\text{actual leaf area } (m^2) \text{ plant}^{-1} \times \text{no. of plants } m^2}{\text{Land area } (m^2)}$$

3.7.1.5 Total dry matter accumulation

The five samples collected from destructive sampling zone for LAI analysis were also used to study the dry matter accumulation at different stages of growth. The leaves, culms and panicles (during panicle emergence stage) of each clump were separated at different growth stages. These parts were first air dried in the shade and then dried in the hot air oven at 85^0C till a constant weight was obtained. The dry weight of the individual portion was recorded and sums of their dry weights were taken as total dry weight per plant. Dry matter accumulation was expressed in grams per square meter (g m^{-2})

3.7.1.6 Crop growth rate

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

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

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

3.7.1.7 Relative growth rate

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

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

Where, W_1 and W_2 are the plant dry weight on two successive occasions t_1 and t_2 respectively (the interval between t_1 and t_1 being in days).

3.7.2 Post harvest study

3.7.2.1 Panicle length

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

3.7.2.2 Number of panicles m^{-2}

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

3.7.2.3 Total number of grains panicle^{-1}

The panicles initially used for recording panicle length and panicle weight were also used for the purpose of counting total number of grains panicle^{-1}. The number of fertile and sterile grains of the panicles was counted separately and total number of grains was calculated.

3.7.2.4 Number of fertile grains panicle^{-1}

The panicles initially used for recording panicle length and panicle weight were also used for the purpose of counting total number of grains panicle^{-1}. The number of fertile grains of the panicles were counted and averaged as number of fertile grains panicle^{-1}.

3.7.2.5 Fertility percentage

It was calculated by dividing the number of fertile grains in total number of grains and expressed in percentage.

$$\text{fertility percentage} = \frac{\text{No. of fertile grains panicle}^{-1}}{\text{Total No. of grains panicle}^{-1}} \text{ x } 100$$

3.7.2.6 1000-grain weight

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

3.7.2.7 Grain and straw yield

Before harvest all the border rows were removed. The net plot areas of individual plots were harvested manually. The produce from the net plot of each treatment was left in the field for sun dry. Then the bundles were taken to the threshing floor where it was threshed plot wise using power operated thresher. The grains were cleaned and sundried for at least 3-4 days. The weight of grain, straw and chaffs were recorded separately. The grain and straw weight of three replications were averaged out. The yield was finally calculated into tons per hectare (t ha^{-1}) at 14 per cent moisture content.

3.7.2.8 Grain-straw ratio

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

3.7.2.9 Harvest index

Harvest index (HI) is obtained by dividing the grain yield by the total biomass yield (plant weight) excluding the underground potion (roots) and expressed in dimensionless number (Donald, 1962).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \text{ x } 100$$

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

3.8 Plant analysis

At harvest, plant samples were collected randomly to study the uptake of different nutrients (N, P, and K) by the rice crop. A composite sample of each treatment from the three replications was taken for this purpose. The oven dried samples were finely ground and were analysed for estimation of nitrogen, phosphorus and potassium content using the appropriate methods.

3.8 Method used for plant nutrient analysis

Nutrient	Method used
Nitrogen	Micro Kjeldahl (Tandon, 1993)
Phosphorus	Nitric acid and Perchloric acid in ratio 3:2 is used for digestion followed by addition of venadomolybdate solution followed by spectrophotometric determination (Tandon, 1993)
Potassium	Flame photometric determination after digestion in HNO_3:$HClO_4$ (3:2) system (Tandon, 1993)

3.9 Nutrient uptake

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

3.10 Comparative economics

Gross and net returns (Rs. ha^{-1}) were computed considering that prevailing market price of input and produce. Net return was calculated by deducting the cost of cultivation from the gross return. Benefit-cost ratio, which represents the return per rupee invested, was worked out for different treatments by dividing to gross return with corresponding cost of cultivation.

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

3.11 Statistical analysis

Data collected on various observations on Indian mustard were analyzed statistically by following standard analysis of variance technique (ANOVA) as described by Gomez and Gomez (1984). Test of significance of the treatment differences was done on the basis of ‘F’ test. The differences between treatments were compared with critical difference at 5 per cent level of significance (P= 0.05).

EXPERIMENTAL FINDINGS

During the period of study, data regarding growth parameters, yield attributes, yield, nutrient uptake and economics of rice varieties as influenced by different levels of fertiliser and splitting schedule of nitrogen were observed and recorded. The data on these parameters were analyzed statistically to evaluate the significance of variation in between various treatments which are presented in this chapter.

4.1 Phenological development and duration

Rice has 3 major growth stages: vegetative, reproductive and ripening stage in its life cycle. In this experiment three phenophases were studied: sowing to PI, sowing to 50% flowering and sowing to maturity. The time taken to different phenophases as influenced by different levels of fertiliser and splits of nitrogen are presented in table 4.1.

Table 4.1 Effect of fertility level and nitrogen splits on Phenology (days) of rice varieties

Treatment	Days to panicle initiation	Days to 50% flowering	Days to maturity
$V_1F_1S_1$	80	106	144
$V_2F_1S_1$	81	108	144
$V_3F_1S_1$	92	119	150
$V_4F_1S_1$	72	98	135
$V_1F_1S_2$	80	107	144
$V_2F_1S_2$	82	109	144
$V_3F_1S_2$	92	119	151
$V_4F_1S_2$	73	98	135
$V_1F_2S_1$	82	109	145
$V_2F_2S_1$	83	111	146
$V_3F_2S_1$	93	120	153
$V_4F_2S_1$	75	89	136
$V_1F_2S_2$	82	109	145
$V_2F_2S_2$	83	111	146
$V_3F_2S_2$	93	120	154
$V_4F_2S_2$	75	90	136

4.1.1 Days to panicle initiation

Among the varieties, Ashutosh took longer period (93 days) for panicle initiation than other 3 varieties but Swarna variety took very less period (74 days) for panicle initiation. But the other two varieties Hasanta and Mrunalini took almost same time for initiation of panicle. With respect to different levels of fertiliser and split application of nitrogen, there is no marked variation in days to panicle initiation in all rice varieties in kharif season.

4.1.2 Days to 50% flowering

The different rice varieties differed among themselves for attainment of phenophase from sowing to 50% flowering. Ashutosh required the maximum time (120 days) to attain 50% flowering than other three varieties, but Swarna required the minimum (94 days) to attain 50% flowering. The variation in length of days to attain 50% flowering due to different fertility levels and split application of nitrogen observed in the experiment led to near- similar (108 days) life cycle of all rice varieties during kharif season.

4.1.3 Days to maturity

Ashutosh required the maximum time (153 days) to attain maturity whereas Swarna took the minimum time to attain maturity (136 days). The other two rice varieties Hasanta and Mrunalini required almost same time (145 days) from sowing to harvesting. The different fertility levels and split application of nitrogen have no marked variation on this particular phenophase i.e. days to maturity. However,

Ashutosh variety when fertilised with 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} under 4 split application of nitrogen (¼ at basal + ½ at tillering + 1/8 at PI + 1/8 at flowering) required the maximum time (154 days) to mature.

4.2 Growth studies

4.2.1 Plant height

The data regarding plant height of different rice varieties grown under medium land conditions as influenced by different levels of fertilizer and split application of nitrogen were recorded and embodied in table 4.2. By critically examining the data, it is revealed that there is existence of marked variation in plant height among different treatments at different growth stages. Height of the plants increased progressively and reached the maximum height at harvest. The mean plant height varied from 58.31 cm at 30 DAT to 115.52 cm at harvest. A rapid increase in height was seen up to 75DAT and after that the rate slowed down.

Height of the plant increased significantly with increase in nitrogen doses. The maximum plant height of 116.71cm was observed with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering) followed by 115.75 cm and 115.45 cm with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits ¼ basal + ½ tillering + ¼ PI and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Rice variety Ashutosh recorded the maximum plant height among all the varities at all growth stages. Ashutosh was observed with an average height of 66.63 cm at 30DAT, increased up to 123.34 cm at harvest which was followed by Mrunalini and Hasanta with 116.74 cm and 114.72 cm plant height at harvest, respectively. On the other hand Swarna variety has attained only up to 107.3 cm height during harvest.

The interaction effect due to fertility × variety at all the stages of growth was found to be significant.

Table 4.2 Effect of fertility level and nitrogen splits on plant height (cm) of rice varieties

Treatment	**Plant height (cm)**					
Fertility level (kg $N:P_2O_5:K_2O$ ha^{-1})	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**Harvest**
F1- 80:40:40						
S1(3 splits)	56.27	76.30	98.78	107.44	111.72	114.18
S2(4 splits)	57.52	77.43	99.85	108.72	113.15	115.45
F2- 100:50:50						
S1(3 splits)	59.12	80.34	101.85	110.17	113.67	115.75
S2(4 splits)	60.34	81.55	103	111.47	115.02	116.71
SEm ±	0.14	0.05	0.05	0.07	0.09	0.07
CD (P= 0.05)	0.51	0.20	0.19	0.27	0.32	0.25
Variety						
V1-Hasanta	56.80	76.15	95.5	106.30	112.81	114.72
V2-Mrunalini	59.77	81.55	99.4	110.37	113.95	116.74
V3-Ashutosh	66.63	89.60	115.39	118.87	120.9	123.34
V4-Swarna	50.05	68.32	93.2	102.25	105.90	107.3
SEm ±	0.08	0.06	0.07	0.06	0.06	0.09
CD (P= 0.05)	0.23	0.18	0.20	0.19	0.18	0.26
F x V						
SEm ±	0.16	0.12	0.14	0.13	0.12	0.18
CD (P= 0.05)	0.47	0.36	0.41	0.39	0.36	0.52

4.2.2 Number of tillers m^{-2}

The data pertaining to tiller density of different rice varieties grown under medium land conditions as influenced by different levels of fertilizer and split application of nitrogen were recorded and presented in table 4.3. A critical observation of the data exhibited that the number of tillers m^{-2} increased up to 60 DAT and then a gradual decrease in the tiller number was observed till harvest. The average number of tillers m^{-2} showed a progressive increase from 153.26 at 30 DAT to 399.77 at 60 DAT and then the number decreased to 330.67 at harvest.

