# SCHEDULE OF NITROGEN APPLICATION IN RICE (*ORYZA SATIVA* L.) AS INFLUENCED BY PLANTING TIME


**BY**

KAVINDER

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## CERTIFICATE-I

This is to certify that this thesis entitled "**Schedule of nitrogen application in rice (*Oryza sativa* L.) as influenced by planting time**", submitted for the degree of **Doctor of Philosophy** in the subject of **Agronomy** of the **Chaudhary Charan Singh Haryana Agricultural University, Hisar**, is a bonafide research work carried out by Mr. **Kavinder,** Admission No. **2016A12D** under my supervision and that no part of the thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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# ABBREVIATIONS

| | | | |
|---|---|---|---|
| % | Per cent | m | Meter |
| @ | At the rate of | $m^2$ | Square meter |
| 0C | Degree Celsius | Max. | Maximum |
| $^0N$ | Degree north | Min. | Minimum |
| BSS | Bright sunshine hours | Mm | Millimeter |
| CD | Critical difference | mm/day | Millimeter per day |
| cv. | Cultivar | MOP | Murate of potash |
| DAP | Diammonium phosphate | N | Nitrogen |
| DAS | Days after sowing | No. | Number |
| DAT | Days after transplanting | No./$m^2$ | Number per meter square |
| dS/m | Deci-Siemens per meter | NS | Non-Significant |
| EC | Electrical conductivity | P | Phosphorus |
| *et al.* | (et ali or et alia) and other people | pH | Pouvoir hydrogen |
| Evap. | Evaporation | q/ha | Quintal per hectare |
| Fig | Figure | RF | Rainfall |
| FAO | Food & Agriculture organization | R.H. | Relative Humidity |
| G | Gram | RHE | Relative humidity during evening |
| g/ha | Gram per hectare | RHM | Relative humidity during morning |
| g/$m^2$ | Gram per meter square | Rs./ha | Rupees per hectare |
| g/plant | Gram per plant | S. No. | Serial number |
| g/g/day | Gram per gram per day | SEm+ | Standard error of mean |
| g/$m^2$/day | Gram per meter square per day | SMW | Standard meteorological weak |
| ha | Hectare | spp. | Species |
| hrs | Hours | *viz.* | (Videlicet) namely |
| K | Potassium | $ZnSo_4$ | Zinc sulphate |
| kg/ha | Kilogram per hectare | | |

# CHAPTER–I

## INTRODUCTION

Rice (*Oryza sativa* L.) is one of the principal food crops and is a staple food for more than half of the world's population. It is a widely grown food crop and occupies 11% of the cultivated area in the world (Wani *et al*, 2017). Rice is a key to the food security in Asia where more than 90 % of the world's rice is produced. The crop has wide physiological adaptability and hence is grown successfully not only in tropical or sub-tropical regions but also in many temperate areas with an altitude of up to 2000 m above mean sea level (Okon *et al*., 1998).

India has the largest area under rice and is the second largest producer of rice after China. It is the main food crop in India contributing around 45 % to total food grains production and thus holds the key to food security in the country. Rice in India is grown over an area of about 44 million hectares (Mha) with a production of 106.3 million tons (MT). At the current population growth rate (1.5 %), India needs to produce around 125 MT of rice by 2025 as compared to its present production of 106.3 MT (Kumar *et al*., 2009). Further expansion in area under rice is very difficult in view of shortage of water and rapid urbanization. Hence increase in rice production to achieve the projected production targets is a major challenge for the farm scientists. In Haryana, rice is the major *Kharif* season food crop which occupied an area of 1.42 Mha with production of 4.88 MT during 2017-18 (Anonymous, 2018). Although productivity of rice in Haryana (3.44 t/ha) is more than the national average (2.42 t/ha) yet it is less than the global average yield (5.0 t/ha) of irrigated rice (Bijay-Singh and Singh, 2017). Therefore, there is need to increase the productivity of rice under the limited resources, especially land and water, in order to safeguard and sustain the food security in India.

The yield and quality of rice are not only controlled by genetic factors, but are also largely by environmental factors including climate, soil type, soil water and management factors (Hiroyuki *et al*., 2002), of which planting time and fertilization are of prime importance. Planting time is a major management factor in rice cultivation which influences the growth and yield of rice as it indirectly determines the weather conditions to which the plants are exposed during different development stages (Iqbal *et al*., 2008). Rice in Haryana is raised mainly by transplanting method of crop establishment under irrigated lowland conditions. But sometimes the transplanting is delayed mainly due to non-availability of enough labour and water during the limited peak transplanting period resulting into reduction in the crop yield under late planting. Optimum planting time for successful rice production widely depends on varietal life duration, sensitivity to photoperiod, temperature, rainfall and other environmental factors. Optimum time of rice planting ensures optimum temperature and photoperiod for vegetative, reproductive or grain filling phases which is required for high yield and good quality of the crop. Time of planting assumes greater importance due to short growing season of rice (140-145 days) in Haryana. The yield of late transplanted rice crop is reduced because of reduction in its vegetative phase and also due to coincidence of its grain filling phase with the lower temperature (Hussain *et al*., 2009). Gangwar and Sharma (1997) observed higher number of panicles in early transplanted rice than in late transplanted rice due to its longer vegetative growth period. It is, therefore, essential to generate adequate information relating to planting time to obtain better growth and productivity of rice. There is need to increase the productivity of the late planted rice crop by manipulation of agronomic practices including the nutrient application schedule (dose and time of application) as the schedule of the late planted crop may differ from that of the timely or early planted crop.

Rice crop is a heavy feeder of nutrients and responds immensely to application of nutrients. In view of the higher nutrient needs of rice crop and adoption of exhaustive cropping systems like rice-wheat in rice growing regions of Indo-Gangetic Plains, including Haryana, greater nutrient supply is needed for the crop as the soils are deficient in nutrients. A higher crop output per unit area, therefore, demands considerable amounts of externals inputs such as fertilizers for supply of nutrients to the crop.

Among nutrients, N is the most important macronutrient for rice and is one of the most yield limiting factor in irrigated rice worldwide (Samonte *et al*., 2006) as it is required in greater quantities in view of the higher crop needs and low N status of rice soils (Jayanthi *et al*., 2007). Nitrogen is absorbed by rice during the vegetative growth stages to contribute in growth during reproduction and grain-filling period through translocation (Bufogle *et al*., 1997). Nitrogen is essential constituent of many compounds such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins in plants (Azarpour *et al*., 2011). Application of N fertilizer either in excess or less than the optimum dose affects both yield and quality of rice to considerable extent and hence proper N management is of immense importance (Manzoor *et al*., 2006). Hence before making recommendations for the nitrogen fertilizer dose for any crop, one should evaluate the efficiency and optimum rate for different application levels for better growth and yield of rice (Noor 2017).

The optimum schedule of N fertilizer and transplanting dates are crucial factors for the productivity of rice. Plant growth, phenology and yield of rice crop may vary due to transplanting time and N application schedule. Synchrony of nitrogen supply with crop demand is essential in order to ensure higher nitrogen use efficiency and crop yields (Fageria and Baligar, 2005). It has been observed that yield of rice crop is decreased under late planting because of reduction in yield attributing traits *viz*. number of effective tillers/$m^2$ and grains/panicle (Ram *et al*., 2005). These yield attributes can be increased appreciably by supply of N at optimum rate and appropriate time to minimise the reduction in yield under late planting as N is one of the most important factors promoting growth and yield of the crop. Singh *et al.* (1997) observed that response to N may vary with the date of planting indicating that N requirement of rice may depend upon the date of transplanting. The dose and timing of N fertilizer need to be standardized to meet the crop's demand at different growth stages. Timely and split application of N allows more efficient use of N throughout and growing season as it provides desired amounts of N to the crop during peak periods of growth and may reduce leaching of nitrate-N in the soil (Fageria 2010, Lampayan *et al.*, 2010). Nitrogen is usually applied to rice crop in several splits to secure proper synchrony of N supply with the crop demand but the number of splits, amount of N per split and time of application may vary considerably depending upon duration of vegetative period in timely and late planted crop. Timing of N application can also be done with the help of leaf colour chart (LCC) which is an inexpensive, portable and easy to use tool (Nainwal *et al*., 2013).

Both scented (*Basmati*) and non-scented (high yielding) varieties of rice are grown in Haryana. Among the non-scented varieties, medium duration varieties are more common and respond better to N application because of their higher yield potential. Therefore, N management in such varieties is more important to achieve higher yields even under late planting. But the information on the dose and time of application of N fertilizer to rice crop under varying time of transplanting is very limited. Moreover, farmers have a tendency to apply more N fertilizer, irrespective of time of planting. Therefore, there is need to find out the optimum schedule of N application in high yielding rice varieties under timely and late planting conditions.

Keeping the above facts in view, the present field investigations entitled "**Schedule of nitrogen application in rice (*Oryza sativa* L.) as influenced by planting time**" was conducted during *Kharif* seasons of 2017 and 2018 with the following objectives:

1. To study the effect of nitrogen application schedule and time of planting on growth, yield and quality of rice
2. To find out suitable dose and time of nitrogen application in rice to get higher crop yield under different planting time
3. To work out the economics of different treatments

# CHAPTER–II

## REVIEW OF LITERATURE

Among different components of agronomy packages for rice cultivation, time of planting and nitrogen fertilization are important factors for obtaining higher yields. Planting time is a major factor in rice cultivation and indirectly determines soil temperature and weather conditions to which the plants are exposed during different development stages. Similarly, nitrogen fertilizer is a key input for rice production. Excess amount of N application can result in excess growth and lodging of crop plants with reduction of yield whereas deficiency of N also reduces the yield due to poor crop growth. Moreover, N application schedule in a crop may vary due to variation in planting time. Therefore, judicious application of N in early and late planted crop form an important aspect of overall nitrogen management in rice for its efficient utilization and higher productivity. In this chapter, an attempt has been made to review the research findings related to various aspects of the present study in India and abroad. The review has been presented here under the following headings:

2.1 Effect of planting time

2.2 Effect of nitrogen levels

2.3 Effect of time of N application

### 2.1 Effect of planting time

Among all non-monetary inputs for crop production, timely sowing or planting assumes great significance for yield maximization as it allows the crop to complete its life phase timely under a specific agro-climate. Time of planting is one of the most important factors deciding the yield potential of rice (Ashraf *et al.*, 2014). The effect on plating time on rice crop is reviewed below.

#### 2.1.1 Effect of planting time on phenology

Rice plants require specific temperature for various phenological stages like panicle emergence, flowering and maturity and all of these events are highly influenced by transplanting date. The phenology of vegetative as well as reproductive growth stages are influenced due to deviation from the optimum transplanting time which ultimately affects the crop yield (Dehgan, 2007).

Chopra *et al.* (2006) reported that more number of days (7-10 days) to attain 50 and 100% flowering were required by the crop transplanted early (June 30) as compared to that planted late (July 18 and August 4). Number of days taken to attain maximum tillering (Lee *et al.*, 1994), 50% heading (Gravois and Helius, 1998) and 100% heading (Song *et al.*, 1996) were reduced with delay in planting or sowing of rice crop. Norman *et al*. (1999) observed that length of vegetative period in rice was greater in early seeded rice as compared to later seeded rice.

However, the findings of Singh and Singh (2000) from Uttrakhand show that days taken to 75% heading were not influenced significantly by different sowing dates (March 15, March 30 and April 15). Time taken for maturity varied comparatively less (116.2 to 120.8 days) under different planting dates (Mandal and Ghosh, 2003). Dixit *et al.* (2004) from Maharashtra reported that panicle initiation started late in early sown crop (June 5-10) and 50% flowering was earlier in late planted crop (June 25). Wani *et al.* (2016) observed that more number of days to reach flowering were taken by the crop sown earlier ($15^{th}$ and $16^{th}$ SMW) while the lowest number of days were taken by the crop sown during $18^{th}$ SMW. Similarly experiments conducted in Louisiana (USA) showed that days from seedling emergence to 50 per cent panicle emergence decreased as planting was delayed (Linscombe *et al.*, 2004).

Chopra and Chopra (2004) reported that rice transplanted on June 30 took 109.5 calendar days and 3125.9 growing degree days from transplanting to maturity which got reduced almost linearly with delay in transplanting. Rai and Kushwaha (2008) from *tarai* region of Uttarakhand reported that delay in planting of rice from 15 June to 15 July decreased number of days to panicle initiation (6 to 8 days), 50 per cent flowering (12 to 15 days) and maturity (6 to 7 days). Lee *et al.* (2001) also noticed reduction in days from sowing to flowering when sowing dates were delayed from 25th April to $5^{th}$ June.

**2.1.2 Effect of planting time on crop growth**

Planting time has a direct influence on the rate of establishment of rice seedling (Tashiro *et al.* 1999). Early sowing of the crop is the best time for obtaining maximum tillering, chlorophyll content, leaf area index and sink capacity (Khalifa, 2009).

Dhiman *et al.* (1995) observed greater plant height and dry matter accumulation per plant in rice crop planted earlier (July 15) than planted late (July 25 and August 5). However, Parihar *et al.* (1995) observed higher plant height and number of effective tillers when rice crop was planted on July 15 as compared to the crop planted early (June 30) and late (July 30). Similarly, Paliwal *et al.* (1996) observed significantly higher plant height under early transplanting (July 25) than that under delayed transplanting (August 10 and 25). Om *et al.* (1997) also found that the plant height, effective tillers/m² and dry matter accumulation were the highest in the crop transplanted on 25 June followed by the crop planted on 5 July, 15 July and 25 July. Singh *et al.* (1997) also obtained more plant height, total tillers and dry matter accumulation in the crop transplanted on 5 July as compared to the crop transplanted on 20 July and 4 August.

Pandey *et al.* (2001) noted that rice hybrid 'PA 6201' gave significantly higher productive tillers per hill and dry matter accumulation per plant when transplanted on 20 July and 4 August than when transplanted on 20 August.

Maximum total and effective tillers per hill, LAI and dry matter accumulation was observed by Nayak *et al.* (2003) with early planting of rice (16 July) than that with planting on 31 July and 16 August. Singh *et al.* (2005) reported that plant height of rice was maximum with earliest transplanting (June 15) which decreased significantly with each delay in planting from June 15 to July 25. A reduction in plant height (13 per cent), leaf area index (10 per cent), and number of tillers (5 per cent) was observed by Rai and Kushwaha (2008) from *tarai* region of Uttarakhand with delay in planting of rice from15 June to 15 July. Brar *et al*. (2012) from Ludhiana reported that rice transplanted on 25 June produced higher tillers per unit area than transplanted on 15 June and 5 July.

But Muhammad *et al.* (2008) observed that plant height of rice crop (172.1 cm) was the highest with transplanting on July 16 as compared to June 1 planting. Mannan *et al.*, (2009) also observed less plant height, number of tillers and dry matter in early planted (22 July) crop but these characters increased with each advancement in planting date until 22 September.

Prabhakar and Reddy (2010) observed the effect of dates of sowing and found that sowing of the nursery early (29$^{th}$ June) resulted into significantly more tillers and LAI as compared to sowing on later date (13 July).

**2.1.3 Effect of planting time on yield attributes and yield**

Yield of a crop is determined by the number of tillers formed during the vegetative growth phase, number of panicles at the end of the vegetative stage, number of spikelets formed in each panicle during panicle development, number of fertile spikelets (grains) determined during flowering stage and final individual grain weight determined during the grain filling phase (Dingkuhn and Kropff, 1996).

Singh *et al.* (1992) noticed that early or late planting significantly reduced the yield attributes and ultimately the yield of rice. Singh and Pillai (1995) from Hyderabad observed more panicles/m$^2$ and higher panicle weight of rice crop under early planting (July 16) as compared to that under late planting (July 31 and August 16). However, Parihar *et al.* (1995) reported no difference in 1000-grain weight of rice due to variation in planting dates. Higher panicles/m$^2$, panicle weight and filled grains/panicle were recorded under 25 July planting with a linear reduction in grain yield with every 15 days delay in planting from 25 July onwards (Balaswamy and Kulkarni, 2001). Similarly, Singh (2003) evinced that yield attributes and yield of rice crop decreased under late transplanting. Chopra *et al.* (2003) at Karnal reported that early transplanting (June 30) resulted into significantly higher panicle length, panicle weight, test weight and seed yield of rice crop as compared to late planting

(July 21, 28 and August 04). A significant reduction in yield attributes and yield was also noticed by Singh *et al.* (2004) under delayed transplanting who got 8.4 and 19.1% higher yield under timely transplanting (July 3) than transplanting on July 10 and 17, respectively. But Dixit *et al.* (2004) observed significantly higher grain yield (53.22 q/ha) under 25 June planting than that under 5, 10 and 15 June planting.

Verma *et al.* (2004) found that early planting (20 July) of rice crop gave significantly higher grain yield than late planting (5 and 20 August). Similarly, Dongarwar *et al.* (2005) obtained higher grain yield under early transplanting on 15 (3129 kg/ha) and 30 July (3261 kg/ha) as compared to late transplanting on 15 August (28.40 q/ha).

But Vange and Obi (2006) indicated that grain yield (t/ha) was the highest with July 30 planting as compared to early planting (June 15 and June 30).

Mahajan *et al.* (2009) from Ludhiana reported that the grain yield of all the rice cultivars was the highest (7.6 t/ha) for 15 June transplanting and lowest (6.4 t/ha) for 5 July transplanting and delay in transplanting beyond 15 June resulted in significant reduction in grain yield of all cultivars, except PAU-201. Akbar *et al.* (2010) concluded that the maximum number of productive tillers/m$^2$, grains/panicle, 1000-grain weight and paddy yield were observed under early planting (20$^{th}$ June) as compared to that under late planting (June 30, July 10 and 20).

Chaudhary *et al.* (2011) reported significant reduction in yield of rice due to delayed transplanting and the grain yield with transplanting on July 5 was 13.6 and 25.3% higher than that with transplanting on 25 July and 4 August, respectively. Brar *et al*. (2012) from Ludhiana reported higher yield of rice crop in June 25 transplanting as compared to transplanting on June 15 and July 5 due to more panicles/m$^2$, 1000-grain weight and less spikelet sterility percentage whereas the yield did not differ significantly under the latter two dates. Manoj *et al.* (2013) concluded that aromatic rice when transplanted on 16 July performed better in terms of yield, yield attributing characters. Mukesh *et al*. (2013) revealed that early transplanting (25 June and 10 July) increased the yield contributing characters and ultimately grain yield of basmati rice as compared to late planting (25 July).

While evaluating the performance of rice hybrids at Faisalabad (Pakistan), Muhammad *et al.* (2015) reported that yield and yield-related characters such as productive tillers/m$^2$, number of kernels, test weight, grain yield, straw yield and biological yield as well as harvest index were significantly higher under medium planting time than those with early and late planting.

Under condition of north east India (Manipur), Singh *et al.* (2017a) indicated that the yield attributes and yield of hybrid rice were significantly higher with transplanting on 21 July as compared to planting on July 6 and August 5.

### 2.1.4. Effect of planting time on nutrient content and uptake of rice

Pandey *et al*. (2008) reported that delayed plantings (August 5 to 20) significantly reduced N concentration and uptake by grain and straw as compare to early planting (July 5 or 20) whereas both the early plantings were at par in respect of N concentration and uptake in grain and straw.

Kabat and Satapathy (2011) from Odisha observed that planting of hybrid rice between July 1 and 15 along with 120 kg N maintained sufficient N concentration in grain and straw during wet season as compared to planting on August 16.

Mandal *et al*. (2011) from Pusa, (Samastipur), Bihar while evaluating the performance of direct seeded rice under different date of sowing (22 June and 12 July**),** found that the N, P and K concentrations in grain and straw do not appear to be a function of dates of sowing. The P and K uptake in grain and K uptake in straw were higher in 22 June sowing.

Kumar *et al*. (2013) studied the effect of dates of transplanting (6, 16 and 26 July) and reported that total uptake of N was significantly higher in 16 July transplanting compared to 6 and 26 July. However, transplanting dates did not show any significant influence on P and K uptake of rice.

### 2.1.5. Effect of planting time on quality

Gill and Shahi (1987) reported an increase in head rice recovery with delay in planting from June 1 to July 30. The crop transplanted late (July 30) gave 7.8-12.5 and 6.2-6.9 per cent higher head rice yield than that transplanted on June 1 and June 30, respectively.

Ali *et al.* (1991) from Pakistan reported that early and late transplanting dates in *Basmati* rice depressed the milling recovery and cooking quality. The optimum transplanting dates for quality were found to be July 1 and July 16 for *Basmati*-379 and *Basmati*-385, respectively.

Results of the experiments conducted under All India Coordinated Rice Improvement Project showed that the hulling and milling per cent in scented rice were more with the early planting on 15 July whereas the head rice recovery was maximum (38.8%) with late planting on 4 August (AICRIP, 1991). Bali and Uppal (1995) from Ludhiana reported that *Basmati* rice transplanted on July 10 had 57 per cent head rice recovery but the recovery decreased to 54 per cent under late planting (July 30). Similarly Singh *et al.* (1997) reported that planting on 20 July increased significantly rice recovery by 0.85 and 0.30 per cent than planting on 5 July and 4 August, respectively.

