Agronomic evaluation of *Pusa Basmati*-1509 for yield and quality under varied transplanting dates and nitrogen levels

Showkat Hussain Mughal
(2013-A-938-M)

Division of Agronomy

Faculty of Agriculture

Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

2015

Agronomic evaluation of *Pusa Basmati*-1509 for yield and quality under varied transplanting dates and nitrogen levels

Showkat Hussain Mughal
(2013-A-938-M)

Thesis

Submitted to

The Faculty of Agriculture
Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

in partial fulfilment of requirement for the award of the degree of

Master of Science in Agriculture
(Agronomy)

2015

Dedicated
to my beloved Parents

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Agronomy

Certificate – I

This is to certify that the thesis entitled, **"Agronomic evaluation of *Pusa Basmati*-1509 for yield and quality under varied transplanting dates and nitrogen levels"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy)**, to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Showkat Husain Mughal (Regd. No. 2013-A-938-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

(Dr. Ashaq Husain)
Chairman
Advisory Committee

Endorsed

Professor & Head,
Division of Agronomy

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Agronomy

Certificate – II

We, the members of the Advisory Committee of **Mr. Showkat Husain Mughal (Regd. No. 2013-A-938-M)**, a candidate for the degree of **Master of Science in Agriculture (Agronomy)** have gone through the manuscript of the thesis entitled, **"Agronomic evaluation of *Pusa Basmati*-1509 for yield and quality under varied transplanting dates and nitrogen levels"** and recommend that it may be submitted by the student in partial fulfillment of the requirements for the award of the degree.

Advisory Committee

Chairman

Dr. Ashaq Hussain
Associate Professor (Agronomy),
RRS/FoA, SKUAST-Kashmir

Members

Dr. Mohd. Anwar Bhat
Associate Professor (Agronomy),
MRCFC, Khuwani

Dr. Javid Ahmad Sofi
Associate Professor (Soil Science),
RCRQA, SKUAST-Kashmir, Shalimar

Dr. S.A. Mir
Prof. and Head, Division of Agri-Statistics,
SKUAST-Kashmir, Shalimar

Dean's Nominee

Dr. N.A. Khan
Professor, Division of Plant Pathology,
SKUAST-Kashmir, Shalimar

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Agronomy

Certificate – III

This is to certify that the thesis entitled, **"Agronomic evaluation of *Pusa Basmati*-1509 for yield and quality under varied transplanting dates and nitrogen levels"** submitted by **Mr. Showkat Hussain Mughal (Regd. No. 2013-A-938-M)** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy)** was examined and approved by the Advisory Committee and External Examiner on …………….

Chairman
Advisory Committee

External Examiner

Professor & Head,
Division of Agronomy

Dean
Faculty of Agriculture,
SKUAST-Kashmir

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Agronomy

Name of the student	:	**Showkat Hussain Mughal**
Registration No.	:	2013-A-938-M
Major Subject	:	Agronomy
Minor Subject	:	Soil Science/Plant Physiology
Major Advisor	:	**Dr. Ashaq Hussain** Associate Professor (Agronomy), RRS and FOA, Wadura
Title of the Thesis	:	**"Agronomic evaluation of *Pusa Basmati*-1509 for yield and quality under varied transplanting dates and nitrogen levels "**

ABSTRACT

A field experiment entitled "Agronomic evaluation of Pusa Basmati-1509 for yield and quality under varied transplanting dates and nitrogen levels" was conducted at Mountain Research Station for Field Crops, Khudwani, SKUAST-K during Kharif 2014 to study the influence of transplanting dates and levels of nitrogen fertilization on growth, yield and quality of scented rice cv. *Pusa Basmati-1509*. The soil of the experimental field was silty clay loam in texture with neutral pH, low in available nitrogen, medium in available phosphorus, potassium and organic carbon. The crop management was done as per recommended package of practices and monetary and non-monetary inputs *viz*. planting dates (20th May, 1st June and 11th June) and nitrogen levels (0, 30, 60, 90 and 120 kg N ha^{-1}) were altered in order to study their effect on growth, yield , quality as well as economics of the crop. The experiment comprising of 15 treatment combinations was laid in split-plot design with three replications, with planting dates in main plots and nitrogen levels in sub plots. Thirty day old seedlings were transplanted on well puddled soil at a hill spacing of 15 x 15 cm with 3 seedlings per hill. Among transplanting dates, early transplanting of 20th May and 1st June significantly increased the growth parameters viz. plant height, leaf area index, tillers m^{-2}, dry matter accumulation, leaf area index and SPAD reading over the late planted crop i.e. 11th June. The highest plant height (88.68 cm), tillers m^{-2} (338.8) and dry matter (94.07 q ha^{-1}) were recorded for the 20th

May transplanting. Yield contributing characters like panicles m^{-2} (337.69), panicle length (24.08 cm), panicle weight (1.58 g), spikelets $panicle^{-1}$ (94.88) and filled grains $panicle^{-1}$ (72.20) were also higher for the 20th May, which resulted in highest grain (41.51 q ha^{-1}), straw (67.21 q ha^{-1}) and biological yield (108.72 q ha^{-1}). Also quality parameters like head rice recovery (44.16 %), grain grade 1 (45.35%), kernel length (9.22 mm) and breadth (1.72 mm), kernel length after cooking (15.74 mm) was improved in the early transplanted crop. However, sterility per cent a negative attribute as far as yield is concerned was highest for the late planted crop, and was in the order of 23.63, 28.55 and 33.59 per cent for 20th May, 1st June and 11th June transplanted crop, respectively. Among the different nitrogen levels (0, 30, 60, 90 and 120 kg N ha^{-1}), all growth parameters were found significantly higher in the nitrogen level of 120 kg ha^{-1} and was closely followed by nitrogen level of 90 kg ha^{-1}. The highest plant height (90.37 cm), tillers m^{-2} (350.2) and dry matter (95.72 q ha^{-1}) were recorded for nitrogen level of 120 kg ha^{-1}. The yield contributing characters *viz.* panicles m^{-2} (345.60), spikelets $panicle^{-1}$ (96.27), panicle length (24.04 cm) and panicle weight (1.69 cm) were also recorded highest for the nitrogen level of 120 kg ha^{-1}. The highest filled grains $panicle^{-1}$ (66.33) was recorded for the nitrogen level of 90 kg ha^{-1}. The uptake of nitrogen by grain and straw at harvest was highest for nitrogen level of 120 kg N ha^{-1}. The highest grain yield (45.55 q ha^{-1}) and biological yield (113.86 q ha^{-1}) were found for nitrogen level of 90 kg ha^{-1}. Straw yield (70.42 q ha^{-1}) was recorded highest by the usage of higher dose of nitrogen i.e. 120 kg ha^{-1} and was closely followed by nitrogen level of 90 kg ha^{-1}. Quality parameters like head rice recovery, kernel length, kernel breadth and kernel length after cooking was also recorded highest for the 120 kg N ha^{-1}. However, sterility per cent (33.14%) was also highest for the treatments receiving 120 kg N ha^{-1}. The other nitrogen levels recorded lower growth, yield and yield contributing characters while as control recorded the lowest. The highest B:C ratio (3.84) was obtained from the treatment which was transplanted in 20th May and received 90 kg N ha^{-1}.

Key words : Pusa Basmati-1509, transplanting dates, nitrogen levels, growth, yield, quality

Signature of Student | Signature of Major Advisor

Dated____________ | Dated ________________

ACKNOWLEDGEMENTS

In the name of Almighty, "Allah", the most Beneficent and Merciful, Billions of peace and Blessings be upon Holy Prophet (SAW). I bow in reverence to Almighty for giving me enough courage, patience and success in this venture.

I take this opportunity to express my sincere and profound gratitude to Dr. Ashaq Hussain, Associate Professor (Agronomy), RRS and FOA, Wadoora and Chairman of my advisory committee for his valuable guidance and constant encouragement throughout the course of study. His dynamic attitude, inspiring guidance and wholehearted encouragement led this task to its success and shall remain a life-long gifted memory for me.

I owe to express my deepest sense of gratitude and heartfelt regards to Dr. K.N. Singh, Associate Director Research (Agriculture), Dr. Raihana Habib Kanth, Professor and Head, Division of Agronomy, RRS and FOA, Wadoora for rendering all kind of help, whenever I needed it. Their professional command and excellent calibre graced me with an unparallel boon in achieving the dignified goal. It is because of their guidance, enthusiastic and affectionate advice and constant encouragement that I could complete these studies in time.

I extend my sincere thanks to members of my advisory committee Dr. Mohd. Anwar Bhat, Associate Professor, Agronomy, MRCFC, Khudwani Dr. Shakeel Ahmad Mir, Head, Division of Agri-Statistics, Dr. Nayar Afaq Kirmani, Associate Professor, Division of Soil Science and Dr. N. A. Khan, Professor, Division of Plant pathology (Dean PG Nominee) for their valuable guidance and suggestions during the study and for helping in finalization of the manuscript.

My sincere gratitude and thanks are to Dr. Sameera Qayoom, Dr. Porshotum Singh, Dr. Lal Singh, Dr. R. Kotru, Dr. Farooq A. Aga, Dr. Amal Sexina, Dr. Naseer A. Dar, and Dr. Manzoor Ahmad, Ganaie, Division of Agronomy, SKUAST-K for their guidance, valuable suggestions, whole hearted support and timely help which made this challenging task to its successful end.

I am highly thankful to all members of teaching/research and supporting staff, especially to Dr. Najeeb-ur-Rehman Sofi, Dr. Aflaq Hamid,Dr. Mohd. Iqbql Jeelani, Dr. Nigeena Nazir, Dr. Bilal Ahmad Lone, Dr. F.A Peer, Dr. F. A. Bahar, Dr. Tasleem Mubarak, Dr. Lateef Ahmad, Mr. Nazir Ahmad Teli for their constant help, encouragement and suggestions as and when needed.

I would like to dedicate a special note of thanks with pride and joy to Mr. Mohd. Ashraf Bukhari[IAS](Commissioner/Secretary Agriculture Production Department, Government of Jammu & Kashmir), Mr. Altaf Ajaz Andrabi (Director Agriculture ,Kashmir Division),Mr. Aijaz Ahmad Raina (District Agriculture Officer, Extension, District Anantnag) and Mr. Mohd. Iqbql Sheikh (Sub-Divisional Agriculture Officer, Sub- Division Achabal) who have gave me an opportunity to enter in to the field of research deserve a special mention.

Special thanks to my friends and colleagues Tawseef Ahmad Bhat, Sheeraz Ahmad Wani, Aijaz Ahmad, Rihana Mohi-ud-din, Hilal Ahmad Bhat, Sham-sul-haq, Mehraj ud Din Khanday, Malik Reyaz Ahmad, Javaid Ahmad Dar, Bilal Ahmad Sheikh, Muzaffar Ahmad Naik, Muzaffar Ahmad Bhat, Nisar Ahmad Ganaie, Mohd. Shafi Dar and Syed Ishtiyaq Qadri for their cooperation, appreciation and nice company during my studies.

I am highly thankful to ARIS and Library staff members of SKUAST-K for their constant encouragement, valuable suggestions and generous help during preparation of this manuscript.

I express my sincere thanks to all concerned instructors, who instructed me from time to time and encouraged me during the period of study. I am also thankful to all the non-teaching staff of Division of Agronomy especially, Mr. Mohd. Shafi, Mr. Mustaq Ahmad, Mr. Gulzar Ahmad and other office and field staff of the Division of Agronomy for their support and cooperation.

All words in the Lexon will be futile and meaningless, if I fail to pay my heart felt reverances to my father Late Assadullah Mughal and my mother Mrs. Hafiza Begum, who nourished and educated me well inspite their hardships and difficulties and for their constant inspiration and heart felt blessings during the course of study. My mother proved a symbol of patience and courage and was the real driving force behind my research work.

Words fail to express my gratitude to my loving sisters (Dr. Shaheena Parveen, Farhat Ara), Son (Mohd. Musa), for their good wishes, moral support, sustained help and constant encouragement which enabled me to complete this uphill task.

I am highly indebted to my life partner Mrs. Rozy Jan for her painstaking efforts, cooperation, enduring patience and encouragement to undertake and complete this project at the cost of her personal convenience and comfort. Her family should not escape my attention, their support and wishes deserve a must mention.

My thanks and appreciation is due for M/s Universal Computers, Shalimar Srinagar for nicely composing this manuscript.

Last but not least, I thank all those who helped me any way during the course of the study. I thank them one and all.

Showkat Hussain Mughal

Place: Shalimar, Srinagar

Dated: ……………………

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

cm	:	Centimetre
m	:	Metre
m^{-2}	:	Per metre square
g	:	Gram
kg	:	Kilogram
q	:	Quintal
KLAC	:	Kernel length after cooking
LAI	:	Leaf area index
SMW	:	Standard meteorological week
GDD	:	Growing degree day
SPAD	:	Soil plant analytical device
ha	:	Hectare
ha^{-1}	:	Per hectare
N	:	Nitrogen
P	:	Phosphorus
K	:	Potassium
FYM	:	Farmyard manure
DAT	:	Days after transplanting
HI	:	Harvest index
CD	:	Critical difference
SEm±	:	Standard error of mean
^{o}C	:	Degree Celsius
mm	:	Millimetre
%	:	Per cent

Chapter - 1

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important crop in India and is also the hub of food security for the global population. At the global level, rice is grown on an area of 155.62 m ha with a production and productivity of 461 MT and 4.09 t ha^{-1}, respectively (Anonymous, 2012). It is the primary food source for more than one third of the world's population and grown in 11% of the world's cultivated area (Islam, 2009). It is the main cash crop and source of livelihood for the rural population in developing regions. Because of the large number of people subsisting on rice, its annual output should be increased by over 5×10^6 t a year to keep pace with population growth (IRRI 1997). It provides 32-59% of the dietary energy and 25-44% of the dietary protein in 39 countries (Shah and Kumar, 2014). Rice is considered as the first cultivated crop of Asia. Its cultivation is of prime importance to food security of Asia, where more than 90% of global rice is produced and consumed (DES, 2012). Rice is the lifeline for Asians as it is not only a dominant food crop but also an important crop in the national economy. It accounts for a major share of cereal consumption, ranging from 40% in India to 97% in Myanmar. Rice contributes 30-76% of total daily calorie intake (Hossain and Pingali, 1998).

India ranks first with respect to area (43.95 m ha) and second in production (106.54 MT), only after China, but the productivity of rice is only 2.42 t ha^{-1} (DES, 2014). India contributes 21.5% of global rice production. Within the country, rice occupies one-quarter of the total cropped area, contributes about 40 to 43 per cent of total food grain production, providing direct employment to 70% of rural population (DES, 2012). But the share of the rice in national economy, as well as the agricultural products export is very low.

The unique varietal group that has distinguished itself because of natural and human selection with acceptance all over the world as specialty rice is called basmati rice. The salient features of basmati rice such as extra long slender grain, length wise excessive elongation on cooking, soft and fluffy texture of cooked rice and pleasant aroma determine its uniqueness. Basmati rice is known as the queen of rice (Singh *et al.,* 2008). Unlike other aromatic rices the unique quality traits of basmati rice" find their expression only when they are grown in the north western foot hills of Himalayas and parts of Punjab, Haryana, Jammu and Kashmir and Western parts of Uttar Pradesh in the Indian Sub-continent. Indian has huge market for basmati rice as it has high demand not only in India but in foreign countries as well. Under the changing scenario of the international agricultural market, there is a tremendous scope for the exploitation of such indigenous rice varieties which are unique in their aroma, taste and cooking quality. There are various scented rice varieties, which are being cultivated on a commercial scale in India, e.g. Vasumati, Yamini, Pusa Sugandh 1, Pusa Sugandh 2, Pusa Sugandh 3, PRH 10, Basmati 370, Ranbir Basmati, Pant Sugandhdhan 15, Sugandhamati, Pusa Sugandh 5, Pusa Basmati - 6, etc. The average selling price of the scented rice varieties is ₹8500/quintal (Anonymous, 2013) as compared to that of the conventional rice varieties which is ₹1500/quintal (Anonymous, 2014), speaks of their scope under decreasing land holding size of 1.15 ha in India (DES, 2014).

Rice is the staple food crop of Jammu and Kashmir, where it is cultivated in temperate, intermediate as well as subtropical zones. The total area under rice cultivation is 0.27 m ha with a production and productivity of 0.90 m t and 3.2 t/ha, respectively (DES, 2013). Of the total rice grown in the state of J&K, aromatic cultivars are cultivated on an area of 3.2 x 10^4 ha with a production of 6.24 x 10^4 t and an average yield of 1.9 t/ha, fetching 45 corers of rupees annually (DES, 2008). The major aromatic rice growing belt of J&K is R.S. Pora of Jammu region, where high quality superior aromatic rice is grown. In Kashmir valley, *japonica* type of aromatic rice is grown in scattered areas and the main varieties are the traditional land races, which farmers have saved and used from very old times. Since, these varieties are highly susceptible to disease as well as lodging and produce very low yields, therefore they are cultivated on a very small area. But recently some new high yielding semi-dwarf basmati varieties like Pusa Sugandh-2, Pusa Sugandh-3 and Pusa Sugandh-5 released by IARI, have been tested at Mountain Research Centre for Field Crops (MRCFC), Khudwani. These varieties produced good yields and proved moderately disease resistant. However, due to their longer duration (165-175 days), these varieties either failed to mature or matured late (20th October). Slow grain filling, low test weight, high sterility, chalkiness and low HRR (<50%) are the other associated problems, when these varieties are sown on the dates recommended for non-basmati types.

In Jammu and Kashmir, the agriculture in general and rice is particular, is facing tremendous challenge for its survival from the horticulture crops, especially apple. As compared to average returns of ₹70000 /ha from the conventional rice varieties, apple cultivation fetches ₹508780 /ha, thus justifying the shift from rice to apple cultivation (Malik, 2014). So, it is need of the hour that the revenue earning potential of the rice be improved through cultivation and popularization of the high value scented rice varieties. The scented rice varieties of Jammu and Kashmir are unique in quality due to soil and climate. There are various scented rice varieties being cultivated in Jammu and Kashmir, e.g., Basmati 370, Saanwal basmati, Ranbir basmati, and Pusa Sughandi. But Pusa Basmati 1509 released in 2013 is superior to others with respect to yield, grain quality, earliness, non-shattering at maturity, non-lodging habit and reduced height. As compared to selling price of ₹10-15/kg for conventional rice varieties, that of Pusa Basmati is ₹ 30-35/kg. The high selling price of the Pusa Basmati and its great demand in national and international market emphasizes the need to improve its yield and quality, so that its demand increases, thus increasing its monetary returns.

Out of the various factors which affect the yield and quality of scented rice, there is ample evidence suggesting a significant impact of nitrogen levels and transplanting dates on its yield and quality. Basmati varieties do not withstand high rates of nitrogen fertilizer to increase yield, as high nitrogen rates of make it prone to lodging, disease and insect pest attacks. Therefore, it is necessary to know the best nitrogen application rate for each variety, as well as its influence on components of yield and other agronomic parameters, such as phenology, plant height and lodging, to obtain better knowledge of productive response. Plant height in rice is positively correlated to the length of maturation cycle (Chaturvedi, 2005). A taller plant is more susceptible to lodging and responds poorly to nitrogen (Yoshida, 1978). The panicles with a low percentage of sterile flowers permit the application of higher doses of nitrogen and produce better yield (Yoshida 1981). Relatively higher dose of nitrogen, i.e., 60 kg/ha, resulted in increased incidence of insect pest attack and lodging, which lowered yield and quality of Basmati rice (Sidhu *et al.*, 2004). Increased rate of nitrogen fertilizer could increase yield but reduce the quality of grains (Conry, 1995). Soils low in nitrogen generally produce aromatic rice grain of better quality, but applications of nitrogen rates higher than those required to produce maximum yield produced low quality grain. The extremely low use efficiency of applied nitrogen in lowland rice fields (Vlek and Byrnes 1986) and the environmental hazards caused by loss of nitrogen from rice fields (Bohlool *et al*., 1992; Cassman *et al*., 1998) pose a great challenge to develop new rice varieties with enhanced nitrogen use efficiency. Plant height showed positive and significant correlation with number of days required to heading and the best time of transplanting of rice crop for balanced vegetative, reproductive growth and maximum grain production appear to be the earliest part of the season (Escuro, 1961). Plant height, tiller number and dry matter accumulation of the crop transplanted on 5th July were more than those of the crops transplanted on 20th July and 4th August (Singh[a] *et al.,* 1997). Late transplanting reduced head rice recovery and grain length breath ratio. Transplanting dates had no effect on crude protein content, but late transplanting increased it (Dhaliwal *et al.*, 1986). Rice planting on 20th July gave higher rice recovery by 0.85 and 0.30% than crop planting on 5th July and 4th August, respectively. The protein content of the grain was decreased with subsequent delay in planting by 1.62 and 1.05% from 5th to 20th July and 20th July to 4th August planting, respectively (Singh[b] *et al.,* 1997).

Time of transplanting assumes greater importance owing to shorter growing season of 140-145 days under Kashmir valley conditions. The important growth phases especially, the grain filling stage coincides with low night temperature, resulting in high sterility percentage. Moreover, the application of higher doses of fertilizer, particularly the nitrogen recommended for non-scented varieties delays the maturity and prolongs the vegetative phase of scented types. Because of the higher percentage of unfilled grains at maturity, genetic potential of scented varieties of rice has not been realized. Planting time is a major factor in rice cultivation and indirectly influences soil temperature and weather conditions to which young seedlings of rice plants are exposed during different developmental stages. The higher productivity of these scented types of rice can be achieved by manipulating the different agronomic factors, particularly the transplanting dates and nitrogen rates.

Similarly, optimum rates of nitrogen application are an important aspect of overall nitrogen management in aromatic rice for efficient nitrogen utilization and higher productivity. The non- judicious use of nitrogen fertilizers leads to decrease in yield. Excess application of nitrogen fertilizer can cause delay in crop maturity as well as high incidence of insect pest and lodging. Pusa Basmati 1509, a short duration basmati rice with high yield potential has been released by IARI, New Delhi, has given promising results in preliminary studies carried out at MRCFC, Khudwani during 2013.There is lack of information on agronomic aspects particularly transplanting date and nitrogen levels on the yield of this variety. Thus, a better scientific understanding is required for the optimization of transplanting date and nitrogen dose for timely maturity and higher yield.

Keeping in view the above facts, the present study entitled "Agronomic Evaluation of Pusa Basmati-1509 for Yield and Quality under Varied

Transplanting Dates and Nitrogen Levels" was undertaken to meet out the following objectives :

1. To study the influence of different transplanting dates on maturity, yield and quality of scented rice
2. To study the influence of different nitrogen levels on maturity, yield and quality of scented rice
3. To estimate its relative economics.

Chapter - 2

REVIEW OF LITERATURE

Rice has shaped the culture, diets and economy of thousands of millions of peoples. For more than half of the humanity rice is life. The production of rice can be increased with the manipulation of transplanting time and nitrogen levels. Time of transplanting may be one of the agronomic strategies to exploit full potential of a variety and its photoperiod sensitivity so as to harness maximum production with improved quality of grain for high premium. Time of transplanting is the most important factor influencing the growth and yield of crop. Transplanting time is indirectly determined by soil temperature and weather conditions to which young seedlings and rice plants are exposed during different development stages. Planting time is of greater importance under the Kashmir conditions where crop growing season is short and sharp decline in temperature is noticed later in the season, which is detrimental for crop growth. The optimum transplanting date is different in different agroecological conditions. Similarly, application of optimum dose of nitrogen to rice is gaining importance because nitrogen is such a key nutrient in crop production that it can never be ignored. Excess amount of N application can result in lodging of plant and reduction of yield and similarly deficiency of N may affect rice yield, so judicious application of N is important for obtaining better yield.

In this chapter, an attempt has been made to review the literature on influence of dates of transplanting and nitrogen input on yield and quality of rice. The information is from the state, country and abroad regarding the impact of sowing dates and nitrogen levels on different aspects of basmati rice.

2.1 Effect of transplanting dates

2.1.1 Growth attributes

Sowing dates significantly affect on growth period and yield of crops. These become more critical in the geographical areas characterized by short growing seasons. Sowing dates affect the growing degree day accumulation, phenology, drymatter accumulation and finally the yield of the crops. An optimum sowing date would be one that synchronises the crop pheno- stages with their optimum climatic growth factors.

There was a linear negative correlation between sowing date and growth period, in the later sowing dates (Peng-fei *et al.*, 2013).

Hossain and Sikdar (2009) from Dinajpur, Bangladesh reported that the plant height of aromatic rice varieties Kataribhog, Radhunipagal, Badshabhog, BRRI dhan 34 and BRRI dhan 38 was significantly influenced by date of transplanting. Longest plant height (142.4 cm) was obtained from 15 July and the shortest (117.05cm) from 14 August transplanting. Plant height gradually decreased with the delay in planting date.

Chopra and Chopra (2004) studied the effect of transplanting dates on phenology and growing degree days accumulation (GDD) and its effect on seed yield and quality of Pusa Basmati-1. The crop transplanted on June 30 took 109.5 calendar days and 3125.9 growing degree days from transplanting to maturity (total phenophases) which got reduced almost linearly with delay in transplanting.

Reddy *et al.* (2004) from Hyderabad observed that the accumulated degree days for the vegetative growth of rice were 1074 and 1128 during *kharif* and *rabi* seasons, respectively.

Dixit *et al.* (2004) from Maharashtra reported that panicle initiation stage started late in early sown crop (5^{th} and 10^{th} June) and 50% flowering was earlier in late crop (25^{th} June). They also observed that rice crop planted on 25^{th} June showed significantly more number of leaves at 60 DAS than the crop planting on 5^{th}, 10^{th} and 15^{th} June.

Linscombe *et al.* (2004) conducted experiments at two locations *viz.* Crowley and St. Joseph in Louisiana and showed that days from seedling emergence to 50% panicle emergence decreased at both locations as planting was delayed.

Mandal and Ghosh (2003) from West Bengal reported that the growing degree days during the periods between sowing and first leaf emergence including fourth leaf emergence and flowering increased with successive delay in sowing. They also reported that the time taken for maturity ranged from 116.2 to 120.8 days for different sowing dates and 105 to 127.3 days for different cultivars.

Nayak *et al.* (2003) from a field experiment on hybrid rice 'PA 6201', reported that early planting on 16^{th} July exhibited the maximum total and effective tillers per clump, LAI and dry matter accumulation than that planted on 31^{st} July and 16 August. One month delay in planting from 16^{th} July reduced total tiller number/hill, LAI and dry matter accumulation by 38, 13 and 18%, respectively.

Lee *et al.* (2001) reported that days from sowing to flowering were shortened as sowing dates were delayed from 25^{th} April to 5^{th} June in a field and phytotron experiment.

Norman *et al.* (1999) reported that the seedling date primarily influenced the length of vegetative period of rice with early seeded rice requiring a greater number of days to accumulate the same number of degree days units compared with later seeded rice. Patel (1999) recorded maximum number of total tillers (482 per m^2) when the crop was transplanted on 15^{th} July, which decreased significantly with delayed planting on 30^{th} July and 14^{th} August.

Productive tillers/m^2 significantly decreased due to delay in transplanting from 25^{th} July to 15^{th} August in hybrid rice (Kumar *et al.*, 1998).

Om *et al.* (1997) conducted an experiment and observed that the plant height, productive tillers/m^2 and dry matter accumulation were highest in the crop transplanted on 25^{th} June followed by 5^{th} July, 15^{th} July and 25^{th} July. Singh[b] *et al.* (1997) from Kanpur found that plant height, total tiller and dry matter accumulation of the crop transplanted on 5th July was more than that of the crop transplanted on 20th July and 4th August.

Paliwal *et al.* (1996) from Warseoni (M.P) found that early transplanting on 25th July produced significantly higher plant height (107.4 cm) than delayed transplanting on 10th and 25th August. Song *et al.* (1996) reported from Korea that delayed sowing decreased the number of days from sowing to heading in two rice cultivars.

Samdhia (1996) from Bhubaneswar found that LAI declined gradually as the planting was delayed beyond 15th July and maximum LAI of 4.64 was recorded at 60 DAP. Singh *et al.* (1996) observed that total tillers/plant in rice transplanted on 16th May and 31st May was significantly more than that of the crop transplanted on 16th June.

First week of June is considered optimum for Kashmir valley (Bali *et al.,* 1995) and first fortnight of July is recommend for north and central India

Dhiman *et al.* (1995) observed that higher plant height and dry matter accumulation/plant in earlier planting on 15th July than in delayed planting on 25th July and 5th August. Parihar *et al*. (1995) from his field experiment at Bilaspur reported that higher plant height of 84.63 and 83.75 cm in 1991 and 1992, respectively and significantly more number of effective tillers in 15th July planting as compared to both early (30th June) and late planting (30th July).

Jand *et al.* (1994) reported that there was a reduction in dry matter accumulation due to late planting (13th July) than crop planted on 13th June and 27th June and the reduction was more in Basmati-370 compared to PR-109. The leaf area index was also found to be higher in early planting.

Vandana *et al.* (1994) reported that dry matter accumulation decreased in test cultivars (PR-106, PR-109 and Basmati-370) with delay in transplanting dates.

Lee *et al.* (1994) while working under southern Alpine conditions reported that the number of days from transplanting to maximum tillering decreased with delay in transplanting date.

Reddy and Reddy (1994) reported that maximum dry matter accumulation/m^2 was recorded when planting was done on 29th August which was significantly higher than that of the crop planted on 30th July and 14th August. Sahu (1994) observed that plant height and leaf area index was significantly higher at all the growth stages under 12th July planting than the other planting dates i.e. 22th July, 1st and 11th August.

Chaudhary and Iqbal (1992) reported from Pakistan that under normal planting, the mean plant height of Basmati cultivars Basmati-370, Basmati-198 and Basmati-385, for five seasons, were 159, 140 and 132 cm, respectively while as late planting was found to reduce plant height. Reddy and Reddy (1992) found that the productive tillers/m^2 and productive tillers/hill were significantly higher when the crop was transplanted on 29th August than that of the crop transplanted on 14th August and 30th July.

Ghadekar *et al.* (1988) from Nagpur observed that the rice transplanting on 9th July recorded higher dry matter accumulation than the transplanting on 25th July. They also reported that the thermal and photo thermal requirement of short duration (IR-8), medium (Sindewahi-75) and long duration (Jagarnath) rice cultivars transplanted at 15 days intervals were measured and recorded highest (1977) thermal unit accumulation in early planting which decreased in late planting (1726). However, reverse was trend with photo thermal units.

Leaf area index generally decreased with delay in transplanting (Mandal *et al.*, 1984). Koyamma *et al.* (1973) found that plant height and number of tillers declined with delay in transplanting.

From the above cited literature it can be concluded that, all growth parameters like plant height, dry matter accumulation (q ha^{-1}), leaf area index, tillers m^{-2} were significantly higher for the early transplanting dates and decreased with delay in transplanting.

2.1.2 Yield attributes

Safdar *et al.* (2013) from Pakistan studied the performance of eight medium grain rice accessions sown on five different sowing dates (16th April, 1st May, 16th May, 1st June and 16th June) to assess their growth and yield performance under early, mid and late sown conditions and reported that paddy yield and number of grains/panicle increased with delay in sowing time up to 16th May whereas days to 100% flowering, tillers/hill and plant height decreased with delayed sowing. Among yield components number of grains/panicle showed positive linear relationship with rice yield which means yield gains were attributed to higher number of grains/panicle rather than higher number of tillers/hill. Maximum number of grains/panicle and paddy yield of almost all rice accessions under mid sown conditions (16th May) seem to be associated with non-coincidence of their reproductive growth periods with heat stress as occurred in early sown conditions (16th April, 1st May).

Tari (2012) conducted an experiment to investigate nitrogen fertilization effect at different transplanting dates on rice yield and yield traits. He used 4 nitrogen levels (60, 90, 120, 150 kg N/ha) and 2 transplanting dates (1st May and 30th May) and found that planting date had a significant effect on total tillers, fertile tillers, panicles/m^2, sterile spikelets/panicle and 1000-grain weight. All measured yield traits were influenced significantly by nitrogen fertilization. Highest number of total tillers, fertile tillers, panicles/m^2 and sterile spikelets/panicle were produced on May 30th transplanting date.

Singh *et al.* (2012) conducted an experiment in Kashmir valley to study influence of low temperature and transplanting dates (25th May, 10th June, 25th June) on rice spikelet sterility, harvest index and yield of rice (*Oryza sativa* L.) cultivars (Jhelum, China-1039, Chenab, Shalimar rice 1) and found that negative effect (% increase from normal early sowing) of late sowing on spikelet sterility was greatest in CV 'Shalimar Rice 1' (15.8-50.9% increase over early and normal sowing) followed by 'Jhelum' (19.2-46%). Under late sown conditions there was reduction in harvest index of cultivars in the order of 'Shalimar Rice 1'> 'Jhelum'> 'Chenab'> 'China 1039'.

Miri (2011) from Iran studied the response of three rice cultivars (Namat, Neda and Dasht) to four transplanting dates (5^{th} May , 20^{th} May, 5^{th} June and 19^{th} June) and found that number of reproductive tillers/hill, grains/panicle, panicle length, 1000-grain weight and plant height was increased when transplanting date was delayed from 5^{th} June onwards.

Akbar *et al.* (2010) from Faisalabad Pakistan studied the effect of six different planting dates for super basmati *viz.* 31^{st} May, 10^{th} June, 20^{th} June, 30^{th} June, 10^{th} July and 20^{th} July and reported higher no. of tillers/m^2, number of grains/ panicle and 1000-grain weight were obtained on 20^{th} June beyond which these components displayed a significant decline. Ahmad *et al*. (2009) found that that early transplanting (1^{st} week of July) enhanced LAI over late transplanting (3_{rd} week of July) significantly throughout the growth period.

Due to delayed transplanting there was a significant reduction in yield attributes, yields and nutrient accumulation. Timely transplanting on 3_{rd} July led to 8.4 and 19.1% higher grain yield than transplanting on 10^{th} and 17^{th} July, respectively (Singh *et al.*, 2004).

Singh (2003) reported that delay in transplanting reduces the yield and yield related components of rice crop.

Chopra *et al.* (2003) from Karnal reported that transplanting of Pusa Basmati-1 on June 30 gave significantly higher panicle length (30.4 cm), panicle weight (3.83 g), 1000-grain weight (21.12 g) and seed yield (56.53 q/ha) than that of July 21, July 28 and August 4.

Singh and Pillai (1995) from Hyderabad reported that panicles/m^2 and panicle weight were maximum under 16th July planting than late planting on 31st July and 16th August. Parihar *et al.* (1995) observed no difference in 1000-grain weight of rice planted on 30th June, 15th July or 30th July.

Singh *et al.* (1992) reported from north-eastern plain zone Ghagra Ghat that 10th July was an optimum time for transplanting of rice. Early or late planting of rice crop reduced the yield attributing characters and yield significantly. The growth, yield attributes and grain yield recorded in 5th July planting were lower than 20th July planting.

Lin and Huang (1992) from China reported that delay in transplanting beyond 5th August reduced grain filling percentage, 1000-grain weight and yield of rice.

Maruyama and Tanaka (1985) reported that the number of spikelets was markedly affected by the length of the period from transplanting to heading.

The conclusion drawn from above cited literature is that the yield attributes like number of panicles m^{-2}, panicle length (cm), panicle weight (g), spikelets panicle^{-1}, filled grains panicle^{-1} and 1000-seed weight were higher in early transplanting dates and it decreases with delay in transplanting.

2.1.3 Quality

Transplanting under Haryana conditions on 25th June and 10th July increased the grain yield and yield contributing characters of basmati rice (*Oryza sativa* L.) as compared to late planting (Mukesh *et al.*, 2013). Although scented rice varieties planted on 25th July gave significantly higher yields of rough rice than those planted on 5th September but late transplanting gave improved quality traits *viz.* higher head-rice recovery, hulling and milling than early-planted rice (Chandra *et al.*, 1997; Mukesh *et al* ., 2013).

Chopra *et al.* (2006) reported that with delay in transplanting from 30th June to 4th August all kernel quality attributes were found to decrease with drastic reduction between 28th July and 4th August planting.

Singh *et al.* (2005) reported that kernel length, hulling percentage and head rice recovery were significantly higher in early planting than late planting.

Singh *et al.* (2005) while studying yield potential of different scented rice cultivars under different fertilizer levels and transplanting dates reported that 25 July planting date recorded higher values of grain quality traits and yield, compared to the 15 July planting date.

Ghosh *et al.* (2004) studied the response of planting date to quality of aromatic rice and reported that delayed planting significantly reduced the amylose content by 0.5%. Chandra *et al.* (1997) reported that rice crop planted on 11th August gave higher head rice recovery than planted on 25th July.

Singh[b] *et al.* (1997) conducted an experiment at Kanpur and observed that 20th July planting gave significantly higher rice recovery by 0.85 and 0.30% than crop planting on 5th July and 4th August, respectively. They further observed that protein content of the grain was significantly decreased with subsequent delay in planting by 1.62 and 1.05% from 5th July to 20th July and 20th July to 4th August planting, respectively.