Table 4.3 Effect of fertility level and nitrogen splits on number of tillers m^{-2} of rice varieties

Treatment	**Number of tillers m^{-2}**					
Fertility level (kg $N:P_2O_5:K_2O$ ha $^{-1}$)	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**Harvest**
F1- 80:40:40						
S1(3 splits)	149.65	282.54	385.81	370.05	345.09	320.51
S2(4 splits)	151.76	285.09	394.6	373.62	350.37	324.86
F2- 100:50:50						
S1(3 splits)	154.55	292.94	406.36	386.17	361.45	336.44
S2(4 splits)	157.07	296.15	412.34	391.75	366.20	340.86
SEm ±	0.11	0.12	0.10	0.11	0.09	0.09
CD (P= 0.05)	0.35	0.38	0.33	0.40	0.29	0.29
Variety						
V1-Hasanta	150.76	280.91	374.4	356.4	332.8	309.63
V2-Mrunalini	160.48	312.92	451.13	430.13	414.75	392.60
V3-Ashutosh	155.32	299.73	408.25	394.57	363.40	337.10
V4-Swarna	146.47	263.15	365.33	340.49	312.16	283.34
SEm ±	0.12	0.10	0.08	0.15	0.10	0.05
CD (P= 0.05)	0.35	0.30	0.25	0.44	0.30	0.15
F x V						
SEm ±	0.24	0.20	0.17	0.30	0.21	0.10
CD (P= 0.05)	0.70	0.61	0.51	0.88	0.61	0.30

The number of tillers m^{-2} increased significantly with increase in levels of fertiliser and split application of nitrogen. The maximum number of tillers m^{-2} (412.34) was observed at 60DAT with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits followed by 406.36 and 394.6 with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

In all the growth stages rice variety Mrunalini was observed with the maximum number of tillers. Starting from 30 DAT Mrunalini was recorded with an average of 160.48 number of tillers which increased up to 451.13 at 60 DAT and then decreased leaving only 392.60 number of tillers at harvest which was followed by Ashutosh and Hasanta having 408.25 and 374.4 number of tillers at 60 DAT then reduced to 337.10 and 309.63 number of tillers at harvest, respectively. However, Swarna variety produced the lowest number of tillers (283.34) at harvest.

The interaction effect between fertility × variety at all stages of growth was found to be significant.

4.2.3 Leaf area index (LAI)

Data regarding LAI of different rice varieties grown under medium land conditions as influenced by different levels of fertilizer and split application of nitrogen were recorded and embodied in table 4.4. From the data it is found that irrespective of fertility level and variety the LAI increased up to 60 DAT and then decreased to the minimum at harvest. The average LAI showed a progressive increase ranging from 0.45 at 30 DAT to 3.83 at 60 DAT and then it decreased to 2.31 at 90 DAT.

LAI showed a significant increase with increase in fertiliser levels and split application of nitrogen. Application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits showed the maximum value of LAI (3.93) at 60 DAT followed by 3.86 and 3.80 with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}in four splits, respectively.

LAI at all growth stages found the maximum for rice variety Mrunalini ranging from 0.57 at 30 DAT to 4.05 during 60 DAT and then decreased to 2.64 at 90 DAT. It was followed by Ashutosh (0.48,3.89,2.36) and Hasanta (0.41,3.74,2.20) at 30DAT, 60DAT and 90DAT respectively. The minimum LAI was recorded in Swarna variety ranging from 0.32 at 30 DAT to 3.62 at 60 DAT and then decreased to 2.04 at 90 DAT.

The interaction effect between fertility × variety at all stages of growth was found to be significant.

Table 4.4 Effect of fertility level and nitrogen splits on Leaf area index of rice varieties

Treatment	Leaf area index (LAI)				
Fertility level (kg $N:P_2O_5:K_2O$ ha^{-1})	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
F1- 80:40:40					
S1(3 splits)	0.38	0.76	3.72	3.19	2.24
S2(4 splits)	0.41	0.82	3.80	3.22	2.29
F2- 100:50:50					
S1(3 splits)	0.47	0.84	3.86	3.27	2.33
S2(4 splits)	0.53	0.87	3.93	3.36	2.39
SEm ±	0.002	0.003	0.003	0.003	0.003
CD (P= 0.05)	0.01	0.01	0.01	0.01	0.01
Variety					
V1-Hasanta	0.41	0.74	3.74	3.17	2.20
V2-Mrunalini	0.57	0.93	4.05	3.49	2.64
V3-Ashutosh	0.48	0.82	3.89	3.29	2.36
V4-Swarna	0.32	0.79	3.62	3.09	2.04
SEm ±	0.003	0.004	0.005	0.004	0.003
CD (P= 0.05)	0.01	0.01	0.01	0.01	0.009
F x V					
SEm ±	0.007	0.009	0.011	0.008	0.006
CD (P= 0.05)	0.02	0.02	0.03	0.02	0.01

4.2.4 Total dry matter production

The data pertaining to total dry matter production of different rice varieties grown under medium land conditions as influenced by different levels of fertilizer and split application of nitrogen were recorded and presented in table 4.5a. By critically examining the data it is revealed that total dry matter of the plants increased progressively and the maximum dry matter accumulation was found at harvest. The average dry matter varied from 456.23 g m^{-2} at 30DAT to 1385.86 g m^{-2}

at harvest. A faster rate of increase in dry matter was seen up to 90DAT and after that the rate slowed down to harvest.

Table 4.5a Effect of fertility level and nitrogen splits on dry matter accumulation ($g\ m^{-2}$) of rice varieties

Treatment	Dry matter accumulation ($g\ m^{-2}$)					
Fertility level (kg $N:P_2O_5:K_2O$ ha $^{-1}$)	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**Harvest**
F1- 80:40:40						
S1(3 splits)	451.84	590.67	879.9	1081.03	1237.37	1365.35
S2(4 splits)	455.02	593.75	884.45	1084.89	1238.5	1369.5
F2- 100:50:50						
S1(3 splits)	458.98	606.16	896.40	1102.23	1258.87	1399.62
S2(4 splits)	459.08	607.16	898.21	1105.23	1265.00	1409.00
SEm ±	0.19	0.23	0.18	0.24	0.19	0.22
CD (P= 0.05)	0.58	0.69	0.57	0.72	0.65	0.66
Variety						
V1-Hasanta	444.86	585.38	858.02	1061.18	1217.75	1362.04
V2-Mrunalini	498.12	644.12	968.66	1176.30	1335.50	1481.40
V3-Ashutosh	479.70	622.91	908.44	1113.80	1271.87	1415.39
V4-Swarna	402.24	545.34	823.85	1022.11	1174.62	1284.63
SEm ±	0.17	0.40	0.22	0.28	0.30	0.51
CD (P= 0.05)	0.51	1.17	0.66	0.83	0.88	1.50
F x V						
SEm ±	0.35	0.80	0.45	0.56	0.60	1.02
CD (P= 0.05)	1.02	2.34	1.32	1.66	1.76	3.00

The total dry matter accumulation of plant increased significantly with increase in nitrogen doses and their split applications. The maximum dry matter accumulation 1409 g m^{-2} was observed at harvest with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering) followed by 1399.62 g m^{-2} and 1369.5 g m^{-2} at harvest with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits (¼ basal + ½ tillering + ¼ PI) and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Among the varieties, Mrunalini accumulated the maximum amount of total dry matter in all stages. The maximum total dry matter (1481.4 g m^{-2}) was observed at harvest which was followed by Ashutosh and Hasanta with 1415.39 g m^{-2} and 1362.04 g m^{-2} of accumulated dry matter, respectively. On the other hand, Swarna variety recorded the lowest total accumulated dry matter (1284.63 g m^{-2}) at harvest.

The interaction effect of fertility levels and split application of nitrogen and varieties was found significant (table 4.5b). The highest dry matter accumulation (1517 g m^{-2}) was recorded in Mrunalini at harvest when 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} was applied in four splits which was followed by Ashutosh (1426 g m^{-1}) and Hasanta (1386 g m^{-2}), respectively at same level of fertility. The lowest total dry matter accumulation was observed in Swarna at harvest under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits of nitrogen.

Table 4.5b Interaction effect of fertility level and nitrogen splits on dry matter accumulation (g m^{-2}) of rice varieties

Variety	**Fertility Level (kg $N:P_2O_5:K_2O$ ha $^{-1}$)**			
	F1- 80:40:40		**F2- 100:50:50**	
	S1(3 splits)	S2(4 splits)	S1(3 splits)	S2(4 splits)
V1- Hasanta	1338.19	1345	1379	1386
V2- Mrunalini	1446.60	1457	1505	1517
V3- Asutosh	1407.58	1405	1423	1426
V4- Swarna	1269.03	1271	1291.5	1307
SEm ±	1.02			
CD (P= 0.05)	3.00			

4.2.5 Crop growth rate (CGR)

Data regarding Crop growth rate was recorded and embodied in table 4.6. This is an indication of crop growth which was computed by taking the rate of change in dry matter production per square meter area. It was calculated for the period between 15-30, 30-45, 45-60, 60-75, 75-90 DAT and from 90 DAT to harvest. The maximum crop growth rate on an average 19.31 g m^{-2} day^{-1} was seen in 45-60DAS and the minimum crop growth rate (9.06 g m^{-2} day^{-1}) was recorded during the period of 90DAT to harvest.

