EVALUATION OF AGRO-TECHNIQUES AND STORAGE METHODS FOR AROMATIC RICE LANDRACES OF WEST BENGAL

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By

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This is to certify that the work recorded in the thesis entitled **"EVALUATION OF AGRO-TECHNIQUES AND STORAGE METHODS FOR AROMATIC RICE LANDRACES OF WEST BENGAL"** submitted by **Sri Koushik Roy**, in partial fulfillment of the requirements for the award of the **Degree of Doctor of Philosophy in Agronomy** of **Bidhan Chandra Krishi Viswavidyalaya**, is a faithful and bona fide research work carried out under my personal supervision and guidance. The results of the investigation reported in the thesis have not so far been submitted for any other Degree or Diploma. The assistance and help received from various sources during the course of investigation have been duly acknowledged.

Mrityunjay Ghosh

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Dedicated

to

My Parents

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LIST OF ABBREVIATIONS

Abbreviation		Full Form
&	:	And
°C	:	Degree centigrade
AICRP	:	All India Co-ordinated Rresearch Project
B.C.K.V.	:	Bidhan Chandra Krishi Viswavidyalaya
C.D.	:	Critical difference
CGR	:	Crop growth rate
cm	:	Centimeter
et al.	:	et alia (=And Others)
g	:	Gram
GDD	:	Growing degree days
ha	:	Hectare
ha^{-1}	:	Per hectare
HTU	:	Heliothermal units
i.e.	:	*Id est* (That Is)
k	:	Light extinction co-eficient
LAI	:	Leaf area index
LTR	:	Light interception ratio
m^2	:	Square Meter
m^{-2}	:	Per square meter
Max.	:	Maximum
Min.	:	Minimum
mm	:	Millimeter
NAR	:	Net assimilation rate
pH	:	Negative logarithm of active hydrogen ion concentration
PTU	:	Photothermal units
r	:	Correlation
R.H.	:	Relative Humidity
R^2	:	Co-efficient of Determination
S. Em	:	Standard Error Of Mean
t	:	Tonne
t ha^{-1}	:	Tonnes per hectare
Temp.	:	Temperature

ABSTRACT

A comprehensive study on "Evaluation of agro-techniques and storage methods for aromatic rice landraces of West Bengal" including two field and one laboratory experiments was done at Bidhan Chandra Krishi Viiswavidyalaya, Kalyani, Nadia, West Bengal, India during the period of 2012-2014.

All fourteen rice cultivars tested in first experiment were long-duration type (>140 days), except Lal Badshabhog (136 days). Mean cultivar pooled growing degree days (GDD) from sowing to emergence, 4^{th} leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 77.7, 423.3, 940.0, 1684.3, 2296.1, 2483.6, 2628.5 and 2772.5°C, respectively. Based on pooled values of grain yield, the varieties could be arranged in different yield-categories as: >3.00 t ha^{-1} (NC 365 and Kataribhog), 2.75–3.00 t ha^{-1} (Badshabhog, Kalonunia, Radhatilak, NC 324, Kalojira and Gobindabhog), 2.50–2.75 t ha^{-1} (Radhunipagal and Tulsimukul), 2.25–2.50 t ha^{-1} (Lal Badshabhog and Kaminibhog) and 2.00–2.25 t ha^{-1} (Tulaipanji and Sitabhog). The correlation studies revealed that the yield components like number of filled grains $panicle^{-1}$ (r =0.397** and test weight (r =0.327**) had significant contributions toward the grain yield compared to number of panicles m^{-2} in the study. Mean cultivar pooled hulling, milling and head rice recovery were 76.9, 68.5 and 61.9%, respectively. Based on pooled values, amylose content was found to vary between 16.60 (Kaminibhog) and 19.03% (Sitabhog), and protein content between 6.77 (Kalojira) and 7.38% (NC 365). The variation in alkali spreading values (3.0 to 4.5) revealed that the tested cultivars had either high-intermediate or intermediate gelatinization temperature. Among fourteen cultivars, six varieties (Badshabhog, Kaminibhog, Lal, Badshabhog, Radhatilak, Radhunipagal and Sitabhog) exhibited >1.80 kernel elongation; while Radhunipagal had the highest intensity of aroma (score 2.45) followed by Gobindabhog and Kalonunia (score 2.35) in the study. Based on these, two native aromatic rice landraces (Gobindabhog and Radhunipagal) might be promoted for large-scale cultivation due to medium grain yield (2.57–2.81 t ha^{-1}), highest volume expansion ratio (2.74) and medium-strong aroma (score 2.35–2.45); while medium-grained Kalonunia and NC 365, and short-grained Radhatilak could also be tried in South Bengal region for better yield potentiality, amylose content and flavour.

Radhatilak rice planted during 2nd week of July took 155.2 days to maturity, which was reduced by 10.5 and 17.1 days for 4th week of July and 2nd week of August planting, respectively. Based on pooled total summed GDD, heliothermal units (HTU) and photothermal units (PTU), three planting times could be arranged as: 2nd week of planting (2912.8°C day, 15376.3°C hour and 36002.7°C hour) > 4th week of July (2648.0°C day, 14663.7°C hour and 32265.8°C hour) > 2nd week of August (2431.2°C day, 13868.4°C hour and 29209.3°C hour). Although Radhatilak paddy planted during 2nd week of July produced the highest grain yield (3.00 t ha^{-1}) and amylose content (18.90%); but the intensity of aroma in grain was improved with delay in planting from 2nd week of July (score 2.36) to 2nd week of August (score 2.44) during *kharif* season. The correlation studies between thermal indices and grain yield revealed that GDD and PTU had positive influence ($P<0.05$ or $P<0.01$) throughout the cropping period, but HTU showed positive impact ($r = 0.235^*$ and $r = 0.378^*$) on economic yield during active tillering to panicle initiation and dough to maturity stage, respectively. Above all, the planting of Radhatilak paddy during 2nd week of July along with fertilizer-based nutrition (50:25:25 kg ha^{-1} of $N:P_2O_5:K_2O$) could be recommended due to highest grain yield (3.14 t ha^{-1}), net return (Rs. 39,798.00 ha^{-1}) and B:C ratio (2.45); but it might be better option for planting during 4th week of July coupled with integrated nutrient management (50% RD inorganic + 50% RD as mustard cake) due to similar grain yield (2.96 t ha^{-1}), lesser duration (144.7 days) and lodging tendency (score 2.67), slightly-better grain quality like head rice recovery (62.1%), amylose content (18.52%) and aroma (score 2.33), and better residual soil status (+6.38% N, +23.89% P_2O_5 and -13.42% K_2O) toward the development of sustainable market potential-based cultivation system of Radhatilak rice in New Alluvial Zone of West Bengal. .

The physical properties of grain (*viz.* kernel length, breadth, shape, colour, chalkiness, etc.), amylose, protein, alkali value of Radhatilak rice did not differ significantly among five storage containers during 9-month post-harvest period. The hulling, milling and head rice recovery usually showed slight increasing trend during the ageing process; but the average intensity of aroma after 3-month (score 2.00) was declined by 18.5% after 6 month (score 1.63) and 34.0% after 9-month period (score 1.32) at Kalyani, West Bengal. Among five storage containers, earthen pot performed best for medium protein content (6.63%), greater elongation ratio (1.84) and aroma (score 1.50) of Radhatilak rice after 9-month storage period in West Bengal.

Chapter 1

INTRODUCTION

1. INTRODUCTION

With the advancement of human civilization, peasant farmers of different regions mostly in Asia and Africa continents have selected a great variety of aromatic rices based on their needs and cultivation practices. These scented rice types vary in plant characteristics, grain size, colour, taste and flavour, and they have been adopted to specific agro-ecological zones of the world. Based on historical documents, it is evident that aromatic rices occupy a prime position in Indian society and culture because of their high quality features and diverse uses in socio-religious system of the country (Ahuja *et al.*, 1995).

In India, aromatic rice is categorized into two types: (i) Basmati: the long-grain ones, which are traditionally cultivated at the foothills of Himalayans in northern states (*viz.* Punjub, Haryana, Uttaranchal, Uttar Pradesh, Himachal Pradesh, etc.) and (ii) non-Basmati: short and medium-grain scented rices, which are grown in small pockets of the native areas in different parts of the country (Nene, 1998). Although Basmati rices have got great patronage from different sections in the country during last four decades; but non-Basmati scented rices get little attention and most of them are not being properly exploited till date for production-based marketing and export.

The state of West Bengal has precious wealth of genetic diversity in aromatic rice (Shovarani and Krishnaiah, 2001). About 35-40 such premium scented rice varieties usually have some special end-uses like cooked table rice, *bhog* (rice intermixed with pulses), *payash* (deserts), *polao*, *pistak* or *pitha* (home-made cake), *chira* (parched or flattened rice). Among them, mostly short-grain fragment varieties like Gobindabhog, Badshabhog, Radhunipagal, Kalojira, Radhatilak, Kaminibhog, etc. are cultivated in the gangetic-alluvium, *rahr* (Laterite) and coastal areas of south Bengal, while medium-grained ones like Tulaipanji, Kalonunia, Kataribhog, etc. in the districts of north Bengal region. Above all, it is estimated that aromatic rice is cultivated in about 1 lakh ha. land in the state during *kharif* season, which results in average production of 3 lakh tonnes scented paddy annually (Bhattacharya, 2003 and Adhikari *et al.*, 2011).

Genetic variations among aromatic rice landraces of West Bengal with regard to the plant characteristics, grain quality and tolerance to biotic and abiotic stresses need to be determined for assessing their adaptability and performance under varied agro-ecological conditions. These non-Basmati type genotypes get varied attentions from the cultivators, millers, traders and consumers due to their variability in yield potentiality, grain quality parameters and cooked preparations within the defined regions and markets. With a view to make a comprehensive road-map for region-specific aromatic rice programme in West Bengal, the collection, characterization and evaluation of indigenous scented rice germplasm in different agro-climatic zones are the priority of present-day agricultural research system, even with a few sporadic attempts in recent times (Banerjee, 2011).

Radhatilak, short-grain scented rice, is traditionally grown in small pockets of the districts like Nadia, Hooghly, Purba Medinipur, etc. *i.e.* on both sides of the river Ganges in West Bengal. The name 'Radhatilak' has been probably originated about 400–500 years ago from the social life system of 'Vaishnavas', the disciples of Shree Chaitanya Mahaprabhu. The word has two parts: 'Radha' and 'Tilak', where 'Radha', is indicated as the lover or *Gopini* of 'Lord Krishna' in Hindu mythology and 'tilak' means sectarian mark painted by the Vaishnavas mostly on their foreheads, chests and arms (Ghosh, Personal Communication, 2013). The variety belongs to long-duration, tall-indica type, which produces short-grains having pleasant aroma. As per provision of PPV & FR Act, 2001, Kadampur Krishi Farmers Club, Nadia, West Bengal submitted the documents under technical supervision of RKVY Project on 'Bengal Aromatic Rice; Bidhan Chandra Krishi Viswavidyalaya, West Bengal to Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA), Govt. of India, New Delhi for registration of 'Radhatilak' rice under 'Farmer's Variety' category (REG/2014/5, dated 06.01.2014).

Farmers in native areas cultivate Radhatilak rice mainly for their own use, in small portions of their agricultural lands either with no or low inputs. In addition, they follow traditional production practices intermixed with a few modern technologies in recent times during *kharif* season as well as they use locally-available storage containers for post-harvest storage. Thus, there is a need and scope for optimization or up-gradation of crop management practices including sowing or planting time, spacing, nutrient, weed and pest management, etc. and storage methods through well-structured research modules.

Among various cultivation practices, appropriate sowing or planting time, and nutrient management are key factors to enhance the productivity upto a sustained level as well as for restoration of soil fertility in Radhatilak rice-based crop sequence. Radhatilak, being an indigenous photosensitive rice crop, is highly influenced by temperature, day length and sunshine hours toward its performance in terms of growth, yield and quality. In the context, sowing or planting period is an important non-monetary practice having weather-based correlations with yield and quality parameters of aromatic rice (Mahata, 2014).

The nutrition of Radhatilak rice is traditionally provided by locally-available organic manures in some small areas, or by over-doses of chemical fertilizers in other districts of the state. Such untested varied nutrient schedules practiced by the farmers need refinement through region-specific research programmes involving different organic sources like farm yard manure (FYM), mustard cake, vermicompost, green manure, bio-fertilizer, etc. and, straight or compound chemical fertilizers available in the market. Although a simple comparative study on chemical and organic nutrient management of Radhatilak rice has been reported in recent times (Paul *et al.*, 2011), but a comprehensive study for standardization of integrated nutrient management system using locally-available organic manures and inorganic fertilizers may result in increased yield and grain quality of Radhatilak rice, hopefully leading to more profit and longer sustainability of the system.

Rice ageing is a complicated process, which involves changes in physical and chemical properties of rice grain, with variations due to storage methods, time and environment. Although the overall starch, protein and lipid contents in rice grain remain essentially unchanged during storage, yet structural changes occur which affect the flavour and texture of cooked rice (Zhou *et. al.,* 2002). On the other hand, low-capacity storage structures have varied influence on grain damage, milling quality, protein content, etc. during year-long storage period (Ilyas *et al.,* 1983). The recent study for storage effects on short-grained aromatic rice, Gobindabhog in West Bengal, India expedites the need for standardization of locally-feasible storage methods for Radhatilak paddy for sustenance of the quality including aroma for a longer period.

Keeping these in view, three sets of investigations were undertaken to identify the suitable scented rice cultivars in New Alluvial Zone of West Bengal, and up-gradation of production technology and storage methods for Radhatilak rice with the following objectives:

i. To identify the suitable indigenous aromatic rice cultivar(s) in New Alluvial Zone of West Bengal during *kharif* season

ii. To standardize the planting time and nutrient management system of Radhatilak rice for greater yield, superior quality and better soil health

iii. To select the best possible storage method(s) for sustenance of grain quality of Radhatilak rice during post-harvest period

Chapter 2

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Rice (Oryza sativa L.) is the most important cereal crop in the developing world and is generally considered as a semi-aquatic annual grass plant (Juliano, 1993). Rice is grown in 114 countries across the world on an area of about 150 million hectares, constituting nearly 11 percent of the world's cultivated land with annual production of over 525 million tonnes, (Rai, 2006).

2.1 Duration and growth environment

2.1.1 Phenology

Agronomically, it was convenient to regard the life history of rice in terms of three growth stages: vegetative (germination to the initiation of panicle primordia), reproductive (panicle primordia initiation to heading) and ripening (heading to maturity).

2.1.1.1 Varietal performance

The indigenous aromatic rice cultivars of West Bengal generally had long growth duration, which were reported as: 140.5 days (Gobindabhog), 139.5 days (Tulusimanjari) (Ghosh *et al.*, 2005); 148.0 days (Radhunipagal and Seetabhog) and 149.0 days (Tulusibhog) (De *et al.*, 2002); 144.3 days (Badshabhog), 145.8 days (Mohonbhog), 140.0 days (Kalojira), 147.3 days (Chinikamini) and 144.3 days (Khasdhan) (Banerjee, 2011). Mean days to 50% flowering of 5 scented rice landraces of West Bengal varied between 119 and 124 days (Sadhukhan and Chattopadhyay, 2001).

2.1.1.2 Effect of planting date

Delay in planting of aromatic Gobindabhog rice from 10 July to 25 July, 10 August and 25 August reduces the total duration by 8.2, 13.3, and 19.7 days respectively at Kalyani, West Bengal, India (Mahata, 2014)

The increasing mean air temperature and sunshine hours day^{-1} with delay in planting from 2 to 23 February accelerated most phenological developments and reduced the duration from sowing to maturity by 10 days for scented rice varieties in West Bengal (Ghosh, 2000).

2.1.2 Growing degree days (GDD), heliothermal units (HTU) and photothermal units (PTU)

The effects of temperature on growth and development of rice plants were complex and optimum temperatures were 25-30°C for seedling emergence and establishment, 25-28°C for rooting, 31°C for leaf elongation, 25-31°C for tillering, 30-35°C for anthesis and 20-25°C for ripening (Yoshida, 1981).

2.1.2.1 Varietal performance

Mean cultivar GDD from sowing to emergence, 4th leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stage were 80.1, 420.9, 932.2, 1448.6, 2177.4, 2358.6, 2536.5 and 2711.0°C day, respectively for seven aromatic rice landraces of West Bengal (Banerjee, 2011).

The summed GDD, HTU and PTU for entire life cycle of Gobindabhog (2800°C day, 16747.5° C hour, 34082.5°C hour) and Tulaipanji (2784°C day, 16596.5°C hour and 33905.0°C hour) were recorded at Kalyani, West Bengal (Ghosh *et al.*, 2005)

2.1.2.2 Effect of planting time

Mahata reported that total summed GDD, HTU and PTU, four planting dates could be arranged as July 10 (2885.1°C, 16194.2°C hour and 35641.1°C hour) > July 25 (2695.7°C, 15988.1°C hour and 32730.2°C hour) > August 10 (2519.6°C, 15464.2°C hour and 30319.0°C hours) > August 25 (2329.8°C, 14567.7°C hour and 27701.0°C hours) of Gobindabhog rice of West Bengal.

Delayed planting at 23 February increased the GDD (2080 *vs.* 2046°C), and HTU (18505 *vs.* 17806°C hour) and PTU (25172 *vs.* 24192°C hour) of scented rice varieties than early planting (2 February) during dry (*boro*) season in West Bengal (Ghosh, 2000).

2.2 Growth and development

2.2.1 Plant height

Plant height referred to the longest distance between the plant base and the tip of the highest leaf (or panicle, whichever longer). Gradual increase in plant height and the elongation of culm resulting in plant height were the characteristics of rice plant during vegetative and reproductive stage, respectively (Yoshida, 1981).

2.2.1.1 Varietal performance

Genetic variation in plant height among scented rice landraces of West Bengal was recorded as: 129.9 cm (Danaguri), 134.3 cm (Kataribhog), 136.1 cm (Badshabhog), 137.3 cm (Radhunipagal) (Sadhukhan and Chattopadhyay, 2001). 128.3 cm (Gobindabhog) and 134.7 cm (Tulshimanjari) (Ghosh *et.al.,* 2005), 127.7 cm (Mohanbhog), 132.3 cm (Kalojira), 129.1 cm (ChiniKamini) and 127.1 cm (Khasdhan).

2.2.1.2 Effect of planting time

Paliwal *et al.,* (1996) found that early transplanting on 25 July produced significantly higher plant height (107.4 cm) than delayed transplanting on 10 and 25 August. Dhiman *et al.,* (1995) observed greater plant height in earlier planting on 15 July than in delayed planting on 25 July and 5 August.

2.2.1.3 Effect of nutrient management

Four aromatic rice varieties (*viz.* Pusa Basmati1, Kasturi, Indrayani, Sugandha) produced taller plants with successive increase in N application from 0 to 120 kg ha^{-1} at 30, 45, 60 and 90 DAT in Maharashtra (Mhaskar *et al.,* 2005).

The plant height of scented rice (*cv.* Mugad Sugandha) was significantly higher at 30, 60, 90 DAS and harvest (32.3, 66.2, 69.3 and 71.8 cm, respectively) with integrated nutrient management (FYM + inorganic fertilizer) over organic management module and farmers' practice in Karnataka, India (Raikar *et al.,* 2009).

2.2.2. Tillering

Tillering in rice began at four to five leaf stages. Tillers initially depended on the nutrient supply from the mother stem, but became autotrophic when they had three leaves and four to five roots (Ishizuka and Tanaka, 1963).

The number of tillers attained its highest value about one month after transplanting, decreased thereafter due to death of some of the last tillers as a result of their failure in competition for light and nutrients (Matsushima, 1957; Ishizuka and Tanaka, 1963).

2.2.2.1 Varietal performance

The average number of tillers m^{-2} over two Basmati rice varieties (Basmati 370 and Pusa Basmati 1) was 147.0, 233.5, 340.5, 313.5 and 302.0 at 28, 42, 56, 70 and 84 DAT, respectively; which showed that the number of tillers m^{-2} increased upto 56 DAT and thereafter declined at Kalyani, West Bengal (Ghosh, 2000).

The variation in number of tiller m^{-2} among seven scented rice landraces of West Bengal was noted as: 289.8 (Gobindabhog) and 351.3 (Chinikamini), 381.5 (Gobindabhog) and 417.7 (Mohanbhog) and 309.7 (Gobindabhog) and 362.7 (Mohanbhog) at 28, 56 and 84 DAT during *kharif* season (Banerjee, 2011).

2.2.2.2 Effect of planting time

Ghosh (2000) reported that late planting (23 February) resulted in greater number of tillers m^{-2} throughout the vegetative and reproductive stages of two Basmati varieties than early or normal planting (2 February) during *boro* season in West Bengal.

According to Banerjee (2011), Gobindabhog rice planted on 10 August produced the highest number of tillers m^{-2} compared to two earlier plantings (10 July and 25 July) and one late planting (25 August) at 28, 56 and 84 DAT in West Bengal.

2.2.2.3 Effect of nutrient management

The application of FYM and vermicompost recorded 412.5 and 456.6 tillers in 1 m^2 area at maximum tillering stage of dwarf scented rice (Kumar *et al.* 2008).

A dwarf scented rice recorded 412.5 and 456.6 tillers in 1 m^2 area at maximum tillering stage with application of FYM and vermicompost, respectively (Sharma *et al.*, 2008). Among seven nutritional treatments, sole or combined use of mustard cake favoured the tiller production in Gobindabhog rice than FYM and vermicompost during *kharif* season in West Bengal (Banerjee, 2011).

2.2.3 Leaf area index (LAI)

The surface area of leaves per plant as the organ of photosynthesis should be an important determinant of photosynthates (Watson, 1947).

The LAI increased gradually and recorded maximum at panicle emergence stage which declined at maturity due to drying of lower leaves (Thakur and Patel, 1999).

2.2.3.1 Varietal performance

The leaf area of 6 aromatic rice landraces increased from 28 to 70 DAT and thereafter declined during *kharif* season in West Bengal. The maximun LAI values of Badshabhog, Seetabhog, Radhunipagal, Tulaipanji and Gobindabhog were recorded as 5.6, 5.2, 5.5, 4.9 and 5.3 respectively at 70 DAT (Sarkar, 1994).

2.2.3.2 Effect of planting time

The LAI values of scented rice varieties increased upto 56 DAT and recorded the maximum of 4.6-5.3 in normal planted (2 February) and 4.8 - 5.9 in late planted crop (23 February) during dry season in West Bengal (Ghosh, 2000).

Gobindabhog rice planted on 10 August recorded the highest LAI values of 1.80, 3.80, 4.84 and 2.81 at 28, 56, 84 DAT and at harvest respectively compared to early (10 July and 25 July) and late planting (25 August) in West Bengal (Mahata, 2014).

2.2.3.3 Effect of nutrient management

The leaf area of Basmati 370 was greater in both inorganic and organic manure treated plots than control and bio-fertilizer treated plots (Dahiphale *et al.*, 2008). Ghosh *et al.* (2004b) reported that basally applied chemical N fertilizer triggered the foliage growth. Thus, application of *Azolla* with or without inorganic fertilizer to two Basmati varieties resulted in lower LAI as compared to urea alone (100 kg N ha^{-1}) at an early stage, which continued thereafter.

2.2.4 Light interception and extinction coefficient (k)

The light extinction co-efficient (k) depended on inclination, arrangement and transmissibility of leaves (Lenka, 1998).

2.2.4.1 Varietal performance

The variation in light transmission ratio (LTR) among seven indigenous scented rice cultivars of West Bengal showed a negative relationship with their respective LAI values. There was a clear decreasing trend in LTR values from 28 DAT (45.9-52.5 %) to 84 DAT (18.4-21.8 %) and thereafter increased due to senescence of leaves at ripening phase (Banerjee, 2011). Mean light extinction coefficient values of 3 aromatic rice varieties, *viz.* Hansraj, Type 3 and Karnal Local were recorded as 0.31, 0.35 and 0.33, respectively (Ghosh *et al.*, 2004*a*).

2.2.4.2 Effect of planting time

There was a curvilinear relationship between the values of LAI and LTR for both planting dates (2 and 23 February), but the k values were slightly higher in late planted (0.25-0.47) than normal planted crop (0.24-0.44) throughout the cropping period between 28 and 84 DAT (Ghosh, 2000).

2.2.5 Dry matter (DM) accumulation

The dry matter production increased progressively from tillering to maturity stage of rice and recorded to be maximum at maturity (Thakur and Patel, 1999).

2.2.5.1 Varietal performance

Total dry matter of 6 aromatic rice landraces of West Bengal increased progressively with the advancement of crop growth or age. Mean cultivar dry matter were 186.5, 281.7, 483.7 and 567.2 g m^{-2} at 28, 49, 70 and 91 DAT, respectively (Sarkar, 1994).

Among 12 cultivars of scented rice comprising mostly Joha types, Kunkuni joha consistently maintained a high rate of dry matter production at all growth stages (Sharma and Haloi, 2001).

2.2.5.2 Effect of planting time

Reddy and Reddy (1994) reported that maximum dry matter accumulation per m^2 was recorded with 29 August planted crop, which was significantly higher than 30 July and 14 August plantings.

2.2.5.3 Effect of nutrient management

Pusa RH 10, the first aromatic rice hybrid in India, produced higher total dry matter (7.5 - 9.0 t ha^{-1}) when manured with *Sesbania sp.* either alone or combined with FYM or wheat straw over untreated control (6.4 t ha^{-1}) (Suman and Bisht, 2010).

2.2.6 Crop growth rate (CGR) and net assimilation rate (NAR)

Chatterjee and Maiti (1981) reported that CGR at the time of grain filling was positively correlated with the number of spikelet $unit^{-1}$ area, ripening grades (the product of the filled grain percentage and 1000 grain weight) and yield $unit^{-1}$ area.

2.2.6.1 Varietal performance

CGR of 12 scented rice varieties showed an increasing trend from 28-49 DAT to 49-70 DAT and thereafter a declining trend during 70-91 DAT. Mean cultivar CGR were 4.87, 9.56 and 4.01 g m^{-2} day^{-1} at 28-49, 49-70 and 70-91 DAT, respectively and average cultivar NAR were 1.80, 2.22 and 0.99 g m^{-2} day^{-1} at 28-49, 49-70 and 70-91 DAT, respectively (Sarkar, 1994).

2.2.6.2 Effect of planting time

Bandi *et al.*, (1995) observed a linear reduction in CGR with delay planting during period between 30-50 DAT, however, the crop growth rate showed a little difference among different dates of planting at later stage of crop growth.

Although early planting (1^{st} week of July significantly increased mean CGR over late planting (3^{rd} week of July) by 10.30% at Faisalabad and 8.26% at Mala Shah Kaku, but late planting resulted in 9.65 % higher CGR than early planting at Gujranwala in Pakistan (Ahmed *et al.*, 2009)

2.2.6.3 Influence of nutrient management

The CGR values at different growth intervals in Gobindabhog rice were generally higher with sole application of mustard cake @ 100% RDN in two splits than other organic manures (*viz.* FYM and vermicompost) and control (Banerjee, 2011).

Easier and faster availability of N due to rapid hydrolysis of urea resulted in higher values of CGR in Basmati rice varieties upto 56-70 DAT with inorganic fertilizers either alone or in combination with *Azolla* over *Azolla* @ 15 t ha^{-1} alone (Ghosh *et al.*, 2004b).

2.3 Yield components and yield

2.3.1 Yield components and associated characters

The yield components of Gobindabhog rice like panicle length (24.7 cm), number of panicles (280.6 m^{-2}), number filled grains (118.6 $panicle^{-1}$) and 1000 grain weight (10.4 g) were reported (Banerjee, 2011).

2.3.1.1 Varietal performance

Genetic variation in panicle length was observed from 22.3 to 25.8 cm (Sadhukhan and Chattopadhyay, 2001), 24.3 to 27.4 cm (De *et al.*, 2002), 19.3 to 20.8 cm (Ghosh *et al.*, 2004*b*) and 23.5 to 25.1 cm (Ghosh *et al.*, 2005) among indigenous aromatic rice cultivars of West Bengal.

The number of panicles m-2 area in indigenous aromatic rice cultivars of West Bengal varied from 207 to 224 (Ghosh *et al.*, 2004*b*) and 252 to 270 (Ghosh, 2000).

The filled grains per panicle in scented rice landraces of West Bengal varied widely from 155.0 to 222.7 (Sadhukhan and Chattopadhyay, 2001), 133.5 to 209.2 (De *et al.*, 2002), 56.4 to 169.9 (Ghosh *et al.*, 2004*b*) and 109.3 to 137.3 (Ghosh *et al.*, 2005).

1000-grain weight of 43 traditional scented rice varieties tested in Assam ranged between 8.4 to 25.5 g (Sarma *et al.*,1990); while it varied between 9.6 to 25.5 g among 26 scented rice germplasm of Orissa (Dikshit *et al.*, 1992) and 10.0 to 31.8 g among 40 aromatic rice cultivars of West Bengal (Deb, 2005).

2.3.1.2 Effect of planting time

Delay in transplanting from 15 July to 14 August of five selected varieties successively reduced the number of fertile tillers hill $^{-1}$ (9.67 to 7.97), while planting on 25 July resulted in highest number of grains $panicle^{-1}$ (102.11) and 1000 grain weight (13.35 g) compared to other three plantings on 15 July, 4 August and 14 August at Dinajpur, Bangladesh (Hossain and Sikdar, 2009)

Singh *et al.* (1997) observed that rice planted on 15 June gave 20.5% higher grain yield than planted on 29 June (27.37 q ha^{-1}) owing to 17.8% more productive tillers m^{-2}, 20% filled grains $panicle^{-1}$ and 29% grain weight $panicle^{-1}$.

2.3.1.3 Effect of nutrient management

Mean number of panicles m^{-2}, filled grains per panicle and 1000-grain weight of two Basmati rice varieties (*viz.* Basmati 370 and Pusa Basmati 1) with application of *Azolla pinnata* @ 15 t ha^{-1} were recorded as 284, 67 and 18.2 g, respectively (Ghosh, 2000).

The panicle length (25.54 cm), number of productive tillers $plant^{-1}$ (7.98) in scented rice (*var.* Mugad Suganda) were higher under integrated nutrient management (*i.e.* 50% RDN through FYM + $N_{50}P_{50}K_{50}$ kg ha^{-1}) than farmer's practice and organic nutrient management in Karnataka (Raikar *et al.*, 2009); while 1000 grain weight of a dwarf scented rice was 19.22 and 19.76 g when grown with FYM and vermicompost, respectively (Sharma *et al.*, 2008).

2.3.2 Yield

2.3.2.1 Grain yield

Grain yield was a complex quantitative trait as the end product of interaction among yield contributing components and was greatly influenced by environment (Bagali *et al.*, 1999).

2.3.2.1.1 Varietal performance

Genetic variation in grain yield was observed among aromatic rice landraces of West Bengal: Badshabhog (3.08 t ha^{-1}), Seetabhog (2.37 t ha^{-1}), Tulaipanji (2.20 t ha^{-1}) (Sarkar, 1994); Kataribhog (1.74 t ha^{-1}), Tulsibhog (2.11 t ha^{-1}) (Ghosh *et al.*, 2004*b*); Gobindabhog (3.11 t ha^{-1}), Tulsimanjari (3.13 t ha^{-1}) (Ghosh *et al.*, 2005), Mohanbhog (2.58 t ha^{-1}), Radhunipagal (2.67 t ha^{-1}), Kalojira (2.94 t ha^{-1}) Chinikamini (2.44 t ha^{-1}) and Khasdhan (2.44 t ha^{-1}) (Banerjee, 2011).

2.3.2.1.2 Effect of planting time

Among the four planting dates, the earlier planting (15 July) resulted in the highest grain yield (2.79 t ha^{-1}) of aromatic rice varieties than the delayed planting on 25 July (2.38 t ha^{-1}), 4 August (2.25 t ha^{-1}) and 14 August (1.85 t ha^{-1}) (Hossain and Shikdar, 2009).

Asraf *et al.* (1989) observed that the planting of Basmati 385 on 15 June resulted in the highest grain yield (5.3 t ha^{-1}) compared to the planting on 1 June, 16 July and 15 August during *kharif* season.

According to Mahata (2014), an indigenous short grained scented rice (*cv.* Gobindabhog) planted on 25 July produced the highest grain yield (3.02 t ha^{-1}), which was 4.13, 14.39 and 17.51 % greater over 10 August, 25 August and 10 July plantings respectively in West Bengal.

2.3.2.1.3 Effect of nutrient management

Pusa Basmati 1 yielded higher (3.22 t ha^{-1}) under inorganic nutrient management over integrated nutrient management (2.86 t ha^{-1}) and organic nutrient management (2.71 t ha^{-1}) at Pantnagar, India, (Singh and Chandra, 2011). However, the seed yield of the scented rice (*cv.* Mugad Suganda) was highest (3.78 t ha^{-1}) under integrated nutrient management (*i.e.* 50% RDN through FYM + $N_{50}P_{50}K_{50}$ kg ha^{-1}), which was 10.31 and 12.48% greater over farmers' practice and organic nutrient management, respectively in Karnataka (Raikar *et al.*, 2009).

Mean grain yield of two Basmati rice varieties (*viz.* Basmati 370 and Pusa Basmati 1) was 3.44 t ha^{-1} under organic nutrient management (*i.e. Azolla pinnata* @ 15 t ha^{-1}), which was 17.7 - 41.0% lower than inorganic N fertilizers either alone or in combination with *Azolla* during dry (*boro*) season in West Bengal (Ghosh *et al.*, 2004b). The application of green manure (*Sesbania sp.*) @ 30 t ha^{-1} + FYM @ 5 t ha^{-1} recorded the highest grain yield (4.4 t ha^{-1}) in aromatic rice hybrid (*cv.* Pusa Rice Hybrid 10), which was 51% greater over control (Suman and Bisht, 2010).