Rao *et al.* (1996) reported that late planting of Pusa Basmati-1, Haryana Basmati-1 and Basmati-370 on 4th August resulted in highest hulling percentage (68.8%) and head rice recovery (46%) compared to early planting. It was further reported that aroma in cooked rice did not differ significantly due to time of planting. Singh *et al.* (1996) in a 4-year field study at Ludhiana taking cv. 'PR 106', found no effect of different dates of transplanting (16, 31 May and 16 June) on the ear length of rice.

Bali and Uppal (1995) from Ludhiana, reported that basmati rice transplanted on 10th July had 57% head rice recovery but the recovery decreased to 54% as a result of delay in planting to 30th July.

Gangwar and Ahamedi (1990) observed that delay in planting after first week of July decreased the number of grains/panicle, 1000 grain weight and grain yield.

Ali *et al.* (1991) while studying the relationship between transplanting time and grain quality of basmati rice in Pakistan reported that early and late transplanting dates depressed the milling recovery and cooking quality. The optimum transplanting dates were found to be 1st July and 16th July for Basmati-379 and Basmati-385, respectively.

Gill and Shahi (1987) reported that crop transplanted on July 30 gave 7.8-12.5% more head rice yield than that transplanted on June 1, and 6.2-6.9% more than that transplanted on 30th June. They observed an increasing trend in head rice recovery with delay in planting from 1st June to 30th July.

The above cited literature reflects that the quality parameters of rice viz. hulling (%), milling (%), superior grain grades, brown rice length and breadth, L/B ratio, KLAC, elongation ratio, HRR, volume expansion and aroma were mostly highest in early transplanting dates.

2.1.4 Yield

The early planted photoperiod sensitive rice varieties passed lag vegetative phase which increased tallness as well as biomass prone to lodge during grain filling stage. On the contrary, the late planting crop suffered due to low temperature during reproductive stage and sometimes panicle cannot emerge properly and some portions remain within the leaf sheath and consequently increases spikelet sterility and give low grain yield (Canet, 1986). Thus, by adjustment of transplanting time, the plant can take advantage of natural conditions favourable for its growth (BRRI, 2004).

Brar *et al.* (2012) conducted an experiment at Punjab Agricultural University (PAU) to investigate the effect of transplanting dates (15th June, 25th June and 5th July) and seedling age (30, 45 and 60 days) on yield, quality and water productivity of two rice cultivars and found that shifting of transplanting date from 15th June to 5th July did not affect paddy grain yield significantly, but yield was numerically superior in 25th June transplanted crop than 15th June and 5th July. There was a significant reduction in grain yield in the crop transplanted on 5th May. Maximum grain yield (6.25 t ha^{-1}) was obtained with 20th June transplanting date (Miri, 2011).

Nahar *et al.* (2009) reported yield reduction of BRRI dhan-46 due to late transplanting on 10th September, 20th September and 30th September was 4.44, 8.88 and 15.55%, respectively compared to 1st September transplanting. In case of BRRI dhan-31 the reduction was to the tune of 6.12, 20.48 and 36.73%, respectively.

Manan *et al.* (2009) in an experiment on fine rice genotypes, transplanted from 22th July to 7th October at an interval of 15 days, reported that crop planted from 7th August to 7th September gave more number of tillers/m^2, panicles/m^2 and grains/panicle which resulted in higher grain yield. Compared to 22nd August planting, grain yield decreased by 11, 10, 26, 43 and 61%, respectively, when crop was planted on 22th July, 7th August, 7th September, 22nd September and 7th October.

Hussain *et al.* (2009) in an experiment on transplanting dates of basmati rice Pusa Sugandh-3 under Kashmir valley conditions studied four planting dates *viz*. 25th May, 2nd June, 9th June and 16th June and reported that delay in planting beyond last week of May result in a significant reduction of grain yield of basmati rice. The magnitude of reduction of grain yield observed with one week delay in planting beyond 25 of May observed was 5.2, 9.9 and 12.3 q/ha. Earlier planting dates of 25th May and 2nd June produced higher straw yield and harvest index than delayed planting of 9th and 16th June.

Several studies carried out under north western plains of India covering the state of Punjab and Pakistan Punjab reveal that optimum date of transplanting is from 16th - 20th July for realizing higher grain yield (Gill *et al.*, 2009; Safdar *et al.*, 2008)

Iqbal *et al.* (2008) reported 25.76% higher yield in the early sown crop (1st week of July) than the late sown crop (3rd week of July) because of longer crop duration of the early sown crop.

Akram *et al*. (2007) from Pakistan studied the effect of different transplanting dates (1st July, 11th July, 21th July and 31st July) on six rice varieties/lines (98801, PK-5262-1-2-1, 97502, 98409, Basmati-385and Super Basmati) and concluded that Basmati-385 and Super Basmati produced higher paddy yield (5.655 t ha^{-1} and 5.612 t ha^{-1}) when transplanted on 1st and 11th July respectively.

Chopra *et al.* (2006) reported that highest seed yield was produced on 21st July (31.13%), followed by 28th July (42.48%) and 4th August (70.50%). Drastic reduction in all the yield parameters was observed at 28th July and 4th August planting.

Ram *et al.* (2005) reported that highest grain yield of rice (73.2 q/ha) was obtained with transplanting of 15th June, followed by transplanting on 5th July and 25th July.

Dongarwar *et al.* (2005) reported that early transplanting on 15th and 30th July resulted a significantly higher grain yield of 31.29 and 32.61 q/ha, respectively than late transplanting on 15th August (28.40 q/ha).

Nayak *et al.* (2003) conducted a field experiment at Bhubaneshwar during wet season of 1999 and 2000 to find out the response of hybrid rice ‘PA 6201’ to dates of planting (16th, 31st July and 16th August) and reported that a fortnight delay in planting from 16th July reduced the grain yield by 7.6 and 4.5% during first year and second year, respectively. One month delay in planting from 16th July reduced the grain yield by 24.3%.

Fine rice grain variety transplanted with 30 days old seedlings during 2nd week of July at Faisalabad Pakistan, produced higher number of effective tillers and higher 1000 grain weight, resulting in maximum grain yield, while delayed transplanting resulted in reduction grain yield (Ahmad *et al.*, 2002).

Asghar *et al*. (2001) from Pakistan reported a higher paddy yield when the rice varieties were transplanted on 20^{th} July and minimum paddy yield was obtained on 20^{th} June and 5^{th} August planting. This indicates too early or too late transplanting of fine rice varieties may suppress their yield. They further reported that straw yield was decreased significantly with the passage of transplanting time, due to short growing season for vegetative growth.

Singh and Singh (2000) reported that the production of Basmati rice can be increased with the manipulation of transplanting time and selection of genotypes with high yield potential.

Experiment conducted in Kanpur on traditional scented rice varieties on different dates of planting showed that time of planting significantly influenced the grain yield and 5^{th} July planting produced significantly higher grain yield of 36.97 q/ha. The reduction in grain yield was 4.86 and 16.20% under 20^{th} July and 4^{th} August planting as compared to the yield levels reported under 5^{th} July planting, respectively (Singh[b] *et al.*, 1997). Om *et al.* (1997) reported a decrease in grain yield of rice with successive delay in transplanting from 25^{th} June to 4^{th} August.

In a field experiment at Waraseoni (MP), Paliwal *et al.* (1996) found that significant reduction in panicle length and grain yield due to delay in transplanting beyond 25^{th} July.

Paliwal *et al.* (1996) reported that transplanting on 25^{th} July recorded significantly higher straw and grain yield compared to that on 10^{th} August and 15^{th} August planting.

Katyal (1996) reported 10.1, 4.1 and 57.1% increase in grain yield in case of 25^{th} June planting over 15^{th} June and 25^{th} July, respectively. Rao *et al.*

(1996) from Cuttack tested the performance of Basmati-370, Kasturi, Pusa Basmati-1 and Haryana Basmati-1 under 4 dates (5^{th} July, 15^{th} July, 25^{th} July and 4^{th} August) of planting. They reported that 15^{th} July to 25^{th} July was the optimum time of transplanting for obtaining higher grain yield of basmati rice. Delayed planting beyond 4^{th} August reduced the yield, which was attributable mainly to restricted tillering and crop growth and the incidence of insect pests. Lower grain yield under early (15^{th} July) planting was ascribed to crop suffering due to heavy rains, water logging and cloudy weather during reproductive period in September.

Bali and Uppal (1995) from Ludhiana reported that earlier transplanting (10^{th} July) of basmati rice increased the total dry matter production, grain and straw yield over late transplanting (30^{th} July). The increase in yield on 10^{th} July planting was 5 and 8.6% in 1989 and 1991, respectively over 30^{th} July transplanting. Early transplanting developed better root density and favoured uptake of N, P and K and thereby increased the grain yield. Bali *et al.* (1995) studied the effect of transplanting dates on rice and observed that delay in transplanting decreased grain yield significantly. These results were also supported by Dhiman *et al.* (1995).

Chaudhary *et al.* (1994) reported that grain yield decreased significantly with delay in transplanting. Paul (1994) reported from Assam that in Sali rice grain yield decreased from 3.1 t/ha on 20^{th} July planting to 2.6 t/ha on 2^{nd} September planting.

Om *et al*. (1993) reported that gradual decrease in grain yield occurs with successive delay in transplanting from 25^{th} June to 4^{th} August.

Reddy and Reddy (1992) tested the performance of rice cultivar Surekha on three dates of transplanting at Warangal, Andhra Pradesh and reported that 29^{th} August planting produced significantly higher yield than 30^{th} July and 14^{th} August planting. The increase in grain yield due to delayed planting was attributed to more productive tillers per unit area. Early transplanting dates received lesser solar radiation due to cloudy weather resulting in greater mortality of tillers and hence poor yield.

Traditional scented rice registered a reduction in grain yield to the extent of of 16.0, 22.2 and 34.5% was recorded under 16th July, 31st July and 5th August planting as compared to 2nd July planting (AICRIP, 1991).

Ashraf *et al.* (1989) from Islamabad, Pakistan studied the performance of basmati-385 under different dates of transplanting (15th June, 1st July, 16th July, 31st July and 31st August) and reported that the grain yield decreased from 5.3 t/ha in 1st July planting to 2.7 t/ha in 15th August planting.

Chandra and Mannan (1989) reported 22 and 50% reduction in grain yield of Gayatri when the crop was planted in mid-August and mid-September respectively, compared with the normal planting (mid-July) at Cuttack.

Om *et al.* (1989) reported that grain yield of Jaya and HKR-120 decreased significantly with delay in planting while testing their performance on three dates of transplanting at Kail Haryana. The reduction in the grain yield due to late planting was 1.31 and 3.90 t/ha under 5th July and 22nd July planting, respectively.

Babu (1988) observed the highest grain yield under July planting and the reduction in grain yield was significant when planting was delayed beyond August 15. Also, reported that, higher yields under 30th July planting were attributed to the cumulative effect of more number of productive tillers and filled spikelets /unit area.

Dhaliwal *et al.* (1986) reported that transplanting of Pusa Basmati-1, Jaya and PR-106 15 days later than recommended date, recorded significant reduction in yield.

Akram *et al.* (1985) conducted a field experiment on cv. Kashmiri Basmati and revealed that 8th June planting gave significant higher yield than that planting on 24th May, 24th June and 8th July.

Trivedi and Kwatra (1983) reported that highest grain yield (8 t ha^{-1}) was obtained with 30th June planted crop which decreased linearly to the lowest level (3 t ha^{-1}) on 15th August planting.

Urkurkar (1983) at Raipur observed while planting dwarf indica rice at 10 days interval from 1st June to 30th August, that transplanting between 11th July and 21st July was the optimum time for obtaining maximum grain yield.

From the literature cited above it can be concluded that grain yield, straw yield, biological yield and harvest index were recorded highest in early transplanting dates and it decreases with delay in transplanting.

2.1.5 Economics

Akbar *et al.* (2010) reported that maximum net income of ₹ 77282 was recorded when rice was sown on 20th June, which was followed by the rice sown at 10th June and 31st May giving net income of ₹ 62820 and 51109, respectively. The minimum net income of ₹ 9907 was observed when rice was sown on 10th July. Thus the net benefit gradually decreased as sowing was done after 20th June and later on.

Singh *et al.* (2000) worked out the economic analysis of basmati rice and reported that timely transplanted (7th July) crop gave 18.7, 18.8 and 14.4% higher return and benefit cost ratio and monetary productivity, respectively than late planted crop. Pusa Basmati-1 gave significantly higher grain yield (2930 kg/ha), net return (₹ 24372/ha) benefit cost ratio (4.54) and monetary productivity (₹ 18053/ha/day) than other varieties.

Singh *et al.* (1999) recorded highest net returns of ₹13075/ha along with maximum benefit cost ratio of 2.08 under 30th December planting followed by 15th December planting (₹ 12125 ha^{-1} net return and benefit cost ratio of 1.93) and 14th January planting (₹ 11825 ha^{-1} net return and benefit cost ratio of 1.88).

Gangwar and Sharma (1998) worked out the economic analysis of different dates of planting of basmati rice at Meerut, Uttar Pradesh. They reported that higher mean net returns of ₹ 12259/ha and benefit cost ratio of 1.88 were recorded under 1st July planting followed by 16th July which recorded net returns of ₹10028/ha and benefit cost ratio of 1.54, further delay in planting reduced the net returns of ₹5211/ha with benefit cost ratio of 0.80 under 16th August planting.

2.2 Effect of nitrogen fertilization levels

2.2.1 Growth attributes

Chakraborty (2011) reported a significant increase in the number of leaves hill^{-1} up to 100 kg N application, while the further increase in the number of leaves hill^{-1} with the increase in the nitrogen dose was found insignificant.

The number of panicles/m^2, panicle length and percentage of spikelet sterility increased with the increase in nitrogen levels (Manan *et al.*, 2010).

Tari *et al.* (2009) reported that nitrogen fertilization levels had significant effect on flag leaf area, flag leaf angle, panicle length and grain yield.

Haefele *et al.* (2008) reported that N application had a significant effect on plant height. The increased plant height with increase in N levels might have been due to enhanced vegetative growth resulting from increase in cell size and meristematic activity.

Sreenivas and Reddy (2008) reported an increase in biomass with increasing levels of nitrogen from 100 to 300 kg ha^{-1}.

Raju *et al.* (2001) reported a significant increase in seedling height of rice at 100 kg N ha^{-1} over control. Application of 150% of recommended dose of N (75 kg ha^{-1}) gave significantly greater dry matter production.

Chopra and Chopra (2000) reported a significant increase in plant height and straw yields with increase in N levels in aromatic rice variety Pusa Basmati-1.

Saharawat *et al*. (1999) showed that nitrogen rate significantly affected plant height. Increasing rate of nitrogen up to 120 kg ha^{-1} increased plant height significantly. Sharma and Singh (1999) reported that application of nitrogen had a significant effect on dry matter accumulation.

Aromatic rices showed significant increase in dry matter production with each successive increment of N from 0 to 180 kg ha^{-1} (Gangaiah and Prasad, 1999).

Tripathi *et al.* (1998) showed significant increase in plant height and dry matter production in basmati rice with successive increment of N up to 90 kg ha^{-1}. Maske *et al.* (1997) reported that increasing nitrogen levels up to 120 kg N ha^{-1} significantly increased leaf area, yield components and grain yield.

Khanda *et al.* (1997) showed that dry matter production increased significantly with the increasing level of N up to 90 kg N ha^{-1}. Navin *et al.* (1996) found that with an increase in the nitrogen rates from 0 to 120 kg ha^{-1} there was an increase in plant height. Hussain and Sharma (1991) reported that application of nitrogen up to 40 kg ha^{-1} increased plant height significantly. At 80 kg and 120 kg N ha^{-1}, the increase in this parameter was insignificant. The highest plant height was obtained from 120 kg N ha^{-1} and the lowest one from the control. Chander and Panday (1996) stated that application of 120 kg N ha^{-1} resulted in a significant increase in number of productive tillers $hill^{-1}$ compared to 60 kg N ha^{-1}.

Amano *et al.* (1993) reported that irrespective of cultivars and nitrogen levels, LAI increased sharply after transplanting attaining a peak at heading stage and then decreased gradually.

Panda and Rao (1991) showed that with increase in nitrogen application up to 120 kg N ha^{-1} there was an increase in dry matter production.

Dubey *et al*. (1991) observed that application of 90 kg N ha^{-1} resulted in a higher number of productive tillers $hill^{-1}$. Pandey *et al*. (1991) concluded that higher grain yield from the increase in nitrogen rate might be attributable to increase in productive tillers $hill^{-1}$. Ghosh *et al*. (1991) reported that application of N increased the number of productive tillers $hill^{-1}$. Idris and Matin (1990) found that maximum tillers hill^{-1} was produced by 140 kg N ha^{-1} which was statistically identical with 60, 80, 100 and 120 kg N ha^{-1}. The minimum tillers hill^{-1} were produced from the control.

Dikshit and Paliwal (1989) reported that application of nitrogen directly increased the chlorophyll content and leaf surface area resulting in an increased photosynthetic process leading to more sugar formation.

Moorthy *et al.* (1988) reported a significant increase in the plant height with application of nitrogen up to 90 kg ha^{-1}.

Reddy (1988) showed the beneficial effect of nitrogen on tillering and vegetative growth. He also found that there was more accumulation of dry matter at all the stages of sampling with increase in nitrogen levels from 0 to 120 kg N ha^{-1} and gave higher values of crop growth rate over 40 and 80 kg N ha^{-1}.

Ram *et al*. (1984) recorded that N application increased the number of tillers hill^{-1}. Nossai and Vargas (1982) stated that number of tillers hill^{-1} was increased linearly with increased N rate. Dixit and Singh (1980) observed that increasing rate of nitrogen application increased number of tillers plant^{-1}.

The above cited literature shows that growth attributes like plant height, dry matter accumulation, LAI and number of tillers increases with increase in nitrogen level.

2.2.2 Yield attributes

Sharma *et al.* (2014) conducted an experiment to find out the effect of nitrogen levels (0, 40, 60 120 and 160 kg N ha^{-1}) on yield components of Basmati rice cultivars and observed that highest value of parameters like number of productive panicles m^{-2} (364.71), panicles length (27.68 cm), numbers of grains panicle^{-1} (63.14), and grain weight (2.18 g) were produced when 160 kg N ha^{-1} was applied.

Yusuf and Balcha (2014) from Ethiopia conducted an experiment to determine grain yield, yield components and N efficiency responses of rice to five N rates (0. 3.5, 7, 10.5 and 14 g N m^{-2}) and reported that grain yield increased from 302-469 g m^{-2}, total biomass 786-1268 g m^{-2}, tillers 477-661 m^{-2}, panicles 456-612 m^{-2} and filled grains $panicle^{-1}$ 80-100 when N rate increased from 0-14 g m^{-2}. Maximum value for panicles (621 m^{-2}) and filled grains $panicle^{-1}$ (110) and that for grain yield (510 g m^{-2}) were obtained at 7 and 10.5 g m^{-2}, respectively.

Sharma *et al.* (2012) reported that the yield contributing characters, panicles per m^2, grains per panicle, yield and B: C ratio was high with nitrogen and phosphorous @ 90 and 45 kg ha^{-1}, respectively. Application of $N_{90}P_{45}$ kg ha^{-1} also showed highest N and P uptake.

Chakraborty (2011) in an experiment with seven doses of inorganic N fertilizer (20, 40, 60, 80, 100, 120, 140 kg ha^{-1}) reported that maximum panicle length (17.1cm), effective tiller number $hill^{-1}$ (62.01), filled grain number $panicle^{-1}$ (66.12), tiller number $hill^{-1}$ (11.27), leaf number $hill^{-1}$ (48.11) and leaf width (9.11 mm) was noted when the field was fertilized with 100 kg N. But no significant improvement of yield attributing characters except the number of filled grain number $panicle^{-1}$ was noted when the dose of fertilizer was increased after 100 kg N ha^{-1}.

Manan *et al.* (2010) reported that the plant height, tiller number, number of panicles, panicle length and straw yield increased with increased nitrogen levels up to 75 kg ha^{-1}. Maximum plant growth at the highest level of nitrogen (100 kg ha^{-1}) caused lodging of plant which increased spikelet sterility and ultimately decreased grain yield.

Kanyika *et al.* (2007) reported that the number of panicles, filled grains per panicle, panicle length and panicle weight increased with increased levels of nitrogen fertilizer. Taxi *et al.* (2007) observed that the N rates had significant effect on panicle length, 1000-grain weight and grain yield.

Haque *et al.* (2006) reported that the tiller number increases with increase in nitrogen levels from 0 to 120 kg N ha^{-1}. Maximum tiller number was noticed at nitrogen level of 120 kg N ha^{-1}, which was statistically at par with 60 kg N ha^{-1}. They also reported that after maximum tillering stage tillers $hill^{-1}$ decreased considerably until maturity. This suggests that during the reproductive and ripening phases the rate of tiller mortality exceeded the tiller production rate.

Manzoor *et al.* (2006) reported that plant height, number of productive tillers $hill^{-1}$, panicle length, number of grains $panicle^{-1}$, 1000 grain weight and paddy yield showed increased trend from 0 to 175 kg ha^{-1}. Maximum paddy yield was obtained from 175 kg ha^{-1} N application treatment which also produced highest values for number of grains per panicle and 1000 grain weight.

Singh *et al.* (2004) reported that increased nitrogen levels had a significant effect on yield attributes (except 1000-grain weight), yields and nutrient accumulation up to 120 kg N ha^{-1}. Also the maximum grain yield (5.87 t ha^{-1}) was recorded at the highest level of N nutrition (180 kg N ha^{-1}) and was 4.2, 15.5 and 39.3% higher than in the 120 kg, 60 kg N ha^{-1} and control treatments, respectively.

Chander and Pandey (1996) found that a significant increase in grains $panicle^{-1}$ was obtained from application of 120 kg N ha^{-1} compared to 60 kg N $ha^{-1.}$

Azad *et al.* (1995) reported that panicle length increased significantly with increase in the rates of nitrogen from 0 to 75 kg ha^{-1}.

Singh and Singh (1993) stated that panicle length and grains $panicle^{-1}$ increased due to application of 60 kg N ha^{-1} over its lower rates.

Hussain and Sharma (1991) observed that application of nitrogen up to 80 kg ha^{-1} increased grain number $pnicle^{-1}$. Nitrogen application @ 120 kg ha^{-1} did not affect the grains $panicle^{-1}$ significantly.

From the above cited literature it can be concluded that, yield attributes increase with increase in nitrogen up to certain level.

2.2.3 Quality

Devi *et al.* (2012) reported that the yield attributes of scented rice under aerobic culture responded up to 150 kg ha^{-1} nitrogen with 4 equal splits of N at ¼ basal + ¼ at active tillering + ¼ panicle initiation and ¼ at heading .Grain quality parameters milling percentage, head rice recovery, kernel length and breadth, amylose content and protein content of rice registered significantly higher values with 150 kg ha^{-1} nitrogen.

Khalid and Chaudhry (1999) reported that among the different nitrogen levels (0, 40, 80 and 120) used, treatment where N was used @ 80 kg ha^{-1} gave significantly higher percentage of seed protein and amylose content than rest of the treatments.

Sharma and Singh (1999) reported that excess nitrogen application reduced carbohydrate content and resulted in an abnormal development of pollen grains.

Singh *et al.* (1997) reported that protein content, kernel length, breadth and percent recovery of head rice significantly increased with increasing levels of nitrogen.

Perez *et al.* (1996) reported appreciable increase in protein content with the application of nitrogen which was mainly due to higher nitrogen concentration. They also reported that high protein content improves milling and head rice recovery percentage.

The above cited literature reflects that the quality of rice increases with increase in nitrogen levels.

2.2.4 Yield

Pramanik and Bera (2013) tested five levels of nitrogen *viz.* 0, 50, 100, 150 and 200 kg N ha^{-1}. They reported that among the nitrogen levels 200 kg ha^{-1} gave significant higher plant height, number of tillers hill^{-1}, total chlorophyll content, panicle length and straw yield and nitrogen levels of 150 kg ha^{-1} gave significant higher number of effective $tillers^{-1}$, effective tiller index, panicle weight, filled grain $panicle^{-1}$, 1000 grain weight, grain yield, and harvest index as compared to 0, 50, 100 kg N ha^{-1}, during both years. N @ 150 kg ha^{-1} produced significantly highest grain yield of 6286 and 6652 kg ha^{-1} in 2010 and 2011, respectively. The percentage increased in grain yields was to the extent of 72.5, 44.4, 23.8 and 5.1% in first year and 69.9, 44.1, 22.1 and 3.5% in second year over 0, 50, 100 and 200 kg N ha^{-1}, respectively.

Rao *et al.* (2013) reported that grain yield, straw yield, harvest index and nitrogen uptake was maximum at 240 kg ha^{-1} which was significantly superior over lower level (120 kg N ha^{-1}).

Pramanik and Bera (2013) observed significant effect of nitrogen levels on harvest index of hybrid rice. Among different nitrogen levels used (0, 50, 100, 150 and 200 kg N ha^{-1}), they reported that the nitrogen level of 150 kg ha^{-1} registered the highest harvest index (46.40 and 47.07) over 50 kg N ha^{-1} and control, respectively during the both years.

Manan *et al.* (2010) reported that straw yield increased significantly with increase nitrogen rates up to 75 kg N ha^{-1}, and no further increase in straw yield was recorded between at 100 kg N ha^{-1}. They suggested that vigorous crop growth with the nitrogen treatments might have resulted in higher straw yields of fine rice. Also reported that the economic optimum level of nitrogen for the cultivation of Basmati fine rice was about 69-70 kg N ha^{-1}.

Mahajan *et al.* (2010) reported that aromatic cultivars of rice respond differently to nitrogen application as compared to non-aromatic rice. They conducted an experiment to optimize N levels for higher yield and NUE of modern aromatic rice cultivars. They reported that across all genotypes, the mean nitrogen-fertilizer response was highest at 40 kg N ha^{-1} as compared to other N levels (0, 20, and 60 kg N ha^{-1}), indicating that further increase in N level had no effect on crop response to fertilizer. The mean grain yield increased by 64.2% when plots were supplemented with 40 kg N ha^{-1} as compared to control (unfertilized).

Gautam *et al.* (2008) reported that application of 160 kg N ha^{-1} recorded 23.7 and 26.1% more grain yield over no nitrogen application whereas it was 6.4 and 6.1% more over 80 kg N ha^{-1}, respectively, during first and second year of the experimentation.

Luikham *et al.* (2008) reported highest grain yield, net income and cost benefit ratio with the application rate of N at 60 kg^{-1} ha. Singh *et al.* (2005) observed that application of graded levels of N up to 90 kg N ha^{-1} increased grain yield linearly.

Jadhav *et al.* (2004) noticed significant increase in grain and straw yield of Basmati rice up to 120 kg N ha^{-1} under upland conditions.

Singh *et al.* (2003) conducted a study in Uttar Pradesh, India, to determine the effect of nitrogen rates (40, 80, 120, 160 kg N ha^{-1}) on the yield of different cultivars of rice (NDR-359, Jaya, Pant Dhan 10 and Pant Dhan 12) during the kharif seasons of 2002 and 2003. Grain yield was highest in NDR-359 (6.86 t ha^{-1}) with 160 kg N ha^{-1}, followed by 120 kg N ha^{-1}. The grain yield (6.53 t ha^{-1}) obtained from 160 kg N ha^{-1} in Jaya was statistically at par with the application of N at 120 kg N ha^{-1} in NDR-359. Mandal and Swamy (2003) reported that application of N (120 kg ha^{-1}) as urea in equal splits during transplanting, tillering, panicle initiation and flowering resulted in the highest harvest index.

Lawal and Lawal (2002) reported that application of fertilizer up to 80 kg N ha^{-1} significantly increased number of ear bearing tillers $m^{-2}$and grain yield.

Ehsanullah *et al.* (2001) tested three nitrogen levels (75, 100 and 125 kg ha^{-1}) and reported lowest yield of 4.29 t ha^{-1} at the nitrogen level 75 kg N ha^{-1}, and highest yield of 4.72 t ha^{-1} at 125 kg N ha^{-1}.

Singh *et al.* (2000) reported that each incremental dose of N gave significantly higher grain yield of rice over the preceding dose, consequently the crop fertilized with 100 kg N ha^{-1} gave maximum grain yield.

Khalid *et al.* (1999) reported that the application of nitrogen at the rate of 80 kg ha^{-1} was optimum to get higher yield followed by nitrogen level of 120 and 40 kg ha^{-1} in descending order. Lakpale *et al.* (1999) concluded that the grain yield and N accumulation in rice increased significantly by 21.5 and 32.5%, respectively with the application of 120 kg N ha^{-1} compared with that of 100 kg N ha^{-1}.

Choudhuri *et al.* (1998) studied with three rice cultivars *viz*. Haryana Basmati, Kasturi and Pusa. Basmati along with nitrogen rates ranging from 0-100 kg ha^{-1} They observed that mean grain yield was the highest (2.90 t ha^{-1}) with application of 100 kg N. Behera (1998) observed that nitrogen had marked effect of yield of scented rice. Straw yield increased significantly at each successive rate of nitrogen.

Bhale and Salunke (1996) reported that grain yield increased linearly up to 120 kg N ha^{-1}. Chander and Pandey (1996) noted that application of 120 kg N ha^{-1} gave significant increase in grain yield compared with 60 kg N ha^{-1}. Khanda and Dixit (1996) stated that straw yield was significantly influenced by the increased rates of nitrogen. The maximum straw yields of 6.21 t ha^{-1} were obtained at 90 kg N ha^{-1}. Patel and Mishra (1994) found that application of 0, 30, 60, 90 kg N ha^{-1}increased straw yields.

Islam *et al.* (1990) reported that cv. BR1 rice with four rates of nitrogen on the grain yield of rice was highly significant. There was an increasing trend in grain yield with an increase in rates of nitrogen up to 80 kg N ha^{-1}. However, with further increase in nitrogen application there was some decrease in grain yield. They also found that straw yields increased correspondingly with increased in nitrogen applications.

Akram *et al.* (1985) studied the effect of planting dates and fertilizer levels on grain yield and protein content of cv. Kashmir Basmati. They reported considerable variability in grain yield and protein content with different combinations of transplanting dates and fertilizer levels. They reported maximum grain yield (4.48 t ha^{-1}) when crop was transplanted on June 8 with fertilizer level of $N_{90}P_{45}$.

Prosad (1981) found that increasing rate of nitrogen application from 0 to 120 and 200 kg ha^{-1} increased biological yield but decreased harvest index.

From the above literature it is concluded that the yield of rice crop increases with increase in nitrogen levels up to certain limit.

2.2.5 Nutrient uptake

With the increase in N rate from 0-14 g m^{-2}, grain N concentration increased from 1.44-1.53%, straw N concentration from 0.79 to 0.93%, grain N uptake from 4.36 to 7.18 g m^{-2}, straw N uptake from 3.82 to 7.45 g m^{-2} and total plant N 8.18-14.63 g m^{-2}. Maximum value for grain N concentration (1.58%), total grain N uptake (8.04 g m^{-2}) and total plant N uptake (14.81 g m^{-2}) were obtained at 10.5 g m^{-2}. Agronomic efficiency decreased from 29-12, apparent recovery 0.76-0.46 and physiological efficiency 38-26 when N rate increased from 3.5-14 g m^{-2} (Yusuf and Balcha, 2014).

Rao *et al.* (2013) reported that N uptake increased with increase in the levels of nitrogen up to 240 kg ha^{-1}. N uptake at 240 kg N ha^{-1} was higher in grain, straw and total uptake was comparable with 210 kg N ha^{-1}. The minimum (13.4 kg ha^{-1}) N uptake was with 120 kg N ha^{-1}.

Tayefe *et al.* (2011) conducted an experiment using three rice cultivars (Hashemi, Kazemi and Khazar) and four nitrogen levels [(N_1-control (no N fertilizer); N_2-30 kg ha^{-1} N (at transplanting time); N_3-60 kg ha^{-1} N (at transplanting, and tillering times); N_4-90 kg ha^{-1} N)] to study the effects of nitrogen fertilizer on nitrogen use efficiency, yield and characteristics of nitrogen uptake. They reported that total N uptake, physiological nitrogen use efficiency (PNUE), apparent nitrogen recovery efficiency (ANRE) and agronomic nitrogen use efficiency (ANUE) varied in different cultivars significantly and Khazar variety had the highest contents. Total N uptake, physiological N use efficiency (PNUE), agronomic nitrogen use efficiency (ANUE) was varied significantly with the increment of the amount of nitrogen applied. As total N uptake increased with increasing in N fertilizing contents but physiological N use efficiency (PNUE), Agronomic Nitrogen use efficiency (ANUE) decreased

Prudente *et al.* (2008) conducted an experiment to determine the effect of different levels of N on N uptake, yield components and dry matter yield of *japonica* (*Hatsuboshi*) and *indica* (*IR-13*) rice varieties. They reported an increasing trend in the N uptake, rice yield, panicle number, tiller number and dry matter production, with increased amount of applied N fertilizer. Higher correlations (p=0.001) were found between the yield (r = 0.96; r = 0.99), number of panicles (r = 0.98; r = 0.96) and number of tillers (r = 0.96; r = 0.97) and N uptake (r = 0.97; r = 0.95) of *japonica* and *indica* rice varieties and applied N, respectively.

Quanbao *et al.* (2007) showed that apparent nitrogen recovery efficiency (ANRE) was increased with increasing N application in sandy soil while it was increased firstly and reached to the maximum at 225 kg ha^{-1} N application, then declined significantly under 300 kg ha^{-1} N application in clay soil. It indicated that it was not useful for improvement of ANRE with more or less N application.

Nitrogen fertilization has a vital role in determining the percentage nitrogen in the rice grains and nitrogen uptake by the rice plants (Ebaid and Ghanem, 2001).

Sharma and Singh (1999) reported positive effect of N uptake on grain yield due to increase in sink size, because spikelet degeneration decreases linearly with increasing N concentration in the leaf at anthesis.

Dalal and Dixit (1987) reported that higher levels of N application resulted in better N uptake, leading to greater dry matter production and its translocation to sink.

The growth duration, native soil fertility and cultural practices affect N absorption pattern, which in turn affects the amount of N in plants leading to profound effect on N use efficiency (Cruz and Wada, 1994).

Nitrogen taken up during early growth stages accumulates in the vegetative parts of the plant and is utilized for grain formation. A large portion of the nitrogen is absorbed during differentiation. The leaves and stems contain a large portion of the nitrogen taken up by the plant (Milkkelson, 1982).

The recovery of N fertilizer applied to the rice crop would range from 30 to 40%. However, with improved cultural practices, such recovery can increase up to 65% (De Datta, 1981).

Pillai and Rajat (1980) studied the nutrient uptake studies in rice variety *Jaya* as influenced by graded levels of N and time of N application and reported the grain nitrogen content was highest, when nitrogen was applied in two split doses at planting and panicle initiation. The apparent recovery of N was maximum (54%) at 100 kg N ha^{-1}, beyond which there was a decline in percentage recovery of applied nitrogen. Split application of N and continuous shallow submergence resulted in higher recovery of added nitrogen leading to better uptake of P and K, as well.

2.3 Effect of transplanting dates and nitrogen levels

Islam *et al.* (2008) in an experiment on the effect of nitrogen levels and transplanting dates on the yield of aromatic rice cv. Kalizira reported that most of the yield and yield contributing characters were significantly influenced by nitrogen levels and transplanting dates. The highest grain yield was observed on 10^{th} August with nitrogen rate of 100 kg ha^{-1}. Also highest grain length, grain breadth and imbibition ratio were also observed on the same date and nitrogen level. While the lowest yield was obtained for crop planted on 4^{th} September with no nitrogen applied.

Kumar and Ikrammullah (2004) conducted an experiment with 4 nitrogen levels (0, 50, 100 and 150 kg ha^{-1}) and 2 planting dates (15^{th} July and 30^{th} August) to determine the nitrogen requirement of scented rice cultivars under normal and late planting. They reported that productive tillers m^{-2}, filled grains $panicle^{-1}$, panicle weight, grain yield, net returns and benefit: cost (BC) ratio, increased with increasing nitrogen rate and decreased with delay in planting.

Pal *et al.* (2001) studied the effect of transplanting time (28^{th} July and 8^{th} August) and N level (0, 30, 60 and 90 kg ha^{-1}) on the production potential and profitability of scented rice. They reported that transplanting time did not influence the grain yield while the increasing N levels up to 60 kg ha^{-1} increased the grain yield and net return.

Chapter - 3

MATERIALS AND METHODS

The present investigation entitled **“Agronomic Evaluation of Pusa Basmati-1509 for Yield and Quality under Varied Transplanting Dates and Nitrogen Levels”** was carried out at the Mountain Research Centre for Field Crops, Khudwani, SKUAST-K during *Kharif* 2014. The details of climatic conditions, materials used and methods employed during the course of investigation have been described in this chapter.