Crop growth rate increased significantly with increase in levels of fertiliser and split application of nitrogen. The maximum CGR (19.40 g m^{-2} day^{-1}) was observed at 45-60DAT with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits followed by that of 19.34 g m^{-2} day^{-1} and 19.28 g m^{-2} day^{-1} with application of

100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Table 4.6 Effect of fertility level and nitrogen splits on Crop growth rate ($g\ m^{-2}\ day^{-1}$) of rice varieties

Treatment	Crop growth rate ($g\ m^{-2}\ day^{-1}$)				
Fertility level (kg $N:P_2O_5:K_2O$ ha^{-1})	**30-45 DAT**	**45-60 DAT**	**60-75 DAT**	**75-90 DAT**	**90 DAT-harvest**
F1- 80:40:40					
S1(3 splits)	9.24	19.24	13.36	10.16	8.53
S2(4 splits)	9.25	19.28	13.40	10.49	8.73
F2- 100:50:50					
S1(3 splits)	9.81	19.34	13.72	10.44	9.38
S2(4 splits)	9.87	19.40	13.80	10.65	9.60
SEm ±	0.04	5.12	0.007	0.008	0.02
CD (P= 0.05)	0.13	17.73	0.023	0.025	0.06
Variety					
V1-Hasanta	9.36	18.04	13.54	10.43	9.61
V2-Mrunalini	9.73	21.63	13.84	10.61	9.72
V3-Ashutosh	9.54	19.03	13.69	10.53	9.56
V4-Swarna	9.53	18.56	13.21	10.16	7.33
SEm ±	0.05	0.03	0.01	0.01	0.02
CD (P= 0.05)	0.17	0.10	0.02	0.02	0.06
F x V					
SEm ±	0.11	0.07	0.01	0.02	0.04
CD (P= 0.05)	0.34	0.20	0.04	0.04	0.12

Among the rice varieties, Mrunalini was recorded with the maximum CGR (21.63 g $m^{-2}day^{-1}$) during 45-60 DAT which was followed by Ashutosh (19.03 g m^{-2} day^{-1}) and Hasanta (18.04 g m^{-2} day^{-1}) in the same period, respectively. On the other hand, Swarna was found with the minimum crop growth rate (7.33 g m^{-2} day^{-1}) during the period of 90DAT to harvest.

The interaction effect between fertility × variety at all stages of growth was found to be significant.

4.2.6 Relative growth rate (RGR)

Data regarding relative growth rate was recorded and embodied in table 4.7. It was calculated for the period between 15-30, 30-45, 45-60, 60-75, 75-90 DAT and from 90 DAT to harvest. The maximum relative growth rate on an average (0.0263 g g^{-1} day^{-1}) was observed in 45-60DAT and the minimum relative growth rate (0.0068 g g^{-1} day^{-1}) was recorded during the period of 90DAT to harvest.

Table 4.7 Effect of fertility level and nitrogen splits on relative growth rate (g g^{-1} day^{-1}) of rice varieties

Treatment	**Relative growth rate (g g^{-1} day^{-1})**				
Fertility level (kg $N:P_2O_5:K_2O$ ha $^{-1}$)	**30-45 DAT**	**45-60 DAT**	**60-75 DAT**	**75-90 DAT**	**90 DAT-harvest**
F1- 80:40:40					
S1(3 splits)	0.018	0.028	0.0136	0.008	0.006
S2(4 splits)	0.017	0.027	0.0137	0.009	0.007
F2- 100:50:50					
S1(3 splits)	0.018	0.026	0.0138	0.008	0.007
S2(4 splits)	0.019	0.027	0.0139	0.009	0.008
SEm ±	0.001	0.003	0.001	0.001	0.003
CD (P= 0.05)	0.002	0.006	0.002	0.002	0.006
Variety					
V1-Hasanta	0.019	0.026	0.014	0.009	0.008
V2-Mrunalini	0.017	0.027	0.012	0.008	0.007
V3-Ashutosh	0.018	0.025	0.013	0.009	0.007
V4-Swarna	0.020	0.028	0.014	0.009	0.006
SEm ±	0.001	0.001	0.001	0.001	0.001
CD (P= 0.05)	0.002	0.002	0.002	0.002	0.002

Relative growth rate varied significantly with variation in levels of fertiliser and splits of nitrogen. The maximum RGR (0.266 g g^{-1} day^{-1}) was observed at 45-60DAT with application of 80:40:40 kg $N:P_2O_5:K_2O$ ha $^{-1}$ in four splits followed by (0.265 g g^{-1} day^{-1}) and (0.263 g g^{-1} day^{-1}) with application of 80:40:40 kg

$N:P_2O_5:K_2O$ ha^{-1} in three splits and 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Among the varieties, Swarna variety recorded the highest average RGR (0.0548 g g^{-1} day^{-1}) from 30DAT to harvest followed by Hasanta (0.0192 g g^{-1} day^{-1}) and Mrunalini (0.0153 g g^{-1} day^{-1}), respectively. The minimum average RGR was recorded in Ashutosh 0.0144 g g^{-1} day^{-1}.

The interaction effect between fertility × variety at all stages of growth was found to be non-significant.

4.3 Yield attributes

Influence of different fertiliser levels and splitting of nitrogen on yield attributing characters of different rice varieties such as panicle length, number of panicles m^{-2}, total number of grains and number of fertile grains $panicle^{-1}$ as well as test weight was studied. The data regarding this study was recorded and embodied in Table 4.8.

4.3.1 Panicle length

From the recorded data, it was observed that the panicle length varied significantly due to fertility levels and split application of nitrogen and it also differed significantly with respect to the varieties.

The average panicle length was 25.56 cm. Length of panicle increased with increase in fertiliser levels. The highest panicle length (26.18 cm) was recorded with application of 100 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering) followed by 25.83 cm and 25.37 cm with application of 100 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits (¼ basal + ½ tillering + ¼ PI) and 80 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Among the varieties, Hasanta was observed with the longest panicle length (29.14 cm) followed by Ashutosh (26.55 cm) and Mrunalini (24.01 cm), respectively. However, the shortest panicle length was observed in variety Swarna (22.55 cm).

4.3.2 Number of panicles m^{-2}

The data on number of panicles m^{-2} revealed that the number of panicles varied significantly according to the fertility levels and split application of nitrogen and it also differed significantly with respect to the varieties.

Increasing levels of fertilisers increased the number of panicles. The average number of panicles was found to be 329.37.More number of panicles was also found when nitrogen is applied in one extra split at flowering stage as compared to the regular three splits. The highest number of panicles per m^{-2} (335.83) was recorded with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering) followed by 331.75 and 327.25 with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} with four splits, respectively.

Among the varieties, the maximum number of panicles 489.33 was recorded in Mrunalini followed by Hasanta (291.75) and Ashutosh (285.66), respectively. Swarna variety was found to have the minimum number of panicles m^{-2} (250.75).

4.3.3 Total grains panicle^{-1}

The total number of grains panicle^{-1} varied significantly due to the fertility levels and split application of nitrogen and also differed significantly according to the varieties.

The total number of grains panicle^{-1} increased with increase in fertiliser level. The average number of grains panicle^{-1} was found to be 194.54. Application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits has showed the highest number of grains panicle^{-1} (198.48) followed by 195.89 and 193.25 with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} with four split application of nitrogen, respectively.

Among the varieties, Mrunalini recorded the highest number of grains panicle^{-1} (221.74) followed by Hasanta (191.42) and Ashutosh (188.90), respectively. Swarna has shown the minimum number of grains panicle^{-1} 176.11.

4.3.4 Number of fertile grains panicle^{-1}

The data on number of fertile grains panicle^{-1} revealed that the number of fertile grains panicle^{-1} varied significantly due to the fertility levels and split application of nitrogen and it also differed significantly with respect to the varieties.

The average number of panicles was found to be 150.621. Increasing levels of fertilisers increased the number of fertile grains panicle^{-1}. More number of fertile grains panicle^{-1} were found when nitrogen is applied in one extra split at flowering stage as compared to the regular three splits. The highest number of fertile grains panicle^{-1} (154.73) were recorded with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits followed by 151.99 and 149.25 with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} with four splits of nitrogen application, respectively.

Among the varieties, Mrunalini recorded the highest number of grains panicle^{-1} (189.20) followed by Ashutosh (163.37) and Hasanta (132.91), respectively. Minimum number of fertile grains panicle^{-1} was found in swarna (116.98).

Table 4.8 Effect of fertility levels and nitrogen splits on yield attributing characters of rice varieties

Treatment	Yield attributing characters					
Fertility level (kg $N:P_2O_5:K_2O$ ha^{-1})	**Panicle length (cm)**	**Number of panicle m^{-2}**	**Total grains Panicle^{-1}**	**Fertile grains Panicle^{-1}**	**Fertility %**	**1000 grain wt**
F1- 80:40:40						
S1(3 splits)	24.85	322.66	190.55	146.49	76.34	18.91
S2(4 splits)	25.37	327.25	193.25	149.25	76.70	19.1
F2- 100:50:50						
S1(3 splits)	25.83	331.75	195.89	151.99	77.10	19.65
S2(4 splits)	26.18	335.83	198.48	154.73	77.49	20.03
SEm ±	0.05	0.45	0.27	0.14	0.10	0.08
CD (P= 0.05)	0.16	1.56	0.92	0.46	0.31	0.26
Variety						
V1-Hasanta	29.14	291.75	191.42	132.91	69.43	17.17
V2-Mrunalini	24.01	489.33	221.74	189.20	85.32	22.08
V3-Ashutosh	26.55	285.66	188.90	163.37	86.48	19.81
V4-Swarna	22.53	250.75	176.11	116.98	66.42	18.64
SEm ±	0.04	0.53	0.27	0.12	0.11	0.06
CD (P= 0.05)	0.13	1.56	0.81	0.34	0.33	0.18
F x V						
SEm ±	0.09	1.06	0.45	0.24	0.23	0.13
CD (P= 0.05)	0.26	3.12	1.31	0.69	0.67	0.37

4.3.5 Fertility percentage

From the recorded data, it is observed that the fertility percentage varied significantly with the fertility levels and split application of nitrogen and it also differed significantly with respect to the varieties.