On the other hand Singh *et al*. (2005) noticed that kernel length, hulling percentage, milling percentage and head rice recovery were significantly higher in early planting. However, Mukesh *et al*. (2013) claimed that late planting improved the quality traits *viz*. hulling, milling and head rice recovery as compared to early planting.

Brar *et al*. (2012) reported that grain length to breath ratio and the recoveries of brown, milled and head rice were not influenced by change in transplanting from June 15 to July 5. But Wani *et al*. (2016) ascertained that head rice recovery of *Basmati* rice showed a significant variation among sowing dates with highest head rice percentage for the sowing during $15^{th}$ SMW (47.50) and lowest for the sowing during 18th SMW (39.50).

**2.1.6. Effect of planting time on Economics**

Chaudhary *et al*. (2011) from Pusa, Bihar obtained higher mean benefit: cost ratio (1.06) under 5 July planting, followed by 15 July (1.03) and both the planting dates proved superior to 25 July and 4 August planting. Singh *et al*. (2012) working in temperate Kashmir valley reported that transplanting on 25 May recorded higher net returns (Rs. 50, 872/ha) and B: C ratio (2.29) as compared to late transplanting (20 June).

Kumar *et al*. (2013) from Umiam, Meghalaya studied the effect of dates of transplanting (6, 16 and 26 July) noticed that 16 July produced maximum net returns (Rs. 15,700/ha) and benefit cost ratio (1.67) than other dates of transplanting. Wani *et al*. (2016) also recorded highest B: C ratio (3.03) with early sowing (15th SMW) followed by that in sowing during 16th SMW and the lowest B: C ratio was obtained with sowing during 18th SMW.

**2.2 Effect of nitrogen levels**

Nitrogen is the most limiting nutrient for rice crop in almost all environments (Yoshida, 1981). Nitrogen supply plays a key role in plant physiological processes and influences the sink size thereby increasing the productivity of rice (Somasundaram *et al*. 2002). Nitrogen is an important component of rice production technology and has immense role in increasing rice productivity (Kumar and Prasad, 2004).

**2.2.1 Effect of nitrogen level on phenology**

Haque *et al.* (2006) reported that irrespective of cultivars, the days required to flowering and maturity were significantly more with increase in the amount of nitrogen applied. Crop maturity was delayed by almost 6-13 days at 60 kg N/ha and by 11-17 days at 120 kg N/ha in various rice varieties. Abou-khalifa *et al.* (2007) found that days to maximum tillering, panicle initiation and heading were increased due to increase in N application levels up to 165 kg/ha.

Mahajan *et al.* (2010) reported that the high level of N fertilizer (60 kg N/ha) delayed flowering by 2-3 days in 'Pusa *Basmati* 1121' and 'Punjab *Basmati* 2' varieties as compared to no N application. Wani *et al.* (2016) reported that flowering and maturity of rice crop were delayed significantly at higher N level of 80 and 60 kg N/ha as compared to that at 40 kg N/ha and control.

### 2.2.2 Effect of Nitrogen level on Growth characters

Salem *et al.* (2011) noted that number of tillers/hill, leaf area index, leaf area ratio, chlorophyll content were increased with increase in N levels up to 165 kg N/ha. Ehsanullah *et al*. (2012) reported that plant height increased gradually with increase in nitrogen fertilization to *Basmati* rice. Maximum plant height (107.60 cm) was recorded at 125 kg N/ha while minimum plant height was (100.6 cm) recorded with 75 kg N/ha.

Sharma *et al*. (2012) observed that number of tillers increased up to 60 days after transplanting (DAT) and thereafter, slight reduction was recorded at 90 DAT. Increasing N levels significantly increased plant height, tillers/$m^2$ and dry matter accumulation. Mondal *et al*. (2013) from West Bengal reported that plant height at all the growth stages and tillering increased steadily with increasing level of fertilizer application and the tallest plants and highest number of tillers/$m^2$ were recorded in plots receiving 150 kg N, 75 kg $P_2O_5$ and 75 kg $K_2O$/ha.

Results of the experiment conducted by Dey *et al.* (2014) at Sriniketan, West Bengal showed that application of 180 kg N/ha improved plant height, number of tillers/$m^2$ and dry matter accumulation. Likewise, Yoseftabar (2013) observed maximum tillers (27.6) with application of 150 kg N/ha and minimum (22.8) with application of 50 kg N/ha.

Kumar *et al.* (2014) working with hybrid rice at Rajendranagar, Hyderabad observed that dry matter production and number of tillers/hill at all the growth stages exhibited significant difference due to increase in N levels and maximum dry matter yield and number of tillers/hill were recorded at 225 kg N/ha compared to all other lower levels of nitrogen. Muhammad *et al.* (2015) from Faisalabad (Pakistan) recorded the highest plant height, leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR) and panicle length in plots where N was applied at 205 kg/ha while the lowest value of these traits was observed at 100 kg N/ha.

Pramanik and Bera (2015) found that the maximum plant height, leaf area index (LAI), crop growth rate (CGR) and total chlorophyll content in crop receiving 150 kg N/ha than the crop receiving lower levels of N (0, 50 and 100 kg/ha).

### 2.2.3 Effect of Nitrogen level on Yield attributes

Verma *et al.* (2009) conducted field experiment on hybrid rice during rainy season at Raipur observed that application of 150 kg N/ha, though at par with 100 kg N/ha resulted in higher effective tillers and grain yield as compared to lower levels of N. However, straw yield, grains/earhead, panicle length and sterility per cent were also significantly higher under 150 kg N/ha as compared to lower levels of N including 100 kg/ha. Significantly higher number of tillers, panicles, filled grains/panicle, 1000-grain weight and grain yield were also registered with application of 150 kg/ha of N than 100 kg/ha of N (Ramesh *et al.*, 2009).

Manan *et al.* (2010) reported that plant height, tiller number, number of panicles, panicle length of rice crop increased with nitrogen levels up to 75 kg/ha. However, higher vegetative growth with more spikelet sterility and thus lower grain yield was observed at higher dose (100 kg/ha).

Chakraborty (2011) found maximum panicle length, effective tiller number/hill, filled grain number/panicle and tiller number/hill when the field was supplied with 100 kg N/ha but no significant improvement of yield attributing characters except the number of filled grains/panicle was observed when the N application dose was increased beyond 100 kg N/ha. Banerjee and Pal (2011) revealed that number of effective tillers/$m^2$, panicle length, filled grains/panicle and 1000-grain weight were increased significantly with increase in N supply rate from 50 to 150 kg/ha.

Metwally *et al.* (2011) studied the response of hybrid rice to nitrogen fertilizer in Egypt and recorded maximum panicle length and grain yield when N was applied @ 200 kg/ha. Sharma *et al.* (2012) reported that yield contributing characters in rice *viz* panicles/$m^2$, grains per panicle, grain yield and B: C ratio was high when N was applied at 90 kg/ha. Abou-Khalifa (2012) noted that higher rate of N application resulted into increase in panicle length, number of grains/panicle, test weight when nitrogen was applied at maximum rate (220 kg/ha).

Pramanik and Bera (2013) noticed that hybrid rice grain yield increased gradually with increase in nitrogen level and maximum grain yield was obtained with 150 kg N/ha. Yoseftabar (2013) tested different levels of nitrogen in hybrid rice and reported maximum paddy yield by applying maximum level of N (300 kg/ha) while minimum grain yield was obtained with 100 kg N/ha. Results of the field experiment conducted by Dey *et al.* (2014) on hybrid rice showed that 180 kg N/ha increased number of panicles/$m^2$, panicle length, number of grains/panicle, percentage of filled grains and 1000-grain weight and ultimately higher crop yield. Muhammad *et al.* (2015) obtained the highest grain yield with application of 205 kg N/ha in hybrid rice at Faisalabad, Pakistan.

Singh *et al*., (2017a) observed that nitrogen application caused a significant increase in yield attributes *viz*. number of panicle/$m^2$, panicle length, number of spikelets per panicle, no of filled grain per panicle, 1000-grain weight and yield (grain and straw yield) with every increase in N application rates up to 180 kg/ha. Djaman *et al*., (2018) while working out optimum fertilizer dose and time for hybrid rice revealed that grain yield increase linearly with increase in N rate and 150 kg N /ha was found optimum.

**2.2.4 Effect of Nitrogen level on nutrient content and uptake of rice**

Kabat and Satapathy (2011) revealed that N content and uptake by both grain and straw increased significantly with increase in levels of N from 60 to 120 kg/ha during wet season in Odisha. Wang *et al.* (2012) observed total N uptake of “super” hybrid rice

Liangyoupeijiu increased linearly with increase in N rate. Lakshmi *et al*. (2014) recorded the highest nutrient uptake at all stages of crop growth at 200 kg/ha of N at Rajendranagar, Hyderabad. Singh *et al.* (2014) recorded higher N uptake (124.0 and 108.0 kg/ha during 2012 and 2013, respectively) by crop with the application of 200 kg N/ha as compared to no N application in direct seeded hybrid rice.

Srivastava *et al.* (2014) observed that 45 kg N/ha applied either through FYM or vermicompost resulted in the maximum NPK uptake by the crop beside enhancing soil electrical conductivity, organic carbon as well as available N, P and K content of the soil.

**2.2.5. Effect of nitrogen levels on quality of rice**

Perez *et al.* (1996) found appreciable increase in protein content of rice grain with the application of nitrogen which was mainly due to higher nitrogen concentration. An improvement in milling and head rice recovery percentage was also associated with high protein content. High-protein rice is more resistant to abrasive milling than low-protein rice (Cagampang *et al.,* 1966).

Singh *et al.* (1997) concluded that protein content, kernel length, breadth and per cent recovery of head rice significantly increased with increasing levels of nitrogen. Li *et al.* (2007) and Gill (1984) reported non-significant effect of nitrogen on length : width ratio of paddy. Gautam *et al.* (2008) recorded significantly higher hulling, milling and head rice recovery in hybrid aromatic rice with the application of 160 kg N/ha as compared to zero nitrogen application on sandy-clay loam soils at IARI, New Delhi.

Kumar *et al.* (2014) working on hybrid rice at Rajendranagar, Hyderabad recorded higher head rice recovery and amylose content in plots which received 225 kg N/ha over the lower levels of N (0, 75, 150 kg N/ha). Similarly, grain quality parameters like milling percentage, head rice recovery, kernel length, breadth, amylose content and protein content of rice registered significantly highest values with 150 kg N/ha (Devi *et al.*, 2012).

Singh *et al.* (2014) observed that all the nitrogen levels (0, 125, 150, 175 and 200 kg/ha) recorded highest brown rice recovery, head rice recovery and amylose content as compared to control in direct-seeded hybrid rice at Ludhiana. Wani *et al*. (2016) reported that head rice recovery differed significantly due to levels of nitrogen and higher head rice per cent was recorded for crop receiving 80 kg N/ha and lowest in crop receiving no N.

**2.2.6 Effect of nitrogen levels on economic of rice**

Higher economic return can be obtained by cultivation of rice with taking benefits of proper nutrient management approach. There are several experimental findings which further established this view. Singh and Srivastava (2001) obtained higher benefit cost ratio (1.35) with 150 kg N/ha followed by 50, 100, 200 kg N/ha and the control in hybrid rice.

Das and Panda (2002) reported that combination of 120 kg N and 80 kg $K_2O$/ha proved to be most remunerative recording a net profit of Rs. 11,294/ha with highest benefit:

cost ratio of 1.44. Similarly, Samrathlal *et al.* (2003) obtained the highest benefit: cost ratio at 100 kg N/ha as compared to 200 kg N/ha in rice crop.

Upendra *et al*. (2004) showed that maximum benefit: cost ratio in rice was obtained with 120 kg N/ha and 40 kg K/ha. Das *et al*. (2008) also observed increase in gross return, net return and B: C ratio by the application of nitrogen and potassium up to 180 kg N/ha and 80 kg $K_2O$/ha, respectively.

Srivastava *et al.* (2014) also found greater net returns with the application of higher dose of N (30 and 45 kg/ha) at Varanasi, Uttar Pradesh.

**2.2.7 Interaction effect of planting time and nitrogen levels on rice**

Muhammad *et al.* (2015) reported that interactions between varying nitrogen rates and transplanting dates on rice growth, yield and related attributes were found to be non-significant. However, a significant interaction between transplanting dates and N levels was reported by Singh *et al*. (2017a) which revealed that the grain yield of rice increased significantly up to 120 kg N/ha under early planting ( up to 21 July) but increase in grain yield was significant up to 180 kg N/ha under late planting (5 August).

**2.3 Effect of nitrogen application timing**

Timely and split application of N may improve a crop's response to N as it provides required amounts of N to the crop during peak periods of growth and may reduce leaching of nitrate-N in the soil (Fageria and Baligar 1999). Time of application of nitrogen has been reported to have a significant influence on various growth characters (Sharma, 1995). Vaiyapuri *et al.* (1998), Sathiya and Ramesh (2009) observed that nitrogen requirement of rice is higher during earlier transplanting to tillering stage and application of nitrogen during these stages improves crop growth parameters.

**2.3.1 Effect of nitrogen application timing on Phenology**

Hoan (1997) noticed that application of 140 kg N/ha at panicle development stage delayed heading and maturity by 2-3 days. Delaying of N application to 30 to 35 days after sowing in no-till water seeded rice resulted in to earlier production (Stevens, 2001).

Samarjeewa *et al*. (2005) observed that the adverse effects of shade on ripening rate of rice were minimised by changing the time of N top dressing in rice. Split application of N delayed heading compared to its application in single dose (El-Reffaee *et al*., 2007).

**2.3.2 Effect of nitrogen application timing on growth**

Akanda *et al*. (1996) reported that N application in split doses (20, 40 and 20 kg/ha at basal, active tillering and panicle initiation, respectively) in rice crop gave the highest total tillers per hill. Alam *et al*. (2002) recorded maximum number of leaves per hill when N was applied in three equal splits (basal, early tillering and panicle initiation) but number of leaves was minimum when N was applied in two equals split (early tillering and flowering), respectively.

Gobi *et al.* (2006) concluded that five splits of nitrogen (50 % basal, 12.5 % active tillering, 12.5 % panicle initiation, 12.5 % heading and 12.5 % flowering) along with four splits of potassium increased plant height at latter stages of growth of rice crop. The highest plant height was recorded when N was applied @ 20 kg/ha as basal plus the remaining quantity @ 20 kg/ha or 30 kg/ha based on LCC observations (Jayanthi *et al.,* 2007).

Nitrogen application in more number of splits (4 or 5) @ 20 or 30 kg/ha based on LCC observations produced significantly higher dry matter at harvest (Jayanthi *et al.*,2007). El-Reffaee *et al.* (2007) obtained higher dry matter by adding N in two, three or four splits compared with single dose as basal application. The results are in agreement with those obtained by Tanaka *et al.* (1993). Nitrogen application in three splits significantly increased above ground total dry matter accumulation over two split N or full N applications at final harvest (Ahmad *et al.*, 2009).

Application of granular urea as 1/3 during final land preparation + 1/3 at 30 DAT + 1/3 at 55 DAT gave the highest number of tillers (Hassanuzzaman *et al.*, 2009). Nitrogen application with LCC value of 4 or application of 150 kg N/ha in four splits (1/6 at 15 DAS, 1/3 at tillering, 1/3 at panicle initiation, 1/6 at flowering) recorded higher number of tillers (Sathiya and Ramesh, 2009).

Islam *et al* (2009) observed that plant height, number of tillers/hill, number of leaves/hill, leaf area/hill, dry matter of root, stem and leaves/hill, total dry matter/hill and chlorophyll content in leaves at 74 DAT increased with split application of N. Lampayan *et al*. (2010) obtained the highest number of tillers in treatment where 100 kg N was applied in 4 splits (basal, 14, 35, and 50 days after emergence) than other treatments.

A significant influence of N application timing in rice crop on shoot dry weight was reported by Fageria (2010) who obtained maximum dry weight when N was applied half at initiation of tillering and half at panicle initiation and was at par with nitrogen applied in 3 equal splits (sowing, active tillering, and panicle initiation). Kaushal *et al.* (2010) found higher plant height by applying 120 kg N/ha as ½ basal, ¼ at tillering and ¼ at panicle initiation.

Raj *et al*. (2014) reported that application of nitrogen in four equal doses at 5-10, 20-25, 40-45 and 60-65 days after emergence resulted into significantly taller plants. Similar findings were also reported by Anil *et al*. (2014) where taller plants were recorded in 4 equal splits of N.

Singh *et al*. (2017a) reported that the highest plant height, number of tillers was recorded with application of 150 kg N/ha in four splits.

Djaman *et al*. (2018) observed better performance of rice with N application in four splits with the application of 10% of N fertilizer rate at grain filling stage. Higher panicles/hill, filled grain weight/panicle and 1000-grain weight were observed when N was applied in 4 splits than in 3 splits.

**2.3.3 Effect of nitrogen application timing on yield and yield attributes**

Alam *et al*. (2002) observed that lowest biological yield was obtained when N was applied in two equal splits at early tillering and flowering stages. Balasubramanian (2002) reported that STCR-based N application recorded more grains/panicle but was found similar with 200 kg N/ha applied in 4 equal splits. Nageswari and Balasubramaniayan (2004) reported more panicles when 150 kg N/ha was applied in five splits as compared to four and three splits. But Singh and Thakur (2007) obtained similar yield with N at 90 kg/ha applied in four (1/4 basal+1/4 at active tillering+1/4 at panicle initiation+1/4 at boot stage) or three (1/3 at basal+1/3 at active tillering and 1/3 at panicle initiation) splits.

Sharma *et al*. (2007) obtained the highest grain yields with the application of ½ N at 20 DAS+ ¼ N at tillering + ¼ N at panicle initiation (PI), which was significantly superior to other schedules of nitrogen viz. ¼ N at 20 DAS + ½ at tillering + ¼ at PI, ½ N at sowing (S) + ¼ at tillering + ¼ at PI and ¼ N at S + ½ at T + ¼ at PI.

Kumar *et al*. (2007) reported no-significant differences in 1000-grain weight and panicle length with split application of N. Fageria (2010) also reported significant influence of N timing treatments on grain yield and obtained maximum grain yield with application of nitrogen in three equal splits at sowing, active tillering, and at panicle initiation. Moreover, Hirzel *et al*. (2011) confirmed highest productivity of flooded rice crop in Chile with application of 33% N at sowing, 33% at tillering, and 34% at panicle initiation or 50% N at sowing and 50% at panicle initiation.

Pandey *et al*. (2010) conducted field experiment to study the performance of hybrid rice to scheduling of irrigation and nitrogen level. Nitrogen scheduling of 40+20+30+10 per cent at basal, active tillering, panicle initiation and flowering increased effective tillers and grain yield of hybrid rice.

Youseftabar *et al*. (2012) reported that increasing split application of N increased 1000 grain weight with 2, 3 and 4 split N applications. Yoseftabar (2013) reported maximum grain yield of rice with nitrogen applied in three equal splits at basal, mid tillering and panicle initiation.

Singh *et al*. (2017a) concluded that application of N at 150 k/ha in four equal splits (before last puddling, 15, 30 and 45 DAT) increased yield attributing parameters (effective tillers, grains/panicle and 1000-grain weight) which ultimately resulted into higher grain and straw yield.

**2.3.4 Effect of nitrogen application timing on nutrient content and uptake of rice**

Bhattacharya and Singh (1992) registered a significant increase in the N uptake by applying N in four splits than its application in three splits in direct seeded rice. Nitrogen uptake of the crop is favoured by additional supply of nitrogen during maximum growth phase (Patel and Thakur, 1997). A single application of N at the 4-5 leaf stage resulted in greater N uptake by rice than did mid-season N applications (Grigg *et al*., 2000). Souza *et al*. (1999) reported that top dressing of 20 kg N/ha and 40 kg N/ha at 20 days after anthesis showed an increased N content in grains in proportion to the provided N dose. Wopereis-Pura *et al*. (2002) observed an improvement in the content of nitrogen in the grain due to an additional late application of 30 kg N/ha at booting.

Cabangon *et al*. (2004) and Belder *et al*. (2005) noticed that increasing the number of N application splits from two to four resulted in higher total N uptake. Gupta *et al*. (2011) noticed significantly higher uptake of N when N was applied using LCC 5 as threshold than that by using LCC 4 as the threshold.

**2.3.5 Effect of nitrogen application timing on Quality**

Sharif (1994) reported that applying N in splits as per need of the crop can considerably improve the quality of rice. Perez *et al.* (1996) observed that late application of N fertilizer at the time of flowering improved milling and nutritional quality of rice grain. Wopereis-Pura *et al.* (2002) reported higher milling and head rice recovery as a result of an extra late N application at boot stage on top of 2 N-dressings with a total of 120 kg N/ha.