3.1 Location

The field experiment entitled “Agronomic evaluation of Pusa Basmati-1509 for yield and quality under varied transplanting dates and nitrogen levels” was conducted at Mountain Research Centre for Field Crops, Khudwani of Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir during *kharif* 2014. The site is situated at 34^{o} N latitude and 74^{o} E longitude at an altitude of 1560 metres above mean sea level.

3.2 Climate and weather conditions

The experimental site falls in a mid to high altitude humid temperate zone, characterized by hot summers and very cold winters. The average precipitation is 812 mm (average of past 20 years) most of which is received from December to April in the form of snow and rains as a result of western disturbances mainly. The minimum and maximum temperature ranges between -4.5 to 33.1^{o}C, exhibits a considerable fluctuation both in summer and winter. The mean meteorological data recorded during the cropping season at nearby Meteorological Observatory of IMD at Qazigund, are presented in Appendix-1 and Fig. 1. The total rainfall received during the experimentation period was 896.6 mm and total sunshine hours were 1164 hours. The mean minimum and maximum temperatures ranged from 12.40 and 25.70 ^{o}C, respectively. There were heavy and continuous rains from 1st September to 9th September, 2014 and rainfall during this period was 619.70 mm, which resulted in

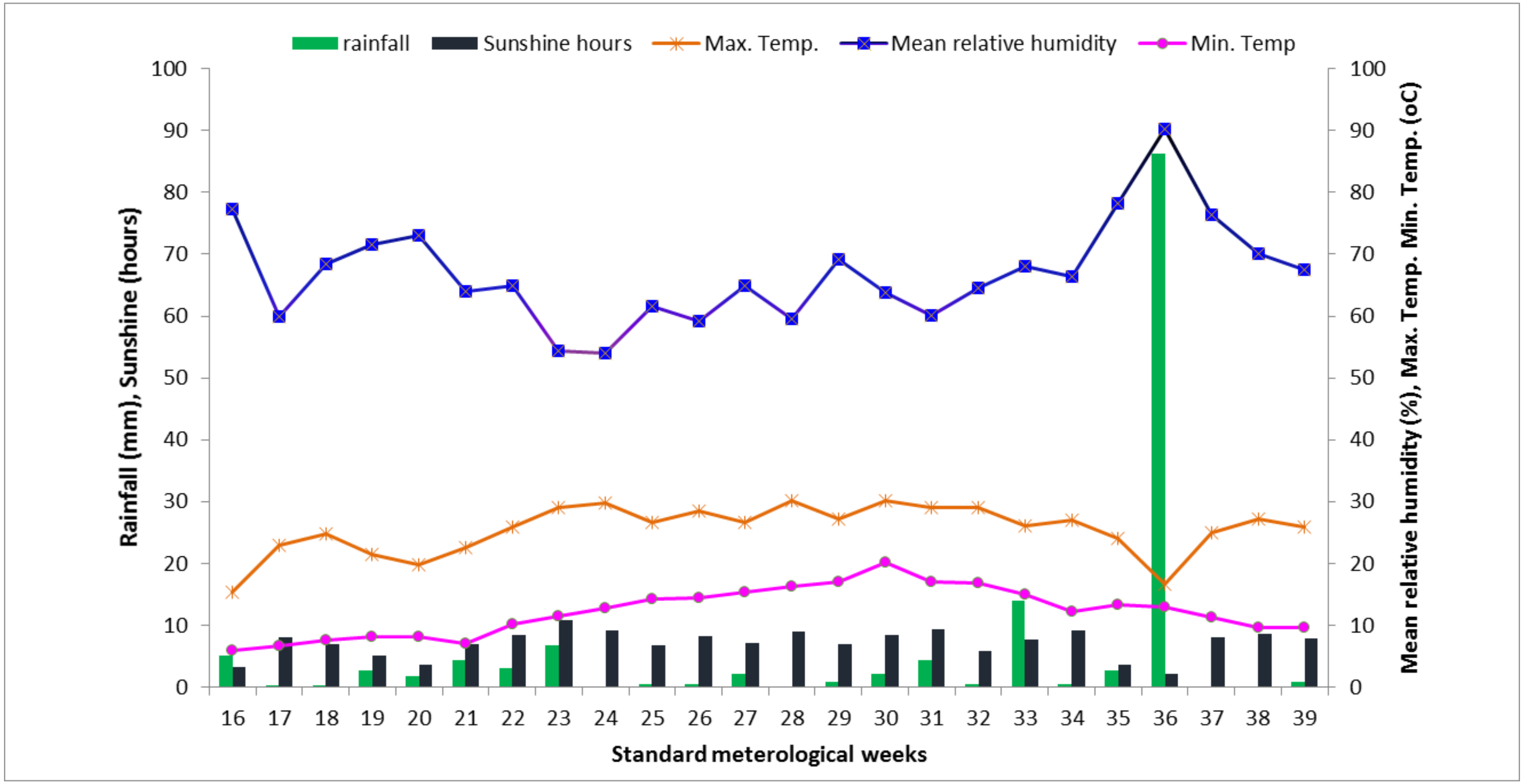

Fig. 1 : **Mean weekly meteorological parameters during crop growth period**

devastating floods in Kashmir.

3.3 Physico-chemical properties of soil

The soil samples were taken from 0-15 cm depth from randomly selected spots before laying out of the experiment and at the end of experiment from each plot. These samples were air dried on paper and after that the samples were grinded separately and sieved through 2 mm mesh. The samples were composited and subjected to chemical analysis. The results of composite sample drawn at beginning of the experiment revealed that the soil was high in organic carbon with slightly neutral in pH. The data on soil physiochemical properties has been presented in Table 3.1.

3.4 Cropping history of experimental plot

The details of the crops raised over the area of the experimental field prior to laying out of the present study are presented in Table 3.2.

3.5 Experimental details

The experiment comprised of 2 factors (transplanting dates and nitrogen levels) was laid out in a split-plot design with three replications as per lay out plan shown in Fig. 2. The treatment details are given below:

3.5.1 Treatments

**(A) Main plot treatments : ** 03 (*Transplanting dates*)

D_1 = 20^{th} May

D_2 = 1^{st} June

D_3 = 11^{th} June

**(B) Sub plot treatments : ** 05 (*Nitrogen levels kg N ha^{-1}*)

N_0 : Control

N_1 : 30

N_2 : 60

N_3 : 90

N_4 : 120

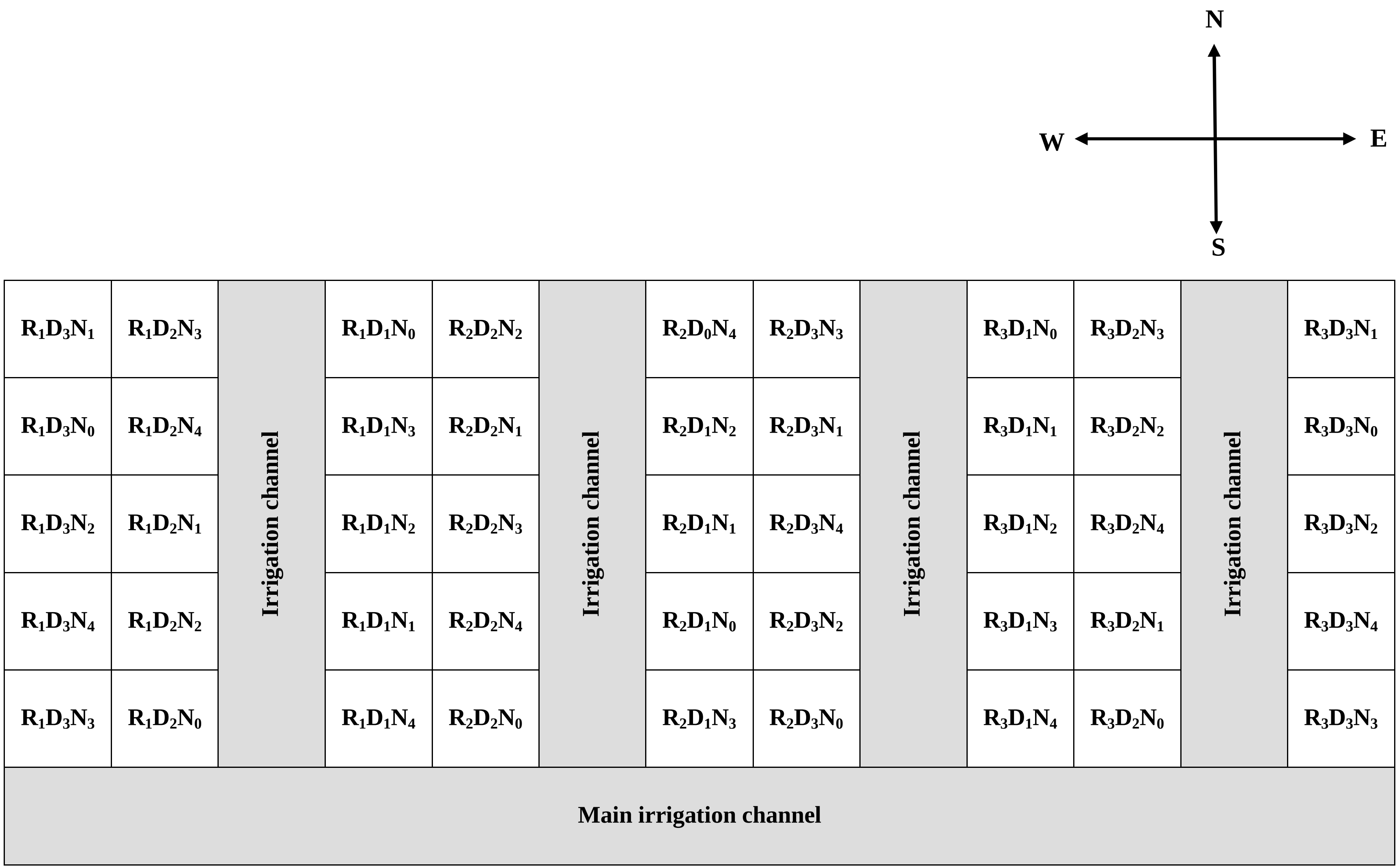

Fig. 2 : Layout plan of the experimental field

Table 3.1: Soil analysis report of experimental field before the start of experiment

Particulars	Value	Rating	Method Applied
A. Particle size distribution (%)			
Coarse sand	1.8		
Fine sand	14.2		
Silt	69.4		International Pipette Method (Piper, 1966)
Clay	14.6		
Texture	Silty clay loam		
B. Chemical characteristics			
Electrical conductivity dSm^{-1} at $25^{o}C$	0.22	Normal	Sloubridge conductivity metre (Piper, 1966)
pH (1:2.5 soil water suspension)	6.5	Normal	Blackman's glass electrode pH metre (Jackson, 1973)
Organic carbon (%)	0.91	High	Walkely and Black rapid titration method (Jackson, 1973)
Available nitrogen (kg ha^{-1})	235.0	Low	Alkaline Potassium per magnate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha^{-1})	18.5	Medium	Olsen *et al.* (1954)
Available potassium (kg ha^{-1})	268	Medium	Ammonium acetate method (Jackson, 1973)

Table 3.2 : Cropping history of the experimental field

Year	*Kharif*	*Rabi*
2011-2012	Rice	Rapeseed
2012-2013	Rice	Rapeseed
2014	Rice (experimental)	

Number of treatment combinations	:	15
Number of replications	:	3
Design of experiment	:	Split-plot
Number of plots	:	45
Spacing	:	15 cm × 15 cm
Gross plot size	:	3.15 m × 2.4 m = 7.56 m^2
Net plot size	:	2.85 m × 2.4 m = 6.84 m^2
Variety	:	Pusa Basmati-1509
Location of experiment	:	MRCFC, Khudwani

3.6 Description of rice variety

Pusa Basmati 1509 is a basmati rice variety developed by the Division of Genetics, Indian Agricultural Research Institute, New Delhi and released in 2013 for commercial cultivation.

Pusa Basmati 1509 is a semi-dwarf (95-100 cm) Basmati rice variety with sturdy stem and plant height ranging from 95 - 100 cm. Therefore, it does not lodge. It takes115-120 days for seed to seed maturity, the shortest duration for any basmati rice variety released so far. This variety has recorded a yield in the range of 4.2 to 6.5 tonns/ha in large scale demonstrations conducted in the Basmati growing regions of Punjab, Haryana, Delhi and Uttar Pradesh. Quality wise, this genotype possess aromatic extra-long slender grains (8.41mm) with very occasional grain chalkiness, very good kernel length after cooking (19.1 mm), desirable alkali spreading value (7.0) and intermediate amylose content (21.24%). The chief characteristics of the variety are: dark green foliage with a plant height of 110-115 cm, erect flag leaf, long panicle with high grain number, long slender fine grains without awns, 8-12 tillers $hill^{-1}$, 300-400 panicles m^{-2}, takes 80-90 days to flowering, panicle type is long with 150-200 grains with full panicle exertion, 1000-grain weight (g) is 24.0, kernel length (mm) is 7.48, kernel breadth (mm) is 1.8, l/b ratio is 4.03, kernel appearance is long slender and translucent, hulling recovery is 80.0%, milling recovery is 70.6%, head rice recovery is 52.2%. Resistant to brown spot and moderately resistant to blast.

3.7 Details of field operations

Different field operations during the course of study were performed at different dates. The details of field operations are given in Table 3.3.

3.7.1 Field preparation

Before transplanting the land was first ploughed with tractor 2-3 times, secondary operations were performed in order to pulverize the soil and after that the field was laid on the basis of statistical design used in the experiment.

3.7.2 Nutrient management

After land preparation whole phosphorus, potassium and half of nitrogen was applied in different plots in the form of DAP (SSP for control), MOP, and urea respectively for the first planting date. The other half of nitrogen was applied in two equal splits one at active tillering and other at panicle initiation stage. Nutrients were applied in the other two planting dates in the same fashion.

3.7.3 Transplanting of seedling

Thirty days old seedlings of the variety Pusa Basmati-1509 uprooted from the nursery beds were transplanted on the same day in the experimental field for first planting date. Three robust seedlings per hill were transplanted at spacing

Table 3.3: Details of various field operations (2014)

Operation	Transplanting date (2014)			Remarks
	1^{st}	2^{nd}	3^{rd}	
Lay out of nursery	19^{th} April	29^{th} April	8^{th} May	Manually
Sowing of nursery	21^{th} April	31^{nd} April	11^{th} May	Manually
Preparatory tillage	03^{th} May	15^{th} May	25^{th} May	Tractor (2-3 ploughs)
Secondary ploughing	10^{th} May	22^{nd} May	1^{st} June	Harrowing (2 turns)
Lay out	14^{th} May	27^{th} May	5^{th} June	Manually (using ropes)
Irrigation for puddling	18^{th} May	29^{th} May	8^{th} June	Flood irrigation
Puddling and levelling of plots	19^{th} May	30^{th} May	10^{th} June	Manually
Uprooting of seedlings	20^{th} May	1^{st} June	11^{th} June	Manually
Basal application of fertilizer as per treatment	20^{th} May	1^{st} June	11^{th} June	Broadcasting
Transplanting of seedlings (2-3 seedling/hill)	20^{th} May	1^{st} June	11^{th} June	3-4 seedling/hill Manually
Herbicide application (Butachlor 5G @ 1.5 Kg ha^{-1})	22^{nd} May	3^{rd} June	13^{th} June	Broadcasting
Hand weeding	18^{th} June	1^{st} July	9^{th} July	Manually
1^{st} top dressing of N as per treatment	20^{th} June	3^{rd} July	11^{th} July	Broadcasting
2^{nd} top dressing of N as per treatment	20^{th} July	25^{th} July	2^{nd} August	Broadcasting
Irrigation and drainage	20^{th} May to 25^{th} August	1^{st} June to 6^{th} September	11^{th} June to 14^{th} September	From transplanting to soft dough stage 3-5 cm water level was maintained and alternate drying and wetting was followed after this stage till physiological maturity comes. Excess water was drained out and irrigation was stopped at maximum tillering stage for some days till small hairline cracks appeared. At pre-heading stage irrigation was withheld for 5-6 days.
Harvesting	15^{th} September	22^{th} September	26^{th} September	Manually

of 15 cm x 15 cm by line planting, skilled labours and ropes were used for transplanting. Spacing was maintained in between rows as well as plants. Similar procedure was followed for other two planting dates. The variations in the growth of different transplanting dates were noticed (Plate-1).

3.7.4 Weed management

Pre-emergence application of herbicide butachlor 5 G was applied @ 1.5 kg a.i. 3 days after transplanting in uniform layer and water was impounded in the field for three days. First manual weeding was done 30 days after transplanting (DAT) for complete removal of weeds for each planting date.

3.7.5 Irrigation management

Continuous flooding at a shallow depth of 5 cm was kept to facilitate tiller production and promote firm root anchorage in the soil during the succeeding 5-week period after planting. Water was drained out after 35 DAT and 21-25 days after flowering.

3.7.6 Plant protection measures

No plant protection measures were taken during the course of experiment.

3.7.7 Harvesting and threshing

Harvesting was done immediately after the physiological maturity indices were seen i.e. at 20% grain moisture content. The border of each plot was removed in order to overcome its effect. The seed moisture was checked by using the instrument seed moisture meter (INDOSAW digital moisture testing machine, OSAW Industrial Products Pvt. Ltd.) and expressed in%. The harvested crop was sun dried in the field for 2-3 days, and was tied in to small bundles and biological weight of each bundle (plot-wise) was taken with electronic power balance.

Plate-1 : Crop growth differences among transplanting dates

Threshing was done manually, plot-wise yield was recorded accordingly and transformed into hectare basis.

3.8 Observations recorded

3.8.1 Physico-chemical characteristics of soil

3.8.1.1 Soil fertility status before start of experiment (N, P, K in kg ha^{-1} and organic carbon in%)

Soil samples that were collected before field preparation were subjected to chemical analysis for available N, P and K and organic carbon using standard methods presented as follows:

a) Organic carbon

The organic carbon was determined by Walkely and Black rapid titration method, given by Jackson (1973) and calculated in per cent. The initial amount of carbon seen in soil was 0.91% i.e. high.

b) Available nitrogen

The available soil nitrogen was determined by using Alkaline Potassium Permagnate Method (Subbiah and Asija, 1956) and was calculated in kg ha^{-1}. The initial soil status for nitrogen calculated was 235.0 kg ha^{-1} i.e. low.

c) Available phosphorus

The available phosphorus in soil was determined by using the 0.5 N $NaHCO_3$ at pH 8.5 (Olsen *et al.*, 1954) and recorded in kg ha^{-1}. The initial soil status for phosphorus determined from a composite soil sample was 18.5 kg ha^{-1} i.e. medium.

d) Available potassium

The available potassium in soil was determined by using the method of extraction with 1N ammonium acetate at pH 7.0 (Jackson, 1973) and was recorded in kg ha^{-1}. The initial soil status for potassium was 268.0 kg ha^{-1} i.e. medium.

3.8.1.2 Soil fertility status after harvesting of rice (N, P, K in kg ha^{-1} and organic carbon in%)

After the crop was harvested, soil samples were randomly taken from the field and subjected to chemical analysis for available N, P, K status in kg ha^{-1} and organic carbon in% using the same procedures as were used for analysing initial chemical status of soil.

3.8.2 Plant chemical analysis

3.8.2.1 Nitrogen content

Nitrogen content was estimated by digesting 0.5 g sample with 10 ml concentrated sulphuric acid and digestion mixture. Total nitrogen was determined by micro Kjeldahls method. N uptake grain and straw of crop were calculated by multiplying dry matter production with corresponding values of their content and expressed as kg ha^{-1}.

3.8.2.2 Phosphorus content

Phosphorus content of ground samples of grain and straw were determined by "Vanado-Molybdo-phosphoric yellow colour method" using systronics spectro-photometer by digestion in tri acid mixture (HNO_3: $HClO_4$: H_2SO_4 at the rate of 10:4:1). Subsequently phosphorus uptake by grain and straw of crop was calculated by multiplying dry matter production with corresponding values of their content and was expressed as kg ha^{-1}.

3.8.2.3 Potassium content

K content (%) in the plant sample was determined by flame photometer (Jackson, 1973). K uptake by grain and straw of crop were calculated by multiplying dry matter production with corresponding values of their content and was expressed as kg ha^{-1}.

3.8.3 Biometric observations

Two penultimate rows from two sides of each plot were used for dry matter studies. Observations on plant height, tiller number, leaf area index and phenological stages were taken from tagged plants and for dry matter accumulation was taken from the plants selected randomly from 2nd row from two sides to each plot without disturbing the other rows of the same plot.

3.8.3.1 Plant height

Plant height was taken from 5 randomly selected tagged plants at from each plot at 15 days intervals from 25th June till harvest. Height was measured from the soil surface to apex of tallest leaf during vegetative period up to tip of panicle after emergence of panicles. The data was tabulated and analysed statistically.

3.8.3.2 Dry matter accumulation

Plant samples were collected from penultimate rows on either side of each plot at 15 days interval from 25th June till harvesting the crop. The plant samples were taken in long paper bags marked as per treatments allotted. After sun drying for 4-6 days, the samples was dried in an oven for about 48 hours at temperature of 60-65°C till constant weight was achieved. Dry weight of plant samples was converted in grams meter^{-2} and then to q ha^{-1}.

3.8.3.3 Number of tillers m^{-2}

Tiller number was recorded from 25 June till harvest at 15 days interval from 5 randomly tagged hills of each plot and subsequently the number was transformed to tillers per m^{-2}.

3.8.3.4 Leaf area index (LAI)

LAI was recorded at 15 days interval from 25 June till harvest. The leaves of plants from three randomly selected hills per plot were detached from the joint of leaf blade and leaf sheath. The leaves were divided in three categories on the basis of their length. One leaf from each category was selected and its length (L) and maximum width (W) were measured. Number of leaves from each category was also counted. Leaf area of selected leaves was calculated with the following formula outlined by Bhan and Pandey (1996).

$$\text{Leaf area} = L \times W \times 0.802$$

Total leaf area of a category was computed by multiplying the leaf area of the selected leaf with the number of leaves in that category. Leaf area of all 3 categories was summed up and average leaf area m^{-2} per hill was worked out. This was multiplied by 44.4 to get the leaf area m^{-2} of land area or LAI.

3.8.3.5 SPAD reading

Five randomly selected hills from the penultimate row were tagged for SPAD reading. The readings were taken from 25th June to 8th September at 15 days interval from ten youngest fully developed leaves from each plot and average SPAD value was taken.

3.8.3.6 Phenological studies

Numbers of days taken by the crop from each plot to reach mid tillering, panicle initiation, anthesis, milking, dough and maturity stage from the days after transplanting were keenly observed and recorded. Panicle initiation was determined by dissecting five main stems of plants from penultimate rows of each plot every other day after mid tillering to check for primordial growth. When 90% of the main stems showed primordial growth, it was considered as the panicle initiation stage. Anthesis was determined when 50% of the panicles were present in the centre of the plot.

3.8.3.7 Growing degree days (GDD)

GDD was calculated for different phenophases using the formula given by Summerfield *et al.* (1992) :

$$GDD=\sum_{i=1}^{n}\frac{T_{max}+T_{min}}{2}-T_{base}$$

Where, T_{max} is the maximum temperature

T_{min} is the minimum temperature

T_{base} is the base temperature = 10 ^{o}C for rice

3.8.4 Yield attributes

All the yield contributing characters were studied at maturity of crop. Five hills per plot were selected randomly for studying the yield contributing characters.

3.8.4.1 Number of tillers hill^{-1}

Number of tillers was counted at harvest from 5 randomly selected hills of each plot and averaged to get tiller number hill^{-1}.

3.8.4.2 Effective tillers hill^{-1}

Panicle bearing tillers were counted at harvest from 5 randomly selected hills of each plot and averaged to get effective tillers hill^{-1}.

3.8.4.3 Panicle length (cm)

Length of panicle was recorded by measuring 10 selected panicle from base of panicle up to the end of terminal rachillae and average was calculated to get the mean length of panicle.

3.8.4.4 Panicle weight (g)

Ten selected panicle from each plot were used for recording weight in grams and then average was used for statistical analysis.

3.8.4.5 Spikelets panicle^{-1}

Number of spikelets from 10 panicles randomly selected from each plot were counted and averaged to calculate number of spikelets panicle^{-1}.

3.8.4.6 Filled grains panicle^{-1}

Number of filled grains of 10 randomly selected panicles from each plot was recorded and their average was calculated and expressed as filled grains panicle^{-1}.

3.8.4.7 Sterility percentage

This was calculated from the number of fully developed grains and sterile spikelets (unfilled) as a ratio between unfilled grains to total number of spikelets per panicle on the basis of following formula:

$$\text{Sterility percentage} = \frac{\text{Total number of spikelets} - \text{Number of filled grains}}{\text{Total number of spikelets}} \times 100$$

3.8.4.8 1000-grain weight

Grain samples from each plot collected separately at threshing time were dried properly. 1000-grains from each of these samples were taken randomly and their weights were recorded in grams.

3.8.5 Yield

3.8.5.1 Biological yield

The bundle weight of each net plot was recorded three days of sun drying after harvest on electronic balance and was converted into in q ha^{-1} to express biological yield.

3.8.5.2 Grain yield

The total weight of grains (rough rice) harvested from the net plot area was recorded, and moisture content of the samples was determined with the help of moisture meter (INDOSAW digital moisture testing machine, OSAW Industrial Products Pvt. Ltd.). The grain weight was adjusted to 14% moisture with the help of formula given by Yoshida *et al.* (1976):

$$\text{Adjusted weight} = \frac{100\text{-M} \times \text{W}}{100\text{-}14}$$

Where, M is the measured moisture content (%) and W is the recorded grain weight per plot (kg).

The grain yield from the net plot area (kg/plot) at 14% moisture was then converted to q ha^{-1}.

3.8.5.3 Straw yield

Straw yield of each plot was computed by deducting the grain yield from the respective biological yield and expressed in q ha^{-1}.

3.8.5.4 Harvest index (%)

Harvesting index was computed by the following formula:

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

3.8.6 Quality parameters

3.8.6.1 Physical grain quality parameters

3.8.6.1.1 Grain moisture content at harvest

Grain samples from each plot were collected separately at threshing time. Moisture content in grain was determined by moisture meter and expressed in percent (INDOSAW digital moisture testing machine, OSAW Industrial Products Pvt. Ltd. India)

3.8.6.1.2 Grain grading (specific gravity method)

The grain grading was done by specific gravity method given by Malikk *et al.* (1988). A weighed quantity of 100 g of rough rice from each treatment was taken. Then two salt concentrations of 10 and 20% were made (by dissolving 100 g and 200 g of salt in 1000 ml of water respectively). The weighed quantity of rough rice were first put into 10% solution, the percentage of rice which floated in the solution formed the grade three (G III). The quantity of rice which remains in the bottom of solution were taken out and put into 20% salt solution. The quantity which floated formed the grade two (G II) and the quantity which remained in the bottom form grade one (G I).

3.8.6.1.3 Hulling (%)

The weighed quantity of 100 g of rough rice was dehulled in Satake Rice Huller (Satake Corporation, Hiroshima-ken, Japan). The brown rice obtained was collected and weighed. The hulling percentage was calculated as per the following formula:

$$\text{Hulling (\%)} = \frac{\text{Weight of brown rice (g)}}{\text{Weight of rough rice (g)}} \times 100$$

3.8.6.1.4 Milling (%)

The quantity of brown rice obtained in the above step was milled in Satake Rice Polisher (Satake Corporation, Hiroshima-ken, Japan). The milled rice dispensed was weighed and the milling%age was calculated as per the following formula:

$$\text{Milling (\%)} = \frac{\text{Weight of milled rice (g)}}{\text{Weight of rough rice (g)}} \times 100$$

3.8.6.1.5 Brown rice length and breadth (mm)

Approximately, 10 g of rough rice from each plot was dehulled in Satake Rice Huller (Satake Corporation, Hiroshima-ken, Japan) to obtain brown rice. 20 kernels of brown rice were selected and length and breadth were measured in mm by using ordinary graph paper.

3.8.6.1.6 L/B ratio

Length to breadth ratio was computed by formula, average length divided by average breadth of 20 rice kernels.

3.8.6.1.7 Kernel length elongation after cooking

About 20 milled kernels from each treatment were taken in 50 ml volumetric flasks and 25-30 ml water was added. The flasks were then put in a water bath for 8-10 minutes for cooking. The cooked kernels were put on a graph paper for length measurement. The values were averaged for stastical analysis.

3.8.6.1.8 Elongation ratio

The elongation ratio was measured by dividing KLAC with kernel length before cooking.

3.8.6.1.9 Gel consistency

Gel consistency was estimated following the procedure of Cagampang *et. al*. (1973) as under :

- Placed 10 milled grains in the mortar and pestle and grind them to obtain fine flour (100 mesh).
- 100 mg of flour taken in triplicates in test tubes. Added 0.2 ml of thymol blue reagent, mixed gently and added 2.0 ml of 0.2 N KOH solution and mixed the contents on a vortex.
- Kept the test tubes in water bath at 90-100 ^{o}C for 8 minutes and placed one glass marble on each test tube.
- After removing the test tubes from water bath, cooled them for 5 minutes and mixed the contents on a vortex.
- Kept the test tubes in the low temperature bath at 0-2 ^{o}C for 20 minutes.
- Removed the test tubes from ice bath and laid them horizontally for one hour over ruler or graph paper.
- Measured the length of the blue coloured gel from the inside bottom of the test tube to the gel front as gel consistency of the sample. The scoring was done as given in Table 3.4.

Table 3.4 : Scoring of gel consistency

Length of gel front	Gel Consistency
26-40 mm	Hard gel consistency
41-60 mm	Medium gel consistency
61-100 mm	Soft gel consistency

3.8.6.1.10 HRR (head rice recovery)

The paddy grain samples from each plot were milled by using rubber roller mill. The milled samples from each plot were taken and the whole grains + 75% whole grains were counted separately. The% head recovery was determined as

$$\text{Head recovery (\%)} = \frac{\text{No. of whole kernels + 75\% whole kernels}}{\text{Total No. of kernels}} \times 100$$

3.8.6.1.11 Aroma

A simple laboratory technique to evaluate rices for presence of aroma was developed at IRRI (1971). One gram of freshly harvested milled rice is placed into centrifuge tube (50 ml round bottom). About 20 ml distilled water is added. The tubes are then covered with aluminium foil. The samples are placed in a boiling water bath for 10 minutes. The cooked samples are allowed to cool and the presence of aroma was determined for every sample. The samples were scored and ranked from 1 to 15, where rank 1 is strongly aromatic and rank 15 is non aromatic.

3.8.6.1.12 Volume expansion

A known volume of milled rice was put into a 10 ml measuring cylinder (2 ml), then it was cooked and again put in the cylinder to measure the increase in volume after cooking.

3.8.6.2 Chemical quality parameters

3.8.6.2.1 Protein content (%)

Protein content of rice was determined from N content by Kjeldahl method. Protein content (%) was calculated by N content of the grain multiplying by the factor 5.95.

3.8.6.2.2 Amylose content (%)

Amylose content was estimated following the procedure of Juliano (1971) using the following procedure.

a. Amylose standard curve

The standard curve is based on amylase concentration in the standard amylose solution (known concentration of amylose) *vs* absorbance at 620 nm. The standard working solutions are prepared and absorbance is noted. Standard curve is drawn by taking amylose concentration on x axis and net optical density (absorbance) on y axis (Fig. 3). Equation in graph can be directly used to determine the concentration of amylose in the biological samples. Alternately, it can be calculated using multiplication factor (MF).

b. Analysis of amylose content in rice sample

- Grind thirty milled and well-polished grains of each sample in mortar and pestle.
- Took 50 mg rice flour in a 50 ml falcon tube, added 0.5 ml of 95% ethanol and 4.5 ml of 1.0 N NaOH.
- Shaked thoroughly and heated the tube in boiling water for 15 minutes to dissolve the mass, cooled to room temperature and made up to the 50 ml mark with distilled water.
- Drained 5 ml of the above solution into a 100 ml volumetric flask.
- To this, 1 ml of 1.0 N acetic acid added and 2 ml of iodine solution and

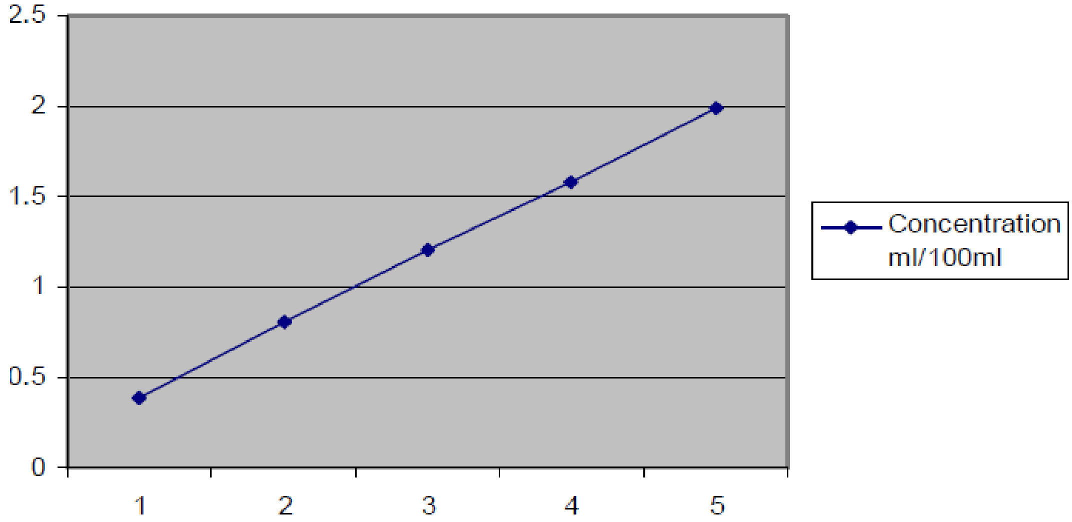

Fig. 3 : Standard curve for amylose

made up the volume to 100 ml by distilled water. Shaked to make the contents uniform.

- Covered the flasks containing the above reaction mixture with black cloth and measured absorbance (OD) after 20 minutes at 620 nm in a spectrophotometer.
- Amylose content was calculated by the following formula :

% Amylose (w/w) in the rice flour = A x dilution factor x 2 x extract volume /1000

= A x 20 x 50 x 2 /1000

= A x 2

Where, 'A' is the amount of amylose in µg/ml based on O.D.

Table 3.5: Classification of amylose content

Class	Amylose content (%)
Waxy	1-2
Very Low	2.1-9
Low	9.1-20
Intermediate	20.1-25
High	25.1-33

3.8.7 Relative economics

Relative economics of different treatments was worked out on the basis of grain and straw yield per hectare. The cost of inputs and outputs were estimated as per prevailing market rates. The cost of cultivation was considered common in all treatments while the cost of nitrogen fertilizers which varied due to their requirements as per treatment.

3.8.7.1 Gross returns

3.8.7.2 Net returns

The net returns were calculated by subtracting the cost of cultivation from gross returns

3.8.7.3 Incremental benefit cost ratio (IBCR)

Benefit : cost ratio (net returns per rupee invested for each treatment) was calculated by dividing the net returns with the cost of cultivation.

$$\text{Benefit cost ratio} = \frac{\text{Net returns}}{\text{Cost of cultivation}}$$

3.9 Statistical analysis

All the collected data were analyzed by following the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Chapter - 4

EXPERIMENTAL FINDINGS

This chapter deals with interpretation of data generated during the course of investigation. The experimental findings are summarized in Tables and Figures and described in the text under appropriate heads.

4.1 Biometric observations

4.1.1 Plant height

The data on periodic plant height is presented in Table-4.1 and illustrated in Fig. 4 and 5. Perusal of data reveals that plant height increased constantly up to 24^{th} August and thereafter remained almost static till harvest. Further, it is evident from the figure that plant height followed a typical sigmoid curve with greatest increase between 25^{th} July to 24^{th} August *viz.* the period coinciding with late tillering to flowering.

The data further indicates that mean plant height varied from 82.16 cm to 88.68 cm due to change in transplanting dates. During all stages plant height was significantly higher in 20^{th} May transplanting as compared to 1^{st} June and 11^{th} June transplanting dates. The lowest plant height was recorded in 11^{th} June transplanting date.

Mean plant height varied between 79.30 to 90.37 cm. The further data reveals that plant height was also significantly influenced by different levels of nitrogen at all crop growth stages. The application of 120 kg N ha^{-1} recorded significantly taller plants than all other nitrogen levels and was closely followed by the application of 90 kg N ha^{-1}. The other nitrogen levels recorded significantly lower plant height. However, the lowest plant height was recorded in control treatment at all the crop growth stages.

The interactions between dates of transplanting and nitrogen levels were found to be non-significant.