On an average about 76.91% of grains are fertile. The fertility percentage showed an increasing pattern with increase in levels of fertiliser. The second split of application that is an extra nitrogen split application at flowering stage has shown superior effect over the first split of application up to PI stage. Application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits has shown the highest percentage of fertility (77.49%) followed by 77.10% and 76.70% with application of 100:50:50 kg NPK ha^{-1} in three splits and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Among the varieties, Ashutosh recorded the highest fertility percentage (86.47%) followed by Mrunalini (85.32%) and Hasanta (69.43%) respectively. The lowest fertility percentage was found in variety swarna (66.41%).

4.3.6 1000-grain weight

The 1000-grain weight of panicle (test weight) varied significantly due to the fertility levels and split application of nitrogen and also differed significantly according to the varieties.

Increasing levels of fertiliser increased the thousand grain weight of panicles. The average test weight found to be 19.42 g. Higher 1000-grain weight was also found when nitrogen is applied in one extra split at flowering stage as compared to the regular three splits. The highest 1000-grain weight (20.03g) was recorded with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits followed by 19.65g and 19.10g with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Among the varieties, Mrunalini recorded the highest test weight (22.08 g) followed by Ashutosh (19.81 g) and Hasanta (17.17 g), respectively. The lowest test weight was found in swarna (18.64 g).

4.4 Yield

4.4.1 Grain Yield

The grain yield of rice recorded a significant variation due to different fertility levels with split application of nitrogen and varieties. The grain yield of rice increased with increase in fertility level and split application of nitrogen (Table 4.9a). Application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} with split application of nitrogenous fertiliser S2 (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering stage) recorded the highest grain yield of 4.87 t ha^{-1} than S1(¼ basal + ½ tillering + ¼ PI) and less fertility level

(80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}). The fertility level of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} at both the split levels recorded significantly less grain yield.

Among different varieties, Mrunalini recorded the highest grain yield of 5.06 t ha^{-1} than other 3 varieties and Swarna recorded the lowest grain yield of 3.70 t ha^{-1}.

The interaction between fertility level×variety was found to be significant. Maximum grain yield of 5.61 t ha^{-1} was recorded when Mrunalini variety was fertilised with 100:50:50 kg $N:P_2O_5:K_2O$ $ha^{-1}$with 4 split applications.

4.4.2 Straw yield

The straw yield of rice also followed the similar trend and showed significant variation (Table 4.9a). Maximum straw yield of 7.2 t ha^{-1} was observed at fertility level of F_2S_2 (100:50:50 kg $N:P_2O_5:K_2O$ $ha^{-1}$with 4 split applications.) while the minimum straw yield of 5.21 t ha^{-1} was in F_1S_1(80:40:40 kg $N:P_2O_5:K_2O$ $ha^{-1}$with 3 splits). Among the varieties, Mrunalini recorded the highest straw yield of 5.21 t ha^{-1} than other 3 varieties and Swarna recorded the lowest straw yield of 5.15 t ha^{-1}.

The interaction between fertility level × variety was found to be significant.

4.4.3 Grain: straw ratio

Data presented in (Table 4.9a) revealed that the grain: straw varied significantly due to fertility levels and split application of nitrogen. The grain: straw ratio decreased with increase in fertiliser dose and split application of nitrogen. The highest grain: straw ratio of 0.77 was noticed with less fertility level of 80:40:40 kg $N:P_2O_5:K_2O$ $ha^{-1}$with 3 split applications and lowest of 0.67 in F_2S_2.

Among the varieties, Hasanta and Ashutosh recorded the highest grain: straw of 0.75 followed by Swarna (0.72) and Mrunalini(0.68).

The interaction effect of fertility level and variety was found to be significant. The highest grain: straw of 0.82 was recorded in variety Hasanta when fertilised with 80:40:40 kg $N:P_2O_5:K_2O$ $ha^{-1}$with 3 split applications and the lowest of 0.64 in variety Mrunalini fertilised with F_2S_2.

4.4.4 Harvest index

The harvest index varied significantly due to both the fertility levels and rice varieties. The data revealed that the harvest index did not vary significantly by different levels of fertility and their split application as well as in varieties. However the fertiliser dose of 80:40:40 kg $N:P_2O_5:K_2O$ $ha^{-1}$with 3 split application of nitrogen recorded the highest Harvest index of (43.77%) and the lowest harvest index of (40.20%) at 100:50:50 kg $N:P_2O_5:K_2O$ $ha^{-1}$with 4 split applications.

Table 4.9a Effect of fertility levels and nitrogen splits on grain yield, straw yield, grain: straw ratio and harvest index of rice varieties

Treatment	Yield			
Fertility level (kg N:P_2O_5:K_2O ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Grain: Straw	Harvest index (%)
F1- 80:40:40				
S1(3 splits)	4.03	5.21	0.77	43.77
S2(4 splits)	4.20	5.62	0.74	42.81
F2- 100:50:50				
S1(3 splits)	4.40	6.16	0.71	41.72
S2(4 splits)	4.87	7.2	0.67	40.20
SEm ±	0.02	0.01	0.004	0.001
CD (P= 0.05)	0.04	0.04	0.012	0.004
Variety				
V1-Hasanta	4.27	5.70	0.75	43.00
V2-Mrunalini	5.06	7.41	0.68	40.67
V3-Ashutosh	4.47	5.99	0.75	42.86
V4-Swarna	3.70	5.15	0.72	41.89
SEm ±	0.03	0.01	0.006	0.002
CD (P= 0.05)	0.10	0.03	0.018	0.006
F x V				
SEm ±	0.07	0.15	0.01	0.004
CD (P= 0.05)	0.21	0.44	0.03	0.012

Table 4.9b Interaction effect of fertility levels and nitrogen splits on grain yield of rice varieties

Variety	Fertility Level (kg N:P_2O_5:K_2O ha^{-1})			
	F1- 80:40:40		**F2- 100:50:50**	
	S1(3 splits)	S2(4 splits)	S1(3 splits)	S2(4 splits)
V1- Hasanta	4.03	4.07	4.35	4.63
V2- Mrunalini	4.59	4.91	5.12	5.61
V3- Asutosh	4.11	4.28	4.47	5.03
V4- Swarna	3.40	3.54	3.67	4.19
SEm ±	0.07			
CD (P= 0.05)	0.21			

Among the varieties, Hasanta recorded the highest harvest index of (43.00%) followed by Ashutosh (42.86%), Swarna (41.89%) and the lowest in case of Mrunalini (40.67%). The interaction effect between fertility level × variety was found to b significant.

4.5 Nutrient Studies

4.5.1 Nutrient Content

Data on nutrient content that is N,P and K content (%) in grain and straw of different rice varieties grown under medium land conditions as influenced by different levels of fertilizer and split application of nitrogen were recorded and presented in table 4.10a.

Table 4.10a Effect of fertility levels and nitrogen splits on nutrient content (%) of rice varieties

Treatment	Nutrient content					
Fertility level (kg $N:P_2O_5:K_2O$ ha^{-1})	**N Content (%)**		**P content (%)**		**K content (%)**	
F1- 80:40:40	Grain	Straw	Grain	Straw	Grain	Straw
S1(3 splits)	1.30	0.38	0.29	0.12	0.23	1.58
S2(4 splits)	1.29	0.39	0.30	0.13	0.23	1.57
F2- 100:50:50						
S1(3 splits)	1.28	0.37	0.29	0.11	0.22	1.56
S2(4 splits)	1.26	0.37	0.30	0.11	0.22	1.54
SEm ±	0.002	0.001	0.001	0.0007	0.001	0.001
CD (P= 0.05)	0.008	0.004	0.006	0.002	0.004	0.00
Variety						
V1-Hasanta	1.30	0.38	0.30	0.12	0.23	1.58
V2-Mrunalini	1.24	0.35	0.26	0.10	0.21	1.5
V3-Ashutosh	1.27	0.37	0.28	0.12	0.22	1.54
V4-Swarna	1.33	0.41	0.33	0.13	0.24	1.62
SEm ±	0.002	0.002	0.001	0.001	0.001	0.001
CD (P= 0.05)	0.006	0.006	0.004	0.004	0.004	0.004
F x V						
SEm ±	0.004	0.004	0.002	0.003	0.002	0.003
CD (P= 0.05)	0.012	0.012	0.008	0.008	0.008	0.01

Nutrient content in straw and grain varied according to the fertilizer levels and split application of nitrogen. The highest nitrogen content in grain 1.30% was observed under application of 80:40:40 $N:P_2O_5:K_2O$ kg ha^{-1} at three splits which was followed by 1.29% and 1.28% with application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}at four splits and 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} at three splits respectively. The highest nitrogen content in straw 0.39% was found under application 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}in four splits followed by 0.38% with application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}in three splits.

In grain, P content was found same (0.30%) under both the fertiliser levels. Hence there was no significant difference. However P content in straw was found the highest (0.13%) under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}in three splits.

There was no significant difference found in K content (%) of grain under application of both the fertiliser levels. On the other hand, the highest K content in straw of 1.58% was found under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}in three splits followed by 1.57% with application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}in four splits.

Among the varieties, the lowest N, P and K content in both straw and grain was observed in Mrunalini and the highest N,P and K content was found in Swarna variety.

The interaction effects of fertility × variety on N content (%), P content (%) and K content (%) were found to be significant.

4.5.2 Nutrient uptake

The data pertaining to total dry matter production of different rice varieties grown under medium land conditions as influenced by different levels of fertilizer and split application of nitrogen were recorded and presented in table 4.10b.