The sole or combined use of mustard cake @ 100% RDN to Gobindabhog rice resulted in higher grain yield (2.83 t ha^{-1}) compared to FYM and vermicompost during *kharif* season in West Bengal (Banerjee, 2011). However, the application of mustard cake @ 0.5 t ha^{-1} + $N_{40}P_{20}K_{20}$ kg ha^{-1} produced the highest grain yield of

Gobindabhog rice (2.48 t ha^{-1}), which was 27.1, 15.3 and 9.7% greater over unfertilized control, mustard cake @ 0.5 t and 1 t ha^{-1}, respectively (Mondal *et al.*, 2013).

2.3.2.2 Straw yield

2.3.2.2.1 Varietal performance

The straw yield in scented rice cultivars was found to vary between 5.48 and 6.53 t ha^{-1} (De *et al.*, 2002) and 7.62 and 7.88 t ha^{-1} (Ghosh, 2000) in West Bengal, India.

2.3.2.2.2 Effect of planting time

According to Chowdhury *et al.* (2011), the highest straw yield (5.71 t ha^{-1}) was obtained from earliest planting (5 July) of aromatic rice (cv. Rajendra Suwasani) while lowest straw yield (4.86 t ha^{-1}) was recorded with delayed planting (4 August) at Pusa, Bihar, India.

2.3.2.2.3 Effect of nutrient management

Application of vermicompost with fertilizer N and bio-fertilizer increased the rice yield by 16% over the application of fertilizer N alone. Vermicompost applied with FYM recorded higher grain and straw yield of rice (Jeyabal and Kuppuswamy, 2001).

2.3.2.3 Harvest index

2.3.2.3.1 Varietal performance

The harvest index of aromatic rice landraces of West Bengal was recorded as 0.20 (Radhunipagal), 0.26 (Seetabhog) (De *et al.*, 2002), 0.28 (Gobindabhog), 0.29 (Tulsimanjari) (Ghosh, 2000), 0.29 (Kataribhog) and 0.30 (Tulsibhog) (Ghosh *et al.*, 2004*b*).

2.3.2.3.2 Effect of planting time

The planting of aromatic Gobindabhog rice on or after 25 July upto 25 August resulted in significantly higher Harvest index (0.35-0.36) an e arly planting on 10 July (0.33) during both the years of investigation in West Bengal, India (Mahata, 2014).

2.3.2.3.3 Effect of nutrient management

The results revealed that application of inorganic fertilizers recorded higher seed yield (4.27 t ha^{-1}) and harvest index (0.43) compared to organic manuring in Pusa Basmati (Loganadhan and Rajeswari, 2005).

2.3.3 Lodging

2.3.3.1 Effect of nutrient management

The study on sole or combined use of different organic manures on Gobindabhog rice recorded that sole application of mustard cake in two splits caused complete lodging (score 5.67) of plants at hard dough stage compared to less lodging (score 4.33) in FYM and vermicompost (Banerjee, 2011).

2.4 Grain quality

2.4.1 Milling quality

The milling process generally consisted of 3 major steps: (i) shelling or dehulling of rough rice to remove the husks, (ii) milling or polishing the brown rice and (iii) separating whole grains from broken kernels. Thus, milling yield of rough rice was the estimate of the quantity of head rice expressed as percentage (Khush *et al.*, 1979).

2.4.1.1 Varietal performance

Basmati rice varieties had very low head rice recovery as compared to Thai aromatic (Khao Dawk Mali 105) and Cambodian rice varieties (Sidhu *et al.*, 2001).

Seven indigenous selected rice cultivars of West Bengal showed variation in hulling (72.3-76.9 %), milling (66.5-71.8 %) and head rice recovery (59.7-64.4 %) (Banerjee, 2011).

2.4.1.2 Effect of planting time

Milling quality of rice *cv.* Basmati 385 and Basmati 380 decreased with both early and late plantings (Ali *et al.*, 1991). However, Rao *et al.* (1996) observed that late planting slightly improved the quality traits such as hulling, milling and head rice recovery of four Basmati type rice cultivars, *viz.* Basmati 370, Kasturi, Pusa Basmati 1 and Haryana Basmati.

A linear reduction in head rice recovery of scented rice varieties was noticed with delay planting from 2 February (50.9%) to 23 February (48.3%) during dry season in West Bengal, which might be due to higher ambient temperature during grain ripening period in late planted crop resulting in development of sun-cracks in rice kernels and making them prone to breakage during milling (Ghosh, 2000).

Blanche and Linocombe (2009) recommended that the ideal planting time could be 1 and 15 April for optimum whole kernel milling yield (660-662 g kg^{-1}) based on a study between eight cultivars and seven planting dates for 3 years in United States of America.

2.4.1.3 Effect of nutrient management

The hulling (77.0%), milling (68.1%) and head rice recovery (35.9%) in organic manured pots were higher compared to 76.5, 67.5 and 32.6%, respectively in chemical fertilizer applied pots (*cv.* Pusa Basmati) (Loganadhan and Rajeswari, 2005).

Although vermicompost had no significant effect on the head rice recovery of scented rice (Murali and Setty, 2000), but FYM gave higher total and head milled rice recovery in Pusa Basmati 1 than the commercial manures and chemical fertilizers (Prakash *et al.*, 2002).

2.4.1.4 Effect of storage container and time

Five storage structures were evaluated for head rice yield (*cv.* CR 1014) after 12 months storage period, wherein the storage containers could be arranged as: Bamboo bin (63.3%) > Plastic silo (62.3%) > Hopper bin (60.7%) Mud-brick bin or Untreated gunny bag (56.3%) (Ilyas *et al.*,1983).

The milled and head rice recovery of rice hybrids were increased with ageing of grains from one month (65.76 and 57.26%) to six month period (70.6 and 61.66%) probably due to reduced breakage during milling at two locations each of Uttar Pradesh and Andhra Pradesh in India (Singh *et al.*, 2009).

On the contrary, the milling quality of Gobindabhog rice showed slight declining trend during storage time from 60 to 180 days in West Bengal. Five storage containers with respect to head rice recovery could be arranged as Earthen pot (62.1%) > Polythene bag (61.8%) > Galvanized Iron bin (61.5%) > Markin cloth bag (61.3%) > Jute bag (61.1%) (Mahata, 2014).

2.4.2 Physical properties of grains

2.4.2.1 Length, breadth and L / B ratio

2.4.2.1.1 Varietal performance

Genetic variation in kernel length and L/B ratio of scented rice landraces of West Bengal were recorded as: 4.31 mm and 1.88 (Radhunipagal), 4.63 mm and 2.13 (Danaguri), 4.69 mm and 2.14 (Badshabhog), 5.83 mm and 2.86 (Kataribhog) (Sadhukhan and Chattopadhyay, 2001); and 4.13 mm and 2.16 (Gobindabhog) and 3.90 mm and 2.10 (Tulsimanjari) (Ghosh *et al.*, 2005).

Among 43 traditional scented rice cultivars in Assam, variation in kernel length (5.7 to 9.9 mm), breadth (1.8 to 30 mm) and L / B ratio (2.4 to 4.3) were observed (Sarma *et al.*, 1990). Similarly, length (3.7 to 7.0 mm) and L / B ratio (1.6 to 3.5) showed wide variation among 26 aromatic rice germplasm collected from 6 districts of Orissa, of which 19 genotypes had short bold, 6 long slender and 1 long bold type grains (Dikshit *et al.*, 1992).

2.4.2.1.2 Effect of planting time

Dhaliwal *et al.* (1986) reported that the L/B ratio of both paddy and milled rice was higher at normal than late planting. Singh *et al.*, (1997) opined that the kernel length of Pusa Basmati 1 and Kasturi decreased with early or late planting.

2.4.2.1.3 Effect of nutrient management

Silva and Brandao (1987) reported that application of nitrogen did not significantly affect the length as well as breadth of grains. Similarly, kernel length and L/B ratio of rice (*cv.* Rajendra Suwasani) remained unaffected under inorganic or integrated nutrient management in Bihar (Chowdhury *et al.*, 2011).

2.4.2.1.4 Effect of storage container and time

The kernel length, breadth and L/B ratio of indigenous short grain aromatic rice (*cv.* Gobindabhog) remained unaffected due to variation in storage container, even at different post harvest storage period in West Bengal, India (Mahata, 2014).

2.4.2.2 Chalkiness

Chalkiness in rice kernel was an important criteria to determine the grain appearance, which could be scored by visual rating method. Ikehashi and Khush

(1979) classified the rice grains into several types: white center (core), white belly, milky white and opaque. The chalky areas were not as hard as the translucent areas because the starch granules in chalky areas were less densely packed as compared to translucent areas. Thus, the grains with chalkiness were prone to breakage during milling (Del Rosario *et al.*, 1968).

2.4.2.2.1 Varietal performance

Chalky kernel was more frequently associated with bold grain than with slender shape of comparable length (Nakatat and Jackson, 1973; Somrith, 1974).

From among 138 rice cultivars tested, Bhashyam and Srinivas (1981) found that the cultivars with grain breadth of <2 mm recorded translucent grains, while almost all the grains with breadth of >2.8 mm had white core. However, white core and grain length or L / B ratio appeared to be unrelated.

Indian Basmati rice varieties generally had chalky grains than Thai aromatic rice (var. Khao Dawk Mali 105) and Cambodian varieties (Sidhu *et al.*, 2001).

2.4.2.2.2 Effect of planting time

Chalkiness in milled rice increased with delay in transplanting (Oh *et al.*, 1991). Grain quality of 6 early and 5 late *indica* rice cultivars grown in the early and late seasons was analyzed and lower chalkiness was observed in rice grown in the late season (Zhu *et al.*, 1993).

2.4.3 Cooking quality

2.4.3.1 Amylose content

Many of the cooking and eating characteristics of milled rices were influenced by the ratio of two kinds of starches: amylose and amylopectin (Sanjiva Rao *et al.*, 1952). According to IRRI (1972), rice varieties were commonly grouped into waxy (0-2% amylose) and non-waxy (>2% amylose) types. Again, non-waxy (non-glutinous) rices were classified into very low amylose (2-9%), low amylose (9-20%), intermediate amylose (20-25%) and high amylose (25% and above) content.

Low amylose rices cooked moist and sticky, but rice with high amylose content cooked dry, became hard upon cooling and showed high volume expansion (not necessarily elongation) with a high degree of flakiness.

Although amylose content was a genetical trait, but it could vary due to the influence of temperature during grain ripening, followed by nitrogen fertilization and the degree of milling (Gomez, 1979).

2.4.3.1.1 Varietal performance

Amylose content of grain showed wide variation among indigenous aromatic rice cultivars of West Bengal like NC 324 (15.7%), Radhunipagal (16.8%), Badshabhog (18.0%), Danaguri (18.1%), Kataribhog (20.0%) (Sadhukhan and Chattopadhyay, 2001), and Gobindabhog (17.5%) and Tulsimanjari (19.5%) (Ghosh *et al.*, 2005) and Tulaipanji (20.0%) (Sarkar, 1994).

Rice of Basmati varieties have intermediate amylose content as compared to Khao Dawk Mali 105 and Combodian varieties (Sidhu *et al.*, 2001).

2.4.3.1.2 Effect of planting time

Delay in planting from 2 to 23 February reduced the amylose content by 0.5% in scented rice varieties during dry (*boro*) season in West Bengal (Ghosh *et al.*, 2004a). There was a decreasing trend in amylose content in rice (*cv.* Rajendra Suwasani) with delay in planting from 5 July (24.96%) to 4 August (23.93%) during wet (*kharif*) season in Bihar (Chowdhury *et al.*, 2011).

2.4.3.1.3 Effect of nutrient management

The amylose content in Pusa Basmati 1 (27.9-28.8%) was significantly lower in FYM treated plots than the commercial manures and untreated control, except processed city waste (Prakash *et al.*, 2002). The cultivar apparent amylose content did not differ significantly with fertilizer input or management method in U.S.A. (Champagne *et al.*, 2007).

Organic cultivation exhibited higher amylose content (25.3%) than conventional fields 21.7% at Pantnagar, India (Singh and Chandra, 2011).

2.4.3.1.4 Effect of storage container and time

The ageing of paddy of Thai scented rice (*cv.* KDML 105) had no significant effect on amylose content with the values of 16.74, 16.80 and 16.83% at cold room (20 ± 50°C) and warehouse (40 ± 50°C) condition for 10-month post harvest storage, respectively (Kanlayakrit and Maweang, 2013).

2.4.3.2 Protein content

The protein content in brown and milled rice were relatively low, about 8% and 7%, respectively (Nanda and Coffman, 1979); but rice protein was more nutritious than other cereal proteins. Milled rice protein consisted of at least 80% or more of glutelin (alkali-soluble), 10% globulin (salt-soluble), 5% albumin (water-soluble) and <5% prolamin (alcohol-soluble) (Cagampang *et al.,* 1966).

The protein content in rice grains was the result of interaction between genetic properties and agro-ecological condition, which was profoundly affected by the cropping season and crop management practices (Gomez, 1979).

2.4.3.2.1 Varietal performance

The crude protein content of 26 scented rice landraces collected from 6 districts of Orissa varied between 6.25 and 9.45% (Dikshit *et al.*, 1992).

Mean crude protein content in grain of 30 local rice cultivars of Assam was 10.75%, with a range between 8.40 (Laxman Sali) and 14.00% (Khairan). Analyses of protein fractions revealed that mean albumin, globulin, prolamin and glutelin content were 2.43, 3.82, 2.13 and 18.15 mg g^{-1} dry matter, respectively (Kandali and Borah, 1994).

Protein content in grain showed variations among indigenous rice cultivars of West Bengal like Tulaipanji (6.1%), Kalonunia (6.2%), Badshabhog (6.8%) and Gobindabhog (7.8%) (Pandey *et al.,* 2013).

2.4.3.2.2 Effect of planting time

The protein content of rice (*cv.* Kashmir Basmati) remained unaffected due to variation in time of transplanting on 24 May, 8 June, 24 June and 8 July (Akram *et al.,* 1985). However, the protein content in rice grain was significantly decreased with delay in planting from 5 July to 4 August at Kanpur in India (Dhaliwal *et al.,* 1986).

2.4.3.2.3 Effect of nutrient management

The application of FYM resulted in higher protein content (7.94-8.03%) in Pusa Basmati 1 than the commercial manures (*viz.* processed city waste, vermicompost and oil cake pillets) and chemical fertilizers (Prakash *et al.*, 2002), while *in-situ* incorporation of dhaincha (*Sesbania cannabina*) increased the crude protein content in rice than sunhemp and FYM (Hemlatha *et al.*, 2000). The application of mustard cake either sole or combined with chemical fertilizers recorded significantly higher protein content (6.3-7.3%) over unfertilized control (6.0%) in Gobindabhog rice (Mondal *et al.*, 2013).

The organic management method for diverse rice cultivars reduced protein content and a change in texture with better consumer acceptance (Champagne *et al.*, 2007).

2.4.3.2.4 Effect of storage container and time

The protein content of rice grain was not affected by the type of storage bins or the position (top, middle and bottom) of grains within the bin, but it increased with storage (8.5 – 8.8 %) over initial sample (8.4%) (Ilyas *et al.*, 1983).

2.4.3.3 Alkali spreading value (ASV) / Gelatinisation temperature

Alkali digestibility test was done to determine the gelatinization temperature of rice starch (Little *et al.*, 1958). Time required for cooking was determined by gelatinization temperature, which was the range of temperature wherein at least 90% of the starch granules swell irreversibly in hot water. Final gelatinization temperature ranged between 55-79°C, which could be classified as low (55-69°C), intermediate (70-74°C) and high (74-79°C).

2.4.3.3.1 Varietal performance

The alkali spreading value in most of fine and scented rice cultivars varied between 3.1 and 7.0 (Chowdhury and Ghosh, 1978). The indigenous aromatic rice cultivars of West Bengal showed variation in alkali scores as: Badshabhog (4.75), Danaguri (5.0), Radhunipagal (5.25) and Kataribhog (5.3) (Sadhukhan and Chattopadhyay, 2001). Among seven scented rice landraces, five cultivars (*viz.* Badshabhog, Gobindabhog, Khasdhan, Mohonbhog and Chinikamini) had intermediate and two genotypes (*viz.* Kalojira and Radhunipagal) low gelatinization temperature (Banerjee, 2011).

2.4.3.3.2 Effect of planting time

Sowing and transplanting dates had significant effect on alkali clearing value but spreading remained unaffected with sowing dates (Dhaliwal *et al.*, 1986).

2.4.3.3.3 Effect of nutrient management

According to Ali *et al.* (1992), alkali value was higher when N applied in splits. However, the alkali digestion value of rice was unaffected by different nutrient management treatments either inorganic fertilizers alone or in combination with organic matters like rice straw, compost, pig manure, etc. (Jeong *et al.*, 1996).

2.4.3.3.4 Effect of storage container and time

The ageing of grains of four rice hybrids did not affect the gelatinization temperature with mean alkali values of 4.64, 4.61 and 4.71 at 1, 3 and 6 month storage period, respectively for two years at two locations in India (Singh *et al.*, 2009).

2.4.4 Processing quality

2.4.4.1 Kernel elongation

Rice kernel absorbed water during cooking and increased in length, breadth and volume (Sood, 1979). Elongation ratio (ER) of cooked rice appeared to be a principal deciding factor for scented rice (Chowdhury and Ghosh, 1978).

Kernel elongation was influenced by both genetic factors and enviroment, especially temperature at the time of ripening (Dela Cruz *et al.*, 1989) as well as by ageing and pre-soaking before cooking.

2.4.4.1.1 Varietal performance

The length of cooked kernel and elongation ratio varied widely among scented rice landraces of West Bengal like 6.90 mm and 1.77 (Tulsimanjari), 7.10 mm and 1.72 (Gobindabhog) (Ghosh *et al.*, 2005), 7.13 mm and 1.53 (Danaguri), 7.32 mm and 1.56 (Badshabhog), 9.00 mm and 1.55 (Kataribhog), (Sadhukhan and Chattopadhyay, 2001); 6.95 mm and 1.82 (Mohanbhog), 6.88 mm and 1.73 (Radhunipagal), 6.80 mm and 1.79 (Kalojira) and 7.17 mm and 1.74 (Khasdhan) (Banerjee, 2011).

2.4.4.1.2 Effect of planting time

Elongation ratio of Gobindabhog rice was found to increase progressively with delay in planting from 10 July to 25 August in West Bengal, India (Mahata, 2014).

2.4.4.1.3 Effect of nutrient management

The application of *Azolla* either alone or in combination with inorganic N fertilizers to two Basmati rice varieties did not exert any significant influence in grain elongation ratio (Ghosh *et al.*, 2004*a*). However, longer kernel length after cooking in Pusa Basmati 1 was reported with application of compost @ 10 t ha^{-1} (Singh *et al.*, 2000a).

2.4.4.1.4 Effect of storage container and time

The elongation ratio of Thai aromatic rice variety (*cv.* KDML 105) increased from freshly harvested paddy (1.20) to ten months storage paddy at room temperature (1.45) and warehouse condition (1.46) (Kanlayakrit and Maweang, 2013).

2.4.4.2 Volume expansion

Expansion of volume dependent on surface area of the milled rice kernel (Bhattacharya and Sowbagya, 1971).

2.4.4.2.1 Varietal performance

The volume expansion ratio of aromatic rice cultivars of West Bengal was recorded as: Badshabhog (7.42), Gobindabhog (7.71), Kalonunia (6.00) and Tulaipanji (5.25%) (Pandey *et al.*, 2013).

2.4.4.2.2 Nutrient management

Rao *et al.* (1993) reported that application of N did not adversely affect the volume expansion of rice.

2.4.4.3 Aroma

Aroma, a special feature of rice, was emitted in fields, storage as well as during milling, cooking and eating (Gibson, 1976 and Efferson, 1985). Tsuzuki *et al.* (1981) and Buttery *et al.* (1983*b*) reported about 114 volatile compounds responsible for aroma, of which 2-acetyl-1-pyrroline had been demonstrated to be the major aroma principle in cooked rice (Buttery *et al.*, 1983*a*).

2.4.4.3.1 Varietal performance

Genetic variation in aroma was observed among 26 scented rice germplasm collected from 6 districts of Orissa: one good, seven fair and eighteen high degree of scent (Dikshit *et al.*, 1992). Among aromatic rice landraces of West Bengal, Kataribhog had mild aroma, while Radhunipagal, Seetabhog, Tulsibhog and Tulsimanjari possessed moderate aroma (De *et al.*, 2002; Ghosh *et al.*, 2004*b*). However, Sadhukhan and Chattopadhyay (2001) scored medium (Badshabhog), strong (Danaguri and Kataribhog), and very strong aroma (Radhunipagal) for scented rice cultivars of the state.

2.4.4.3.2 Effect of planting time

Aroma content in Basmati *cv.* Pusa was higher in late sowings (21 August and 7 September) both at Moymensingh and Rangpur in Bangladesh than early sowing (6 August) probably due to better aroma synthesis at lower temperature (<20°C) during grain filling period (Dutta *et al.*, 1999).

2.4.4.3.3 Effect of nutrient management

Grains of Gobindabhog rice processed strong aroma with all nutritional treatments including unfertilized control, which indicated that mustard cake and chemical fertilizers had no influence on variation in aroma during wet (*kharif*) season in West Bengal (Mondal *et al.*, 2013). However, the intensity of aroma in Basmati *cv.* Pusa was found higher with the application of N @ 25 kg ha^{-1} (score 1.74 - 1.96) or 50 kg ha^{-1} (score 1.57 - 1.93) over control (score 1.28 - 1.38), when grown at two locations in Bangladesh (Dutta *et al.*, 1999).

2.4.4.3.4 Effect of storage container and time

2-acytyl-1-pyrroline, 'popcorn' like flavour compound, was decreased in aromatic rice (*cv.* Khao Dawk Mali 105) during post-harvest storage, but its concentration was not changed significantly after 7-week of storage. The preservation of 2-acytyl-1-pyrroline was affected by package materials like low density polythene (LDPE) and nylon mesh bags, but the effect was moderate (Yoshihashi *et al.*, 2005).

The average aroma score of Gobindabhog rice over five containers after 2-months storage (score 2.53±0.18) delayed by 13.83 % after 4-month (score 2.18±0.06) and 29.64% after 6-month (score 1.78±0.37). Among five storage container, earthen pot performed best for retention of aroma compared to galvanized iron bin, polythene bag, markin cloth bag and jute bag during long time storage in West Bengal, India (Mahata, 2014).

2.5 Nutrient uptake by the crop and fertility status of the soil

2.5.1 Nutrient uptake

2.5.1.1 Effect of nutrient management

The average of seven organic nutritional treatments (*viz.* FYM, vermicompost and mustard cake) for Gobindabhog rice was noted as N uptake (19.94, 27.78, 33.79 and 38.51 kg ha^{-1}), P uptake (8.69, 10.23, 10.84 and 13.41 kg ha^{-1}), k uptake (20.84, 36.86, 45.55 and 51.70 kg ha^{-1}) at 28, 56, 84 DAT and at harvest, respectively in West Bengal (Banerjee, 2011).

The nutrient uptake particularly N was found higher in Pusa Basmati 1 when treated with FYM as compared to commercial manures and chemical fertilizers (Prakash *et al.*, 2002).

Kumari *et al.*, (2010) reported that application of vermicompost @ 2.5 t ha^{-1} to scented rice (*cv.* Birsamati) recorded mean uptake of N, P and K as 30.3, 5.6, 35.5 kg ha^{-1}, respectively.

2.5.2 Residual fertility status

2.5.2.1 Effect of nutrient management

Organic manures (*viz.* dhaincha, sunhemp and FYM) applied to rice improved the soil fertility status like organic carbon, available N, P and K content in soil at post-harvest stage (Hemlatha *et al.*, 2000) in Tamilnadu during 1996-98.

Organic mode of nutrient supply recorded significantly higher soil organic carbon, whereas available N, P and K were favoured by integrated nutrient management in Basmati rice-based cropping system at Pantnagar in India (Singh and Chandra, 2011).

The integrated dose of FYM @ 0.5 t ha^{-1} + N_{40} P_{20} K_{20} kg ha^{-1}applied to Gobindabhog rice during *kharif* season resulted in better soil residual status (+8.04% N, +27.84% P_2O_5 and -5.58% K_2O) compared to other nutrient management practices in West Bengal (Mahata, 2014).

2.6 Cost of cultivation, net return and benefit-cost ratio

Kumari *et al.,* (2010) reported that among organic sources, green manuring + FYM fetched significantly higher net return (Rs. 35,975 ha^{-1}) and B:C ratio (2.61) of scented rice (*cv.* Birsamati). According to Banerjee (2011), the cost of production of Gobindabhog rice varied between Rs. 18,582 and Rs. 25,440 ha^{-1} due to differences in forms and quantities of organic manures used against the unfertilized control (Rs. 13,218 ha^{-1}). Among organic nutritional treatments, combined application of FYM (@ 50% RDN) + Mustard cake (@ 50% RDN) resulted in highest net return (Rs. 19,190 ha^{-1}) and greater B: C ratio (1.87) in West Bengal.

Chapter 3

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 Location of the study

Two field experiments were conducted during wet (*kharif*) season of 2012and 2013and a post-harvest storage study was made during 2013 and 2014 at 'C' Block Farm of Bidhan Chandra KrishiViswavidyalaya, Kalyani, Nadia, West Bengal, India and grain quality analysis was done at Aromatic Rice Laboratory, Department of Agronomy, Bidhan Chandra KrishiViswavidyalaya, Mohanpur, Nadia, West Bengal, India (Plate 3.1 and 3.12). Details of the materials used, experimental procedures followed and techniques adopted are described in the chapter.

3.2 Meteorological features of the experimental season

The farm is situated at 22°59′N latitude, 88°27′E longitude and at an elevation of 9.75 m above mean sea level, so it is within the New Alluvial Zone of West Bengal. The crop seasons of the humid sub-tropical climatic region are broadly classified as: dry and warm or pre-*kharif* (March – May), wet and warm or *kharif* (June – October) and dry and cool or *rabi* (November – February). The summer temperature in the region is generally high but winter is short and mild. The temperature begins to rise from the end of February and the maximum is reached during April-May. Again, it starts to decline from mid-October reaching the minimum about 10°C by January. The long-term average of annual rainfall is about 1396 mm; of which south-west monsoon accounts for 70 – 80% with its onset in the region during second week of June. The relative humidity remains high during monsoon months *i.e.* from July to October.

The details of the meteorological parameters pertaining to the periods of the experimentation are presented in Tables 3.1 and 3.2; Fig. 3.1 and 3.2.

The month-wise minimum and maximum temperature were found to vary between 11.7 and 35.4°C during 2012 and 12.5 and 34.2°C during 2013. The rainfall received during cropping period were 1025.60 mm and 970.61 mm, in the first and second year respectively; with monthly rainfall ranging between 7.3 (December) and 287.8 mm (September) during 2012 and 0.0 mm (November and December) and

314.5 mm (August) during 2013. The monthly average maximum relative humidity was found to vary between 90.9 and 96.6% during first year and 83.8 and 96.9% during second year of study; while minimum relative humidity varied between 55.4 and 81.8% during 2012 and between 55.6 and 82.0% during 2013. The bright sunshine hour per day was generally low in high rainfall months mainly due to cloudy days and it ranged between 4.0 (July) and 7.6 (October) hour during 2012, and between 4.5 (October) and 8.1 (November) hour during 2013.

Table 3.1

Meteorological data pertaining to the periods of experimentation (2012 to 2014)

Month	Rainfall (mm)	Temperature (° C)		Relative humidity (%)		Bright sunshine (hour)
		Maximum	Minimum	Maximum	Minimum	
2012						
June	184.0	35.4	27.6	90.9	67.4	4.9
July	264.0	32.4	26.5	95.1	81.8	4.0
August	203.3	32.4	26.4	96.4	79.6	5.0
September	287.8	32.9	26.0	96.6	76.4	5.7
October	29.0	33.5	22.5	92.7	59.6	7.6
November	50.2	29.5	17.3	93.0	55.4	6.5
December	7.3	25.5	11.7	95.3	59.2	5.3
2013						
June	6.9	34.2	26.4	94.1	78.6	4.7
July	180.3	33.4	26.5	95.2	80.8	5.0
August	314.5	32.8	26.0	96.5	82.0	4.7
September	228.4	34.1	26.0	95.2	75.6	5.3
October	240.5	31.4	23.9	96.9	78.8	4.5
November	0.0	30.0	16.4	83.8	55.6	8.1
December	0.0	27.0	12.5	84.5	59.7	6.2

[Source: AICRP on Agro-meteorology, B.C.K.V., Kalyani, Nadia, W.B., India]

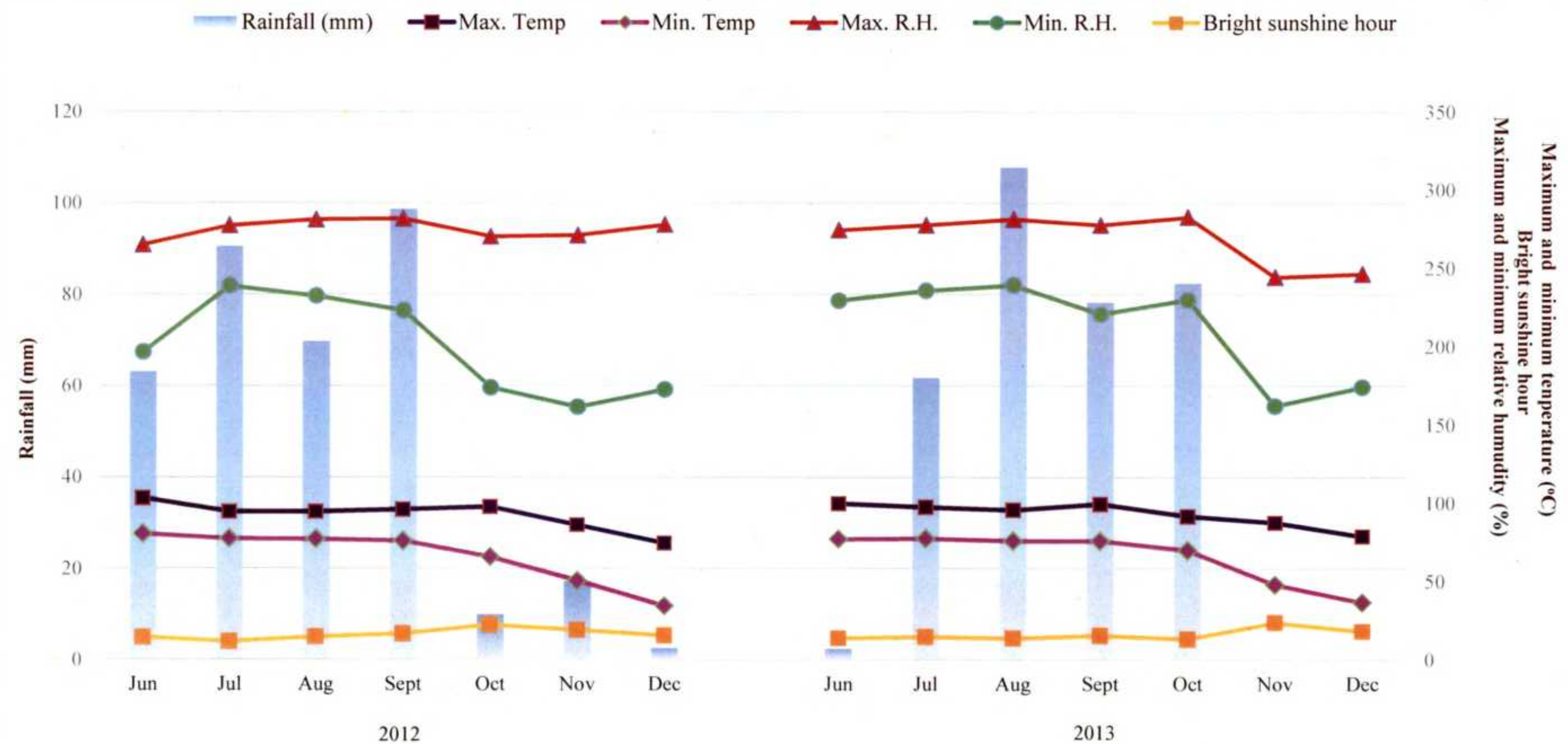


Fig. 3.1: Meteorological conditions pertaining to the periods of experimentation (2012-2013)

Table 3.2
Meteorological data pertaining to the periods of post harvest storage period(2013 and 2014)

Month	Temperature (°C)		Relative humidity (%)	
	Maximum	Minimum	Maximum	Minimum
2013				
January	25.1	9.7	93.6	49.0
February	29.4	13.5	91.0	44.9
March	36.2	20.0	88.5	34.2
April	37.6	24.2	88.0	43.3
May	34.4	25.7	90.7	68.6
June	34.2	26.4	94.1	78.6
July	32.4	26.5	95.1	81.8
August	32.4	26.4	96.4	79.6
September	32.9	26.0	96.6	76.4
2014				
January	24.3	10.4	86.1	62.5
February	28.5	13.7	85.3	52.8
March	34.0	18.9	85.7	46.5
April	39.4	24.9	85.7	37.9
May	37.6	26.7	87.5	56.1
June	35.4	27.0	93.2	75.5
July	32.9	26.9	95.8	83.3
August	34.2	26.5	94.7	77.2
September	34.0	25.8	94.5	77.4

[Source: AICRP on Agro-meteorology, B.C.K.V., Kalyani, Nadia, W.B., India]

The average maximum and minimum temperature during the storage period (January to September) of 2013 (1st year) were 32.7°C and 22.0°C respectively and during the storage period (January to September) of 2014 (2nd year) they were 33.4°C and 22.3°C respectively.

The month-wise recorded maximum and minimum relative humidity (%) revealed that it was varied between of 34.2 and 96.6% during the storage period of 2013 (1st year) and between 37.9 and 95.8% during the storage period of 2014 (2nd year).