Table 4.1 : Effect of transplanting dates and nitrogen levels on periodic plant height (cm)

Treatment	Date of observation						
	25th June	**10th July**	**25th July**	**9th Aug.**	**24th Sept.**	**8th Sept.**	**At harvest**
Transplanting dates							
20th May	35.09	43.18	53.85	68.47	85.88	88.00	88.68
1st June	30.39	40.17	50.78	65.09	81.06	85.57	86.18
11th June	25.10	32.51	44.33	54.87	71.30	81.12	82.16
SEm±	0.61	0.51	0.74	0.93	1.08	0.81	0.59
CD p≤0.05)	2.35	2.00	2.83	3.62	4.20	3.19	2.41
Nitrogen levels (kg ha^{-1})							
Control	25.52	33.79	44.27	57.73	73.13	79.27	79.3
30	28.66	37.25	47.95	59.89	75.66	82.79	82.71
60	30.63	38.94	50.15	62.71	79.59	85.22	86.98
90	32.04	40.73	51.9	65.18	81.85	88.49	88.99
120	34.12	42.39	53.98	68.53	85.84	89.73	90.37
SEm±	0.64	0.58	0.53	0.60	0.49	0.59	0.37
CD (p≤0.05)	1.90	1.70	1.60	1.82	1.43	1.81	1.09

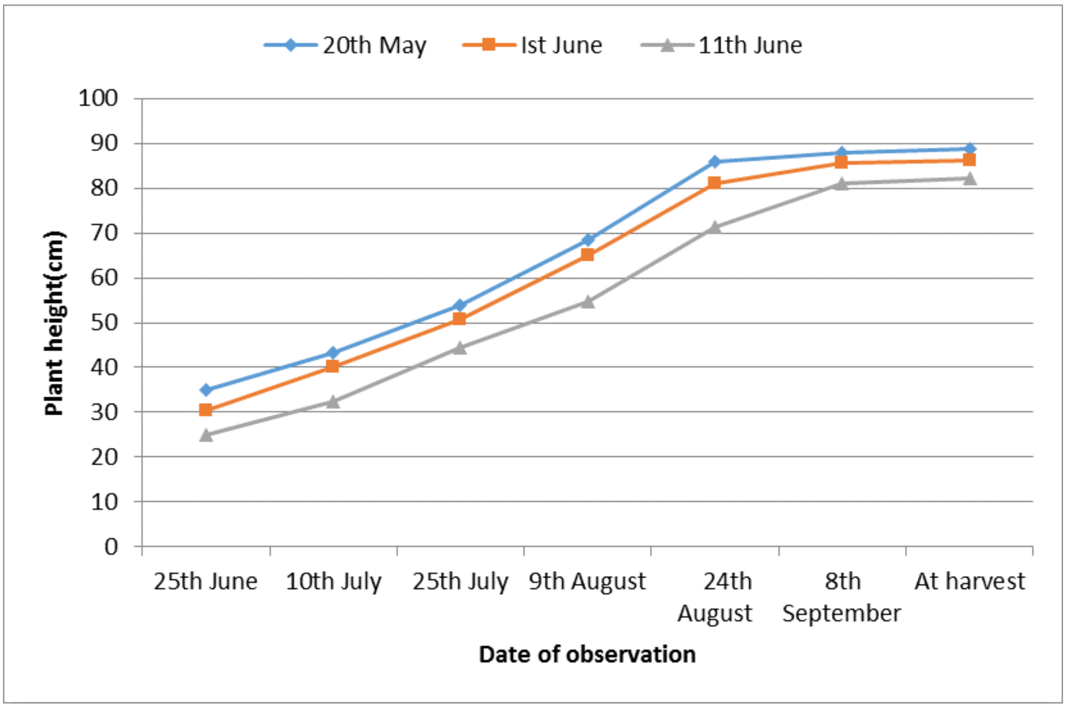

Fig. 4 : Influence of transplanting dates on periodic plant height

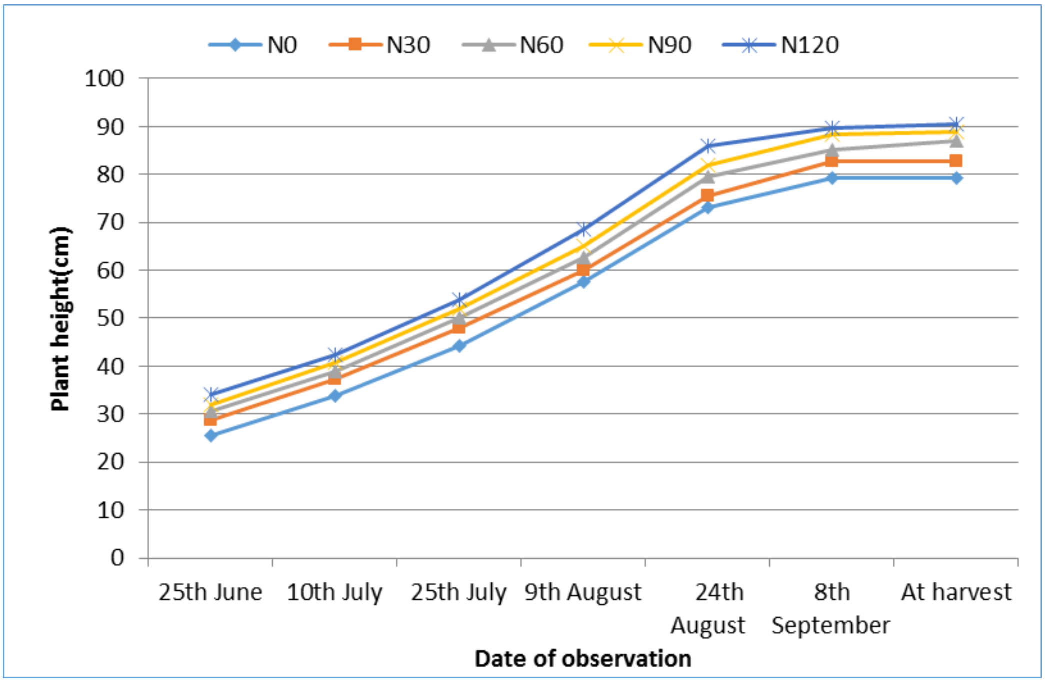

Fig. 5 : Influence of nitrogen levels on periodic plant height

4.1.2 Dry matter accumulation

The data on periodic dry matter accumulation is presented in Table-4.2 and illustrated graphically in Fig. 6 and 7. It was found that dry matter accumulation increased slowly up to 10th July and increased at a faster rate up to 9th August in the first two transplanting dates. However, in 11th June transplanting dry matter accumulation recorded an increase at a rapid pace up to 24th August and thereafter showed a steady increase till harvest. Further, it is evident from the figure that the periodic dry matter production followed a typical sigmoid curve with greatest increase up to 9th August for 20th May and 1st June transplanting dates and up to 24th August for 11th June transplanting date.

Perusal of the data indicates that transplanting dates recorded a significant effect on dry matter accumulation at all the growth stages except on 25th June for 20th May and 1st June transplanting dates. At all growth stages 20th May transplanting date was significantly superior than the 1st June and 11th June transplanting dates. At harvest 20th May transplanting was at par with 1st June transplanting date.

Dry matter production was significantly influenced by various nitrogen levels at all the stages. Application of 120 kg N ha^{-1} resulted in a significantly higher dry matter production as compared to other nitrogen levels. The lowest dry matter production was recorded in control treatment at all the stages. Percentage increase in dry matter recorded was 15.79, 14, 10.2 and 5.6% over control.

The interaction effect between transplanting dates and nitrogen levels were found to be non-significant.

4.1.3 Number of tillers m^{-2}

The data on periodic tiller number m^{-2} is presented in Table-4.3 and illustrated graphically in Fig. 8 and 9. The perusal of data indicated that for 20th May and 1st June transplanting tiller number increased continuously up to 25th July whereas, for 11th June transplanting it increased continuously up to 9th August i.e.

Table 4.2 : Effect of transplanting dates and nitrogen levels on dry matter accumulation (q ha^{-1})

Treatment	Date of observation						
	25th June	**10th July**	**25th July**	**9th Aug.**	**24th Sept.**	**8th Sept.**	**At harvest**
Transplanting dates							
20th May	6.95	32.09	70.88	87.62	90.37	92.70	94.07
1st June	6.79	24.86	61.89	82.89	86.64	89.47	90.73
11th June	1.60	7.41	33.95	57.32	77.83	80.08	81.75
SEm±	0.10	0.40	0.53	0.72	0.64	0.78	1.22
CD p≤0.05)	0.39	1.54	2.06	3.05	3.50	3.15	4.74
Nitrogen levels (kg ha^{-1})							
Control	3.87	18.90	46.17	66.77	76.53	78.81	80.31
30	4.50	21.62	52.18	71.51	81.65	83.8	85.42
60	5.08	23.35	55.52	76.89	87.35	87.94	89.28
90	5.55	25.20	59.67	79.55	89.56	91.27	93.51
120	6.55	26.97	64.33	85.02	91.65	95.26	95.72
SEm±	0.08	0.37	0.45	0.95	0.84	0.83	0.71
CD (p≤0.05)	0.23	1.16	1.33	2.82	2.54	2.52	2.13

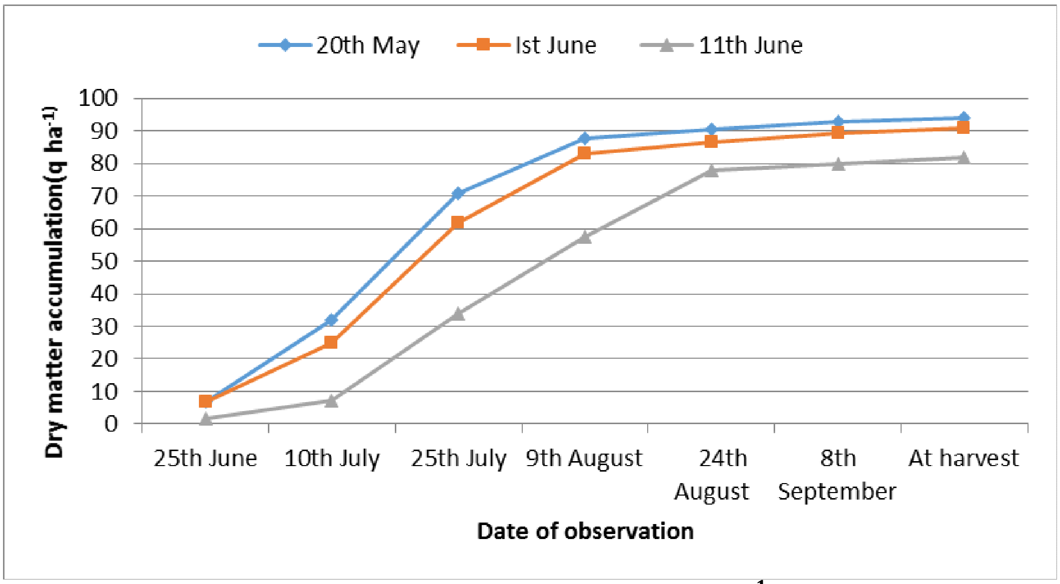

Fig. 6 : Periodic dry matter accumulation (q ha^{-1}) as influenced by transplanting dates

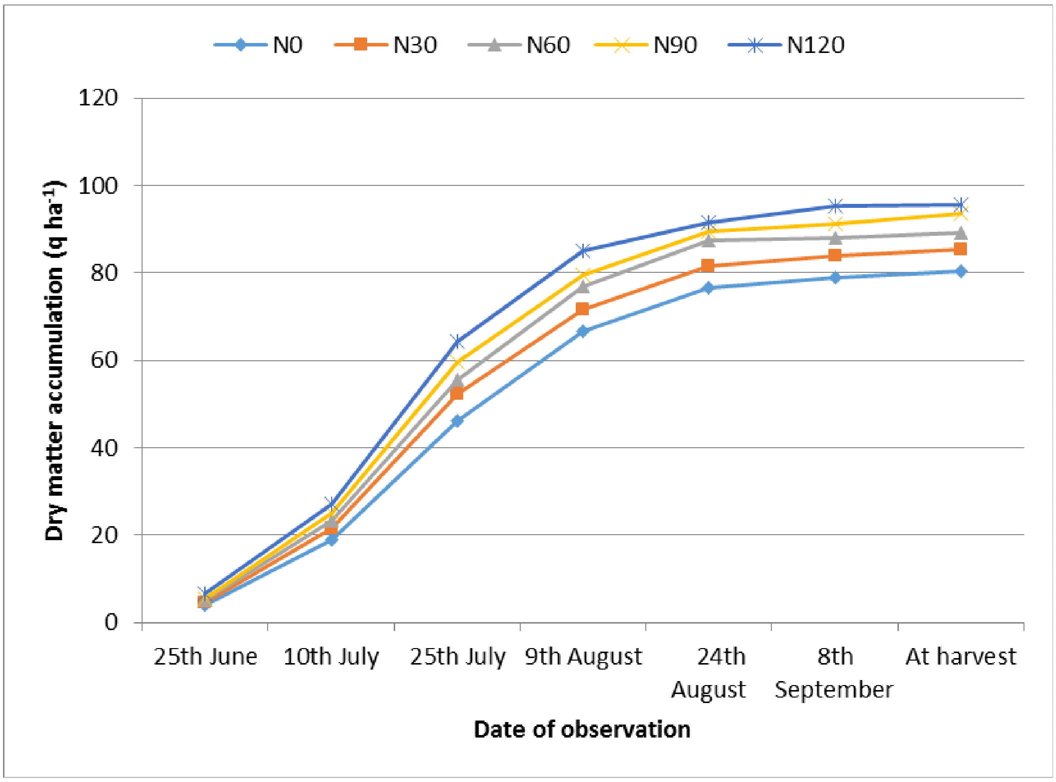

Fig. 7 : Periodic dry matter accumulation (q ha^{-1}) as influenced by nitrogen levels

the period coinciding with the maximum tillering stage and thereafter showed a steady decrease till harvest.

A further examination of data revealed that 20th May transplanting recorded higher tiller number m^{-2} as compared to 1st June and 11th June transplanting dates. However, from 24th August to harvest 20th May and 1st June transplanting dates were at par. The lowest tiller number was recorded in case of 11th June transplanting date.

Perusal of data depicted that tiller number m^{-2} was significantly influenced by different levels of nitrogen at all crop growth stages. The highest tillers m^{-2} were recorded for treatments receiving 120 kg N ha^{-1} but the same was at par with the nitrogen level of 90 kg N ha^{-1}, except tiller number recorded at 25th June, followed by the treatments receiving 60 kg N ha^{-1}. However, the lowest number of tillers m^{-2} were recorded for the control treatment.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.1.4 Leaf area index

The data pertaining to leaf area index is presented in Table-4.4 and illustrated graphically in Fig. 10 and 11. It was found that leaf area index increased continuously up to 25th July for 20th May and 1st June transplanting and up to 9th August for 11th June transplanting and thereafter showed a continuous decrease up to harvest.

Perusal of data indicated that transplanting dates showed significant difference in leaf area index at all growth stages. The crop transplanted on 20th May recorded significantly higher LAI over 1st June and 11th June transplanting date.

Leaf area index was also significantly influenced by different levels of nitrogen at all the stages. The significantly higher LAI was recorded with the application higher doses of nitrogen i.e. 120 kg N ha^{-1} over its preceding levels of nitrogen.

The interaction effect of transplanting dates and nitrogen levels were found to be non significant.

4.1.5 SPAD reading

The data on SPAD reading is presented in Table-4.5 and depicted by Fig. 12 and 13. It was found that SPAD reading increased significantly up to 9th August for 20th May and 1st June transplanting and up to 24th August for 11th June transplanting and thereafter showed a steep decrease.

Perusal of data indicated that transplanting dates showed a significant difference on SPAD reading at all the growth stages, except, on 9th August reading. The crop transplanted on 20th May recorded higher SPAD reading as compared to crop transplanted on 1st June and 11th June. The lowest SPAD reading was recorded for crop transplanted on 11th June.

Among the different nitrogen levels the examination of data revealed that SPAD reading was significantly influenced by nitrogen fertilization levels at all crop growth stages. Significantly higher SPAD reading was recorded with the application of 120 kg N ha^{-1}. The other nitrogen levels (90, 60 and 30 kg N ha^{-1}) recorded significantly lower SPAD values while as the lowest values were recorded for the control.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

Table 4.3 : Effect of transplanting dates and nitrogen levels on periodic tiller number m^{-2}

Treatment	Date of observation						
	25th June	**10th July**	**25th July**	**9th Aug.**	**24th Sept.**	**8th Sept.**	**At harvest**
Transplanting dates							
20th May	241.6	310.1	397.9	348.3	342.3	339.3	338.8
1st June	210.4	280.6	381.6	333.0	329.0	326.0	325.5
11th June	135.5	201.2	271.9	365.3	309.6	307.6	306.6
SEm±	3.2	2.9	3.4	3.5	3.7	3.7	3.7
CD p≤0.05)	9.7	11.7	13.5	14.1	14.9	14.9	14.9
Nitrogen levels (kg ha^{-1})							
Control	179.4	249.6	319.2	308.3	283.9	282.3	280.7
30	187.5	258.8	344.5	329.1	310.6	310.9	310.2
60	195.8	266.8	357.4	354.7	337.4	334.7	334.1
90	203.7	273.3	364.4	363.2	346.3	343.7	342.9
120	212.9	276.6	367.1	368.1	356.5	352.9	350.2
SEm±	2.0	2.1	2.2	2.4	2.6	2.6	2.6
CD (p≤0.05)	5.9	6.3	6.7	7.1	7.9	7.9	7.9

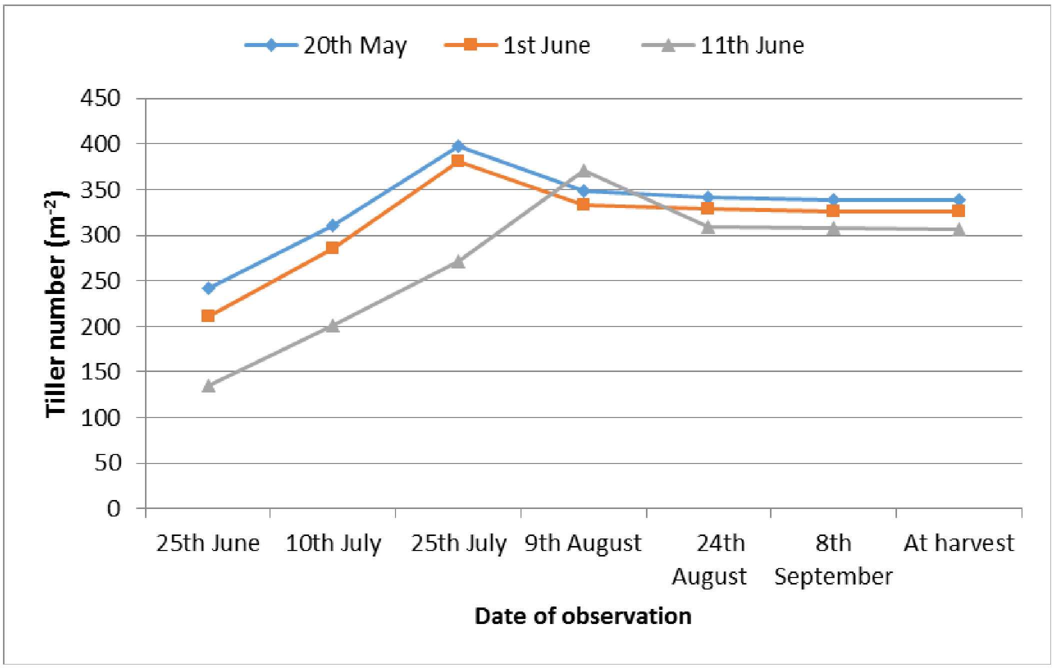

Fig. 8 : Periodic tiller number m^{-2} as influenced by transplanting dates

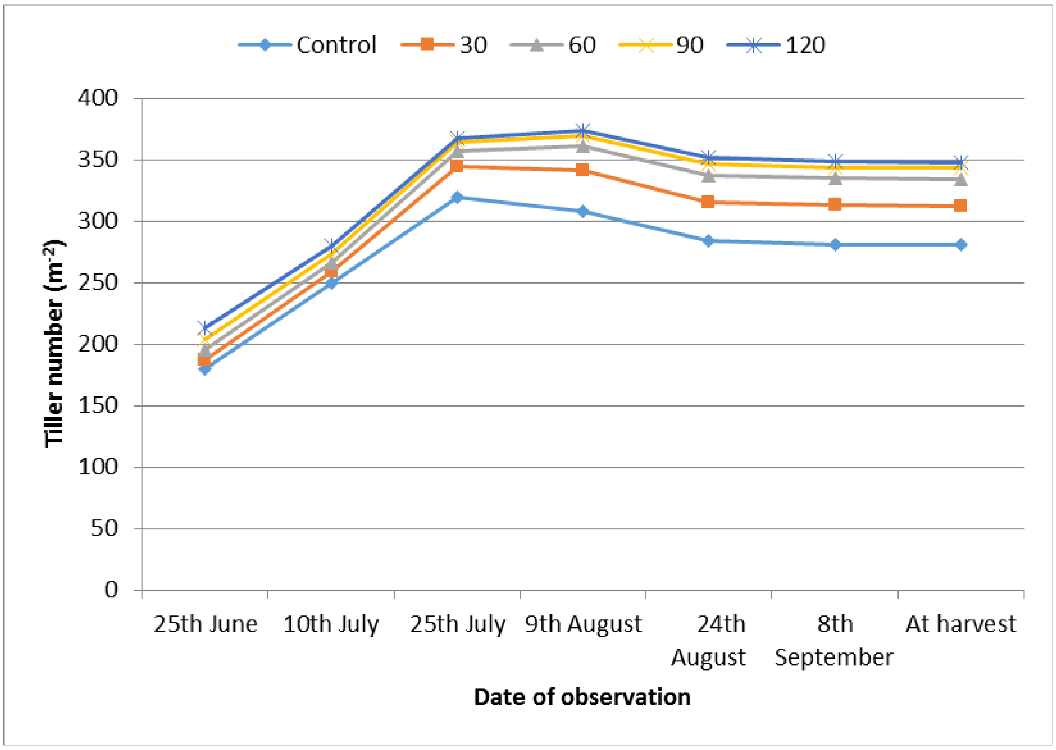

Fig. 9 : Periodic tiller number m^{-2} as influenced by nitrogen levels

Table 4.4: Periodic leaf area index as influenced by transplanting dates and nitrogen levels

Treatment	Date of observation				
	25th June	**10th July**	**25th July**	**9th August**	**24th August**
Transplanting dates					
20th May	1.11	2.70	4.42	4.36	3.75
1st June	1.01	2.57	4.25	4.03	3.57
11th June	0.32	1.03	2.63	3.81	3.24
SEm±	0.02	0.02	0.04	0.07	0.08
CD ($p \leq 0.05$)	0.08	0.06	0.17	0.26	0.32
Nitrogen levels (kg ha^{-1})					
Control	0.64	1.80	3.23	3.49	2.82
30	0.74	2.00	3.63	3.89	3.14
60	0.83	2.15	3.86	4.20	3.60
90	0.91	2.25	3.98	4.28	3.87
120	0.96	2.30	4.12	4.45	4.17
SEm±	0.002	0.002	0.04	0.06	0.07
CD ($p \leq 0.05$)	0.007	0.005	0.13	0.17	0.22

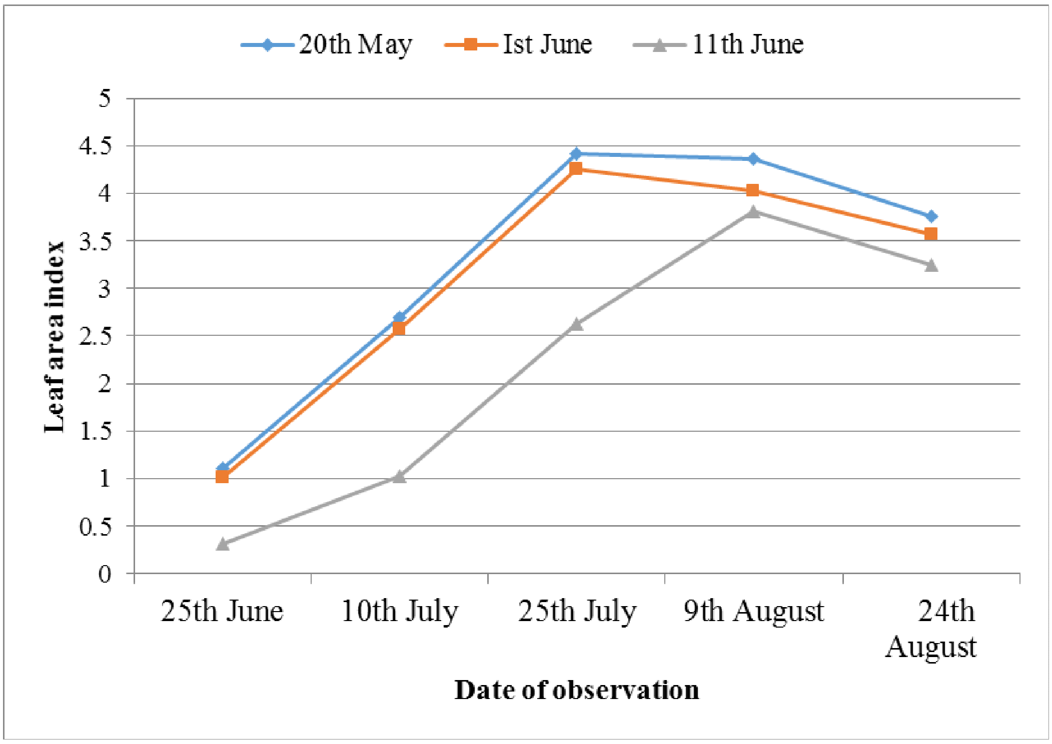

Fig. 10 : Periodic leaf area index as influenced by transplanting dates

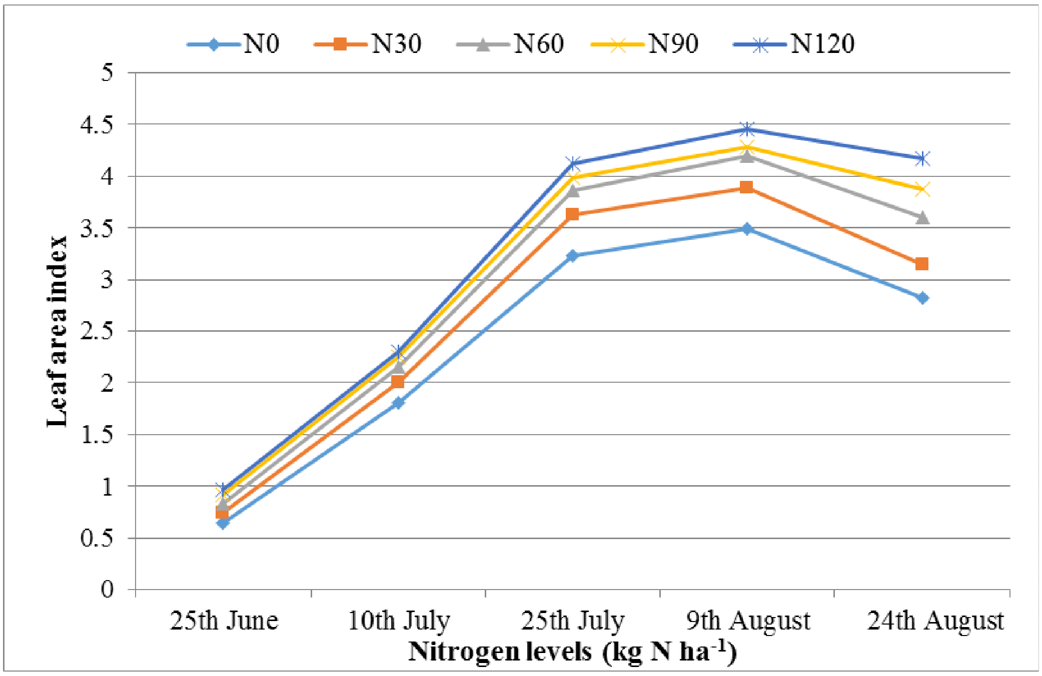

Fig. 11 : Periodic leaf area index as influenced by nitrogen levels

Table 4.5: Effect of transplanting dates and nitrogen levels on SPAD reading

Treatment	Date of observation					
	25th June	**10th July**	**25th July**	**9th Aug.**	**24th Aug.**	**8th Sept.**
Transplanting dates						
20th May	35.23	38.31	40.97	41.32	35.90	26.79
1st June	30.69	35.22	37.79	39.45	32.72	23.80
11th June	28.51	33.14	35.62	38.10	38.31	29.30
SEm±	0.47	0.49	0.52	0.72	0.86	0.92
CD (p≤0.05)	1.97	2.02	2.05	N S	3.36	3.62
Nitrogen levels (kg ha^{-1})						
Control	29.70	33.14	34.94	36.54	30.90	22.13
30	30.64	34.78	37.33	38.93	34.05	24.82
60	31.44	35.68	38.46	39.93	36.33	27.59
90	32.40	36.62	39.45	40.88	37.83	28.60
120	33.20	37.58	40.46	41.82	39.13	30.01
SEm±	0.31	0.11	0.29	0.26	0.45	0.62
CD (p≤0.05)	0.95	0.88	1.01	0.77	1.35	1.87

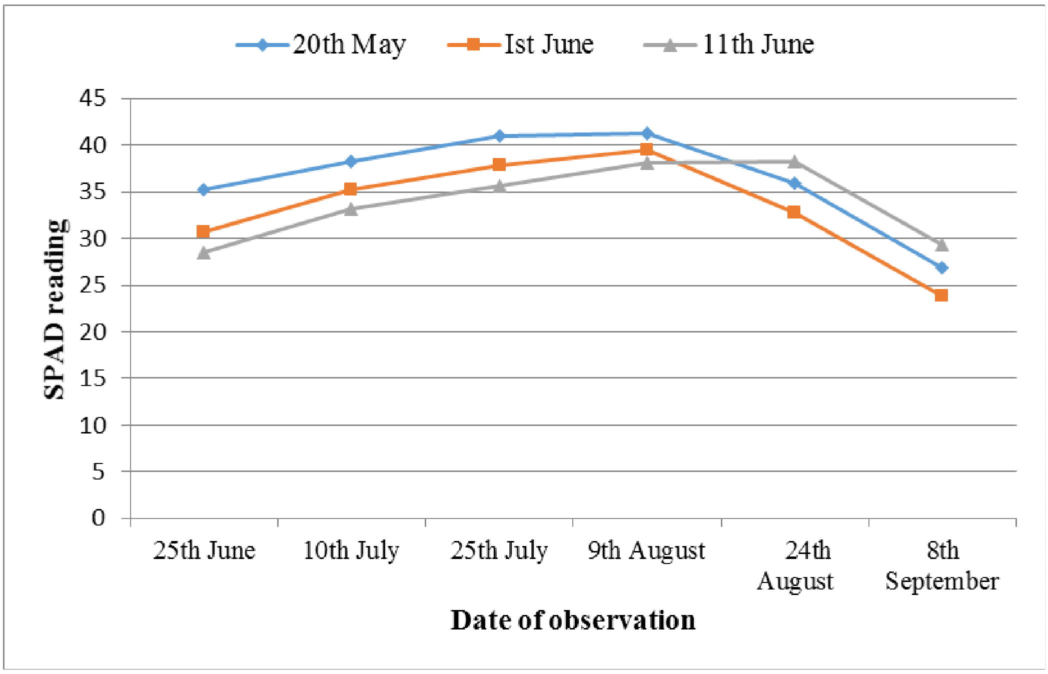

Fig. 12 : SPAD reading as influenced by transplanting dates

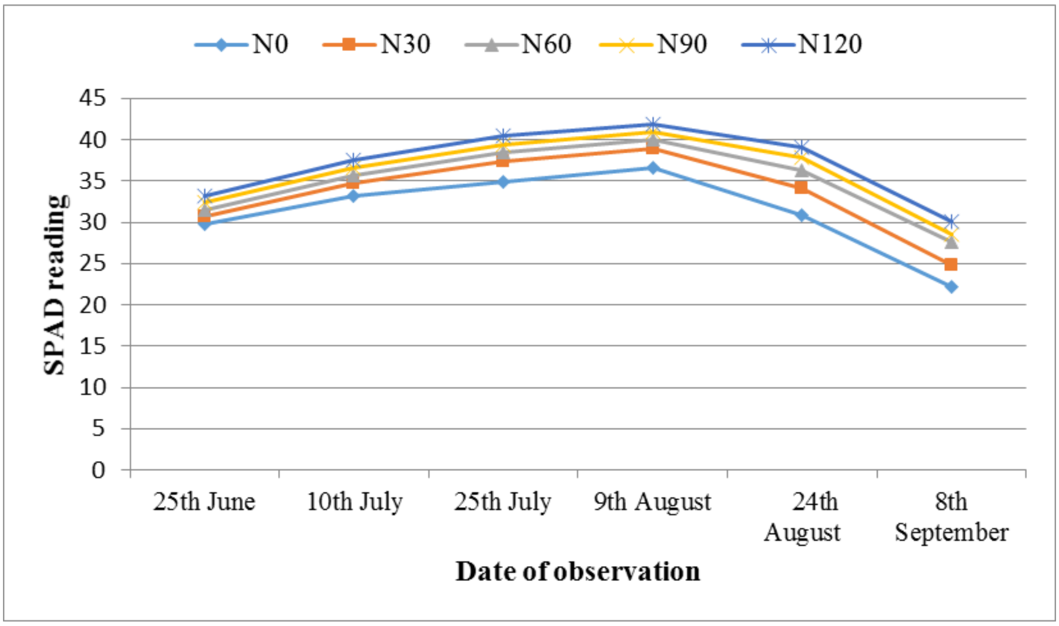

Fig. 13 : SPAD reading as influenced by nitrogen levels

4.1.6 Phenological studies

The data pertaining to days taken to phonological stages has been presented in Table-4.6 and Fig. 14 and 15. Perusal of the data indicates that different phenological stages of rice crop viz. mid tillering, panicle initiation, flowering, milking, dough and maturity varied significantly due to effect of various treatments.

As far as transplanting dates are concerned, earlier transplanted crop took more number of days to reach various phenological stages as compared to late sown crop. The 20th May transplanting date took significantly higher number of days to reach mid tillering (37.57), panicle initiation (55.81), flowering (84.33), milking (97.36), dough (105.73) and harvest (118.38), whereas the 11th June transplanting date took significantly the lesser number of days to reach different phenological stages.

As regards the different nitrogen levels 120, 90 and 60 kg N ha^{-1} took significantly more number of days to reach different phenological stages while significantly lower number of days was taken by 30 and 0 kg N ha^{-1} to reach different phenological stages, indicating that higher doses of nitrogen prolonged the crop growth stages.

4.1.7 Growing degree days (GDD)

The data relating to GDD has been presented in Table-4.7. Perusal of the data indicates that with change in transplanting dates and nitrogen levels, GDD accumulation also varied for the crop. Transplanting dates induced a variation in GDD accumulation required to reach various phenological stages. 20th May and 1st June transplanting dates required significantly higher number of GDDs to reach flowering, milking, dough and harvest, whereas the 11th June transplanting date required significantly the lower number of GDDs to reach different phenological stages. Thus early sown crop accumulated more GDDs to reach to different phonological stages as compared to late sown crop.