Devi *et al.* (2012) reported that split application of N as 1/4 at sowing + 1/4 at active tillering + 1/4 at panicle initiation and 1/4 at heading resulted in significantly higher values of milling recovery, head rice recovery, kernel length and breadth of scented.

**2.3.6 Effect of nitrogen application timing on Economics**

An additional application of 30 kg N/ha at booting gave a benefit cost ratio ranging from 2.8 in the wet season to 5.4 in the dry season (Wopereis-Pura *et al*., 2002). Maximum net return of Rs.46,170/ha and the highest B: C ratio of 4.08 was obtained by applying nitrogen as 50% basal, 12.5% active tillering, 12.5% panicle initiation, 12.5% heading and 12.5 % flowering (Gobi et *al.,* 2006). Benefit cost ratio of 44.2 to 55.8 was achieved when N was applied as per LCC reading (<4), compared to benefit cost ratio of 37.3 to 38.1 in simple split application of N at fixed growth stages (Gupta *et al*., 2011).

# CHAPTER–III

## MATERIALS AND METHODS

The present field experiment entitled "**Schedule of nitrogen application in rice (*Oryza sativa* L.) as influenced by planting time**" was conducted during *Kharif* season of 2017 and 2018 at Research Farm of Rice Research Station, Kaul (Kaithal) of Chaudhary Charan Singh Haryana Agricultural University, Hisar. The details of the materials used and methods adopted are described in this chapter.

### 3.1 Experimental site

Kaul (Kaithal) is situated at a latitude 29° 51' N, longitude 76° 41' E and an altitude of 241 meter above mean sea level and is 30 km away from the holy city of Kurukshetra. It is located in North Eastern part of Haryana, the heart of the rice-growing region, and often called "Rice Bowl of Haryana". The experimental site has sub-tropical and sub-humid climate characterized by hot desiccating winds of average velocity during summer and moderate to severe cold in winter. The average annual rainfall in the area is around 700 mm which is received mainly (around 80%) during the period from July to September. The temperature may rise up to 45 °C during summer season and often dips up to 5 °C during the winter months of December and January.

### 3.2 Weather during the crop season

The weather data during the growing period of the experimental crop was recorded from Meteorological Observatory situated at the Research Farm of Rice Research Station, Kaul (Kaithal) in 2017 and 2018 and presented in Tables 3.2.1 and 3.2.2, respectively and also depicted in Fig. 3.1. and 3.2. The data on various weather parameters showed that average weekly (standard meteorological weeks or SMW) maximum and minimum temperatures varied from 28.3 to 41.0 °C (mean 34.2 °C ) and 14.0 to 24.0 °C (mean 23.1 °C ), respectively during 2017 and 29.1 to 43.8 °C (mean 33.9 °C) and 13.6 to 26.6 °C (mean 22.8 °C ), respectively during 2018. The total rainfall during the crop growing period was 844.3 mm and 851.0 mm during 2017 and 2018, respectively. The daily relative humidity ranged from 32 to 96 per cent during 2017 and from 19 to 96 per cent during 2018. Average bright sunshine hours during the crop duration were more (10.7) in 2017 than in 2018 (6.1) indicating that weather conditions were more favourable in 2017 than in 2018.

**Table 3.2.1: Mean weekly values of weather parameters during cropping season *Kharif* 2017**

| SMW | Temperature (°C) | | Relative humidity (%) | | Average wind velocity (km/hr) | Bright sunshine (hr) | Pan evaporation (mm/day) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | M | E | | | | |
| 20 | 41.0 | 24.0 | 62.0 | 32.3 | 5.5 | 8.4 | 10.1 | 0.0 |
| 21 | 39.4 | 24.0 | 62.9 | 32.0 | 5.8 | 7.9 | 9.6 | 0.0 |
| 22 | 37.2 | 23.9 | 69.0 | 43.6 | 9.0 | 9.7 | 9.7 | 0.0 |
| 23 | 39.3 | 25.9 | 67.0 | 45.0 | 8.1 | 7.1 | 11.1 | 48.0 |
| 24 | 38.4 | 23.7 | 75.0 | 40.1 | 6.6 | 9.4 | 9.2 | 20.2 |
| 25 | 34.7 | 24.4 | 80.7 | 53.1 | 5.4 | 6.4 | 7.7 | 12.0 |
| 26 | 33.3 | 25.5 | 90.3 | 70.7 | 6.7 | 4.4 | 7.0 | 169.1 |
| 27 | 33.8 | 26.3 | 88.6 | 70.4 | 5.6 | 5.5 | 6.0 | 36.2 |
| 28 | 34.0 | 26.9 | 84.1 | 70.6 | 5.5 | 7.4 | 6.4 | 16.2 |
| 29 | 34.0 | 26.7 | 85.9 | 71.9 | 4.2 | 5.8 | 5.6 | 4.7 |
| 30 | 33.2 | 26.0 | 87.4 | 73.7 | 8.5 | 8.3 | 6.8 | 30.2 |
| 31 | 31.3 | 25.4 | 94.0 | 82.1 | 5.8 | 2.2 | 4.9 | 141.7 |
| 32 | 33.5 | 26.4 | 92.6 | 78.6 | 3.8 | 5.2 | 6.1 | 21.4 |
| 33 | 34.0 | 26.0 | 90.4 | 71.7 | 4.2 | 9.3 | 5.9 | 0.0 |
| 34 | 32.1 | 24.8 | 95.6 | 81.7 | 4.2 | 3.5 | 5.5 | 97.0 |
| 35 | 32.9 | 24.5 | 94.4 | 80.0 | 4.5 | 7.0 | 2.9 | 145 |
| 36 | 32.0 | 23.5 | 92.7 | 73.1 | 3.0 | 9.2 | 4.2 | 5.1 |
| 37 | 32.9 | 23.8 | 93.3 | 68.9 | 2.6 | 10.2 | 4.5 | 0.0 |
| 38 | 32.6 | 21.3 | 95.1 | 68.0 | 2.2 | 6.7 | 3.6 | 91.5 |
| 39 | 33.0 | 21.5 | 96.4 | 63.6 | 2.2 | 7.6 | 2.6 | 6.0 |
| 40 | 34.1 | 19.2 | 94.0 | 49.4 | 2.1 | 10.1 | 3.7 | 0.0 |
| 41 | 33.6 | 19.1 | 95.9 | 45.9 | 1.5 | 7.3 | 2.7 | 0.0 |
| 42 | 34.0 | 15.8 | 93.7 | 37.1 | 1.1 | 7.9 | 2.5 | 0.0 |
| 43 | 31.5 | 14.0 | 91.0 | 39.1 | 1.3 | 7.7 | 2.0 | 0.0 |
| 44 | 28.3 | 14.5 | 96.1 | 55.9 | 1.6 | 3.4 | 1.2 | 0.0 |
| Mean | 34.2 | 23.1 | 86.7 | 59.9 | 4.4 | 7.1 | 5.7 | |

**Table 3.2.2: Mean weekly values of weather parameters during cropping season *Kharif* 2018**

| SMW | Temperature (°C) | | Relative humidity (%) | | Average wind velocity (km/hr) | Bright sunshine (hr) | Pan evaporation (mm/day) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | M | E | | | | |
| 20 | 39.3 | 22.1 | 59.6 | 30.4 | 6.5 | 6.9 | 8.2 | 7.5 |
| 21 | 43.8 | 22.1 | 50.9 | 18.9 | 5.9 | 10.1 | 9.1 | 0.0 |
| 22 | 40.3 | 23.7 | 70.7 | 52.6 | 8.6 | 8.8 | 9.0 | 0.0 |
| 23 | 36.9 | 25.5 | 80.3 | 53.6 | 8.5 | 6.7 | 8.9 | 53.7 |
| 24 | 39.2 | 25.6 | 70.3 | 43.0 | 4.7 | 3.2 | 7.1 | 25.0 |
| 25 | 35.4 | 25.5 | 78.1 | 45.9 | 1.4 | 7.6 | 4.7 | 27.0 |
| 26 | 35.2 | 25.4 | 81.9 | 62.0 | - | 6.1 | 5.5 | 63.2 |
| 27 | 34.2 | 25.7 | 89.7 | 65.3 | 3.6 | 7.0 | 6.1 | 30.5 |
| 28 | 34.7 | 26.6 | 89.3 | 72.7 | 6.6 | 6.0 | 5.4 | 5.5 |
| 29 | 34.1 | 26.3 | 91.7 | 81.7 | 4.5 | 4.0 | 3.8 | 48.2 |
| 30 | 32.0 | 25.4 | 94.9 | 82.7 | 3.2 | 2.2 | 4.5 | 197.3 |
| 31 | 33.1 | 25.3 | 87.7 | 75.6 | 4.8 | 6.8 | 3.2 | 0.0 |
| 32 | 32.1 | 25.0 | 91.0 | 82.4 | 4.0 | 4.3 | 1.7 | 46.5 |
| 33 | 32.9 | 25.6 | 91.9 | 77.0 | 3.2 | 3.8 | 3.3 | 38.4 |
| 34 | 32.5 | 25.3 | 94.3 | 84.6 | 3.7 | 4.0 | 4.0 | 123.0 |
| 35 | 33.0 | 25.1 | 90.9 | 87.1 | 2.9 | 3.5 | 1.8 | 3.2 |
| 36 | 31.4 | 24.0 | 95.6 | 82.1 | 2.9 | 4.2 | 1.2 | 29.0 |
| 37 | 32.6 | 23.8 | 92.9 | 77.9 | 3.7 | 7.9 | 1.6 | 1.8 |
| 38 | 31.3 | 22.0 | 91.4 | 77.3 | 4.6 | 6.3 | 3.9 | 26.5 |
| 39 | 29.1 | 20.7 | 96.3 | 76.1 | 3.9 | 6.8 | 2.2 | 124.7 |
| 40 | 32.4 | 18.5 | 95.6 | 52.0 | 2.1 | 8.7 | 0.9 | 0.0 |
| 41 | 29.6 | 16.9 | 94.1 | 48.7 | 3.3 | 7.1 | 1.4 | 0.0 |
| 42 | 31.5 | 15.4 | 92.7 | 38.1 | 2.0 | 7.4 | 1.4 | 0.0 |
| 43 | 30.5 | 13.6 | 92.3 | 40.9 | 1.5 | 6.9 | 1.1 | 0.0 |
| 44 | 29.4 | 13.8 | 89.9 | 49.4 | 3.0 | 4.1 | 1.3 | 0.0 |
| Mean | 33.9 | 22.8 | 86.2 | 62.3 | 4.1 | 6.0 | 4.1 | |

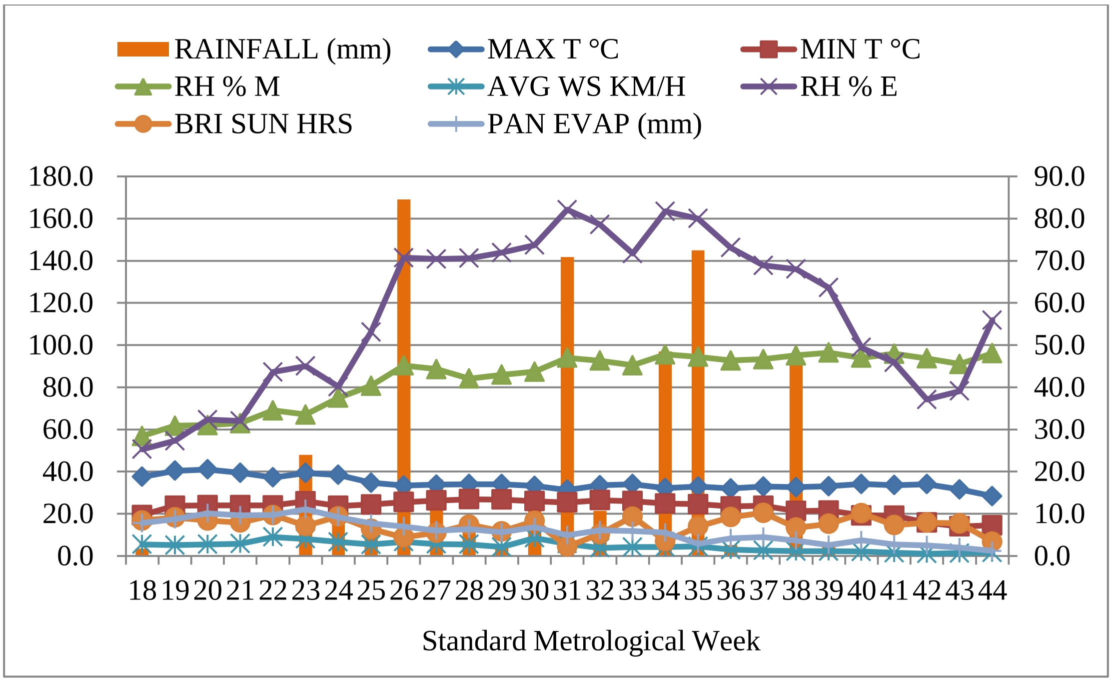


**Fig. 3.1: Mean weekly values of weather parameters during cropping season *Kharif* 2017**

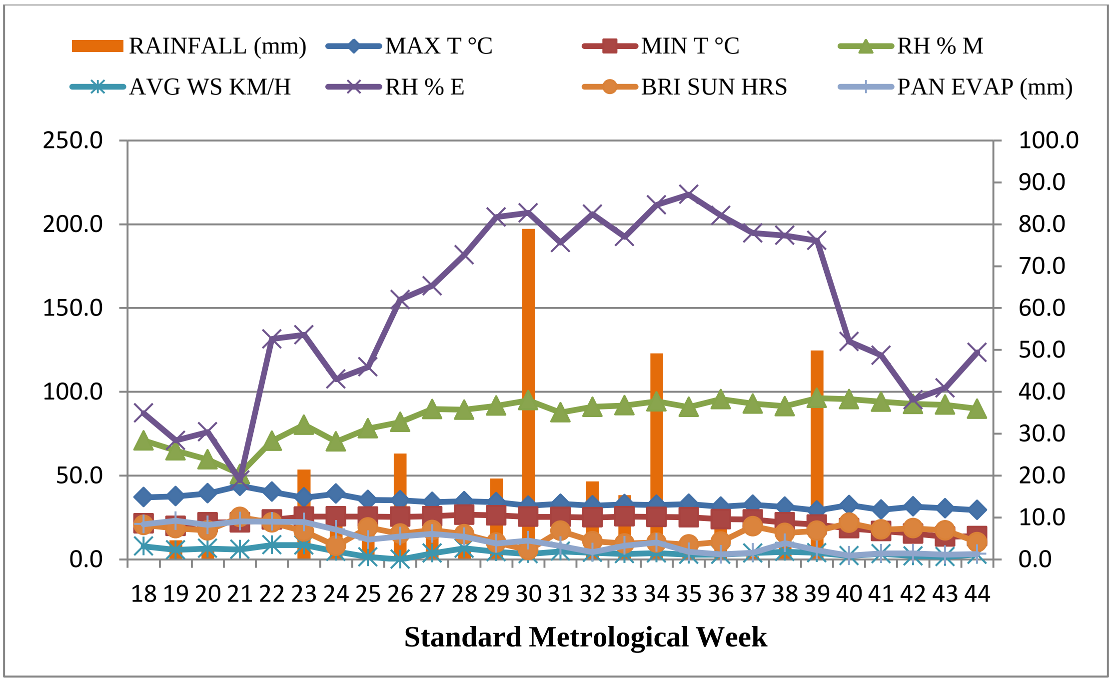


**Fig. 3.2: Mean weekly values of weather parameters during cropping season *Kharif* 2018**

## 3.3 Cropping history of the field

The cropping history of the field for the last three years is given in the Table 3.3.

**Table 3.3: Cropping history of the experimental field**

| Year | Season | |
|---|---|---|
| | ***Kharif*** | ***Rabi*** |
| 2015-16 | Rice | Wheat |
| 2016-17 | Rice | Wheat |
| 2017-18 | Rice (Experimental crop) | Wheat |
| 2018-19 | Rice (Experimental crop) | Wheat |

## 3.4 Soil characteristics

### 3.4.1 Physical and chemical properties of the soil

To know the physical (mechanical) and chemical composition of the soil, composite soil samples were collected from 0-15 cm soil depth from the experimental field before preparatory tillage and were subjected to mechanical and chemical analysis. The results obtained from soil analysis presented in Table 3.4.1 revealed that soil of the experimental field was loamy in texture, alkaline in reaction, low in organic carbon and available nitrogen, medium in available phosphorus and high in available potash (Tamhane *et al.*,1958).

**Table 3.4.1: Physical and chemical properties of the soil**

| Component | 2017 | 2018 | Method used |
|---|---|---|---|
| **Physical/mechanical composition** | | | |
| Sand (%) | 41.3 | 41.5 | International pipette method (Piper, 1966) |
| Silt (%) | 32.6 | 32.6 | |
| Clay (%) | 26.1 | 25.9 | |
| Texture | Loam | Loam | |
| **Chemical composition** | | | |
| pH (1:2) | 8.0 | 8.0 | Glass electrode pH meter method (Jackson, 1973) |
| EC ($dSm^{-1}$) | 0.26 | 0.26 | Conductivity bridge method (Richards, 1954) |
| Organic carbon (%) | 0.42 | 0.41 | Walkley and Black's method (Walkley and Black, 1934) |
| Available N (kg $ha^{-1}$) | 103 | 101 | Alkaline potassium permanganate method (Subbiah and Asija, 1956) |
| Available P (kg $ha^{-1}$) | 26 | 25.7 | Olsen's method (Olsen *et al.*, 1954) |
| Available K (kg $ha^{-1}$) | 832 | 830 | Flame photometer method (Richards, 1954) |

## 3.5 Experimental details

The field experiment consisted of three transplanting times, four N application levels and four timings of N application. The experiment was conducted in split plot design with three replications keeping planting time and N levels in main plots and time of N application in sub-plots. The layout of the treatments in the experimental field is depicted in Fig. 3.3. The details of the treatments are as follows:

**Treatments**

a) Planting time:

$P_1$: 3rd week of June

$P_2$: 1st week of July

$P_3$: 3rd week of July

b) N levels (kg/ha)

$N_1$: 90

$N_2$: 120

$N_3$: 150

$N_4$: 180

c) Time of N application

$T_1$: ½ at transplanting + ½ at 21 DAT

$T_2$: ½ at 21 DAT + ½ at 42 DAT

$T_3$: 1/3rd at transplanting + 1/3rd at 21 DAT + 1/3rd at 42 DAT

$T_4$: LCC based

| | | |
|---|---|---|
| Experimental Design | : | Split plot |
| Main plot treatments | : | Planting time and N levels |
| Sub-plot treatments | : | Time of N application |
| Replications | : | 3 |
| Size of plot | : | 4.8 x 4.2 m (gross), 4.4 x 3.9 m (net) |
| Season | : | **K***harif* 2017 and 2018 |
| Variety | : | HKR 127 (non-scented/high yielding variety of medium duration) |

**3.6 Cultural operations**

The details of cultural operations performed during the crop growth season are given below.

**3.6.1 Field preparation**

The experimental field was cultivated twice using disc harrow followed by planking and then it was levelled to ensure the uniform distribution of irrigation water across the field and uniform crop stand. The main field (field to be transplanted) was subjected to puddling (twice) with puddler followed by planking and was allowed for sedimentation (settling of the silt) for at least 5 hours before transplanting.