Nitrogen uptake

The highest nitrogen uptake in grain (61.43 kg ha^{-1}) was observed under application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits followed by 56.32 kg ha^{-1} and 54.28 kg $ha^{-1}$with application of the same dose of fertilise in three splits and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively. Similarly the highest nitrogen uptake in straw (26.72 kg ha^{-1}) was found under application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits followed by 23.05 kg ha^{-1} and 22.07 kg ha^{-1} with application of the same dose of fertilise in three splits and 80:40:40 kg N:P_2O_5:K_2O ha^{-1} in four splits, respectively.

Among the varieties, Mrunalini was recorded with the highest nitrogen uptake both in grain (63 kg ha^{-1}) and straw (26.40 kg ha^{-1}) which was followed by Ashutosh and Hasanta with 56.77 kg ha^{-1},55.65 kg ha^{-1} in grain and 22.18 kg ha^{-1},21.96 kg ha^{-1} in straw, respectively. However, the variety Swarna was recorded with the lowest nitrogen uptake in both grain (49.22 kg ha^{-1}) and straw (21.28 kg ha^{-1}).

Phosphorus uptake

The highest P uptake in grain (17.93 kg ha^{-1}) was observed under application of 100:50:50 kg N:P_2O_5:K_2O ha $^{-1}$ in four splits followed by 16.51 kg ha^{-1} and 16.46 kg ha^{-1} with application of 80:40:40 kg N:P_2O_5:K_2O ha^{-1}in four splits and 100:50:50 kg N:P_2O_5:K_2O ha^{-1} in three splits, respectively. Similarly the highest P uptake in straw 7.95 kg ha^{-1} was found under application of 100:50:50 kg N:P_2O_5:K_2O ha^{-1} in four splits followed by 7.30 kg ha^{-1} and 7.27 kg ha^{-1} with application of 80:40:40 kg N:P_2O_5:K_2O ha^{-1}in four splits and 100:50:50 kg N:P_2O_5:K_2O ha^{-1} in three splits, respectively.

Among the varieties, Mrunalini was recorded with the highest phosphorus uptake both in grain 18.05 kg ha^{-1} and straw 7.61 kg ha^{-1} which was followed by Ashutosh and Hasanta with 16.58 kg ha^{-1}, 16.50 kg ha^{-1} in grain and 7.24 kg ha^{-1}, 7.17 kg ha^{-1}, respectively. However the variety Swarna was recorded with the lowest phosphorus uptake in both grain (15.28 kg ha^{-1}) and straw (7.07 kg ha^{-1}).

Potassium uptake

The highest K uptake in grain (10.75 kg ha^{-1}) was observed under application of 100:50:50 kg N:P_2O_5:K_2O ha^{-1} in four splits followed by 9.90 kg ha^{-1} and 9.78 kg ha^{-1} with application of the same dose of fertilise in three splits and 80:40:40 kg N:P_2O_5:K_2O ha^{-1}in four splits, respectively. Similarly the highest K uptake in straw 111.9 kg ha^{-1} was found under under application of 100:50:50 kg N:P_2O_5:K_2O ha^{-1} in four splits followed by 95.97 kg ha^{-1} and 88.27 kg ha^{-1} with application of the same dose of fertilise in three splits and 80:40:40 kg N:P_2O_5:K_2O ha^{-1} in four splits, respectively.

Among the varieties, Mrunalini recorded the highest K uptake in grain and straw 10.69 kg ha^{-1}, 111.4 kg ha^{-1} followed by Ashutosh 10.19 kg ha^{-1}, 92.58 kg ha^{-1}

and Hasanta 10.03 kg ha^{-1}, 90.36 kg ha^{-1}, respectively. However the variety Swarna was recorded with the lowest potassium uptake in both grain (9.02 kg ha^{-1}) and straw (83.73 kg ha^{-1}).

Table 4.10b Effect of fertility levels and nitrogen splits on total nutrient uptake (kg ha^{-1}) of rice varieties

Treatment	Nutrient uptake						
Fertility level (kg $N:P_2O_5:K_2O$ ha^{-1})	N **uptake (kg ha^{-1})**		**P uptake (kg ha^{-1})**		**K uptake (kg ha^{-1})**		**Total uptake (kg ha^{-1})**
F1- 80:40:40	Grain	Straw	Grain	Straw	Grain	Straw	
S1(3 splits)	52.61	19.99	15.50	6.58	9.50	81.99	186.20
S2(4 splits)	54.28	22.07	16.51	7.30	9.78	88.27	198.22
F2- 100:50:50							
S1(3 splits)	56.32	23.05	16.46	7.27	9.90	95.97	209.00
S2(4 splits)	61.43	26.72	17.93	7.95	10.75	111.9	236.72
SEm ±	0.213	0.097	0.073	0.070	0.097	0.239	0.387
CD (P= 0.05)	0.739	0.33	0.25	0.24	0.33	0.82	1.34
Variety							
V1-Hasanta	55.65	21.96	16.50	7.17	10.03	90.36	201.70
V2-Mrunalini	63.00	26.40	18.05	7.61	10.69	111.4	237.26
V3-Ashutosh	56.77	22.18	16.58	7.24	10.19	92.58	205.56
V4-Swarna	49.22	21.28	15.28	7.07	9.02	83.73	185.62
SEm ±	0.496	0.115	0.164	0.107	0.105	0.205	0.794
CD (P= 0.05)	1.44	0.33	0.48	0.31	0.30	0.59	2.31
F x V							
SEm ±	0.992	0.231	0.329	0.215	0.193	0.442	1.58
CD (P= 0.05)	2.89	0.67	0.96	0.63	0.56	1.29	4.63

Total Nutrient uptake

The total nutrient uptake was found maximum 236.72 kg ha^{-1} under application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits followed by 209 kg ha^{-1} and 198.22 kg ha^{-1} with application of the same dose of fertilise in three splits and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Among the varieties, Mrunalini was recorded with the highest total nutrient uptake of (237.26 kg ha^{-1}) followed by Ashutosh (205.56 kg ha^{-1}) and Hasanta 201.70 kg ha^{-1}, respectively. The variety Swarna recorded the lowest total nutrient uptake of 185.62 kg ha^{-1}.

4.6 Residual Soil Fertility

Physico-chemical properties of the soil after harvest of paddy are presented in table 4.11

4.6.1 Available Organic Carbon (%)

The maximum Organic Carbon (0.728%) was recorded under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in 3 splits followed by 0.726% and 0.723% under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in 4 splits and application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Among the varieties, Swarna was recorded with the highest organic carbon (0.729%) followed by Hasanta (0.725%) and Ashutosh (0.724%) respectively.

4.6.2 Available Nitrogen (kg ha^{-1})

The maximum available nitrogen (235.62 kg ha^{-1}) was recorded under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in 3 splits followed by 230.71 kg ha^{-1} and 226.84 kg ha^{-1} under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in 4 splits and application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Among the varieties, Swarna was recorded with the highest available nitrogen (237 kg ha^{-1}) followed by Hasanta 236.57 kg ha^{-1} and Ashutosh 233.83 kg ha^{-1}, respectively.

4.6.3 Available Phosphorus (kg ha^{-1})

The maximum available nitrogen (23.86 kg ha^{-1}) was recorded under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in 3 splits followed by 23.52 kg ha^{-1} and 21.71 kg ha^{-1} under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in 4 splits and application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Among the varieties, Swarna was recorded with the highest available phosphorus (24.15 kg ha^{-1}) followed by Hasanta 23.56 kg ha^{-1} and Ashutosh 22.67 kg ha^{-1}, respectively.

Table 4.11 Effect of fertility levels and nitrogen splits on residual soil fertility

Treatment	Residual soil fertility			
Fertility level (kg $N:P_2O_5:K_2O$ ha $^{-1}$)	**Organic Carbon (%)**	**Available N (kg ha^{-1})**	**Available P (kg ha^{-1})**	**Available K (kg ha^{-1})**
F1- 80:40:40				
S1(3 splits)	0.728	235.62	23.86	222.43
S2(4 splits)	0.726	230.71	23.52	218.67
F2- 100:50:50				
S1(3 splits)	0.723	226.84	21.71	214.65
S2(4 splits)	0.721	225.45	20.82	212.54
Variety				
V1-Hasanta	0.725	236.57	23.56	222.43
V2-Mrunalini	0.721	227.28	21.22	213.75
V3-Ashutosh	0.724	233.83	22.67	218.62
V4-Swarna	0.729	237	24.15	225.68

4.6.4 Available Potassium (kg ha^{-1})

The maximum value of available potassium (222.43 kg ha^{-1}) was recorded under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in 3 splits followed by 218.67 kg ha^{-1} and 214.65 kg ha^{-1} under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in 4 splits and application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits, respectively.

Among the varieties, Swarna was recorded with the highest available potassium (225.68 kg ha^{-1}) followed by Hasanta (222.43 kg ha^{-1}) and Ashutosh (218.62 kg ha^{-1}) , respectively.

4.7 Comparative economics

The data pertaining to comparative economics of different rice varieties grown under medium land conditions as influenced by different levels of fertilizer and split application of nitrogen were recorded and presented in table 4.12.

Table 4.12 Effect of fertility levels and nitrogen splits on comparative economics

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit: Cost
$V_1F_1S_1$	42000	61807	19807	1.47
$V_2F_1S_1$	42000	71132	29132	1.70
$V_3F_1S_1$	42000	63238	21238	1.51
$V_4F_1S_1$	42000	52334	10334	1.25
$V_1F_1S_2$	44135	62661	18526	1.42
$V_2F_1S_2$	44135	76175	32040	1.72
$V_3F_1S_2$	44135	65988	21853	1.49
$V_4F_1S_2$	44135	54751	10616	1.24
$V_1F_2S_1$	43055	67375	24320	1.56
$V_2F_2S_1$	43055	79775	36720	1.85
$V_3F_2S_1$	43055	68887	25832	1.59
$V_4F_2S_1$	43055	56974	13919	1.32
$V_1F_2S_2$	45190	72070	26880	1.60
$V_2F_2S_2$	45190	87955	42765	1.95
$V_3F_2S_2$	45190	78196	33006	1.73
$V_4F_2S_2$	45190	65480	20290	1.45

The highest gross return (Rs. 87955 ha^{-1}), net return (Rs. 42765 ha^{-1}) and benefit: cost ratio (1.95) was recorded when Mrunalini variety is fertilized with 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits followed by benefit: cost ratio of (1.85) when the same variety is fertilised with the same fertility level and in three splits.