Table 4.6 : Effect of transplanting dates and nitrogen levels on days taken by rice crop to reach different phenological stages

Treatment	Mid tillering	Panicle initiation	Flowering	Milking	Dough	Harvesting
Transplanting dates						
20th May	37.57	55.81	84.33	97.36	105.73	118.38
1st June	33.06	51.70	80.71	94.79	102.89	114.15
11th June	32.75	50.69	78.26	90.40	98.20	108.11
Nitrogen levels (kg ha^{-1})						
Control	33.01	50.33	82.13	94.41	102.04	112.49
30	33.87	51.26	83.19	95.02	103.02	113.00
60	34.44	52.45	84.17	95.96	103.55	113.56
90	35.08	53.16	85.05	96.90	104.41	114.13
120	35.89	54.49	85.97	98.95	105.13	114.56

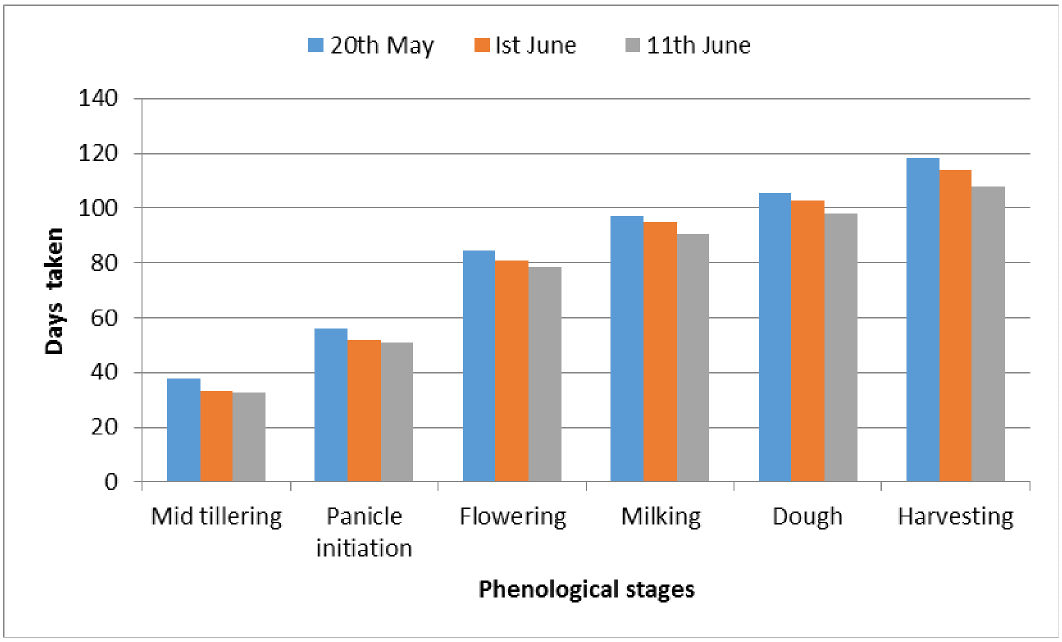

Fig. 14 : Days taken by rice crop to reach different phenological stages, as influenced by transplanting dates

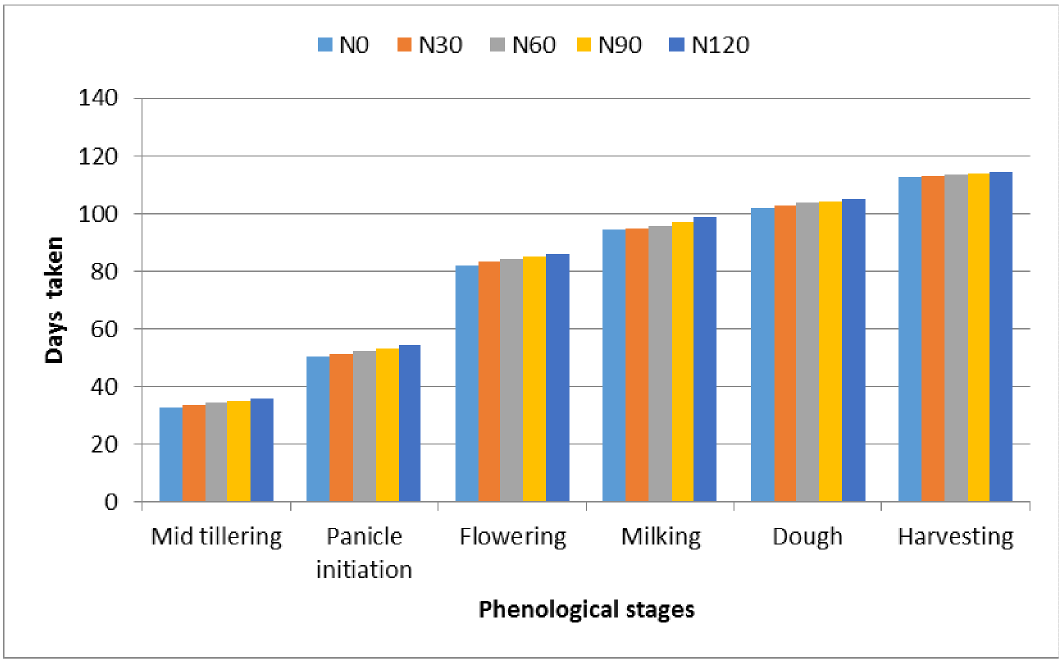

Fig. 15: Days taken by rice crop to reach different phenological stages, as influenced by nitrogen levels

Table 4.7 : Effect of transplanting dates and nitrogen levels on GDD accumulated by rice crop to reach different phenological stages

Treatment	Mid tillering	Panicle initiation	Flowering	Milking	Dough	Harvesting
Transplanting dates						
20th May	479	673	1127	1228	1291	1365
1st June	517	732	1163	1252	1310	1362
11th June	578	807	1182	1261	1316	1355
Nitrogen levels (kg ha^{-1})						
Control	509	705	1140	1230	1297	1353
30	518	722	1151	1242	1302	1356
60	523	740	1159	1249	1305	1361
90	531	754	1166	1253	1310	1363
120	542	764	1171	1261	1314	1368

As regards the different nitrogen levels, more GDDs were required for higher nitrogen levels of 120, 90 and 60 kg N ha^{-1} while lower GDDs were required by treatments receiving lower nitrogen levels of 30 and 0 kg N ha^{-1} to complete the various phenological stages.

4.2 Yield attributes

4.2.1 Panicles m^{-2}

Perusal of data pertaining to panicles m^{-2} (Table-4.8) revealed that transplanting dates had a significant effect on number of panicles m^{-2}. The highest number of panicles m^{-2} were recorded for the 20th May transplanting date (337.69), whereas lowest panicle number was recorded for the 11th June transplanting date (304.22). The% increase in panicles m^{-2} due to 20th May transplanting over 1st and 11th June transplanting was to the extent of 4.08 and 9.91% respectively.

An examination of data revealed that panicles m^{-2} was significantly influenced by different levels of nitrogen. Application of 120 kg N ha^{-1} resulted in a significantly higher number of panicles m^{-2} (345.60) as compared to all other nitrogen levels. However, 120 kg N ha^{-1} was at par with 90 kg N ha^{-1}. The lowest number of panicles m^{-2} (279.30) was recorded in control treatment. The nitrogen levels 90, 60 and 30 kg N ha^{-1} also recorded significant differences among themselves. While% increase in panicle number due to 120, 90, 60 and 30 kg N ha^{-1} over control was to the extent of 19.18, 18.19, 15.93 and 10.12% respectively.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.2.2 Panicle length

The data related to panicle length has been presented in Table-4.8 reveals that there was no significant variation in panicle length by changing the sowing dates. As far as nitrogen levels are concerned significant difference in panicle length was recorded with an application of graded levels of nitrogen levels. The nitrogen level 120 kg N ha^{-1} recorded significantly higher length (24.04 cm) as compared to other nitrogen levels. The lowest panicle length (22.24 cm) was recorded for the control.

The interaction effect of transplanting dates and nitrogen levels was found significant (Table 4.8a). Highest panicle length was recorded with 20th May transplanting (24.60 cm) with application of 120 kg N ha^{-1} and lowest by 11th June transplanting with control treatment (21.33 cm).

4.2.3 Panicle weight

The data on panicle weight is presented in Table-4.8. Perusal of the data reveals that panicle weight was significantly affected by transplanting dates. The highest panicle weight (1.58 g) was recorded for 20th May transplanting date and lowest panicle weight (1.46 g) was recorded for 11th June transplanting. However, panicles weight for the 1st June transplanting date was found at par with 20th May transplanting date.

Further examination of the data reveals that nitrogen levels also significantly influenced the panicle weight. Application of 120 kg N ha^{-1} recorded highest panicle weight (1.69 g) as compared all other nitrogen levels. However, the same was at par with 90 kg N ha^{-1}.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.2.4 Spikelets panicle^{-1}

The data on number of spikelets panicle^{-1} is presented in Table-4.8. Perusal of the data indicated that transplanting dates had a significant effect on spikelets panicle^{-1}. The highest number of spikelets panicle^{-1} was recorded for the 20th May transplanting date (94.88), whereas the lowest spikelet number was recorded for the 11th transplanting (76.62).

Spikelets panicle^{-1} were also significantly influenced by different levels of nitrogen. Application of 120 kg N ha^{-1} resulted in significantly highest number of spikelets panicle^{-1} (96.27) as compared to other nitrogen levels whereas lowest spikelets panicle^{-1} (77.68) were recorded in control treatment.

The interaction effect of transplanting dates and nitrogen levels on spikelets panicle^{-1} presented in Table-4.8b reveals that transplanting of crop on 20th May with application of 120 kg N ha^{-1} resulted in maximum spikelets panicle^{-1} (106.12), which was significantly higher than other treatment combinations. The lowest value for spikelets panicle^{-1} (69.64) was found on 11th June transplanting with control.

4.2.5 Filled grains panicle^{-1}

The data on number of filled grains panicle^{-1} is presented in Table-4.8. Perusal of the data indicated that transplanting dates had a significant effect on the number of filled grains panicle^{-1}. Delay in transplanting date decreased filled grains per panicle so that the highest number of filled grains panicle^{-1} were recorded for the 20th May transplanting (72.20), whereas the lowest filled grain number was recorded for the 11th June transplanting (60.80).

An examination of the data also revealed that filled grains panicle^{-1} was significantly influenced by different levels of nitrogen. Application of 90 kg N ha^{-1} resulted in significantly higher number of filled grains panicle^{-1} (66.33) as compared to lower nitrogen levels. However, further increase in N up to 120 kg N ha^{-1} did not affect the variation in filled grains panicle^{-1}. The other nitrogen levels i.e. 120, 60 and 30 kg ha^{-1} recorded significantly lower number of filled grains panicle^{-1} (64.83, 62.48 and 59.84, respectively) than 90 kg N ha^{-1} level. However, filled grains panicle^{-1} for 90 kg N ha^{-1} was found at par with 120 kg N ha^{-1}.

Table 4.8 : Effect of transplanting dates and nitrogen levels on yield contributing characters

Treatment	Panicles m^{-2}	Panicle length (cm)	Panicle weight (g)	Spikelets $panicle^{-1}$	Filled grains $panicle^{-1}$	Sterility (%)	1000-grain weight (g)
Transplanting dates							
20^{th} May	337.69	24.08	1.58	94.88	72.20	23.68	24.68
1^{st} June	323.90	23.26	1.53	88.52	63.31	28.55	23.51
11^{th} June	304.22	22.56	1.46	76.62	60.80	33.59	20.67
SEm±	2.29	0.36	0.02	0.73	0.61	0.68	0.26
CD ($p \leq 0.05$)	9.24	N S	0.06	2.93	2.37	2.66	1.09
Nitrogen levels (kg ha^{-1})							
Control	279.30	22.24	1.32	77.68	57.03	26.97	21.73
30	310.98	22.99	1.41	81.86	59.84	27.26	22.83
60	332.40	23.37	1.53	86.36	62.48	28.04	23.16
90	341.39	23.82	1.67	93.19	66.33	28.34	24.01
120	345.60	24.04	1.69	96.27	64.83	33.14	25.69
SEm±	1.70	0.08	0.01	0.47	0.54	0.64	0.27
CD ($p \leq 0.05$)	5.09	0.25	0.04	1.42	1.56	1.87	0.80

Table 4.8a : Interaction effect of transplanting dates and nitrogen levels on panicle length (cm)

Treatment	Nitrogen levels (kg ha^{-1})					Mean
	Control	30	60	90	120	
Transplanting dates						
20th May	23.07	24.00	24.20	24.53	24.60	**24.08**
1st June	22.33	23.07	23.33	23.67	23.90	**23.26**
11th June	21.33	21.90	22.57	22.97	24.03	**22.56**
Mean	22.24	22.99	23.37	23.72	24.18	

CD ($p \le 0.05$)

Transplanting dates (D) : N S

Nitrogen levels (N) : 0.24

D × N : 0.43

Table 4.8b : Interaction effect of transplanting dates and nitrogen levels on spikelets panicle^{-1}

Treatment	Nitrogen Levels (kg ha^{-1})					Mean
	Control	30	60	90	120	
Transplanting dates						
20th May	85.80	89.12	93.95	99.42	106.12	**94.88**
1st June	77.60	82.88	88.43	93.60	100.10	**88.52**
11th June	69.64	73.58	76.71	80.54	82.60	**76.62**
Mean	77.68	81.86	86.36	91.19	96.26	

CD ($p \leq 0.05$)

Transplanting dates (D) : 0.93

Nitrogen levels (N) : 0.32

D × N : 0.56

Table 4.8c : Interaction effect of transplanting dates and nitrogen levels on filled grains panicle^{-1}

Treatment	Nitrogen Levels (kg ha^{-1})					Mean
	Control	30	60	90	120	
Transplanting dates						
20th May	68.39	69.99	72.33	75.62	74.69	**72.70**
1st June	54.13	59.43	64.25	69.00	69.73	**63.81**
11th June	48.56	50.10	50.85	54.36	50.09	**51.09**
Mean	57.03	59.84	62.48	66.33	68.32	

CD ($p \leq 0.05$)

Transplanting dates (D) : 2.39

Nitrogen levels (N) : 1.56

D × N : 2.71

Table 4.8d : Interaction effect of transplanting dates and nitrogen levels on spikelet sterility (%)

Treatment	Nitrogen levels (kg ha^{-1})					Mean
	Control	30	60	90	120	
Transplanting dates						
20th May	20.33	21.50	23.00	23.94	29.64	**23.68**
1$_{st}$ June	30.27	28.33	27.39	26.32	30.41	**28.55**
11th June	30.31	31.94	33.74	35.52	39.38	**35.59**
Mean	26.97	27.26	28.04	28.34	29.47	

CD ($p \leq 0.05$)

Transplanting dates (D) : 2.67

Nitrogen levels (N) : 1.87

D × N : 3.23

The interaction effect of transplanting dates and nitrogen levels on filled grains panicle^{-1} was found significant (Table-4.8c). Transplanting of crop on 20th May with application of 90 kg N ha^{-1} resulted in maximum number of filled grains panicle^{-1} (75.62). The lowest number of filled grains panicle^{-1} was found on 11th June transplanting with control nitrogen treatment (48.56).

4.2.6 Sterility percentage

Perusal of data on sterility% indicated that transplanting dates as well as nitrogen levels had a significant effect on sterility percentage (Table-4.8). The highest sterility percentage was recorded for the 11th June transplanting (33.59), whereas 20th May and 1st June transplanting dates recorded lower sterility percentage of 23.68 and 28.55, respectively, indicating that with delay in transplanting of the crop sterility percentage increases.

The data also revealed that sterility percentage was significantly affected by different levels of nitrogen. Application of 120 kg N ha^{-1} resulted in a significantly higher sterility percentage (33.14) and was significantly different from nitrogen level of 90 kg ha^{-1} (28.34). The lowest sterility percentage was recorded in control (26.97). Thus increase in nitrogen levels also increases the sterility percentage of the crop.

The interaction effect of transplanting dates and nitrogen levels on sterility percentage was found significant (Table-4.11d). Transplanting of crop on 20th May with application of 0 kg N ha^{-1} i.e. control, resulted in minimum percentage of spikelet sterility (20.33). The highest spikelet sterility percentage was found on 11th June transplanting with application of 120 kg N ha^{-1} (39.38).

4.4.7 1000-grain weight (g)

The data on 1000 grain weight presented in Table 4.8 indicated that transplanting dates as well as nitrogen levels had significant effect on 1000 grain weight. The highest 1000 grain weight (24.68 g) was recorded for 20th May transplanting and lowest (20.67 g) by 11th June transplanting date.

Perusal of the data on different nitrogen levels indicated that significant increase in 1000 grain weight was recorded by increasing nitrogen level. Application of 120 kg N ha^{-1} recorded highest 1000 grain weight (25.69 g), though it was at par with 90 kg N ha^{-1}. The other nitrogen levels i.e. 90, 60 and 30 kg N ha^{-1} recorded lower 1000 grain weight (24.01, 23.16 and 22.83 g, respectively) than 120 kg N ha^{-1}. The lowest 1000 grain weight (21.73 g) was recorded for control treatment.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.3 Yield

4.3.1 Grain yield

Grain being an economic component of the crop is an important crop parameter, which reflects the resultant impact of all crop growth parameters and yield attributes that are affected by various input treatments. The data on grain yield is presented in Table-4.9 and illustrated graphically in Fig. 16 and 17.

As far as the influence of transplanting dates on grain yield is concerned, it was observed that early transplanting i.e. 20th May recorded significantly higher grain yield (41.51 q ha^{-1}) than other transplanting dates. The increase in grain yield for the 20th May transplanting was 14.98 and 27.60% over 1st June and 11th June planting. This indicated that early sowing increased grain yield than late sowing.

As far as levels of nitrogen are concerned significant difference in grain yield was recorded with increase in nitrogen levels. The highest grain yield (45.55 q ha^{-1}) was recorded for 90 kg N ha^{-1} and lowest grain yield was recorded for the control (19.87 q ha^{-1}). The application of 60 and 30 kg N ha^{-1} recorded significantly higher grain yield (38.96 and 31.50 q ha^{-1}, respectively) than control, but were significantly inferior to the higher nitrogen level, i.e. 90 and 120

Table 4.9: Effect of transplanting dates and nitrogen levels on grain, straw and biological yield (q ha^{-1})

Treatment	Grain yield	Straw yield	Biological yield	Harvest index (%)
Transplanting dates				
20th May	41.51	67.21	108.72	37.67
1st June	35.29	64.83	100.12	34.86
11th June	30.05	61.80	91.85	32.42
SEm±	0.97	0.55	1.84	0.60
C.D ($p \leq 0.05$)	3.89	2.31	7.41	2.48
Nitrogen levels (kg ha^{-1})				
Control	19.87	60.05	79.92	25.13
30	31.50	61.11	92.61	34.11
60	38.96	63.25	102.21	38.13
90	45.55	68.31	113.86	40.02
120	42.25	70.42	112.67	37.51
SEm±	0.59	0.33	1.48	0.53
CD ($p \leq 0.05$)	1.74	1.01	4.45	1.60

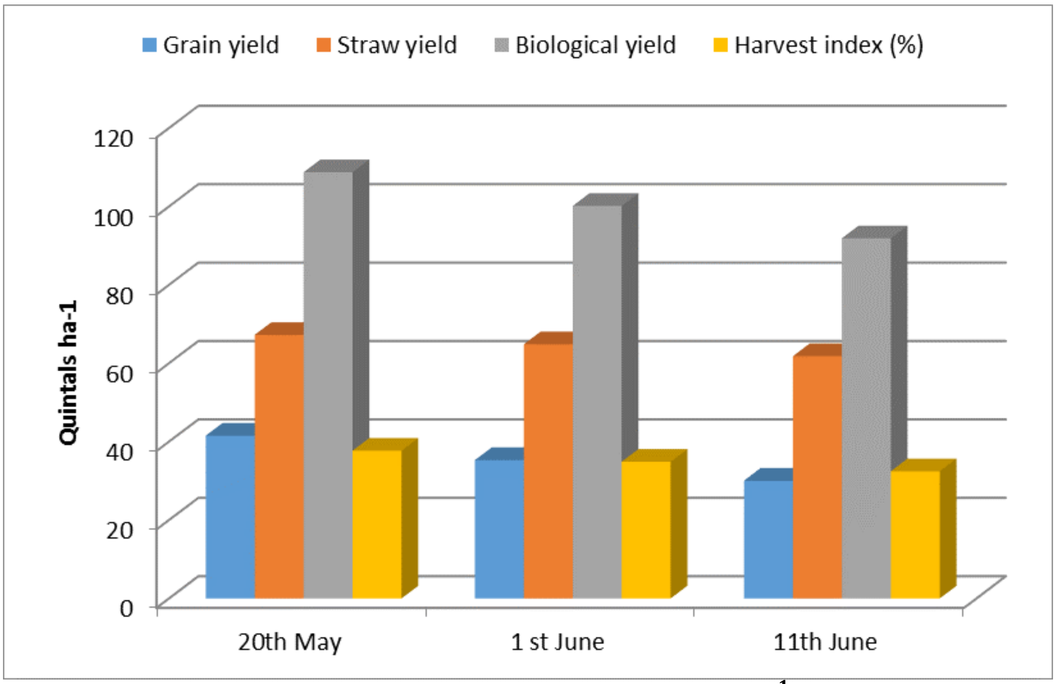

Fig. 16 : **Grain, straw and biological yield (q ha^{-1}), as influenced by transplanting dates**

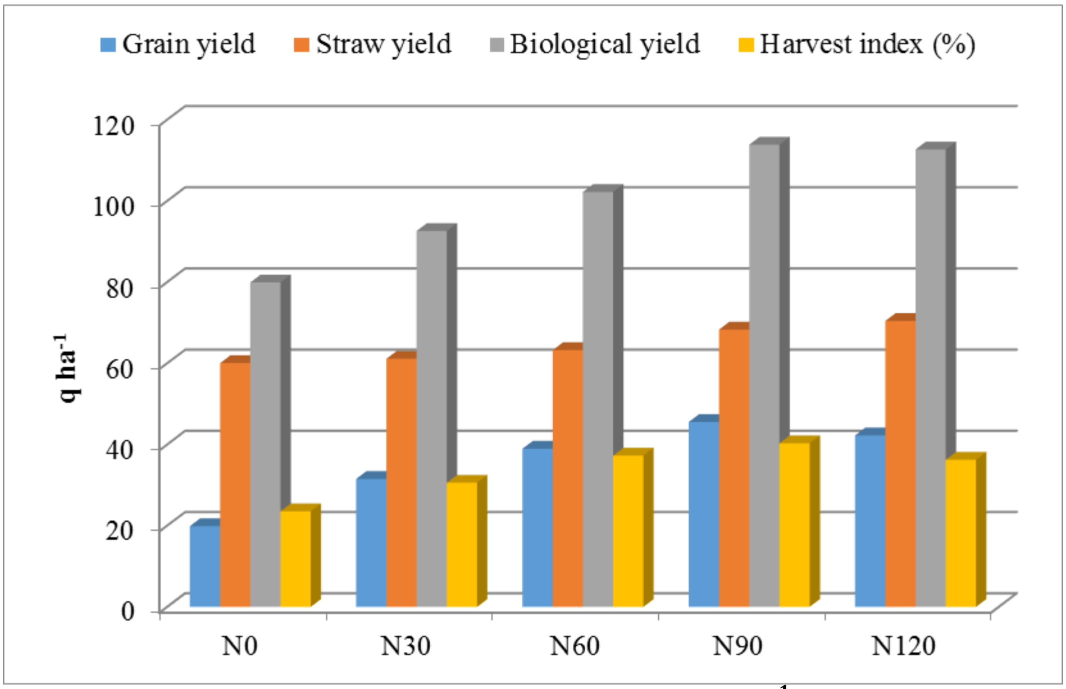

Fig. 17 : **Grain, straw and biological yield (q ha^{-1}), as influenced by nitrogen levels**

kg N ha^{-1}. The per cent increase in grain yield due to 120, 90, 60 and 30 kg N ha^{-1} over control is to the extent of 52.97, 56.38, 49 and 36.92% respectively.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.3.2 Straw yield

The data on straw yield is presented in Table-4.9 and illustrated graphically in Fig. 16 and 17. Transplanting dates had a significant effect on straw yield. The highest straw yield of 67.21 q ha^{-1} was obtained from the crop planted on 20th May and lowest straw yield from the crop planted on 11th June (61.80 q ha^{-1}). However, the crop planted on 1st June recorded significantly higher straw yield (64.83 q ha^{-1}) than 11th June transplanting.

Nitrogen application increased the straw yield significantly with increased nitrogen levels up to 120 kg N ha^{-1} (Table 4.9). The highest straw yield (70.42 q ha^{-1}) was produced when the crop received 120 kg N ha^{-1} and lowest straw yield was recorded by the crop receiving no nitrogen i.e. control.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.3.3 Biological yield

The data pertaining to biological yield is presented in Table-4.9 and illustrated graphically in Fig. 16 and 17. Transplanting dates had a significant effect on the biological yield. The maximum biological yield of 108.72 q ha^{-1} was obtained from the crop transplanted on 20th May, followed by 1st June (100.12 q ha^{-1}). The lowest biological yield of 91.85 q ha^{-1} was recorded from 11th June transplanted crop.

Nitrogen application increased the biological yield significantly with increase in levels up to 90 kg ha^{-1} (Table-4.9). However, the same was at par with 120 kg N ha^{-1} (112.67 q ha^{-1}). The per cent increase in biological yield due to 120, 90, 60 and 30 kg N ha^{-1} was to the extent of 29.07, 29.80, 21.80 and 13.32%, over control, respectively.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.3.4 Harvest index

The data related to harvest index has been presented in Table-4.9. The data indicate that 20^{th} May transplanting recorded significantly higher harvest index over the late dates of transplanting. The harvest index for 20^{th} May, 1^{st} June and 11^{th} June transplanting was 37.67, 34.86 and 32.42%, respectively.

Among the nitrogen levels significant differences were recorded for harvest index. The highest harvest index of 40.02% was recorded with the use of nitrogen level of 90 kg ha^{-1}, while the lowest harvest index of 25.13 was recorded for the control. The harvest index of 37.51, 38.13 and 34.11 was recorded for nitrogen levels of 120, 60 and 30 kg ha^{-1} respectively, and were significantly superior to control.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.4 Quality parameters

4.4.1 Physical grain quality parameters

4.4.1.1 Grain moisture content at harvest

The data on grain moisture content is presented in Table-4.10. No significant difference was noticed in the grain moisture content at harvest among the different transplanting dates and nitrogen levels.

4.4.1.2 Grain grading

The data pertaining to grain grading is presented in Table-4.10. Perusal of the data indicated that, grain grading is significantly affected by manipulating transplanting dates and nitrogen levels (Plate-2). As regards the transplanting dates, highest percentage of grade I (45.35%) was recorded for the crop transplanted on 20th May, which was significantly higher than crop transplanted on 1st June and 11th June (25.32 and 13.27%, respectively). The percentage of grade II and III increased significantly with delay in transplanting. The 20th May transplanting date recorded the lower percentage of grade II and grade III (25.42 and 26.23, respectively), while as crop transplanted on 11th June recorded the highest percentage of grade II and grade III (33.93 and 52.80%, respectively).

An examination of the data revealed that, the percentage of Grade I increased with increase in nitrogen level up to 90 kg N ha^{-1} (32.84) and it decreased with increase in the nitrogen level up to 120 kg N ha^{-1} (28.92), however, for Grade II the highest value was recorded at 120 kg N ha^{-1} (34.06%) and lowest for control. For Grade III, highest value was found for the crop with control treatment (50.32%), which was significantly higher than other nitrogen levels. The lowest percentage of Grade III (34.93%) was recorded by the crop receiving 90 kg N ha^{-1} which got increased with 120 kg N ha^{-1} (37.02%) .

4.4.1.3 Hulling (%)

The data on hulling percentage of basmati rice is presented in Table-4.10. Perusal of the data indicated that transplanting dates has a significant effect on hulling percentage. The highest hulling percentage of hulling was recorded by the crop transplanted on 20th May (74.20%), which was significantly higher than 1st June and 11th June transplanting dates. The lowest hulling percentage was found with 11th June transplanting date (66.75%), which was at par with 1st June transplanting date (68.75%).

Table 4.10: Effect of transplanting dates and nitrogen levels on grain moisture content, grain grading, hulling and milling (%)

Treatment	Grain moisture content	Grain grading			Hulling	Milling
		G I	G II	G III		
Transplanting dates						
20th May	21.73	45.35	25.42	29.23	74.20	64.43
1st June	21.76	25.32	30.20	44.48	68.75	62.49
11th June	21.88	13.27	33.93	52.80	66.75	61.90
SEm±	0.50	0.89	0.66	1.06	1.27	0.46
CD ($p \le 0.05$)	N S	3.48	2.65	4.15	4.94	1.86
Nitrogen levels (kg ha^{-1})						
Control	21.42	24.25	25.43	50.32	66.1	61.29
30	21.62	26.97	27.52	45.54	68.55	62.25
60	21.78	30.28	30.03	39.69	70.18	62.89
90	21.97	32.84	32.23	34.93	72.08	63.72
120	22.16	28.92	34.06	37.02	72.58	64.54
SEm±	0.32	0.43	0.44	0.75	0.62	0.15
CD ($p \le 0.05$)	N S	1.29	1.34	2.26	1.87	0.42

G I

G II

G III

Plate-2: Grain grades of *Pusa Basmati*-1509

The data further reveals that, graded nitrogen levels had a significant effect on hulling percentage. Application of 120 kg N ha^{-1} resulted in numerically higher hulling percentage (72.58%), but the same was at par with 90 kg N ha^{-1} (72.08%). Control produced the lowest hulling percentage (66.10%).

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.4.1.4 Milling (%)

The data pertaining to milling percentage is presented in Table-4.10. Transplanting dates had a significant effect on milling percentage. The maximum milling percentage of 64.43% was obtained from the crop transplanted on 20^{th} May. The lowest milling percentage of 61.90% was recorded from the crop transplanted late i.e. 11^{th} June and the same was at par with crop transplanted on 1^{st} June (62.49%[1]).

Nitrogen application increased the milling percentage significantly with increase in levels up to 120 kg ha^{-1} (Table-4.10). The highest milling percentage (64.54) was found in application of 120 kg N ha^{-1} and was closely followed by the crop received 90 kg N ha^{-1} (63.72%). Both the nitrogen levels recorded significantly higher milling percentage than those obtained at the lower nitrogen levels. The lowest milling percentage (61.29%) was produced by the crop receiving no nitrogen.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.4.1.5 Brown rice length and breadth (mm)

Perusal of data on brown rice length and breadth indicated that sowing dates as well as nitrogen levels had a significant effect on brown rice length and breadth (Table-4.11). The highest brown rice length and breadth was recorded for the 20^{th} May transplanting (9.22 mm and 1.72 mm respectively), whereas 11^{th} June transplanting date recorded significantly lower brown rice length and breadth of 8.06 mm and 1.59 mm, respectively. However for breadth 20th May transplanting was found at par with 11th June transplanting date.

The data also revealed that brown rice length and breadth was significantly affected by different levels of nitrogen. Application of 120 kg N ha^{-1} resulted in higher brown rice length and breadth (9.02 and 1.71 mm respectively) and for brown rice breadth 60 kg N ha^{-1} was at par with nitrogen level of 90 and 120 kg N ha^{-1}. The lowest brown rice length and breadth was recorded in control (8.51 and 1.61 mm, respectively). Thus increase in nitrogen levels also increases the brown rice length and breadth of the grain.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.4.1.6 L/B ratio

Perusal of the data pertaining to length breadth ratio (Table-4.11) indicated that among the sowing dates higher length breadth ratio was recorded for the early sowing date i.e. 20th May (5.39), which was found at par with 1st June transplanting. The lowest value was recorded for late sowing i.e. 11th June (5.10).

As regards the different levels of nitrogen significant difference in length breadth ratio was noticed. The highest head length breadth ratio of 5.32 was recorded for usage of 120 kg N ha^{-1} and lowest 5.23 for control. Also was found that, length breadth ratio at 60 kg N ha^{-1} was at par with 90 and 120 kg N ha^{-1}.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.4.1.7 Kernel length elongation after cooking (KLAC)

The data on KLAC reading is presented in Table-4.11. Perusal of data indicated that with delay transplanting dates, KLAC decreased. Highest value of KLAC was found with transplanting of crop on 20th June (15.74 mm), which was found at par with 1st June transplanting date (15.68 mm). However with further delay in transplanting up to 11th June KLAC decreased significantly.

Among the different nitrogen levels the examination of data revealed that KLAC reading was significantly influenced by nitrogen levels. The significantly higher KLAC reading (15.79 mm) was recorded with the application of 120 kg N ha^{-1}. While the lowest values were recorded for the control (13.96 mm).

The interaction effect of transplanting dates and nitrogen levels on KLAC was found significant (Table-4.11a), the highest value of KLAC (16.93 mm) was found when crop was transplanted on 20th May with application of 120 kg N ha^{-1} and lowest (14.43 mm) with 11th June transplanting and control nitrogen treatment.

4.4.1.8 Elongation ratio

The data regarding elongation ratio has been presented in Table-4.11. The perusal of the data reveals that there was no significant variation in elongation ratio by changing the transplanting dates.

A further examination of data indicated that application of 120 kg N ha^{-1} resulted significantly higher elongation ratio than all lower nitrogen levels. The lowest value was recorded for control treatment (1.62).

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

Table 4.11 : Effect of transplanting dates and nitrogen levels on brown rice length, breadth, rice length, KLAC and elongation ratio

Treatment	Brown rice			Kernel length after cooking (mm)	Elongation ratio
	Length (mm)	Breadth (mm)	L/B ratio		
Transplanting dates					
20th May	9.22	1.72	5.39	15.74	1.71
1st June	9.11	1.70	5.37	15.68	1.72
11th June	8.06	1.59	5.10	13.35	1.66
SEm±	0.02	0.01	0.03	0.20	0.05
CD ($p \leq 0.05$)	0.10	0.05	0.13	0.80	N S
Nitrogen levels (kg ha^{-1})					
Control	8.51	1.61	5.23	13.96	1.62
30	8.72	1.64	5.26	14.54	1.66
60	8.83	1.67	5.29	14.95	1.70
90	8.92	1.69	5.32	15.39	1.73
120	9.02	1.71	5.32	15.79	1.76
SEm±	0.02	0.01	0.01	0.11	0.01
CD ($p \leq 0.05$)	0.07	0.03	0.03	0.33	0.03

Table 4.11a : Interaction effect of transplanting dates and nitrogen levels on kernel length after cooking

Treatment	Nitrogen Levels (kg ha^{-1})					Mean
	Control	30	60	90	120	
Transplanting dates						
20th May	13.87	15.47	15.90	16.51	16.93	**15.74**
1st June	15.07	15.30	15.71	16.06	16.25	**15.68**
11th June	14.43	14.97	15.35	15.70	16.30	**15.35**
Mean	14.46	15.24	15.65	16.09	16.49	

CD ($p \leq 0.05$)

Transplanting dates (D) : 0.21

Nitrogen levels (N) : 0.33

D × N : 0.57

4.4.1.9 Gel consistency

Table-4.12 revealed that there was no significant variation in gel consistency by changing the transplanting dates. Also, as regards the nitrogen levels, no significant difference was noticed in the gel consistency. An examination of data reveals that the gel consistency of Pusa Basmati 1509 falls under the category of soft gel consistency.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.4.1.10 Head rice recovery (HRR)

Perusal of the data pertaining to HRR (Table-4.12) indicated that among the transplanting dates higher head rice recovery was recorded for the early transplanting date i.e. 20th May (44.16%), which was found at par with 1st June transplanting and significantly lower for 11th June (41.40%).

Graded levels of N significantly affected HRR. The highest head rice recovery 44.06% was recorded at 120 kg N ha^{-1} and lowest 41.96% for control.

The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

Table 4.12 : Effect of transplanting dates and nitrogen levels on GC, protein content, amylose content, HRR and volume expansion

Treatment	Gel consistency (mm)	Protein content (%)	Amylose content (%)	Head rice recovery (%)	Volume expansion (ml)
Transplanting dates					
20th May	91.33	7.50	21.24	44.16	3.94
1st June	92.00	7.38	21.22	43.67	3.60
11th June	93.33	7.30	21.21	41.40	3.35
SEm±	1.19	0.02	0.23	0.18	0.02
CD ($p \leq 0.05$)	N S	0.08	N S	0.68	0.10
Nitrogen levels (kg ha^{-1})					
Control	87.11	7.26	20.39	41.96	3.46
30	89.89	7.34	20.78	42.56	3.53
60	93.00	7.40	21.34	43.20	3.65
90	95.33	7.47	21.74	43.09	3.72
120	95.78	7.53	21.87	44.06	3.78
SEm±	0.77	0.02	0.13	0.14	0.02
CD ($p \leq 0.05$)	2.31	0.06	0.39	0.43	0.06

4.4.1.11 Aroma

The data pertaining to aroma is presented in Table-4.13. Perusal of the data indicated that transplanting dates influenced the aroma of scented rice. It was found that aroma of rice decreases with delay in transplanting date. Different nitrogen levels did not follow a specific trend for aroma. However, 20^{th} May transplanting with application of 90 kg N ha^{-1} resulted in highest aroma (Rank 1) and lowest rank (15) for aroma was found by 11^{th} June transplanting with application of 120 kg N ha^{-1}. The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.4.1.12 Volume expansion

The data on volume expansion is presented in Table-4.12. The data indicated that volume expansion is influenced by transplanting dates and nitrogen levels. The 20^{th} May transplanting recorded significantly higher value for volume expansion (3.94) and lowest by 11^{th} June transplanting (3.35).

Among the nitrogen levels application of 120 kg N ha^{-1} recorded significantly higher volume expansion. The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.4.2 Chemical quality parameters

4.4.2.1 Protein content (%)

Perusal of the data pertaining protein content (Table-4.12) indicated that among the transplanting dates higher protein content was recorded for the early transplanting date i.e. 20^{th} May (7.50%) and lowest for late transplanting i.e. 11^{th} June (7.30%).