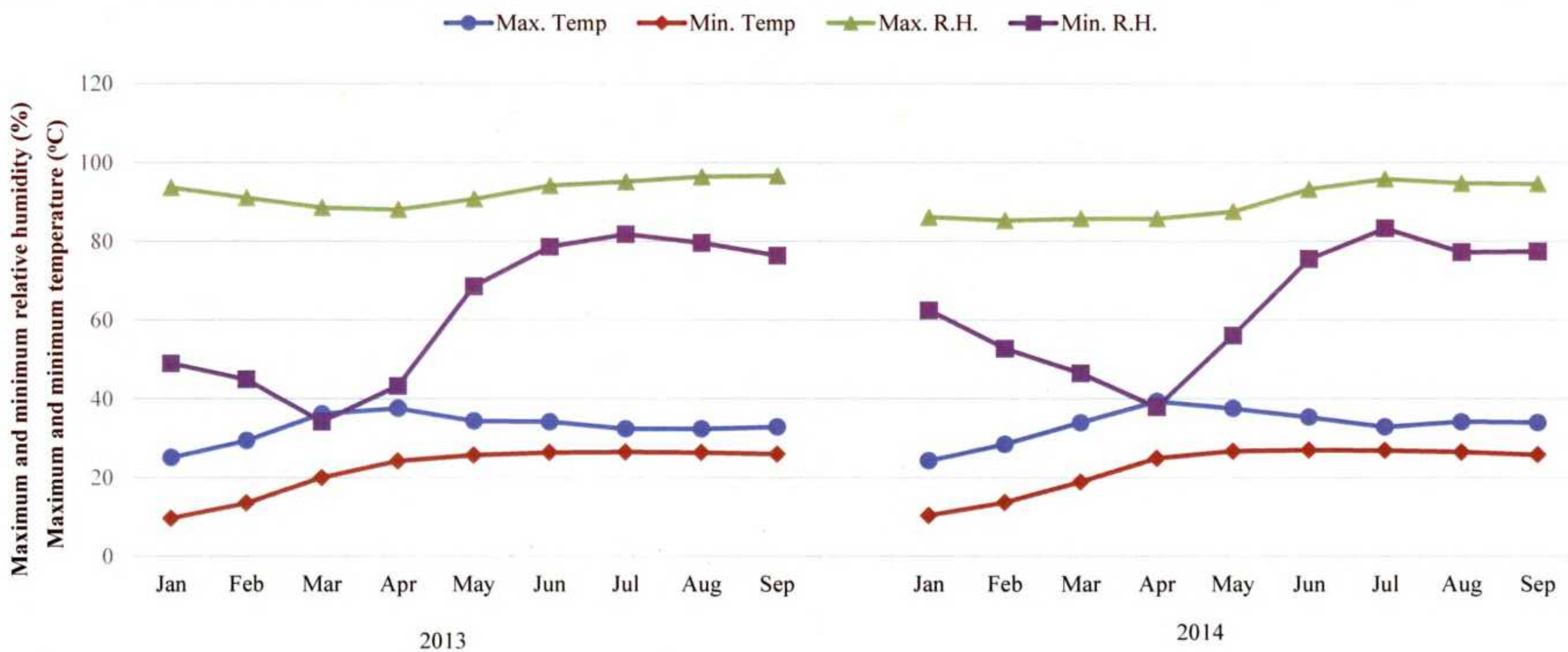


Fig. 3.2: Meteorological conditions during storage periods at Kalyani, Nadia, West Bengal (2013 and 2014)

3.3 Soil

The experiment was conducted on a low land, well-drained alluvial soil (order-Entisol) that belonged to the textural class of clay-loam. The physico-chemical properties of the soil of the experimental plots have been summarized in Table 3.3.

Table 3.3
Physico-chemical properties of the experimental soil (0 – 15 cm soil depth)

Sl. No.	Property	Value	Method used
1	Mechanical Composition		International pipette method (Piper, 1950)
	Sand (%)	42.8	
	Silt (%)	30.0	
	Clay (%)	27.2	
2	Soil texture	Clay loam	USDA system (Brady, 1996)
3	Soil pH	6.9	Blackman's pH meter method (Jackson,1973)
4	Organic carbon (%)	0.59	Walkley and Black method (Jackson, 1973)
5	Available Nitrogen (kg ha^{-1})	330.8	Macro Kjeldahl method (Jackson, 1973)
6	Available phosphorus (kg ha^{-1})	42.7	Olsen's method (Jackson, 1973)
7	Available potassium (kg ha^{-1})	239.2	Flame photometric method (Jackson, 1973)

3.4 Previous cropping history

The cropping sequence of paddy (*kharif*) – fallow or lentil – (*rabi)*was generally practiced in experimented field during last 20 years. More specifically, some indigenous scented rice cultivars during *kharif*(July- November) and green gram during *pre kharif*(February – May) were grown in preceding four years (2008, 2009, 2010 and 2011) of the investigation.

3.5 Experimental details

3.5.1 Experiment No.1

Evaluation of indigenous aromatic rice cultivars in New Alluvial Zone of West Bengal during *kharif* season

The first experiment was conducted to study the varietal performance of 14 indigenous aromatic rice cultivars in New Alluvial Zone of West Bengal during *kharif* season of 2012 and 2013. The experiment was laid out in a randomized block design (R.B.D.) with 3 replications and 14 scented rice cultivars were randomly allocated to the plots within each block. Details of the treatments are described in Table 3.4 and the layout of the experiment is depicted in Fig. 3.3.

Table 3.4
Details of treatments of Experiment No. 1

Treatment code	Indigenous aromatic rice cultivar
V_1	Badshabhog
V_2	Gabindabhog
V_3	Kalojira
V_4	Kalonunia
V_5	Kaminibhog
V_6	Kataribhog
V_7	LalBadshabhog
V_8	NC 324
V_9	NC 365
V_{10}	Radhatilak
V_{11}	Radhunipagal
V_{12}	Sitabhog
V_{13}	Tulaipanji
V_{14}	Tulsimukul

Generally, 24–25 days old seedlings at 4–5 leaf stage of all 14 cultivars were transplanted using 2–3 hill^{-1}at a spacing of 15cm × 15cm in 4m × 3m plots. A uniform fertilizer dose of farm yard manure (FYM) @ 2 t and $N_{40}P_{20}K_{20}$ kg ha^{-1} was applied to all the experimental units in the study. Of which, full FYM and phosphate, ¼ N and ½ K_2O were given as basal, whereas ½ N as first top dressing at 3 weeks after

Plate 3.1: "C" Block Farm, B.C.K.V., Kalyani, Nadia, West Bengal

Plate 3.2: Land preparation by power tiller

Plate 3.3: Transplanting of scented rice seedlings in main field of Experiment No. 1

Plate 3.4: Observation on growth parameters in plots of Experiment No. 1

Plate 3.5: Harvesting of Radhatilak paddy in Experiment No. 2

Plate 3.6: Threshing of aromatic rice varieties of Experiment No. 1

Field activities at "C" Block Farm, Kalyani, Nadia, West Bengal

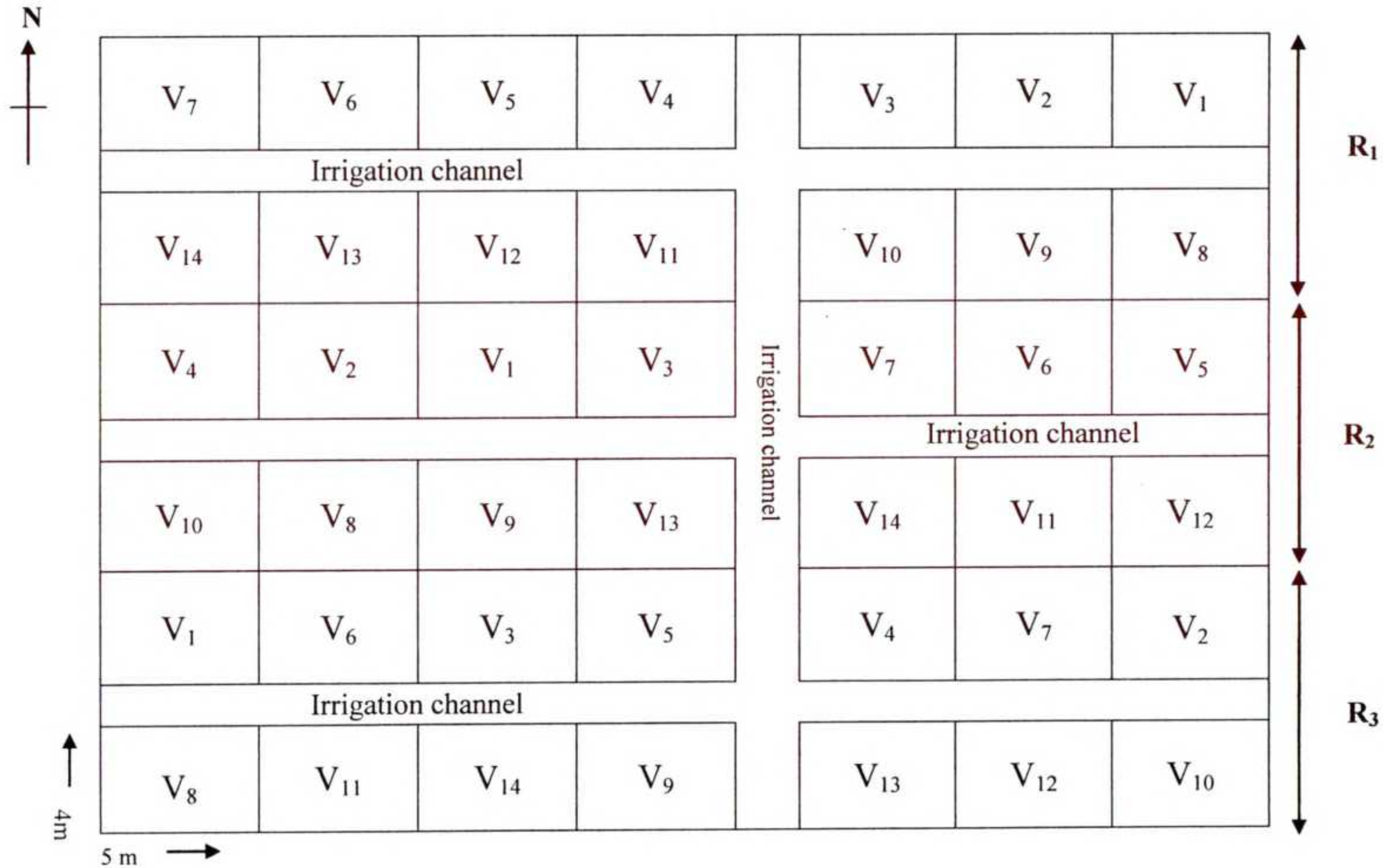


Fig. 3.3: Layout of the Experiment No. 1

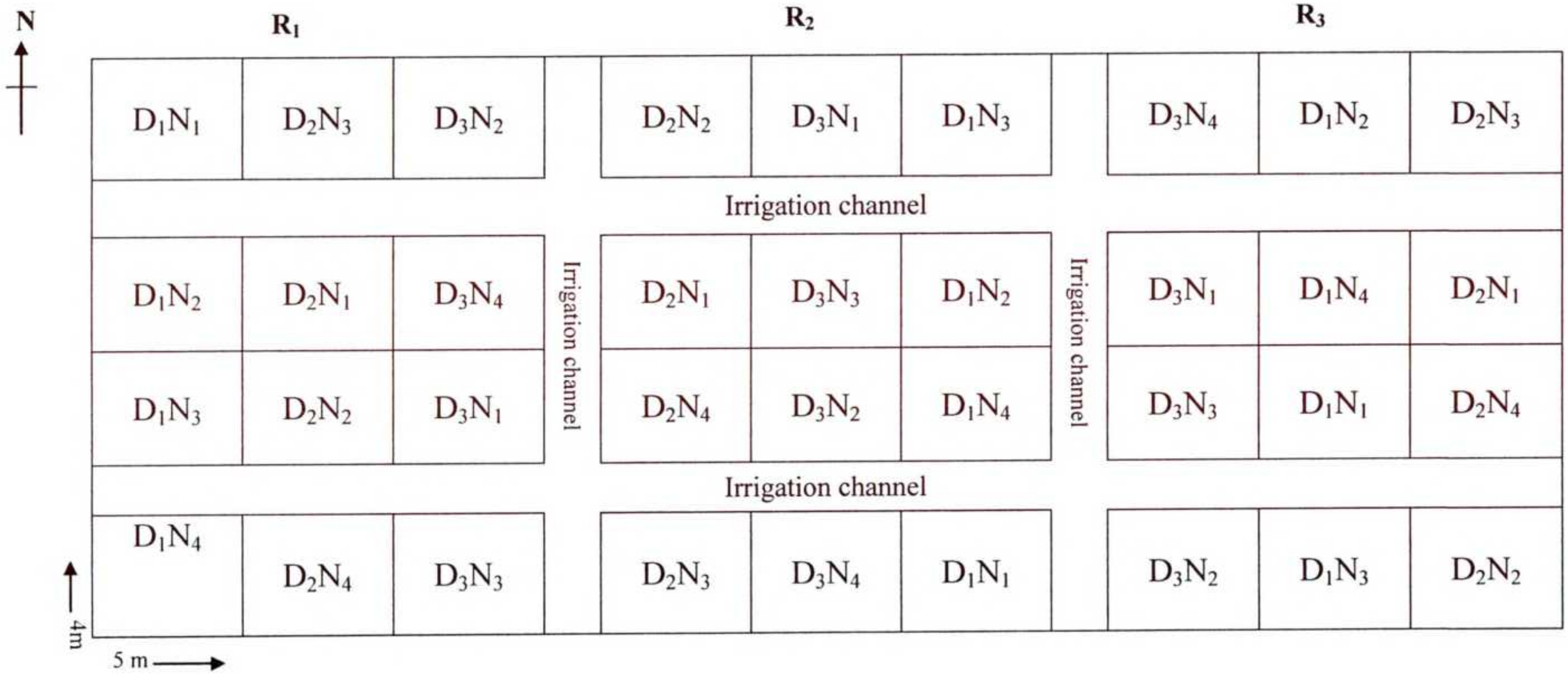


Fig. 3.4: Layout of the Experiment No. 2

transplanting (WAT) and rest ¼ N and ½ K_2O at 6 WAT were applied. N, P and K were given in the form of urea, single super phosphate (SSP) and muriate of potash (MoP) in the experiment.

3.5.2 Experiment No. 2

Standardization of planting time and nutrient management system for better yield and quality of Radhatilak rice during *kharif*season

The second field study was conducted during *kharif* season of 2012 and 2013 to standardize the planting time and nutrient management system for Radhatilak rice towards greater yield, superior quality and better soil health. The field experiment was laid out in a split-plot design consisting of 3 planting times in main plots and 4 nutrient management systems in sub-plots with 3 replications. Details of the treatments are given in Table 3.5 and layout of the experiment is shown in Fig. 3.4.

Table 3.5
Details of treatments of Experiment No. 2

Treatment	Code	Particular
Main plot 3 planting times	D_1	2^{nd} week of July
	D_2	4^{th} week of July
	D_3	2^{nd} week of August
Sub-plot 4 nutrient management systems	F_1	50:25:25 kg ha^{-1} of N:P_2O_5:K_2O (100% RD as inorganic *i.e.* 12.5:25:18.75 kg ha^{-1} of N:P_2O_5:K_2O as basal +25 kg ha^{-1} of N at 3 WAT + 12.5:6.25 kg ha^{-1} of N:K_2O at 6 WAT)
	F_2	50% RD as inorganic +50% RD as Mustard cake (*i.e.* 12.5:12.5:9.375 kg ha^{-1} of N:P_2O_5:K_2O as basal + 0.5 t ha^{-1} of Mustard cake at 3 WAT + 12.5:3.125 kg ha^{-1} of N: K_2O at 6 WAT)
	F_3	25% RD as inorganic + 25% RD as FYM +50% RD as Mustard cake (*i.e.* 6.25 kg ha^{-1}P_2O_5 and 2.5 t ha^{-1} of FYM as basal +0.5 t ha^{-1} of Mustard cake at 3 WAT+ 12.5:6.25 kg ha^{-1} of N: K_2O at 6 WAT)
	F_4	25 % RD as FYM +75 % RD as Mustard cake (*i.e.* 2.5 t ha^{-1} of FYM as basal + 0.5 t ha^{-1} of Mustard cake at 3 WAT + 0.25 t ha^{-1} of Mustard cake at 6 WAT)

Radhatilak rice seedlings at the age of 24 – 25 days old were transplanted at a spacing of 15 cm × 15 cm in 4 m × 3 m size experimental plots.

3.5.3 Experiment No. 3

Effect of storage containers on grain quality of Radhatilak rice

The effect of storage containers on quality of Radhatilak rice during different length of storage periods was tasted in a completely randomized design (C.R.D.) with 4 replications during 2012 and 2013. Details of the treatments used in the study are described in table 3.6 and Plate 3.7, 3.8, 3.9, 3.10 and 3.11.

Table 3.6

Details of treatments of Experiment No. 3

Treatment	Code	Particular
5 storage containers	C_1	Earthen pot [locally available]
	C_2	Galvanized iron bin [sheet thickness 0.50 mm]
	C_3	Gunny bag (Jute made) [capacity 100 kg, weight 1.02 kg]
	C_4	Markin cloth bag [locally available]
	C_5	Polythene bag [capacity 50 kg, thickness 130-150 gsm]

3.6 Collection of seed

All aromatic rice cultivars selected for the study were of indigenous types and their native areas were identified in different parts or districts of West Bengal. Seeds of fourteen genotypes @ 1 kg each were collected from State Agricultural Universities, Government Department, etc. during March to May, 2012 (Table 3.7).

Plate 3.7: Earthen pot
[Locally available]

Plate 3.8: Galvanized Iron Bin
[Sheet thickness 0.50 mm]

Plate 3.9: Gunny bag
[Locally available]

Plate 3.10: Markin Cloth bag
[Locally available]

Plate 3.11: Polythene bag
[Locally available]

Plate 3.12: Laboratory analysis at Aromatic rice laboratory, B.C.K.V., Nadia, West Bengal

Storage containers used in the laboratory for Experiment No. 3

Table 3.7

Source of seeds and native areas / districts of aromatic landraces of West Bengal

Cultivar	Source	Native Area / District
Badshabhog	Rice Research Station,Govt. of W.B., Chinsurah,Hooghly	Bankura,Burdwan, Hooghly, Murshidabad, Purbaand PaschimMedinipur
Gabindabhog	RKVY Project, on 'Bengal Aromatic Rice', B.C.K.V., Nadia	Burdwan, Bankura,Hooghly, Nadia etc.
Kalojira	Regional Research Sub Station, B.C.K.V., Chakdah, Nadia	Jalpaiguri, Nadiaand Purba Medinipur
Kalonunia	Rice Research Station, Govt. of W.B., Chinsurah, Hooghly	Jalpaiguri and Coochbehar
Kaminibhog	Regional Research Sub Station, B.C.K.V., Chakdah, Nadia	Nadia, Purulia, PurbaMedinipur
Kataribhog	Regional Research Sub Station, U.B.K.V., Majhian, DakshinDinajpur	Maldah and DakshinDinajpur
LalBadshabhog	Regional Research Sub Station, B.C.K.V., Chakdah, Nadia	Purulia and Bankura
NC 324	Rice Research Station, Govt. of W.B., Chinsurah, Hooghly	Hooghly, Nadia, Burdwan, Bankura etc.
NC 365	Rice Research Station, Govt. of W.B., Chinsurah, Hooghly	Coochbehar, Jalpaiguri, Nadia,
Radhatilak	Rice Research Station, Govt. of W.B., Chinsurah, Hooghly	Nadia, Hooghly and PurbaMedinipur
Radhunipagal	Regional Research Sub Station, B.C.K.V., Chakdah, Nadia	Birbhum, Bankura, PaschimMedinipur
Sitabhog	Rice Research Station, Govt. of W.B., Chinsurah, Hooghly	Nadia, Burdwan and Bankura,
Tulaipanji	RKVY Project 'Bengal Aromatic Rice', U.B.K.V., Majhian	Uttar and DakshinDinajpur
Tulsimukul	Regional Research Sub Station, B.C.K.V., Chakdah, Nadia	Bankura, Birbhum and Purulia

3.7 Field and cultural operations

Proper care was taken for treatment-wise management of both nursery beds and experimental plots starting from seeding to harvest of the crop. A schedule of various field operations is given in Table 3.8.

3.7.1 Preparation of wet nursery bed

Raised wet nursery beds of 4 m length and 1m width were prepared about 30 days before transplanting during *kharif* season.

3.7.2 Sowing of seeds and raising of seedlings

Seeds of 14 aromatic rice cultivarswere broadcasted in separate wet nursery beds separately in the first experiment and seeds of Radhatilak paddy were sown as par sowing time schedule in the second field investigation (Plate 3.1). The beds were kept saturated by allowing water in the channel only during first week and thereafter, a thin layer of standing water was maintained in the beds till the uprooting of seedlings.

3.7.3 Land preparation and layout

The field was thoroughly ploughed twice with a tractor under dry condition and thereafter with a power-tiller in standing water so that proper puddling could be made (Plate 3.2).

The layout of two field experiments were made separately as per treatments and replications assigned and then the plots under each replication were demarcated by earthen bunds, thoroughly levelled and water was filled in.

3.7.4 Transplanting

24-25 days old rice seedlings @ 2–3 $hill^{-1}$ were transplanted at a spacing of 15 cm × 15 cm in a shallow depth (3- 4 cm) in puddled field during *kharif* season of both the years of investigation (Plate 3.3).

3.7.5 Nutrient management

Nutrient management practices for two field experiments were different with regard to dose and time of application. Although uniform integrated nutrient dose of

Table 3.8
Schedule of field operations during the periods of experimentation

Sl. No.	Particular	Experiment No. 1		Experiment No. 2					
		2012	2013	2012			2013		
				D_1	D_2	D_3	D_1	D_2	D_3
1	Seed bed preparation								
	1st ploughing (Power tiller)	08.06.2012	07.06.2013	05.06.2012	05.06.2012	05.06.2012	07.06.13	07.06.13	07.06.13
	2nd ploughing (Power tiller)	20.06.2012	21.06.2013	14.06.2012	01.07.2012	18.07.2012	13.06.11	01.07.13	17.07.13
	Lay out	20.06.2012	21.06.2013	14.06.2012	01.07.2012	18.07.2012	13.06.11	01.07.13	17.07.13
2.	Sowing of seeds in nursery beds	21.06.2012	22.06.2013	15.06.2012	02.07.2012	19.07.2012	14.06.2013	02.07.2013	18.07.2013
3.	Land preparation								
	1st ploughing (Tractor)	20.06.2012	24.06.2013	14.06. 2012	14.06. 2012	14.06.2012	16.06.13	16.05.13	16.06.13
	2nd Ploughing (Tractor)	09.07.2012	07.07.2013	02.07. 2012	18.07.2012	02.08.2012	29.06.13	15.07.13	29.07.13
	3rd Ploughing (Power tiller)	16.07.2012	17.07.2013	10.07. 2012	24.07.2012	11.08.2012	07.07.13	24.07.13	13.08.13
	Lay out preparation	16.07.2012	17.07.2013	10.07. 2012	25.07.2012	12.08.2012	07.07.13	24.07.13	13.08.13
4.	Transplanting of seedling	17.07.2012	18.07.2013	12.07.2012	26.07.2012	13.08.2012	10.07.2013	26.07.2013	14.08.2013
5.	Nutrient management								
	Basal application	16.07.2012	17.07.2013	11.07. 2012	25.07.2012	12.08.2012	09.07.13	25.07.13	13.08.13
	1st top dressing	07.08.2012	09.08.2013	02.08. 2012	16.08.2012	03.09.2012	01.08.13	17.08.13	04.09.13
	2nd top dressing	28.08.2012	30.08.2013	23.08. 2012	06.09.2012	24.09.2012	23.08.13	07.09.13	26.09.13
6.	Intercultural operation								
	1st hand weeding	06.08.2012	08.08. 2013	01.08. 2012	15.08.2012	02.09.2012	30.07.13	16.08.13	03.08.13
	2nd hand weeding	25.08.2012	28.08. 2013	21.08. 2012	05.09.2012	23.09.2012	22.08.13	05.09.13	24.09.13
7	Irrigation	As and when required		As and when required					
8	Harvesting	20.11.2012	23.11.2013	20.11.12	26.11.12	05.12.12	22.11.13	27.11.13	06.12.13

FYM 2t + N_{40} P_{20} K_{20} kg ha^{-1} was applied in the first investigation, but organic manure (*viz*. FYM and mustard cake) and chemical fertilizers (*viz.* Urea, SSP and MoP) in different combinations as per treatment schedule were given in the second experiment.

3.7.6 Weed Control

Hand weeding twice at 3 and 6 WATwas done to remove the weeds from all the plots of both the field experiments.

3.7.7 Water management

A shallow depth (2-3 cm) of standing water was maintained from transplanting to maximum tillering stage, which was gradually increased to 4-5 cm upto flowering. Thereafter, it was reduced to 2-3 cmup to 2 weeks prior to maturity. The water requirement of the crop was mainly met by the south-west monsoon, but irrigation was given as and when necessary depending on the amount and distribution of rainfall.

3.7.8 Harvesting and threshing

The crop was harvested by sickles at ground level, when 80% of the panicles with 80% grains in each panicle were matured. The produce was dried in the sun for 2-3 days and then it was threshed with a pedal thresher at the threshing floor. After proper cleaning and drying, the grains and straws of each net plot were weighed separately and the yield wascalculated in terms of t ha^{-1}(Plate 3.5 and 3.6).

3.8 Methods of calculating growth environment

3.8.1 Growing degree days (GDD)

Degree day was obtained as the difference between the mean daily temperature and the base temperature (Nuttonson, 1955):

$$GDD = \sum_{i=1}^{n} [(\frac{T_{max} + T_{min}}{2}) - T_b]$$

where, $T_{max.}$ and$T_{min.}$were the maximum and minimum air temperature of a day, T_b was the base temperature (10°C for rice) and n was the number of days to attain a phenophase.

The degree days for different phenophases of the crop was calculated andthen they were summed up for the entire cropping period.

3.8.2 Heliothermal units (HTU)

The degree day multiplied by actual duration of bright sunshine hours for the corresponding day was termed as heliothermal unit (Singh *et.al.*, 1990).

$$HTU = \sum_{i=1}^{n}[GDD \times \text{ Bright sunshine hour}]$$

The heliothermal units for different phenological stages of crop were calculated and then they were summed up for the entire life cycle.

3.8.3 Photothermal Units (PTU)

The photothermal unit was calculated by the following formula as suggested by Nuttonson (1948):

$$PTU = \sum_{i=1}^{n}[GDD \times \text{Average day length (hour)}]$$

The photothermal units for different phenophases were calculated and then they were summed up for the entire crop growing period.

3.9 Methods of recording biometrical observations

3.9.1 DUS testing

The test variety Radhatilak was evaluated in the open field at 'C' Block Farm, B.C.K.V., Kalyani, Nadia, West Bengalduring *kharif* season of 2012 and 2013 following conventional agronomic practices. Each test experimental unit consisted of 6 meter row length consisting 30 rows including row to row distances of 30 cm and plant to plant distance of 20 cm. The DUS testing following the PPV & FRA DUS Test Guidelines for Rice (PPV & FRA, 2007) was done to describe the morphological and related characteristics of indigenous aromatic rice variety, Radhatilak (Plate 3.4).

3.9.2 Plant height

Five plants randomly selected in each plot were tagged at early vegetative stage. The height of such five plants of each plot were measured from the ground level to the tip of the leaf at 28 DAT (*i.e.* at active tillering stage), 56 DAT (*i.e.* at panicle initiation stage), 84 DAT (*i.e.* at 50% flowering stage) and at maturity stage. Mean plant height (cm) was worked out at above-mentioned growth stages.

3.9.3 Tiller counting

The number of tillers of five tagged plants of each plot was recorded at 28, 56 and 84 DAT, which were converted into number of tillers m^{-2} area.

3.10 Methods of calculating growth attributes

For growth analyses, 5 randomly selected hills $plot^{-1}$ was collected at 28, 56, 84 DAT and at maturity stage. The roots, leaves, stem and panicles (after emergence) were separated and they were dried in a hot air oven at a temperature of 80±1°C for 8-12 hours, till constant weights were recorded.

3.10.1 Leaf area index (LAI)

A rectangular bit of 10 cm length was cut from 10 leaves selected from 5 randomly collected plant samples and the width of each cut leaf was measured. The area of cut leaves was calculated and all green leaf laminae of those 5 hills were also separately dried and weighed. Thereafter, total leaf area was calculated by area-weight relationship between cut leaves and total green foliage of the crop. Since leaf area index (LAI) appeared to be the area of green surface $unit^{-1}$ area of land surface, it was calculated by using the following formula (Watson, 1958).

$$\text{LAI} = \frac{\text{Leaf area of plants in unit area } \left(\text{cm}^2\right)}{\text{Ground surface in unit area } \left(\text{cm}^2\right)}$$

3.10.2 Dry matter accumulation

Dry weights of different plant parts as described earlier were recorded and summed up to convert into total dry matter (g) in 1 m^2 area at 28, 56, 84 and 112 DAT.

3.10.3 Crop growth rate (CGR)

Crop growth rate (CGR) represented total dry weight of plants gained in unit area land per unit time and it was calculated by using the following formulagiven by Watson (1958):

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

where, W_1 and W_2 were the dry weights of aerial plant parts per unit land area at times t_1 and t_2, respectively.

3.10.4 Net assimilation rate (NAR)

Net assimilation rate (NAR) could be defined as the rate of increase in whole plant dry weight per unit leaf area and it was calculated by the following formula (Watson, 1958):

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{Log_e L_2 - Log_e L_1}{L_2 - L_1}$$

where, W_1 and W_2 were total dry weight of plants, and L_2 and L_1 were total leaf area of plants per unit land area at times t_1 and t_2, respectively.

3.10.5 Light transmission ratio (LTR)

The light intensity was recorded with the help of a lux meter (Lutron make, Model LX101, Thailand) by keeping the sensor on the top of the canopy and at ground surface. Thus, light transmission ratio was calculated by using the following formula (Yoshida, *et.al.*, 1972):

$$LTR (\%) = \frac{I_1}{I_0} \times 100$$

where, I_1 and I_0 were the light intensity at ground surface and top of the canopy, respectively.

3.10.6 Light extinction co-efficient (k)

The light extinction co-efficient (k) for Beer's law was calculated by the following formula (Saeki, 1963).

$$k = \frac{Log_e \frac{I_0}{I_1}}{F}$$

where, I and I_0 were the light intensities at ground level and top of the canopy, respectively; F was the leaf area index and log_e was the base of natural log.

3.11 Methods of recording yield components, associated characters and determining yield

3.11.1 Panicle length

The length of 10 randomly selected panicles of each plot was measured and mean was worked out.

3.11.2 Number of panicles unit^{-1} area

The number of matured panicles was counted from 1 m^2 area of each plot.

3.11.3 Number of filled grains panicle^{-1}

The number of filled grains of 10 randomly selected panicles of each plot was counted separately and the average was worked out.

3.11.4 Test weight of grain

1000 well-filled grains were collected from the produce of each plot and the weight was taken with a digital Precision Balance (Afcoset, Model FX 200G, India).

3.11.5 Grain yield

The grains obtained from each net plot area were weighed separately to determine the grain yield (t ha^{-1}).

3.11.6 Straw yield

After threshing, the straw bundles of each net plot area were allowed to dry in the sun for about 2-3 days and then they were weighed separately to determine the straw yield in terms of t ha^{-1}.

3.11.7 Harvest index (HI)

Harvest index was calculated by using the following formula:

$$HI = \frac{\text{Economic (grain) yield}}{\text{Biological (grain + straw) yield}}$$

3.11.8 Lodging

The rating of lodging of plants was done at hard dough stage following the scale proposed by IRRI (1996) (Table 3.9)

Table 3.9

Rating of lodging of rice plants

Score	Description
1	No Lodging
3	Most plants slightly lodge (most means > 50%)
5	Most plants completely lodge (most means > 50%)
7	Most plants nearly flat (most means > 50%)
9	All plants flat

3.12 Methods of determining quality characteristics of grain

At first, the impurities and foreign matters like other crop seeds, straw, chaff, sand, stones, mud pieces, dust, etc. were removed to make the clean samples of each plot for determination of quality attributes of grain.

The quality parameters of rice samples obtained from three experiments were determined at Aromatic Rice Laboratory, Department of Agronomy, Bidhan Chandra KrishiViswavidyalaya, Mohanpur, Nadia, West Bengal, India.

3.12.1 Milling quality

100 g clean paddy sample was dehulled with a Rice Sheller (Indosaw make, India) and the weight of brown rice was taken. Then the brown rice was milled or polished for 12 seconds with a Rice Miller (Indosaw make, Model 6701, India) to remove the bran and embryo and the weight of milled rice was recorded. The grading of rice was done with a rice sizing device (Indosaw make, Model 6701, India) for separation of whole kernels from the broken ones and the weight of head rice was noted.

Milling qualities like hulling, milling and head rice recovery were calculated with the following formulae:

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

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

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

3.12.2 Physical properties of grain

3.12.2.1 Length, breadth and L / B ratio

10 milled rice kernels from each sample were placed lengthwise and breadthwise separately on graph paper and the cumulativelength as well as breadth were recorded. Then the average length and breadth of kernel were worked out.

Length and breadth ratio (L/B ratio) of rice kernel was calculated by the followingformula:

$$\text{L/B ratio} = \frac{\text{Length of rice kernel (mm)}}{\text{Breadth of rice kernel (mm)}}$$

3.12.2.2 Classification

The classification of rice kernel was made following the chart (Table 3.10) suggested by Govindswami (1985).

Table 3.10
Classification of rice kernel according to size and shape

Group	Length of kernel (mm)	Length-breadth ratio
Long slender (LS)	6.0 or above	3.0 or above
Short slender (SS)	Less than 6.0	3.0 or above
Medium slender (MS)	Less than 6.0	2.5 to 3.0
Long bold (LB)	6.0 or above	Less than 3.0
Short bold (SB)	Less than 6.0	Less than 2.5

3.12.2.3 Kernel colour

The colour of rice kernel was determined by visual rating method.

3.12.2.4 Chalkiness

The presence or absence of chalkiness or abdominal white in rice kernel was determined by Illuminant Purity Work Brand (Indosaw make, Model 6714, India)

3.12.3 Cooking and nutritional quality

3.12.3.1 Amylose content

Amylose content in milled rice was estimated following the method suggested by Juliano (1971).