**3.6.2 Seed treatment**

For nursery sowing, one kg seed of each variety was soaked for 24 hours in a solution containing 1 litre of water, 1.0 g carbendazim (50 WP) and 0.1 g streptocycline. The treated seeds

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **PATH** | | | | | | | | | | | | | | | | | | |
| | **$P_1$** | | | | | | **$P_2$** | | | | | | **$P_3$** | | | | | | |
| | | **$R_1$** | | **$R_2$** | | **$R_3$** | | **$R_1$** | | **$R_2$** | | **$R_3$** | | **$R_1$** | | **$R_2$** | | **$R_3$** |
| | **$N_1$** | **$T_1$** | | **$T_2$** | | **$T_3$** | **$N_1$** | **$T_1$** | | **$T_2$** | | **$T_3$** | **$N_1$** | **$T_1$** | | **$T_2$** | | **$T_3$** |
| | | **$T_2$** | | **$T_3$** | | **$T_4$** | | **$T_2$** | | **$T_3$** | | **$T_4$** | | **$T_2$** | | **$T_3$** | | **$T_4$** |
| | | **$T_3$** | | **$T_4$** | | **$T_1$** | | **$T_3$** | | **$T_4$** | | **$T_1$** | | **$T_3$** | | **$T_4$** | | **$T_1$** |
| | | **$T_4$** | | **$T_1$** | | **$T_2$** | | **$T_4$** | | **$T_1$** | | **$T_2$** | | **$T_4$** | | **$T_1$** | | **$T_2$** |
| | **$N_2$** | **$T_1$** | | **$T_2$** | | **$T_3$** | **$N_2$** | **$T_1$** | | **$T_2$** | | **$T_3$** | **$N_2$** | **$T_1$** | | **$T_2$** | | **$T_3$** |
| | | **$T_2$** | | **$T_3$** | | **$T_4$** | | **$T_2$** | | **$T_3$** | | **$T_4$** | | **$T_2$** | | **$T_3$** | | **$T_4$** |
| **PATH** | | **$T_3$** | **CHANNEL** | **$T_4$** | **CHANNEL** | **$T_1$** | | **$T_3$** | **CHANNEL** | **$T_4$** | **CHANNEL** | **$T_1$** | | **$T_3$** | **CHANNEL** | **$T_4$** | **CHANNEL** | **$T_1$** |
| | | **$T_4$** | | **$T_1$** | | **$T_2$** | | **$T_4$** | | **$T_1$** | | **$T_2$** | | **$T_4$** | | **$T_1$** | | **$T_2$** |
| | **$N_3$** | **$T_1$** | | **$T_2$** | | **$T_3$** | **$N_3$** | **$T_1$** | | **$T_2$** | | **$T_3$** | **$N_3$** | **$T_1$** | | **$T_2$** | | **$T_3$** |
| | | **$T_2$** | | **$T_3$** | | **$T_4$** | | **$T_2$** | | **$T_3$** | | **$T_4$** | | **$T_2$** | | **$T_3$** | | **$T_4$** |
| | | **$T_3$** | | **$T_4$** | | **$T_1$** | | **$T_3$** | | **$T_4$** | | **$T_1$** | | **$T_3$** | | **$T_4$** | | **$T_1$** |
| | | **$T_4$** | | **$T_1$** | | **$T_2$** | | **$T_4$** | | **$T_1$** | | **$T_2$** | | **$T_4$** | | **$T_1$** | | **$T_2$** |
| | **$N_4$** | **$T_1$** | | **$T_2$** | | **$T_3$** | **$N_4$** | **$T_1$** | | **$T_2$** | | **$T_3$** | **$N_4$** | **$T_1$** | | **$T_2$** | | **$T_3$** |
| | | **$T_2$** | | **$T_3$** | | **$T_4$** | | **$T_2$** | | **$T_3$** | | **$T_4$** | | **$T_2$** | | **$T_3$** | | **$T_4$** |
| | | **$T_3$** | | **$T_4$** | | **$T_1$** | | **$T_3$** | | **$T_4$** | | **$T_1$** | | **$T_3$** | | **$T_4$** | | **$T_1$** |
| | | **$T_4$** | | **$T_1$** | | **$T_2$** | | **$T_4$** | | **$T_1$** | | **$T_2$** | | **$T_4$** | | **$T_1$** | | **$T_2$** |
| | **MAIN CHANNEL** | | | | | | | | | | | | | | | | | | |

**FIG. 3.3: LAYOUT PLAN OF THE EXPERIMENT**

were then allowed to sprout/germinate by keeping them covered by wet gunny bags for 2 days and sprinkling water frequently on them.

### 3.6.3 Nursery raising

The area kept for nursery (1/20$^{th}$ of the area to be transplanted) was first irrigated to permit the germination of weeds and was ploughed (near field capacity) to kill the germinated weeds. Nursery was raised on flat beds by wet method, preparing the nursery area by ploughing and then by puddling. The sprouted seeds of rice variety HKR 127 were sown in puddled nursery bed @ 40 g/m$^2$ on May 25 during both the years (2017 and 2018) and for all the transplanting dates. For controlling the weeds in nursery, Sofit (pretilachlor 30 EC + safener) @ 15 g/100 m$^2$ of nursery area was applied at 2 days after sowing (DAS) by mixing it with 1.5 kg sand. The nursery area was supplied with 50 kg N (through urea), 25 kg $P_2O_5$ (through SSP) and 25 kg $ZnSO_4$/ha. Half dose of N (25 kg/ha) and full dose of P and Zn were applied at the time of sowing (basal) whereas the remaining half dose of N was top-dressed after 15 days of sowing. Additional dose of N @ 25 kg/ha was also applied after 35 days of sowing in the nursery of crop transplanted during first and third week of July ($P_1$ and $P_2$). The nursery area was irrigated daily in the evening to keep the soil moist.

### 3.6.4 Transplanting

Before transplanting, the main field was prepared well by puddling twice with puddler followed by planking. Rice seedlings (25-30 days old for $P_1$, 40-45 days old for $P_2$ and 55-60 days old for $P_3$) from the nursery under standing water were uprooted gently to avoid root injury and washed with water to remove the mud from then roots. The uprooted seedlings were then transplanted in the main field at 20 cm x 15 cm spacing with two seedlings/hill.

### 3.6.5 Application of fertilizers

The transplanted plots were supplied with 60 kg $P_2O_5$/ha (through SSP) and 25 kg $ZnSO_4$/ha at the time of transplanting whereas N with various doses and timings of application was applied according to the treatments.

### 3.6.6 Irrigation

The transplanted crop was kept under shallow submergence (5 cm water) for the initial period of 15 days of transplanting by applying irrigation as and when required. Thereafter, the crop was irrigated after two days of disappearance of ponded water. The irrigation was skipped if sufficient rain was received. The irrigation was stopped 10 days prior to harvest.

### 3.6.7 Weed control

For weed control, pretilachlor (50 EC) @ 2 litres/ha was applied after 2 days of transplanting by mixing it with sand. Moreover, hand weeding was also done in the crop at 30 days after transplanting (DAT) to control the weeds emerging later on.

### 3.6.8 Plant protection measures

The insecticide Cartap hydrochloride (4G) at 18.75 kg/ha mixed with 25 kg sand was applied during both the years to control insects viz. leaf folder and stem borer. Spray of fungicide validamycin (3L) at 1125 ml/ha using 500 litres of water/ha was also done to control the sheath blight disease.

### 3.6.9 Harvesting and threshing

The rice crop was harvested manually at physiological maturity. The crop harvested from the net plots of each treatment was collected in respective plots. Then, threshing of crop from each plot was done manually by beating it against drum and the grains obtained after threshing were cleaned by winnowing. The yield of grains from each plot was recorded after sun drying it to 14% moisture.  The straw yield from each plot was also recorded after drying the straw in the sun for about one week. The yield of grains as well of straw from each treatment plot was converted to kg/ha. The sum of grain and straw yield from individual plot was considered as biological yield.

## 3.7 Observation Recorded

### 3.7.1 Soil studies

#### 3.7.1.1 Soil nutrient status

After harvesting of the crop the soil samples from each treatment plots were taken at 0-15 cm soil depth and were analysed for determination of available nutrient (N, P and K) status of the soil by standard procedure. Nitrogen was analysed by Alkaline Permanganate method (Subbiah and Asija, 1956), P by Olsen's method (Olsen *et al.*, 1954) and K by Flame Photometric method (Richards, 1954).

### 3.7.2 Phenological studies

#### 3.7.2.1 Days to panicle initiation

The data on days taken to panicle initiation were recorded by counting the number of days from nursery sowing to the day when panicle formation had started in rice plants.

#### 3.7.2.2 Days taken to 50% flowering

The data on days taken to 50 per cent flowering were recorded by counting the number of days from nursery sowing to the day when panicles had emerged in 50 per cent of the plants.

#### 3.7.2.3 Days taken to physiological maturity

The data on days to maturity were recorded by counting the number of days from nursery sowing to the day when the plants had attained physiological maturity.

### 3.7.3 Growth studies

#### 3.7.3.1 Plant height (cm)

The height of the longest tiller from five randomly selected plants (hills) in each plot was measured at 30, 60, 90 DAT and at maturity (harvest) and averaged over the plants. The height of plant was measured from the base to tip of last fully opened leaf of plant till panicle emergence and from base of plant to the tip of panicle after the panicle emergence.

#### 3.7.3.2 Number of tillers/$m^2$

Number of tillers was recorded from five randomly selected hills in each plot at 30, 60, 90 DAT and at harvest and expressed as number of tillers/$m^2$.

#### 3.7.3.3 Dry matter accumulation

Dry matter accumulation by the crop was recorded periodically at 30, 60, 90 DAT and at harvest. Three randomly selected hills from the second row of each plot were cut from the base and the collected plant biomass was first chopped and sun dried and then oven dried at 65±5 °C till a constant weight was achieved. The weight of dried samples was recorded and expressed as g/$m^2$.

### 3.7.4 Yield and yield attributes

#### 3.7.4.1 Panicle length

The ten representative panicles were randomly selected from each plot and their length was measured from neck node to the apex. The average of their length was expressed as panicle length (cm).

#### 3.7.4.2 Number of panicles/$m^2$

The number of effective tillers or panicles from five randomly selected hills in each plot was recorded at maturity stage and expressed as number of panicles/$m^2$.

#### 3.7.4.3 Number of grains/panicle

At maturity, the number of grains of ten randomly selected panicles per plot was counted and expressed as number of grains/panicle.

#### 3.7.4.4 1000-grain weight

Two lots of one thousand grains were taken from the threshed produce (grain) of each plot and weighed. Their average weight was recorded and expressed in grams on the basis of 14 per cent moisture content.

#### 3.7.4.5 Grain yield

The crop from each plot (net plot) was harvested and threshed manually. The weight of grains (grain yield) was recorded and then converted to kg/ha.

#### 3.7.4.6 Straw yield

The straw from threshed crop of each net plot was sun dried for 3 days and weighed. The yield of straw/plot was then converted into straw yield/ha.

**3.7.4.7 Biological yield (kg/ha)**

The biological yield was obtained by adding grain yield and straw yield of each plot and expressed in kg/ha.

**3.7.4.8 Harvest Index**

Harvest index was determined by the ratio of economical yield (grain yield) to the biological yield (grain + straw) expressed in percentage. The harvest index (HI) for each plot was computed using following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

**3.7.5 Quality parameters**

The following grain quality parameters were determined by the methods described below.

**3.7.5.1 Kernel length**

The length of ten rice kernels from each treatment was recorded after hulling (removal of husk or hull) with the help of laboratory huller or sheller (Satake Rice Sheller, Satake Engg. Co. Japan) and average kernel length was worked out.

**3.7.5.2 Length breadth ratio**

The length and breadth of ten rice kernels from each treatment was recorded after hulling of paddy and the ratio of average length to average breadth of these kernels was worked out.

**3.7.5.3 Hulling percentage (hulling recovery)**

The samples (100 g) of unhusked rice (paddy) from grain lot of each plot (treatment) were hulled with the help of laboratory huller or sheller (Satake Rice Sheller, Satake Engg. Co. Japan). The weight of the sample after hulling (brown rice) was recorded and expressed as percentage of unhusked rice. The hulling recovery was computed by following formula.

$$\text{Hulling recovery (\%)} = \frac{\text{Weight of hulled rice (g)}}{\text{Weight of paddy (g)}} \times 100$$

**3.7.5.4 Milling percentage (milling recovery)**

The samples of hulled grains (brown rice) were milled (polished) with the help of Rice Polisher of Satake Engg. Co. (Japan) to remove the polish (bran) and to get commercial rice (white kernels). The weight of the sample after milling was recorded and expressed as percentage of unhusked rice. The milling recovery was computed by the following formula.

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

**3.7.5.5 Head rice recovery**

The white kernels obtained after milling were separated with the help of a grading device into two categories i.e. whole kernels (minimum two-third of the original kernel size) and broken kernels (less than two-third of the original kernel size). The weight of whole kernels (head rice) was taken and expressed as percentage of unhusked rice. The head rice recovery was computed by the following formula.

$$\text{Head rice recovery (\%)} = \frac{\text{Weight of head rice}}{\text{Weight of paddy (g)}} \times 100$$

**3.7.6 Economics**

**3.7.6.1 Cost of cultivation**

The cost of cultivation (Rs./ha) of each treatment was worked out by taking into account the prevailing market rates of various inputs and services.

**3.7.6.1 Gross returns**

The gross returns (Rs./ha) from different treatments were calculated by multiplying grain yield (kg/ha) of a treatment with the minimum support price (Rs./kg) of the produce (paddy).

**3.7.6.2 Return over variable cost**

The return over variable cost (Rs./ha) of a treatment was estimated by subtracting its cost of cultivation (Rs./ha) from gross returns (Rs./ha) obtained from it.

**3.7.6.3 Benefit cost ratio (B: C)**

It was determined by the ratio of gross returns to cost of cultivation as given in the following formula.

$$\text{B: C} = \frac{\textit{Gross Return (Rs/ha)}}{\textit{Cost of cultivation (Rs./ha)}} \times 100$$

**3.7.7 Nutrient studies**

**3.7.7.1 Nitrogen content and uptake**

The grain and straw samples from each treatment collected after threshing were dried in oven at 65±5˚ C till a constant weight was achieved. The samples were then analysed for N, P, and K content following Kjeldahl's apparatus (Piper, 1966), Vanedomolybdo-phosphoric yellow colour method (Jackson, 1973) and Flame photometer method (Jackson, 1973), respectively. The uptake of N, P and K by rice grains and straw of each treatment was estimated by multiplying N, P and K contents with respective grain yield and then expressed as kg/ha.

**3.7.7.2 Nutrient use efficiency**

Nutrient use efficiency (NUE) of nitrogen was determined by dividing the total grain yield (kg/ha) by the quantity of the nutrient applied. Sometimes, it is also called partial factor productivity and is expressed as kg grain produced per kg of nutrient applied.

$$\text{NUE} = \frac{\text{Grain yield (kg/ha)}}{\text{Amount of nutrient added (kg/ha)}} \times 100$$

Different nitrogen use efficiency indices were worked out as per the following formulae given by Dobermann (2007).

**Agronomical efficiency (AE):** It denotes yield increase per unit of nitrogen applied and is expressed as:

$$\text{AE} = \frac{(\text{Y} - \text{Y}_\text{o})}{\text{F}}$$

Y = Yield of harvested portion of crop obtained with a given level of N applied;

$Y_o$= Yield obtained with reference level of N applied (90 kg/ha);

F = Amount of additional N applied

**Physiological efficiency (PE):** It is the additional biological yield obtained with a given N level over the yield obtained with reference N level per unit of additional nutrient uptake over the reference N level.

$$\text{PE} = \frac{(\text{BY}_\text{n} - \text{BY}_\text{o})}{(\text{U}_\text{n} - \text{U}_\text{o})}$$

$BY_n$= Biological yield obtained with a given N level;

$BY_0$= Biological yield obtained with reference N level;

$U_n$ = N uptake in aboveground crop biomass with a given N level;

$U_0$= N uptake in aboveground crop biomass with reference N level

**Agro physiological efficiency (APE):** It is the additional grain or economic yield obtained with a given N level over that obtained with the reference N level per unit of additional N uptake over the reference N level.

$$\text{APE} = \frac{(\text{Y} - \text{Y}_\text{o})}{(\text{U} - \text{U}_\text{o})}$$

Y = Yield (economic yield) of crop obtained with a given N level;

$Y_o$= Yield obtained with reference N level (90 kg/ha);

U = N uptake in aboveground crop biomass with given N level;

$U_o$= N uptake in aboveground crop biomass with reference N level

**Apparent Recovery Efficiency (ARE):** It is the difference in nutrient uptake in above-ground parts of the plant with a given N level and the reference N level relative to the quantity of N applied.

$$\text{ARE} = \frac{(\text{U} - \text{U}_\text{o})}{\text{F}}$$

U = N uptake in aboveground crop biomass with given N level;

$U_o$= N uptake in aboveground crop biomass with reference N level (90 kg/ha);

F = Amount of additional N applied;

**Utilization efficiency (UE):** It is the additional biological yield obtained with given N level over that with reference N level per unit of nutrient applied.

$$\text{UE} = \frac{(\text{BY}_\text{n} - \text{BY}_\text{o})}{\text{F}}$$

$BY_n$= Biological yield obtained with given N level;

$BY_o$= Biological yield obtained with reference N level;

U = N uptake in aboveground crop biomass with given N level;

F = Amount of additional N applied;

**Partial Nutrient Balance (PNB):** It is expressed as nutrient output per unit of nutrient input (a ratio of “removal to use”).

$$\text{PNB} = \frac{\text{U}_\text{H}}{\text{F}}$$

F = amount of additional nitrogen applied;

$U_H$= nitrogen content of harvested portion of the crop;

**Nutrient Efficiency Ratio (NER):** It is the total biomass produced per unit of nitrogen uptake.

$$\text{NER} = \frac{\text{BY}}{\text{U}}$$

BY= Biological yield;

U = N uptake in aboveground crop biomass with given N level.

**Nutrient Harvest Index (NHI):** It is the ratio (of nutrient uptake by grain or economic part) to total nutrient uptake by plant.

$$\text{NHI} = \frac{\text{Nutrient uptake by grain}}{\text{Total nitrogen uptake by crop biomass}}$$

**Nutrient Increment Efficiency (NIE):** It is the additional grain (economic) yield obtained with a given N level over that obtained with the previous N level per unit of preceding N level.

$$\text{NIE} = \frac{Y_n - Y_{n-1}}{Y_{n-1}}$$

$Y_n$= Grain yield obtained with $N_n$ amount of nitrogen,

$Y_{n-1}$= Grain yield obtained with $N_{n-1}$ amount of nitrogen

**Partial Production Efficiency (PPE):** It is the additional grain yield over the previous N level per unit of additional N applied over preceding N level. It is expressed in kg/kg.

$$\text{PPE} = \frac{GY_n - GY_{n-1}}{N_n - N_{n-1}}$$

$GY_n$= Grain yield obtained with $N_n$ amount of nitrogen,

$Y_{n-1}$= Grain yield obtained with $N_{n-1}$ amount of nitrogen

**3.8 Statistical Analysis**

The data on various parameters recorded during the crop season were subjected to statistical analysis using "Analysis of Variance" technique as described by Gomez and Gomez (1984). The significance of treatment effects was judged with the help of "F" (Variance ratio) test and critical difference (CD) was worked out at 5 per cent level of significance to compare the treatment effects or differences.

$$\text{CD} = \sqrt{\frac{\text{2 error of variance}}{n}} \times \text{t at 5 \% level of significance}$$

Where,

n = number of observations of that factor for which CD is to be calculated.

t = value of percentage point of 't' distribution for error degree of freedom at 5% level of significance

# CHAPTER–IV

## RESULTS

In this chapter, results of the present field experiment entitled "**Schedule of nitrogen application in rice (*Oryza sativa* L.) as influenced by planting time**" are described with the help of the data presented in form of tables and suitable illustrations under the following heads:

4.1 Phenological parameters

4.2 Growth parameters

4.3 Yield attributes

4.4 Yield parameters

4.5 Quality parameters

4.6 Nutrient use studies

4.7 Economics

### 4.1 Phenological parameters

The data pertaining to phenological parameters of rice crop as influenced by date of transplanting as well as dose and time of N application are presented in Table 4.1.

**Table 4.1: Phenological stages of the crop as influenced by transplanting time and schedule of N application**

| Treatment | Days to panicle initiation | | Days to 50% flowering | | Days to maturity | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **Time of transplanting** | | | | | | |
| $P_1$ | 92.0 | 88.0 | 115.0 | 108.0 | 145.0 | 138.0 |
| $P_2$ | 84.0 | 80.0 | 110.0 | 104.0 | 140.0 | 134.0 |
| $P_3$ | 75.0 | 72.0 | 101.0 | 95.0 | 131.0 | 124.0 |
| **Levels of N (kg/ha)** | | | | | | |
| $N_1$ | 83.6 | 80.0 | 108.6 | 102.3 | 138.6 | 132.0 |
| $N_2$ | 83.6 | 80.0 | 108.6 | 102.3 | 138.6 | 132.0 |
| $N_3$ | 83.6 | 80.0 | 108.6 | 102.3 | 138.6 | 132.0 |
| $N_4$ | 83.9 | 80.0 | 108.9 | 102.4 | 138.9 | 132.0 |
| **Time of N application** | | | | | | |
| $T_1$ | 83.6 | 80.0 | 108.6 | 102.3 | 138.6 | 132.0 |
| $T_2$ | 83.6 | 80.0 | 108.6 | 102.3 | 138.6 | 132.0 |
| $T_3$ | 83.6 | 80.0 | 108.6 | 102.3 | 138.6 | 132.0 |
| $T_4$ | 83.9 | 80.0 | 108.9 | 102.4 | 138.9 | 132.0 |

($P_1$: 3rd week of June, $P_2$: 1st week of July, $P_3$: 3rd week of July)

($N_1$: 90, $N_2$: 120, $N_3$: 150, $N_4$: 180 kg/ha)

($T_1$: ½ at transplanting + ½ at 21 DAT, $T_2$: ½ at 21 DAT + ½ at 42 DAT, $T_3$: 1/3 at transplanting + 1/3 at 21 DAT + 1/3 at 42 DAT and $T_4$: LCC based)

The data show that the crop phonological growth stages *viz.* panicle initiation, flowering and maturity were influenced markedly by time of transplanting whereas dose or time of N application had little effect. The crop transplanted earlier took more days to attain panicle initiation, flowering and maturity whereas the days taken to attain these stages were reduced with each delay in transplanting. During the two years, panicle initiation in late (3$^{rd}$ week of July) transplanted crop took 16-17 days less as compared to that in very early (3$^{rd}$ week of June) transplanted crop. Similarly the late transplanted crop took 13-14 days less to flower and 14 days less to mature as compared to very early planted crop. Compared to the very early transplanted crop, panicle initiation in the crop transplanted during first week of July occurred earlier by 8 days whereas both flowering and maturity were earlier by 4-5 days.