Table 4.13 : Effect of transplanting dates and nitrogen levels aroma

Treatments	**Rank**
20^{th} May × 0 kg N ha^{-1}	4
20^{th} May × 30 kg N ha^{-1}	3
20^{th} May × 60 kg N ha^{-1}	2
20^{th} May × 90 kg N ha^{-1}	1
20^{th} May × 120 kg N ha^{-1}	5
1^{st} June × 0 kg N ha^{-1}	8
1^{st} June × 30 kg N ha^{-1}	7
1^{st} June × 60 kg N ha^{-1}	11
1^{st} June × 90 kg N ha^{-1}	6
1^{st} June × 120 kg N ha^{-1}	10
11^{th} June × 0 kg N ha^{-1}	14
11^{th} June × 30 kg N ha^{-1}	13
11^{th} June × 60 kg N ha^{-1}	12
11^{th} June × 90 kg N ha^{-1}	9
11^{th} June × 120 kg N ha^{-1}	15

As regards the different levels of nitrogen also difference in protein content was noticed. The highest protein content 7.53% was recorded for usage of 120 kg N ha^{-1} and lowest 7.26% for control. The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.4.2.2 Amylose content (%)

The data pertaining to amylose content is presented in Table-4.12. The data indicated that amylose content was not influenced by transplanting dates.

Application of 120 kg N ha^{-1} resulted in highest value for amylose content (21.87), but the same was found statistically at par with 90 kg N ha^{-1} (21.74). The lowest value for amylose content was found in control treatment (20.39). The interaction effect of transplanting dates and nitrogen levels were found to be non-significant.

4.5 Physico-chemical characteristics of soil

4.5.1 Soil fertility status after harvesting of rice

Perusal of the data regarding final soil status revealed that available nitrogen, phosphorus and potassium was low, medium and medium respectively. As regards O.C, it was in medium range (Table-4.14). As regards the final available nitrogen, the data revealed that plots receiving no nitrogen fertilizer recorded lowest final available nitrogen. However, regarding the available phosphorous and potassium the higher content was found in the control plots receiving no nitrogen but only phosphorous and potassium. However, the organic carbon% was almost same in all the treatment combinations.

Table 4.14: Effect of transplanting dates and nitrogen levels on final soil status for available NPK (kg ha^{-1}) and organic carbon (%)

Treatment	N	P	K	OC
Transplanting dates				
20^{th} May	201.0	18.3	166.7	0.87
1^{st} June	216.1	18.8	168.1	0.90
11^{th} June	221.3	19.4	170.2	0.88
Nitrogen levels (kg ha^{-1})				
Control	175.7	19.8	175.6	0.88
30	197.5	19.3	170.8	0.88
60	207.3	18.3	165.8	0.88
90	230.5	18.2	165.2	0.89
120	253.0	18.6	164.2	0.88
Initial status	235	18.5	268	0.91

4.6 Plant chemical analysis

4.6.1 N, P and K concentrations and their uptake in grain and straw at harvest

4.6.1.1 N, P and K concentrations in grain and straw (%)

The data on N, P and K content in grain and straw, as affected by different treatments is presented in Table-4.15. Perusal of the data revealed that N, P and K content did not showed any significant variation by altering the sowing dates. Also, as regards the different nitrogen levels, the data on P and K content in grain and straw did not show any significant difference. However, the N content in grain and straw increased with increase in N level up to 120 kg N ha^{-1}. The highest value for N content was recorded by the crop receiving 120 kg N ha^{-1} (1.27 and 0.74%, respectively). The lowest value was recorded for control.

4.6.1.2 Nitrogen uptake

The data pertaining to nitrogen uptake by grain, straw and total uptake (Table 4.16) were significantly influenced by transplanting dates. Significantly higher N uptake of 52.42, 44.57 and 96.99 kg ha^{-1} by grain straw and total uptake, respectively were recorded by the crop transplanted on 20th May and lowest were found on 11th June transplanting.

Among the different nitrogen levels, application of 120 kg N ha^{-1} recorded maximum nitrogen uptake in grains, straw and total uptake (58.57, 52.03 and 110.59 kg ha^{-1}, respectively) which was significantly higher than all other treatments. The lowest nitrogen uptake was found for control.

4.6.1.3 Phosphorous uptake by grain and straw

The data pertaining to phosphorous uptake by grain, straw and total uptake were significantly influenced by different transplanting dates (Table 4.16). 20th May recorded maximum phosphorous uptake (7.04 kg ha^{-1}, 17.10 kg ha^{-1} and 24.14 kg ha^{-1}, respectively), which was significantly higher than other transplanting dates. The lowest value (3.81 kg ha^{-1}, 13.65 kg ha^{-1}, respectively) was recorded by the crop transplanted on 11th June.

Table 4.15 : Effect of transplanting dates and nitrogen levels on NPK content (%) in grain and straw

Treatment	Grain			Straw		
	N	P	K	N	P	K
Transplanting dates						
20th May	1.26	0.17	0.35	0.66	0.25	1.53
1st June	1.24	0.14	0.33	0.62	0.23	1.49
11th June	1.23	0.13	0.33	0.58	0.22	1.47
SEm±	0.02	0.01	0.02	0.04	0.03	0.05
CD ($p \leq 0.05$)	NS	NS	NS	NS	NS	NS
Nitrogen levels (kg ha^{-1})						
Control	1.22	0.13	0.32	0.50	0.13	1.40
30	1.23	0.13	0.33	0.57	0.18	1.44
60	1.24	0.14	0.33	0.62	0.23	1.50
90	1.25	0.15	0.34	0.68	0.29	1.54
120	1.27	0.16	0.36	0.74	0.33	1.58
SEm±	0.002	0.01	0.01	0.002	0.02	0.03
CD ($p \leq 0.05$)	0.006	NS	NS	0.007	NS	NS

Among the nitrogen levels maximum uptake of phosphorous (P) grain, straw and total uptake (7.63, 23.46 and 31.09 kg ha^{-1}, respectively) were recorded at 120 kg N ha^{-1}. The lowest value was recorded for control.

4.6.1.4 Potassium uptake by grain and straw

The data pertaining to potassium (K) uptake by grain, straw and total uptake (Table 4.16) revealed that 20th May transplanting recorded significantly highest K uptake by grain, straw and total uptake (14.48, 102.84 and 117.32 kg ha^{-1}, respectively). The lowest value was recorded by 11th June transplanting.

Among the nitrogen levels, 120 kg N ha^{-1} recorded significantly higher K uptake by grain, straw and total (16.49, 111.31 and 127.80 kg ha^{-1}, respectively) over other nitrogen levels, which was followed by 90, 60 and 30 kg N ha^{-1}. The lowest value for K uptake by grain was recorded for control.

4.7 Relative economics

A critical examination of Fig. 18 shows that the crop shows a diminishing return pattern to nitrogen fertilization. The same results are also revealed by the negative values of x^2. A polynomial equation has shown the best fit for the observed data as indicated by the highest R^2 value of 0.987. On the basis of the yield response equation the economic optimum dose of N worked out at 100 kg ha^{-1}.

4.7.1 Net returns

Highest net returns ha^{-1} (₹ 168879) were also found with early transplanting of 20th May along with the application of 90 kg N ha^{-1} and lowest net returns ha^{-1} (₹ 43592) for 11th June transplanting with control treatment (Table-4.17) .

4.7.2 Incremental benefit cost ratio (IBCR)

Transplanting on 20th May and application of 90 kg N ha^{-1} also recorded the highest B: C ratio (3.84) and lowest with 11th June transplanting with control treatment (1.02) (Table-4.17).

Table 4.16 : Effect of transplanting dates and nitrogen levels on NPK uptake (kg ha^{-1}) in grain and straw

Treatment	N			P			K		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Transplanting dates									
20th May	52.42	44.57	96.99	7.04	17.10	24.14	14.48	102.84	117.32
1st June	45.22	40.60	85.88	5.29	15.11	20.40	12.12	96.50	108.62
11th June	37.10	32.27	69.37	3.81	13.65	17.46	10.02	90.88	100.90
SEm±	1.24	0.98	3.11	0.15	0.31	0.84	0.36	1.42	2.66
CD ($p \leq 0.05$)	4.84	3.85	9.32	0.61	1.28	2.49	1.43	5.57	8.01
Nitrogen levels (kg ha^{-1})									
Control	24.32	30.36	54.68	2.61	8.05	10.66	6.36	84.20	90.56
30	35.96	35.89	71.85	4.04	11.39	15.43	9.52	91.09	100.61
60	48.50	39.47	87.97	5.64	14.40	20.04	12.99	95.70	108.69
90	57.21	44.66	101.87	6.97	19.40	26.37	15.67	101.40	117.07
120	58.57	52.03	110.60	7.63	23.46	31.09	16.49	111.31	127.80
SEm±	0.74	0.56	2.18	0.11	0.18	0.56	0.23	1.20	2.24
CD ($p \leq 0.05$)	2.20	1.69	6.54	0.33	0.54	1.68	0.68	3.61	6.74

Table 4.17 : Relative economics of Pusa Basmati-1509 (₹ ha^{-1}) as influenced by transplanting dates and nitrogen levels

Treatment	Cost of cultivation	Gross returns	Net returns	B: C ratio
20th May × 0 kg N ha^{-1}	42910	124696	81786	1.91
20th May × 30 kg N ha^{-1}	43268	152568	109300	2.53
20th May × 60 kg N ha^{-1}	43626	190285	146659	3.36
20th May × 90 kg N ha^{-1}	43984	212863	168879	3.84
20th May × 120 kg N ha^{-1}	44342	210062	165720	3.73
1st June × 0 kg N ha^{-1}	42910	105711	62801	1.46
1st June × 30 kg N ha^{-1}	43268	141645	98377	2.27
1st June × 60 kg N ha^{-1}	43626	171177	127551	2.92
1st June × 90 kg N ha^{-1}	43984	192484	148500	3.38
1st June × 120 kg N ha^{-1}	44342	196432	152090	3.43
11th June × 0 kg N ha^{-1}	42910	86502	43592	1.02
11th June × 30 kg N ha^{-1}	43268	118154	74886	1.73
11th June × 60 kg N ha^{-1}	43626	145897	102271	2.34
11th June × 90 kg N ha^{-1}	43984	170186	126202	2.87
11th June × 120 kg N ha^{-1}	44342	176446	132104	2.98

Labour	:	₹	150/day
FYM	:	₹	600/t
Tractorization	:	₹	5000/ha
Urea	:	₹	5.5/kg
DAP	:	₹	22.5/kg
MOP	:	₹	17/kg
Butachlor	:	₹	32/kg
Seed	:	₹	40/kg
Grain	:	₹	32/kg
Straw	:	₹	700/q

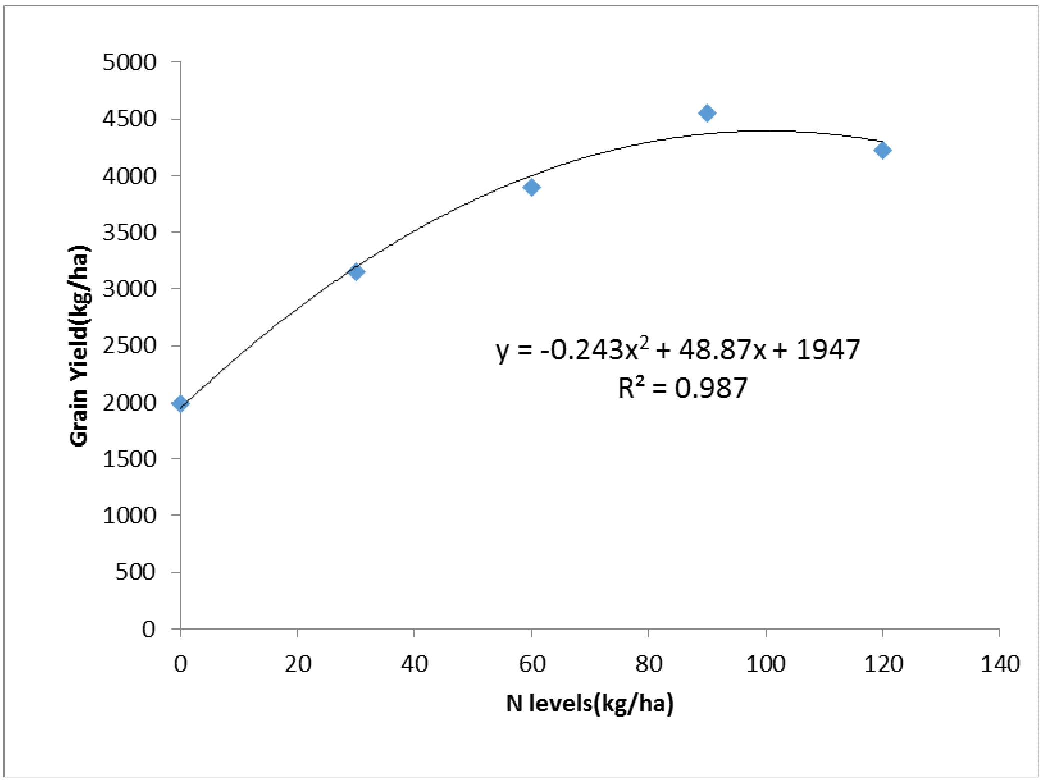

Fig. 18 : Response of grain yield to nitrogen levels

Chapter - 5

DISCUSSION

An attempt has been made in this chapter to discuss the results obtained from field experiment viz Agronomic evaluation of pusa basmati-1509 for yield and quality under varied transplanting dates and nitrogen levels and assign possible reasons responsible for these effects with the help of relevant information reported by various researchers and also with the help of results obtained in the present study.

5.1 Growth parameters

Transplanting dates showed significant variation in the plant height at all stages of plant growth. Early transplanted (20^{th} May and 1^{st} June) crop recorded significantly greater plant height, than the late transplanted (11^{th} June) crop. The increase in plant height in the crops transplanted on early dates might have been due to better temperature and weather conditions experienced by the crop at later growth stages especially at the internode elongation stage which is favoured more at higher temperatures. Also early transplanted crops had longer vegetative and overall growth period due to which plants synthesized more photosynthates which were utilized for growth of vegetative organs of the plant. The crop transplanted late in the season experienced comparatively lower temperatures during the later growth stages and thus plant height remained low. The decrease in plant height with delay in transplanting dates has been also reported by Miah and Pathan (1989), Chaudhary and Iqbal (1992) and Paliwal *et al.* (1996).

The plant height increased gradually due to successive increase in level of nitrogen fertilizer application. The nitrogen level of 120 kg N ha^{-1} recorded significantly taller plants as compared to control, 90, 60 and 30 kg N ha^{-1}. The increase in plant height with increased nitrogen levels may be attributed to the fact that nitrogen enhances the vegetative growth of plants resulting from increase in cell division, elongation and meristematic activity. Zhilin *et al.* (1997) also reported increase in the plant height with successive increments of nitrogen. The results were also in accordance with the findings of Singh and Sharma (1987), Moorthy *et al.* (1988), Tripathi *et al.* (1998), Chopra and Chopra (2000), Raju *et al.* (2001), Meena *et al.* (2003) and Haefele *et al.* (2008).

Dry matter production is considered as a reliable index of crop vigour. The optimal accumulation of dry matter by the crop is important as it may be followed by adequate transfer of assimilates to the sink resulting in higher yields. Transplanting dates were found to have a significant variation on dry matter production. Earlier transplanting i.e. 20th May and 1st June recorded more dry matter production than the late transplanted crop of 11th June. The increased dry matter production of the earlier dates can be attributed to the longer vegetative growth period of earlier transplanting dates and better weather conditions experienced by the earlier sowing dates during the critical growth stages which resulted in increased growth parameters like plant height, LAI, tillers m^{-2} which ultimately resulted in higher dry matter production. Jand *et al*. (1994) also reported higher dry matter accumulation in the earlier transplanting dates compared to the later sowing dates. Similar results were also reported by Vandana *et al*. (1994).

Nitrogen has significant effect on growth parameters like plant height, LAI, tiller number etc which contributes to the greater dry matter of the plant. Among the different nitrogen levels significant difference in dry matter was noticed. The nitrogen level of 120 kg ha^{-1} was found significantly superior than 90, 60, 30 kg N ha^{-1}and control. The results corroborate the findings of Dalal and Dixit (1987), Panda and Rao (1991), Khanda *et al.* (1997), Gangaiah and Prasad (1999), Sreenivas and Rajiv Reddy (2008) and Rao *et al.* (2013).

Significant differences in tillers m^{-2} were recorded among the different transplanting dates tested during the course of investigation. The 20th May and 1st June transplanting dates recorded significantly higher number of tillers m^{-2}. This may be attributed to the longer vegetative period of earlier sowing dates. Also, better environmental conditions were experienced by the earlier sowing dates from early tillering to panicle initiation. Moreover, the decrease in tillers m^{-2} in the 11th June transplanting during later growth stages might have been due to lower temperature which causes tiller mortality. Since tiller production is temperature driven process favoured by higher temperature and also by nutrient balance of soil. The trend observed for tillers m^{-2} during the crop growth stages can easily be traced from the weather data recorded during the course of investigation. The results were in conformity with the findings of Matsushima *et al*. (1996), Lalitha *et al.* (2000).

The results showed that the number of tillers m^{-2} increased gradually with increasing level of nitrogen application. Significant effect on tillers m^{-2} was noticed only up to 90 kg N ha^{-1}. The results showed the importance of plant nutrition for increasing the tillering capacity of aromatic rice. Nitrogen being an important component of protein, nucleic acids, enzyme system and harmones stimulate the metabolic growth and therefore enhanced vegetative growth and tiller number. Enhanced tillering by increased nitrogen application might be attributed to more nitrogen supply to plant at active tillering stage. The beneficial effect of nitrogen on tillering and vegetative growth was also reported by Reddy (1988). The results are in conformity with the findings of Roy and Sattar (1992), Jiang *et al.* (1993), Nawaz (2002), Meena *et al.* (2003), Kumar and Ikrammullah (2004), Haque *et al.* (2006), Manan *et al.* (2010), Chakraborty (2011) and Pramanik and Bera (2013).

The leaves of a plant are normally its main organ of photosynthesis and the total area of leaves per unit ground area called leaf area index (LAI), has therefore, been proposed by Watson (1947) as the best measure of the capacity of crop producing dry matter and called it as *productive capital*. The study showed that leaf area index increased continuously up to 25th July for 20th May and 1st June transplanting and up to 9th August for 11th June transplanting date, the period coinciding with the active tillering and flowering stage, thereafter decreased gradually up to harvest. The decrease in leaf area after flowering might be attributed to senescence of lower leaves due to shading. Similar findings were reported earlier by Shukla *et al.* (1995) and Sitaramaiah *et al.* (1998). The higher LAI was registered by the 20th May transplanting. This might be attributed to the comparatively longer vegetative period experienced by the earlier sowing dates and more favourable temperature conditions during flowering stage. The higher LAI in the earlier sowing dates was also reported by Jand *et al.* (1994). By adjusting the sowing time, the plant can take advantage of natural conditions favourable for its growth (BRRI, 2004).

The nitrogen level of 120 kg N ha^{-1} registered the maximum LAI. The increase in LAI with successive nitrogen levels might have been due to the important role of nitrogen for the growth and development of plant. Nitrogen has a prominent role in the leaf area index as it is an important component of chlorophyll. More the nitrogen applied more will be the growth of crop and increase in LAI accordingly. The results were in line with the findings of Kusuda (1993), Amano *et al.* (1993), Maske *et al.* (1997), Tari *et al.* (2009) and Chakraborty (2011).

Soil plant analytical device (SPAD) is the direct measure of index of greenness of the plant. The more the SPAD reading the more is the greenness in plants which actually gives us indirect relation of chlorophyll content or N content of the plants. It was found that SPAD reading increased significantly up to 9th August for 20th May and 1st June transplanting and up to 24th August for 11th June transplanting and thereafter showed a steep decrease. This might be due to the fact and late transplanting delayed the peak growth of rice crop and nitrogen concentration decreases in the plant from the late reproductive period to harvest.

Among the transplanting dates 20th May recorded higher SPAD reading as compared to crop transplanted on 1st June and 11th June. The lowest SPAD reading was recorded for crop transplanted on 11th June. Early transplanting might have resulted in synchronization of the crop growth stages vis-a-vis its dimatric requirements that resulted in maintenance of higher growth rates and greenness in early transplanted crop. The results are in line with that of Fayaz *et al*. (2015).

An examination of data reveals that SPAD reading was significantly influenced by different levels of nitrogen at all the crop growth stages. Application of 120 kg N ha^{-1} resulted in significantly higher SPAD reading as compared to nitrogen levels of 90, 60, 30 and 0 kg N ha^{-1}. Since SPAD gives the indirect measurement of leaf nitrogen, the higher SPAD values with increase in nitrogen levels might have been due to more uptake of nitrogen. Nitrogen is an essential part of many compounds of plant, such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins (Azarpour *et al*., 2011). Chlorophyll pigments play an important role in the photosynthetic process as well as biomass production. Higher photosynthesis rate is supported by leaf chlorophyll content in leaf blades (Hassan *et al*., 2009). Higher values of chlorophyll content with increased nitrogen rates were also reported by Peng *et al.* (1996), Chen *et al.* (1997), Babu *et al.* (2000), Balasubramanian *et al.* (2000), Kumar *et al.* (2000), Islam *et al.* (2009), Hassan *et al.* (2009), Gholizadeh *et al.* (2011), Youseftabar *et al.* (2012) and Pramanik and Bera (2013).

Transplanting date and location strongly influenced crop duration and grain yield of genotypes. The investigation revealed that 20th May transplanting took more number of days than both 1st June and 11st June transplanting to reach mid tillering, panicle initiation, flowering, milking, dough and harvest. However, the lowest number of days was taken by the 11th June transplanting date. Rice plant require a particular temperature for attaining its phenological stages such as panicle initiation, flowering, panicle exertion from flag leaf sheath and maturity and these are much influenced by the transplanting dates (Yoshida, 1981). Temperature is the main driving force for development in photoperiod insensitive genotypes and heat unit accumulation and thus crop duration depends on the genotypic cardinal temperatures such as temperature sum, and base and optimum temperatures (Dingkuhn and Kropff, 1996). It might have been due to the higher temperature experienced by the 11th June transplanting date during the vegetative stage which shortened its basic vegetative phase while the prolonging of the vegetative phase of the 20th May transplanting might be probably of lower temperature during initial growth stages. Transplanting date primarily influences the length of vegetative period of rice with early sown rice requiring a greater number of days to accumulate the same number of degree days units compared with later sown rice was also reported by Norman *et al.* (1999). A linear negative correlation between transplanting dates and growth period, in the later sowing dates was also reported by Peng-fei *et al.* (2013). The results were also in conformity with Lee *et al.* (1994), Song *et al.* (1996), Sinha and Chatterjee (1997), Gravois and Helius (1998), Lalitha *et al.* (2000), Lee *et al.* (2001), Dixit *et al.* (2004), Linscombe *et al.* (2004) and Chopra *et al.* (2006).

Among the nitrogen levels 120 and 90 kg ha^{-1} took significantly more number of days to reach different phenological stages than 60, 30 kg N ha^{-1} and control. Delayed flowering with higher nitrogen dose may be due to more vegetative growth, as reflected by increased plant height, LAI, SPAD, which delayed maturity. The results are in accordance with and Haque *et al.* (2006), Abou-khalifa *et al.* (2007) and Mahajan *et al.* (2010).

Since the duration to reach different phenological stages was more in case of 20th May transplanting and least for the 11th June transplanting date, hence 20th May transplanting date required more GDDs to complete its growing cycle and least were required for the 11th June transplanting date). Similar trend was observed in case of nitrogen levels where more GDDs were required by nitrogen levels of 120 and 90 kg N ha^{-1} and least for 60, 30 kg N ha^{-1} and control. The results were in conformity with Chopra and Chopra (2004) who also reported that growing degree days from transplanting to maturity (total phenophases) got reduced almost linearly with delay in transplanting. Similar results were also reported by Ghadekar *et al.* (1988), Mandal and Ghosh (2003) and Reddy *et al.* (2004).

5.2 Yield attributes

In general, the number of panicles m^{-2} was significantly influenced by transplanting dates and nitrogen levels. Transplanting date had a significant effect on the number of panicles m^{-2}. The maximum number of panicles m^{-2} was obtained from the transplanting of rice on 20^{th} May and was closely followed by 1^{st} June transplanting. Grain yield of cereals is highly dependent upon the number of panicles produced m^{-2} (Power and Alessi, 1978 and Nerson, 1980). This might be due to better environmental factors like more effective use of light, temperature, nutrients etc during the critical growth stages like panicle initiation, flowering and grain filling periods which caused less tiller mortality in the earlier sowing dates, and consequently increased panicles m^{-2}. The results were in accordance with Singh and Pillai (1995) and Singh (2003).

Nitrogen levels played an important role in increasing number of panicles m^{-2} as it increase tiller number in rice. The results showed that the number of panicles m^{-2} increased gradually due to increasing level of nitrogen application up to 120 kg ha^{-1}. The increase in panicles m^{-2} observed for this treatments were due to positive role of nitrogen in the growth, and development of plant. Increased nitrogen application ensures better availability of nitrogen to plants during the tillering period of rice, which might have resulted in more productive tillers and consequently the panicle m^{-2}. Increasing trend of panicle at the higher levels of nitrogen was also observed by BRRI (2002). The results are also in conformity with those of Tripathi and Jaishwal (2006), Kanyika *et al.* (2007), Bera and Pramanik (2010) and Mahajan *et al.* (2010).

Among the transplanting dates no significant difference in panicle length was noticed. The length of the rice panicle determines the number of grains it can hold, and consequently rice yield; it is therefore one of the most important traits assessed in yield-related research (Huang, *et al.*, 2013). The results are in accordance with Akram *et al.* (2007).

The panicle length varied markedly among different nitrogen levels. The maximum panicle length was recorded by the crop receiving 120 kg N ha^{-1}. The findings are in conformity with those of Sharma *et al*. (2014), Mannan *et al*. (2010) and Mannan *et al*. (2012).

More panicle weight was recorded by the crop transplanted on 20^{th} May, which was at par with 1^{st} June transplanting. The panicle weight is associated with the yield, as more panicle weight contributes to more yield due to the fact that presence of more grains increases the weight of the panicle. The more panicle weight of early dates might be due to better environmental conditions during grain filling and growth stages, which resulted in proper filling of grains and increased the weight of the panicle.

Nitrogen levels played an important role in increasing the weight of the panicle. Maximum panicle weight was recorded by the crop receiving 120 kg N ha^{-1}, which was significantly higher than 60, 30 and 0 kg N ha^{-1}, but was at par with 90 kg N ha^{-1}. The more panicle weight at higher doses of nitrogen might be due to better availability of N to plants at panicle initiation and growth stage, which might have resulted in more grains thus more panicle weight. The results are also in accordance with that of Mahajan *et al*. (2010).

Significantly more number of spikelets $panicle^{-1}$ were recorded for the 20^{th} May and 1^{sr} June transplanting than the 11^{th} June transplanting date. This might have been caused by more favourable temperature during panicle initiation and flowering stages of the 20^{th} May and 1^{sr} June transplanting. Tsai (1989) also reported higher spikelet number $panicle^{-1}$ in the earlier transplanting dates. The results were also in accordance with the findings of Maruyama and Tanaka (1985).

Also, more spikelets $panicle^{-1}$ at the nitrogen levels of 120 and 90 kg ha^{-1} levels as compared to the 60, 30 kg ha^{-1} and control were observed. This might have been due to the fact that spikelet degeneration decreases linearly with increasing N levels due to increase in nitrogen concentration in the leaf at anthesis. The nitrogen levels 120 and 90 kg N ha^{-1} are at par with each other. The results were in line with of Sharma and Singh (1999).

The number of filled grains $panicle^{-1}$ decreased significantly due to delay in transplanting date. Transplanting dates and nitrogen levels played an important role in regulating the grain development process in aromatic rice. The highest number of filled grains $panicle^{-1}$ was recorded in crop transplanted on 20^{th} May and it was significantly greater than the crop sown on 1^{st} June and 11^{th} June, respectively. The lower number of filled grains $panicle^{-1}$ in the later transplanting dates might be attributed to the lower temperature prevalent during the flowering and grain filling period which caused the lower pollen germination and consequently increased the unfilled grains per panicle. The flowering period of the last date of transplanting coincided with the devastating floods and low temperature. The day and night temperature during that week was dropped to 14.1 and 11.7 ^{o}C, respectively. The decrease in grains per panicle with delay in planting time was also reported by BRRI (1989), Lin and Huang (1992), Bali *et al*. (1993) and Singh[a] *et al*. (2005).

The number of filled grains panicle $^{-1}$ varied markedly among the different nitrogen levels. The highest number of filled grains $panicle^{-1}$ was produced in crop receiving 90 kg N ha^{-1} but was at par with application of 120 kg N ha^{-1}. The results indicated that application of low dose of fertilizer did not meet the nutrient needs of the crop particularly during the panicle initiation stage and grain filling period resulting in lower number of filled grains $panicle^{-1}$. Also, the more number of grains $panicle^{-1}$ obtained in treatments received higher nitrogen rates were probably due to better nitrogen status of plant during panicle growth period. The results are in conformity with the finding of Singh and Sharma (1987), Munda *et al.* (1994), Kumar *et al.* (2003), Raju and Suneetha Devi (2005), Srivastava *et al.* (2006), Zaidi *et al.* (2007), Huang *et al.* (2008), Narendra Pandey *et al.* (2008), Chakraborty (2011) and Rao *et al.* (2013).

Among the transplanting dates, the highest sterility% was recorded for the 11th June transplanting date, it could also be attributed to the lower temperature during the heading and grain filling period. Halappa *et al.* (1974); Magor (1984); BRRI (1989); Bali *et al.* (1993); Singh[a] *et al.* (2005); Nahar *et al.* (2009); Shimizu and Kumo (1967) and Bali *et al.* (1995) reported that performance of rice is greatly influenced by the date of transplanting due to the effect of cold hazard and incidence of biotic stress. Deviation from the optimum transplanting time may cause incomplete and irregular panicle exertion, increased spikelet sterility. Temperature has an important role in the grain filling process. Both high and low temperature is an important cause of spikelet sterility. Late transplanting exposes the reproductive phases as well as phenological events of crop in an unfavourable temperature regime thereby causing high spikelet sterility and poor growth of the plant. Delayed transplanting under Kashmir conditions exposes the flowering period of rice to lower temperature. Yield losses due to low temperatures are a result of incomplete pollen formation and subsequent floret sterility. Low temperature causes various types of injuries in rice plants, but the most important one is spikelet sterility. They reported that filled grain production decreased significantly with the delay of planting which was due to occurrence of low temperature at anthesis and spikelet primordial formation. Wide range of abnormal spikelets, all of which were induced under the low temperature treatments at the young panicle primordium differentiation stage. Late planting, low temperature at the pollen development stage may cause a sharp decline in fertile or filled spikelets particularly in the photo insensitive cultivars, which causes poor pollen germination and hence lower yields. Similar results were also reported by Sahu *et al.* (1983), Ashraf *et al.* (1989), Chandra and Mannan (1989).

Among the different nitrogen levels the higher spikelet sterility was recorded for the 120 kg N ha^{-1}. This might be due to the reason that higher doses of nitrogen produced profuse tillering, which led to competition among the tillers and reduced the quantity of photosynthates from source to sink, which would have resulted in more number of ill-filled grains, there by increased the sterility%. The increase in spikelet sterility with increase in nitrogen levels were also reported by Jadhav *et al.* (2004) and Manan *et al.* (2010).

Transplanting dates had a significant effect on 1000 grain weight. The maximum 1000 grain weight was obtained from the crop transplanted on 20th May, and was closely followed by the crop transplanted on 1st May. The higher of 1000 grain weight of early transplanting dates might be due to favourable environmental conditions like temperature and humidity during grain filling and development process experienced by the crop. The similar findings were also recorded by Tari *et al.* (2007) and Akbar *et al*. (2010)

Nitrogen application increased the 1000 grain weight significantly with increase in levels up to 120 kg ha^{-1}. Increase in grain weight at higher nitrogen rates might be primarily due to increase in chlorophyll content of leaves which led to higher photosynthetic rate and ultimately plenty of photosynthates available during grain development. The results are in line with those of Awan *et al.* (1984), Rafey *et al.* (1989), Manzoor *et al*. (2006) and Gill and Walia (2014).

5.3 Yield and harvest index

The grain yield decreased with delay in transplanting date. Yield in any given environment is the result of the yield components developed in different developmental phases and growth stages. Transplanting time played an important role in regulating the grain yield of aromatic rice. Yield potential is determined by the number of tillers formed during the vegetative growth phase, the number of panicles produced at the end of the vegetative stage, the number of spikelets formed in each panicle during panicle development, the number of fertile spikelets determined during the flowering stage, and the final individual grain weight determined during the grain filling phase (Dingkuhn and Kropff, 1996). The results were in accordance with findings of Mohammed *et al.* (2001), Chopra *et al.* (2003), Chopra and Chopra (2004), Singh *et al.* (2004), Ram *et al.* (2005), Iqbal *et al.* (2008), Hussain *et al.* (2009) and Akbar *et al.* (2010).

The nitrogen levels also exerted a significant effect on grain yield of aromatic rice. The grain yield increased steadily with the increase in nitrogen level up to the 90 kg N ha^{-1}, with further increase in N levels there was a decrease in grain yield. Behera (1998) also reported that improvements in grain yield can be attributed to increments in yield components. Increases in yield components are associated with better nutrition, plant growth and increased nutrient uptake (Kumar and Rao, 1992; Thakur, 1993). The results were also in conformity with Marazi *et al.* (1993), Bali *et al.* (1995), Sharma and Singh (1999), Bhowmick and Nayak (2000), Ehsanullah *et al.* (2001), Pal *et al.* (2001), Meena *et al.* (2003), Boling *et al.* (2004), Jadhav *et al.* (2004), Sidhu *et al.* (2004), Singh *et al.* (2004), Gautam *et al.* (2008) and Mannan *et al.* (2010).

Transplanting dates had a significant effect on straw yield. The maximum straw yield was obtained from the crop transplanted on 20th May. The higher straw yield in the early transplanted crops was due to higher growth and yield parameters like tiller number m^{-2}, dry matter, etc. which contributed to higher straw yield. The higher straw yield in the early transplanted crops was also reported by Bali and Uppal (1995) and Paliwal *et al*. (1996).

Nitrogen application increased the straw yield significantly with increased nitrogen levels up to 120 kg N ha^{-1}. The highest straw yield was produced in crop receiving 120 kg N ha^{-1}. The vigorous crop growth for the nitrogen treatments might have resulted in higher straw yields. Salam *et al.* (2004) also reported higher straw yield with successive increase in nitrogen levels. The results were also in conformity with those of Jadhav *et al.* (2004), Islam *et al.* (2008), Manan *et al.* (2010), Pramanik and Bera (2013) and Rao *et al.* (2013).

Transplanting dates had a significant effect on biological yield. The maximum biological yield of was obtained from the crop transplanted on 20th May, and was closely followed by the crop transplanted on 1st June. Higher biological yield under early sown crop were also reported by Mohapatra (1989).

Nitrogen application increased the biological yield significantly with increase in levels up to 90 kg ha^{-1}. Gangaiah and Prasad (1999) also reported higher biological yield with increased nitrogen levels. Similar results have been also reported by Manzoor *et al.* (2006), Islam *et al.* (2008) and Sreenivas and Reddy (2008).

Transplanting dates and varying levels of nitrogen had a significant effect on harvest index. The maximum harvest index was obtained from the crop transplanted on 20th May. This might be due to the proper crop growth and development and assimilate accumulation in the grains.

The nitrogen levels also exerted significant effect on harvest index of aromatic rice. The nitrogen level of 90 kg ha^{-1} registered the highest harvest index. The decrease in harvest index at the lower nitrogen levels might be due to lower availability of translocates required for grain filling. The results are in conformity with those of Mahajan and Tripathi (1992), Dehal and Mishra (1994), Pramanik and Bera (2013) and Rao *et al.* (2013).

5.4 Quality attributes

Perusal of data indicated that transplanting dates as well as nitrogen application had no significant effect on grain moisture content at harvest.

Transplanting dates and nitrogen levels had a significant effect on different grades of aromatic rice. Among the transplanting dates 20th May recorded the highest percentage of grade one i.e. G I, with delay in transplanting the percentage of G I i.e. superior grade decreases while as the percentage of G II and G III i.e. inferior grades increases significantly. The good percentage of G I during earlier transplanting might be to better temperature at the time of flowering and grain filling stages, while during flowering and grain filling stages the late transplanting date i.e. 11th June experienced unfavourable weather conditions which causes incomplete filling of grains.

The percentage of G I increased significantly and that of G III decreased continuously when nitrogen level was increased up to 90 kg N ha^{-1}, whereas the percentage of G III increased significantly up to 120 kg N ha^{-1}. At 120 kg N ha^{-1} the percentage of G I decreases and that of G III increases. This might due the availability of nutrients during flowering and grain filling stages at higher nitrogen levels. For Grade III, highest value was found for the crop with control treatment (50.32%), which was significantly higher than other nitrogen levels. The production of inferior grades at 120 kg N ha^{-1} might be due to more sterility at higher level of nitrogen.