3.12.3.2 Protein content

Total nitrogen content in grain was determined by modified Kjeldahl method (Jackson, 1973) and then it was multiplied by a conversion factor of 5.95 to obtain the crude protein content in rice grain (Sadasivam and Manickam, 1996).

3.12.3.4 Alkali spreading value / Gelatinization temperature

Gelatinization temperature of rice was estimated by alkali digestibility test (Little *et al.*, 1958).

Then whole milled rice kernels without cracks were selected and they were placed in glass petridishes (mm diameter). 10 ml of 1.7 % potassium hydroxide (KOH) solution was added in each petridish and enough space was provided between the kernels to allow for spreading. The petridishes were covered with lids and incubated for 23 hours at room temperature (about 30°C). Kernel appearance and disintegration of endosperm after incubation were visually rated on a 7point numerical spreading scale (Table 3.11; Plate 3.1).

Table 3.11
Scale for scoring alkali spreading value and gelatinization temperature

Spreading	Alkali spreading score	Gelatinization temperature
Kernel not affected	1	High
Kernel swollen	2	High
Kernel swollen, collar complete and narrow	3	High-intermediate
Kernel swollen, collar complete and wide	4	Intermediate
Kernel split or segregated, collar complete and wide	5	Intermediate
Kernel dispersed, merging with collar	6	Low
Kernel completely dispersed and intermingled	7	Low

3.12.4 Processing quality

3.12.4.1 Kernel elongation

The length of 10 whole milled rice kernels of each sample was recorded as described earlier and then they were cooked in water bath (Labline make, India) for 8 minutes. After cooking, the lengths of cooked rice kernels were measured on a graph paper and the elongation ration (ER) was calculated with the following formula:

$$ER = \frac{\text{Length of cooked rice kernel (mm)}}{\text{Original kernel length (mm)}}$$

3.12.4.2 Volume expansion ratio

The volume of 1 g of raw milled rice was measured before cooking as well as the volume of cooked rice sample was also determined by water displacement method. The ratio was calculated by the following formula:

$$VER = \frac{\text{Volume of raw rice kernel (ml.)}}{\text{Volume of cooked rice kernel (ml.)}}$$

3.12.4.3 Aroma

200 mg milled rice of each sample was kept in petridish and 10 ml of 0.1 N KOH solution was added to it (Nagraju*et.al.*, 1991). After 20 minutes, the intensity of aroma was scored by a panel of experts (Table 3.12).

Table 3.12

Scoring of aroma in rice

Score	Description
0	No aroma
1	Mild aroma
2	Medium aroma
3	Strong aroma

3.13 Methods of chemical analyses

3.13.1 Soil analyses for available nitrogen, available phosphorus and available potassium

Soil Samples were collected from 15 cm depth before transplanting (one composite sample) as well as from 5 randomly selected places of each plot at 28, 56, 84 DAT and after harvesting of the crop. The samples collected from the field were dried in the shade, grounded in powder form and sieved.

Analyses of soil samples were done at laboratory to determine total nitrogen, available phosphorus and potassium following the procedures given in Table 3.13.

Table 3.13
Details of chemical studies made on the soil samples

Sl. No.	Nutrient	Method	Reference
1	Available nitrogen ($kg\ ha^{-1}$)	Macro-Kjeldahl method (Kjeldahl digestion and distillation unit, IIMC make, India)	Jackson, 1973
2	Available phosphorus ($kg\ ha^{-1}$)	Olsen's method (Spectrophotometer, Systronics make, India)	Jackson, 1973
3	Available potassium ($kg\ ha^{-1}$)	Flame-photometric method (Flamephotometer, Systronics make, India)	Jackson, 1973

3.13.2 Plant samples analysis for uptake of nitrogen, phosphorus and potassium

The plant samples collected from each plot at 28, 56 and 84 DAT for calculation of dry matter accumulation as well as grain and straw samples after harvesting of the crop were analysed at laboratory to determine the percentage of total nitrogen, phosphorus and potassium. The nutrient content values were multiplied by their respective dry matter values at different growth stages to find out the uptake of major nutrient during the cropping period. The details of the producers adopted are given in Table 3.14.

Table 3.14

Details of chemical studies made of the plant and grain samples

Sl. No.	Nutrient	Method	Reference
1	Total nitrogen (%)	Modified Kjeldhal method (Kjeldahl digestion and distillation unit, IIMC make, India)	Jackson, 1973
2	Total phosphorus (%)	Vandomolybdo phosphoric yellow colour method (Spectrophotometer, Systronics make, India)	Jackson, 1973
3	Total potassium (%)	Flame photometer method using the extract obtained from tri-acid mixture(Flamephotometer, Systronics make, India)	Jackson, 1973

3.14 Economic analysis

Total cost of cultivation ha^{-1}in Experiment No. 2 was calculated considering the expenditure on total land preparation, seed, transplanting, weeding, plant protection, harvesting, threshing, etc. along with different types of organic manures (*viz.* FYM, vermicompost and mustard cake) depending upon the particulars of treatments in the study. Gross return was determined by the values of grain and rice straw as obtained from different nutritional treatments. Then net return and benefit-cost ratio was calculated involving gross return and total cost of cultivation. The wage rate, cost of inputs, value of produces were supported by the Directorate of Farms, Bidhan Chandra KrishiViswavidyalaya, Mohanpur, Nadia, West Bengal and local markets during the periods of experimentation.

3.15 Methods of statistical analyses

The data collected as described earlier were subjected to statistical analyses by the analysis of variance (ANOVA) method suitable for randomized block design (R.B.D) in the first experiment, split-plot design in the second experiment and Completely Randomized Design (C.R.D.) in the third experiment (Gomez and Gomez, 1984). The significance of different sources of variation was tested by Fisher and Snedecor's F test for appropriate degrees of freedom. Fisher and Yates table was consulted to test 'F' statistics and for computation of critical difference (C.D.) at 5% level of significance.

The correlation and regression studies were made to reveal the associations between dependent and predictor set of variables in the investigation (Gomez and Gomez, 1984).

All statistical analyses were done using SPSS (version 20.0, 2011) on a desktop P.C.

Exp II treatments
RD 50% from mustard cake / 0.5 t

Chapter 4

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1 Experiment No. 1

Evaluation of indigenous scented rice cultivars in New Alluvial Zone of West Bengal

4.1.1 Phenology and growth environment

4.1.1.1 Phenological development and duration

Rice had 3 major growth stages: vegetative, reproductive and ripening in its life cycle. A total of eight phenophases were studied in the experiment; of which four phenophases (*viz.* sowing to emergence, emergence to 4th leaf emergence, 4th leaf emergence to active tillering and active tillering to panicle initiation) were under vegetative stage, one phenophase (panicle initiation to 50% flowering) under reproductive stage and three phenophases (*viz.* 50% flowering to milk, milk to dough and dough to maturity) under ripening stage. The crop spent the first two phenophases (*viz.* sowing to emergence and emergence to 4th leaf emergence) in the seedbed and rest six phases in the main field.

Among fourteen aromatic rice landraces studied in the experiment, the number of days to maturity, pooled over two years, varied between 136.0 days (Lalbadshabhog) and 154.7 days (Kaminibhog) (Table 4.1.1; Fig. 4.1.1; Plate 4.1.1, 4.1.2, 4.1.3 and 4.1.4). Perusal of data revealed that all the tested cultivars were long-duration types (>140.0 days), except Lal Badshabhog (V_7) in the study. The differences in duration among the cultivars could be attributed to the variation in length of vegetative phase (75.1 to 91.1 days) along with similar or slight variation in reproductive or ripening phase. Lalbadshabhog (V_7) required minimum days for vegetative (76.0 and 74.2 days) and reproductive stage (30 and 30 days) during both the years of the experimentation; while Kalojira (V_5) completed the ripening stage within the lowest period (30.0 and 29.0 days) during both 2012 and 2013 in the investigation.

Based on pooled values, mean cultivar days from sowing to emergence, 4th leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 4.1, 21.3, 47.8, 86.3, 117.6, 128.7, 138.0 and 148.5 days, respectively.

Table 4.1.1

Effect of cultivars on phenological development of aromatic rice during *kharif* season

Cultivar	Vegetative stage											
	Sowing to Emergence (day)			Emergence to 4th leaf emergence (day)			4th leaf emergence to Active tillering (day)			Active tillering to Panicle initiation (day)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	4.0	4.0	4.0	17.7	17.0	17.3	25.7	25.3	25.5	39.3	38.3	38.8
V_2	4.3	3.7	4.0	16.7	17.3	17.0	25.3	24.3	24.8	38.3	37.3	37.8
V_3	3.3	3.3	3.3	16.7	16.0	16.3	26.3	25.3	25.8	38.7	36.3	37.5
V_4	4.3	4.3	4.3	18.0	17.7	17.8	28.0	26.3	27.2	39.7	37.3	38.5
V_5	5.0	4.7	4.8	17.7	17.7	17.7	28.0	27.7	27.8	42.7	39.0	40.8
V_6	4.0	4.0	4.0	16.7	17.0	16.8	26.0	26.3	26.2	42.0	39.0	40.5
V_7	3.3	3.3	3.3	16.7	16.3	16.5	25.7	25.3	25.5	30.3	29.3	29.8
V_8	4.3	4.3	4.3	16.3	17.7	17.0	28.7	27.7	28.2	41.0	37.3	39.2
V_9	4.3	4.0	4.2	17.7	18.0	17.8	27.3	28.0	27.7	41.7	39.7	40.7
V_{10}	4.3	4.0	4.2	16.7	17.0	16.8	26.7	26.0	26.3	39.0	38.0	38.5
V_{11}	4.3	4.0	4.2	17.7	16.7	17.2	27.7	26.3	27.0	40.0	39.7	39.8
V_{12}	4.3	4.3	4.3	18.3	17.7	18.0	27.7	27.0	27.3	42.3	38.7	40.5
V_{13}	4.0	4.0	4.0	16.3	17.0	16.7	26.0	24.3	25.2	39.3	38.0	38.7
V_{14}	3.7	4.3	4.0	18.7	16.3	17.5	27.7	26.3	27.0	39.0	38.0	38.5
Mean	4.1	4.0	4.1	17.3	17.1	17.2	26.9	26.2	26.5	39.5	37.6	38.5
S.Em(±)	0.33	0.24	0.20	0.33	0.25	0.21	0.40	0.33	0.26	0.39	0.45	0.30
C.D. at 5%	NS	0.69	0.57	0.97	0.74	0.59	1.16	0.96	0.73	1.12	1.31	0.84

Table 4.1.1 (contd.)

Effect of cultivars on phenological development of aromatic rice during *kharif* season

Cultivar	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (day)			50% flowering to Milk (day)			Milk to Dough (day)			Dough to Maturity (day)			Sowing to Maturity (day)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	30.0	31.3	30.7	11.7	10.0	10.8	8.3	10.0	9.2	11.7	9.7	10.7	148.3	145.7	147.0
V_2	31.0	30.7	30.8	11.3	11.3	11.3	9.0	8.7	8.8	10.0	9.3	9.7	146.0	142.7	144.3
V_3	33.0	30.7	31.8	11.0	10.3	10.7	9.0	9.0	9.0	10.0	9.7	9.8	148.0	140.7	144.3
V_4	31.0	30.3	30.7	10.7	11.3	11.0	9.3	9.7	9.5	12.0	11.0	11.5	153.0	148.0	150.5
V_5	32.3	31.0	31.7	10.7	11.3	11.0	9.3	9.7	9.5	12.0	10.7	11.3	157.7	151.7	154.7
V_6	32.0	30.7	31.3	11.3	11.3	11.3	8.7	9.3	9.0	13.0	11.0	12.0	153.7	148.7	151.2
V_7	30.0	30.0	30.0	11.0	10.3	10.7	9.3	10.0	9.7	11.0	10.0	10.5	137.3	134.7	136.0
V_8	31.7	31.7	31.7	11.7	10.7	11.2	10.3	9.7	10.0	10.3	10.7	10.5	154.3	149.7	152.0
V_9	32.7	31.7	32.2	11.7	11.0	11.3	9.0	9.0	9.0	10.0	10.0	10.0	154.3	151.3	152.8
V_{10}	32.0	31.3	31.7	11.3	12.0	11.7	9.3	8.7	9.0	10.7	10.0	10.3	150.0	147.0	148.5
V_{11}	33.0	31.0	32.0	11.3	10.3	10.8	8.3	10.0	9.2	10.3	10.7	10.5	152.7	148.7	150.7
V_{12}	34.0	31.3	32.7	12.3	11.0	11.7	8.0	9.3	8.7	10.7	10.3	10.5	157.7	149.7	153.7
V_{13}	31.0	29.7	30.3	11.3	11.3	11.3	9.7	9.0	9.3	9.7	9.3	9.5	147.3	142.7	145.0
V_{14}	31.0	31.3	31.2	10.3	9.7	10.0	10.0	10.7	10.3	9.7	10.0	9.8	150.0	146.7	148.3
Mean	31.8	30.9	31.3	11.3	10.9	11.1	9.1	9.5	9.3	10.8	10.2	10.5	150.7	146.3	148.5
S.Em(±)	0.15	0.33	0.18	0.45	0.33	0.28	0.35	0.33	0.24	0.40	0.34	0.26	0.44	0.54	0.35
C.D. at 5%	0.44	0.97	0.52	NS	0.96	0.79	1.01	0.97	0.68	1.16	0.99	0.75	1.27	1.57	0.99

NS = Not significant

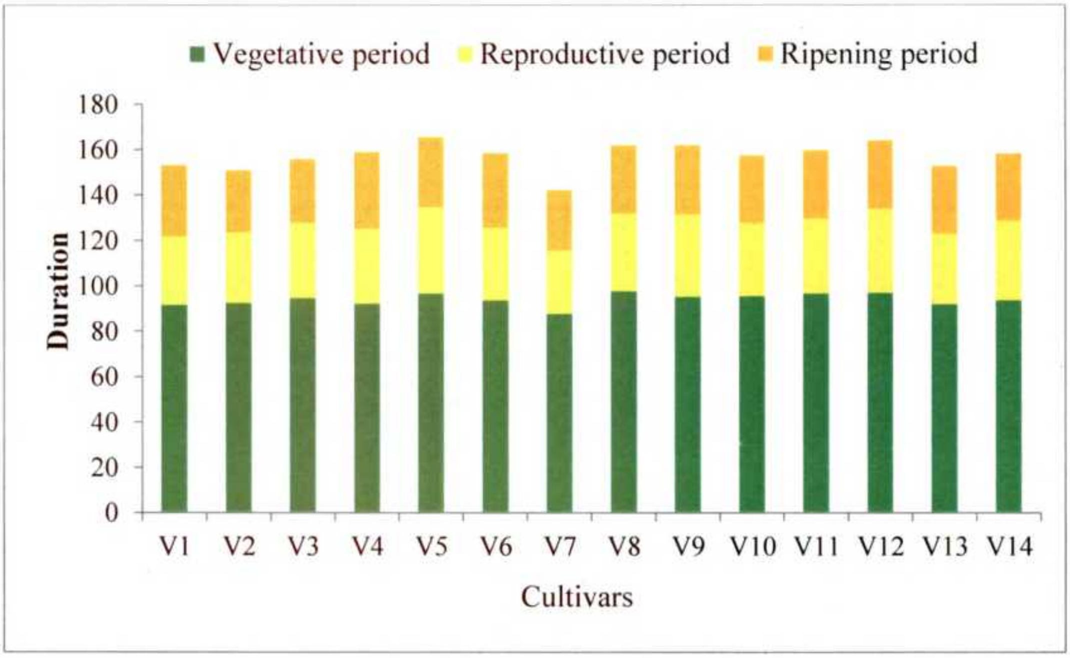


Fig. 4.1.1: Effect of cultivars on duration of growth stages of aromatic rice (Pooled of two years)

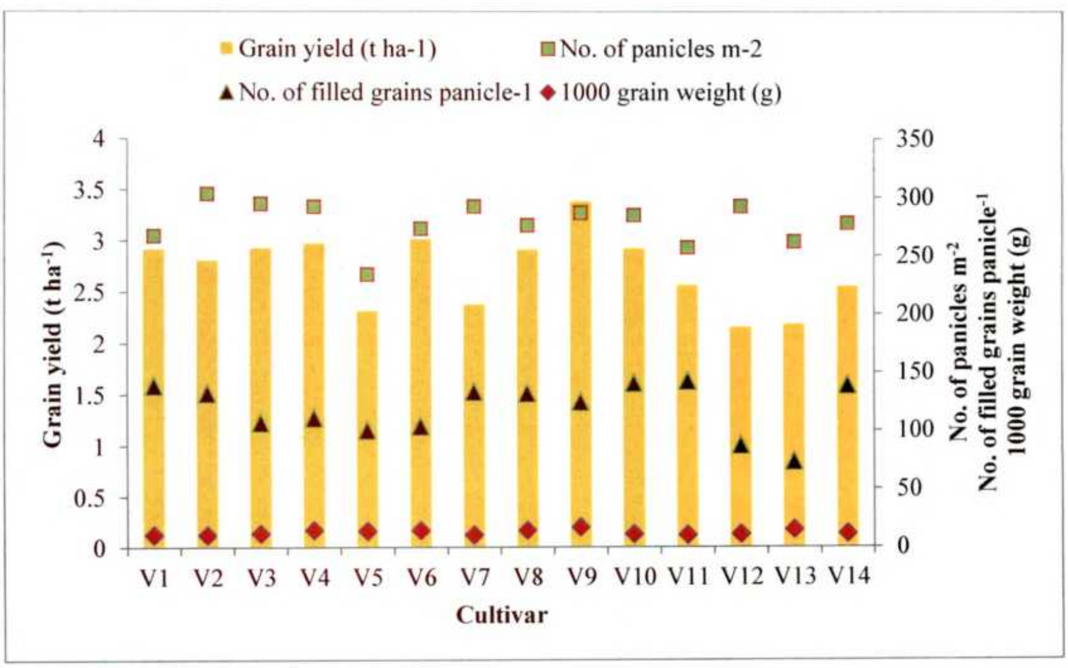


Fig. 4.1.2: Effect of cultivars on yield components and grain yield of aromatic rice (Pooled of two years)

The flowering period of all scented rice cultivars was recorded during the month of October, while they are ready for harvesting during November in 2012 and 2013at Kalyani, West Bengal. The week wise classification for 50% flowering and maturity could be summarized as: 1st week of October and 1st week of November (Lal Badshabhog), 2nd week of October and 2nd week on November (Gobindabhog and Kalojira), 3rd week of October and 3rd week of November (Badshabhog, Kalonunia, Kataribhog, NC 324, Radhatilak, Radhunipagal, Tulaipanji and Tulsimukul) and 4th week of October and 4th week of November (Kaminibhog and NC 365). Deb (2005) reported somewhat simi8lar observation on flowering period and maturity of most of the tested cultivars grown in Bankura, West Bengal.

4.1.1.2 Growing degree days (GDD)

Mean air temperature for different phenophases were: 28.0 and 30.2°C (sowing to emergence), 30.3 and 30.0°C (emergence to 4th leaf emergence), 29.2 and 29.7°C (4th leaf emergence to active tillering), 29.2 and 29.5°C (active tillering to panicle initiation), 29.6 and 29.4°C (panicle initiation to 50% flowering), 26.6 and 27.3°C (50% flowering to milk), 25.2 and 25.9°C (milk to dough) and 24.0 and 23.6°C (dough to maturity) during 2012 and 2013, respectively (Table 4.1.2).

Mean cultivar GDD from sowing to emergence, 4th leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 77.7, 423.3, 940.0, 1684.3, 2296.1, 2483.6, 2628.5 and 2772.5°C, respectively.

Based on the pooled data, Lalbadshabhog (V_7) required the lowest GDD for completion of vegetative (1469.5°C) and reproductive stage (595.1°C), while NC 365 (V_9) completed the ripening phase with lowest heat units (445.5°C).

The growing degree days for entire life-cycle, pooled over two years, varied between 2598.9°C (Lalbadshabhog) and 2853.1°C (Kaminibhog) (Table 4.1.3), which could be supported by the fact that lengthening in growth duration (Table 4.1.1) generally resulted in higher amount of accumulated heat. Similar findings on summed GDD for entire growth duration of different scented rice cultivars was reported by (Banerjee, 2011). All fourteen varieties recorded lower summed GDD in the second year compared to the first year of investigation.

Table 4.1.2

Mean air temperature at different phenophases of aromatic rice during *kharif* season

Cultivar	Vegetative stage											
	Sowing to Emergence (°C)			Emergence to 4th leaf emergence (°C)			4th leaf emergence to Active tillering (°C)			Active tillering to Panicle initiation (°C)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	28.2	30.2	29.2	30.2	30.0	30.1	29.3	29.8	29.5	29.1	29.4	29.3
V_2	27.9	30.4	29.2	30.3	29.9	30.1	29.3	29.8	29.6	29.2	29.3	29.2
V_3	28.3	30.5	29.4	30.1	30.0	30.0	29.4	29.8	29.6	29.1	29.3	29.2
V_4	27.9	30.1	29.0	30.3	29.9	30.1	29.2	29.6	29.4	29.1	29.5	29.3
V_5	28.0	30.0	29.0	30.4	30.0	30.2	29.2	29.6	29.4	29.2	29.6	29.4
V_6	27.9	30.2	29.1	30.2	30.0	30.1	29.3	29.7	29.5	29.1	29.5	29.3
V_7	28.3	30.5	29.4	30.1	30.0	30.0	29.3	29.8	29.6	29.4	29.2	29.3
V_8	27.9	30.1	29.0	30.3	30.0	30.1	29.3	29.6	29.4	29.1	29.6	29.4
V_9	27.9	30.2	29.1	30.3	29.9	30.1	29.2	29.6	29.4	29.1	29.6	29.4
V_{10}	27.9	30.2	29.1	30.3	30.0	30.1	29.3	29.7	29.5	29.1	29.4	29.3
V_{11}	27.9	30.2	29.1	30.3	30.0	30.1	29.2	29.7	29.5	29.1	29.5	29.3
V_{12}	27.9	30.1	29.0	30.3	29.9	30.1	29.2	29.6	29.4	29.2	29.6	29.4
V_{13}	27.9	30.2	29.1	30.9	30.0	30.4	29.0	29.8	29.4	29.2	29.3	29.2
V_{14}	28.1	30.1	29.1	30.2	30.0	30.1	29.2	29.7	29.4	29.1	29.4	29.3
Mean	28.0	30.2	29.1	30.3	30.0	30.1	29.2	29.7	29.5	29.2	29.5	29.3

Table 4.1.2 (contd.)

Mean air temperature at different phenophases of aromatic rice during *kharif* season

Cultivar	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (°C)			50% flowering to Milk (°C)			Milk to Dough (°C)			Dough to Maturity (°C)			Sowing to Maturity (°C)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	29.8	29.4	29.6	27.2	27.7	27.4	25.4	25.8	25.6	24.0	23.5	23.8	28.6	28.8	28.7
V_2	29.8	29.7	29.7	27.4	28.0	27.7	25.7	25.6	25.6	24.3	24.9	24.6	28.7	28.9	28.8
V_3	29.7	29.7	29.7	26.9	28.6	27.7	25.5	25.8	25.6	23.9	25.3	24.6	28.7	29.0	28.8
V_4	29.7	29.3	29.5	26.3	27.3	26.8	25.4	26.0	25.7	23.9	23.1	23.5	28.5	28.7	28.6
V_5	29.3	29.2	29.2	25.7	26.3	26.0	24.3	25.3	24.8	23.6	22.3	23.0	28.4	28.5	28.4
V_6	29.7	29.3	29.5	26.3	27.0	26.7	25.4	26.0	25.7	23.9	23.1	23.5	28.5	28.7	28.6
V_7	29.7	30.0	29.8	29.0	28.4	28.7	27.4	28.0	27.7	25.6	25.7	25.6	29.0	29.2	29.1
V_8	29.6	29.3	29.4	26.2	26.6	26.4	24.7	25.7	25.2	23.9	22.8	23.4	28.5	28.6	28.6
V_9	29.5	29.2	29.3	25.9	25.9	25.9	24.6	25.2	24.9	23.9	22.4	23.1	28.5	28.6	28.5
V_{10}	29.7	29.4	29.6	26.8	27.3	27.0	25.4	25.8	25.6	23.6	23.2	23.4	28.6	28.7	28.7
V_{11}	29.6	29.3	29.4	26.1	26.9	26.5	25.0	26.0	25.5	23.8	23.0	23.4	28.5	28.7	28.6
V_{12}	29.2	29.2	29.2	25.5	26.6	26.1	23.9	25.6	24.7	23.6	22.8	23.2	28.4	28.6	28.5
V_{13}	29.8	29.7	29.7	27.2	27.9	27.5	25.4	25.7	25.6	24.0	24.8	24.4	28.7	28.9	28.8
V_{14}	29.7	29.4	29.6	26.5	27.8	27.1	25.5	25.8	25.6	23.3	23.2	23.2	28.6	28.8	28.7
Mean	29.6	29.4	29.5	26.6	27.3	27.0	25.2	25.9	25.6	24.0	23.6	23.8	28.6	28.8	28.7

Table 4.1.3

Growing degree days of different aromatic rice cultivars at different phenophases during *kharif* season

Cultivar	Vegetative stage											
	Sowing to Emergence (°C day)			Emergence to 4th leaf emergence (°C day)			4th leaf emergence to Active tillering (°C day)			Active tillering to Panicle initiation (°C day)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	72.5	80.8	76.6	356.8	339.3	348.0	495.4	500.5	497.9	753.1	744.2	748.6
V_2	77.8	74.6	76.2	337.9	345.6	341.7	489.6	481.7	485.6	734.7	721.1	727.9
V_3	61.0	68.3	64.7	334.7	319.3	327.0	509.6	502.3	505.9	740.1	701.1	720.6
V_4	77.8	87.1	82.4	365.4	352.3	358.8	537.3	517.2	527.2	759.1	729.1	744.1
V_5	90.2	93.4	91.8	360.1	352.9	356.5	536.7	542.1	539.4	820.4	764.5	792.4
V_6	71.6	80.8	76.2	337.4	339.3	338.4	502.6	518.4	510.5	802.6	760.9	781.7
V_7	61.0	68.3	64.7	335.0	326.0	330.5	496.5	502.4	499.5	587.4	562.2	574.8
V_8	77.8	87.1	82.4	331.2	352.7	342.0	552.7	541.9	547.3	784.6	731.3	757.9
V_9	77.8	80.8	79.3	358.3	358.6	358.4	525.6	549.0	537.3	797.8	777.6	787.7
V_{10}	77.8	80.8	79.3	337.9	339.3	338.6	515.4	512.5	513.9	746.4	739.1	742.8
V_{11}	77.8	80.8	79.3	358.3	332.9	345.6	531.8	518.8	525.3	765.0	774.0	769.5
V_{12}	77.8	87.1	82.4	372.0	352.3	362.1	530.8	529.3	530.0	813.2	758.0	785.6
V_{13}	71.6	80.8	76.2	337.4	339.3	338.4	496.2	482.6	489.4	753.6	734.1	743.8
V_{14}	66.3	87.1	76.7	376.9	326.7	351.8	531.2	518.8	525.0	746.3	739.0	742.7
Mean	74.2	81.3	77.7	349.9	341.2	345.6	517.9	515.5	516.7	757.5	731.1	744.3
S.Em(±)	5.76	4.48	3.65	6.46	4.94	4.07	7.89	6.11	4.99	7.41	8.62	5.68
C.D. at 5%	NS	13.03	10.36	18.78	14.35	11.54	22.92	17.75	14.15	21.55	25.05	16.13

NS = Not significant

Table 4.1.3 (contd.)

Growing degree days of different aromatic rice cultivars at different phenophases during *kharif* season

Cultivar	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (°C day)			50% flowering to Milk (°C day)			Milk to Dough (°C day)			Dough to Maturity (°C day)			Sowing to Maturity (°C day)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	595.1	607.8	601.4	200.2	177.3	188.7	128.4	158.1	143.3	163.9	130.4	147.1	2765.2	2738.3	2751.7
V_2	614.7	602.6	608.7	196.7	203.7	200.2	141.0	135.4	138.2	142.8	138.9	140.8	2735.1	2703.5	2719.3
V_3	651.5	603.3	627.4	186.2	191.8	189.0	139.1	141.9	140.5	139.0	148.3	143.6	2761.1	2676.2	2718.6
V_4	610.6	586.9	598.7	174.0	196.6	185.3	143.7	154.3	149.0	166.7	144.3	155.5	2834.5	2767.7	2801.1
V_5	622.5	596.0	609.2	167.1	184.3	175.7	133.8	147.8	140.8	163.0	131.7	147.3	2893.6	2812.5	2853.1
V_6	630.2	591.4	610.8	184.7	193.0	188.9	133.8	149.5	141.7	180.9	143.7	162.3	2843.9	2776.9	2810.4
V_7	590.2	600.0	595.1	208.4	190.3	199.4	162.2	180.0	171.1	171.1	156.9	164.0	2611.7	2586.1	2598.9
V_8	621.4	609.8	615.6	189.0	177.5	183.2	151.9	152.1	152.0	144.0	136.9	140.4	2852.5	2789.2	2820.9
V_9	637.1	607.7	622.4	185.6	175.2	180.4	130.9	136.4	133.7	139.2	123.7	131.4	2852.3	2808.8	2830.5
V_{10}	631.5	607.2	619.3	189.8	207.1	198.4	143.7	136.7	140.2	145.2	131.8	138.5	2787.6	2754.3	2771.0
V_{11}	646.6	596.9	621.7	182.7	174.8	178.8	124.9	159.8	142.4	142.3	138.5	140.4	2829.3	2776.5	2802.9
V_{12}	651.9	602.5	627.2	191.5	183.1	187.3	110.9	145.1	128.0	145.5	132.3	138.9	2893.6	2789.6	2841.6
V_{13}	614.0	583.7	598.8	194.6	202.9	198.7	149.3	141.1	145.2	135.7	138.4	137.1	2752.4	2702.8	2727.6
V_{14}	612.0	606.7	609.3	170.6	171.5	171.0	154.7	168.6	161.6	128.7	131.7	130.2	2786.5	2750.1	2768.3
Mean	623.5	600.2	611.8	187.2	187.8	187.5	139.2	150.5	144.8	150.6	137.7	144.1	2800.0	2745.2	2772.6
S.Em(±)	3.01	6.41	3.54	7.49	5.27	4.58	5.32	5.03	3.66	5.62	5.07	3.79	5.99	6.91	4.57
C.D. at 5%	8.74	NS	10.05	21.78	15.31	13.00	15.45	14.62	10.38	16.34	14.74	10.74	17.41	20.08	12.97

NS = Not significant

Plate 4.1.1: Seedbed of Experiment No. 1

Plate 4.1.2: Seedling stage of Experiment No. 1

Plate 4.1.3: Maximum tillering stage of Experiment No. 1

Plate 4.1.4: Dough stage of Experiment No. 1

Plate 4.1.5: Lodging at maturity stage of Experiment No. 1

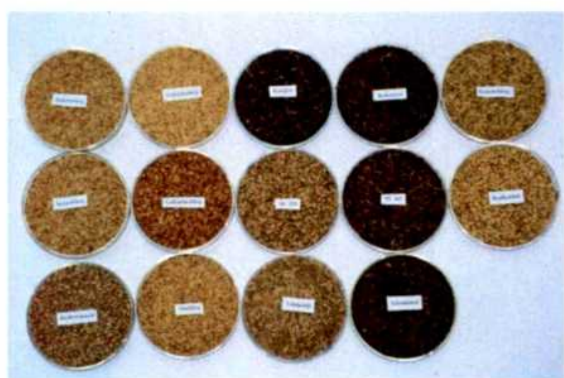


Plate 4.1.6: Harvested grains of Experiment No. 1

Phenological stages and grains of Aromatic rice cultivars of West Bengal

4.1.1.3 Heliothermal units (HTU)

Mean bright sunshine for different phenophases were: 1.16 and 4.59 hours (sowing to emergence), 4.63 and 4.40 hours (emergence to 4th leaf emergence), 3.85 and 4.72 hours (4th leaf emergence to active tillering), 4.99 and 4.54 hours (active tillering to panicle initiation), 6.56 and 5.09 hours (panicle initiation to 50% flowering), 8.59 and 4.25 hours (50% flowering to milk), 5.54 and 7.08 hours (milk to dough) and 7.05 and 8.72 hours (dough to maturity) during 2012 and 2013, respectively (Table 4.1.4).

The variation in the bright sunshine hours between two years (Table 4.1.4) resulted in notable differences in accumulated HTU at different phenophases in the investigation. Although the first year crop of all the varieties recorded greater summed HTU during the growth stages of emergence to 4th leaf emergence (1648.4 *vs.* 1547.09°C hour) active tillering to panicle initiation (3918.9 *vs.*3478.4°C hour), panicle initiation to 50% flowering (4124.3 *vs.* 3176.6°C hour) and 50% flowering to milk (1607.3 *vs.* 851.9°C hour); but had lower HTU requirements during the phenophases of sowing to emergence (89.4 *vs.* 374.2°C hour), 4th leaf emergence to active tillering (2018.0 *vs.* 2497.5°C hour), milk to dough (786.1 *vs.* 1075.3°C hour) and dough to maturity (1050.5 *vs.* 1192.6°C hour) compared to second season crop at Kalyani, West Bengal (Table 4.1.5).

Mean cultivar HTU from sowing to emergence, 4th leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 231.8, 1830.0, 4087.8, 7786.4, 11436.8, 12666.4, 13597.1 and 14718.6°C hour, respectively.

Perusal of pooled data for life cycle revealed that four cultivars (Kaminibhg, Sitabhog, NC 365 and NC 324) recorded summed HTU of >15000°C hour, while nine varieties accumulated >14000°C hour and only one genotype (Lal Badshabhog) had >13000°C hour in the study.