DISCUSSION

The field experiment entitled "Response of rice variety to fertility level and split application of nitrogen fertiliser under medium land condition" was conducted at the Agronomy Main Research Station of the College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar during the *kharif* season of 2017.The main objective was to study the effect of fertility levels and split application of nitrogen on growth and yield of rice varieties. During the period of investigation, the data obtained on various growth, yield and yield attributing characters, nutrient uptake and production economics, as influenced by different fertility levels and nitrogen splits in different varieties, have been recorded. In this chapter, a critical analysis of the findings has been done to assign and discuss possible reasons in order to establish the cause and effect relationship among different treatments for the existing variation in plant characters and yield as induced by different fertility levels and variety, duly supported by the earlier established scientific views of research workers.

5.1 Crop and Weather

The growth and yield of a crop is mostly controlled by the genotype, agro-management techniques and the environment to which the crop is exposed. Among the environmental factors, the important weather parameters such as rainfall, relative humidity, temperature, evaporation etc. play a key role in affecting growth and development of any crop including rice. The weather elements account for bringing about 76% of variation in crop productivity (Ram Krishna *et al.,* 2003). Though rice plant is highly adaptable to the seasonal variation and can be grown successfully in wide range of environmental conditions, there is requirement of a specific range of these weather elements during different growth stages in order to fully express its yield potential in a given time and space. Any imbalance in the requirements of the above weather elements leads to reduction in yield.

Temperature and rainfall affect rice yield directly by influencing the physiological processes involved in grain production and indirectly through diseases and insects. In general, the temperature in tropics is conducive for rice growth throughout the year. For successful fertilization also temperature plays a crucial role.

However, extreme temperatures are detrimental for growth of the rice plant. Depending on the growth stages, injury to rice plant may occur when the daily mean temperature drops below 20˚ C or rise above 35˚C (Yoshida, 1981). During the period of rice growth, the mean monthly temperature ranged between 21.3˚C to 29.65˚C and this temperature favoured the plant in attaining better yield potential.

Sunshine hours had no significant correlation with tillers m^{-2} but highly correlated with number of ear-bearing tillers. It plays a crucial role in production and accumulation of dry matter in sinks. Moomaw and Vergara (1964) found that the sunshine hours should be around 240 hrs from flower initiation to physiological maturity that results in higher dry matter accumulation in rice grains. The daily bright sunshine hours (BSH) during the cropping season ranged from 2 hr day^{-1} in July to 7 hr day^{-1} in December which favoured the crop growth and yield.

The total rainfall received during the period of cropping season *i.e.* July to December of 2017 was 1364.1 mm. The month of July received the highest rainfall of 445.9 mm whereas the month of December has received the lowest rainfall of 36.3mm. The rainfall received during the cropping season was about 21.37% more than normal and was sufficient to meet the water need of the crop throughout the growing season. During the period of excess rain, main focus was on draining out the excess water from the crop fields.

A range of 72-80 per cent relative humidity is favourable for growth and production of rice (Angladette, 1966). During the period of investigation the relative humidity varied from 91 to 93 per cent during forenoon hours and 47.6 to 78 per cent during afternoon hours with an average of 85 per cent in July, 69.5 per cent in December and 72.5 per cent in November, which was quite close to the requirement of the crop.

Hence, the weather was quite conducive for the growth and development of the crop during the period of crop growth and thereby it favoured the yield.

5.2 Phenology and growth studies

The ultimate purpose of growing a crop plant is to get higher yield. In general, growth of a plant refers to the permanent and irreversible increase in size and form resulting in the formation, enlargement and maturity of the cells. Growth of a plant grown individually differs from a plant grown under a community in many ways as the performance of a plant grown in a community is influenced by the mutual interference of resources.

Phenology of a plant indicates the dates of first occurrence of biological events in their annual cycle. The growth and development (phenotype) of crop plant are directly related to their genetic constitution, though environmental factors and cultural practices do influence growth and development by their direct and indirect effect on different metabolic processes of the plant (Gardner *et al.*, 1988). No marked variation in phenophases was observed with respect to different levels of fertiliser and split application of nitrogen. Among the varieties, Ashutosh took maximum time to attain all the phenophases irrespective of fertiliser levels and splits of nitrogen. Pradhan *et al.* (2013) also observed a marked variation in phenophases among rice varieties.

The magnitude of growth of a plant is generally expressed in the terms of plant height, tiller number, dry matter accumulation as well as various growth analysis components like leaf area index and crop growth rate. All the important growth parameters were recorded during the present investigation at 15 days interval starting from 30DAT till harvest. Most of the growth parameters varied significantly with the treatments.

As per the general relationship between growth and time, the growth of the rice plant in terms of height continued to increase progressively till maturity stage irrespective of the varieties and fertility levels. The rate of increase in plant height was maximum (1.46 cm day^{-1}) between 45 to 60 DAT. Low light intensity might have induced more production of auxin which as an growth promoter, facilitated better growth in form of increased height.

A rapid growth in height was observed up to 60 DAT followed by a reduced rate of increase in plant height till harvest. The mean plant height varied from 58.31 cm at 30 DAT to 115.52 cm at harvest. The increasing rate of plant height coincided with the maximum tillering to panicle initiation stage of the crop growth. During the reproductive growth phase increase in plant height up to 60 DAT must be due to speedy segregation of nodes and elongation of internodes during this phase. However, the rate of elongation decreased further due to diversion of photosynthates from vegetative to reproductive parts and their subsequent accumulation as starch in grains which is considered as the major economic portion of the rice plant. Mahmud *et al.* (2012) also recorded a progressive increase in plant height of rice hybrids up to flowering.

The maximum plant height of 115.75 cm was observed during harvest under application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits (¼ basal + ½ tillering + 1/8 PI+ 1/8 flowering) over the lower fertility level. This might be due to better balanced nutrition of plants which preferably stimulated the cell division and multiplication and hence resulted in increased internode length. The increase in N levels was responsible for increased number of leaves which gave higher photosynthesis, metabolic activity and cell division. This attributed to increased growth of rice (Jaiswal and Singh, 2001).

Among the varieties, Ashutosh recorded higher plant height (123.34 cm) whereas; Swarna was observed with shorter height (107.3cm). This might be due to the genetic variability existing among the varieties. Ashutosh was recorded with the maximum plant height (124.5 cm) under application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four split doses.

Mahmud *et al*. (2012) found that maximum tillering was obtained at panicle initiation stage irrespective of varieties and then declined up to maturity. Khalifa (2012) observed maximum number of tillers at 60 DAT. In the current study, a rapid tillering continued up to 60 DAT and after that the tiller number reduced up to harvest. Mortality of late formed tillers due to shading of the upper tillers is might be the reason.

In this experiment, at harvest maximum number of tillers (340.86 tillers m^{-2}) was observed under application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits. This might be due to the better utilisation of resources as an extra split of nitrogen is applied at flowering stage which helps in converting majority of tillers into effective tillers. The variety Mrunalini was observed with the highest number of tillers (392 tillers m^{-2}), whereas Swarna produced the minimum number of tillers (283.34 tillers m^{-2}). As the tillering ability of any variety is genetically determined, the higher tillering ability of Mrunalini is due to its superiority in genetic constitution over other varieties. Among the different treatment combinations, Mrunalini gave the maximum number of tillers m^{-2} (402.76) with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits.

Foliar growth is another markable component of plant growth which comprises of number of leaves and leaf areas, which in all together give rise to leaf area index (LAI). LAI has direct effect on growth as it determines the extent of photosynthetic surface and thereby influences the photosynthetic efficiency of a plant. A progressive increase in LAI was seen up to 60 DAT and then declined due to gradual senescence of leaves.

The LAI varied significantly with variation in fertility levels and split application of nitrogen. The highest value of LAI was found in 60 DAT (3.93) with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits as compared to the lower fertiliser level. This might be due to the higher dose of nitrogen which resulted in an increase in foliar growth and thereby increasing leaf area.

Higher LAI was noticed in variety Mrunalini at all the growth stages as compared to the other varieties. The maximum LAI value (4.05) recorded at 60 DAT which gradually declined reaching to 2.64 at 90 DAT. This might be due to the capability of the variety to produce higher number of leaves with greater leaf area which resulted in higher LAI as compared to other varieties. The gradual decline in LAI after 60 DAT might be due to death of some ineffective tillers that results in lack of solar radiation which is required to carry out photosynthetic activity.

Dry matter accumulation (DMA) at different stages of growth can be said as the sum total of vegetative growth *i.e.* growth in height and foliage. Rate of crop dry matter accumulation is the product of total incident solar radiation, the absorption of incident solar radiation by the crop canopy and the efficiency of conversion of the absorbed solar radiation into plant dry matter. The DMA showed a progressive increase with age till maturity stage of the crop. However, the rate of increase was rapid till 60 DAT and then it increased in a slower rate. This might be due to the higher rate of photosynthesis which is the result of higher number of tillers and higher LAI and in later stage it declined due to reduction in photosynthesis as a result of senescence of tillers and leaves. The highest rate of dry matter accumulation was observed between 45 DAT to 60 DAT (209.3 g m^{-2}) coinciding with the peak vegetative growth phase.