The hulling percentage of scented rice was significantly influenced time of transplanting and nitrogen levels. The highest hulling percentage was recorded by the crop transplanted on 20th May, which might have been due to more number of filled grains recorded for earlier transplanting date. The percentage of late transplanting might be due to less number of filled grains of delayed transplanting dates. Increase in nitrogen level increased the hulling percentage significantly. The better nitrogen availability to the crop at higher nitrogen levels might has resulted in better grain filling and more number of filled grains which attributed to more hulling percentage. The results were found in line with that of Srivastava and Singh (2007). Transplanting dates had a significant effect on milling percentage. The highest milling percentage was obtained from the crop transplanted on 20th May. The high milling percentage of 20th May transplanting date might be due to proper filling and formation of bold seeds than late transplanting dates. Milling percentage of aromatic rice increased by increase in nitrogen level up to 120 kg N ha^{-1}. The results agree with the findings of Srivastava and Singh (2007).

Transplanting dates and nitrogen levels have significantly influenced the brown rice length and breadth (Plate-3). As far as transplanting dates are concerned, the highest brown rice length and breadth was recorded for the 20th

Plate-3: Quality of *Pusa Basmati*-1509

May transplanting. The results are in conformity with those of Islam *et al*. (2008) and Mukesh *et al*. (2013).

Brown rice length and breadth was significantly affected by different levels of nitrogen. Application of 120 kg N ha^{-1} resulted in higher brown rice length and breadth but was at par with nitrogen level of 90 kg N ha^{-1}. The results are in line with those of Sharma *et al*. (2012) and Maqsood *et al*. (2013).

Length breadth ratio of brown rice was significantly influenced by transplanting dates and nitrogen levels. The 20th May transplanting recorded highest L/B ratio. The results are in conformity with that of Islam *et al*. (2008).

Nitrogen levels significantly influence the L/B ratio. The findings are in accordance with those of Srivastava and Singh (2007), Sharma *et al*. (2012) and Maqsood *et al*. (2013).

Transplanting dates and nitrogen levels had a significantly effect on kernel length after cooking (KLAC). Highest value of KLAC was found with transplanting of crop on 20th June, which was found at par with 1st June transplanting date.

The nitrogen levels also exerted significant positive effect on KLAC. Significantly higher KLAC reading was recorded with the application of 120 kg N ha^{-1}. The findings are in line with those of Mahajan *et al*. (2011), Guatam *et al*. (2008) and Srivastava and Singh (2007).

Transplanting dates did not show any significant effect on elongation ratio, however with increase in nitrogen level the elongation ratio also increases significantly. Application of 120 kg N ha^{-1} resulted in highest value for elongation ratio, which was significantly higher than all other nitrogen levels. The elongation ratio is the important cooking quality traits of rice. The higher values of these traits are desirable and much preferred by the consumers. The results are in conformity with that of Mahajan *et al*. (2011).

Transplanting dates and nitrogen levels does not influenced the gel consistency of scented rice. However, an examination of data reveals that the gel consistency of pusa basmati 1509 falls under the category of soft gel consistency.

Among the transplanting dates higher head rice recovery was recorded for the 20th May transplanting date and lowest for 11th June transplanting date. Gao and Zang (1994) also reported that rice yield and quality are not only controlled by genetic factors, but are also largely influenced by environmental factors. Similar results were obtained by Bali and Uppal (1995) from Ludhiana, who reported that basmati rice sown earlier had higher head rice recovery than late sown crop. Lower grain quality traits under late sowing were also reported by Singh[b] *et al.* (2005) and Chopra *et al.* (2006).

As regards the different levels of nitrogen significant difference in head rice recovery was noticed. The highest head rice% was recorded for crop receiving 120 kg N ha^{-1}. The results were also in accordance with the findings of Devi *et al.* (2012) who also reported improvement in the quality parameters of aromatic rice with increase in nitrogen levels. Increase in quality of rice with higher nitrogen levels were also reported by Perez *et al.* (1996), Singh[b] *et al.* (1997) and Khalid and Chaudhry (1999).

Transplanting dates influenced the aroma of scented rice. It was found that aroma of rice decreases with delay in transplanting date. Different nitrogen levels did not follow a specific trend for aroma of Pusa Basmati. However, 20th May transplanting with application of 90 kg N ha^{-1} resulted in highest aroma (Rank 1). Srivastava and Singh (2007) also found an increase in aroma up to certain nitrogen level and that it decreases.

Volume expansion of scented rice was significantly influenced by transplanting dates and nitrogen levels. Among the transplanting dates 20th May transplanting recorded significantly higher value for volume expansion (3.94) and lowest by 11th June transplanting (3.35). Hossain *et al*. (2007) also found highest volume expansion in case of earlier transplanting dates.

Among the nitrogen levels application of 120 kg N ha^{-1} recorded highest value for volume expansion (3.78), which was significantly higher than all other nitrogen levels? The lowest value for volume expansion was found for control (3.46). The increase in volume expansion with increase in nitrogen levels was also reported by Srivastava and Singh (2007).

Among transplanting dates highest protein content was recorded for the crop transplanted on 20th May (7.50%) and lowest for late transplanting i.e. 11th June (7.30%).

As regards the different levels of nitrogen also difference in protein content was noticed. The highest protein content was recorded for application of 120 kg N ha^{-1} and lowest for control. Increased protein content with increased level of nitrogen applied is due to the fact that nitrogen forms the principal constituent of protein and indisputably protein content would be always in direct proportion with the dose of applied nitrogen. Findings of the present investigation are in agreement with those of Jadhav *et al.* (2003), Singh *et al.* (2007) and Singh[b] *et al.* (1997). The application of nitrogen increased the protein content which, in turn, might have improved the hulling percentage and head rice recovery by increasing the resistance of grains to abrasive milling process. High-protein rice is more resistant to abrasive milling than low-protein rice (Cagampang *et al*., 1966). High protein content also has been reported to improve milling and head rice recovery percentage (Perez *et al*., 1996).

The data pertaining to amylose content indicates that amylose content was not influenced by transplanting dates. The result is in agreement with Hossain *et al*. (2007). However, the amylose content of Pusa Basmati 1509 falls in intermediate category which is in line to those of Sidhu (1989) and Maqsood *et al*. (2013).

Application of 120 kg N ha^{-1} resulted in highest value for amylose content, which was found statistically at par with 90 kg N ha^{-1}. The lowest value for amylose content was found in control treatment. The increased rates of N application were at a greater advantage in terms of increased growth. This increased growth probably resulted in higher interception of radiation and thus greater production of photosynthates. Stimulation of growth could provide increased assimilates and metabolites resulting in increased amylose content. The results are in line with those of Devi *et al*. (2012)

5.5 Nutrient concentration and uptake

Perusal of data revealed that N, P and K content did not showed any significant variation among the different transplanting dates. Also, as regards the different nitrogen levels, the data on nitrogen content, it increases with increase in nitrogen levels. The highest value was recorded for 120 kg N ha^{-1} and lowest for control. This might be due to the fact that N, P and K content of a variety is a genetic trait and is least affected by management practices. Sang and Kang (2012) also found no significant difference in the nitrogen content with varying nitrogen levels.

The data on N, P and K uptake in grain, straw and total uptake revealed that significantly higher N, P and K uptake was recorded for the 20^{th} May transplanting and lowest for the 11^{th} June transplanting. This could be attributed to the higher dry matter accumulation of the earlier sowing dates.

The N, P and K uptake was significantly different among the different nitrogen levels, and was found to increase with increase in nitrogen levels. Increased nitrogen uptake with application of increasing nitrogen levels from 0 to 120 Kg N ha^{-1} might be due to increased root growth that absorbs more nutrients from the soil at higher N level resulting in higher nitrogen concentration in dry matter. Also this might be attributed to the fact that high nutrient uptake of the crop is favoured by additional supply of nitrogen during maximum growth phase. Patel and Thakur (1997) also support same findings. The beneficial effect of increasing nitrogen levels on the N, P and K uptake was also reported by Ebaid and Ghanem, (2001). The results were also in accordance with the Dalal and Dixit (1987), Shinano *et al.* (1995), Gangaiah and Prasad (1999), Fageria *et al.* (2003), Srivastava *et al.* (2006), Zaidi *et al.* (2007), Narendra *et al.* (2008), Prudente *et al.* (2008), Tayefe *et al.* (2011) and Rao *et al.* (2013).

5.6 Soil nutrient status

As regards the final available nitrogen, data revealed that plots receiving no nitrogen fertilizer recorded lowest final available nitrogen. However, regarding the available phosphorous and potassium, the higher content of phosphorous and potassium was found in the control plots receiving no nitrogen. However, the organic carbon% was almost same in all the treatment combinations. The lower nitrogen status of the plots receiving no nitrogen fertilizer is probably due to uptake of nitrogen by the crop from the soil for dry matter production and no replacement of nitrogen taken by fertilizers. However, higher phosphorous and potassium content of soil receiving no nitrogen fertilizer may probably be attributed to the lower crop growth and dry matter production of these treatments compared to other treatments.

5.7 Economics

The economics of transplanting time and application of nitrogen levels calculated for gross return ha^{-1}, net return ha^{-1} and B:C ratio invested for aromatic rice show that transplanting time significantly influenced the economics of aromatic rice production. In aromatic rice higher gross return and net return ha^{-1} was with transplanting date of 20th May with the nitrogen application of 90 kg ha^{-1}. Transplanting on 20th May and application of 90 kg ha^{-1} nitrogen fertilizer also recorded higher B:C ratio (3.84). This might be due to better growth and higher yield of the aromatic rice grown on 20th May with the application of 90 kg N ha^{-1}. Higher B:C ratio in the early planted crop with application of higher nitrogen level was also reported by Gangwar and Sharma (1998), Singh *et al.* (2000), Pal *et al.* (2001), Kumar and Ikrammullah (2004) and Akbar *et al.* (2010).

Chapter - 6

SUMMARY AND CONCLUSION

The field experiment entitled, "Agronomic Evaluation of Pusa Basmati-1509 for Yield and Quality under Varied Transplanting Dates and Nitrogen Levels" was carried out during *kharif* 2014 at Mountain Research Centre for Field Crops, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Khudwani. The experiment was laid out in a split-plot design with three transplanting dates (20th May, 1st June, 11th June) and five nitrogen levels (0, 30, 60, 90 and 120 kg N ha^{-1}). The soil of the experimental field was silty clay loam, low in available nitrogen, medium in available phosphorus and potassium and neutral in reaction. The treatment effects in various characters under study have been described in detail in preceding chapters. The important findings are summarized here under:

6.1 Effect of transplanting dates

All growth parameters like plant height, dry matter accumulation (q ha^{-1}), leaf area index, tillers m^{-2} were significantly higher for the 20th May transplanting and lowest for the 11th June transplanting.

Days taken to reach various phenological stages were more in case of 20th May transplanting and were closely followed by 1st June. The lowest number of days was taken by the 11th June transplanting.

The yield contributing characters viz. number of panicles m^{-2}, panicle length (cm), panicle weight (g), spikelets panicle^{-1}, filled grains panicle^{-1} and 1000-seed weight were significantly highest in case of 20th May transplanting and was closely followed by 1st June transplanting. The yield contributing characters were lowest for the 11th transplanting date. The highest sterility percentage was however, found in the 1th June transplanting date.

Highest grain yield, straw yield, biological yield and harvest index were recorded with the 20th May, followed closely by the 1st June transplanting, while the lowest was found in case of 11th June transplanting date.

All the grain quality parameters like hulling%, milling%, superior grain grades, brown rice length and breadth, L/B ratio, KLAC, elongation ratio, HRR, volume expansion and aroma were highest with 20th May transplanting, which was closely followed by 1st June transplanting, while lowest was found in case of 11th June transplanting date. No significant difference was, however, found among all the transplanting dates for grain moisture content, gel consistency and amylose content.

As far as N, P and K uptake is concerned, higher N, P and K uptake were found in the 20th May and 1st June transplanting and lowest for the 11th June transplanting. However, the N, P and K content were not found significantly different among the transplanting dates.

6.2 Findings on levels of nitrogen fertilization

The nitrogen level of 120 kg N ha^{-1} recorded significantly higher growth parameters like plant height (cm), dry matter accumulation (q ha^{-1}), leaf area index, tillers m^{-2} and was closely followed by nitrogen level of 90 kg N ha^{-1}. The other nitrogen levels (60, 30 and 0 kg N ha^{-1}) recorded significantly lower growth parameters. However, the lowest plant height, LAI, dry matter and growth parameters were recorded for the control plot (0 kg Nha^{-1}).

Days taken to reach various phenological stages were more in case of higher nitrogen levels of 120, 90 and 60 kg N ha^{-1} and lower in case of 30 and 0 kg N ha^{-1}.

The yield contributing characters viz. number of panicles m^{-2}, panicle length (cm), panicle weight (g), spikelets panicle^{-1} and 1000-seed weight were significantly highest in case of nitrogen level of 120 kg N ha^{-1} and was closely followed by nitrogen level of 90 kg N ha^{-1}. However, filled grains panicle^{-1} were found highest for application of 90 kg N ha^{-1}. The nitrogen levels of 60, 30 and 0 kg N ha^{-1} recorded significantly lower yield contributing characters. However, the yield contributing characters were lowest for the control treatment. The highest sterility percentage was, however, found in the nitrogen levels of 120 and 90 kg N ha^{-1} and lowest for control.

Highest grain yield and harvest index were recorded with the nitrogen level of 90 kg N ha^{-1}, while as highest value for straw yield was recorded at 120 kg N ha^{-1}. However, the lowest values were recorded for the control treatment.

The grain quality parameters viz. hulling (%), milling (%), superior grain grades, brown rice length and breadth, L/B ratio, KLAC, elongation ratio, HRR, volume expansion and amylose content were significantly highest in case of nitrogen level of 120 kg N ha^{-1} and was closely followed by nitrogen level of 90 kg N ha^{-1}. The nitrogen levels of 60, 30 and 0 kg N ha^{-1} recorded significantly lower yield contributing characters. Highest aroma was found with application of 90 kg N ha^{-1} and no significant difference was, however, found among all the nitrogen levels for the gel consistency

Nitrogen, phosphorus and potassium uptake was found highest in the nitrogen level of 120 kg N ha^{-1} and was closely followed by nitrogen level of 90 kg N ha^{-1}, while the lowest values were recorded for control treatment. The nitrogen level of 120 kg ha^{-1} recorded highest value for N content. Whileas, P and K content was not found significantly different in all the nitrogen levels tested.

CONCLUSION

Based on one year study, it can be suggested that for realizing economically higher grain yield under the temperate climatic conditions of Kashmir valley, it is advantageous to transplant the scented rice variety Pusa Basmati-1509 earlier in the season (20^{th} May) with nitrogen application of 100 kg N ha^{-1} to achieve the higher net returns and the higher B:C ratio.

LITERATURE CITED

Abou-Khalifa, A.A.A. 2007. Response of rice varieties to nitrogen fertilization under varied agro-ecological conditions. *Egyptian Journal of Plant Breeding* **11**(2): 681-691.

Ahmad, A., Iqbal, S., Ahmad, S, Khaliq, T., Nasim, W., Husnain, Z., Hussain, A., Zia-ul-haq, M. and Hoogenboom, G. 2009. Seasonal growth, radiation interception, its conversion efficiency and biomass production of *oryza sativa* L. under diverse agroenvironments in Pakistan. *Pakistan Journal of Botany* **41**(3): 1241-1257

Ahmad, I., Akhter, M. and Nazir, M.S. 2002. Agronomic traits of fine rice as affected by transplanting time. *Asian Journal of Plant Sciences* **1**(4):318-319.

AICRIP, 1991. *Annual Progress Report*, 1990-91. All India Coordinated Rice Improvement Programme, Agronomy Chapter, pp. 171-180.

Akbar, N., Iqbal, A., Khan, H.Z., Hanif, M.K. and Bashir, M.U. 2010. Effect of different sowing dates on the yield components of direct seeded fine rice. *Journal of Plant Breeding and Crop Sciences* **2**: 312-315.

Akram, H.M., Ali, A., Nadeem, M.A. and Iqbal, M.S. 2007. Yield and yield components of rice varieties as affected by transplanting dates. *Journal of Agricultural Research* **45**(2):105-111

Akram, M., Cheema, A.A., Awan, M.A. and Maqbool, A. 1985. Effect of planting date and fertilizer level on grain yield and protein content of rice. *Pakistan Journal of Agriculture Research* **6**(3): 165-167.

Ali, A., Karim, M.A., Ali, S.S., Ali, L. and Majid, A. 1991. Relationship of transplanting time to grain quality in Basmati-385. *International Rice Research News* **16**(5): 11.

Amano, T., Zhu, Q., Wang, Y., Inoue, N. and Tanaka, H. 1993. Case studies on high yields of paddy rice in Jiangsu province, China. I. Characteristics of grain production. *Japan Journal of Crop Science* **62**(2): 267-274.

Anonymous 2013. Fixation of procurement rates for Kamad/Muski-Budgi seeds for Kharief 2013. Directorate of Agriculture, Kashmir.

Anonymous 2014. Fixation of procurement rates for paddy, maize and potato seeds for Kharief 2014. Directorate of Agriculture, Kashmir.

Anonymous, 2012. Agriculture statistics at a glance, Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India, New Delhi.

Asghar, M., Sadiq, M., Mehdi, S.M., Sarfraz,M., Hassan, G. and Ahmad, R. 2001. Optimum transplanting date for rice production. *Online Journal of Biological Sciences* **1**(4):259-260.

Ashraf, M., Mahmood, S. and Munsif, M. 1989. Relationship of transplanting time and grain yield of Basmati-385. *International Rice Research News* **14**(1): 8.

Awan, l.U., K.H. Ahmad and D.U.S. Gandapur. 1984. Effect of different nitrogen application on rice grain yield. IRRI Newsleter, **9**(6): 26.

Azad, A. K., Gaffer, M. A., Samante, S. C., Kashem, M. A. and Islam, M. T. 1995. Response of BR10 rice to different levels of nitrogen and spacing. *Bangladesh Journal of Scientific Industrial Research* **30**(1): 31-38.

Azarpour, E., Tarighi, F., Moradi, M. and Bozorgi, H.R. 2011 .Evaluation effect of different nitrogen fertilizer rates under irrigation management in rice farming. *World Applied Sciences Journal* **13**(5): 1248-1252.

Babu, A.M. 1988. Effect of planting time and fertilizers on growth and yield of rice. *Oryza* **25**(3): 319-322.

Babu, R.J., Kailash, Y.K., Vishal, A.N. and Kumar, S.N. 2000. Site specific nutrient management in rice through LCC and SPAD meter. *Journal of Applied Science* **42**: 234-241.

Balasubramanian, V., Morales, A.C., Thiyagarajan, T.M., Babu, M. and Hai, L.H. 2000. Adaptation of the chlorophyll meter (SPAD) technology for real-time N management in rice: a review. *International Rice Research Note (IRRN)* **13**(2) : 28-35.

Bali, A.S., Singh, K. N. and Khan, G. M. 1993. Effect of transplanting dates on promising genotypes of rice (*Oryza sativa*) under Kashmir Valley conditions. *Indian Journal of Agronomy* **37**(4): 805-809.

Bali, A.S., Singh, K.N., Balli, A.S., Ganai, B.A. and Hasan, B. 1995. Effect of transplanting dates, number and age of seedling on rice. *Indian Journal of Agronomy* **40**(3) : 504-507.

Bali, A.S. and Uppal, H.S. 1995. Effect of date of transplanting and water management practices on yield of basmati rice. *Indian Journal of Agronomy* **40**(20): 186-192.

Behera, A. K. 1998. Response of scented rice (*Oryza sativa*) to nitrogen under transplanting condition. *Indian Journal of Agronomy* **43**(1) 64-67.

Bera, A.K. and Pramanik, K. 2010. Response of rice hybrid to different sourcrs of phosphorus and homobrassinolide under lateritic zone of West Bengal.

In*: Abstract of National Symposium on Sustainable rice production system under changed climate*, 27th to 29th November, 2010 at Central Rice Research Institute, Cuttack, Orissa, India. pp- 55.

Bhale, V.M. and Salunke, V.D. 1996. Response of upland irrigated rice to nitrogen applied through urea and super granules. *Mysore Journal of Agricultural Sciences* **27**(1): 1-4.

Bhan, V.M. and Pandey, H. K. 1966. Measurement of leaf area of rice. *Journal of Agronomy* **58**: 454-458.

Bhowmick, N. and Nayak, R. L. 2000. Response of hybrid rice *(Oryza saliva)* varieties to nitrogen, phosphorus and potassium fertilizers during dry (boro) season in West Bengal. *Indian Journal of Agronomy* **45**(2):323-326.

Bohlool, B.B., Ladha, J.K., Garrity, D.P. and George, T. 1992. Biological nitrogen fixation for sustainable agriculture: A perspective. **In** : *Biological nitrogen fixation for sustainable agriculture* (Ed. J.K. Ladha, T. George, and B.B. Bohlool), 1-12. Dorchect, The Netherlands: Kluwer Academic Publisher in Cooperation with the International Rice Research Institute.

Boling, A., Tuonga, A.T.P., Jatmikob, S.Y. and Buraca, M.A. 2004. Yield constraints of rainfed lowland rice in Central Java, Indonesia. *Field Crop Research* **2**(3): 351-360.

Brar, S.K., Mahal, S.S., Brar, A.S., Vashist, K.K., Sharma, N. and Buttar, G.S. 2012. Transplanting time and seedling age affect water productivity, rice yield and quality in north west India. *Agricultural Water Management* **115**:217-222.

BRRI (Bangladesh Rice Research Institute). 1989. Annual internal review for 1988. Plant Physiology Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh, pp: 59.

BRRI (Bangladesh Rice Research Institute). 2002. Annual Internal Review, held on 22 December-26 December, Soil Sci. Divn, *Bangladesh Rice Res. Inst. Gazipur*. pp. 3-6, 25-26.

BRRI (Bangladesh Rice Research Institute). 2004. *Adunick Dhaner Chash* (Bengla), Pub. No. 5. Bangladesh Rice Res. Inst. Gazipur, pp.12-35.

Cagampang, G.B., Cruz, L.J., Espiritu, S.G., Santiago, R.G. and Juliano, B.O. 1966. Studies on the extraction and composition of rice proteins. *Cereal Chem*istry **43**:145-155.

Cagampang, G.B., Perez, C.M. and Juliano, B.O. 1973. A gel consistency test for eating quality of rice. *Journal of the Science of Food and Agriculture* **24**: 1589-1594.

Canet, R. 1986. Effect of sowing time on yield of rice varieties in two locations in Cuba. *Intl. Rice Res. Newsl*. **11**(3): 28.

Cassman, K.G., Peng, S., Olek, D.C., Ladha, J.K., Reichhardt, W., Dobermann, A. and Singh, U. 1998. Opportunities for increased nitrogen use efficiency from improved resource management in irrigated rice systems. *Field Crops Res*earch **56**:7-19.

Chakraborty, K. 2011. Influence of inorganic N fertilizer on plant characters, yield generation and the incidence of yellow stem borer *Scirpophaga incertulas*, walker in the field of local scented paddy cultivar *Tulaipanji*.

Chander, S. and Pandey, J. 1996. Effect of herbicide and nitrogen on yield of scented rice (*Oryza sativa*) under different rice cultures. *Indian Journal of Agronomy* **41**(2): 209-214.

Chandra, D. and Manan, G.B. 1989. Influence of date of planting, age of seedling and plant population on productivity of long duration "Gayatri" rice (*Oryza sativa). Indian Journal of Agricultural sciences* **59**(7): 422-426.

Chandra, D., Lodh, S. B., Shoo, K. M. and Nanda, B. B. 1997. Effect of date of planting and spacing on grain yield and quality of scented rice (*Oryza sativa)* varieties in wet season in coastal Orissa. *Indian Journal of Agricultural Sciences* **67**(3): 93-97.

Chaturvedi, I. 2005. Effect of nitrogen fertilization on growth, yield and quality of hybrid rice. *Journal of Central European Agric*ulture **6**:611-618.

Chaudhary, A.M. and Iqbal, M.S. 1992. Production technology for basmati rice. *Technology Bulletin.* Rice Research Institute, Kala Shah Kuku, Punjab (Pakistan) 17-23.

Chaudhary, J.K., Kurmi, K., Baruah, R. K.S.M. and Das, G.R. 1994. Performance of lowland transplanted rice varieties under late planting in Assam, India. *International Rice Research Notes* **19**(3): 20-25.

Chen, C.H.T., Li, C.C. and Kao, C.H. 1997. Senescence of rice leaves, changes of chlorophyll, protein and polyamine contents and ethylene production during senescence of a chlorophyll-deficient mutant. *Journal of Plant Growth Regulation* **10**: 201-205.

Chopra, N.K. and Chopra, N. 2000. Effect of row spacing and nitrogen level on growth, yield and seed quality of scented rice under transplanted conditions. *Indian Journal of Agronomy* **45**: 304-308.

Chopra, N.K. and Chopra, N. 2004. Influence of transplanting dates on heat-unit requirement of different phenological stages and subsequent yield and quality of scented rice (*Oryza sativa)* seed. *Journal of Agricultural Sciences* **74**(8): 415-419.

Chopra, N.K., Chopra, N. and Sinha, A.K. 2003. Influence of dates of transplanting on production and quality of scented rice (*Oryza sativa)* seed. *Indian Journal of Agricultural Sciences* **73**: 112-116.

Chopra, N.K., Chopra, N., Yadav, R.N. and Nagar, K.C. 2006. Effect of transplanting dates on seed yield and quality of paddy cv. Pusa-44. *Seed Research* **34**(2): 218-220.

Choudhuri, B.T., Turkhede, A.B., Chore, C.N., Jitode, D.J. and Thorat, A.W. 1998. Performance of Basmati rice varieties under various levels of nitrogen with organic manure. *Journal of Soils and Crops* **8**(l): 41-43.

Conry, M. J. 1995. Comparisons of early, normal and late sowing at three rates of nitrogen on the yield, grain nitrogen and screening contents of Blenheim spring malting barley in Ireland. *Journal of Agricultural Science, Cambridge* **125**:183-88.

Cruz, P.C. and Wada, G. 1994. Genetic variation in nitrogen uptake by rice and the effects of management and soil fertility. **In**: *Rice Roots, Nutrient and Water Use*. [Ed. G.J.D. Kirk]. International Rice Research Institute, Manila, Philippines, pp: 29-40.

Dalal, P.K. and Dixit, L. 1987. Response of medium duration rice varieties (dwarf indica to levels of nitrogen. *Indian Journal of Agronomy* **32**(3): 286-287.

De Datta, S. K. 1981. Principles and practices of rice production. John Wiley and Sons, New York, pp: 375.

Dehal, P. and Mishra, G. 1994. Interaction of spacing and nitrogen in rice. *Oryza* **31**(2):149-150.

DES, 2008. Digest of Statistics 2007-08, Directorate of Economics and Statistics, Government of Jammu and Kashmir.

DES, 2012. Directorate of Economics and Statistics, Ministry of Agriculture, Government of India. Agricultural Statistics at a Glance.

DES, 2013. Economic Survey. 2013-14. Directorate of Economics and Statistics, Government of Jammu and Kashmir.

DES, 2014. Directorate of Economics and Statistics, Ministry of Agriculture, Government of India. Agricultural Statistics at a Glance.

Devi, M.G., Reddy S.T., Sumati, V., Pratima, T. and John, K. 2012. Nitrogen management to improve the nutrient up-take, yield and quality parameters of scented rice under aerobic culture. *International Journal of Applied Biology and Pharmaceutical Technology* **3**: 340-344.

Dhaliwal, Y.S., Nagi, P.S., Sidhu, G.S. and Sekhon, K.S. 1986. Physico-chemical, milling and cooking quality of rice as affected by sowing and transplanting dates. *Journal Science of Food and Agriculture* **37**(9): 881-887.

Dhiman, S.D., Om, H., Singh, B. and Singh, B. 1995. Yield stabilization of scented dwarf rice under late planting through spacing and seedling age. *Haryana Agricultural University Journal of Research* **25** (3): 95-99.

Dikshit, P.R. and Paliwal, A.K. 1989. Effect of nitrogen and sulphur on the yield and quality of rice. *Agricultural Science Digest* **9**: 171-174.

Dingkuhn, M. and Kropff, M. 1996. Rice. **In** : Photoassimilate distribution in plants and crops, source-sink relationships (Eds. E. Zamski and A.A. Schaffer). Marcel Dekker, Inc., New York/Basel/Hong Kong, pp. 519-547.

Dixit, A.J., Gaikwad, V.V., Jadhav, M.G. and Thorat, S.T. 2004. Effect of sowing times on phenology and growth of hybrid rice parents. *Journal of Agrometeorology* **6**: 72-76.

Dixit, R.S. and Singh, M.M. 1980. Response of rice varieties to N levels under rainfed seeded conditions. *Intl. Rice Res. Newsl.* **28**(2): 26-28.

Dongarwar, U.R.; Shinde, V.S. and Mondhe, C.B. 2005. Performance of scented rice varieties under differnt transplanting date in eastern Vidarbh zone. *PKV Research Journal* **29**(2) : 239-241.

Dubey, O.P., Upadhyaya, S.P., Dixit, J.P. and Gray, D.C. 1991. Response of short duration paddy varieties to nitrogen under rainfed condition. *Indian Journal of Agronomy* **36**(2): 225-256.

Ebaid, R.A. and Ghanem, S.A. 2001. Effect of nitrogen fertilization and planting dates on rice crop production. *Journal Agricultural Sciences Mansoura University* **26**(4): 1833-1840.

Ehsanullah, H.M.A., Nawaz, M.U. and Cheema, M.S. 2001. Effect of Various Levels and Methods of Nitrogen Application on Nitrogen Use Efficiency in Rice Supper Basmati. *International Journal of Agriculture & Biology* **3**(1): 61-63.

Escuro, P.B. 1961. The response of rice varieties to season of planting. *Field Crop Abst.,* **14**: 1700.

Fageria, N.K. and Baligar, V.C. and Miller, D.K. 2003. Methodology for evaluation of lowland rice genotypes for nitrogen use efficiency. *Journal of Plant Nutrition* **26**: 1315-1333.

Fayaz, A., Singh. P., Qayoom, S., Ahmad, L., Lone, B., Singh, L. and Singh, K.N. 2015. Influence of different dates of sowing and spacing on growth and yield of scented rice cv. Pusa Sughandhi-3 under temperate conditions of Kashmir. *Journal of Cereals and Oilseeds* **6**(4): 20-23.

Gangaiah, B. and Prasad, R. 1999. Response of scented rice to fertilizers. *Indian Journal of Agronomy* **44**: 294-296.

Gangwar, B. and Ahamedi, R. 1990. Effect of planting time on growth, yield and incidence of insect pests in rice. *Oryza* **27** : 497-500.

Gangwar, K.S. and Sharma, S.K. 1998. Influence of planting dates on productivity of traditional scented rice varieties. *International Rice Research News* **22**(1): 88-92.

Gao, R.S. and Zhang, S.P. 1994. Climatic and Ecological Base of Rice Quality. Shaanxi Science and Technology Press, Xi'an (in Chinese).

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

Ghadekar, S.R., Morey, D.K. and Zilpe, Y.P. 1988. Effect of transplanting dates on dry matter, yield and accumulation of photo thermal units in rice (*Oryza sativa)* at Nagpur. *Indian Journal of Agricultural Sciences* **58**(5): 339-341.

Gholizadeh, A., Amin, M.S.M., Anuar, A.R. and Aimrun, W. 2011. Evaluation of SPAD chlorophyll meter in two different rice growth stages and its temporal variability. *European Journal of Science Research* **37**(4): 591-598.

Ghosh, B.C., Raghavaian, C.V. and Jana, M.K. 1991. Effect of seed rate and nitrogen on growth and yield of direct sown rice (*Oryza sativa* L.) under intermediate deep water condition. *Indian Journal of Agronomy* **36**: 227-228.

Ghosh, M., Mandal, B.K., Mandal, B.B., Lodh, S.B. and Dash, A.K. 2004. Effect of planting date and nitrogen management on yield and quality of aromatic rice. *Journal of Agricultural Sciences* **142**(2): 183-191.

Gill, J.S. and Walia, S.S. 2014. Influence of FYM, brown manuring and nitrogen levelson direct seeded and transplanted rice (*Oryza sativa* L.) : A review. *Research Journal of Agriculture and Environmental Management* **3**(9):417-426.

Gill, M.S., Gill, J.S. and Gill, G.K. 2009. Effect of time of transplanting on performance of different basmati rice (*Oryza sativa* L.) cultivars. *Environment and Ecology* **27**:1757-1759.

Gill, P.S. and Shahi, H.N. 1987. Effect of transplanting schedule and post-harvest time interval for threshing on milling and quality characteristics of rice. *Indian Journal of Agricultural Sciences* **57**(12): 889-894.

Gomez, K.A and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research. Second Edition A Wiley- Inter Science Publication, John Wiley and Sons, Inc. New York, pp. 680.

Gravois, K.A. and Helius, R.S. 1998. Seeding date effect on rough rice yield and head rice selection for stability. *Euphytica* **102**: 151-159.

Haefele, S.M., Jabbar, S.M.A., Siopongco, J.D.L.C., Tirol-Padre, A., Amarante, S.T., Cruz, P.C. and Cosici., W.C. 2008. Nitrogen use efficiency in selected rice genotypes under different water regimes and nitrogen levels. *Field Crops Research* **107**:137-46.

Halappa, G., Khan, T.A., Mahadevappa, N. and Venkataraman, M.N. 1974. Optimum time of Planting for high yielding varieties of paddy in *kharif* season of tank fed tracts of Karnataka. *Mysore Journal of Agricultural Sciences* **8**: 488-492.

Haque, K.M.S., Khaliq, Q.A. and Aktar, J. 2006. Effect of nitrogen on phenology, light interception and growth in aromatic rice. *International Journal for Sustainable Crop Production* **1**(2): 01-06.

Hassan, M.S., Kheir, A., Haqu, M. M., Azad, A. K., Hamed, A. 2009. Genotypic variation in traditional rice varieties for chlorophyll content, SPAD value and nitrogen use efficiency. *Bangladesh Journal of Agriculture Research* **34**(3): 505-515.

Hossain, M. and P.L. Pingali. 1998. Rice research technological progress, and impact on productivity and poverty: an overview. **In** : *Impact of Rice Research* (Eds. Pingali, P.L. & Hossain, M.), Los Baños, Philippines, IRRI.

Hossain, M.F. and Sikdar, M.S.I. 2009. Performance of aromatic rice varieties under different transplanting date in *aman* season. *Journal of Agroforestry and Environment* **3**(1): 41-44.

Hossain, M.F., Bhuiya, M.S.U. and Ahmad, M. 2007. Chemical and physical properties of aromatic rice varieties as influenced by transplanting date in transplant *aman* season. *Journal of the National Science Foundation of Sri Lanka* **35**(2): 127-132

Huang, C., Tang, W., Duan, L., Jiang, N., Chen, G., Xiong, L. and Liu, Q. 2013. Rice panicle length measuring system based on dual camera imaging. *Computers and Electronics in Agriculture* **98** : 158-165.

Huang, J., He, F., Cui, K., Buresh, R. J., Xu, B., Gong, W. and Peng, S. 2008. Determination of optimal nitrogen rate for rice varieties using a chlorophyll meter. *Field Crops Research* **105** : 70-80.

Hussain, A., Bhat, M.A., Ganai, M.A. and Hussain, T. 2009. Influence of planting dates and spacing schedules on performance of Basmati rice Pusa Sugandh-3 under Kashmir valley conditions. *Environment and Ecology* **27** : 396-398.

Hussain, S.M. and Sharma U.C. 1991. Response of rice to nitrogen fertilizer in acidic soil of Nagaland. *Indian Journal of Agricultural Sciences* **61**(9): 660-664.

Idris, M. and Matin, M.A. 1990. Response of four exotic strains of *Aman rice* to urea *Bangladesh Journal of Agricultural Sciences* **17**(2): 271-275.

International Rice Research Institute, 1971. Annual Report for 1970, Los Banos, Laguna Philippines, pp 265.

Iqbal, S., Ahmad, S.A., Hussain, A., Ali, M.A., Khaliq, T. and Wajid, S.A. 2008. Influence of transplanting date and nitrogen management on productivity of cultivars under variable environments. *International Journal of Agriculture and Biology* **10**: 288-292.

IRRI, 1997. Rice Almanac, 2nd ed. International Rice Research Institute, Los Banos, the Philippines. International Rice Research Institute. 1971. Annual Report for 1970. Los Baños, Laguna, Philippines. pp. 265.

Islam, M.R., Haque, M.S. and Bhuiya, Z.H. 1990. Effect of nitrogen and sulphur fertilization on yield response and nitrogen and sulphur composition of rice. *Bangladesh Journal of Agricultural Sciences* **17**(2): 299-302.