**4.2 Growth parameters**

**4.2.1 Plant height**

The data pertaining to plant height (cm) of the crop recorded at 30, 60, 90 days after transplanting (DAT) and at maturity (harvest) is presented in Table 4.2.1. A perusal of the data shows that plant height increased with the advancement of crop age and the increase was highest during the period from 30 to 60 DAT and minimum during the period from 90 DAT to maturity.

Plant height decreased significantly under very late transplanting as compared to earlier dates of transplanting (3$^{rd}$ week of June and 1$^{st}$ week of July) except at initial growth stage (30 DAT) when the plant height did not differ significantly due to time of transplanting. However, the plant height obtained with the two earlier dates of transplanting (3$^{rd}$ week of June and 1$^{st}$ week of July) remained at par at all the stages of the crop.

The plant height at 60 DAT, 90 DAT and maturity increased significantly with each successive increase in N application level, except that the height obtained with the highest dose (180 kg N/ha) was statistically at par with that obtained with 150 kg N/ha. However, the height at 30 DAT did not differ significantly due to variation in N application rate.

After 30 DAT, the plant height did not differ significantly due to difference in time of application of N in the crop. At 30 DAT, application of N in two equal splits 0 (basal) and 21 DAT or as per LCC schedule, being at par, resulted into more plant height than the N application in two equal splits at 21 and 42 DAT ($T_2$) or in three equal splits at 0, 21 and 42 DAT ($T_3$) during both the years.

**Table 4.2.1: Plant height (cm) at different growth stages of the crop as influenced by time of transplanting and schedule of N application**

| Treatment | 30 DAT | | 60 DAT | | 90 DAT | | Harvest | |
|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **Date of transplanting** | | | | | | | | |
| **$P_1$** | 57.7 | 61.2 | 103.1 | 102.9 | 121.4 | 117.7 | 122.1 | 118.0 |
| **$P_2$** | 58.9 | 61.1 | 102.2 | 102.1 | 119.3 | 119.6 | 120.3 | 119.8 |
| **$P_3$** | 61.3 | 60.3 | 97.5 | 95.7 | 101.5 | 99.7 | 106.5 | 100.7 |
| **CD (p= 0.05)** | NS | NS | 4.5 | 4.1 | 4.5 | 5.2 | 2.3 | 3.5 |
| **Levels of N (kg/ha)** | | | | | | | | |
| **$N_1$** | 58.0 | 59.6 | 88.4 | 87.8 | 99.5 | 100.9 | 101.7 | 101.2 |
| **$N_2$** | 58.4 | 60.5 | 101.3 | 100.1 | 115.2 | 111.6 | 117.7 | 112.1 |
| **$N_3$** | 58.7 | 60.6 | 107.4 | 106.6 | 120.6 | 118.0 | 122.2 | 118.5 |
| **$N_4$** | 59.4 | 62.8 | 106.8 | 106.4 | 120.9 | 118.8 | 124.5 | 119.3 |
| **CD (p= 0.05)** | NS | NS | 5.1 | 4.7 | 5.1 | 5.9 | 2.6 | 4.0 |
| **Time of N application** | | | | | | | | |
| **$T_1$** | 60.9 | 63.4 | 100.7 | 99.5 | 112.9 | 111.2 | 116.4 | 111.6 |
| **$T_2$** | 57.3 | 58.4 | 100.1 | 99.9 | 113.6 | 111.5 | 116.3 | 112.2 |
| **$T_3$** | 56.8 | 58.9 | 101.8 | 100.7 | 114.7 | 112.4 | 116.4 | 112.9 |
| **$T_4$** | 59.4 | 62.8 | 101.1 | 100.8 | 115.0 | 114.2 | 116.1 | 114.5 |
| **CD (p= 0.05)** | 2.3 | 2.9 | NS | NS | NS | NS | NS | NS |

NS= Not Significant

### 4.2.2 Number of tillers/m$^2$

The data pertaining to number of tillers/m$^2$ of the crop recorded at 30, 60, 90 DAT and maturity presented in Table 4.2.2 show that the tiller number increased with the crop age up to 60 DAT and declined thereafter. During both the years, numbers of the tillers/m$^2$ were influenced significantly by time of transplanting. The tiller number at 60, 90 and maturity decreased significantly under late transplanting as compared to earlier dates of transplanting (3$^{rd}$ week of June and 1$^{st}$ week of July) whereas the number of tillers at initial growth stage (30 DAT) did not vary due to the time of transplanting. However, number of tillers obtained with the two earlier dates of transplanting remained at par at all the stages of the crop.

The number of tillers at 60 DAT onwards increased significantly with each successive increase in N application level, except that the number of tillers obtained with the highest dose (180 kg N/ha) was statistically at par with that obtained with 150 kg N/ha during both the years. However, the number of tillers at 30 DAT did not differ significantly due to variation in N application dose.

Number of tillers also differed significantly due to difference in time of application of N in the crop and the trends were similar during both the years. Application of N in three equal splits at 0 (basal), 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$), being at par, resulted into the highest number of tillers, followed by application of N in two equal splits at 21 and 42 DAT ($T_2$) whereas the tiller number was the lowest when N was applied in two equal splits at 0 and 21 DAT ($T_1$).

**Table 4.2.2 Number of tillers/m$^2$ at different stages of rice crop as influenced by transplanting time and N application schedule**

| Treatment | 30 DAT | | 60 DAT | | 90 DAT | | Harvest | |
|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **Date of transplanting** | | | | | | | | |
| **$P_1$** | 72 | 67 | 308 | 278 | 258 | 238 | 248 | 229 |
| **$P_2$** | 68 | 65 | 297 | 270 | 256 | 235 | 248 | 227 |
| **$P_3$** | 67 | 65 | 268 | 234 | 231 | 200 | 220 | 189 |
| **CD (p= 0.05)** | NS | NS | 13 | 9 | 10 | 7 | 9 | 7 |
| **Levels of N (kg/ha)** | | | | | | | | |
| **$N_1$** | 69 | 65 | 260 | 233 | 223 | 200 | 213 | 190 |
| **$N_2$** | 67 | 64 | 289 | 260 | 248 | 224 | 238 | 214 |
| **$N_3$** | 69 | 66 | 311 | 271 | 261 | 235 | 250 | 226 |
| **$N_4$** | 70 | 67 | 308 | 278 | 262 | 238 | 254 | 230 |
| **CD (p= 0.05)** | NS | NS | 15 | 10 | 11 | 8 | 11 | 8 |
| **Time of N application** | | | | | | | | |
| **$T_1$** | 71 | 68 | 271 | 244 | 233 | 209 | 223 | 199 |
| **$T_2$** | 65 | 61 | 285 | 255 | 245 | 221 | 236 | 212 |
| **$T_3$** | 69 | 66 | 299 | 268 | 257 | 233 | 248 | 224 |
| **$T_4$** | 71 | 68 | 306 | 275 | 259 | 234 | 248 | 225 |
| **CD (p= 0.05)** | 3 | 4 | 12 | 10 | 9 | 9 | 9 | 9 |

### 4.2.3 Dry matter accumulation

A perusal of data presented in Table 4.2.3 reveals that dry matter accumulation in terms of dry weight (g/m$^2$) of the crop increased with the advancement of crop age and maximum dry weight was attained at the crop maturity. Maximum increase in the dry weight occurred during the period from 30 to 60 DAT and minimum during the period from 90 DAT to maturity during both the years. At all the stages, the crop dry weight (g/m$^2$) decreased significantly when the crop was transplanted very late (3$^{rd}$ week of July) than when transplanted earlier (3$^{rd}$ week of June and 1$^{st}$ week of July) except at initial growth stage (30 DAT) when the dry weight did not differ significantly due to time of transplanting. However, the dry weight obtained with the two earlier dates of transplanting (3$^{rd}$ week of June and 1$^{st}$ week of July) remained at par at all the stages of the crop.

The dry matter accumulation at 60 DAT, 90 DAT and maturity increased significantly with each successive increase in N application rate, except that the dry weight (g/m$^2$) obtained with the highest dose (180 kg N/ha) and with 150 kg N/ha was statistically at par. However, dry matter accumulation at 30 DAT did not differ significantly due to variation in N application rate.

Dry matter accumulation also differed significantly due to variation in time of N application to the crop. Application of N in three equal splits at 0, 21 and 42 DAT, being at par with LCC based N application, resulted into the highest dry weight of the crop which was significantly higher than that obtained with N application in two equal splits at 0 and 21 DAT ($T_1$) or at 21 and 42 DAT ($T_2$) during both the years. Among the latter two timings of N application, the dry weight was significantly higher with $T_2$ than with $T_1$.

**Table 4.2.3 Dry weight (g/m$^2$) of crop plants at different stages of rice crop as influenced by transplanting time and schedule of N application**

| Treatment | 30 DAT | | 60 DAT | | 90 DAT | | Harvest | |
|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **Date of transplanting** | | | | | | | | |
| **$P_1$** | 139 | 152 | 1157 | 1013 | 1517 | 1337 | 1760 | 1524 |
| **$P_2$** | 138 | 156 | 1135 | 1000 | 1481 | 1331 | 1710 | 1519 |
| **$P_3$** | 127 | 153 | 771 | 612 | 988 | 801 | 1147 | 916 |
| **CD (p= 0.05)** | NS | NS | 56 | 67 | 71 | 59 | 54 | 37 |
| **Levels of N (kg/ha)** | | | | | | | | |
| **$N_1$** | 133 | 153 | 861 | 713 | 1129 | 962 | 1314 | 1106 |
| **$N_2$** | 139 | 156 | 1024 | 852 | 1322 | 1129 | 1530 | 1291 |
| **$N_3$** | 134 | 153 | 1103 | 963 | 1419 | 1259 | 1633 | 1425 |
| **$N_4$** | 133 | 154 | 1096 | 970 | 1445 | 1274 | 1678 | 1456 |
| **CD (p= 0.05)** | NS | NS | 64 | 77 | 82 | 68 | 62 | 42 |
| **Time of N application** | | | | | | | | |
| **$T_1$** | 139 | 158 | 933 | 790 | 1202 | 1066 | 1398 | 1225 |
| **$T_2$** | 123 | 146 | 1010 | 861 | 1299 | 1130 | 1505 | 1295 |
| **$T_3$** | 136 | 154 | 1070 | 918 | 1409 | 1208 | 1623 | 1375 |
| **$T_4$** | 141 | 158 | 1071 | 929 | 1405 | 1220 | 1630 | 1383 |
| **CD (p= 0.05)** | 6 | 7 | 54 | 67 | 69 | 57 | 70 | 62 |

## 4.3 Yield attributes

### 4.3.1 Panicle length

The data on panicle length (Table 4.3) revealed that the length of rice panicle was significantly higher with earlier transplanting (3$^{rd}$ week of June and 1$^{st}$ week of July) and reduced significantly under late planting during both the years. However, panicle length obtained with the two earlier dates of transplanting was statistically similar. But the panicle length did not differ significantly due to variation in N application rate and time of N application during both the years.

**4.3.2 Number of panicles/m$^2$**

Transplanting time had significant effect on number of effective tillers or panicles/m$^2$ (Table 4.5). The panicle number/m$^2$ reduced significantly when transplanting was delayed beyond first week of July during both the years. However, number of panicles/m$^2$ obtained with the two earlier dates of transplanting (3$^{rd}$ week of June and 1$^{st}$ week of July) remained at par during both the years.

Rates of N application had significant influence on number of panicles/m$^2$. Each successive increase in rate of N application from 90 to 180 kg N/ha increased the panicle number significantly during both the years. However, the difference in number of panicles obtained with 150 and 180 kg N/ha was not significant.

Time of N application also had significant impact on number of panicles/m$^2$ of the crop. The highest numbers of panicles were obtained when N was applied equally in three splits at 0, 21 and 42 DAT or as per LCC schedule and were significantly higher in comparison, when N was applied in two equal splits at 21 and 42 DAT or 0 and 21 DAT during both the years. Further the crop supplied with N in two equal splits at 21 and 42 DAT had significantly more panicles/m$^2$ than the crop supplied with N at 0, and 21 DAT. The panicle number did not vary significantly when N was applied in three splits or as per LCC.

**Table 4.3. Yield attributes of rice as influenced by transplanting time and schedule of N application**

| Treatment | Panicle length (cm) | | No. of panicles/m$^2$ | | No. of grains/ panicle | | 1000-grain weight (g) | |
|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **Date of transplanting** | | | | | | | | |
| $P_1$ | 25.0 | 24.5 | 243.0 | 225.3 | 137.8 | 134.4 | 26.8 | 25.2 |
| $P_2$ | 24.5 | 24.2 | 242.9 | 222.5 | 133.7 | 136.7 | 26.6 | 25.7 |
| $P_3$ | 23.4 | 23.3 | 217.8 | 188.1 | 98.2 | 92.4 | 26.4 | 26.2 |
| **CD (p= 0.05)** | 0.7 | 0.6 | 8.3 | 6.4 | 4.2 | 3.6 | NS | NS |
| **Levels of N (kg/ha)** | | | | | | | | |
| $N_1$ | 23.7 | 23.4 | 209.8 | 188.2 | 118.3 | 116.6 | 26.2 | 25.6 |
| $N_2$ | 24.5 | 24.1 | 234.7 | 211.1 | 123.9 | 120.8 | 26.8 | 25.2 |
| $N_3$ | 24.4 | 24.2 | 245.3 | 222.9 | 124.8 | 123.6 | 26.4 | 25.9 |
| $N_4$ | 24.6 | 24.3 | 248.6 | 225.8 | 125.8 | 123.6 | 27.0 | 26.2 |
| **CD (p= 0.05)** | NS | NS | 9.6 | 7.4 | 4.8 | 4.1 | NS | NS |
| **Time of N application** | | | | | | | | |
| $T_1$ | 24.1 | 23.7 | 220.3 | 197.5 | 120.9 | 118.6 | 26.3 | 25.7 |
| $T_2$ | 24.4 | 24.1 | 232.2 | 208.8 | 124.0 | 121.6 | 26.6 | 25.7 |
| $T_3$ | 24.6 | 24.2 | 242.8 | 220.8 | 124.2 | 122.2 | 26.7 | 25.6 |
| $T_4$ | 24.2 | 24.0 | 243.1 | 220.9 | 123.7 | 122.3 | 26.9 | 25.8 |
| **CD (p= 0.05)** | NS | NS | 8.2 | 7.8 | NS | NS | NS | NS |

### 4.3.3 Number of grains/panicle

The data (Table 4.3) revealed that time of transplanting had significant effect on number of grains/panicle and the effect was similar during both the years. The grains number per panicle were higher in early planting (up to 1$^{st}$ week of July) and reduced significantly when transplanting was delayed to third week of July. However, the number of grains/panicle did not differ significantly when the planting was done either during 3$^{rd}$ week of June or 1$^{st}$ week of July.

An examination of data revealed that number of grains/panicle increased significantly with increase in dose of applied N from 90 to 120, 150 and 180 kg N/ha during both the years. However, number of grains/panicle did not increase significantly when N application rate was increased beyond 120 kg N/ha. But the number of grains/panicle was not affected significantly due to variation in time of N application.

### 4.3.4 1000-grain weight

Test weight (1000-grain weight) of the crop was not influenced significantly due to change in transplanting time during both the years (Table 4.3). Similarly N application rates and time of N application had no significant influence on 1000-grain weight.

## 4.4 Yield parameters

### 4.4.1 Grain yield

Grain yield (averaged over N application schedule) of the crop was influenced by time of transplanting (Table 4.4.1.1). The highest grain yield was obtained with the early planting (3$^{rd}$ week of June or 1$^{st}$ week of July) and the yield reduced significantly under late planting (3$^{rd}$ week of July) during both the years. However, the yield obtained with the earliest planting (3$^{rd}$ week of June) was found to be at par with yield obtained with planting during first week of July. During the two years, grain yield of the crop transplanted late was reduced by 36 to 41 per cent as compared to the crop transplanted very early (3$^{rd}$ week of June) whereas the reduction in the grain yield was 34 to 42 per cent as compared to the crop planted during first week of July.

A significant influence of N application levels was observed on the mean grain yield (averaged over transplanting time or time of N application) of rice crop and the effect was in similar fashion during both the years. A significant increase in grain yield was observed with each successive increase in N application rate up to 150 kg N/ha. However, the yield did not increase significantly when N supply was increased from 150 to 180 kg N/ha. The lowest grain yield was recorded with application of 90 kg N/ha. During the two years, maximum increase in the yield (14.5-16.0 %) was recorded when N supply was increased from 90 kg to 120 kg whereas the increase was reduced to 7.6-9.3 % when N supply was increased from 120 kg to 150 kg/ha with little increase in the yield when N supply was increased further to 180 kg/ha.

**Table 4.4.1.1 Yield parameters of rice crop as influenced by transplanting time and schedule of N application**

| Treatment | Grain yield (kg/ha) | | Straw yield (kg/ha) | | Biological yield (kg/ha) | | Harvest Index (%) | |
|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **Date of transplanting** | | | | | | | | |
| $P_1$ | 7130 | 6803 | 8048 | 7617 | 15178 | 14420 | 46.99 | 47.20 |
| $P_2$ | 6962 | 6924 | 7870 | 7711 | 14831 | 14635 | 46.95 | 47.36 |
| $P_3$ | 4564 | 4016 | 5129 | 4452 | 9693 | 8468 | 47.01 | 47.58 |
| **CD (p= 0.05)** | 208 | 204 | 261 | 297 | 470 | 486 | NS | NS |
| **Levels of N (kg/ha)** | | | | | | | | |
| $N_1$ | 5312 | 5055 | 6083 | 5571 | 11396 | 10625 | 46.50 | 47.75 |
| $N_2$ | 6162 | 5791 | 6910 | 6412 | 13073 | 12204 | 47.23 | 47.54 |
| $N_3$ | 6630 | 6332 | 7403 | 7093 | 14033 | 13425 | 47.28 | 47.18 |
| $N_4$ | 6770 | 6478 | 7666 | 7299 | 14436 | 13777 | 46.92 | 47.05 |
| **CD (p= 0.05)** | 241 | 235 | 302 | 343 | 543 | 561 | NS | NS |
| **Time of N application** | | | | | | | | |
| $T_1$ | 5777 | 5461 | 6472 | 6058 | 12249 | 11519 | 47.13 | 47.52 |
| $T_2$ | 6154 | 5768 | 6929 | 6458 | 13083 | 12225 | 47.02 | 47.33 |
| $T_3$ | 6478 | 6210 | 7341 | 6882 | 13818 | 13092 | 46.87 | 47.50 |
| $T_4$ | 6466 | 6218 | 7321 | 6976 | 13787 | 13194 | 46.90 | 47.15 |
| **CD (p= 0.05)** | 172 | 177 | 220 | 227 | 391 | 387 | NS | NS |

When averaged over transplanting time or N levels, grain yield also differed significantly due to difference in time of N application in the crop. Application of N in three equal splits at 0, 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$), being at par, gave significantly higher grain yield than the N application in two equal splits at 0 and 21 DAT ($T_1$) or at 21 and 42 DAT ($T_2$) during both the years. Supply of N in two equal splits at 21 and 42 DAT proved better than N supply in two equal splits at 0 and 21 DAT as it gave significantly higher grain yield than the latter.

The interactional effect of transplanting time and level of N application on grain yield of rice was found significant during both the years (Table 4.4.1.2) which revealed that the yield of the crop transplanted during third week of June ($P_1$) or first week of July ($P_2$) increased significantly with each increase N application levels up to 150 kg N/ha but the late planted (3$^{rd}$ week of July) crop responded (in terms of grain yield) significantly up to 180 kg N/ha. However, the highest grain yield was obtained when the crop was transplanted earlier (up to 1$^{st}$ week of July) and supplied with 150 or 180 kg N/ha. Under all the levels of N application, the crop yield obtained with the two earlier timings of transplanting remained at par but both these timings proved better than the late transplanting under all the levels of N supply. Hence the late transplanted rice crop can be supplied with higher dose of N (180 kg/ha) to increase its yield than the early transplanted crop in which 150 kg N/ha is sufficient for obtaining higher yield.