The fertility level and split application of nitrogen showed significant effect on dry matter accumulation in all the growth stages. At harvest, the highest dry matter accumulation (1409 g m^{-2}) was recorded with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits. This might be due to increase in assimilation of photosynthates that attributed to better balanced nutrition in higher levels of fertiliser which resulted in higher dry matter accumulation. Among the varieties, Mrunalini was observed with higher dry matter accumulation (1481.4 g m^{-2}) at harvest as compared to other varieties. It was also found with the highest accumulated dry matter (1481.4 g m^{-2}) at harvest when fertilised with of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} under four split application.

The maximum crop growth rate (19.31 g m^{-2} day^{-1}) was observed between 45-60 DAT and the minimum is observed at ripening stage (9.06 g m^{-2} day^{-1}). This might be due to greater accumulation of dry matter in the initial stages as a result of higher photosynthesis rate. Application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} under four splits resulted in higher CGR (19.40 g m^{-2} day^{-1}) at 45-60 DAT period. This might be due to the better utilisation of resources at higher fertility level that resulted in higher crop growth rate.

Among the varieties, Mrunalini observed with higher CGR (21.63 g m^{-2} day^{-1}) at 45-60 DAT as compared to other varieties. The best result was also obtained in Mrunalini when fertilised with of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} under four split application. This variation in crop growth rate among the varieties might be because of peculiar genetic drive for accumulation of photosynthates at different growth stages.

The relative growth rate (RGR) was found the maximum (0.026 g g^{-1} day^{-1}) during 45-60 DAT. This might be due to the peak tillering rate at this stage. Application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits resulted in the maximum RGR (0.028 g g^{-1} day^{-1}) at 45-60 DAT. This might be due to better availability of nutrients and compatibility of micro-environment which resulted in higher growth rate even at lowest fertility level. Swarna variety was found to produce higher RGR (0.028 g g^{-1} day^{-1}) followed by Mrunalini (0.027 g g^{-1} day^{-1}) during 45-60 DAT.

Thus, from the above discussion, it is found that the growth performance with regards to plant height, tiller number, dry matter accumulation, LAI, crop growth rate and relative growth rate were higher under higher fertility level (100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1}) in four split application of nitrogen due to balance level of nutrient supply which resulted in better utilisation of resources adding to better growth performance of crop. Likewise, among the varieties, Mrunalini was found to give higher plant height, higher number of tillers, higher LAI, higher dry matter accumulation with greater crop growth rate but Swarna was observed with higher relative growth rate at low fertility level.

5.3 Yield and yield attribute

Yield of a crop is influenced by its yield attributing characters. The major yield attributing characters in rice include panicle length, number of panicles m^{-2}, total number of grains $panicle^{-1}$, number of fertile grains $panicle^{-1}$, fertility%, 1000-grain weight etc.

In present investigation, application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits resulted in the highest panicle length (26.18 cm), higher number of panicles m^{-2}

(335.83), higher number of total grains panicle^{-1} (198.48), higher number of fertile grains panicle^{-1} (154.73), the maximum fertility% (77.49%) and the highest 1000-grain weight (20.03 g).

The increase in panicle length with higher fertility level might be due to better growth and dry matter accumulation ensuring better photosynthetic efficiency which resulted in increasing the source strength to accumulate photosynthates which in turn increased the size of the sink i.e. increase in length of the panicle.

The higher number of panicles m^{-2} might be due to higher early growth with the higher fertility level which increased tiller production and reduced tiller mortality due to balanced nutrition. As the panicle length was more it accommodated more number of spikelets.

The total number of grains panicle^{-1} (filled grains) is one of the important parameters contributing towards grain yield. The application of higher dose of fertiliser produced better growth that resulted in increased accumulation of photosynthates and translocation of these photosynthates to the reproductive part thereby increasing the number of filled grains per panicle. The increase in panicle length also increased the accommodation of total number of grains panicle^{-1}.

The number of fertile grains panicle^{-1} was increased with increase in level of fertiliser because of higher photosynthetic efficiency and more effective translocation of photosynthates to the grain resulting in well filled grain and also with increased fertility percentage.

The test weight of grain was the highest at higher fertility level because of better grain filling by balanced nutrition and sufficiency in nutrient availability. Higher photosynthetic efficiency as well as more effective translocation of photosynthates to the grain might also have increased the grain filling and weight of grain.

Among the varieties, Hasanta recorded the highest panicle length (29.14 cm). However, Mrunalini was observed with the highest number of panicles m^{-2} (489.33), higher number of total grains panicle^{-1} (221.74), higher number of fertile grains panicle^{-1} (189.20) and the highest 1000-grain weight (22.08 g). The highest fertility percentage was found in Ashutosh (86.47%). This variation in yield attributing characters among the varieties might be due to the variation in genetic potential between them. The higher number of fertile grains in Mrunalini might be due to its better dry matter partitioning ability. The test weight of a particular variety is more or less fixed.

Grain yield is a function of interaction of various yield components such as number of effective tillers m^{-2}, grains $panicle^{-1}$ and grain weight. It is also a result of cumulative effect of several growth factors mainly comprising of genetic, environmental and management aspects corresponding to meet the optimum need of the crop at different growth stages.

During ripening, about 70% of nitrogen absorbed by the straw will be translocated to the grain. Nitrogen content of the grain tends to be maintained at a certain percentage. When a large number grains relative to the size of vegetative parts is produced, more nitrogen will be needed to support grain growth and there will be a sharper drain in leaf nitrogen content. Some grains may suffer from nitrogen shortages. So to produce high yield, it is essential to maintain the level of leaf nitrogen required for higher photosynthetic activity. This requirement can be met when nitrogen absorption by a crop is continued after heading. (Yoshida, 1981)

The maximum grain yield (4.87 t ha^{-1}) was observed under application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits. This might be due to better growth and more effective translocation of photosynthates that resulted in production of more number of effective tillers, total grains, higher number of fertile grains $panicle^{-1}$, fertility percentage and test weight. Better chlorophyll development might have improved the vegetative and reproductive growth of the crop which influenced directly or indirectly in increasing the production potential under higher fertility level. Due to the application of an extra split of nitrogen at flowering stage, balanced nutrient availability will be there in post flowering phase which might have encouraged dry matter partitioning leading to better grain filling and higher test weight supplementing to higher grain yield. Higher leaf area under higher fertility level also added to the increased dry matter partitioning that resulted in higher grain yield. Ramasamy *et al.* (1997) also reported that application of late nitrogen dose at flowering stage developed leaf senescence, enhanced grain filling and increased yield of rice.

Application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits also resulted in higher straw yield (7.2 t ha^{-1}) and lowest grain: straw ratio (0.67) and harvest index (40.20%). This might be due to the imbalance in nutrient availability and uptake. Another probable reason for increasing straw yield is the more number of tiller production under higher fertility level. There might be imbalance in potassium availability at high level of nutrient application which was mainly responsible for improper translocation of photosynthates from source (vegetative part) to sink (reproductive part) that resulted in lower harvest index and grain: straw ratio.

Each variety is having its specific genetic potential to produce exclusive yield attributing abilities and yield under favourable environmental condition. In the present study, Mrunalini recorded higher grain yield (5.06 t ha^{-1}) and straw yield (7.41 t ha^{-1}) and the lowest grain: straw ratio (0.68) and harvest index (40.67%). The yield advantage of this variety over others might be attributed to the higher value of yield attributing characters such higher number of panicles m^{-2}, more number of grains $panicle^{-1}$, more number of fertile grains $panicle^{-1}$, higher fertility% and maximum 1000-grain weight etc.

The interaction effect also revealed higher grain of Mrunalini under application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits recorded significantly higher grain yield (5.61 t ha^{-1}) and straw yield (8.76 t ha^{-1}).

5.4 Nutrient Studies

The nutrient uptake capacity of a plant depends upon the availability of nutrients and absorption capacity of plant which results in crop yield. Nutrient uptake is controlled by availability of both added and inherent sources of nutrients in the soil and absorption capacity, ramification and distribution of plant roots.

The variation in nutrient content under application of different fertility levels found to be very less. Higher nitrogen content in grain (1.30%) and higher potassium content in straw (1.58%) was observed under application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in three splits and higher grain nitrogen content (0.39%) was found under same fertility level when applied in four splits. The maximum P content in both grain (0.30%) and straw (0.13%) was recorded when fertilised with 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits. This might be due to the existence of inverse relationship between the nutrient content and the yield which is stated under the Inverse yield nitrogen law (Wilcox, 1929). This inverse relationship is due to the dilution effect of the nutrients in plant body in higher yield. Another probable reason behind this inverse relationship is higher interplant competition in plants with comparatively more growth which results in less nutrient content.

Among the varieties, Swarna was observed with the highest N (1.33%,0.41%), P (0.33%,0.13%) and K (0.24%,1.62%) content both in grain and straw as compared to other varieties. This might be due to the lower yield potential of Swarna variety as compared to the other varieties.

Higher nitrogen uptake (61.43 kg ha^{-1} in grain, 26.72 kg ha^{-1} in straw), phosphorous uptake (17.93 kg ha^{-1} in grain, 7.95 kg ha^{-1} in straw) and potassium uptake (10.75 kg ha^{-1} in grain, 111.9 kg ha^{-1} in straw) was recorded under application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits of nitrogen. This might be due to the higher biomass production under the higher fertility level as compared to the lesser dose. Higher uptake of nitrogen might be due to better established roots, better plant growth and yield under increased N level (Jaiswal and Singh, 2001).

Among the varieties Mrunalini was recorded with the highest total nutrient uptake (237.26 kg ha^{-1}) and Swarna was recorded with the lowest total nutrient uptake (185.62 kg ha^{-1}). Pradhan *et al*. (2013) also noticed that the lowest uptake of nitrogen by grain and straw was found in 'Swarna' variety. Though Mrunalini was observed with the lowest nutrient content both in grain and straw, its uptake is higher because of the genetic potential of the variety to produce higher total biomass production as compared to other varieties.