Islam, M.S., Hossain, M.A., Chowdhury, M.A.H. and Hannan, M.A. 2008. Effect of nitrogen and transplanting date on yield and yield components of aromatic rice. *Journal of Bangladesh Agricultural University* **6**: 291-296.

Islam, M.S.H., Bhuiya, M.S.U., Rahman, S. and Hussain, M. 2009. Evaluation of SPAD and LCC based nitrogen management in rice (*Oryza sativa L*.). *Bangladesh Journal of Agricultural Research* **34**(4): 661-672.

Jackson, M.L. 1973. Soil chemical analysis. 2nd Median Reprint, Prentices Hall of India. Private Limited., New Delhi, p. 498.

Jadhav, A.S., Dhoble, M.V. and Chavan, D.A. 2003. Effect of irrigation and nitrogen on yield and quality of Basmati rice. *Journal of Maharastra Agriculture University* **28**(2):187-188

Jadhav, J.S., Dhoble, M.V. and Chavan, A. 2004. Leaf area pattern and dry matter production in Basmati Rice under Upland Condition. *Journal of Maharastra Agriculture University* **29**(1): 42-44.

Jand, V., Bains, G.S. and Movi, H.S. 1994. Effect of different dates of transplanting on biomass production and its partitioning in various plant parts of rice crop. *Journal of Ecology* **21**(1): 13-18.

Jiang, P., Hong, X., Fen, L. and Si, J. 1993. The concept of “three highs and one stable” to increase rice yield in China. *International Rice Commission Newsletter (FAO)* **42**: 19-20.

Juliano, B.O. 1971. A simplified assay for milled rice amylase. *Cereal Science Today* **16**(10): 334-339.

Kanyika, W.A., Saka, A.R. and Muiha, P. 2007. Response of Nunkile rice variety to fertilizer nitrogen application and plant spacing under irrigated conditions in Malawi. *Malawi Journal of Agricultural Sciences* **3**: 58-69.

Katyal, S. K. 1996. Effect of transplanting times on hybrid rice in Haryana, India. *International Rice Research News* **22**: 2-6.

Khalid, M. and Chaudhry, A.M. 1999. Impact of nitrogen levels and its application methods on yield and kernel quality of fine rice. *Pakistan Journal of Agricultural Sciences* **36**: 1-2.

Khalid, M., Saifi, M.A. and Choudhary, F.M. 1999. Effect of different application methods and nitrogen levels on yield and yield components of fine rice. *Journal of Agricultural Sciences* **36**: 1-2.

Khanda, C. M. and Dixit, L. 1996. Effect of zinc and nitrogen fertilization on yield and nutrient uptake of summer rice (*Oryza sativa*). *Indian Journal of Agronomy* **41**(3): 368-372.

Khanda, L. N., Dixit, L. and Panda, S. C. 1997. Effect of zinc and graded levels of nitrogen on growth, yield and nutrient uptake of rice (*Oryza sativa*). *Oryza* **34**: 43-46.

Koyamma, T.; Kali, S.E. and Chammek, C. 1973. Effect of transplanting time on rice plant growth and grain yield in Thailand. *Tech. Bul. Trop. Agric Res. Centre* **5** : 32.

Kumar, D.R. and Ikramullah, M. 2004. Influence of nitrogen levels and planting dates on productivity and profitability of scented rice varieties. *Journal-of-Research-ANGRAU* **32**(4): 5-9.

Kumar, K. and Rao, K.V.P. 1992. Nitrogen and phosphorus requirement of upland rice in Manipur. *Oryza* **29**: 306-309.

Kumar, M., Singh, R.P., and Rana, N.S. 2003. Effect of organic inorganic sources of nutrition on productivity of rice (*Oryza sativa*). *Indian Journal of Agronomy* **48**(3): 175-177.

Kumar, M.R.; Subbaiah, S.V. and Pillai, G.K. 1998. Response of rice hybrids to different dates of planting in vertisols of Andhra Pradesh. *Oryza* **35**(3) : 285-287.

Kumar, R.M., Padmja, K., Subbaiah, S.V. 2000 .Varietal response to different nitrogen management methods in an irrigated transplanted rice ecosystem in a vertisol of Andhra Pradesh India. *International Rice Research Note (IRRN),* pp. 32-34.

Kusuda, M. J. 1993. Influence of nitrogen fertilization on growth characters of rice (*Oryza sativa*) under semi-arid conditions. *Indian Journal of Agronomy* **23**: 113-117.

Ladha, J.K., Kirk, G.J.D., Bennett, J., Peng, S., Reddy, C.K., Reddy, P.M. and Singh, U. 1998. Opportunities for increased nitrogen use efficiency from improved lowland rice germplasm. *Field Crops Res*. **56**:41-71.

Lakpale, R., Pandey, N. and Tripathi, R.S. 1999. Effect of levels of nitrogen forms of pre-conditioned urea on yield and N-status in plot and soil of rainfed rice. *Indian Journal of Agronomy* **44**(1): 89-93.

Lalitha, K., Raji-Reddy, D. and Narsimha-Rao, S.B.S. 2000. Influence of temperature on duration of tillering in lowland rice varieties. *Journal of Agrometeorology* **2**(1): 65-67.

Lawal, M.I. and Lawal, A.B. 2002. Influence of nitrogen rate and placement methods on growth and yield of rice (*Oryza sativa* L.) at Kadawa. *Nigerian Journal* **23**(3): 403-441.

Lee, C.K., Lee, B.V., Shin, J.C. and Yoon, Y.H. 2001. Heading date and final leaf number as affected by sowing date and prediction of heading date based on leaf appearance model in rice. *Korean Journal of Crop Science* **46**(2): 195-201.

Lee, D.J., Shim, I.S., Seo, J.H., Cho, K.J. and Chae, J.C. 1994. Growth and grain yield of infant seedling in rice as affected by different planting date in Southern Alpine area. RDA. *Journal of Agricultural Science Rice* **36**(1): 1-7.

Lin, T.F. and Huang, F.M. 1992. The effect of planting dates on the yield and quality of rice cultivar Taichung Sen-10 grown in the second crop season. *Bulletin of Taichung District Agriculture Improvement Station* **34**: 227-233.

Linscombe, S.D., Jordan, D.L., Burns, A.B. and Viator, R.P. 2004. Rice response to planting date differs at two locations in Louisiana. *Online Crop Management*.

Luikham, E., Yamtong, K. and Anal, M. S. 2008. Effect of planting geometry and nitrogen levels on productively of black aromatic rice (*Oryza sativa* L.) under rainfed conditions. *Agriculture Science Digest* **28** (2): 153 -154.

Magor, N.P. 1984. A cropping pattern model for rainfed lowland rice in Bangladesh. M.Sc Ag. Thesis. Faculty of Agriculture. The University of Sydney, Sydney N.S.W., Australia, pp: 3-38

Mahajan, G., Sekhon, N. K., Singh, N. N., Kaur, R. and Sidhu, A.S. 2010. Yield and nitrogen-use efficiency of aromatic rice cultivars in response to nitrogen fertilizer. *Journal of New Seeds* **11**: 356-368.

Mahajan, G., Singh, J. and Sharma, N. 2011. Enhancing the performance of direct seeded basmati rice through seed priming and nitrogen management. *Oryza* **48**(4): 380-382.

Mahajan, K.K. and Tripathi, B.R. 1992. Effect of increasing levels of different Urea based fertilizers on yield and nitrogen nutrition of rice in an alfisal. *Oryza* **29**(2):101-106.

Malik, Z.A. 2014. Economics of apple cultivation "with special reference to South Kashmir-India". *Journal of Economics and Sustainable Development* **5**(9): 125-130.

Malikk, S., Aguilar, A.M. and Vergara, B.S. 1988. Use of high density seeds to increase rice (*Oryza sativa* L.) grain yield. *Philippine Journal of Crop Sciences* **13**(3): 141-144.

Mandal, B.K., Sainik, T.R. and Ray, P.K. 1984. Effect of age of seedlings and levels of nitrogen on the productivity of rice. *Oryza* **21**(2) : 232-252.

Mandal, N. and Ghosh, M. 2003. Thermal time indices and yield correlations for hybrid rice in tarai zone of west Bengal. *Journal of Agrometeorology* **5**(2): 98-101.

Mandal, S. and Swamy, S.N. 2003. Effect of time of N application on yield and yield attributes of rice (*Oryza sativa* L.) cultivars. *Environment and Ecology* **21**(2): 411-413.

Mannan, M.A., Bhuiya, M.S.U., Hossain, S.M.A. and Akhand, M.I.M. 2009. Study on phenology and yielding ability of Basmati fine rice genotypes as influenced by planting date in Aman season. *Bangladesh Journal of Agricultural Research* **34**: 373-384.

Mannan, M.A., Bhuiya, M.S.U., Akhand, M.I.M. and Zaman, M.M. 2012. Growth and yield of basmati and traditional aromatic rice as influenced by water stress and nitrogen levels. *Journal of Science Foundation* **10**(2): 52-62.

Mannan, M.A., Bhuiya, M.S.U., Hossain, S.M.A. and Akhand, M.I.M. 2010. Optimization of nitrogen rate for aromatic basmati rice (*Oryza sativa* L.). *Bangladesh Journal of Agricultural Research* **35**: 157-165.

Manzoor, Z., Awan, T.H., Zahid, M.A. and Faiz, F.A. 2006. Response of rice crop (Super Basmati) to different nitrogen levels. *Journal of Animal and Plant Sciences* **16**: 52-55.

Maqsood, M., Shehzad, M.A., Ali, S.N.A. and Iqbql, M. 2013. Rice culture and nitrogen rate on yield and quality of rice (*Orzyza sativa* L.). *Turkish Journal of Agriculture and Forestry* **37**: 665-673

Marazi, A.R., Khan, G.M., Singh, K.H. and Bali, A.S. 1993. Response of rice (*Oryza sativa*) to different N levels and water regimes in Kashmir Valley. *Indian Journal of Agricultural Sciences* **63**(11): 726-727.

Maruyama, S. and Tanaka, T. 1985. Influence of transplanting dates on the growth and yield of paddy rice. *Bulletin of the Hokuriku National Agricultural Experiment Station* **27**: 80-99.

Maske, R.S., Gautam, P.K. and Yadhaw, M.P. 1997. Influence of different nitrogen levels on growth, yield and quality of rice (*Oryza sativa*). *Advance Journal of Food Science and Technology* **5**(4): 396-402.

Matsushima, S., Tanaka, T. and Hoshino, T. 1996. Analysis, of yield-determining process and its application to yield-prediction and culture improvement of lowland rice. LXXV, Temperature effects on tillering in case of leaves and culm, culm-bases and roots being independently treated. *Proceedings of Crop Science Society of Japan* **34**: 478-483.

Meena, S.L., Surendra, S., Shivay, Y.S. and Singh, S. 2003. Response of hybrid rice (*Oryza sativa*) to nitrogen and potassium application in sandy clay loam soils. *Indian Journal Agricultural Sciences* **73**(1): 8-11.

Miah, N.M. and Pathan, M. S. 1989. Effect of low temperature on yield and some agronomic characters of rice. *International Rice Research News* **14**(1): 15-19.

Mikkelson, D.S. 1982. Timing and method of nitrogen applied for rice. *Proceedings of Second National Rice Research Institute Conference. Cairo* 6-10 Feb., **2**: 83-291.

Miri, K. 2011. Yield and yield attributes of rice cultivars as influenced by transplanting dates in Sarbaz region. *International Journal of Agriculture and Crop Sciences* **3**(3):72-75.

Mohammed, I., Kumar, D.R. and Ikramullah, M. 2001. Influence of nitrogen on grain yield and quality traits of scented rice varieties under normal and late planting. *Crop Research Hisar* **22**(2): 297-299.

Mohapatra, A.K. 1989. Effect of dates of planting, age of seedling and levels of nitrogen on biological yield and harvest index of rice. *Environmental Ecology* **7**(4): 896-898.

Moorthy, B.T.S., Nanda, B.B. and Rao, K.S. 1988. Effect of graded levels of nitrogen on yield and quality of rice varieties for shallow lowland. *Oryza* **35**(2): 178-180.

Mukesh., Singh, I., Pannu, R.K., Prasad, D. and Ram, A. 2013. Effect of different transplanting dates on yield and quality of basmati rice *(Oryza sativa)* varieties. *Indian Journal of Agronomy* **58**(2):256-258.

Munda, G.C., Chaudhri, P.B. and Patel, C.S. 1994. Variety, date of transplanting and space on high altitude rice. *Indian Journal of Hill Farming* **7**(1): 96-98.

Nahar, K., Hasanuzzaman, M. and Majumder, R.R. 2009. Effect of low temperature stress in transplanted aman rice varieties mediated by different transplanting dates. *Academic Journal of Plant Sciences* **2**(3): 132-138.

Narendra, P., Verma, A.K. and Tripathi, R.S. 2008. Effect of planting dates and N levels on N concentration in the leaf, grain yield and N uptake by hybrid rice. *Oryza* **45**(1): 18-22.

Navin, K, Singh, V.K., Thakur, R.B. and Kumar, N. 1996. Effect of level and time of N-application on the performance of winter rice. *Journal of Applied Biotechnology* **6**(1-2): 48-53.

Nawaz, H.M.A. 2002. Effect of various levels and methods of nitrogen application on nitrogen use efficiency in rice Super Basmati. M.Sc. Thesis, Deptt. Agron, Univ. Agric., Faisalabad

Nayak, B.C.; Dalei, B.B. and Chodhury, B.K. 2003. Response of hybrid rice to date of planting, spacing and seedling rate during wet season. *Indian Journal of Agronomy* **48** (3) : 172-174.

Nerson, H. 1980. Effects of population density and number of ears on wheat yield and its components. *Field Crops Research* **3**: 225-234.

Norman, R.J., Salton, N.A. and Moldenharer, K.A.V. 1999. Development of the DD50 database for new rice cultivars **In** : B.R. Wells Rice Research Studies 1998 ([Eds. R.J. Norman and T.H. Johnston]. *Research Series* **468**: 250-256.

Nossai, E. and Vargas, Z. P. 1982. Response of 1R8 rice variety to nitrogen fertilizer under irrigated field condition. *Agric. Res. J. Kerala* **36**(4): 294.

Olsen, S.R., Cole, C.V., Watanable, F.S. and Dean, L.A. 1954. Estimation of available phosphorous in soil by extraction with Sodium Carbonate. U.S.D. Cir. No. 939, Washington, p.19.

Om, H., Joon, R.K. and Singh, O.P. 1989. Effect of time of transplanting and age of seedling on growth and yield of dwarf rice. *Indian Journal of Agronomy* **34**(3): 325-329.

Om, H., Singh, O.P. and Joon, R.K. 1993. Effect of time of transplanting and spacing on basmati rice. *Haryana Journal of Agronomy* **9**(1): 87-91.

Om, H.; Katyal, S.K. and Dhiman, S.D. 1997. Effect of time of transplanting and rice hybrids on growth and yield. *Indian Journal of Agronomy* **42** (2) : 261-264.

Pal, S.K., Thakur, R., Singh, M.K., Verma, U.N. and Upasani, R.R. 2001. Production potential of scented rice genotypes under different planting time and nitrogen level. *Journal of Research Birsa Agriculture University* **13**(2): 153-157.

Paliwal, A.K., Kandalkar, V.S., Paraye, P.M. and Tomer, N.S. 1996. Effect of transplanting time on grain yield and its attributes in dwarf scented rice (*Oryza sativa*) varieties. *Indian Journal of Agricultural Sciences* **66**(1): 48-50.

Panda, M. and Rao, C.N. 1991. Influence of nitrogen on photosynthesis and productivity of rice in dry and wet season. *Oryza* **28**: 37-40.

Pandey, S.K., Singh, R. and Singh, B.B. 1991. Effect of different doses of N on dwarf and tall varieties of rice *Indian Journal of Agronomy* **61**(2): 135-138.

Parihar, S.S., Verma, V.K., Shukla, R.K., Pandey, D. and Sharma, R.B. 1995. Response of transplanted rice (*Oryza sativa*) to planting time and irrigation schedule. *Indian Journal of Agronomy* **40**(3): 402-406.

Patel, J.R. 1999. Response of rice to time of transplanting, spacing and age of seedlings. *Indian Journal of Agronomy* **44**(2) : 344-346.

Patel, S.R. and Mishra, N.N. 1994. Effect of different forms of urea and levels of nitrogen on the yield and nitrogen uptake of rice. *Advances in Plant Sciences* **7**(2): 327-401.

Patel, S.R. and Thakur, D.S. 1997. Yield of rice as influenced by split application of nitrogen. *Journal of Maharashtra Agricultural University* **22**(2): 215-216.

Paul, S.R. 1994. Effect of age of seedlings and dates of transplanting on grain yield of Sali rice in Assam. *Annual Agricultural Research* **15**(1): 126-128.

Peng, S., Garcia, F.V., Laza, R.C., Sanico, A.L., Visperas, R.M. and Cassman, K.G. 1996. Increased N-use efficiency using a chlorophyll meter on high-yielding irrigated rice. *Field Crop Research* **47**(2): 243-252.

Peng-fei, L., Zhi-hua, Z., Yan-xia, Z., Shao-hua, X., Ming-zhu, J., Wen-jing, H. and Xu-hu, Z. 2013. Effects of sowing date, basic seedling, nitrogen rate and field water on early rice "Liangyou 9168". *Advance Journal of Food Science and Technology* **5**(4): 414-417.

Perez, C.M., Juliano, B.O., Liboon, S.P., Alcantara, J.M. and Cassman, K.G. 1996. Effects of late nitrogen fertilizer application of head rice yield, protein content and grain quality of rice. *Cereal Chemistry Journal* **73**(5): 556-560.

Pillai, K.G. and Rajat, D. 1980. Nutrient uptake of rice variety *Jaya* at different levels and timings of nitrogen application under two systems of water management. *Proceedings: Plant Sciences* **89**(4): 257-267.

Piper, C.S. 1966. *Soil and Plant analysis*. Hans Publishers, Bombay.

Power, J.F. and Alessi, J. 1978. Tiller development and yield of standard and semi-dwarf spring wheat varieties as affected by nitrogen fertilizer. *Journal of Agricultural Science* **90**:97-108.

Pramanik, K. and Bera, A.K. 2013. Effect of seedling age and nitrogen fertilizer on growth, chlorophyll content, yield and economics of hybrid rice (*Oryza sativa* L.). *International Journal of Agronomy and Plant Production* **4**: 3489-3499.

Prosad, M. 1981. Biological yield and harvest index of rice. *Oryza* **18**(1): 31-34.

Prudente, J.A., Sigua, G.C., Kongchum, M. and Prudente, A.D. 2008. Improving yield and nutrient uptake potentials of japonica and indica rice varieties with nitrogen fertilization. *World Journal of Agricultural Sciences* **4**(4): 427-434.

Quanbao, Y., Hongcheng, Z., Haiyan, W., Ying, Z., Benfo, W., Ke, X., Zhongyang, H., Qigen, D. and Ke, X. 2007. Effects of nitrogen fertilizer on nitrogen use efficiency and yield of rice under different soil conditions. *Agricultural Sciences in China* **1**(1): 30-36.

Rafey, A., P.A. Khan and V.C. Srivastava. 1989. Effect of N on growth, yield and nutrient uptake of upland rice. *Indian Journal of Agronomy* **34**(1) : 133-135.

Raju, M.S. and Suneeta Devi, K.B. 2005. Performance of rice hybrids at different level of nitrogen and phosphorus application. *Oryza* **42** (1): 27-30.

Raju, R.A., Reddy, M.N. and Gangwar, B. 2001. Nursery fertilization of rice (*Oryza sativa*) with native weed vegetation. *Indian Journal of Agronomy* **46**(2): 272-274.

Ram, G., Joshi, B.S. and Trimuriy, V.S. 1984. Effect of nitrogen levels and application time on direct sown rice. *Intl. Rice Res. Newsl*. **9**(2): 2.

Ram, M., Singh, I., Om, H. and Nandal, D.P. 2005. Performance of Rice (*Oryza sativa)* varieties and hybrids under varying time of transplanting in Haryana. *Haryana Journal of Agronomy* **21**(1): 18-20.

Rao, K.S., Moorthy, B.T.S., Dash, A.B. and Lodh, S.B. 1996. Effect of time of transplanting on grain yield and quality traits of Basmati-type scented rice (*Oryza sativa*) varieties in coastal Orissa. *Indian Journal of Agricultural Sciences* **66**(6): 333-337.

Rao, V.P., Subbaiah, G. and Sekhar, K.C. 2013. Response of rice varieties to high level nitrogen on dry matter production, yield and nitrogen uptake of rice. *International Journal of Applied Biology and Pharmaceutical Technology* **4**(4): 216-218.

Reddy, D.R., Sreenivas, G., Sudhakar, T.R. and Rao, S.B.S.N. 2004. Growth of rice varieties in terms of degree days under South Telangana agroclimatic conditions. *Journal of Agrometeorology* **6**(2): 274-277.

Reddy, G.R.S. 1988. Levels of nitrogen and forms of urea in relation to growth and yield of rice. *Indian Journal of Agricultural Sciences* **63**(8): 467-472.

Reddy, K.S. and Reddy, B.B. 1992. Effect of transplanting time, plant density and seedling age on growth and yield of rice (*Oryza sativa). Indian Journal of Agronomy* **31**(1): 18-21.

Reddy, K.S. and Reddy, B.B. 1994. Effect of planting time, population density and seedling age on yield and yield parameters of rice. *Indian J. Agril. Res.* **28** (3) 171-176.

Roy, B.C. and Satter, S.A. 1992. Tillering dynamics of transplanted rice as influenced by seedling age. *Trop. Agriculture (Trinidad)* **69**: 351-356.

Sadar, M.E., Noorka, I.R., Tanveer, A., Tariq, S.A. and Rauf, S. 2013. Growth and yield of advanced brreding lines of medium grain rice as influenced by different transplanting dates. *The Journal of Animal and Plant Sciences* **23**(1):227-231.

Safdar, M.E., Ali, A., Muhammad, S., Sarwar, G. and Awan, T.H. 2008. Effect of transplanting dates on paddy yield of fine grain rice genotypes. *Pakistan Journal of Botany* **40**(6):2403-2411.

Saharawat, K. L., Datta, S. and Singh, B. N. 1999. Nitrogen responsiveness of low land rice varieties under irrigated condition in West Africa. *Intl. Rice Res. Notes* **24**(2): 30.

Sahu, D.K. 1994. Effect of date of transplanting and potassium on growth and yield of lowland rice. *Oryza* **31**(1): 38-39.

Sahu, G., Rao, C.N. and Murthy, K.S. 1983. Influence of temperature and solar radiation on growth and yield of rice. *Oryza* **20**(1): 51-54.

Salam, M.A., Ali, F., Anwar, M.P. and Bhuiya, M.S.U. 2004. Effect of level nitrogen and date of transplanting on the yield and yield attributes of transplanted *Aman* rice under SRI method. *Journal of Bangladesh Agricultural University* **2**(1): 31-36.

Samdhia, S. 1996. Relative performance of hybrids rice under different dates and densities of planting. *IRRN*, **21**(2) : 81-82.

Sang, W.G. and Kang, S. G. 2012. *Korean Journal of Crop Science ISSN* 2287-8432.

Shah, R.A. and Kumar, S. 2014. Effect of integrated nutrient management on vegetative growth and yield of transplanted hybrid rice (*Oryza sativa L.*) crop. *International Journal of Agriculture and Crop Sciences* **7**(11): 863-869.

Sharma, A.R. and Singh, D.P. 1999. *Rice.* In *:* Crop yield physiology and process (Eds. Smith, D.L. and C. Hamel) Springerverlag Berlin. Heidelberg, pp.109-138.

Sharma, D., Sangwal, P. K., Singh, I. and Sangwan, A. 2012. Influence of different N and P levels on profitability, plant nutrient content, yield and quality in basmati cultivars. *International Journal of IT, Engineering and Applied Science Research* **1**: 1-4.

Sharma, R., Gangwar, R.K., Yadav, V. and Kumar, R. 2014. Response of Basmati rice (*Oryza Sativa*) cultivars to graded nitrogen levels under transplanted condition. *International Journal of Research in Applied, Natural and Social Science* **2**(9):33-38.

Shimizu, M. and Kumo, K. 1967. Some cyto-histological observations on the morphogenetically abnormal rice spikelets caused by a low temperature. *Proceedings of the Crop Science Society of Japan* **36**: 489-502.

Shinano, T., Osaki, M. and Tadano, T. 1995. Comparison of growth efficiency between rice and soybean at the vegetative growth stage. *Soil Science Plant Nutrition* **41**: 471- 480.

Shukla, V.K., Sharma, R.S. and Srivastava, S.K. 1995. Effect of planting geometry, weed management and N- levels on morphological growth pattern of rice. *Oryza* **32**(4): 310-312.

Sidhu, G.S. 1989. Quality rice for export purpose. In: Annual AICRIP Workshop Held at Haryana Agricultural University, Hisar, India, pp. 19-22.

Sidhu, M.S., Sikka, R. and Singh, T. 2004. Performance of transplanted basmati rice in different cropping systems as affected by N application. *IRRN* **29**:63-65.

Singh, A.K. 2003. Performance of rice (*Oryza sativa*) in response to transplanting time and varieties. *Journal of Agrometeorology* **5**(1): 105-111.

Singh, C.B., Aujla, T.S., Sandhu, B.S. and Khera, K.L. 1996. Effect of transplanting date and irrigation regime on growth, yield and water use efficiency in rice in northern India. *Indian Journal of Agricultural Sciences* **66** (3): 137-141.

Singh, G. and Singh, P. 1993. Effect of method of seedling and level of nitrogen on yield and yield attributes of rice (*Oryza sativa* L) under affected condition. *Indian Journal of Agronomy* **38**(4): 551-554.

Singh, G., Kumar, A., Shahi, U.P. and Kumar, K. 2003. Response of rice varieties to nitrogen levels and false smut in mid western plain zone of U.P. *Journal of Farming System Research and Development* **14**(1): 138-139.

Singh, G., Singh, O.P, Singh, B.B, Singh, R.S. and Yadaw, R.A. 1992. Effect of transplanting dates and densities of nurseries on yield and yield attributes of rainfed lowland rice. *Crop Research* **5**(3): 565-567.

Singh[a], I., Ram, M., Om, H. and Nandal, D.P. 2005. Effect of time of transplanting on performance of non-scented rice (*Oryza sativa*) varieties in Haryana. *Haryana Journal of Agronomy* **21**(2): 104-106.

Singh[a], K.M.; Pal, S.K.; Verma, U.N. and Thakur, R. 1997. Effect of time and method of planting on performance of rice cultivar under medium land of Bihar plateau. *Indian Journal of Agronomy* **42** (3) : 443-445.

Singh, K.N. and Sharma, D.K. 1987. Response to nitrogen of rice in sodic soil. Intererrnational Rice Research *News Letter* **12**(3): 45.

Singh, M. K., Thakur, R., Verma, U. N., Upassani, R. R. and Pal, S. K. 2000. Effect of planting time and nitrogen on production potential of basmati rice (*Oryza sativa*) cultivars in Bihar Plateau. *Indian Journal of Agronomy* **45**(2): 300-303.

Singh[b], M.V., Tripathi, H.N. and Tripathi, H.P. 1997. Effect of nitrogen and planting date on yield and qualities of scented rice. *Indian Journal of Agronomy* **42**(2): 602-606.

Singh, P., Panotra, N., Singh, P., Singh, K.N. and Kanht, R.H. 2012. Spikelet sterility, harvest index and yield of rice (*Oryza sativa*) cultivars as influenced by low temperature and transplanting dates in temperate Kashmir. *Indian Journal of Agronomy* **57**(4): 362-366

Singh[b], R. P., Brennan, J. P., Farrell, T., Williams, R., Reinke, R., Lewin, L. and Mullen, J. 2005. Economic Analysis of Improving Cold Tolerance in Rice in Australia. **In**: *Research Literature*, 2005. Cooperative Research Centre for Sustainable Rice Production, Australia.

Singh, R.P., Singh, N., Mehta, S. and Godara, A.K. 2008. Adoption of fertilizers and weedicides in basmati paddy crop in Kurukshetra Distt. (Haryana). *Agric. Sci. Digest* **28**(1): 36-38.

Singh, S. P. and Pillai, K. G. P. 1995. Effect of time of planting on grain yield and economic returns of traditional scented rice varieties. *Annual Agricultural Research* **16**(1): 74-76.

Singh, S. P., Rani, S., Sreedevi, B., Krishnaveni, B. and Pillai, K. G. 1999. Effect of planting dates on grain yield and quality of dwarf scented rice varieties. *Oryza* **36**(4): 388-390.

Singh, S.P., Singh, H., Malik, J.P.S. , Singh, S. and Mani, S.C. 2007. Excellent performance of rice hybrids under aerobic farming. *Indian Farmers' Digest*, pp 16-19.

Singh, T., Shivay, Y. S. and Singh, S. 2004. Effect of date of transplanting and nitrogen on productivity and nitrogen use indices in hybrid and non-hybrid aromatic rice. *Acta Agronomica Hunagarica* **52**(3): 245-252.

Singh, V.P. and Singh, V.K. 2000. Effect of sowing date and nitrogen level on productivity of spring sown rice (*Oryza sativa*) varieties in low hills of Uttranchal. *Indian Journal of Agronomy* **45**(3): 560-563.

Sinha, S.K. and Chatterjee, S.D. 1997. Flowering behaviour of rainfed lowland rice varieties during dry season in West Bengal, India. *International Rice Research Notes* **22**(1): 28-29.

Sitaramaiah, K.V., Madhuri, J. and Reddy, N.S. 1998. Physiological efficiency of rice hybrids. *International Rice Research Notes* **23**(2): 32-33.

Song, Y., Oh, N. and Hwang, C. 1996. Growth and response of yield characters of dry seeded rice at different seeding dates in plain area. RDA. *Journal of Agricultural Sciences* **38**(2): 20-31.

Sreenivas, G. and Raji Reddy, D. 2008. Assessment of modified weather on rice yields using CERES rice model in Andhra Pradesh. *ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture.*

Srivastava, P.C. and Singh, U.S. 2007. Effect of graded level of nitrogen and sulphur and their interaction on yields and quality of aromatic rice. *Journal of Plant Nutrition* **30**: 811-828

Srivastava, V.K., Govinda, S.B., Avijit Sen, J.S., Singh, J.P. and Gouda, S.K. 2006. Response of hybrid rice to application of nitrogen, magnesium and boron. *Annals of Agricultural Journal* **61**(9): 644-645.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the determination of available nitrogen in soil. *Current Science* **25** : 259-260.

Summerfield, F.J., Collison, S.T., Elis, R.H., Robert, E.H. and Penningde Vries, F.W.T. 1992. Photothermal responses of flowering in rice (*Oryza sativa*). *Annals of Botany* **69**: 101-112.

Tari, B.D., Pirdashti, H.A. and Naasiri, M. 2009. Investigation of some agronomical traits of rice under different transplanting dates, planting spaces and nitrogen fertilization levels in north of Iran. *World Applied Science Journal* **6**(8): 1021-1027.

Tari, D.B. 2012. Determination nitrogen fertilization effect at different transplanting dates on rice yield and yield traits. *American-Eurasian Journal of Agricultural and Environmental Sciences* **12**(5):678-681.

Tari, D.B., Pirdashti, H., Nasiri, M., Gazanchian, A. and Hoseini, S.S. 2007. Determination of morphological characteristics affected by different agronomical treatments in rice (IR6874-3-2 Promising Line). *Asian Journal of Plant Science* **6**(1): 61-65.

Taxi, D. B., Pirdashti, H., Nasiri, M., Gazanchian, A. and Hoseine, S.S. 2007. Determination of morphological characteristics affected by different treatments in rice (IR 6874-3-2).

Tayefe, M., Gerayzade, A., Amiri, E. and Zade, N.A. 2011. Effect of nitrogen fertilizer on nitrogen uptake, nitrogen use efficiency of rice. *International Conference on Biology, Environment and Chemistry IPCBEE* **24**.

Thakur, R.B. 1993. Performance of summer rice (*Oryza sativa*) to varying levels of nitrogen. *Indian Journal of Agronomy* **38**(2) : 187-190.

Tripathi, H.P. and Jaishwal, L.M. 2006. Effect of nitrogen on yield attributes and yield of rice hybrids under irrigated conditions. *Oryza* **43**(3) : 249-250.

Tripathi, H.P., Jaiswal, L.M. and Verma, D.K. 1998. Effect of nitrogen on growth and yield of scented rice varieties under irrigated conditions. *Oryza* **35**(3): 277-278.

Trivedi, K.K. and Kwatra, K.L. 1983. Effect of dates of transplanting and hill spacing on growth and yield of rice. *Journal of Agricultural Research of Haryana* **33**: 15-19.

Tsai, J.C. 1989. Seasonal and regional differences in rice gain yield in response to air temperature and solar radiation. *Journal of Agricultural Research of China* **38** : 19-29.

Urkurkar, J.S. 1983. Optimum transplanting time for rice: an agro-meterological approach. *International Rice Research News* **8**(6): 21-24.

Vandana, J., Ains, G.S.B. and Mavi, H.S. 1994. Effect of different dates of transplanting on biomass production and its portioning in various parts of rice crop. *Indian Journal of Ecology* **21**(1): 13-18.

Vlek, P. L. G. and B. H. Byrnes. 1986. The efficacy and loss of fertilizer N in lowland rice. *Fertilizer Research* **9**:131-47.

Watson, D.J. 1947. Comparative physiological studies on the growth of field crops. I. variation in net assimilation rate and leaf area between species and varieties within and between years. *Annals of Botany* **11**: 41-76.

Yoshida, S., Forno, D., Cook, J. and Gomez, K. A. 1976. Laboratory Manual for Physiological studies of rice. 3rd Eds. The IRRI. Los Banos, Philippines.

Yoshida, S. 1978. *Tropical climate and its influence on rice*. Research Paper No. 20. International Rice Research Institute. Los Banos, Philippines.

Yoshida, S. 1981. *Fundamental of rice crop science*. International Rice Research Institute. Los Banos, Philippines.

Youseftabar, S., Fallah, A. and Daneshian, J. 2012. Effect of split application of nitrogen fertilizer on SPAD values in hybrid rice (Grh1). *International Journal of Agriculture and Crop Sciences* **4**(10): 647-651.

Yusuf, E. and Balcha, A. 2014. Effect of nitrogen application on grain yield and nitrogen efficiency of rice (*Oryza sativa* L.). *Asian Journal of Crop Science* **6**(3):273-280.

Zaidi, S.F., Sharma, V.K. and Tripathi, H.P. 2007. Effect of nitrogen on yield, N uptake and nitrogen use efficiency of hybrid rice. *Oryza* **44**(2): 181-183.

Zhilin, L., Sarker, R.S., Nayak, S.K., Ravi, I. and Li, J.L. 1997. Physiological effect of nitrogen application on aromatic rice. *Journal of South China Agricultural University* **18**: 13-17.

APPENDIX – I

Mean weekly meteorological parameters during crop growth period

Standard meteorological weeks	Temperature (^oC)		Rainfall	Mean relative humidity	Sun shine (Hours)
	Maximum	Minimum			
16	15.4	5.9	5.1	77.36	3.19
17	22.9	6.6	0.1	59.93	8.10
18	24.8	7.5	0.3	68.36	6.90
19	21.5	8.1	2.6	71.48	5.07
20	19.8	8.1	1.8	73.07	3.57
21	22.6	7	4.4	64.07	6.96
22	25.9	10.2	3.1	64.86	8.37
23	29.1	11.4	6.8	54.29	10.90
24	29.8	12.7	0	54.07	9.13
25	26.7	14.2	0.5	61.5	6.77
26	28.5	14.4	0.4	59.14	8.24
27	26.7	15.3	2.2	64.86	7.20
28	30.1	16.2	0	59.5	9.06
29	27.1	17	0.8	69.14	6.94
30	30.1	20.2	2.1	63.86	8.39
31	29	17.1	4.3	60.14	9.33
32	29.1	16.9	0.5	64.5	5.86
33	26.1	14.9	13.9	68.07	7.73
34	27	12.2	0.4	66.29	9.07
35	24.1	13.4	2.7	78.21	3.61
36	16.6	12.9	86.3	90.29	2.10
37	25	11.3	0	76.29	8.10
38	27.1	9.6	0	70.14	8.66
39	25.8	9.7	0.8	67.5	7.94

[Source : Meteorological Observatory, IMD, Qazigund, Anantnag]

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Agronomy
-::o::-

CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner **Dr. Amarjeet Singh Bali, Former Director Research, SKUAST-Jammu** during Viva-Voce examination held on 27-11-2015 have been incorporated in the manuscript entitled "**Agronomic evaluation of *Pusa Basmati*-1509 for yield and quality under varied transplanting dates and nitrogen levels"** submitted by **Mr. Showkat Hussain Mughal (Regd. No. 2013-A-938-M)**.

(Dr. Ashaq Hussain)
Chairman
Advisory Committee