4.1.1.4 Photothermal units (PTU)

Mean cultivar PTU, pooled over two years, from sowing to emergence, 4th leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and

Table 4.1.4

Mean bright sunshine hours at different phenophases of aromatic rice during *kharif* season

Cultivar	Vegetative stage											
	Sowing to Emergence (hour)			Emergence to 4th leaf emergence (hour)			4th leaf emergence to Active tillering (hour)			Active tillering to Panicle initiation (hour)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	1.24	4.53	2.88	4.57	4.33	4.45	3.93	4.91	4.42	4.95	4.44	4.69
V_2	1.11	4.93	3.02	4.76	4.33	4.55	3.84	4.95	4.39	5.08	4.25	4.66
V_3	1.34	5.33	3.34	4.36	4.43	4.39	3.94	4.92	4.43	4.97	4.11	4.54
V_4	1.11	4.33	2.72	4.67	4.42	4.54	3.80	4.58	4.19	4.96	4.70	4.83
V_5	1.14	4.14	2.64	4.87	4.55	4.71	3.77	4.33	4.05	5.13	4.86	4.99
V_6	1.10	4.53	2.81	4.64	4.33	4.48	3.91	4.73	4.32	4.81	4.68	4.74
V_7	1.34	5.33	3.34	4.44	4.41	4.42	3.82	4.98	4.40	5.23	3.98	4.61
V_8	1.11	4.33	2.72	4.71	4.49	4.60	3.82	4.39	4.10	4.97	4.89	4.93
V_9	1.11	4.53	2.82	4.60	4.36	4.48	3.85	4.39	4.12	4.98	4.83	4.91
V_{10}	1.11	4.53	2.82	4.76	4.33	4.54	3.92	4.78	4.35	4.89	4.54	4.72
V_{11}	1.11	4.53	2.82	4.60	4.39	4.50	3.84	4.74	4.29	4.92	4.68	4.80
V_{12}	1.11	4.33	2.72	4.61	4.42	4.51	3.83	4.54	4.18	5.12	4.81	4.96
V_{13}	1.10	4.53	2.81	4.74	4.33	4.53	3.83	5.10	4.46	4.98	4.27	4.62
V_{14}	1.22	4.33	2.78	4.53	4.52	4.53	3.81	4.69	4.25	4.94	4.50	4.72
Mean	1.16	4.59	2.87	4.63	4.40	4.52	3.85	4.72	4.28	4.99	4.54	4.77

Table 4.1.4 (contd.)

Mean bright sunshine hours at different phenophases of aromatic rice during *kharif* season

Cultivar	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (hour)			50% flowering to Milk (hour)			Milk to Dough (hour)			Dough to Maturity (hour)			Sowing to Maturity (hour)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	6.10	4.95	5.52	9.27	4.55	6.91	6.59	6.92	6.76	6.43	9.05	7.74	5.40	5.10	5.25
V_2	5.83	5.28	5.56	9.18	4.58	6.88	7.35	5.57	6.46	5.38	8.69	7.03	5.34	5.01	5.18
V_3	6.14	5.37	5.76	9.31	5.50	7.41	5.70	3.24	4.47	6.86	8.48	7.67	5.39	4.94	5.17
V_4	6.84	4.89	5.86	9.41	4.13	6.77	4.19	7.86	6.02	7.27	9.06	8.17	5.43	5.16	5.29
V_5	7.21	5.20	6.21	7.30	4.04	5.67	5.39	8.51	6.95	7.56	8.88	8.22	5.50	5.23	5.37
V_6	6.74	4.84	5.79	9.41	3.90	6.66	3.86	8.34	6.10	7.30	8.97	8.13	5.44	5.16	5.30
V_7	5.72	5.43	5.58	5.54	4.02	4.78	9.27	4.90	7.08	6.68	5.95	6.31	5.30	4.79	5.05
V_8	6.91	4.99	5.95	9.31	3.71	6.51	4.09	8.39	6.24	7.48	8.89	8.19	5.45	5.18	5.32
V_9	7.07	5.29	6.18	8.27	4.14	6.21	4.66	8.56	6.61	7.26	8.84	8.05	5.45	5.22	5.34
V_{10}	6.34	4.94	5.64	9.31	4.37	6.84	5.00	7.84	6.42	7.43	9.18	8.31	5.43	5.14	5.28
V_{11}	6.99	4.85	5.92	9.23	3.54	6.39	3.42	8.32	5.87	7.43	9.18	8.30	5.44	5.18	5.31
V_{12}	7.24	5.04	6.14	6.05	3.80	4.93	7.11	8.29	7.70	7.34	9.02	8.18	5.50	5.18	5.34
V_{13}	6.02	5.21	5.62	9.31	4.61	6.96	6.15	5.38	5.77	6.61	8.71	7.66	5.38	5.01	5.19
V_{14}	6.69	4.94	5.82	9.36	4.67	7.01	4.79	6.98	5.88	7.70	9.14	8.42	5.42	5.13	5.28
Mean	6.56	5.09	5.82	8.59	4.25	6.42	5.54	7.08	6.31	7.05	8.72	7.88	5.42	5.10	5.26

Table 4.1.5

Heliothermal units of different aromatic rice cultivars at different phenophases during *kharif* season

Cultivar	Vegetative stage											
	Sowing to Emergence (°C hour)			Emergence to 4th leaf emergence (°C hour)			4th leaf emergence to Active tillering (°C hour)			Active tillering to Panicle initiation (°C hour)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	91.2	371.9	231.5	1660.8	1515.6	1588.2	1966.6	2520.1	2243.3	3865.2	3454.7	3659.9
V_2	91.2	366.3	228.7	1633.6	1545.0	1589.3	1897.6	2442.0	2169.8	3864.7	3212.2	3538.4
V_3	83.1	360.7	221.9	1500.0	1461.0	1480.5	2034.1	2528.0	2281.1	3814.5	3027.3	3420.9
V_4	91.2	382.0	236.6	1734.0	1599.8	1666.9	2067.2	2448.1	2257.7	3906.8	3575.8	3741.3
V_5	107.2	392.0	249.6	1777.6	1650.9	1714.2	2043.2	2430.4	2236.8	4358.9	3866.0	4112.5
V_6	83.1	371.9	227.5	1594.4	1515.6	1555.0	1989.1	2523.7	2256.4	4004.4	3711.3	3857.9
V_7	83.1	360.7	221.9	1530.0	1482.4	1506.2	1915.6	2557.2	2236.4	3160.7	2369.7	2765.2
V_8	91.2	382.0	236.6	1586.4	1629.5	1607.9	2136.3	2459.9	2298.1	4041.8	3723.5	3882.6
V_9	91.2	371.9	231.5	1674.4	1609.9	1642.1	2048.3	2491.5	2269.9	4116.1	3911.0	4013.6
V_{10}	91.2	371.9	231.5	1633.6	1515.6	1574.6	2038.0	2523.7	2280.9	3793.5	3509.5	3651.5
V_{11}	91.2	371.9	231.5	1674.4	1507.9	1591.1	2069.7	2531.3	2300.5	3907.5	3777.3	3842.4
V_{12}	91.2	382.0	236.6	1742.7	1599.8	1671.2	2055.9	2485.6	2270.8	4310.9	3799.8	4055.4
V_{13}	83.1	371.9	227.5	1594.4	1515.6	1555.0	1944.8	2516.5	2230.7	3889.4	3288.7	3589.1
V_{14}	83.1	382.0	232.6	1742.1	1521.7	1631.9	2045.7	2507.5	2276.6	3829.6	3470.3	3649.9
Mean	89.4	374.2	231.8	1648.4	1547.9	1598.2	2018.0	2497.5	2257.8	3918.9	3478.4	3698.6
S.Em(±)	6.11	6.12	4.32	41.31	28.53	25.10	52.13	32.60	30.74	47.59	54.71	36.25
C.D. at 5%	NS	NS	12.27	120.06	82.93	71.23	NS	NS	NS	138.31	159.02	102.89

NS = Not significant

Table 4.1.5 (contd.)

Heliothermal units of different aromatic rice cultivars at different phenophases during *kharif* season

	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (°C hour)			50% flowering to Milk (°C hour)			Milk to Dough (°C hour)			Dough to Maturity (°C hour)			Sowing to Maturity (°C hour)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	3681.6	3138.7	3410.2	1856.3	863.3	1359.8	863.4	1117.6	990.5	1032.1	1172.8	1102.5	15017.1	14154.8	14585.9
V_2	3648.5	3305.8	3477.1	1803.7	977.5	1390.6	1045.7	773.8	909.8	754.1	1200.4	977.2	14739.1	13822.9	14281.0
V_3	4052.8	3360.5	3706.7	1734.6	1079.9	1407.3	816.4	481.7	649.1	941.4	1256.8	1099.1	14977.0	13556.1	14266.5
V_4	4189.6	2995.3	3592.4	1636.1	882.8	1259.5	626.0	1221.1	923.5	1197.3	1302.0	1249.7	15448.1	14406.9	14927.5
V_5	4466.9	3222.5	3844.7	1231.1	785.3	1008.2	712.2	1254.1	983.1	1215.9	1165.9	1190.9	15913.1	14767.2	15340.1
V_6	4265.9	2989.5	3627.7	1737.7	828.2	1283.0	541.5	1245.3	893.4	1306.2	1282.6	1294.4	15522.4	14468.2	14995.3
V_7	3491.9	3364.2	3428.0	1163.0	788.2	975.6	1499.1	927.3	1213.2	1162.9	959.4	1061.1	14006.3	12809.1	13407.7
V_8	4299.8	3163.4	3731.6	1757.5	717.2	1237.3	619.7	1275.5	947.6	1062.3	1211.3	1136.8	15594.9	14562.2	15078.6
V_9	4504.5	3339.9	3922.2	1539.1	753.9	1146.5	615.4	1166.0	890.7	998.6	1089.6	1044.1	15587.4	14733.8	15160.6
V_{10}	4046.9	3131.0	3589.0	1767.8	972.5	1370.2	740.5	1078.5	909.5	1068.2	1201.4	1134.8	15179.7	14304.1	14741.9
V_{11}	4523.3	3015.0	3769.2	1684.3	690.2	1187.2	436.1	1328.3	882.2	1045.6	1265.7	1155.7	15432.0	14487.6	14959.8
V_{12}	4694.6	3157.6	3926.1	1182.2	750.0	966.1	782.5	1203.6	993.0	1053.1	1190.6	1121.9	15913.1	14569.0	15241.0
V_{13}	3753.5	3159.0	3456.2	1812.3	983.5	1397.9	941.0	781.3	861.2	882.9	1199.5	1041.2	14901.6	13815.9	14358.7
V_{14}	4120.1	3129.3	3624.7	1595.7	853.6	1224.7	765.8	1200.1	983.0	986.1	1197.9	1092.0	15168.2	14262.4	14715.3
Mean	4124.3	3176.6	3650.4	1607.3	851.9	1229.6	786.1	1075.3	930.7	1050.5	1192.6	1121.5	15242.9	14194.3	14718.6
S.Em(±)	45.54	54.55	35.53	77.68	41.46	44.02	60.93	57.61	41.93	48.23	46.24	33.41	38.83	59.71	35.62
C.D. at 5%	132.37	158.55	100.83	225.78	120.50	124.94	177.09	167.43	118.98	140.18	134.40	94.81	112.87	173.56	101.07

NS = Not significant

Table 4.1.6

Photothermal units of different aromatic rice cultivars at different phenophases during *kharif* season

Cultivar	Vegetative stage											
	Sowing to Emergence (°C hour)			Emergence to 4th leaf emergence (°C hour)			4th leaf emergence to Active tillering (°C hour)			Active tillering to Panicle initiation (°C hour)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	968.8	1079.0	1023.9	4706.4	4470.8	4588.6	6364.7	6429.3	6397.0	9313.1	9205.3	9259.2
V_2	1039.5	995.7	1017.6	4458.3	4554.6	4506.4	6296.9	6190.6	6243.8	9100.9	8936.4	9018.7
V_3	815.6	912.4	864.0	4421.5	4213.1	4317.3	6558.5	6464.2	6511.4	9165.7	8699.6	8932.7
V_4	1039.5	1162.7	1101.1	4817.0	4638.0	4727.5	6888.7	6632.2	6760.4	9353.5	9003.9	9178.7
V_5	1204.3	1246.3	1225.3	4744.7	4643.8	4694.2	6877.9	6943.8	6910.9	10085.2	9412.8	9749.0
V_6	957.1	1079.0	1018.1	4453.8	4470.8	4462.3	6465.1	6655.9	6560.5	9917.5	9397.0	9657.3
V_7	815.6	912.4	864.0	4424.9	4300.6	4362.7	6392.6	6463.5	6428.1	7314.1	7001.8	7157.9
V_8	1039.5	1162.7	1101.1	4371.4	4643.8	4507.6	7097.8	6944.6	7021.2	9670.8	9015.9	9343.4
V_9	1039.5	1079.0	1059.3	4724.4	4721.7	4723.1	6744.7	7033.2	6889.0	9829.5	9570.0	9699.8
V_{10}	1039.5	1079.0	1059.3	4458.3	4470.8	4464.5	6623.5	6580.5	6602.0	9228.4	9137.1	9182.7
V_{11}	1039.5	1079.0	1059.3	4724.4	4387.7	4556.1	6822.1	6663.7	6742.9	9431.8	9558.8	9495.3
V_{12}	1039.5	1162.7	1101.1	4903.5	4638.0	4770.8	6803.9	6784.9	6794.4	10003.5	9345.8	9674.6
V_{13}	957.1	1079.0	1018.1	4453.8	4470.8	4462.3	6383.8	6202.7	6293.3	9329.5	9093.3	9211.4
V_{14}	886.4	1162.7	1024.5	4970.1	4304.6	4637.4	6811.3	6663.2	6737.3	9202.7	9136.8	9169.7
Mean	991.5	1085.1	1038.3	4616.6	4494.9	4555.8	6652.3	6618.0	6635.1	9353.3	9036.7	9195.0
S.Em(±)	76.85	59.69	48.65	84.89	64.38	53.27	100.42	78.04	63.59	91.37	106.20	70.05
C.D. at 5%	223.36	173.49	138.07	246.73	187.12	151.17	291.88	226.83	180.46	265.57	308.66	198.78

NS = Not significant

Table 4.1.6 (contd.)

Photothermal units of different aromatic rice cultivars at different phenophases during *kharif* season

Cultivar	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (°C hour)			50% flowering to Milk (°C hour)			Milk to Dough (°C hour)			Dough to Maturity (°C hour)			Sowing to Maturity (°C hour)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	7064.2	7220.7	7142.4	2316.2	2052.7	2184.4	1467.0	1807.5	1637.2	1848.1	1471.8	1659.9	34048.5	33737.1	33892.8
V_2	7309.6	7179.3	7244.4	2278.9	2364.6	2321.8	1613.0	1551.6	1582.3	1614.1	1573.3	1593.7	33711.2	33346.2	33528.7
V_3	7735.9	7201.2	7468.6	2152.3	2231.9	2192.1	1587.0	1631.5	1609.2	1566.0	1684.7	1625.4	34002.6	33038.6	33520.6
V_4	7217.8	6968.3	7093.1	2003.9	2274.5	2139.2	1633.5	1761.4	1697.5	1867.3	1625.7	1746.5	34821.2	34066.8	34444.0
V_5	7324.3	7044.2	7184.2	1912.8	2121.7	2017.3	1512.0	1678.1	1595.0	1814.8	1475.9	1645.3	35476.0	34566.6	35021.3
V_6	7456.5	7014.7	7235.6	2127.6	2230.6	2179.1	1521.4	1704.6	1613.0	2026.7	1616.4	1821.6	34925.6	34169.1	34547.3
V_7	7091.1	7219.2	7155.2	2444.4	2235.0	2339.7	1878.7	2088.1	1983.4	1956.4	1796.5	1876.4	32317.8	32017.2	32167.5
V_8	7340.1	7223.0	7281.6	2172.0	2047.6	2109.8	1721.0	1731.5	1726.2	1608.8	1537.9	1573.3	35021.3	34307.0	34664.2
V_9	7515.4	7174.1	7344.8	2128.6	2013.3	2071.0	1481.0	1548.1	1514.6	1555.0	1385.3	1470.2	35018.3	34524.8	34771.6
V_{10}	7488.0	7210.5	7349.3	2190.9	2394.2	2292.5	1637.4	1559.6	1598.5	1633.0	1485.2	1559.1	34298.9	33916.9	34107.9
V_{11}	7637.2	7075.9	7356.6	2098.6	2020.0	2059.3	1416.6	1822.4	1619.5	1593.3	1557.5	1575.4	34763.5	34165.1	34464.3
V_{12}	7669.7	7131.9	7400.8	2187.3	2110.5	2148.9	1249.5	1651.4	1450.4	1619.1	1486.3	1552.7	35476.0	34311.4	34893.7
V_{13}	7293.1	6951.7	7122.4	2252.2	2355.9	2304.0	1705.4	1617.1	1661.3	1530.6	1568.2	1549.4	33905.5	33338.6	33622.1
V_{14}	7242.2	7204.7	7223.5	1967.1	1985.9	1976.5	1760.6	1926.5	1843.6	1446.0	1485.0	1465.5	34286.5	33869.3	34077.9
Mean	7384.7	7130.0	7257.3	2159.5	2174.2	2166.8	1584.6	1720.0	1652.3	1691.4	1553.6	1622.5	34433.8	33812.5	34123.1
S.Em(±)	36.32	75.92	42.08	86.42	60.82	52.84	60.97	57.38	41.86	63.55	57.68	42.91	67.01	77.37	51.18
C.D. at 5%	105.57	220.67	119.42	251.17	176.77	149.94	177.22	166.77	118.80	184.70	167.66	121.77	194.75	224.88	145.23

NS = Not significant

maturity stages were 1038.3, 4555.8, 6635.1, 9195.9, 7257.3, 2166.8, 1652.3 and 1622.5°C hour, respectively (Table 4.1.6). Based on pooled data, the stage-wise mean PTU were determined as: 21424.2°C hour (vegetative), 7257.3°C hour (reproductive) and 5441.6°C hour (ripening) in the investigation.

Among fourteen rice cultivars tested in the study, Lal Badshabhog (V_7) required the lowest photothermal units (32317.8 and 32017.2°C hour) for entire life-cycle during both 2012 and 2013. Thus, the genotypes with greater PTU might accumulate higher amount of heat in conjunction with day length during the period of excess days over the earliest mature one. Like GDD, all fourteen cultivars accumulated greater summed PTU from sowing to maturity in the first year than second year of investigation.

4.1.2 Growth attributes

4.1.2.1 Plant height

Plant height was increased consistently from 28 days after transplanting (DAT) to harvesting stage during both 2012 and 2013 (Table 4.1.7). Mean cultivar plant height was 65.1, 105.5, 133.8 and 140.0 cm at 28, 56, 84 DAT and harvesting stage, respectively. Thus, the rate of increase in plant height was much evident upto 84 DAT *i.e.* upto flowering stage; but it was somewhat slower thereafter due to exertion of panicles only.

The maximum and minimum plant height were recorded with NC 324 (69.5 cm) and Tulaipanji (57.5 cm) at 28 DAT; Kaminibhog (112.8 cm) and Kataribhog (97.2 cm) at 56 DAT; Lal Badshabhog and (141.9 cm) and Kataribhog (123.4 cm) at 84 DAT; and Lal Badshabhog (148.7 cm) and Kataribhog (131.0 cm) at harvest, respectively. Perusal of pooled data revealed that eight scented rice cultivars (Lal Badshabhog, NC 365, Tulsimukul, Radhunipagal, Kalonunia, NC 324, Kaminibhog and Kalojira) had the plant height of >140.0 cm; while the plants of rest six varieties (Radhatilak, Tulaipanji, Gobondabhog, Badshabhog, Sitabhog and Kataribhog) reached the final height between 130.0 and 140.0 cm at maturity in the experiment.

All fourteen aromatic rice landraces in the study generally produced taller plants at four stages of observation during 2013 than 2012. This might be due to the

Table 4.1.7

Effect of cultivars on plant height at different growth stages of aromatic rice during *kharif* season

Cultivar	Plant height (cm)											
	28 DAT			56 DAT			84 DAT			At harvest		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	60.4	65.9	63.2	100.8	107.9	104.4	127.9	132.0	130.0	131.7	137.2	134.5
V_2	57.7	65.5	61.6	98.3	103.0	100.7	126.3	129.9	128.1	131.5	138.3	134.9
V_3	63.1	68.5	65.8	99.8	109.9	104.8	134.5	137.9	136.2	137.9	145.2	141.5
V_4	66.0	69.9	68.0	108.9	107.1	108.0	136.7	141.5	139.1	142.5	145.1	143.8
V_5	65.1	72.7	68.9	106.7	118.9	112.8	133.2	140.2	136.7	140.2	143.4	141.8
V_6	62.1	63.4	62.7	94.3	100.0	97.2	120.2	126.6	123.4	125.3	136.7	131.0
V_7	64.7	68.5	66.6	106.7	111.9	109.3	140.3	143.5	141.9	149.5	147.9	148.7
V_8	67.3	71.8	69.5	104.6	111.3	108.0	133.7	136.1	134.9	142.8	144.0	143.4
V_9	61.8	70.1	66.0	102.6	114.6	108.6	137.5	142.3	139.9	146.6	147.5	147.1
V_{10}	59.7	66.9	63.3	100.7	105.2	103.0	128.7	132.7	130.7	135.0	140.2	137.6
V_{11}	66.5	67.6	67.0	105.7	115.3	110.5	135.2	141.8	138.5	142.8	145.0	143.9
V_{12}	67.1	71.6	69.4	101.7	102.6	102.1	124.2	129.2	126.7	129.2	134.7	131.9
V_{13}	54.8	60.3	57.5	93.9	103.1	98.5	126.1	130.2	128.1	131.5	138.5	135.0
V_{14}	58.7	65.5	62.1	103.4	114.9	109.2	137.4	141.0	139.2	143.2	146.1	144.7
Mean	62.5	67.7	65.1	102.0	109.0	105.5	131.6	136.1	133.8	137.8	142.1	140.0
S.Em(±)	1.96	1.57	1.26	3.04	3.19	2.20	2.60	2.91	1.95	2.00	1.61	1.28
C.D. at 5%	5.71	4.56	3.57	8.83	9.28	6.25	7.55	8.45	5.53	5.82	4.68	3.65

Values presented under 28, 56 and 84 DAT refer to closely at active tillering, panicle initiation and 50% flowering stage, respectively

DAT = Days after transplanting, NS = Not significant

fact that plant height, as an index of vegetative growth, was positively influenced by greater mean air temperature and bright sunshine hours during the vegetative stage, *i.e.* from fourth leaf emergence to active tillering (29.7 *vs.* 29.2°C, 4.72 *vs.* 3.85 hours) and active tillering to panicle initiation (29.5 *vs.* 29.2°C) in 2013 than those in 2012 (Table 4.1.2 and Table 4.1.4). The observation was further supported by positive correlations between plant height and GDD (r = 0.271*), and HTU (r = 0.346**) during fourth leaf emergence to active tillering stage of scented rice varieties in the study (Table 4.1.16 and Table 4.1.17)

4.1.2.2 Tillering pattern

Mean cultivar tillers in 1 m^2 area, pooled over two years, were 263.1, 363.2, and 319.1 at 28, 56 and 84 DAT, respectively (Table 4.1.8; Plate 4.1.3). Thus, tillering patern of scented rice in the study showed increasing trend from 28 to 56 DAT (*i.e.* vegetative stage) and declined thereafter due to death of some unproductive or late tillers.

Significant variation in number of tillers m^{-2} among fourteen rice cultivars was observed at all the stages of observation during both the years of the experimentation. Although Radhatilak (V_{10}) had the highest tillering ability (294.0 m^{-2}) at 28 DAT, but Gobindabhog (V_2) produced the maximum number of tillers m^{-2} at 56 DAT (400.3) and 84 DAT (353.9) in the study. On the other hand, Kaminibhog (V_5) exhibited lowest tillering habit throughout the cropping period. The anthocyanin colouration on nodes and internodes of the stem was usually absent in twelve cultivars, while medium and strong pigmentation was noted in NC 324 (V_8) and Radhunipagal (V_{11}), respectively (Plate 4.1.8)

All fourteen landraces produced mostly greater number of tillers in 1 m^2 area at 28, 56 and 84 DAT during the first year than the second year of investigation.

4.1.2.3 Leaf area index

The foliage growth of rice, in terms of LAI, was increased consistently upto 84 DAT and declined thereafter due to drying and withering of leaves during the ripening phase (Table 4.1.9). Mean cultivar LAI, pooled over two years, was 1.68, 3.69, 4.89 and 2.81 at 28, 56, 84 DAT and at harvest, respectively.

Table 4.1.8

Effect of cultivars on tillering pattern at different growth stages of aromatic rice during *kharif* season

Cultivar	Number of tillers m^{-2}								
	28 DAT			56 DAT			84 DAT		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	278.7	269.6	274.1	388.5	365.7	377.1	337.2	325.6	331.4
V_2	264.8	284.4	274.6	397.9	402.8	400.3	345.2	362.7	353.9
V_3	278.7	284.4	281.5	394.9	363.1	379.0	341.9	360.7	351.3
V_4	209.9	219.7	214.8	359.7	338.4	349.1	306.4	303.1	304.7
V_5	203.2	210.3	206.8	322.8	325.2	324.0	271.6	281.2	276.4
V_6	296.8	256.5	276.7	380.3	346.5	363.4	328.7	294.7	311.7
V_7	294.3	275.5	284.9	394.9	358.3	376.6	329.7	330.4	330.1
V_8	237.6	257.3	247.5	363.9	346.5	355.2	306.9	308.7	307.8
V_9	278.7	248.7	263.7	389.1	337.7	363.4	340.3	293.6	316.9
V_{10}	304.4	283.7	294.0	366.8	371.1	368.9	322.7	321.3	322.0
V_{11}	243.5	258.0	250.7	357.3	336.0	346.7	313.9	297.5	305.7
V_{12}	289.1	286.3	287.7	386.1	367.1	376.6	336.9	320.5	328.7
V_{13}	264.0	264.1	264.1	362.0	350.4	356.2	334.4	314.1	324.3
V_{14}	280.5	244.2	262.4	366.1	329.3	347.7	310.5	294.1	302.3
Mean	266.0	260.2	263.1	373.6	352.7	363.2	323.3	314.9	319.1
S.Em(±)	7.38	9.53	6.03	11.58	12.62	8.56	10.84	9.66	7.26
C.D. at 5%	21.46	27.69	17.10	33.66	36.67	24.30	31.52	28.08	20.61

Values presented under 28, 56 and 84 DAT refer to closely at active tillering, panicle initiation and 50% flowering stage, respectively
DAT = Days after transplanting, NS = Not significant

Table 4.1.9

Effect of cultivars on LAI at different growth stages of aromatic rice during *kharif* season

Cultivar	Leaf area index (LAI)											
	28 DAT			56 DAT			84 DAT			At harvest		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	1.60	1.70	1.65	3.61	3.67	3.64	4.70	4.83	4.77	2.91	2.86	2.89
V_2	1.69	1.71	1.70	3.66	3.62	3.64	4.74	4.92	4.83	2.83	3.01	2.92
V_3	1.60	1.86	1.73	3.58	3.83	3.70	4.92	5.06	4.99	2.80	3.11	2.96
V_4	1.56	1.81	1.69	3.66	3.88	3.77	4.92	4.96	4.94	2.99	3.01	3.00
V_5	1.59	1.62	1.61	3.66	3.70	3.68	4.63	4.62	4.62	2.67	2.48	2.58
V_6	1.69	1.78	1.74	3.68	3.84	3.76	5.02	5.16	5.09	2.64	2.91	2.78
V_7	1.65	1.75	1.70	3.69	3.78	3.74	4.93	5.06	5.00	2.71	2.84	2.78
V_8	1.75	1.71	1.73	3.70	3.73	3.72	4.89	4.99	4.94	2.70	2.80	2.75
V_9	1.72	1.89	1.80	3.84	3.92	3.88	5.02	5.09	5.06	3.09	2.93	3.01
V_{10}	1.68	1.69	1.69	3.62	3.77	3.69	4.86	5.00	4.93	2.91	2.83	2.87
V_{11}	1.54	1.61	1.58	3.47	3.59	3.53	4.84	4.89	4.87	2.82	2.80	2.81
V_{12}	1.67	1.76	1.71	3.68	3.76	3.72	4.84	4.90	4.87	2.60	2.80	2.70
V_{13}	1.50	1.64	1.57	3.53	3.72	3.63	4.72	4.88	4.80	2.64	2.75	2.69
V_{14}	1.53	1.68	1.61	3.51	3.63	3.57	4.69	4.74	4.72	2.52	2.77	2.64
Mean	1.63	1.73	1.68	3.64	3.75	3.69	4.84	4.94	4.89	2.77	2.85	2.81
S.Em(±)	0.11	0.08	0.07	0.10	0.14	0.09	0.06	0.13	0.07	0.11	0.07	0.07
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.19	NS	0.21	NS	0.20	0.19

Values presented under 28, 56 and 84 DAT refer to closely at active tillering, panicle initiation and 50% flowering stage, respectively

DAT = Days after transplanting

The LAI did not vary significantly among the tested varieties at 28 and 56 DAT during both the years and pooled values; but it showed significant differences at 84 DAT for 2012 and pooled values as well as at harvest for 2013 and pooled values in the investigation. All fourteen aromatic rice cultivars recorded the maximum LAI at 84 DAT, which was found to vary between 4.63 (Kaminibhog) and 5.02 (Kataribhog and NC 365) during 2012 as well as between 4.62 (Kaminibhog) and 5.16 (Kataribhog) during 2013. Sarkar (1994) reported similar maximum LAI values for aromatic rice landraces of West Bengal during wet season.

The comparison between two years indicated that LAI of fourteen cultivars at 28, 56, 84 and harvest was generally greater in the second year compared to first year.

4.1.2.4 Light transmission ratio (LTR)

The light interception by the crop canopy at different growth stages showed that the values of light transmission ratio (LTR) were consistently decreased upto 84 DAT and increased thereafter (Table 4.1.10). The above trend of light interception might be due to foliage growth, tiller production and panicle exertion upto 84 DAT and senescence of leaves, death of unproductive tillers, etc. during the ripening phase.

Mean cultivar LTR, pooled over two years, was 36.9, 24.7, 14.4 and 17.5% at 28, 56, 84 DAT and at harvest, respectively. The variations in LTR values among the cultivars, in general, showed inverse relationship with their respective values of LAI because of the influence of foliage growth on penetration of light at different stages of observation.

Although light interception values varied significantly among tested genotypes at 28 and 56 DAT for two years as well as at harvest for second year and pooled values; but it did not show significant differences at 84 DAT (*i.e.* 50% flowering stage) for both 2012 and 2013. Based on pooled data, the maximum LTR value was noted with Tulaipanji (39.6%), Lal Badshabhog (27.5%), Radhunipagal (16.3%) and Kalonunia (19.7%) at 28, 56, 84 DAT and harvest, respectively. The genotype NC 324 (V_8), intercepted the lowest light at 28 DAT (33.3%) and harvest (16.1%); while NC 365 (V_9) recorded the lowest LTR values at 56 (22.0%) and 84 DAT (13.4%) in the study.

The comparison between two years showed that the LTR values of fourteen cultivars at all the stages of observation were generally greater during 2012 than 2013.

Table 4.1.10

Effect of cultivars on light interception at different growth stages of aromatic rice during *kharif* season

Cultivar	Light interception (%)											
	28 DAT			56 DAT			84 DAT			At harvest		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	41.2	36.2	38.7	26.6	23.8	25.2	15.8	13.6	14.7	18.5	16.9	17.7
V_2	37.4	38.3	37.9	28.8	24.4	26.6	15.4	13.0	14.2	19.5	17.2	18.4
V_3	41.5	31.8	36.7	24.6	23.5	24.1	14.5	14.4	14.5	17.8	16.5	17.1
V_4	37.4	32.5	35.0	23.6	23.7	23.7	14.5	13.4	14.0	20.3	19.1	19.7
V_5	40.2	34.9	37.5	25.4	23.5	24.5	14.0	14.3	14.2	19.4	18.2	18.8
V_6	39.9	34.8	37.4	25.5	22.4	24.0	13.9	13.6	13.8	18.3	17.5	17.9
V_7	39.8	35.5	37.7	27.3	27.7	27.5	18.6	12.1	15.3	18.8	16.9	17.8
V_8	34.1	32.4	33.3	26.9	21.7	24.3	14.8	12.2	13.5	17.7	14.4	16.1
V_9	36.9	31.4	34.2	23.1	20.8	22.0	14.4	12.4	13.4	18.2	15.9	17.1
V_{10}	37.7	35.6	36.7	27.1	23.6	25.3	15.8	13.8	14.8	16.3	17.2	16.8
V_{11}	39.4	34.7	37.1	24.8	22.5	23.6	17.8	14.8	16.3	16.1	16.3	16.2
V_{12}	35.2	36.7	36.0	27.7	24.9	26.3	14.2	12.7	13.5	17.0	16.2	16.6
V_{13}	40.7	38.6	39.6	26.3	24.9	25.6	17.1	13.6	15.4	17.6	15.7	16.7
V_{14}	39.8	38.0	38.9	23.9	22.2	23.0	15.4	14.4	14.9	19.7	16.8	18.3
Mean	38.7	35.1	36.9	25.8	23.5	24.7	15.4	13.5	14.4	18.2	16.8	17.5
S.Em(±)	1.49	1.49	1.05	1.16	0.85	0.72	1.11	0.92	0.72	1.25	0.72	0.72
C.D. at 5%	4.34	4.33	2.99	3.36	2.47	2.03	NS	NS	NS	NS	2.09	2.04

Values presented under 28, 56 and 84 DAT refer to closely at active tillering, panicle initiation and 50% flowering stage, respectively
DAT = Days after transplanting, NS = Not significant

Table 4.1.11

Effect of cultivars on light extinction co-efficient at different growth stages of aromatic rice during *kharif* season

Cultivar	Light extinction co-efficient (k)											
	28 DAT			56 DAT			84 DAT			At harvest		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	0.56	0.60	0.58	0.40	0.42	0.41	0.50	0.56	0.53	0.68	0.76	0.72
V_2	0.59	0.57	0.58	0.36	0.42	0.39	0.50	0.58	0.54	0.67	0.71	0.69
V_3	0.56	0.62	0.59	0.43	0.41	0.42	0.53	0.50	0.52	0.74	0.72	0.73
V_4	0.64	0.62	0.63	0.44	0.40	0.42	0.53	0.55	0.54	0.60	0.64	0.62
V_5	0.58	0.65	0.62	0.41	0.42	0.42	0.57	0.56	0.57	0.71	0.81	0.76
V_6	0.55	0.59	0.57	0.41	0.43	0.42	0.54	0.53	0.54	0.76	0.72	0.74
V_7	0.56	0.60	0.58	0.37	0.35	0.36	0.40	0.61	0.51	0.79	0.77	0.78
V_8	0.62	0.67	0.64	0.38	0.45	0.42	0.51	0.60	0.56	0.78	0.91	0.85
V_9	0.58	0.63	0.61	0.42	0.45	0.44	0.51	0.60	0.55	0.66	0.79	0.73
V_{10}	0.59	0.61	0.60	0.39	0.42	0.40	0.48	0.53	0.51	0.77	0.76	0.77
V_{11}	0.60	0.66	0.63	0.44	0.46	0.45	0.43	0.52	0.47	0.81	0.80	0.81
V_{12}	0.63	0.57	0.60	0.37	0.39	0.38	0.53	0.59	0.56	0.84	0.81	0.83
V_{13}	0.61	0.58	0.60	0.41	0.40	0.40	0.46	0.56	0.51	0.79	0.85	0.82
V_{14}	0.61	0.57	0.59	0.45	0.46	0.46	0.51	0.54	0.53	0.74	0.79	0.77
Mean	0.59	0.61	0.60	0.41	0.42	0.41	0.50	0.56	0.53	0.74	0.78	0.76
S.Em(±)	0.05	0.04	0.03	0.02	0.02	0.02	0.04	0.04	0.03	0.07	0.04	0.04
C.D. at 5%	NS	NS	NS	0.07	0.07	0.05	0.10	0.12	0.08	0.21	0.12	0.12

Values presented under 28, 56 and 84 DAT refer to closely at active tillering, panicle initiation and 50% flowering stage, respectively
DAT = Days after transplanting, NS = Not significant

4.1.2.5 Light extinction co-efficient (k)

The values of light extinction co-efficient (k) for all fourteen scented rice cultivars showed a decreasing trend between 28 and 56 DAT, while steady or little increasing phase between 56 and 84 DAT, and rapid increasing trend between 84 DAT and at harvest (Table 4.1.11). Mean cultivar k, pooled over two years, was 0.60, 0.41, 0.53 and 0.76 at 28, 56, 84 DAT and at harvest, respectively.