5.5 Comparative economics

The economics of production is the most important aspect of a study since no farmer shall follow a practice that is not remunerative to them even if the yield and gross return becomes high and soil fertility is maintained.

The highest cost of cultivation (Rs. 45190 ha^{-1}) was found under application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits. This might be due to the use of more fertiliser as compared to the lesser level. The human labour requirement for application of fertiliser of an extra split at flowering stage was also included. Mrunalini variety when fertilised with 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits of nitrogen resulted in the maximum net return (Rs.42765 ha^{-1}) and B:C ratio (1.95). This might be due to the higher value of yield attributing characters that ultimately resulted in increase in yield which is the cause for higher gross and net return.

SUMMARY AND CONCLUSION

A field experiment was conducted during *kharif* season of 2017 to study the "Response of rice variety to fertility level and split application of nitrogen fertiliser under medium land condition" at Agronomy Main Research Station, Orissa University of Agriculture and Technology, Bhubaneswar. The experiment was laid out in Split-plot design with sixteen treatment combinations and three replications. Two fertility levels (100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} and 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}) each with two different splitting schedules of nitrogen (¼ basal + ½ tillering + ¼ PI) and (¼ basal + ½ tillering + 1/8 PI+ 1/8 flowering) were assigned to four different varieties (Hasanta, Mrunalini, Ashutosh and Swarna). The soil of the experimental site was sandy loam, acidic in reaction (pH 5.6), medium in organic carbon (0.71 %), low in available nitrogen (223 kg ha^{-1}), medium in available phosphorus (20 kg ha^{-1}) and medium in potassium (211 kg ha^{-1}). Fertility levels with different splits of nitrogen were allocated to main plots and the varieties were accommodated in subplots.

Observations on phenology, growth, yield and yield attributing characters, nutrient content and uptake, residual soil fertility and comparative economics under application of different levels of fertiliser and splits of nitrogen were recorded, analysed and salient findings of the above investigation are summarised below:

1. Rice variety Ashutosh required maximum time for panicle initiation, days to 50% flowering and days to maturity irrespective of levels of fertilizer and split application of nitrogen while Swarna took the minimum time to attain all the three phenophases.

2. The maximum plant height of 116.71cm was observed with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering) at harvest. Rice variety Ashutosh was recorded with the maximum plant height (123.34 cm) among all the varieties.

3. The maximum number of tillers m^{-2} of 412.34 was observed at 60 DAT with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits. In all the growth

stages, rice variety Mrunalini was observed with the maximum number of tillers m^{-2} at 60DAT (451.13).

4. Application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits showed the maximum value of LAI 3.93 at 60 DAS. LAI at all growth stages was found the maximum for rice variety Mrunalini reaching the maximum value (4.05) at 60 DAT.

5. The maximum dry matter accumulation 1409 g m^{-2} was observed at harvest with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering). Among the varieties, Mrunalini has accumulated the maximum amount of total dry matter 1481.4 g m^{-2} at harvest.

6. The maximum crop growth rate 19.40 g m^{-2} day^{-1} was observed at 45-60DAS with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits. Among the rice varieties, Mrunalini was recorded with the maximum CGR 21.63 $gm^{-2}day^{-1}$ during 45-60 DAT.

7. The maximum RGR 0.266 g g^{-1} day^{-1} was observed at 45-60 DAT with application of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits. Among the varieties, Swarna was recorded with the maximum RGR (0.0275 g g^{-1} day^{-1}) at 45-60 DAT.

8. The maximum panicle length at harvest (26.18 cm) was recorded with application of 100 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering). Among the varieties, Hasanta was observed with the longest panicle length (29.14 cm) at harvest.

9. Increasing levels of fertiliser increased the number of panicles. The highest number of panicles m^{-2} (335.83) was recorded with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits that is ¼ basal + ½ tillering + 1/8 PI + 1/8 flowering. Among the varieties, the maximum number of panicles m^{-2} (489.33) was recorded in Mrunalini.

10. Application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering) has shown the highest number of grains $panicle^{-1}$ (198.48). Among the varieties, Mrunalini was recorded with the highest number of grains $panicle^{-1}$ (221.74).

11. The highest number of fertile grains $panicle^{-1}$ (154.73) were recorded with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits. Among the varieties, Mrunalini was recorded with the highest number of grains $panicle^{-1}$ (189.20).

12. Application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering) has shown the highest percentage of fertility that is 77.49%. Among the varieties, Ashutosh recorded the highest fertility percentage (86.47%).

13. Increasing levels of fertilisers increased the 1000 grain weight. The maximum 1000 grain weight (20.03g) was recorded with application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits. Among the varieties, Mrunalini recorded the highest test weight (22.08 g).

14. The grain yield of rice increased with increase in fertility level and split application of nitrogen. Application of 100:50:50 kg $N:P_2O_5:K_2O$ $ha^{-1}$with four splits of nitrogenous fertiliser (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering stage) recorded the highest grain yield of 4.87 t ha^{-1} than three splits and less fertility level (80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1}). Among different varieties, Mrunalini recorded the highest grain yield of 5.06 t ha^{-1}.

15. The maximum straw yield of 7.2 t ha^{-1} was observed at fertility level of 100:50:50 kg $N:P_2O_5:K_2O$ $ha^{-1}$with 4 split applications. Among the varieties, Mrunalini recorded the highest straw yield of 5.21 t ha^{-1} than other 3 varieties. However, the maximum straw yield of 8.76 t $ha^{-1}$was recorded when Mrunalini variety was fertilised with 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in 4 split applications.

16. The Grain: Straw ratio decreased with increase in fertiliser dose and split application of nitrogen. The highest Grain: Straw ratio of 0.77 was noticed with less fertility level of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in 3 split applications. Among the varieties, Hasanta and Ashutosh recorded the highest Grain: Straw of 0.75. On the other hand highest Grain: Straw of 0.82 was recorded in variety Hasanta when fertilised with 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} in 3 split applications.

17. The fertiliser dose of 80:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} with 3 split application of nitrogen recorded the highest Harvest index of (43.77%). Among the varieties, Hasanta recorded the highest harvest index of (43.00%).

18. The highest nitrogen uptake (61.43 kg ha^{-1}, 26.72 kg ha^{-1}), phosphorus uptake (17.93 kg ha^{-1}, 7.95 kg ha^{-1}) and potassium uptake (10.75 kg ha^{-1},111.91kg ha^{-1}) both in grain and straw was observed under application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits. Among the varieties, Mrunalini was recorded with the highest total nutrient (NPK) uptake of (237.26 kg ha^{-1}).

19. Mrunalini variety when fertilised with 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits of nitrogen resulted in the maximum net return (Rs. 42765 ha^{-1}) and B:C ratio (1.95).

CONCLUSION

From the above experiment it is concluded that application of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} in four splits of nitrogen (¼ basal + ½ tillering + 1/8 PI + 1/8 flowering) in rice variety Mrunalini produced the maximum grain yield of 5.61 ton ha^{-1} and straw yield of 7.27 ton ha^{-1} with the maximum net return (Rs.42765 ha^{-1}) and B-C ratio (1.95) under medium land condition. So the treatment can be recommended to the farmers for getting higher productivity and profitability. However, as the recommendation is based on findings of one year experiment, it needs further verification before final documentation.

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APPENDIX-I

Cost computation (Rs.)

Treatment	grain yield **(t ha^{-1})**	straw yield **(t ha^{-1})**	price of grain (Rs. **ha^{-1})**	price of straw (Rs. **ha^{-1})**	gen cost of cultivation (Rs. **ha^{-1})**	Additional cost		total cost ofcultivation (Rs. **ha^{-1})**	Gross return (Rs. **ha^{-1})**	Net return (Rs. **ha^{-1})**	B:C
						Fertiliser (Rs. **ha^{-1})**	Labourer (Rs. **ha^{-1})**				
$V_1F_1S_1$	4.03	4.89	56917	4890	42000	-	-	42000	61807	19807	1.47
$V_2F_1S_1$	4.59	6.41	64719	6413	42000	-	-	42000	71132	29132	1.70
$V_3F_1S_1$	4.11	5.24	57998	5240	42000	-	-	42000	63238	21238	1.51
$V_4F_1S_1$	3.40	4.30	48034	4300	42000	-	-	42000	52334	10334	1.25
$V_1F_1S_2$	4.07	5.18	57481	5180	42000	-	2135	44135	62661	18526	1.42
$V_2F_1S_2$	4.91	6.89	69278	6897	42000	-	2135	44135	76175	32040	1.72
$V_3F_1S_2$	4.28	5.64	60348	5640	42000	-	2135	44135	65988	21853	1.49
$V_4F_1S_2$	3.54	4.79	49961	4790	42000	-	2135	44135	54751	10616	1.24
$V_1F_2S_1$	4.35	6.04	61335	6040	42000	1055	-	43055	67375	24320	1.56
$V_2F_2S_1$	5.12	7.58	72192	7583	42000	1055	-	43055	79775	36720	1.85
$V_3F_2S_1$	4.47	5.81	63074	5813	42000	1055	-	43055	68887	25832	1.59
$V_4F_2S_1$	3.67	5.22	51747	5227	42000	1055	-	43055	56974	13919	1.32
$V_1F_2S_2$	4.63	6.69	65377	6693	42000	1055	2135	45190	72070	26880	1.60
$V_2F_2S_2$	5.61	8.76	79195	8760	42000	1055	2135	45190	87955	42765	1.95
$V_3F_2S_2$	5.03	7.27	70923	7273	42000	1055	2135	45190	78196	33006	1.73
$V_4F_2S_2$	4.19	6.30	59173	6307	42000	1055	2135	45190	61807	20290	1.45

Sale rate : cost: N@ Rs. 13.00 kg $^{-1}$
grain – Rs. 1410 qtl^{-1} P@ Rs. 50.00 kg $^{-1}$
straw – Rs. 100 qtl^{-1} K@ Rs. 29.50 kg $^{-1}$