**Table 4.4.1.2 Interactional effect of transplanting time and levels of N application on grain yield (kg/ha) of rice crop**

| Time of transplanting | Levels of N application (kg/ha) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | | | | | 2018 | | | | |
| | $N_1$ | $N_2$ | $N_3$ | $N_4$ | Mean | $N_1$ | $N_2$ | $N_3$ | $N_4$ | Mean |
| $P_1$ | 6403 | 7093 | 7513 | 7512 | 7130 | 6156 | 6728 | 7157 | 7169 | 6803 |
| $P_2$ | 6248 | 6920 | 7339 | 7339 | 6962 | 6211 | 6810 | 7329 | 7344 | 6924 |
| $P_3$ | 3286 | 4473 | 5037 | 5460 | 4564 | 2797 | 3835 | 4510 | 4922 | 4016 |
| Mean | 5312 | 6162 | 6630 | 6770 | | 5055 | 5791 | 6332 | 6478 | |
| CD (p=0.05) | 417 | | | | | 408 | | | | |

**4.4.2 Straw yield**

Mean straw yield (averaged over N application schedule) of the crop was influenced by time of transplanting (Table 4.4.1.1). The highest straw yield was obtained with the early transplanting (3rd week of June or 1st week of July) and the yield reduced significantly under late planting (3rd week of July) during both the years. However, the earliest planting ($P_1$) was found to be at par with the planting during first week of July ($P_2$) in respect of straw yield.

There was significant increase in straw yield with each increase in N levels from 90 to 180 kg N/ha (Table 4.4.1.1). However, the straw yield with N levels of 150 and 180 kg /ha was statistically at par during both the years The lowest straw yield was recorded with application of 90 kg N/ha.

The straw yield was also affected significantly by time of N application (Table 4.4.1.1). The highest yield was obtained with application of N in three equal splits at 0, 21 and 42 DAT ($T_3$) which, though at par with LCC based N application, gave significantly higher yield than the N application in two splits.

**4.4.3. Biological yield**

The data on biological yield of rice crop presented in Table 4.4.1.1 show that biological yield was higher with early transplanting ($P_1$ and $P_2$) of rice crop but decreased significantly under late planting ($P_3$) during both the years. The biological yield with earlier dates of transplanting (3rd week of June and 1st week of July) was, however, at par.

The biological yield increased significantly with each increase in N levels up to 180 kg/ha (Table 4.4.1.1). However, the yield observed in the crop receiving 180 kg N/ha was at par with that obtained with 150 kg N/ha. The lowest biological yield was observed in the crop receiving 90 kg N/ha.

Biological yield differed significantly due to difference in time of application of N (Table 4.4.1.1) in the rice crop. But application of N in three splits (1/3 basal + 1/3 21 DAT + 1/3 42 DAT) or as per LCC schedule ($T_4$), being at par, resulted into significantly higher biological yield than the N application in two equal splits at 21 and 42 DAT ($T_2$) during both the years. The lowest yield was observed when N was applied in two equal splits at 0 and 21 DAT ($T_1$).

**4.4.4 Harvest index**

Harvest index (Table 4.4.1.1), the ratio of grain yield to biological yield, did not vary significantly due to change in transplanting time of the crop. Similarly the harvest index remained significantly un-affected by N application schedule (dose and time).

**4.5 Quality parameters**

The data pertaining to grain quality parameters *viz*. kernel length, hulling percentage, milling percentage and head rice recovery are presented in Table 4.5 and is explained under following heads.

**4.5.1 Kernel length**

Effect of different transplanting time on kernel length was found to be non-significant during both the years. Moreover, the kernel length did not differ significantly due to variation in N application schedule.

**4.5.2 Length breadth ratio**

Effect of different transplanting time on kernel length: breadth was found to be non-significant during both the years. Moreover, the kernel length: breadth did not differ significantly due to variation in N application schedule.

**4.5.3 Hulling percentage**

Hulling recovery from rice grains (paddy) was improved with delay in transplanting of the crop. Late transplanting (3$^{rd}$ week of July) resulted into the highest hulling percentage and proved significantly better than earlier planting. The hulling recovery observed with the two earlier transplanting i.e. 3$^{rd}$ week of June and 1$^{st}$ week of July did not differ significantly. The hulling recovery was not influenced significantly due to variation in the schedule of N application (both dose and time).

**4.5.4 Milling percentage**

Like hulling percentage, the milling recovery of rice grains was improved by delay in transplanting and the recovery was the highest when the crop was transplanted during third week of July. But the crop transplanted during 3$^{rd}$ week of June and 1$^{st}$ week of July was statistically at par in respect of the milling recovery. The milling recovery was not influenced significantly due to variation in the schedule of N application.

### 4.5.5 Head rice recovery

Head rice recovery (HRR) improved significantly with each delay in transplanting and the highest HRR was recorded under late planting (3rd week of July), followed by that under early planting ($P_2$) whereas the lowest recovery was recorded under very early planting ($P_1$) during both the years. The data further revealed that HRR was not influenced significantly by schedule of N application (both dose and time) in rice.

**Table 4.5. Quality parameters of rice as influenced by transplanting time and schedule of N application**

| Treatment | Kernel length (mm) | | Length: Breadth | | Hulling Recovery (%) | | Milling Recovery (%) | | Head Rice Recovery (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **Date of transplanting** | | | | | | | | | | |
| $P_1$ | 6.75 | 6.91 | 3.08 | 3.39 | 76.35 | 73.38 | 68.83 | 67.98 | 53.06 | 50.67 |
| $P_2$ | 6.87 | 6.88 | 3.03 | 3.36 | 76.66 | 73.28 | 69.17 | 68.33 | 55.92 | 52.69 |
| $P_3$ | 6.73 | 7.05 | 2.99 | 3.24 | 77.48 | 73.95 | 69.77 | 69.40 | 58.54 | 55.79 |
| **CD (p= 0.05)** | NS | NS | NS | NS | 0.32 | 0.51 | 0.53 | 0.54 | 2.02 | 1.57 |
| **Levels of N (kg/ha)** | | | | | | | | | | |
| $N_1$ | 6.75 | 6.90 | 3.00 | 3.28 | 76.61 | 73.58 | 69.37 | 69.03 | 55.35 | 54.39 |
| $N_2$ | 6.87 | 7.04 | 3.06 | 3.38 | 76.75 | 73.28 | 68.75 | 68.28 | 55.33 | 52.28 |
| $N_3$ | 6.74 | 6.90 | 2.97 | 3.31 | 77.06 | 73.75 | 69.39 | 68.31 | 56.29 | 52.31 |
| $N_4$ | 6.77 | 7.02 | 3.11 | 3.33 | 76.97 | 74.11 | 69.50 | 68.67 | 56.39 | 53.25 |
| **CD(p= 0.05)** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Time of N application** | | | | | | | | | | |
| $T_1$ | 6.77 | 6.95 | 2.99 | 3.37 | 76.83 | 73.67 | 69.19 | 68.56 | 56.36 | 52.72 |
| $T_2$ | 6.81 | 6.96 | 2.97 | 3.37 | 76.89 | 73.75 | 69.31 | 68.64 | 55.86 | 53.00 |
| $T_3$ | 6.79 | 6.96 | 3.13 | 3.27 | 76.89 | 73.72 | 69.17 | 68.41 | 55.67 | 53.33 |
| $T_4$ | 6.76 | 6.99 | 3.03 | 3.31 | 76.78 | 73.58 | 69.36 | 68.67 | 55.47 | 53.16 |
| **CD (p= 0.05)** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

## 4.6 Nutrient uptake studies

### 4.6.1 Nutrient (NPK) content in grain

The data on content of nutrients (N, P and K) in rice grain as influenced by transplanting time and N application schedule (Table 4.6.1) showed that N content (%) in the grain was significantly lower under late transplanting as compared to that under earlier transplanting (3rd week of June and 1st week of July) whereas the N content under the two early plantings was found to be at par during both the years. But P and K content of the grain did not vary significantly due to change in transplanting time of the crop.

The grain N content registered a significant increase with each successive increase in the level of applied N and hence the highest N content was observed when the crop was supplied with the highest dose of N (180 kg/ha). The increase in N application rate had no significant effect on the P and K content of the grain.

Content of N in the grain was influenced significantly by the time of N application in the crop. Application of N in three equal splits (0, 21 and 42 DAT) or as per LCC, being at par with each other, resulted into significantly higher grain N content, followed by N application in two splits at 21 and 42 DAT ($T_2$) whereas the N content was the lowest when N was applied in two equal splits at 0 and 21 DAT ($T_1$). But contents of P and K in rice grain recorded under different time of N application did not vary significantly among themselves.

**Table 4.6.1 Nutrient content in rice grain as influenced by transplanting time and schedule of N application in rice crop**

| Treatment | Nutrient (NPK) content in grain (%) | | | | | |
|---|---|---|---|---|---|---|
| | N | | P | | K | |
| | 2017 | 2018 | 2017 | 2017 | 2018 | 2017 |
| **Date of transplanting** | | | | | | |
| $P_1$ | 1.61 | 1.58 | 0.43 | 0.42 | 0.19 | 0.20 |
| $P_2$ | 1.61 | 1.59 | 0.43 | 0.41 | 0.19 | 0.19 |
| $P_3$ | 1.35 | 1.33 | 0.38 | 0.41 | 0.20 | 0.18 |
| **CD (p= 0.05)** | 0.02 | 0.02 | NS | NS | NS | NS |
| **Levels of N (kg/ha)** | | | | | | |
| $N_1$ | 1.21 | 1.18 | 0.40 | 0.39 | 0.20 | 0.18 |
| $N_2$ | 1.51 | 1.49 | 0.41 | 0.41 | 0.19 | 0.18 |
| $N_3$ | 1.68 | 1.67 | 0.42 | 0.43 | 0.19 | 0.20 |
| $N_4$ | 1.70 | 1.67 | 0.42 | 0.42 | 0.19 | 0.20 |
| **CD (p= 0.05)** | 0.03 | 0.02 | NS | NS | NS | NS |
| **Time of N application** | | | | | | |
| $T_1$ | 1.40 | 1.37 | 0.40 | 0.39 | 0.19 | 0.18 |
| $T_2$ | 1.45 | 1.43 | 0.40 | 0.39 | 0.19 | 0.19 |
| $T_3$ | 1.62 | 1.60 | 0.42 | 0.43 | 0.20 | 0.19 |
| $T_4$ | 1.63 | 1.60 | 0.43 | 0.44 | 0.19 | 0.20 |
| **CD (p= 0.05)** | 0.02 | 0.01 | NS | NS | NS | NS |

**4.6.2 Nutrient (NPK) content in straw**

Data on content of nutrients (N, P and K) in straw of rice crop under different transplanting time and N application schedule (Table 4.6.2) showed that the contents of N were significantly higher when the crop was transplanted earlier (up to 1$^{st}$ week of July) but decreased significantly under late planted conditions ($P_3$) during both the years However, the straw N content observed with earlier planting time *viz*. $P_1$ and $P_2$ did not differ significantly.

But contents of P and K in the straw were not affected significantly due to change in transplanting time.

The straw N content increased significantly with each increase in level of N supply to the crop. The highest N content in straw was observed in crop receiving 180 kg N/ha whereas it was the lowest with 90 kg N/ha. On the other hand, concentration of P and K in was not influenced significantly by levels of N supply. The effects were similar during both the years.

Time of N application also had significant effect on the straw N content but had no effect on contents of P and K in the straw. The straw N concentration was at par when N was applied in three equal splits ($T_1$) or as per LCC schedule ($T_4$) but decreased significantly when N was applied in two splits at 21 and 42 DAT and further decreased significantly when N was applied in two equal splits at 0 and 21 DAT. The results were similar during both the years.

**Table 4.6.2 Nutrient (NPK) content in rice straw as influenced by transplanting time and schedule of N application in rice crop**

| Treatment | Nutrient content (%) | | | | | |
|---|---|---|---|---|---|---|
| | N | | P | | K | |
| | 2017 | 2018 | 2017 | 2017 | 2018 | 2017 |
| **Date of transplanting** | | | | | | |
| **$P_1$** | 0.45 | 0.43 | 0.13 | 0.13 | 1.75 | 1.71 |
| **$P_2$** | 0.44 | 0.42 | 0.14 | 0.13 | 1.75 | 1.71 |
| **$P_3$** | 0.33 | 0.31 | 0.14 | 0.14 | 1.73 | 1.69 |
| **CD (p= 0.05)** | 0.02 | 0.02 | NS | NS | NS | NS |
| **Levels of N (kg/ha)** | | | | | | |
| **$N_1$** | 0.37 | 0.35 | 0.13 | 0.13 | 1.75 | 1.71 |
| **$N_2$** | 0.39 | 0.37 | 0.14 | 0.13 | 1.75 | 1.70 |
| **$N_3$** | 0.42 | 0.40 | 0.14 | 0.13 | 1.74 | 1.69 |
| **$N_4$** | 0.45 | 0.43 | 0.14 | 0.14 | 1.73 | 1.69 |
| **CD (p= 0.05)** | 0.03 | 0.02 | NS | NS | NS | NS |
| **Time of N application** | | | | | | |
| **$T_1$** | 0.36 | 0.34 | 0.14 | 0.13 | 1.75 | 1.71 |
| **$T_2$** | 0.40 | 0.37 | 0.14 | 0.14 | 1.75 | 1.70 |
| **$T_3$** | 0.43 | 0.41 | 0.13 | 0.13 | 1.74 | 1.70 |
| **$T_4$** | 0.44 | 0.42 | 0.14 | 0.13 | 1.74 | 1.69 |
| **CD (p= 0.05)** | 0.02 | 0.02 | NS | NS | NS | NS |

### 4.6.3 Nutrient (NPK) uptake in grain

The data pertaining to uptake of N, P and K (kg/ha) by rice grains revealed that uptake of N, P and K by grains differed significantly due to change in transplanting time and N application schedule (Table 4.6.3) and the results were similar during both the years.

Uptake of all the nutrients (N, P and K) was found to decrease significantly under late transplanting ($P_3$) as compared to earlier planting schedule. However, the uptake of N, P and K by grain was statistically similar under both the early transplanting schedules ($P_1$ and $P_2$).

The grain uptake of N, P and K registered an increase with each successive increase in level of N supply to the crop but the increase was significant up to N supply rate of 150 kg/ha as the uptake with the highest rate (180 kg N/ha) was statistically similar to that with 150 kg N/ha. The lowest uptake was recorded by the crop receiving 90 kg N/ha.

The uptake of all the nutrients was at par when N was applied in three equal splits at 0, 21 and 42 DAT ($T_3$) or per LCC schedule ($T_4$) but decreased significantly when N was applied in two splits at 21 and 42 DAT. The lowest uptake was observed when N was applied in two splits at 0 and 21 DAT ($T_1$).

**Table 4.6.3 Nutrient uptake in rice grain as influenced by transplanting time and schedule of N application in rice crop**

| Treatment | Nutrient uptake in grain (kg/ha) | | | | | |
|---|---|---|---|---|---|---|
| | N | | P | | K | |
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **Date of transplanting** | | | | | | |
| $P_1$ | 116 | 109 | 30.8 | 28.6 | 13.9 | 13.8 |
| $P_2$ | 114 | 111 | 29.9 | 28.6 | 13.5 | 13.5 |
| $P_3$ | 63 | 55 | 17.6 | 16.7 | 9.3 | 10.5 |
| **CD (p= 0.05)** | 3 | 3 | 0.9 | 0.8 | 0.6 | 0.4 |
| **Levels of N (kg/ha)** | | | | | | |
| $N_1$ | 66 | 62 | 21.7 | 20.0 | 10.7 | 9.4 |
| $N_2$ | 94 | 88 | 25.7 | 24.4 | 11.8 | 10.8 |
| $N_3$ | 114 | 108 | 28.2 | 27.0 | 13.0 | 12.8 |
| $N_4$ | 117 | 110 | 28.9 | 27.0 | 13.2 | 13.1 |
| **CD (p= 0.05)** | 4 | 3 | 1.0 | 0.9 | 0.7 | 0.6 |
| **Time of N application** | | | | | | |
| $T_1$ | 84 | 78 | 23.5 | 21.5 | 10.8 | 10.1 |
| $T_2$ | 92 | 86 | 25.2 | 22.6 | 12.1 | 11.3 |
| $T_3$ | 107 | 101 | 27.8 | 26.7 | 12.9 | 12.3 |
| $T_4$ | 108 | 102 | 28.1 | 26.8 | 12.9 | 12.6 |
| **CD (p= 0.05)** | 3 | 5 | 0.8 | 0.7 | 0.5 | 0.4 |

### 4.6.4. Nutrient (NPK) uptake in straw

The data pertaining to nutrient (NPK) uptake (kg/ha) by rice straw presented in Table 4.6.4 revealed that the uptake of all the nutrients, while remaining at par under the two early transplanting schedules ($P_1$ and $P_2$), decreased significantly under late transplanting ($P_3$) during both the years.

Uptake of N in the straw improved significantly with each successive increase in dose of N and the highest uptake of N was observed with 180 kg N/ha. The uptake of P and K also increased with each increase in N application rates but the increase was significant with increase in the rate up to 150 kg N/ha as the uptake obtained with 180 kg N/ha was at par with that obtained with 150 kg N/ha. The lowest nutrient uptake was recorded by the crop receiving 90 kg N/ha.

The highest straw uptake of all the nutrients was observed when N was applied in three equal splits at 0, 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$) which was significantly higher than that obtained with N application in two equal splits at 21 and 42 DAT ($T_2$) or at 0 and 21 DAT (T1). The lowest uptake was recorded with $T_1$ which was significantly lower than that with $T_2$.

**Table 4.6.4 Nutrient uptake in rice straw as influenced by transplanting time and schedule of N application in rice crop**

| Treatment | Nutrient uptake in straw (kg/ha) | | | | | |
|---|---|---|---|---|---|---|
| | N | | P | | K | |
| | 2017 | 2018 | 2017 | 2018 | 2018 | 2017 |
| **Date of transplanting** | | | | | | |
| **$P_1$** | 36.0 | 32.6 | 10.3 | 9.8 | 141 | 130 |
| **$P_2$** | 35.1 | 32.5 | 11.0 | 10.0 | 137 | 132 |
| **$P_3$** | 17.9 | 14.7 | 7.7 | 6.7 | 89 | 75 |
| **CD (p= 0.05)** | 2.3 | 2.0 | 0.9 | 0.8 | 4 | 6 |
| **Levels of N (kg/ha)** | | | | | | |
| **$N_1$** | 23.0 | 20.0 | 7.7 | 7.5 | 106 | 96 |
| **$N_2$** | 28.7 | 25.5 | 9.4 | 8.8 | 121 | 110 |
| **$N_3$** | 32.1 | 29.5 | 10.4 | 9.4 | 129 | 120 |
| **$N_4$** | 34.2 | 31.8 | 10.8 | 9.7 | 133 | 124 |
| **CD (p= 0.05)** | 3.0 | 2.8 | 0.9 | 0.5 | 5 | 7 |
| **Time of N application** | | | | | | |
| **$T_1$** | 25.2 | 22.4 | 8.9 | 8.1 | 113 | 104 |
| **$T_2$** | 28.3 | 24.6 | 9.5 | 8.8 | 121 | 111 |
| **$T_3$** | 31.8 | 29.5 | 10.0 | 9.2 | 128 | 117 |
| **$T_4$** | 32.7 | 30.4 | 10.1 | 9.3 | 127 | 118 |
| **CD (p= 0.05)** | 2.2 | 2.0 | 0.5 | 0.3 | 4 | 5 |

### 4.6.5 Nitrogen use efficiency

The data pertaining to nitrogen use efficiency of the crop presented in Table 4.6.5 revealed that the nitrogen use efficiency of the crop differed significantly due to the transplanting time and schedule of N application in rice crop. Nitrogen use efficiency was significantly higher (47.1 to 55.5 kg/kg N) under earlier schedules of transplanting (3rd week of June and 1st week of July) as compared to late transplanting during both the years. The efficiency was, however, at par in the two early schedules.

The N-use efficiency decreased progressively with each successive increase in the dose of applied N to the crop during both the years and the highest efficiency (49.9 to 59.0 kg/kg N) was achieved with the lowest dose of N (90 kg/ha).

The efficiency of N was significantly higher (42.7 to 50.3) when N was applied in three equal splits ($T_3$) or as per LCC schedule, followed by N application in two equal splits at 21 and 42 DAT ($T_2$) and the lowest efficiency of N use was observed in $T_1$. The differences in N use efficiency in different treatments were significant except that the efficiency in $T_3$ and $T_4$ treatments was at par.