The k values differed significantly among the tested varieties at 56, 84 DAT and at harvest for both the years and pooled values, excluding at 28 DAT in the investigation. The lowest k values of Kataribhog (0.57) at 28 DAT, Lal Badshabhog (0.36) at 56 DAT, Radhunipagal (0.47) at 84 DAT and Kalonunia (0.62) at harvest indicated more upright leaves compared to the other genotypes in the experiment. Based on the range of k values, it could be concluded that, all 14 cultivars usually had horizontal or droopy types of leaves as evident in tall-*indica* rice.

4.1.3 Flag leaf and Grain characteristics

4.1.3.1 Flag leaf

4.1.3.1.1 Length and breadth

The length and breadth of flag leaf were measured during second year of investigation only (Table 4.1.12). Among fourteen rice cultivars, Kalonunia (V_4) recorded the maximum length (47.33 cm) and breadth (1.38 cm) of flag leaf; while Kaminibhog (28.17 cm) and Sitabhog (1.04 cm) had the lowest flag leaf length and width, respectively.

4.1.3.1.2 Angle with axis

The angle of flag leaf with axis was found to vary widely between Gobindabhog (45.2°) and Kalojira (104.5°) in the study (Table 4.1.12).

4.1.3.2 Grain

4.1.3.2.1 Length and breadth

The variations in grain length revealed that one genotype (NC 365) recorded the grain length of >8.00 mm, four cultivars (Kalonunia, Kataribhog, NC 324, and Tulaipanji) had grains of 7.00–8.00 mm length, seven varieties (Kaminibhog,

Table 4.1.12

Effect of cultivars on flag leaf and grain characteristics of aromatic rice during *kharif* season

Cultivar	Flag leaf			Grain						Awn		
	Length (cm)	Breadth (cm)	Angle with axis (°)	Length	Breadth	Lemma and palea		Sterile lemma		Present/ Absent	Mean length / Range (mm)	Colour
						Colour	Code	Colour	Code			
V_1	40.77	1.29	92.8	6.44	2.31	Gold and gold furrows on straw background	2	Straw	1	Absent	-	-
V_2	40.08	1.22	43.5	6.25	2.32	Gold and gold furrows on straw background	2	Straw	1	Absent	-	-
V_3	35.60	1.13	104.5	5.81	2.70	Black	9	Purple	4	Absent	-	-
V_4	47.33	1.38	71.5	7.73	2.45	Black	9	Purple	4	Present	7.6 (2-10)	Black
V_5	28.17	1.17	70.7	6.50	2.91	Brown spots on straw	3	Straw	1	Absent	-	-
V_6	40.92	1.28	51.0	7.51	2.49	Gold and gold furrows on straw background	2	Straw	1	Absent	-	-
V_7	40.68	1.19	52.7	6.40	2.24	Brown (tawny)	5	Red	3	Absent	-	-
V_8	34.05	1.23	38.2	7.49	2.37	Purple spots / furrows on straw	7	Purple	4	Absent	-	-
V_9	45.32	1.33	88.7	8.12	2.48	Black	9	Purple	4	Present	11.9 (2-15)	Black
V_{10}	34.47	1.18	86.3	6.45	2.57	Purple spots / furrows on straw	7	Red	3	Absent	-	-
V_{11}	40.96	1.24	65.8	5.78	2.35	Purple spots / furrows on straw	7	Purple	4	Absent	-	-
V_{12}	41.02	1.04	89.7	6.36	2.30	Gold and gold furrows on straw background	2	Straw	1	Absent	-	-
V_{13}	30.00	1.15	56.2	7.39	2.36	Gold and gold furrows on straw background	2	Straw	1	Present	30.2 (25-30)	Straw
V_{14}	43.90	1.28	46.0	6.33	2.61	Black	9	Purple	4	Absent	-	-
Mean	38.80	1.22	68.4	6.75	2.46							
S.Em(±)	1.98	0.05	8.78	0.026	0.013							
C.D. at 5%	5.75	0.14	25.51	0.077	0.038							

Radhatilak, Badshabhog, Lal Badshabhog, Sitabhog, Tulsimukul, and Gobindabhog) possessed grains of 6.00–7.00 mm length and only one (Radhunipagal) had the smallest grain of 5.00–6.00 mm length in the experiment (Table 4.1.12; Plate 4.1.11, 4.1.12, 4.1.13, 4.1.13 and 4.1.16).

Fourteen scented rice varieties showed little variation in grain breadth with a range between 2.24 (Lal Badshabhog) and 2.91 (Kaminibhog) during 2013 in the investigation.

4.1.3.2.2 Colour of lemma, palea and sterile lemma

Among fourteen scented rice cultivars, five varieties (Badshabhog, Gobindabhog, Kataribhog, Sitabhog and Tulaipanji) had the grain colour of gold and golden furrows on straw background (score 2), one cultivar (Kaminibhog) possessed the grains having brown spots on straw background (score 3), one variety Lal Badshabhog had brown (tawny) coloured grain (score 5), three genotypes (NC 324, Radhatilak and Radhunipagal) possessed the grains of purple spots / furrows on straw background (Score 7) and four genotypes (Kalojira, Kalonunia, NC 365 and Tulsimukul) possessed black coloured grain (score 9) in the investigation (Table 4.1.12; Plate 4.1.6, 4.1.11, 4.1.12, 4.1.13, 4.1.14 and 4.1.16).

The colour of sterile lemma of the tested cultivars varied as: straw (Badshabhog, Gobindabhog, Kaminibhog, Kataribhog, Sitabhog and Tulaipanji), purple (Kalojira, Kalonunia, NC 324, NC 365, Radhunipagal and Tulsimukul) and red (Lal Badshabhog and Radhatilak) in the experiment (Table 4.1.12; Plate 4.1.11).

4.1.3.3 Awn

4.1.3.3.1 Length

With regard to the presence or absence of awn, it was observed that the grains of three cultivars (Kalonunia, NC 365, and Tulaipanji) possessed awns and rest eleven genotypes were awnless (Table 4.1.12; Plate 4.1.12, 4.1.14 and 4.1.16). Perusal of data on awn length and range of variation of three varieties revealed that Tulaipanji (V_{13}) could be classified as long awned (mean 30.2 mm and range 25–30 mm); while Kalonunia (mean 7.6 mm and range 2-10 mm) and NC 365 (mean 11.9 mm and range 2-15 mm) might be of medium awn category.

4.1.3.3.2 Colour

Tulaipanji (V_{13}) had straw coloured awn, while Kalonunia (V_4) and NC 365 (V_9) possessed black coloured awn at the tip of lemma in grain (Table 4.1.12; Plate 4.1.12).

4.1.4 Yield components and associated characters

4.1.4.1 Panicle length

Fourteen aromatic rice cultivars differed significantly with regard to panicle length during both 2012 and 2013 (Table 4.1.13; Plate 4.1.7). NC 365 (V_9) produced the longest panicle (28.1 and 28.3 cm) during both the years of experimentation; while Radhunipagal (V_{11}) had the shortest panicle length (24.1 and 23.7 cm) during 2013 and pooled over two years.

4.1.4.2 Number of panicles m^{-2}

The number of panicles m^{-2} varied significantly among fourteen aromatic rice landraces during *kharif* season of both 2012 and 2013 (Table 4.1.13; Fig. 4.1.2). Lal Badshabhog (V_7) produced the highest number of panicles (310.0) during first year; while Gobindabhog (V_2) and Kalojira (V_3) recorded maximum number of panicles (301.1) in 1 m^2 area during second year and Gobindabhog (V_2) had the greatest number of panicles (302.6) m^{-2} for pooled over two years in the study. Kaminibhog (V_5) recorded the lowest number of panicles (237.1 and 230.4) m^{-2} during 2012 and 2013, respectively. Similar type of findings for number of panicles m^{-2} for indigenous scented rice cultivars was reported by Banerjee (2011).

4.1.4.3 Number of filled grains panicle^{-1}

There was significant variation among fourteen scented rice genotypes with regard to the number of filled grains panicle^{-1} during both the years of experimentation (Table 4.1.13; Fig. 4.1.2; Plate 4.1.9 and 4.1.10). Badshabhog (144.9) and Radhunipagal (140.5) produced the maximum number of filled grains panicle^{-1} during 2012 and 2013, respectively; while Tulaipanji (V_{12}) recorded the lowest number of filled grains panicle^{-1} (66.4 and 80.0) during both the years of study. Hossain *et al.* (2008) reported similar number of grains panicle^{-1} for Badshabhog (136.8), but slightly greater for Kalijira (121.8) and lesser for Radhunipagal (124.3) at Dinajpur, Bangladesh.

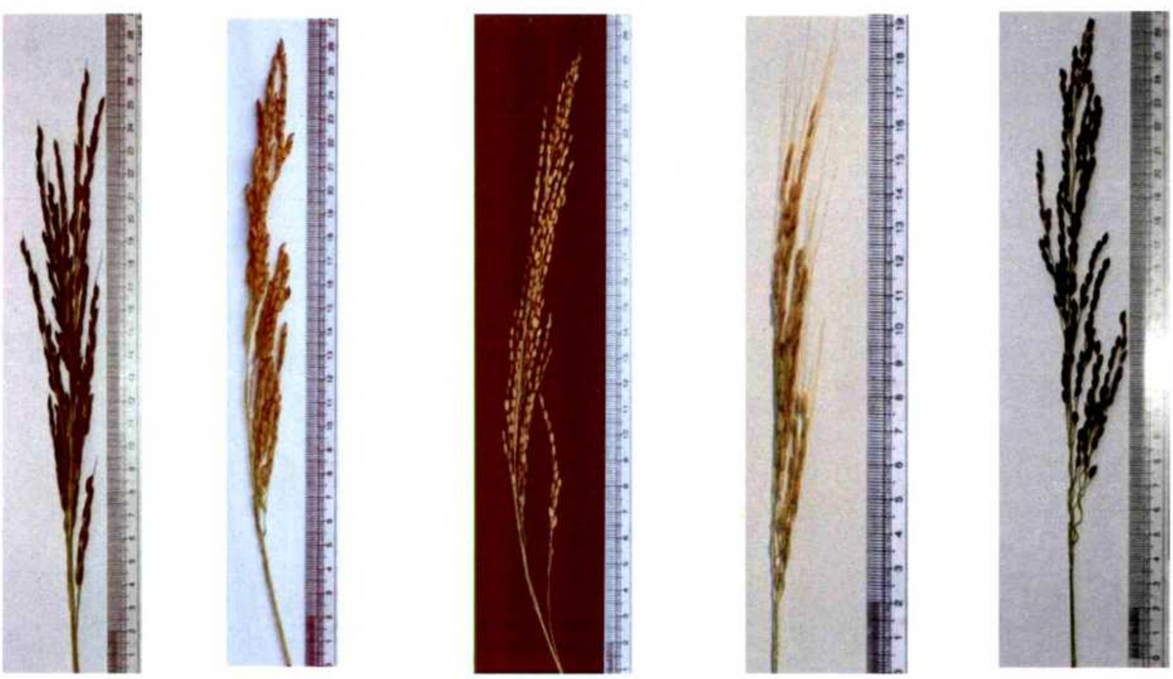
Table 4.1.13

Effect of cultivars on yield components of aromatic rice during *kharif* season

Cultivar	Panicle length (cm)			Yield components								
				No. of panicles m^{-2}			No. of filled grains $panicle^{-1}$			1000 grain weight (g)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	24.4	25.9	25.2	270.3	262.9	266.6	144.9	132.5	138.7	10.93	10.67	10.80
V_2	25.1	25.8	25.5	304.0	301.1	302.6	131.7	132.4	132.1	10.57	10.43	10.50
V_3	25.0	26.7	25.8	287.4	301.1	294.2	103.1	111.2	107.2	11.82	11.88	11.85
V_4	27.1	28.0	27.6	293.3	290.3	291.8	109.7	112.7	111.2	14.87	14.83	14.85
V_5	24.7	25.5	25.1	237.0	230.3	233.7	94.4	106.8	100.6	13.85	14.26	14.05
V_6	23.8	25.9	24.9	265.2	280.7	272.9	97.8	110.2	104.0	14.77	14.42	14.59
V_7	26.0	27.3	26.6	310.0	274.0	292.0	133.7	132.8	133.2	10.70	10.50	10.60
V_8	23.6	24.6	24.1	282.9	269.6	276.3	127.8	135.9	131.9	14.39	14.33	14.36
V_9	28.1	28.3	28.2	301.1	272.6	286.8	118.9	130.0	124.5	17.06	17.11	17.09
V_{10}	23.2	25.7	24.5	280.0	289.2	284.6	143.2	137.5	140.4	10.88	11.02	10.95
V_{11}	23.3	24.1	23.7	250.3	263.7	257.0	144.1	140.5	142.3	10.37	10.39	10.38
V_{12}	25.0	25.1	25.0	296.6	288.1	292.4	80.9	93.3	87.1	10.97	10.92	10.94
V_{13}	23.6	24.3	23.9	260.0	264.4	262.2	66.4	80.0	73.2	15.24	14.61	14.93
V_{14}	24.9	25.8	25.3	280.0	276.3	278.1	141.2	135.7	138.5	11.63	11.70	11.66
Mean	24.8	25.9	25.4	279.9	276.0	277.9	117.0	120.8	118.9	12.72	12.65	12.68
S.Em(±)	0.61	0.42	0.37	7.20	6.31	4.79	3.40	3.61	2.48	0.13	0.08	0.08
C.D. at 5%	1.77	1.21	1.05	20.92	18.35	13.58	9.88	10.49	7.03	0.38	0.24	0.22

NS = Not significant

Badshabhog Gobindabhog Kalojira Kalonunia Lal Badshabhog Radhatilak



NC 365 Radhatilak Radhunipagal Tulaipanji Tulsimukul

Plate 4.1.7: Panicles of aromatic rice cultivars of West Bengal, India

The number of filled grains panicle^{-1} in most of the varieties was greater in 2013 than 2012, which could be explained by higher mean air temperature (25.9°C *vs.* 25.2°C) and bright sunshine hour (7.08 *vs.* 5.54 hours) during milk to dough stage in second year than first year (Table 4.1.2 and 4.1.4). The observation was also supported by positive correlation (r =0.228*) between number of filled grains panicle^{-1} and GDD at milk to dough stage of fragrant rices in the investigation (Table 4.1.16).

4.1.4.4 1000 grain weight

Test weight, being a genetical character, differed significantly among fourteen aromatic rice cultivars tested in the experiment (Table 4.1.13; Fig. 4.1.2)

The range of variation in 1000 grain weight was 10.37 g (Radhunipagal) to 17.06 g (NC 365) during 2012, and 10.39 g (Radhunipagal) to 17.11 g (NC 365) during 2013. Deb (2005) reported much wider variations in test weight of folk fragrant rice genotypes of West Bengal compared to the above findings in the investigation.

4.1.5 Yield and lodging

4.1.5.1 Grain yield

Grain yield, an end product of interaction among yield components, differed significantly due to cultivars in the study (Table 4.1.14; Fig. 4.1.2). The highest grain yield was recorded with NC 365 (3.37 and 3.41 t ha^{-1}) during both the years of experiment. Sitabhog (2.04 t ha^{-1} and 2.17 t ha^{-1}) produced the lowest grain yield during both the years of investigation, respectively. Based on pooled grain yield, fourteen varieties could be arranged as: NC 365 (3.39 t ha^{-1}) > Kataribhog (3.05 t ha^{-1}) > Badshabhog and Kalonunia (2.98 t ha^{-1}) > Radhatilak (2.93 t ha^{-1}) > NC 324 (2.92 t ha^{-1}) > Kalojira (2.91 t ha^{-1}) > Gobindabhog (2.81 t ha^{-1}) > Radhunipagal (2.57 t ha^{-1}) > Tulsimukul (2.52 t ha^{-1}) > Lal Badshabhog (2.38 t ha^{-1}) > Kaminibhog (2.32 t ha^{-1}) > Tulaipanji (2.19 t ha^{-1}) > Sitabhog (2.11 t ha^{-1}). Similar findings on grain yield of scented rice landraces of West Bengal were reported by Sarkar (1994) and Banerjee (2011).

The correlation studies revealed that the yield components like number of filled grains panicle^{-1} (r = 0.397**) and test weight (r = 0.326**) contributed most towards the grain yield of indigenous scented rice compared to number of panicles m^{-2} in the study (Table 4.1.21).

Table 4.1.14

Effect of cultivars on grain yield, straw yield, harvest index and lodging of aromatic rice during *kharif* season

Cultivar	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Harvest index			Lodging (score)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	2.88	3.08	2.98	5.84	5.71	5.77	0.33	0.35	0.34	2.33	3.00	2.67
V_2	2.77	2.85	2.81	5.31	5.51	5.41	0.34	0.34	0.34	3.67	3.00	3.33
V_3	2.96	2.87	2.91	5.81	5.51	5.66	0.34	0.34	0.34	2.33	3.67	3.00
V_4	3.02	2.94	2.98	5.67	5.79	5.73	0.35	0.34	0.34	5.67	6.33	6.00
V_5	2.27	2.37	2.32	5.62	5.25	5.44	0.29	0.31	0.30	3.00	3.00	3.00
V_6	2.97	3.12	3.05	5.66	5.31	5.48	0.34	0.37	0.36	4.33	4.33	4.33
V_7	2.44	2.33	2.38	5.74	5.60	5.67	0.30	0.29	0.30	3.00	4.33	3.67
V_8	2.87	2.97	2.92	5.29	5.52	5.40	0.35	0.35	0.35	3.67	4.33	4.00
V_9	3.37	3.41	3.39	5.96	6.09	6.02	0.36	0.36	0.36	3.67	3.00	3.33
V_{10}	2.87	2.98	2.93	5.40	5.13	5.27	0.35	0.37	0.36	4.33	3.67	4.00
V_{11}	2.53	2.61	2.57	5.55	5.72	5.64	0.31	0.31	0.31	4.33	3.67	4.00
V_{12}	2.04	2.17	2.11	5.60	5.25	5.42	0.27	0.29	0.28	2.33	3.00	2.67
V_{13}	2.13	2.25	2.19	5.28	5.09	5.19	0.29	0.31	0.30	7.00	7.67	7.33
V_{14}	2.45	2.58	2.52	5.57	5.14	5.36	0.31	0.33	0.32	3.67	4.33	4.00
Mean	2.68	2.75	2.72	5.59	5.47	5.53	0.32	0.33	0.33	3.81	4.10	3.95
S.Em(±)	0.07	0.13	0.07	0.12	0.11	0.08	0.006	0.011	0.006	0.86	0.96	0.64
C.D. at 5%	0.21	0.37	0.21	0.35	0.32	0.23	0.019	0.031	0.017	2.50	NS	1.83

NS = Not significant

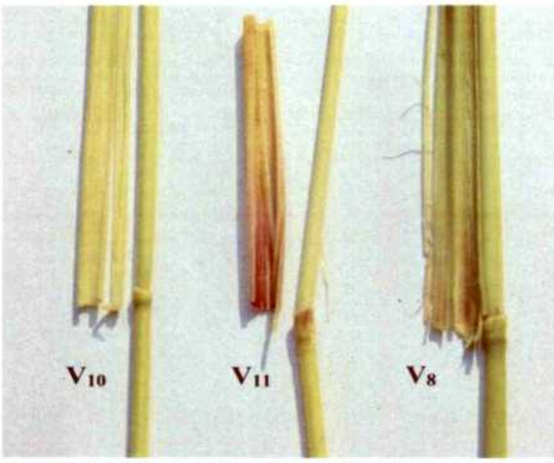


Plate 4.1.8: Difference in anthocyanin colouration on node and internode of Radhatilak, Radhunipagal and NC 324

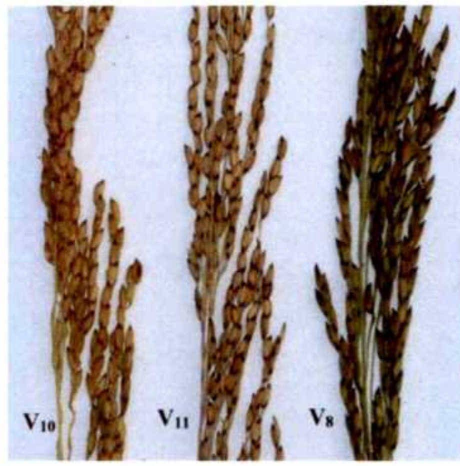


Plate 4.1.9: Difference in panicle characteristics of Radhatilak, Radhunipagal and NC 324

Plate 4.1.10: Difference in panicle characteristics of Kalojira, Tulsimukul, Kalonunia and NC 365

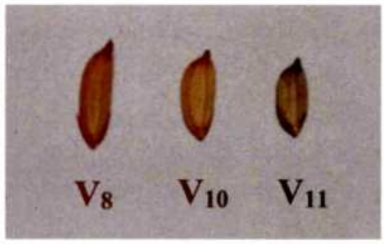


Plate 4.1.11: Variations in grains of purple spot on yellow background

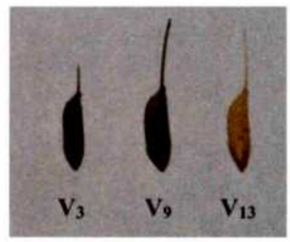


Plate 4.1.12: Difference in awn characteriscts

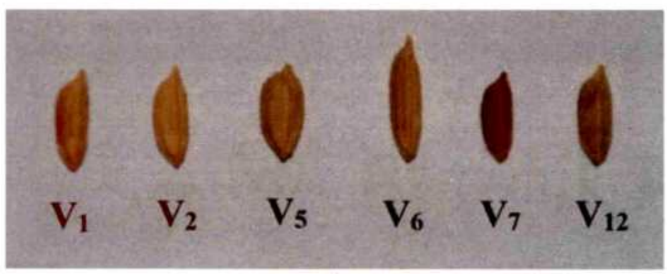


Plate 4.1.13: Variations in yellow coloured grains

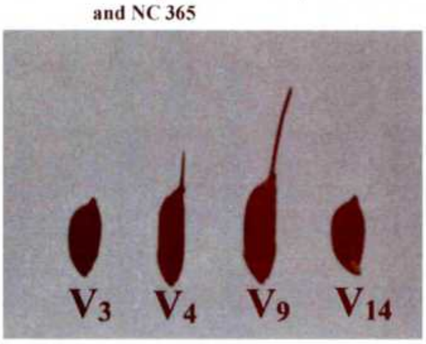


Plate 4.1.14: Variations in black coloured grains

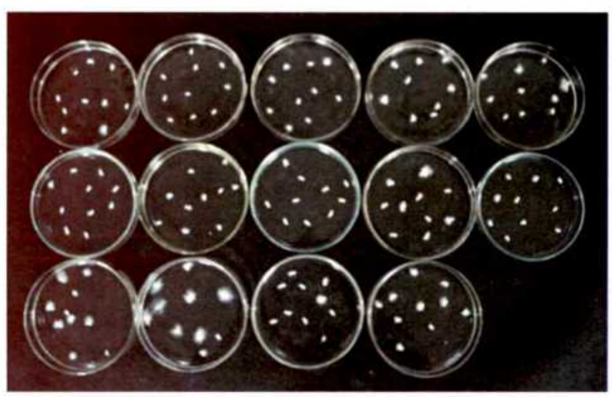


Plate 4.1.15: Alkali digestibility test of 14 aromatic rice varieties

Panicle and grain characteristics of aromatic rice cultivar

The heat use efficiency of fourteen aromatic rice cultivars were determined as: $y = -0.0122x + 36.549$ (Badshabhog), $y = -0.0005x + 4.2379$ (Gobindabhog), $y = -0.0009x + 5.4141$ (Kalojira), $y = 0.0017x - 1.7779$ (Kalonunia), $y = -0.0009x + 5.0112$ (Kaminibhog), $y = -0.0021x + 9.0059$ (Kataribhog), $y = -0.0034x + 11.289$ (Lal Badshabhog), $y = -0.0022x + 9.0399$ (NC 324), $y = 0.0009x + 0.7734$ (NC 365), $y = -0.0015x + 7.0845$ (Radhatilak), $y = -0.0011x + 5.5222$ (Radhunipagal), $y = -0.0012x + 5.3794$ (Sitabhog), $y = -0.0015x + 6.4076$ (Tulaipanji) and $y = -0.0013x + 5.989$ (Tulsimukul) (Fig. 4.1.3).

4.1.5.2 Straw yield

Straw yield, an index of vegetative growth, was found to differ significantly among fourteen scented rice cultivars during 2013 and pooled over two years (Table 4.1.14). The highest and lowest straw yields were recorded with NC 365 (5.96 and 6.09 t ha^{-1}) and Tulaipanji (5.28 and 5.09 t ha^{-1}) during both 2012 and 2013.

4.1.5.3 Harvest index

The variations in grain and straw yields due to cultivars resulted in differences in harvest index among fourteen rice varieties tasted in the study (Table 4.1.14). It was found to vary between 0.27 (Sitabhog) and 0.36 (NC 365) during 2012 and between 0.30 (Lalbadshabhog and Sitabhog) and 0.37 (Radhatilak) during 2013.

4.1.5.4 Lodging

Mean lodging score over two years were: 2.67 (Badshabhog and Sitabhog), 3.00 (Kalojira and Kaminibhog), 3.33 (Gobindabhog and NC 365), 3.67 (Lalbadshabhog), 4.00 (NC 324, Radhatilak, Radhunipagal and Tulsimukul), 4.33 (Kataribhog), 6.00 (Kalonunia), and 7.33 (Tulaipanji) (Table 4.1.14; Plate 4.1.5).

Based on the scores it could be concluded that the plants of Badshabhog and Sitabhog lodged slightly at hard dough stage; Kalojira, Kaminibhog, Gobindabhog, NC 365, Lalbadshabhog, NC 324, Radhatilak, Radhunipagal, Tulsimukul and Kataribhog showed slightly to moderately lodging; while Kalonunia lodged completely to nearly flat and Tulaipanji showed nearly flat condition in the experimental field.

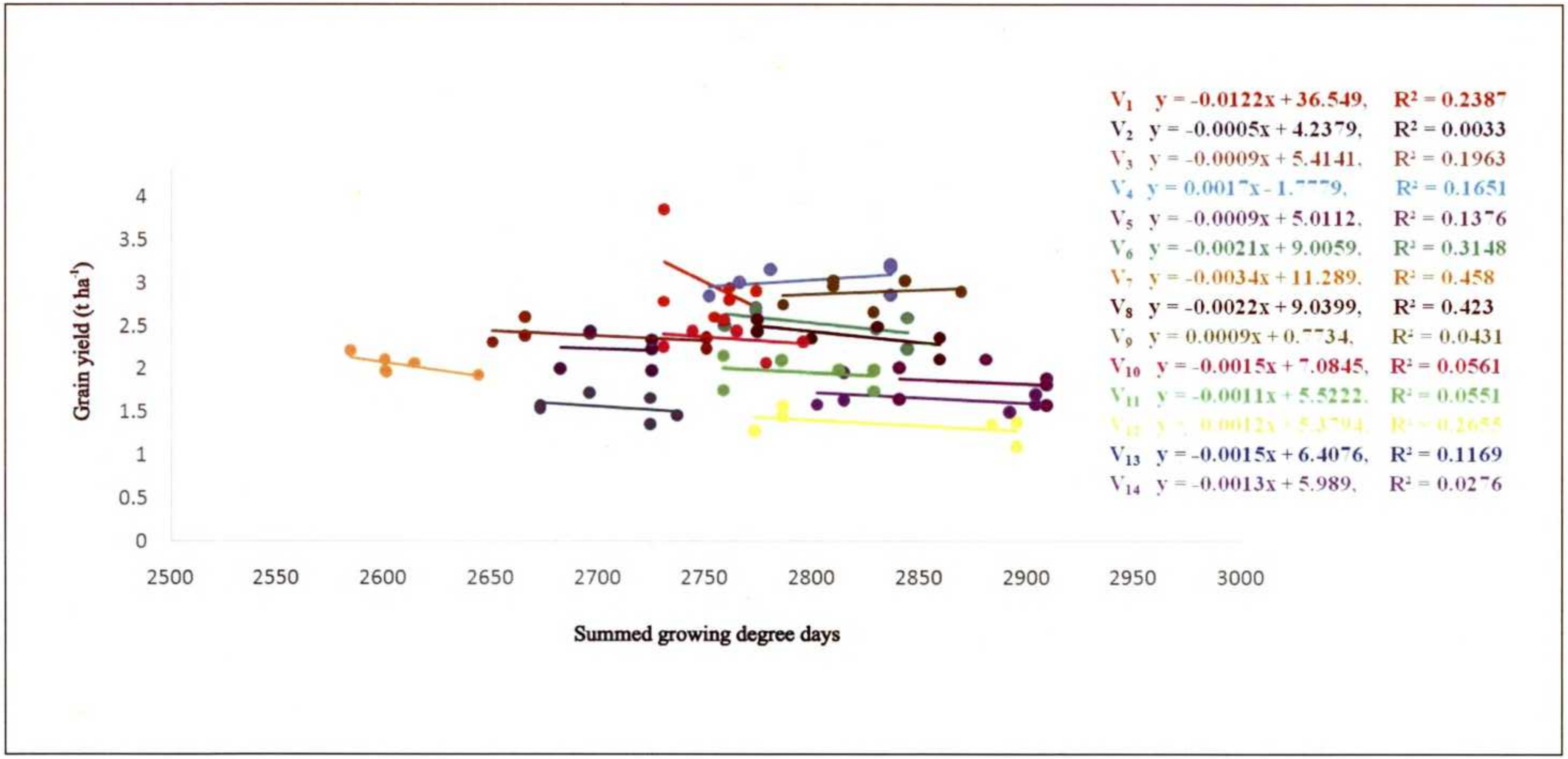


Fig. 4.1.3: Effect of cultivars on heat use efficiency of aromatic rice (Pooled of two years)

4.1.6 Grain quality

4.1.6.1 Milling quality

4.1.6.1.1 Hulling

Hulling recovery varied significantly among fourteen aromatic rice cultivars during 2013 and pooled over two years (Table 4.1.15; Fig. 4.1.4). The highest brown rice yield was obtained with NC 324 (79.6 and 77.8%) in both the years, while Tulaipanji (75.3%) and Sitabhog (75.4%) recorded the lowest hulling recovery during 2012 and 2013, respectively.

4.1.6.1.2 Milling

There was significant variation in milling recovery among fourteen scented rice landraces during both the years of experimentation (Table 4.1.15; Fig. 4.1.4). Tulsimukul (V_{14}) recorded the highest milling recovery (68.2 and 69.6 %) during 2012 and pooled over two years, while Tulaipanji (V_{13}) had the lowest milled rice yield (67.0 and 66.5%) during 2013 and pooled values in the investigation. Mean cultivar milling recovery was 67.1% in 2012 and 69.8% in 2013, and perusal of data indicated greater milling yield of all rice cultivars in second year than first year of the study.

4.1.6.1.3 Head rice

The variation in head rice recovery among aromatic rice cultivars was noted between 58.91 (Tulaipanji) and 64.51% (NC 324) during 2012; while between 59.46 (Kalonunia) and 62.88% (Kalojira) during 2013 (Table 4.1.15; Fig. 4.1.4). Banerjee (2011) reported similar HRR values (59.7–64.4%) for seven indigenous scented rice varieties of West Bengal.