**Table 4.6.5 Nitrogen use efficiency in rice crop as influenced by transplanting time and schedule of N**

| Treatment | Nitrogen use efficiency (kg grain/kg N) | |
|---|---|---|
| | **2017** | **2018** |
| **Date of transplanting** | | |
| **$P_1$** | 55.5 | 53.0 |
| **$P_2$** | 54.2 | 53.9 |
| **$P_3$** | 34.4 | 30.1 |
| **CD (p= 0.05)** | 1.6 | 1.6 |
| **Levels of N (kg/ha)** | | |
| **$N_1$** | 59.0 | 56.1 |
| **$N_2$** | 51.3 | 48.3 |
| **$N_3$** | 44.2 | 42.2 |
| **$N_4$** | 37.6 | 36.0 |
| **CD (p= 0.05)** | 1.9 | 1.9 |
| **Time of N application** | | |
| **$T_1$** | 44.3 | 42.0 |
| **$T_2$** | 47.5 | 44.5 |
| **$T_3$** | 50.3 | 48.0 |
| **$T_4$** | 50.1 | 48.0 |
| **CD (p= 0.05)** | 1.4 | 1.5 |

A perusal of the data in the Table 4.6.6 showed that planting time had a significant effect on various nitrogen use efficiency indices. The indices viz. agronomical efficiency (AE), physiological efficiency (PE), agro physiological efficiency (APE), utilization efficiency (UE), partial production efficiency (PPE), nutrient increment efficiency (NIE) and nutrient efficiency ratio (NER) were significantly higher when rice crop was planted late (3rd week of July) than when planted earlier (3rd week of June and 1st week of July).

**Table 4.6.6. Various Nitrogen Use Efficiencies of rice crop as influenced by transplanting time and schedule of N application (Pooled data of two years)**

| Treatment | AE | PE | APE | ARE | UE | PPE | NIE | PNB | PNUE | NHI | NER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date of transplanting** | | | | | | | | | | | |
| $P_1$ | 12.60 | 27.33 | 12.93 | 26.73 | 9.66 | 12.60 | 0.11 | 0.95 | 41.82 | 131.05 | 104.06 |
| $P_2$ | 12.99 | 25.26 | 12.37 | 26.96 | 10.00 | 12.99 | 0.12 | 0.96 | 43.08 | 130.57 | 104.14 |
| $P_3$ | 22.46 | 61.46 | 29.73 | 20.54 | 17.00 | 22.46 | 0.43 | 0.82 | 39.40 | 127.21 | 127.68 |
| CD (p= 0.05) | 3.6 | 6.6 | 2.95 | 2.06 | 2.3 | 3.6 | 0.03 | 0.11 | NS | 0.5 | 0.63 |
| **Levels of N (kg/ha)** | | | | | | | | | | | |
| 90 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 51.45 | 133.35 | 137.83 |
| 120 | 26.44 | 49.98 | 52.10 | 26.85 | 13.56 | 26.44 | 0.20 | 0.94 | 43.07 | 127.95 | 110.75 |
| 150 | 21.62 | 51.51 | 24.69 | 37.45 | 18.12 | 21.62 | 0.32 | 0..91 | 36.56 | 127.59 | 101.19 |
| 180 | 16.01 | 50.57 | 23.10 | 34.68 | 17.20 | 16.01 | 0.37 | 0.88 | 34.65 | 129.56 | 98.43 |
| CD (p= 0.05) | 4.1 | 7.6 | 3.41 | 2.38 | 2.7 | 4.1 | 0.03 | NS | 10.9 | 0.5 | 0.72 |
| **Time of N application** | | | | | | | | | | | |
| $T_1$ | 19.12 | 41.67 | 19.79 | 27.55 | 14.56 | 19.12 | 0.32 | 0.88 | 43.52 | 128.83 | 123.58 |
| $T_2$ | 15.45 | 34.07 | 16.14 | 27.11 | 11.97 | 15.45 | 0.21 | 0.90 | 42.61 | 130.11 | 117.75 |
| $T_3$ | 14.59 | 36.14 | 18.37 | 21.85 | 10.86 | 14.59 | 0.18 | 0.94 | 39.69 | 129.51 | 103.94 |
| $T_4$ | 14.92 | 40.18 | 19.08 | 22.47 | 11.50 | 14.91 | 0.18 | 0.93 | 39.91 | 130.01 | 102.93 |
| CD (p= 0.05) | 3.6 | NS | 2.66 | 2.4 | 2.7 | 3.6 | 0.06 | NS | NS | 0.5 | 0.96 |

All the indices, except PNB, were also influenced significantly due to levels of N application in rice crop. Maximum increase in AE, PE, APE, ARE, UE, PPE and NIE was observed when N application level was increased from 90 to 120 kg/ha. The highest values of AE, APE and PPE were observed when N was applied at 120 kg/ha and these efficiencies decreased when N level was increased further to 150 or 180 kg/ha whereas NHI and NER were highest with the lowest level of N (90 kg/ha).

Nitrogen application levels above 120 kg/ha, however, increased the efficiencies *viz*. ARE, UE and NIE while NER was decreased with increase in N levels above 90 kg/ha. The indices *viz*. AE, APE, ARE, UE, PPE, NIE and NER were highest when N fertilizer was applied in two equal splits at 0 and 21 days after transplanting ($T_1$) whereas NHI was the lowest with $T_1$.

### 4.6.6 Soil nutrient (NPK) status

The data pertaining to nutrient (NPK) status of the soil as influenced by transplanting time and N application schedule in rice crop is given in Table 4.6.7. The soil N and P status was lower in early transplanting and increased with delay in planting during both then years. The highest soil nutrient (N and P) status was observed with very late planting ($P_3$). However, N status under earlier plantings ($P_1$ and $P_2$) was statistically at par. But the soil K status did not vary significantly due to time of transplanting of the crop during both the years.

Each successive increase in supply of N significantly increased the N status of the soil up to the highest N dose during both the years. But reverse was true for the P status. The N supply levels, however, had no significant effect on the soil K status.

**Table 4.6.7 Nutrient status (kg/ha) of soil as influenced by transplanting time and schedule of N application in rice**

| Treatments | N | | P | | K | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **Date of transplanting** | | | | | | |
| $P_1$ | 100.9 | 104.8 | 28.9 | 30.8 | 818 | 823 |
| $P_2$ | 101.1 | 105.2 | 30.1 | 32.1 | 819 | 824 |
| $P_3$ | 104.0 | 108.0 | 33.0 | 35.1 | 822 | 827 |
| **CD (p= 0.05)** | 1.2 | 1.1 | 0.3 | 0.4 | NS | NS |
| **Levels of N (kg/ha)** | | | | | | |
| $N_1$ | 89.3 | 93.0 | 34.1 | 35.7 | 825 | 830 |
| $N_2$ | 97.1 | 101.1 | 32.0 | 34.0 | 821 | 826 |
| $N_3$ | 107.0 | 111.3 | 29.2 | 32.0 | 818 | 822 |
| $N_4$ | 116.6 | 120.6 | 27.7 | 30.3 | 815 | 820 |
| **CD (p= 0.05)** | 1.4 | 1.3 | 0.4 | 0.5 | NS | NS |
| **Time of N application** | | | | | | |
| $T_1$ | 98.1 | 101.8 | 32.6 | 34.7 | 828 | 833 |
| $T_2$ | 101.0 | 105.0 | 31.0 | 34.3 | 824 | 829 |
| $T_3$ | 104.0 | 108.3 | 29.2 | 31.0 | 813 | 818 |
| $T_4$ | 104.9 | 108.9 | 29.2 | 31.0 | 814 | 819 |
| **CD (p= 0.05)** | 1.3 | 1.2 | 0.4 | 0.4 | 10 | 9 |

Application of N in three equal splits at 0, 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$), being at par, resulted into significantly higher soil N content, followed by N application in two equal splits at 21 and 42 DAT ($T_2$) and the lowest N status was observed when N was applied in two equal splits at 0 and 21 DAT ($T_1$). But P status of the soil was highest in $T_1$, followed by that in $T_2$ whereas it was the lowest in $T_3$ or $T_4$, the latter two being statistically at par. The effects were similar during both the years.

The time of N application also had significant effect on K status of the soil. The K status was significantly higher in plots where N was applied in two equal splits ($T_1$ or $T_2$) than the plots of treatments $T_3$ and $T_4$. However, the K status did not differ significantly between the plots of treatments $T_1$ and $T_2$ also between the plots of treatments $T_3$ and $T_4$. The results were similar during both the years.

## 4.7 Economics

### 4.7.1 Cost of cultivation

The data presented in Table 4.7.1 indicated that cost of cultivation during both the years, when averaged over the N application schedule, was the highest under very early transplanting schedule ($P_1$) and decreased as the transplanting was delayed. The lowest cost of cultivation was found under late planting ($P_3$). During the two years the cost of cultivation under late transplanting ($P_3$) was less by Rs. 4549 as compared to that under early planting ($P_1$) whereas it was less by Rs. 2466 as compared to that under medium schedule of planting ($P_2$). The earliest planting ($P_1$) also incurred an extra cultivation cost of Rs. 2083/- as compared to $P_2$.

The cost of cultivation of rice crop, when averaged over the planting time and N application time increased markedly with each increase in the rate of N application and the lowest cost was recorded under the lowest dose of N (90 kg/ha) during both the years.

The cost of cultivation, when averaged over the planting time and N application rate, was lower when N was applied in two equal splits ($T_1$ and $T_2$) compared to when it was applied in three equal splits ($T_3$) or as per LCC ($T_4$) during both the years. The difference in cost of cultivation under $T_1$ and $T_2$ treatments was marginal during both the years. The same is true for the difference in cultivation cost under $T_3$ and $T_4$.

**4.7.2. Gross Returns**

Gross return (Table 4.7.1), when averaged over the N application schedule, was found to be appreciably higher (Rs. 45100 to 45308/- based on mean of the two years) with earlier plantings ($P_1$ and $P_2$) of the crop as compared to late planting ($P_3$) during both the years while the earlier plantings did not differ much in respect of gross profit obtained from them.

The gross return from rice crop, when averaged over the planting time and N application time, increased markedly with each increase in the rate of N application and the highest return was obtained with the highest dose of N (180 kg/ha) during both the years (Table 4.7.1). However, the difference in gross profit obtained with 150 and 180 kg N/ha was not appreciable.

The gross income, when averaged over the planting time and N application rate, was higher when N was applied in three equal splits ($T_3$) or as per LCC ($T_4$) than when applied in two equal splits ($T_1$ and $T_2$) whereas the gross income with $T_3$ and $T_4$ was comparable during both the years (Table 4.7.1). Based on mean of the two years, the gross return from $T_3$ was higher by Rs. 12275 and Rs. 6539 over that obtained from $T_1$ and $T_2$, respectively while $T_2$ exceeded $T_1$ by Rs. 5736.

**Table 4.7.1 Cost of cultivation, gross returns and benefit cost ratio in rice crop as influenced by transplanting time and schedule of N application**

| Treatment | Cost of Cultivation (Rs./ha) | | | Gross Returns (Rs./ha) | | | Return over variable cost (Rs./ha) | | | Benefit Cost Ratio (B: C) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | Mean | 2017 | 2018 | Mean | 2017 | 2018 | Mean | 2017 | 2018 | Mean |
| **Date of transplanting** | | | | | | | | | | | | |
| $P_1$ | 72288 | 72240 | 72264 | 110339 | 124214 | 117276 | 38051 | 51973 | 45012 | 1.53 | 1.62 | 1.58 |
| $P_2$ | 70184 | 70178 | 70181 | 107735 | 126401 | 117068 | 37552 | 56223 | 46888 | 1.53 | 1.66 | 1.60 |
| $P_3$ | 67754 | 67675 | 67715 | 70630 | 73307 | 71968 | 2876 | 5632 | 4254 | 1.04 | 1.06 | 1.05 |
| **Levels of N (kg/ha)** | | | | | | | | | | | | |
| $N_1$ | 68444 | 68406 | 68425 | 82216 | 92252 | 87234 | 13772 | 23846 | 18809 | 1.19 | 1.27 | 1.23 |
| $N_2$ | 69569 | 69515 | 69542 | 95307 | 105712 | 100509 | 25738 | 36197 | 30968 | 1.36 | 1.46 | 1.41 |
| $N_3$ | 70635 | 70592 | 70614 | 102622 | 115621 | 109121 | 31987 | 45029 | 38508 | 1.45 | 1.54 | 1.50 |
| $N_4$ | 71654 | 71611 | 71633 | 104795 | 118310 | 111552 | 33141 | 46698 | 39920 | 1.46 | 1.55 | 1.51 |
| **Time of N application** | | | | | | | | | | | | |
| $T_1$ | 69907 | 69861 | 69884 | 89371 | 99688 | 94529 | 19464 | 29827 | 24646 | 1.27 | 1.35 | 1.31 |
| $T_2$ | 69962 | 69906 | 69934 | 95214 | 105316 | 100265 | 25252 | 35411 | 30332 | 1.35 | 1.43 | 1.39 |
| $T_3$ | 70217 | 70178 | 70198 | 100257 | 113352 | 106804 | 30039 | 43174 | 36607 | 1.42 | 1.52 | 1.47 |
| $T_4$ | 70215 | 70179 | 70197 | 100098 | 113538 | 106818 | 29883 | 43359 | 36621 | 1.42 | 1.52 | 1.47 |

### 4.7.3 Return over variable cost

Return over variable cost (Table 4.7.1) when averaged over the N application schedule and also over the two years, was found to be appreciably higher (Rs. 45012 in $P_1$ and Rs. 46888 in $P_2$) with the earlier transplanting ($P_1$ and $P_2$) as compared to late planting ($P_3$) while the late planting gave mean net income of only Rs. 4254/-. The differences in net income from $P_1$ and $P_2$ plantings were neither appreciable nor consistent over the two years.

The return over variable cost from rice crop, when averaged over the planting time and N application time, increased markedly with each increase in the rate of N application and the highest return was obtained with the highest dose of N (180 kg/ha) during both the years (Table 4.7.1). However, the difference in net profit obtained with 150 and 180 kg N/ha was not appreciable.

The return over variable cost, when averaged over the planting time and N application rate, was higher when N was applied in three equal splits ($T_3$) or as per LCC ($T_4$) than when applied in two equal splits ($T_1$ and $T_2$) whereas the net income with $T_3$ and $T_4$ was comparable during both the years (Table 4.7.1). Based on mean of the two years, the net return from $T_3$ was higher by Rs. 11961/- and Rs. 6275/- over that obtained from $T_1$ and $T_2$, respectively while $T_2$ exceeded $T_1$ by Rs. 5686/-.

**Table 4.7.2 Return over variable cost (Rs./ha) obtained from different N levels under varying transplanting time**

| Transplanting time | Levels of N application (kg/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2017 | | | | 2018 | | | |
| | $N_1$ | $N_2$ | $N_3$ | $N_4$ | $N_1$ | $N_2$ | $N_3$ | $N_4$ |
| $P_1$ | 28350 | 37914 | 43454 | 42486 | 41750 | 51096 | 57906 | 57140 |
| $P_2$ | 28137 | 37376 | 42883 | 41812 | 44784 | 54642 | 63081 | 62384 |
| $P_3$ | -15171 | 1925 | 9625 | 15124 | -14997 | 2853 | 14100 | 20572 |

A perusal of the return over variable cost obtained from different N levels under various times of transplanting (Table 4.7.2) revealed that the net profit under the two early transplanting schedules ($P_1$ and $P_2$) increased appreciably with increase in N application level up to 150 kg/ha with slight decrease in net return at 180 kg N/ha. But under late transplanting ($P_3$) the return over variable cost increased up to N application rate of 180 kg N/ha. The late planting gave very low net income or even resulted into loss of income at lowest N levels (90 kg/ha) and hence late planting was more profitable when N was applied at 180 kg/ha. The highest net profit (Rs. 42883 to 43454/ha in 2017 and Rs. 57906 to 63081/ha in 2018) was obtained when the crop was supplied with 150 kg N/ha and transplanted early (up to 1$^{st}$ week of July). However, the profit obtained from the two earlier plantings did not differ appreciably when supplied with the same dose of N (150 kg/ha). The net profit obtained from the late transplanting ($P_3$) reduced miserably as compared to that from earlier planting schedules ($P_1$ and $P_2$) even when late transplanted crop was supplied with the highest dose of N (180 kg/ha).

**4.7.4 Benefit Cost ratio (B: C)**

Benefit cost ratio (B: C), when averaged over the N application schedule, was found to be appreciably higher with the earlier transplanting ($P_1$ and $P_2$) as compared to late planting ($P_3$) while the two earlier plantings were comparable in respect of B: C during both the years (Table 4.7.1). The benefit cost ratio, when averaged over the planting time and N application time, increased markedly with each increase in the rate of N application up to 150 kg N/ha during both the years and the highest B: C was achieved with 150 or 180 kg N/ha as B: C obtained with 150 and 180 kg N/ha was comparable. When averaged over the planting time and N application rate, the B: C was significantly higher when N was applied as per $T_3$ or $T_4$ (LCC) than when applied as per $T_1$ or $T_2$ whereas it was at par under $T_3$ and $T_4$ (Table 4.7.1). The lowest B: C was obtained with $T_1$.

CHAPTER–V

# DISCUSSION

The results of present field investigation entitled "**Schedule of nitrogen application in rice (*Oryza sativa* L.) as influenced by planting time**" presented in previous chapter are discussed in this chapter with the help of available relevant literature and relevant observations in the present study under the following heads.

**5.1 Phenological parameters**

**5.2 Growth parameters**

**5.3 Yield attributes**

**5.4 Yield parameters**

**5.5 Quality parameters**

**5.6 Nutrient uptake studies**

**5.7 Economics**

## 5.1 Phenological parameters

The crop phenological growth stages *viz.* panicle initiation, flowering and maturity were influenced markedly by time of transplanting. The crop transplanted earlier took more days to attain panicle initiation, flowering and maturity as compared to the crop planted very late ($3^{rd}$ week of July) during both years (Table 4.1). Panicle initiation in very late ($3^{rd}$ week of July) transplanted crop took 16-17 lesser days as compared to the early ($3^{rd}$ week of June) transplanted crop. Similarly, very late transplanted crop took 13-14 lesser days to flower and mature as compared to the early planted crop. As compared to the early transplanted crop, panicle initiation in the late ($1^{st}$ week of July) transplanted crop occurred earlier by 8 days whereas, both flowering and maturity were earlier by 4-5 days during both years. This indicated that vegetative period of the crop was shortened due to delayed planting. Sowing time 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 planted rice (Norman *et al.,* 1999). A linear negative correlation between sowing time and growth period was also reported by Peng-fei *et al.* (2013). The results were also in conformity with that reported by Lalitha *et al.* (2000), Lee *et al.* (2001), Dixit *et al.* (2004), Linscombe *et al.* (2004) and Chopra *et al.* (2006).

During both years, the level and time of nitrogen application doses did not affect the occurrence of various phenological stages of rice (Table 4.1). Wani *et al*. (2018) stated that temperature is main driving force for development in photoperiod insensitive rice genotypes and hence no effect of N application schedule on phenology of rice crop in the present study may be due to the fact that only one type of variety (photo insensitive) was used. Similar observations were also made by Gebremariam and Baraki (2016). Singh (2011) also reported that days taken to 50 per cent flowering did not vary with varied splits at the same level of N application.

**5.2 Growth parameters**

Late transplanting ($3^{rd}$ week of July) of the crop reduced the plant height, number of tillers/$m^2$ and dry matter accumulation at 60 DAT, 90 DAT and at maturity in comparison to early transplanting ($3^{rd}$ week of June and $1^{st}$ week of July) during both the years of study. This might be due to reduction in the vegetative period of the crop under late planting. Moreover, availability of more time for growth with optimum photoperiod and temperature for the growth of the early planted might have resulted into more nitrogen absorption for the synthesis of protoplasm responsible for rapid cell division that increase the plant in shape and size. These results are supported by the findings of Prabhakar and Reddy, (2010) and Wani *et al*. (2016) who found that early transplanting of rice results in better growth as compared to late transplanting.

All the growth parameters *viz.* plant height, number of tillers/$m^2$ and dry matter accumulation of rice at 60 DAT, 90 DAT and at maturity increased with each successive increase in N application level during both years. The increase in growth parameters with increased nitrogen levels may be attributed to the fact that nitrogen enhances the vegetative growth of plants. Moreover, greater absorption of nitrogen by plants under higher N supply contributes more to crop growth during the reproduction and grain filling through translocation (Bufogle *et al*., 1997). Enhanced tillering by increased nitrogen application might be attributed to more nitrogen supply to plant at active tillering stage. The favourable effect of increased N supply on growth parameters like plant height and tiller number might be responsible for the higher dry weight of the crop at higher N supply levels. The results are in accordance with the findings of Gautam *et al.* (2008), Lampayan *et al*. (2010), Manan *et al.* (2010), Chakraborty (2011) and Pramanik and Bera (2013) and Dey *et al.* (2014).

Application of N in three equal splits at basal, 21 DAT and 42 DAT ($T_3$) or as per LCC schedule ($T_4$), being at par, resulted into more tillers/$m^2$ (Table 4.2.2) and dry matter accumulation/$m^2$ (Table 4.2.3) than the N application in two equal splits at 0 (basal) and 21 DAT or two equal splits at 21 and 42 DAT. More tillers obtained with $T_3$ or $T_4$ might be due to N application in more splits which ensured the more uniform availability of N for longer growth period of the crop. More dry matter accumulation with N application schedules of $T_3$ and $T_4$ might be due to more number of tillers recorded under these treatments. These findings are in agreement with that of Lampayan *et al*. (2010) and Singh *et al*. (2017a) who recorded the highest number of tillers with application of N in four splits. Higher growth parameters in LCC based is attributed to the balanced nature of this treatment with respect to balance timing as it maintained leaf nitrogen concentration which helped to avoid tiller mortality (Islam *et al.,* 2009).