The correlation study revealed that head rice recovery exhibited a positive relationship ($p<0.01$) with the hulling yield of aromatic rice, but negative effect ($r = -0.416^{**}$) with kernel length in the investigation (Table 4.1.22)

4.1.6.2 Physical properties of grain

4.1.6.2.1 Kernel length

The genetic variability toward the length of kernel was observed in the study (Table 4.1.18; Fig. 4.1.4; Plate 4.1.16). NC 365 (5.31 and 5.23 mm) and Radhunipagal (3.69 and 3.65 mm) recorded the highest and lowest kernel length, respectively during both the years of experiment.

Table 4.1.15

Effect of cultivars on milling quality at different growth stages of aromatic rice during *kharif* season

Cultivar	Milling quality								
	Hulling (%)			Milling (%)			Head rice recovery (%)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	77.31	76.07	76.69	67.57	70.17	68.87	63.19	62.13	62.66
V_2	77.96	76.60	77.28	67.93	69.87	68.90	62.86	61.10	61.98
V_3	76.94	77.03	76.99	67.57	69.74	68.65	61.93	62.88	62.41
V_4	75.72	76.00	75.86	66.33	68.22	67.28	60.14	59.46	59.80
V_5	76.48	77.00	76.74	65.80	68.29	67.04	62.26	60.25	61.26
V_6	77.90	76.63	77.27	66.53	70.66	68.60	62.84	62.23	62.54
V_7	78.17	77.20	77.68	67.87	70.55	69.21	62.23	62.61	62.42
V_8	79.59	77.83	78.71	66.03	71.89	68.96	64.51	61.22	62.87
V_9	76.49	76.53	76.51	67.97	69.73	68.85	61.11	60.90	61.01
V_{10}	76.73	75.87	76.30	67.13	70.05	68.59	61.12	62.14	61.63
V_{11}	77.10	75.77	76.44	67.83	70.52	69.18	63.23	62.51	62.87
V_{12}	79.04	75.43	77.24	66.10	70.24	68.17	63.35	60.79	62.07
V_{13}	75.33	75.77	75.55	66.03	67.04	66.54	58.91	59.57	59.24
V_{14}	78.40	76.57	77.48	68.20	70.92	69.56	64.21	62.69	63.45
Mean	77.37	76.45	76.91	67.06	69.85	68.46	62.28	61.46	61.87
S.Em(±)	0.68	0.58	0.45	0.53	0.63	0.41	0.72	0.35	0.40
C.D. at 5%	1.97	NS	1.27	1.54	1.82	1.16	2.08	1.00	1.13

NS = Not significant

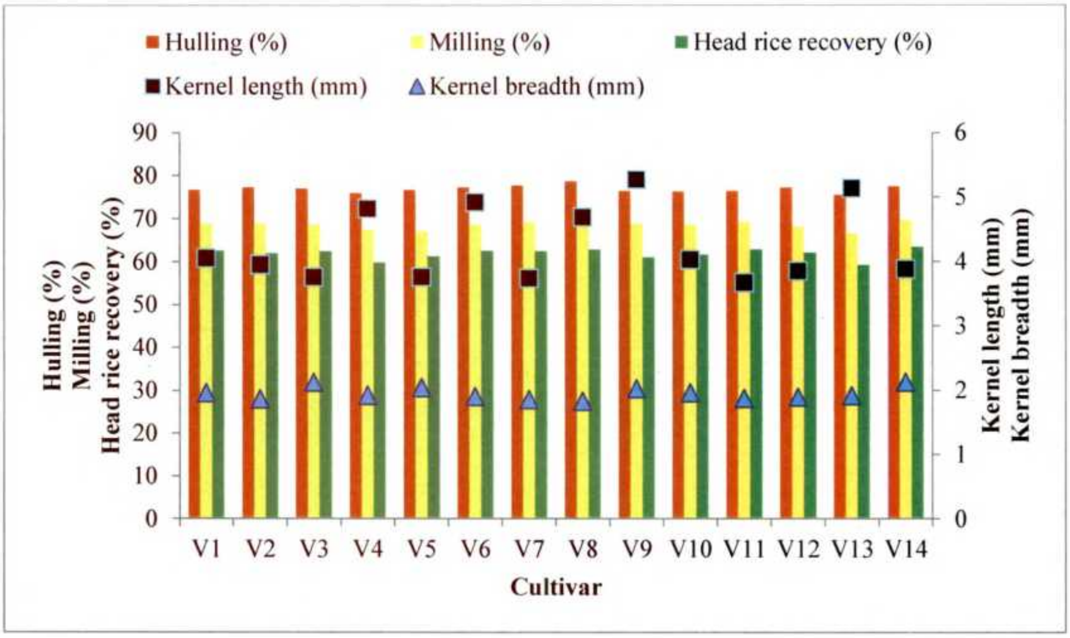


Fig. 4.1.4: Effect of cultivars on milling quality, kernel length (mm) and kernel breadth (mm) of grains of aromatic rice (Pooled of two years)

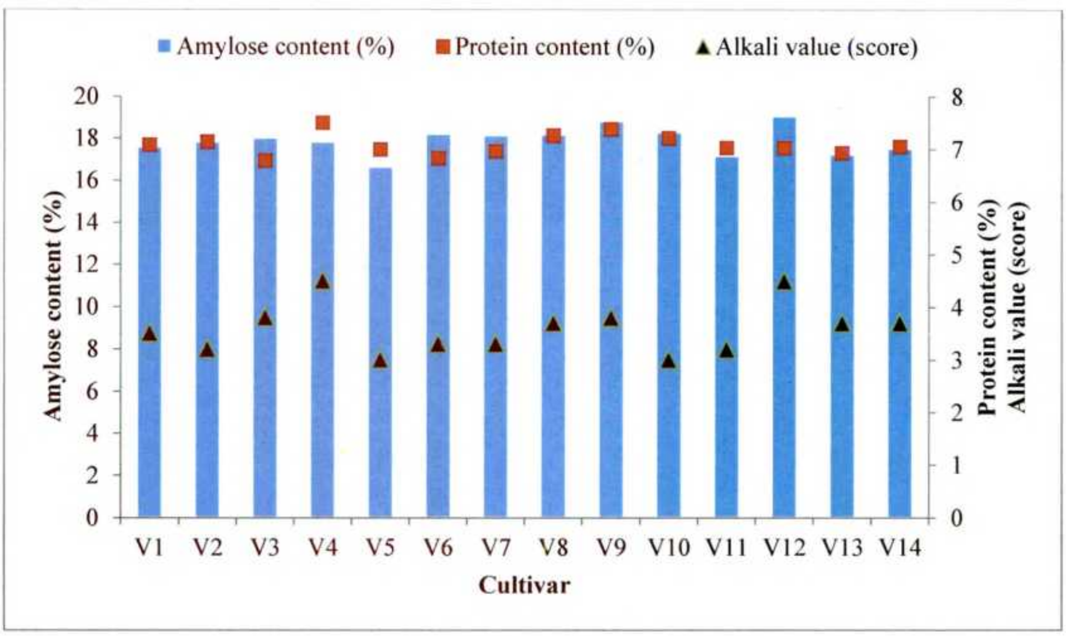


Fig. 4.1.5: Effect of cultivars on amylose content (%), protein content (%) and alkali value of grains of aromatic rice (Pooled of two years)

Table 4.1.16

Correlations between GDD at different growth stages and yield associated parameters of aromatic rice

	GDD_{S-E}	GDD_{E-4L}	GDD_{4L-AT}	GDD_{AT-PI}	$GDD_{PI-50\%F}$	$GDD_{50\%F-Mi}$	GDD_{Mi-D}	GDD_{D-M}
Plant height	0.002	-0.051	0.271*	-0.380**	-0.252*	-0.141	0.404**	-0.188
Panicle length	0.022	0.062	0.084	-0.267*	-0.245*	0.017	0.144	-0.083
No. of panicles m^{-2}	-0.336**	-0.091	-0.207	-0.292**	0.016	0.392**	-0.0342	0.046
Filled grains	-0.065	-0.068	0.046	-0.280**	-0.081	-0.069	0.228*	-0.076
1000 grain weight	0.204	0.189	0.345**	0.378**	-0.032	-0.158	-0.111	-0.015
Grain yield	-0.023	-0.050	0.102	0.113	0.029	0.000	-0.060	-0.051
Straw yield	-0.273*	0.248*	0.099	0.015	0.203	-0.070	-0.139	0.218*

GDD_{S-E} = GDD (sowing to emergence); GDD_{E-4L} = GDD (emergence to4th leaf emergence); GDD_{4L-AT} = GDD (4th leaf emergence to active tillering);
GDD_{AT-PI} = GDD (active tillering to panicle initiation); GDD_{PI-F} = GDD (panicle initiation to 50% flowering); GDD_{F-M} = GDD (50% flowering to milk);
GDD_{M-D} = GDD (milk to dough); GDD_{D-M} = GDD (dough to maturity)
Sample size: n = 84; r value ** at 5% and r value * 1% level of significance, respectively

Table 4.1.17

Correlations between HTU at different growth stages and yield associated parameters of aromatic rice

	HTU_{S-E}	HTU_{E-4L}	HTU_{4L-AT}	HTU_{AT-PI}	$HTU_{PI-50\%F}$	$HTU_{50\%F-Mi}$	HTU_{Mi-D}	HTU_{D-M}
Plant height	0.320**	-0.134	0.346**	-0.361**	-0.239*	-0.407**	0.229*	0.132
Panicle length	0.329**	-0.114	0.329**	-0.300**	-0.253*	-0.353**	0.168	0.112
No. of panicles m^{-2}	-0.111	-0.150	-0.107	-0.230*	0.003	0.124	-0.018	-0.135
Filled grains	0.081	-0.089	0.095	-0.244*	-0.156	-0.037	0.142	-0.046
1000 grain weight	-0.004	0.199	-0.008	0.352**	0.106	0.017	-0.081	0.129
Grain yield	0.113	-0.134	0.147	0.012	-0.102	0.043	-0.058	0.111
Straw yield	0.051	0.345	0.129	0.365	0.036	0.396	0.664	0.959

HTUS- E = HTU (sowing to emergence); HTUE- 4L = HTU (emergence to4th leaf emergence); HTU4L- AT = HTU (4th leaf emergence to active tillering);
HTUAT- PI = HTU (active tillering to panicle initiation); HTUPI- F = HTU (panicle initiation to 50% flowering); HTUF- M = HTU (50% flowering to milk);
HTUM- D = HTU (milk to dough); HTUD- M = HTU (dough to maturity)
Sample size: n = 84; r value ** is at 5% and r value * is at 1% level of significance

4.1.6.2.2 Kernel breadth

Kernel breadth, being a genetical character, was found to vary between 1.83 (NC 324) and 2.11 mm (Kalojira and Tulsimukul) during first year, while between 1.82 (Lal badshabhog) and 2.13 mm (Kalojira and Tulsimukul) during second year in the investigation (Table 4.1.18; Fig. 4.1.4; Plate 4.1.16).

4.1.6.2.3 L / B ratio

The maximum and minimum L / B ratio of the kernel were noted with Tulaipanji (2.65 and 2.72) and Kalojira (1.78 and 1.77), respectively during both 2012 and 2013 (Table 4.1.18).

4.1.6.2.4 Kernel type

Based on kernel length and L / B ratio, nine aromatic rice cultivars (Badshabhog , Gobindabhog, Kalojira, Kaminibhog, Lal Badshabhog, Radhatilak, Radhunipagal, Sitabhog and Tulsimukul) were classified in short bold (SB) type; while five genotypes (Kalonunia, Kataribhog, NC 324, NC 365, Tulaipanji) belonged to medium slender (MS) category (Table 4.1.18).

4.1.6.2.5 Chalkiness

Chalkiness or abdominal white was absent in kernels of all fourteen rice cultivars during both 2012 and 2013 (Table 4.1.18).

4.1.6.2.6 Kernel colour

The colour of rice kernel of all fourteen rice varieties tested in the experiment was white (Table 4.18).

4.1.6.3 Cooking quality

4.1.6.3.1 Amylose content

Among fourteen aromatic rice landraces, Sitabhog (19.85%) and Kataribhog (18.83%) recorded the highest amylose content during 2012 and 2013 respectively; while Tulaipanji (16.02%) and Kaminibhog (16.76%) had the lowest amylose content during first year and second year, respectively (Table 4.1.19; Fig. 4.1.5). The range of variation in amylose content noted in the study was in conformity with the findings of Sarkar (1994); Sadhukhan and Chattopadhayay (2001) and Banerjee (2011).

Table 4.1.18

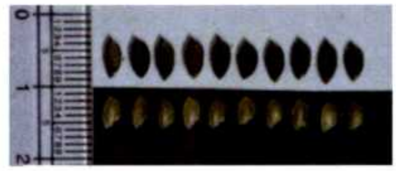
Effect of cultivars on physical properties of grains of aromatic rice during *kharif* season

Cultivar	Physical properties of grain														
	Kernel length (mm)			Kernel breadth (mm)			L / B ratio			Kernel type		Chalkiness		Kernel colour	
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	2012	2013	2012	2013
V_1	4.03	4.07	4.05	2.04	1.87	1.96	1.98	2.18	2.08	**SB**	**SB**	Absent	Absent	White	White
V_2	3.97	3.93	3.95	1.85	1.87	1.86	2.15	2.11	2.13	SB	SB	Absent	Absent	White	White
V_3	3.76	3.77	3.76	2.11	2.13	2.12	1.78	1.77	1.77	SB	SB	Absent	Absent	White	White
V_4	4.79	4.85	4.82	1.90	1.93	1.92	2.52	2.51	2.52	MS	MS	Absent	Absent	White	White
V_5	3.82	3.70	3.76	2.05	2.03	2.04	1.86	1.82	1.84	SB	SB	Absent	Absent	White	White
V_6	4.84	5.00	4.92	1.89	1.92	1.90	2.57	2.61	2.59	MS	MS	Absent	Absent	White	White
V_7	3.77	3.72	3.74	1.88	1.82	1.85	2.01	2.05	2.03	SB	SB	Absent	Absent	White	White
V_8	4.65	4.73	4.69	1.83	1.83	1.83	2.54	2.58	2.56	MS	MS	Absent	Absent	White	White
V_9	5.31	5.23	5.27	2.01	2.03	2.02	2.64	2.57	2.61	MS	MS	Absent	Absent	White	White
V_{10}	4.02	4.03	4.03	1.95	1.97	1.96	2.06	2.05	2.06	SB	SB	Absent	Absent	White	White
V_{11}	3.69	3.65	3.67	1.88	1.87	1.87	1.96	1.96	1.96	SB	SB	Absent	Absent	White	White
V_{12}	3.82	3.87	3.85	1.90	1.88	1.89	2.01	2.05	2.03	SB	SB	Absent	Absent	White	White
V_{13}	5.07	5.20	5.13	1.91	1.92	1.91	2.65	2.72	2.68	MS	MS	Absent	Absent	White	White
V_{14}	3.92	3.85	3.88	2.11	2.13	2.12	1.86	1.81	1.84	SB	SB	Absent	Absent	White	White
Mean	4.25	4.26	4.25	1.95	1.94	1.95	2.19	2.20	2.19						
S.Em(±)	0.056	0.024	0.031	0.034	0.020	0.020	0.048	0.030	0.028						
C.D. at 5%	0.164	0.069	0.087	0.099	0.060	0.056	0.140	0.086	0.080						

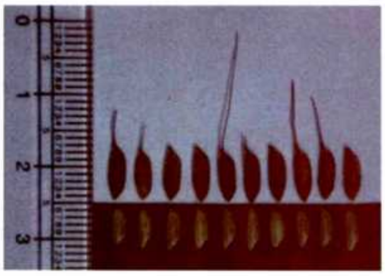
SB = Short bold, MS = Medium slender

Badshabhog

Gobindabhog



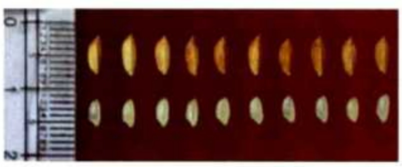
Kalojira



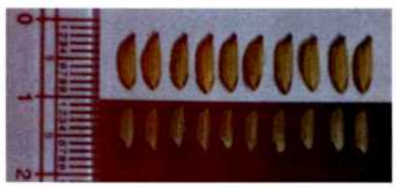
Kalonunia

Kaminibhog

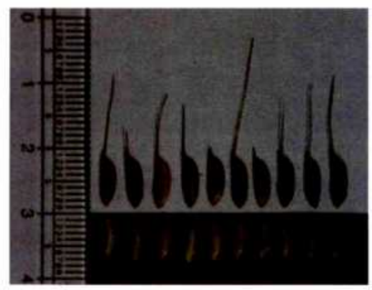
Kataribhog



LalBadshabhog

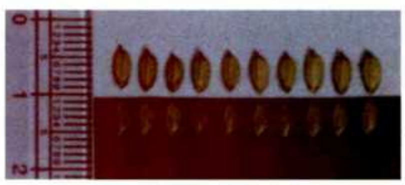


NC 324



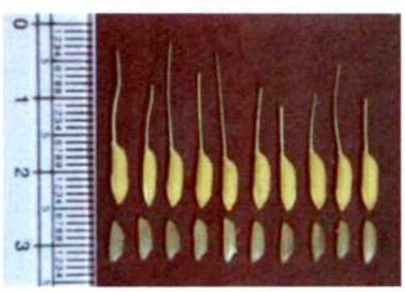
NC 365

Radhatilak



Radhunipagal

Sitabhog



Tulaipanji

Tulsimukul

Plate 4.1.16: Grains and kernels of aromatic rice cultivars of West Bengal, India

Based on pooled data, all fourteen rice cultivars might be categorized in low (9–20%) amylose group, but most of the values were very close to the lower range of intermediate (20–25%) category.

4.1.6.3.2 Protein content

There was significant variation in protein content among fourteen fragnant rice cultivars during 2012 only (Table 4.1.19; Fig. 4.1.5). Kalonunia (V_4) recorded the highest protein content (7.38 and 7.60%) during both the years of investigation; while Lalbadshabhog (6.67%), and, Kalojira (6.84%) and Kataribhog (6.84%) had the lowest protein content during first and second year of experiment, respectively. Dikshit *et al.* (1992) reported similar range of variation in protein content of scented rice germplasm of Orissa, India.

4.1.6.3.4 Alkali value / Gelatinization temperature (GT)

Two aromatic rice genotypes (Kalonunia and Sitabhog) had the highest alkali spreading value (4.7 and 4.3) and two varieties (Kaminibhog and Radhatilak) recorded the lowest alkali value (3.0 and 3.0) during both the years of investigation (Table 4.1.19; Fig. 4.1.5; Plate 4.1.15). Sadhukhan and Chattopadhayay (2001) and Banerjee (2011), reported similar range of alkali spreading values for scented rice landraces of West Bengal.

A careful study on pooled alkali spreading scores revealed that two cultivars, (Kaminibhog and Radhatilak) had high-intermediate gelatinization temperature; while ten genotypes (Badshabhog, Gobindabhog, Kalojira, Kaminibhog, Kataribhog, Lalbadshabhog, NC 324, NC 365, Radhatilak, Radhunipagal, Tulaipanji and Tulsimukul) might be categorized to high-intermediate to intermediate gelatinization temperature group; and rest two genotypes (Kalonunia and Sitabhog) belong to intermediate GT category.

The positive correlation (r = 0.287**) between amylose content and alkali value indicated that low amylose rice in the study generally had high-intermediate gelatinization temperature (Table 4.1.19 and Table 4.1.22), which was similar to the observation of Dela Cruz and Khush (2000).

Table 4.1.19

Effect of cultivars on cooking and nutritional quality of grains of aromatic rice during *kharif* season

Cultivar	Cooking and nutritional quality of grain								
	Amylose content (%)			Protein content (%)			Alkali value (score)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	17.25	17.79	17.52	6.83	7.31	7.07	3.7	3.3	3.5
V_2	17.48	18.05	17.77	7.05	7.21	7.13	3.3	3.0	3.2
V_3	18.51	17.43	17.97	6.70	6.84	6.77	4.0	3.7	3.8
V_4	18.34	17.23	17.78	7.38	7.60	7.49	4.7	4.3	4.5
V_5	16.43	16.76	16.60	7.05	6.94	6.99	3.0	3.0	3.0
V_6	17.52	18.83	18.17	6.81	6.84	6.83	3.3	3.3	3.3
V_7	18.86	17.34	18.10	6.67	7.24	6.96	3.3	3.3	3.3
V_8	18.45	17.80	18.13	7.18	7.34	7.26	3.7	3.7	3.7
V_9	19.64	17.91	18.78	7.33	7.44	7.38	3.7	4.0	3.8
V_{10}	18.82	17.66	18.24	6.98	7.44	7.21	3.0	3.0	3.0
V_{11}	17.30	16.95	17.13	7.11	6.94	7.03	3.0	3.3	3.2
V_{12}	19.85	18.21	19.03	6.71	7.34	7.03	4.7	4.3	4.5
V_{13}	16.32	18.08	17.20	6.94	6.91	6.93	3.7	3.7	3.7
V_{14}	18.18	16.76	17.47	7.13	6.97	7.05	4.0	3.3	3.7
Mean	18.07	17.63	17.85	6.99	7.17	7.08	3.6	3.5	3.6
S.Em(±)	0.647	0.652	0.459	0.11	0.31	0.17	0.33	0.29	0.22
C.D. at 5%	1.880	1.895	1.303	0.33	NS	NS	0.97	0.85	0.63

NS = Not significant

4.1.6.4 Processing quality

4.1.6.4.1 Kernel length after cooking

Among fourteen scented rice cultivars, Kalojira (V_3) and Tulaipanji (V_{13}) recorded the minimum (6.52 and 6.38 mm) and maximum (8.40 and 8.38 mm) cooked kernel length, respectively during both the years of investigation (Table 4.1.20).

There was a positive relationship (r = 0.895**) between raw kernel length and cooked kernel length in the study (Table 4.1.22).

4.1.6.4.2 Elongation ratio

The range of variation in kernel elongation ratio was observed between 1.56 (NC 365) and 1.93 (Sitabhog) during 2012, as well as between 1.57 (NC 365) and 1.90 (Lal Badshabhog and Sitabhog) during 2013 (Table 4.1.20). Based on pooled data, it could be concluded that six cultivars (Badshabhog, Kaminibhog, Lal Badshabhog, Radhatilak, Radhunipagal and Sitabhog) had kernel elongation of >1.80 times after cooking over original length in the study.

4.1.6.4.3 Volume expansion ratio

The tested scented rice cultivars varied significantly among themselves with regard to the volume expansion ratio of kernels after cooking during both the years and pooled values in the experiment (Table 4.1.20). Based on pooled data, the cooked kernels of short-grained Gobindabhog (V_2) and Radhunipagal (V_{11}) expanded most (2.74 times) over their respective original volumes; while two medium-slender varieties, namely Kataribhog (V_9) and Tulaipanji (V_{12}) showed least expansion in volume (2.46 / 2.47) after cooking. However, Pandey *et al.* (2013) reported much greater volume expansion ratio (7.71) for four scented rice landraces of West Bengal.

4.1.6.4.4 Aroma

Among fourteen scented rice cultivars, Radhunipagal (V_{11}) scored the highest intensity of aroma (2.3 and 2.6) during both the years of investigation; which was similar to Gobindabhog (V_2) in 2012 and it was closely followed by Kalonunia (V_4) in 2013 (Table 4.1.20). De *et al.* (2002) reported similar intensity of aroma for

Table 4.1.20

Effect of cultivars on processing quality of grains of aromatic rice during *kharif* season

Cultivar	Processing quality of grains											
	Kernel length after cooking (mm)			Elongation ratio			Volume expansion ratio			Aroma (score)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
V_1	7.35	7.28	7.32	1.82	1.79	1.81	2.69	2.58	2.63	2.10	2.40	2.25
V_2	7.00	7.07	7.03	1.77	1.80	1.78	2.81	2.66	2.74	2.30	2.40	2.35
V_3	6.52	6.38	6.45	1.73	1.69	1.71	2.54	2.58	2.56	2.10	2.40	2.25
V_4	7.85	7.95	7.90	1.64	1.64	1.64	2.50	2.51	2.51	2.20	2.50	2.35
V_5	6.98	7.00	6.99	1.83	1.89	1.86	2.59	2.48	2.53	1.87	2.10	1.98
V_6	7.93	8.10	8.02	1.64	1.62	1.63	2.49	2.42	2.46	2.10	1.87	1.98
V_7	7.02	7.07	7.04	1.86	1.90	1.88	2.74	2.64	2.69	2.00	2.20	2.10
V_8	7.53	7.52	7.53	1.62	1.59	1.60	2.57	2.49	2.53	2.10	2.30	2.20
V_9	8.27	8.20	8.23	1.56	1.57	1.56	2.69	2.55	2.62	2.20	2.40	2.30
V_{10}	7.37	7.38	7.38	1.83	1.83	1.83	2.79	2.62	2.71	2.20	2.40	2.30
V_{11}	6.83	6.92	6.88	1.85	1.89	1.87	2.77	2.71	2.74	2.30	2.60	2.45
V_{12}	7.38	7.35	7.37	1.93	1.90	1.92	2.79	2.62	2.71	1.73	2.00	1.87
V_{13}	8.40	8.37	8.38	1.66	1.61	1.63	2.55	2.40	2.47	1.73	1.97	1.85
V_{14}	6.70	6.83	6.77	1.71	1.77	1.74	2.67	2.56	2.62	2.20	2.20	2.20
Mean	7.37	7.39	7.38	1.75	1.75	1.75	2.66	2.56	2.61	2.08	2.27	2.17
S.Em(±)	0.101	0.061	0.059	0.035	0.018	0.019	0.04	0.03	0.03	0.12	0.11	0.08
C.D. at 5%	0.293	0.177	0.167	0.101	0.051	0.055	0.12	0.10	0.08	0.34	0.33	0.23

Table 4.1.21

Correlations among yield associated parameters of aromatic rice

Parameter	Plant height	Panicle length	No. of panicles m^{-2}	Filled grains	1000 grain weight	Grain yield	Straw yield
Plant height	1						
Panicle length	0.454^{**}	1					
No. of panicles m^{-2}	0.013	0.330^{**}	1				
Filled grains	0.372^{**}	0.073	0.099	1			
1000 grain weight	0.112	0.273^{*}	-0.163	-0.410^{**}	1		
Grain yield	0.152	0.365^{**}	0.177	0.397^{**}	0.326^{**}	1	
Straw yield	0.201	0.376^{**}	0.089	0.150	0.150	0.378^{**}	1

Table 4.1.22

Correlations among grain quality parameters of aromatic rice

Parameter	Hulling %	Milling %	Head rice recovery	Kernel length	Kernel breadth	Amylose %	Protein %	Karnel length after elongation	Elongation ratio	Volume expansion ratio	Alkali spreading value	Aroma
Hulling %	1											
Milling %	-0.183	1										
Head rice recovery %	0.547**	-0.037	1									
Kernel length	-0.154	-0.144	-0.416**	1								
Kernel breadth	-0.068	-0.014	0.054	-0.135	1							
Amylose %	0.175	-0.109	0.087	0.123	-0.063	1						
Protein %	-0.262*	0.073	-0.066	0.177	-0.138	0.030	1					
Karnel length after elongation	-0.220*	-0.177	-0.465**	0.895**	-0.249*	0.135	0.154	1				
Elongation ratio	0.038	0.073	0.246*	-0.850**	-0.045	-0.065	-0.150	-0.529**	1			
Volume expansion ratio	0.191	-0.111	0.334**	-0.474**	-0.095	0.200	0.016	-0.350**	0.498**	1		
Alkali spreading value	0.057	-0.111	-0.112	0.186	-0.007	0.287**	0.077	0.192	-0.128	-0.072	1	
Aroma	-0.141	0.408**	0.033	-0.080	0.031	-0.038	0.271*	-0.215*	-0.101	0.073	-0.155	1

Radhunipagal, but Sadhukhan and Chattopadhayay (2001) scored somewhat better aroma in Badshabhog and Radhunipagal than their respective values in the investigation.

The intensity of aroma in grains of all fourteen varieties was slightly greater or similar in second year than first year, excluding Kataribhog (V_6) in the study. Based on pooled values, two cultivars (Sitabhog and Tulaipanji) had near-medium aroma (score 1.90), two varieties possessed medium flavour (score 2.00) and rest ten genotypes (Badshabhog, Gobindabhog, Kalojira, Kalonunia, Lal Badshabhog, NC 324, NC 365, Radhatilak, Radhunipagal and Tulsimukul) had slightly-better medium or medium-strong aroma (score $\geq$2.00) in milled rice during post-harvest period in New Alluvial Zone of West Bengal, India.

4.2 Experiment No. 2

Standardization of planting time and nutrient management system for better yield and quality of Radhatilak rice during *kharif* season

4.2.1 Plant characteristics

The characteristics of plant and grain of Radhatilak rice were determined following the distinctness, uniformity and stability (DUS) guidelines of Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA), Government of India (Table 4.2.1).

Radhatilak paddy, being a tall-*indica* type, produced long-statured plant (130.0–140.0 cm height at maturity, average 138.0 cm) during *kharif* season at Kalyani, West Bengal. The colour of the coleoptile of germinating seed of Radhatilak rice was greenish-white or green (code 2) (Plate 4.2.2 and 4.2.3). The anthocyanin colouration was either absent or rarely present on nodes and internodes of the stem (Plate 4.2.4).

The leaves of Radhatilak paddy were long (60–75 mm, mean 69.5 mm) and narrow (8–10 mm, mean 9.7 mm) in shape, and green in colour. There was no anthocyanin colouration on inner surface of leaf sheath (Plate 4.2.4). The shape of ligule was split and sickle-shaped auricles were present at both side of the ligule. The attitude of blade of flag leaf was semi-erect (code 3) at early observation and horizontal (code 5) at late observation stage.

Radhatilak paddy showed late heading (code 7) i.e. >50% plants exerted panicles about 119 days after sowing. The colour of lemma and palea was green at anthesis, which turned to golden-yellow with reddish-purple spot at the tip during maturity (Plate 4.21, 4.2.7, 4.2.8, 4.2.9 and 4.2.10). The flower was bi-sexual comprising six yellow coloured anthers and, white feathery stigma (Plate 4.2.5).

The length of main axis of panicle was medium (23.0–25.0 cm, mean 23.2 cm) and the curvature of main axis was found drooping in the study. Radhatilak paddy usually had few (average 10.67) well-exerted (code 7) panicles plant^{-1}. The folk variety, Radhatilak produced grains of very short (code 1) in length and narrow (code 2) in width. The weight of 1000 fully-developed grains was very low (average 10.95 g) (Plate 4.2.1, 4.2.7 and 4.2.9).

Table 4.2.1

Plant characteristics of Radhatilak rice following DUS guidelines

Sl. No.	Characteristics	Code	Remarks measured values etc.
1	Coleoptile: colour	2	Green
2	Basal leaf sheath colour	1	Green
3	Leaf : Intensityof green colour	5	Medium
4	Leaf : anthocyanin colouration	1	Absent
5	Leaf : distribution of anthocyanin colouration	—	—
6	Leaf sheath : anthocyanin colouratin	1	Absent (inner side of leaf sheath)
7	Leaf sheath: intensity of anthocyanin colouration	—	—
8	Leaf: pubescence of blade surface	5	Medium
9	Leaf : Auricles	9	Present
10	Leaf : anthocynin colorations of auricles	1	Colourless
11	Leaf : collar	9	Present
12	Leaf : anthocyanin colouration of collar	1	Absent
13	Leaf : ligule	9	Present
14	Leaf: shape of ligules	3	Split
15	Leaf: colour of ligule	1	1, White
16	Leaf : length of blade	7	Long (69.5 cm)
17	Leaf : width of blade	3	Narrow (9.7 mm)
18	Culm : attitude (for floting rice only)	—	—
19	Culm : attitude	3	Semi-erect
20	Time of heading (50% of plants with panicles	7	Late (119 days)
21	Flag leaf attitude of blade (early observation)	3	Semi-erect
22	Spikelet : density of pubescence of lemma	3	Weak
23	Male sterility	1	Absent
24	Lemma: anthocyanin colouration of keel	1	Absent
25	Lemma: anthocynin of area below apex	1	Absent
26	Lemma: anthocynin colouration of apex	5	Medium
27	Spikelet : colour of stigma	1	White
28	Stem: thickness	5	Medium (0.55 cm)
29	Stem: length (excluding panicle)	7	Long (138.0 cm)
30	Stem: anthocyanin coloration of nodes	1	Absent(Present usually at lower nodes)

31	Stem : intensity of anthocyanin colouration of nodes	—	—
32	Stem : anthocyanin colouration of internodes	1	Absent
33	Panicle: length of main axis	5	Medium (23.2 cm)
34	Flag leaf: attitude of blade (late observation)	5	Horizontal
35	Panicle: curvature of main axis	7	Drooping
36	Panicle: number per plant	3	Few (10.67)
37	Spikelet: colour of tip of lemma	4	Red
38	Lemma & Palea : Colour	8	Purple spot on tip
39	Panicle: awns	1	Absent
40	Panicle: colour of awns (late observation)	—	—
41	Panicle: length of largest awn	—	—
42	Panicle: distribution of awns	—	—
43	Panicle : presence of secondary branching	9	Present
44	Panicle : secondary branches	2	Strong
45	Panicle : attitude of branches	3	Erect to semi-erect
46	Panicle: exertion	7	Well exerted
47	Time of Maturity	7	Late (149 days)
48	Leaf : senescence	5	Medium
49	Sterile lemma: colour	3	Red
50	Grains: weight of 1000 fully developed grains	1	Very low (10.95 g)
51	Grain : length	1	Very short
52	Grain : width	2	Narrow
53	Grain : phenol reaction of lemma	—	—
54	Decorticated grain: length	1	Very short (4.03 mm)
55	Decorticated grain: width	1	Very narrow (1.96 mm)
56	Decorticated grain shape	2	Short bold
57	Decorticated grain: colour	1	White
58	Endosperm: presence of amylose	9	Present
59	Endosperm: content of amylose	3	Low (18.67%)
60	Varieties with endosperm of amylose absent only-polishedgrain : exertion of white core	—	—
61	Gelatinization temperature through alkali spreading value	3	Medium
62	Decorticated grain : aroma	9	Present

Plate 4.2.1: Seed

Plate 4.2.2: Coleoptile and radicle

Plate 4.2.3: Seedling

Plate 4.2.4: Node and internode

Plate 4.2.5: Flower

Plate 4.2.6: Flowering stage

Plate 4.2.7: Change of Grain colour

Plate 4.2.8: Maturity stage

Plate 4.2.9: Compactness of panicle

Plate 4.2.10: Grains

Plate 4.2.11: Kernels

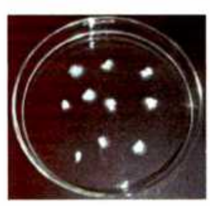


Plate 4.2.12: Alkali digestion test of kernels

Plant and grain characteristics of Radhatilak rice

The length of decorated grain or milled rice kernel was very short (mean 4.03 mm) and the width was very narrow (mean 1.96 mm). Thus, the kernel of Radhatilak rice belonged to short-bold type category. The white-coloured kernels had low amylose (average 18.67%), medium (code 3) gelatinization temperature and pleasant aroma.