**5.3 Yield attributes**

The crop yield attributes *viz*. panicle length, number of panicles/m$^2$ and number of grains/panicle were significantly higher with earlier schedules of transplanting (3$^{rd}$ week of June and 1$^{st}$ week of July) as compared to late transplanting (Table 4.3). The higher number of panicles in earlier planted crop might be due to higher number of tillers. Moreover, the late planted crop produced lowest number of panicles/m$^2$ probably because of the higher mortality rate than in early transplanted crop. Moreover, the production and distribution of photosynthates might be reduced in late planted crop probably because of reduced temperature and sunshine hours coinciding with the grain filling phase of the late transplanted crop resulting in production of lesser number of grains/panicle. The results are in conformity with that of Chopra and Chopra (2004), Ram *et al.* (2005) and Chopra *et al*. (2006), Brar *et al*. (2012). Time of transplanting had no significant effect on 1000-grain weight. The individual grain weight is usually a stable varietal character and the management practice has less effect on its variation (Yoshida, 1981).

Nitrogen levels played an important role in increasing number of panicles/m$^2$ and grains/panicle. Number of panicles/m$^2$ increased significantly due to increasing level of nitrogen application up to 150 kg/ha which might be the consequence of increase in number of tillers and dry weight at higher N levels. Increasing trend of panicle at the higher levels of nitrogen was also observed by BRRI (2002). Higher number of panicles/m$^2$ in treatment where nitrogen was applied in three equal splits doses as (basal, 21 DAT and 42 DAT) or as per LCC schedule (Table 4.3) might be due to the fact that application of N in more splits ensured better availability of nitrogen to plants during the tillering period, which might have resulted into more productive tillers or panicle/m$^2$. The results are in agreement with those of Tripathi and Jaishwal (2006), Kanyika *et al.* (2007), Bera and Pramanik (2010) and Mahajan *et al.* (2010). However, panicle length and 1000-grain weight of rice did not differ significantly due to variation in time of N application. Kumar *et al.* (2007) also observed non-significant differences in 1000-grain weight and panicle length due to split application of N.

**5.4 Yield parameters**

Yield of crop in any given environment is the result of yield components developed in different development phases. Early transplanting (3$^{rd}$ week of June or 1$^{st}$ week of July) recorded significantly higher yield (grain and straw) than late planting (3$^{rd}$ week of July) with the two earlier planting schedules being at par (Table 4.4.1.1). The higher yield of early planted crop might be due to availability of more time for growth period and better photoperiod and temperature during the growth of the plants which resulted into more tillers, dry matter production, panicles and grains/panicle. The results are in general agreement with the findings of 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 yield (grain and straw) increased significantly with each increase in N application levels. However, the increase was significant up to 150 kg N/ha as the yield obtained with 180 kg N/ha was at par with that of 150 kg N/ha. The increase in grain and straw yield could mainly be attributed to the increase in the yield attributes *viz.* number of panicles/$m^2$ and number of grains/panicle. The increase in yield attributes is associated with better availability of N which increased the growth and ultimately the yield attributes and yield. The results are also in conformity with that reported by Boling *et al.* (2004), Sidhu *et al.* (2004), Singh *et al.* (2004), Gautam *et al.* (2008) and Mannan *et al.* (2009). The vigorous crop growth for the nitrogen treatments might have resulted in higher straw yields of rice. Salam *et al.* (2004) also reported higher straw yield with successive increase in nitrogen levels. The results were also in conformity with those of Islam *et al.* (2008), Manan *et al.* (2010), Pramanik and Bera (2013), Rao *et al.* (2013) and Singh *et al*. (2017).

Time of application of N in the rice crop significantly affected rice yield (grain and straw). Application of N in three equal splits at 0, 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$), being at par, resulted into higher yield (grain and straw) than the N application in two equal splits at 0 and 21 DAT ($T_1$) or at 21 and 42 DAT ($T_2$) during both the years (Table 4.4.1.1). This might be due to more dry matter accumulation and effective tillers obtained with $T_3$ and $T_4$ schedules of N application as application of N in more splits ensures more uniform availability of N during crucial or high demanding stage of rice plant. Fageria (2010) also reported that maximum grain and straw yield was obtained with application of nitrogen in three equal splits at sowing, active tillering and at panicle initiation. Hirzel *et al*. (2011), Sharma *et al*. (2012), Youseftabar *et al*. (2012), Yoseftabar (2013), Pramanik and Bera (2013) and Singh *et al*. (2017a) also supported similar results.

The harvest index (HI) determines the percentage ratio of grain yield to total biological yield and is a useful index in evaluating treatment effects on partitioning of photo-assimilates to grain within given environment. The data revealed that there was no significant variation in harvest index due to change in the transplanting dates. Similarly, the harvest index did not differ significantly due to levels and timing of N application. Similar results were reported by Pramanik and Bera (2013), Rao, *et al.* (2013) and Singh *et al*. (2017a).

The interaction between planting time and N levels was found significant for grain yield which revealed that the crop responded up to 150 kg N/ha under early planting whereas the late planted crop ($3^{rd}$ week of July) responded up to 180 kg N/ha (Table 4.4.1.2). Singh *et al*. (2017a) also reported that late planted rice responded to higher dose of N than the timely planted one.

## 5.5 Quality parameters

The quality parameters of rice grains *viz.* hulling, milling and head rice recovery were recorded highest in late transplanting ($3^{rd}$ week of July) as compared to early transplanting ($3^{rd}$ week of June and $1^{st}$ week of July). The improvement in hulling, milling and head rice recovery under late planting might be due to mild temperature coinciding with reproductive and ripening period under delayed transplanting. The climatic variables are known to influence the quality of rice which can be maintained by shifting of transplanting dates (Dhiman *et al.*, 1997, Singh *et al.*, 2005 and Chopra *et al.*, 2006). These findings are in general agreement with those reported by Mukesh *et al*. (2013).

The grain quality parameters did not differ significantly due to levels and timing of N application (Table 4.5). The results were also in accordance with the findings of Li *et al.* (2007) and Gill (1984).

## 5.6 Nutrient uptake studies

The grain and straw of early transplanted ($3^{rd}$ week of June or $1^{st}$ week of July) rice had higher N content (Table 4.6.1 & 4.6.2) than that of the late transplanted rice which might be because of longer growth period resulting into more absorption of nitrogen from the soil. But concentration of P and K in grain and straw was not influenced significantly by time of transplanting. The uptake of N, P and K both in grain and straw was significantly higher with early planting which might be due to higher yield (grain and straw). This result confirms the findings of Pandey *et al*. (2008), Kabat and Satapathy (2011) and Kumar *et al*. (2013).

Increase in nitrogen application levels increased nitrogen content in grain straw but had no effect on contents of P and K. The increase in N concentration might be due to availability of more nitrogen at higher N supply rates leading to more absorption of N by plants. The uptake of N, P and K both in grain and straw increased significantly with increase in level of N which is obviously due to increase in grain and straw yield. These results are in agreement with the findings obtained by Kabat and Satapathy (2011), Wang *et al.* (2012) and Srivastava *et al*. (2014).

The content of N in grain and straw was higher when N was applied in three equal splits (0, 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$) which is because of more uniform supply of N during the crop growth period. However, content of P and K was not affected significantly by time of nitrogen application. The uptake of the entire nutrient was higher when N was applied in three equal splits (0, 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$) which is due to higher grain and straw yield under these treatments (Table 4.6.3 & 4.6.4). Nachimuthu *et al* (2007), Avasthe (2009) and Mahajan and Sekhon (2010) also reported that N uptake increased with increase N splits.

Nitrogen use efficiency (NUE) and various nitrogen efficiency was significantly higher with earlier planting of rice than delayed transplanting (Table 4.6.5). It might be due to higher grain yield under early planting as NUE depends upon the grain yield. The NUE declined with successive increase in dose of nitrogen which might be due to the fact that grain yield response to applied N follows law of diminishing returns. Kour *et al*. (2007) and Singh *et al*. (2007) have reported a decreasing trend in NUE with increasing N rate.

In case of NUE, significantly higher NUE and various nitrogen efficiency was observed in treatment where nitrogen was applied on LCC based or in 3 equal split dosses. It might be due to the fact that splitting the dose of nitrogen reduced the nitrogen losses through ammonia volatilization, denitrification and nitrogen leaching. James and Stribbling (1995), Peng *et al*. (2009) and Guo *et al*. (2010) also reported that split application of nitrogen increased nitrogen uptake and use efficiency and reduction in nitrogen loss by volatilization, leaching and de-nitrification.

**5.6 Economics**

Higher gross returns, net returns and B: C were obtained with early planting ($3^{rd}$ week of June and $1^{st}$ week of July) as compared to late planting (Table 4.7.1) which were obviously due to higher yield with early planting. The returns (gross and net) and B: C ratio increased with increase in N application levels upto 150 or 180 kg N/ha which is also due to increase in crop yield. Application of N in three equal splits (0, 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$) recorded the highest returns and B: C ratio because of the higher crop yield under these treatments. These findings are in general agreement with those reported by Gangwar and Sharma (1998), Singh *et al.* (2000), Pal *et al.* (2001), Kumar and Ikramullah (2004) and Akbar *et al.* (2010).

## CHAPTER–VI

## SUMMARY AND CONCLUSION

The present field experiment entitled **"Schedule of nitrogen application in rice (*Oryza sativa* L.) as influenced by planting time"**, was conducted at Rice Research Station, Kaul (Kaithal) of CCS Haryana Agricultural University, Hisar during *Kharif* seasons of 2017 and 2018 to study the effect of time of planting and nitrogen application schedule and on growth, yield and quality of medium duration non-scented rice and also to find out optimum schedule of nitrogen application to get higher crop yield under timely and late planted conditions. Soil of the experimental field was loamy in texture, alkaline in reaction (pH 8.0), low in organic carbon (0.42%) and available nitrogen (103 kg/ha), medium in available phosphorus (26 kg/ha) and high in available potash (552 kg/ha). The experimental treatments consisted of three transplanting schedules ($P_1$: 3rd week of June, $P_2$: 1st week of July and $P_3$: 3rd week of July), four levels of fertilizer N ($N_1$: 90, $N_2$: 120, $N_3$: 150 and $N_4$: 180 kg/ha) and four timings of fertilizer N application ($T_1$: ½ at transplanting + ½ at 21 DAT, $T_2$: ½ at 21 DAT + ½ at 42 DAT, $T_3$: 1/3 at transplanting + 1/3 at 21 DAT + 1/3 at 42 DAT and $T_4$: LCC based). The treatments were laid out in split plot design with three replications keeping planting time and N levels in main plots and time of N application in sub-plots. The salient findings of the present study are summarized under following heads.

### 6.1 Effect of planting time

- The crop phenological stages *viz.* panicle initiation, flowering and maturity were influenced markedly by time of transplanting. The crop transplanted earlier took more days to attain panicle initiation, flowering and maturity stages and the number of days taken to attain these stages reduced considerably with each delay in planting.
- The crop transplanted late (3rd week of July) took 16-17 and 8 days less to attain panicle initiation stage as compared to the crop planted very early (3rd week of June) and early (1st week of July), respectively. Similarly, time taken to attain 50% flowering or maturity by the late planted crop was reduced by 13-14 and 4-5 days as compared that by the very early and early planted crop, respectively.
- Late transplanting (3rd week of July) of the crop significantly reduced the growth parameters *viz*. plant height, number of tillers/$m^2$ and dry matter accumulation ($g/m^2$) by the crop at 60 DAT, 90 DAT and at maturity in comparison to very early (3rd week of June) or early planting (1st week of July) schedules whereas the growth parameters did not differ significantly under the two early planting schedules.
- The crop yield attributes *viz*. panicle length, number of panicles/$m^2$ and number of grains/panicle, being at par under both the early schedules of transplanting (3rd week of

June and 1st week of July), reduced significantly under late transplanting (3rd week of July). The planting time, however, could not effect any significant variation in 1000-grain weight of the crop.

- Both the early transplanting schedules (3rd week of June and 1st week of July) recorded significantly higher grain and straw yield than the late planting (3rd week of July). However, the yield (grain and straw) obtained with the two earlier planting schedules did not differ significantly with each other. There was no significant variation in harvest index due to change in the transplanting dates.
- The crop grain quality parameters *viz.* hulling, milling and head rice recovery were improved significantly under late transplanting (3rd week of July) as compared to both the early plantings (3rd week of June and 1st week of July). Both the early plantings were at par in respect of the hulling and milling percentage but head rice recovery was higher in early (1st week of July) than in very early (3rd week of June) planting.
- The grain and straw of early transplanted (3rd week of June or 1st week of July) rice had higher N content than that of the late transplanted one. But concentration of P and K in grain and straw did not vary significantly due to time of transplanting.
- The uptake of N, P and K both in grain and straw was higher under early planting and reduced significantly under late planting (3rd week of July). However, the uptake of these nutrients was at par under the two early plantings and was governed by the grain and straw yield.
- Nitrogen use efficiency (NUE) was significantly higher with earlier planting of rice than with late planting. The efficiency of N use was statistically similar under the two early plantings.
- The early planting (up to 1st week of July) gave appreciably higher gross returns, net returns and benefit cost ratio (B: C) than the late planting (3rd week of July). When averaged over the two years, net profit was found to be appreciably higher in early plantings (Rs. 45012 in $P_1$ and Rs. 46888 in $P_2$) as compared to late planting ($P_3$) while the late planting gave mean net income of only Rs. 4254/-.

**6.2 Effect of nitrogen levels**

- The levels of nitrogen application in rice crop had no significant effect on the days taken to attain panicle initiation, 50% flowering and maturity of the crop.
- All the growth parameters *viz.* plant height, number of tillers/$m^2$ and dry matter accumulation of rice at 60 DAT, 90 DAT and at maturity increased with each successive increase in N application level but the increases were significant up to 150 kg N/ha as further increase in N level to 180 kg/ha did not improve the growth parameters significantly over that with 150 kg N/ha.

- The mean yield (grain and straw) increased with each successive increase in N application levels up to 180 kg N/ha. But the increase in yield was significant up to 150 kg N/ha as the yield obtained with 180 kg N/ha was found at par with that of 150 kg N/ha.
- The grain quality parameters *viz.* kernel length as well as hulling, milling and rice recoveries did not differ significantly due to variation in levels of N application.
- Increase in N application levels increased nitrogen content in grain and straw but the increase in N content was significant up to 150 kg N/ha. The N application levels had no significant effect on contents of P and K in grain or straw.
- The uptake of N, P and K both in grain and straw increased with every increase in level of N application but increase in the uptake was significant up to 150 kg N/ha. Nitrogen use efficiency was, however, highest with the lowest dose of (90 kg/ha).
- The returns (gross and net) and B: C increased appreciably with each increase in N application levels and the highest returns and B: C were obtained with 150 or 180 kg N/ha.

**6.3 Effect of time of nitrogen application**

- The time of nitrogen application in rice crop had no significant effect on the time of occurrence of various phenological events *viz.* panicle initiation, 50% flowering and maturity.
- Application of N in three equal splits at basal, 21 DAT and 42 DAT ($T_3$) or as per LCC schedule ($T_4$), being at par, resulted into significantly higher number of tillers/m$^2$ and dry matter accumulation by the crop than the N application in two equal splits at 0 (basal) and 21 DAT or two equal splits at 21 and 42 DAT.
- Among the yield attributing characters, number of panicles/m$^2$ were the highest when nitrogen was applied in three equal splits (basal, 21 DAT and 42 DAT) or as per LCC schedule. The other yield attributes *viz*. panicle length, number of grains/panicle and 1000-grain weight was not influenced significantly due to variation in time of N application.
- Application of N in three equal splits at 0, 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$) gave significantly highest yield (grain and straw), followed by N application in two equal splits at 21 and 42 DAT ($T_2$) whereas the lowest yield was obtained when N was applied in two equal splits at 0 and 21 DAT ($T_1$). The yield obtained with $T_3$ and $T_4$ schedules was statistically equal.
- None of the grain quality parameters differed significantly due to variation in timing of N application.
- The content of N in grain and straw was higher when N was applied in three equal splits (0, 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$). However, content of P and K was not affected significantly by time of nitrogen application.

- The uptake of all the nutrients (N, P and K) was significantly higher when N was applied in three equal splits (0, 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$).
- Nitrogen use efficiency was significantly higher in treatment where nitrogen was applied in three equal splits (0, 21 and 42 DAT) or as per LCC schedule.
- Application of N in three equal splits (0, 21 and 42 DAT ($T_3$) or as per LCC schedule ($T_4$) was most remunerative as it recorded the highest returns (gross and net) and B: C ratio.

**6.4 Interaction effect**

- Interaction between transplanting time and nitrogen application levels was found significant in respect of grain yield during both the years which revealed that grain yield of early transplanted (up to 1$^{st}$ week of July) crop increased significantly up to 150 kg N/ha but the yield of late planted (3$^{rd}$ week of July) crop increased significantly up to 180 kg N/ha. Therefore, the late planted crop (3$^{rd}$ week of July) responded to higher dose of N (180 kg/ha) than the early transplanted crop. But the highest grain yield was obtained when the crop was transplanted early (3rd week of June and 1st week of July) and supplied with 150 or 180 kg N/ha.

**CONCLUSION**

It can be concluded from the results of the present experiment that non-scented medium duration rice crop can be transplanted up to first week of July under the agro-climatic conditions of Haryana. It should be supplied with 150 kg N/ha under timely transplanting (up to 1$^{st}$ week of July) conditions. But if transplanting gets delayed, higher dose of N (180 kg/ha) may be applied to obtain higher yield. However, the highest yield and net profit can be obtained under timely planted conditions.

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## ABSTRACT

| | | |
|---|---|---|
| **Title of thesis** | : | **Schedule of nitrogen application in rice (*Oryza sativa* L.) as influenced by planting time** |
| **Full name of degree holder** | : | **Kavinder** |
| **Title of degree** | : | **Doctor of Philosophy in Agronomy** |
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| **Major subject** | : | **Agronomy** |
| **Number of words in abstract** | : | 428 |
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**Key words:** Transplanting time, growth, nitrogen use efficiency, yield attributes, grain yield, grain quality

A field experiment on rice crop was conducted during *Kharif* season of 2017 and 2018 at Rice Research Station, Kaul (Kaithal) of CCS Haryana Agricultural University, Hisar to find out optimum schedule of nitrogen application in rice under timely and late transplanting for getting higher yield. Soil of the experimental field was loamy in texture, alkaline in reaction (pH 8.0), low in organic carbon (0.42%) and available nitrogen (103 kg/ha), medium in available phosphorus (26 kg/ha) and high in available potash (552 kg K/ha). The experiment consisted of three transplanting dates ($P_1$: 3$^{rd}$ week of June, $P_2$: 1$^{st}$ week of July, $P_3$: 3$^{rd}$ week of July), four levels of N application (90, 120, 150 and 180 kg N/ha) and four timings of N application ($T_1$: ½ at transplanting + ½ at 21 DAT, $T_2$: ½ at 21 DAT + ½ at 42 DAT, $T_3$: 1/3 at transplanting + 1/3 at 21 DAT + 1/3 at 42 DAT and $T_4$: LCC based) laid out in split-plot design with transplanting dates and N levels in main plots and time of N application in sub-plots. The crop growth parameters *viz*. plant height, number of tillers/m$^2$ and dry matter accumulation were reduced significantly under late planting ($P_3$) but grain quality parameters viz. hulling, milling and head rice recovery improved significantly under the late planting. The crop yield attributes (number of panicles/m$^2$ and grains/panicle) and grain yield of rice crop were at par under earlier planting ($P_1$ and $P_2$) but reduced significantly under late transplanting ($P_3$). Uptake of NPK by grain and straw and nitrogen use efficiency was higher with early planting. The yield attributes and yield (grain and straw) of the crop increased with every increase in N application rates but the response was significant up to 150 kg N/ha. Uptake of NPK increased but nitrogen use efficiency decreased with higher N levels. Application of N in three equal splits at 0 (transplanting), 21 and 42 days after transplanting (DAT) or as per LCC was found optimum as it gave the highest yield as well as nitrogen use efficiency. Interaction between transplanting time and N application levels was found significant in respect of grain yield/ha which revealed that a dose of 150 kg N/ha was sufficient in rice transplanted early (up to 1$^{st}$ week of July) whereas the late transplanted (3$^{rd}$ week of July) crop may be supplied with higher dose of N (180 kg/ha) to get higher yield. The highest yield was, however, obtained with the crop transplanted early (up to 1$^{st}$ week of July) and supplied with 150 kg N/ha.

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I, hereby, declare that all the information given in the resume are true to the best of my knowledge.

**Signature of student**

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