4.2.2 Phenology and growth environment

4.2.2.1 Phenological development and duration

4.2.2.1.1 Effect of planting time

Radhatilak rice took 155.2, 144.7 and 138.1 days to maturity, when planted at three different times, *i.e.* 2^{nd} week of July (D_1), 4^{th} week of July (D_2) and 2^{nd} week of August (D_3), respectively; which indicated reduction in life duration by 10.5 days for 2^{nd} planting and 17.1 days for 3^{rd} planting time compared to the earliest one (1^{st} week of July) in the study (Table 4.2.3; Fig. 4.2.1; Plate 4.2.13, 4.2.14, 4.2.15, 4.2,17, 4.2.6 4.2.8 and 4.2.18). It was mainly due to the differences in length of vegetative stage owing to variability in planting times, as time required for both reproductive and ripening phases were more or less same among three planting periods adopted in the investigation.

The pooled data averaged over three planting times revealed that mean days required for Radhatilak rice from sowing to emergence, 4^{th} leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 3.6, 20.9, 48.1., 83.8, 115.0, 124.6, 134.9 and 144.5 days, respectively; which could be summarized as 83.8 days for vegetative, 31.2 days for reproductive and 29.5 days for ripening phase of the crop in the study. Mahata (2014) reported near-similar vegetative (76.8 day), reproductive (34.2 day) and ripening stage (30.7 day) for Gobindabhog paddy during kharif season at Kalyani, West Bengal.

The early (2^{nd} week of July), mid (4^{th} week of July) and late (2^{nd} week of August) planted Radhatilak paddy had the flowering period during 3^{rd} week of October, 4^{th} week of October and 1^{st} week of November, respectively during both 2012 and 2013. They were also ready for harvesting during 3^{rd} week of November, 4^{th} week of November and 1^{st} week of December, respectively at Kalyani, West Bengal.

Table 4.2.2

Mean meteorological parameters at different phenophases of Radhatilak rice during *kharif* season

Treatment	Vegetative stage											
	Sowing to Emergence						Emergence to 4th leaf emergence					
	D_1		D_2		D_3		D_1		D_2		D_3	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Average maximum temperature (°C)	34.33	33.40	32.02	34.51	30.83	33.70	33.05	33.59	32.65	34.12	31.88	32.79
Average minimum temperature (°C)	27.58	26.10	26.49	26.59	25.33	26.67	26.83	26.53	26.54	26.66	26.41	26.29
Mean daily temperature (°C)	30.95	29.75	29.26	30.55	28.08	30.18	29.94	30.06	29.60	30.39	29.14	29.54
Average bright sunshine hour day^{-1}	3.05	5.35	3.27	6.15	4.60	4.97	3.69	3.61	3.81	6.04	4.05	4.42
Total rainfall (mm)	19.63	1.67	5.08	2.22	27.40	2.13	6.39	6.73	8.13	3.33	8.23	7.76

Mean meteorological parameters at different phenophases of Radhatilak rice during *kharif* season

Treatment	Vegetative stage											
	4th leaf emergence to Active tillering						Active tillering to Panicle initiation					
	D_1		D_2		D_3		D_1		D_2		D_3	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Average maximum temperature (°C)	32.28	33.48	31.90	32.48	32.52	32.55	32.08	32.91	32.24	33.51	33.07	33.99
Average minimum temperature (°C)	26.50	26.48	26.30	26.08	26.50	25.92	26.20	25.95	26.25	25.94	26.00	26.00
Mean daily temperature (°C)	29.39	29.98	29.10	29.28	29.51	29.23	29.14	29.43	29.24	29.73	29.53	29.99
Average bright sunshine hour day^{-1}	3.80	4.83	4.26	3.99	5.47	4.03	5.07	4.34	5.26	4.52	5.45	5.48
Total rainfall (mm)	8.07	5.90	9.49	7.69	6.38	12.01	9.23	10.21	7.99	10.57	8.93	5.27

Table 4.2.2 (contd.)

Mean meteorological parameters at different phenophases of Radhatilak rice during *kharif* season

Treatment	Reproductive stage						Ripening stage					
	Panicle initiation to 50% flowering						50% flowering to Milk					
	D_1		D_2		D_3		D_1		D_2		D_3	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Average maximum temperature (°C)	34.02	33.27	34.19	32.48	32.76	31.41	33.24	31.57	34.19	30.60	32.76	30.81
Average minimum temperature (°C)	25.41	25.54	24.28	25.03	21.84	23.60	20.14	24.29	19.39	20.64	18.77	18.91
Mean daily temperature (°C)	29.71	29.41	29.24	28.75	27.30	27.52	26.69	27.93	25.75	25.62	24.01	24.86
Average bright sunshine hour day^{-1}	6.15	5.23	6.96	5.14	7.07	3.86	9.29	5.54	8.14	3.20	4.99	7.46
Total rainfall (mm)	3.66	5.67	2.48	7.38	0.92	9.97	0.00	9.88	0.00	9.48	5.11	0.00

Mean meteorological parameters at different phenophases of Radhatilak rice during *kharif* season

Treatment	Ripening stage											
	Milk to Dough						Dough to Maturity					
	D_1		D_2		D_3		D_1		D_2		D_3	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Average maximum temperature (°C)	30.23	31.23	29.06	30.16	30.11	29.53	29.83	29.53	30.24	29.68	28.66	29.37
Average minimum temperature (°C)	20.62	20.33	19.13	18.01	16.84	14.46	16.88	17.17	17.42	14.62	11.43	15.74
Mean daily temperature (°C)	25.42	25.78	24.09	24.08	23.48	21.99	23.35	23.35	23.83	22.15	20.04	22.55
Average bright sunshine hour day^{-1}	4.89	3.86	4.58	7.58	7.47	9.27	7.65	7.59	7.53	8.98	7.29	7.22
Total rainfall (mm)	0.34	7.81	4.28	0.00	0.00	0.00	4.90	0.00	0.00	0.00	0.00	0.00

Table 4.2.3

Effect of planting time and nutrient management on phenological development of Radhatilak rice during *kharif* season

Treatment	Vegetative stage											
	Sowing to Emergence (day)			Emergence to 4th leaf emergence (day)			4th leaf emergence to Active tillering (day)			Active tillering to Panicle initiation (day)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time												
D_1	3.83	3.92	3.88	17.83	17.92	17.88	29.67	29.42	29.54	42.17	41.33	41.75
D_2	3.33	3.83	3.58	17.75	17.08	17.42	27.67	27.00	27.33	34.08	34.67	34.38
D_3	3.00	3.00	3.00	16.83	17.00	16.92	26.75	25.17	25.96	31.25	31.00	31.13
S.Em (±)	0.048	0.083	0.048	0.076	0.059	0.048	0.096	0.127	0.080	0.118	0.186	0.110
C.D. at 5%	0.189	0.327	0.157	0.299	0.231	0.157	0.378	0.500	0.260	0.463	0.732	0.360
Nutrient management												
N_1	3.33	3.67	3.50	17.67	17.33	17.50	27.89	27.00	27.44	35.78	35.67	35.72
N_2	3.33	3.44	3.39	17.56	17.33	17.44	27.89	27.44	27.67	35.78	35.67	35.72
N_3	3.44	3.56	3.50	17.33	17.33	17.33	28.11	27.22	27.67	35.89	35.44	35.67
N_4	3.44	3.67	3.56	17.33	17.33	17.33	28.22	27.11	27.67	35.89	35.89	35.89
S.Em (±)	0.136	0.101	0.085	0.150	0.079	0.085	0.210	0.200	0.145	0.266	0.227	0.175
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect												
D_1N_1	4.00	4.00	4.00	18.00	18.00	18.00	29.33	29.67	29.50	42.33	41.00	41.67
D_1N_2	3.67	3.67	3.67	18.00	18.00	18.00	30.00	29.33	29.67	42.00	41.67	41.83
D_1N_3	3.67	4.00	3.83	17.67	17.67	17.67	30.00	29.33	29.67	42.33	41.33	41.83
D_1N_4	4.00	4.00	4.00	17.67	18.00	17.83	29.33	29.33	29.33	42.00	41.33	41.67
D_2N_1	3.00	4.00	3.50	18.00	17.00	17.50	27.67	26.67	27.17	34.67	34.67	34.67
D_2N_2	3.33	3.67	3.50	18.00	17.00	17.50	27.33	27.67	27.50	34.33	34.67	34.50
D_2N_3	3.67	3.67	3.67	17.33	17.33	17.33	27.67	27.00	27.33	33.67	34.33	34.00
D_2N_4	3.33	4.00	3.67	17.67	17.00	17.33	28.00	26.67	27.33	33.67	35.00	34.33
D_3N_1	3.00	3.00	3.00	17.00	17.00	17.00	26.67	24.67	25.67	30.33	31.33	30.83
D_3N_2	3.00	3.00	3.00	16.67	17.00	16.83	26.33	25.33	25.83	31.00	30.67	30.83
D_3N_3	3.00	3.00	3.00	17.00	17.00	17.00	26.67	25.33	26.00	31.67	30.67	31.17
D_3N_4	3.00	3.00	3.00	16.67	17.00	16.83	27.33	25.33	26.33	32.00	31.33	31.67
D × N												
S.Em (±)	0.236	0.176	0.147	0.261	0.136	0.147	0.364	0.347	0.252	0.461	0.393	0.303
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D												
S.Em (±)	0.21	0.17	0.14	0.238	0.132	0.136	0.330	0.326	0.232	0.417	0.388	0.285
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.2.3 (contd.)

Effect of planting time and nutrient management on phenological development of Radhatilak rice during *kharif* season

Treatment	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (day)			50% flowering to Milk (day)			Milk to Dough (day)			Dough to Maturity (day)			Sowing to Maturity (day)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time															
D_1	31.83	31.17	31.50	10.33	9.83	10.08	11.42	10.42	10.92	9.58	9.75	9.67	156.67	153.75	155.21
D_2	31.92	31.25	31.58	10.17	9.42	9.79	11.75	10.67	11.21	9.50	9.33	9.42	146.17	143.25	144.71
D_3	31.67	31.17	31.42	9.83	9.50	9.67	11.08	10.08	10.58	9.42	9.50	9.46	139.83	136.42	138.13
S.Em (±)	0.226	0.140	0.133	0.113	0.118	0.082	0.195	0.096	0.109	0.059	0.183	0.096	0.127	0.152	0.099
C.D. at 5%	NS	NS	NS	NS	NS	0.266	NS	0.378	0.355	NS	NS	NS	0.500	0.597	0.323
Nutrient management															
N_1	31.67	31.56	31.61	10.00	9.33	9.67	11.56	10.44	11.00	9.44	9.78	9.61	147.33	144.78	146.06
N_2	31.89	31.11	31.50	10.11	9.67	9.89	11.33	10.33	10.83	9.56	9.22	9.39	147.44	144.22	145.83
N_3	31.78	31.22	31.50	10.00	9.67	9.83	11.56	10.44	11.00	9.67	9.56	9.61	147.78	144.44	146.11
N_4	31.89	30.89	31.39	10.33	9.67	10.00	11.22	10.33	10.78	9.33	9.56	9.44	147.67	144.44	146.06
S.Em (±)	0.195	0.157	0.125	0.140	0.179	0.113	0.160	0.173	0.118	0.190	0.176	0.129	0.255	0.184	0.157
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect															
D_1N_1	31.67	31.33	31.50	10.33	9.67	10.00	11.33	10.33	10.83	9.67	10.33	10.00	156.67	154.33	155.50
D_1N_2	32.00	31.33	31.67	10.00	9.67	9.83	11.67	10.33	11.00	9.33	9.67	9.50	156.67	153.67	155.17
D_1N_3	31.67	31.00	31.33	10.33	10.00	10.17	11.33	10.67	11.00	9.67	9.67	9.67	156.67	153.67	155.17
D_1N_4	32.00	31.00	31.50	10.67	10.00	10.33	11.33	10.33	10.83	9.67	9.33	9.50	156.67	153.33	155.00
D_2N_1	31.67	31.67	31.67	10.00	9.00	9.50	11.67	11.00	11.33	9.67	9.33	9.50	146.33	143.33	144.83
D_2N_2	32.00	30.67	31.33	10.33	9.67	10.00	11.33	10.67	11.00	9.67	9.00	9.33	146.33	143.00	144.67
D_2N_3	32.00	31.67	31.83	10.00	9.67	9.83	12.00	10.33	11.17	9.67	9.33	9.50	146.00	143.33	144.67
D_2N_4	32.00	31.00	31.50	10.33	9.33	9.83	12.00	10.67	11.33	9.00	9.67	9.33	146.00	143.33	144.67
D_3N_1	31.67	31.67	31.67	9.67	9.33	9.50	11.67	10.00	10.83	9.00	9.67	9.33	139.00	136.67	137.83
D_3N_2	31.67	31.33	31.50	10.00	9.67	9.83	11.00	10.00	10.50	9.67	9.00	9.33	139.33	136.00	137.67
D_3N_3	31.67	31.00	31.33	9.67	9.33	9.50	11.33	10.33	10.83	9.67	9.67	9.67	140.67	136.33	138.50
D_3N_4	31.67	30.67	31.17	10.00	9.67	9.83	10.33	10.00	10.17	9.33	9.67	9.50	140.33	136.67	138.50
D × N															
S.Em (±)	0.338	0.272	0.217	0.242	0.309	0.196	0.278	0.299	0.204	0.329	0.304	0.224	0.441	0.319	0.272
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D															
S.Em (±)	0.370	0.274	0.230	0.238	0.293	0.189	0.310	0.276	0.208	0.291	0.321	0.217	0.403	0.315	0.256
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

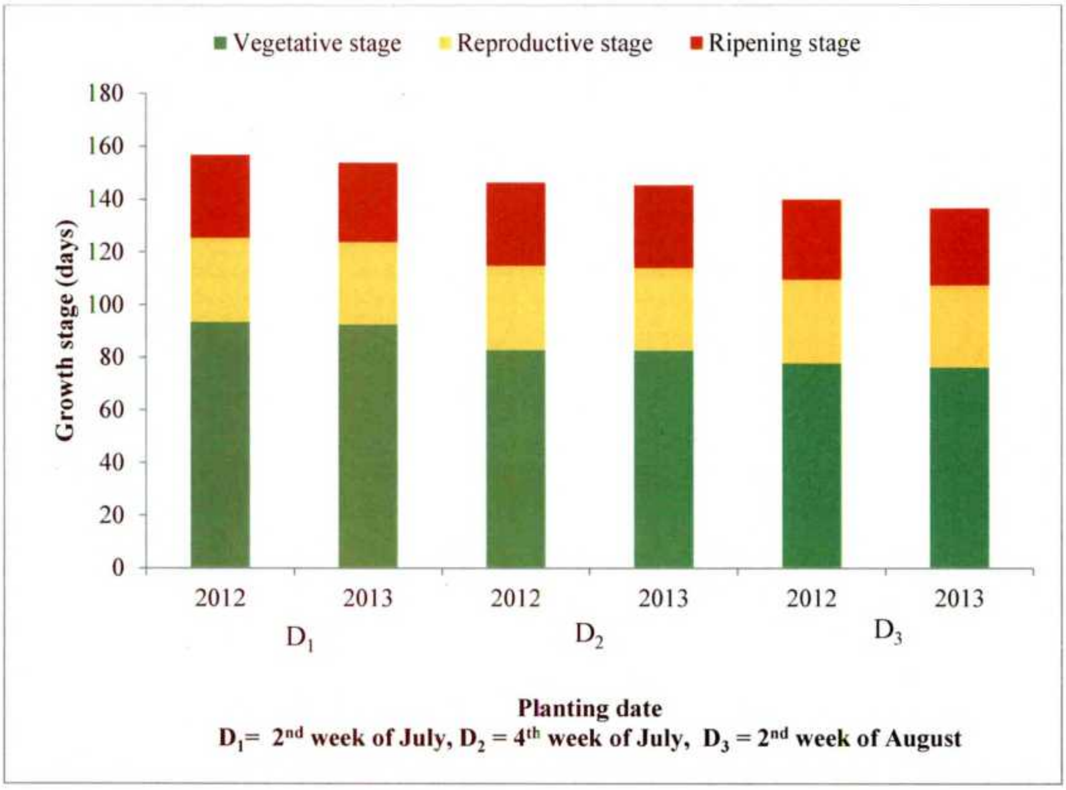


Fig. 4.2.1: Effect of planting time on phenological development of Radhatilak rice during *kharif* season of 2012 and 2013 (pooled over two years)

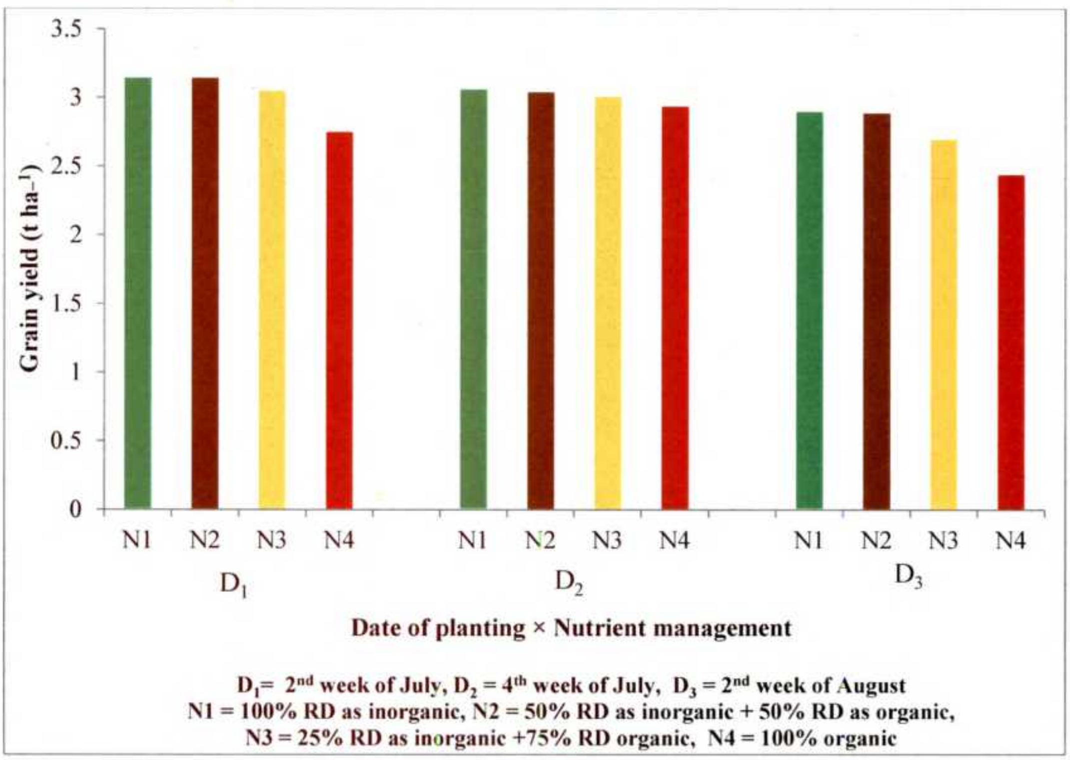


Fig. 4.2.2: Interaction effect between planting time and nutrient management on grain yield of Radhatilak rice during *kharif* season (pooled over two years)

4.2.2.1.2 Effect of nutrient management

There was no significant difference in length of phenophages as well as in duration of Radhatilak rice due to variation in nutrient management practices adopted in the experiment (Table 4.2.3).

4.2.2.1.3 Interaction effect between planting time and nutrient management

The interaction effect between planting time and nutrient management did not show any significant influence on attainment of phenophases and life cycle of Radhatilak rice during both the years of investigation (Table 4.2.3).

4.2.2.2 Growing degree days (GDD)

4.2.2.2.1 Effect of planting time

Mean air temperature for entire life cycle of Radhatilak paddy varied among planting times as: D_1 (28.07, and 28.21°C), D_2 (27.51and 27.57°C), and D_3 (26.39 and 26.98°C) during 2012 and 2013 (Table 4.2.2), which indicated that mean temperature of total life duration decreased slowly with delay in sowing or planting during *kharif* season.

The summed GDD of Radhatilak rice for entire life cycle, pooled over two years, was reduced by 481.6°C day for delay in planting from 2nd week of July (2912.8°C day) to 2nd week of August (2431.2°C day) in the study (Table 4.2.4)

Mean summed GDD of Radhatilak rice from sowing to emergence, 4th leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 72.2, 418.9, 949.6, 1651.9, 2230.8, 2385.7, 2530.9 and 2651.8°C day, respectively.

The pooled accumulated GDD during vegetative, reproductive and ripening phases showed variations due to planting times as: 2nd week of July (1827.5, 604.8 and 470.8°C day), 4th week of July (1631.5, 586.1 and 410.8°C day), and 2nd week of August (1496.6, 545.9 and 381.3°C day).

4.2.2.2.2 Effect of nutrient management

Nutrient management had no significant influence on accumulation of GDD at different phenophases of Radhatilak rice during both the years of experimentation (Table 4.2.4).

Table 4.2.4

Effect of planting time and nutrient management on growing degree days at different phenophases of Radhatilak rice

Treatment	Vegetative stage											
	Sowing to Emergence (°C day)			Emergence to 4^{th} leaf emergence (°C day)			4^{th} leaf emergence to Active tillering (°C day)			Active tillering to Panicle initiation (°C day)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time												
D_1	80.29	77.39	78.84	355.56	359.47	357.51	575.23	587.61	581.42	807.15	803.07	805.11
D_2	64.27	78.78	71.53	347.85	348.38	348.12	528.53	520.47	524.50	655.89	683.84	669.86
D_3	54.25	60.55	57.40	322.21	332.20	327.20	521.89	484.10	502.99	610.46	619.74	615.10
S.Em (±)	0.988	1.771	1.014	1.505	1.253	0.979	1.960	2.249	1.492	2.287	3.621	2.142
C.D. at 5%	3.878	6.954	3.306	5.908	4.921	3.193	7.698	8.830	4.865	8.980	14.220	6.984
Nutrient management												
N_1	65.12	74.00	69.56	345.58	346.68	346.13	539.34	527.07	533.21	690.11	701.87	695.99
N_2	65.13	69.28	67.21	343.64	346.77	345.21	538.88	535.22	537.05	690.16	703.02	696.59
N_3	67.42	71.69	69.56	339.18	346.60	342.89	543.44	531.18	537.31	692.32	697.87	695.09
N_4	67.41	74.00	70.70	339.08	346.68	342.88	545.88	529.43	537.66	692.08	706.09	699.09
S.Em (±)	2.795	2.138	1.759	2.968	1.667	1.702	4.087	4.101	2.895	5.222	4.552	3.464
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect												
D_1N_1	83.70	79.20	81.45	358.30	361.25	359.78	569.08	593.00	581.04	810.28	795.80	803.04
D_1N_2	76.88	71.97	74.43	358.97	361.30	360.13	581.57	585.78	583.68	803.95	810.20	807.08
D_1N_3	76.88	79.20	78.04	352.82	354.07	353.44	581.38	585.87	583.63	810.28	803.27	806.78
D_1N_4	83.70	79.20	81.45	352.15	361.25	356.70	568.90	585.80	577.35	804.07	803.00	803.53
D_2N_1	57.40	82.25	69.83	353.00	346.60	349.80	528.57	514.83	521.70	667.68	682.25	674.97
D_2N_2	64.27	75.32	69.79	353.00	346.80	349.90	521.70	532.20	526.95	660.68	686.38	673.53
D_2N_3	71.13	75.32	73.23	339.27	353.53	346.40	528.57	520.00	524.28	647.72	677.08	662.40
D_2N_4	64.27	82.25	73.26	346.13	346.60	346.37	535.30	514.83	525.07	647.47	689.63	668.55
D_3N_1	54.25	60.55	57.40	325.45	332.20	328.83	520.37	473.38	496.88	592.37	627.55	609.96
D_3N_2	54.25	60.55	57.40	318.97	332.20	325.58	513.38	487.67	500.53	605.83	612.48	609.16
D_3N_3	54.25	60.55	57.40	325.45	332.20	328.83	520.37	487.67	504.02	618.95	613.27	616.11
D_3N_4	54.25	60.55	57.40	318.97	332.20	325.58	533.43	487.67	510.55	624.70	625.65	625.18
D × N												
S.Em (±)	4.842	3.702	3.048	5.141	2.888	2.948	7.080	7.104	5.015	9.045	7.884	5.999
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D												
S.Em (±)	4.308	3.663	2.827	4.700	2.797	2.735	6.437	6.550	4.592	8.160	7.729	5.620
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.2.4 (contd.)

Effect of planting time and nutrient management on growing degree days at different phenophases of Radhatilak rice

Treatment	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (°C day)			50% flowering to Milk (°C day)			Milk to Dough (°C day)			Dough to Maturity (°C day)			Sowing to Maturity (°C day)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time															
D_1	627.5	604.8	616.1	172.5	176.3	174.4	176.1	164.4	170.2	128.1	130.1	129.1	2922.4	2903.1	2912.8
D_2	613.9	586.1	600.0	160.1	147.1	153.6	165.6	150.3	157.9	131.4	113.4	122.4	2667.5	2628.4	2648.0
D_3	547.9	545.9	546.9	137.8	141.2	139.5	149.4	120.9	135.1	94.6	119.2	106.9	2438.5	2423.8	2431.2
S.Em (±)	3.91	2.97	2.45	2.54	1.76	1.54	2.80	1.60	1.61	0.76	2.18	1.15	1.44	1.84	1.17
C.D. at 5%	15.35	11.65	8.00	9.96	6.91	5.03	10.99	6.28	5.26	2.98	8.56	3.76	5.67	7.24	3.82
Nutrient management															
N_1	594.7	585.5	590.1	155.6	150.4	153.0	165.8	146.1	155.9	117.7	123.8	120.8	2674.0	2655.3	2664.7
N_2	599.0	576.9	588.0	156.7	156.1	156.4	163.1	144.2	153.7	118.4	117.3	117.9	2675.0	2648.8	2661.9
N_3	595.5	580.3	587.9	155.4	156.9	156.1	165.1	145.8	155.4	119.9	121.2	120.6	2678.3	2651.5	2664.9
N_4	596.6	573.1	584.8	159.4	156.2	157.8	160.8	144.7	152.8	116.0	121.3	118.6	2677.2	2651.5	2664.4
S.Em (±)	3.21	2.99	2.19	2.40	3.02	1.93	2.10	2.77	1.74	2.69	2.03	1.69	3.33	2.14	1.98
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect															
D_1N_1	624.4	607.8	616.1	172.4	173.0	172.7	175.0	163.1	169.0	129.3	136.9	133.1	2922.4	2909.9	2916.2
D_1N_2	630.2	607.3	618.7	166.8	173.5	170.1	179.6	163.1	171.3	124.3	129.0	126.7	2922.3	2902.1	2912.2
D_1N_3	624.4	602.6	613.5	172.4	179.7	176.0	174.7	168.3	171.5	129.3	129.0	129.2	2922.4	2902.1	2912.3
D_1N_4	631.0	601.5	616.3	178.3	179.2	178.8	175.0	163.1	169.0	129.3	125.5	127.4	2922.4	2898.5	2910.5
D_2N_1	607.8	594.6	601.2	157.2	140.0	148.6	164.5	155.5	160.0	133.2	113.5	123.3	2669.4	2629.4	2649.4
D_2N_2	614.8	574.0	594.4	161.8	151.4	156.6	159.9	149.9	154.9	133.2	109.3	121.2	2669.4	2625.2	2647.3
D_2N_3	617.1	594.6	605.8	158.8	151.1	154.9	169.3	144.4	156.8	133.9	113.5	123.7	2665.7	2629.4	2647.6
D_2N_4	616.0	581.4	598.7	162.6	146.1	154.3	168.8	151.3	160.0	125.2	117.4	121.3	2665.7	2629.4	2647.6
D_3N_1	552.1	554.1	553.1	137.2	138.1	137.6	157.8	119.7	138.8	90.7	121.1	105.9	2430.2	2426.7	2428.4
D_3N_2	552.1	549.6	550.8	141.5	143.4	142.4	149.8	119.7	134.7	97.7	113.6	105.7	2433.5	2419.2	2426.3
D_3N_3	544.8	543.7	544.3	135.1	139.8	137.5	151.2	124.6	137.9	96.6	121.1	108.8	2446.8	2422.9	2434.8
D_3N_4	542.8	536.4	539.6	137.3	143.4	140.4	138.7	119.7	129.2	93.3	121.1	107.2	2443.5	2426.7	2435.1
D × N															
S.Em (±)	5.55	5.19	3.80	4.17	5.22	3.34	3.64	4.79	3.01	4.66	3.52	2.92	5.77	3.71	3.43
C.D. at 5%	NS	NS	NS	NS	NS	NS	10.82	NS	NS	NS	NS	NS	NS	NS	NS
								N × D							
S.Em (±)	6.198	5.383	4.105	4.41	4.85	3.28	4.22	4.45	3.06	4.10	3.75	2.78	5.20	3.70	3.19
C.D. at 5%	NS	NS	NS	NS	NS	NS	14.30	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Plate 4.2.13: Seedlings of Radhatilak rice under different sowing times

Plate 4.2.14: Uprooting of seedling from seedbed

Plate 4.2.15: Vegetative stage of Radhatilak rice under different planting times

Plate 4.2.16: Top dressing of fertilizer in experimental plots

Plate 4.2.17: Maximum tillering stage of Radhatilak paddy

Plate 4.2.18: Harvesting stage of Radhatilak paddy

Phenological stages of Radhatilak rice in Experiment No. 2

4.2.2.2.3 Interaction effect between planting time and nutrient management

Planting time × nutrient management interaction effect on accumulated GDD at various phenophases was found non-significant in either of the years of investigation, except during milk to dough stage in 2012 (Table 4.2.4).

4.2.2.3 Heliothermal units (HTU)

4.2.2.3.1 Effect of planting time

Mean bright sunshine hour for life cycle of Radhatilak paddy varied among planting times as: D_1 (5.45 and 5.04 hours), D_2 (5.48 and 5.70 hours) and D_3 (5.80 and 5.84 hours) during 2012 and 2013 (Table 4.2.2), which indicated slight increasing trend in average sunshine hours for total life duration with delay in planting from 2nd week of July (D_1) to 2nd week of August (D_3) during *kharif* season at Kalyani, West Bengal.

The variation in mean daily temperature and bright sunshine hour among three sowing or planting times (Table 4.2.2) resulted in significant variations in summed heliothermal units at different phenophases of Radhatilak paddy during *kharif* season of both 2012 and 2013.

Based on pooled values for total summed HTU, three planting times could be arranged as: D_1 (15376.3°C hour) > D_2 (14663.7°C hour) > D_3 (13868.4°C hour).

4.2.2.3.2 Effect of nutrient management

The influence of nutrient management on accumulated HTU at different phenophases of Radhatilak paddy was not found significant during both 2012 and 2013 in the study (Table 4.2.5).

4.2.2.3.3 Interaction effect between planting time and nutrient management

There was no significant interaction effect between planting time and nutrient management on accumulation of HTU at all phenophases during both the years of investigation (Table 4.2.5).

4.2.2.4 Photothermal units (PTU)

4.2.2.4.2 Effect of planting time

Although temperature governed the onset of different phenophases of rice, but day length had also influence on photothermal requirements of photo-sensitive tall-

Table 4.2.5

Effect of planting time and nutrient management on heliothermal units at different phenophases of Radhatilak rice

Treatment	Vegetative stage											
	Sowing to Emergence (°C hour)			Emergence to 4th leaf emergence (°C hour)			4th leaf emergence to Active tillering (°C hour)			Active tillering to Panicle initiation (°C hour)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time												
D_1	256.2	436.1	346.1	1371.1	1460.7	1415.9	2298.5	3145.5	2722.0	4146.4	3724.2	3935.3
D_2	212.2	468.9	340.6	1333.6	2141.6	1737.6	2441.4	2134.4	2287.9	3436.4	3709.9	3573.2
D_3	257.1	252.6	254.8	1408.5	1567.8	1488.1	2845.5	2200.7	2523.1	3530.6	3341.4	3436.0
S.Em (±)	6.4	11.5	6.6	10.9	8.4	6.9	20.7	7.5	11.0	10.7	24.6	13.4
C.D. at 5%	24.9	45.2	21.4	42.6	33.0	22.4	81.2	29.3	35.9	41.9	96.5	43.7
Nutrient management												
N_1	243.6	396.0	319.8	1372.9	1722.6	1547.7	2526.2	2486.1	2506.1	3711.5	3573.8	3642.6
N_2	233.4	365.8	299.6	1388.4	1727.9	1558.2	2498.5	2505.5	2502.0	3716.2	3608.7	3662.4
N_3	240.0	385.8	312.9	1369.1	1720.3	1544.7	2533.6	2486.1	2509.9	3705.6	3579.8	3642.7
N_4	250.2	396.0	323.1	1353.9	1722.6	1538.2	2555.6	2496.5	2526.0	3684.6	3605.1	3644.9
S.Em (±)	14.3	12.7	9.6	15.0	8.4	8.6	29.0	24.7	19.0	30.3	30.5	21.5
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect												
D_1N_1	281.4	451.1	366.2	1356.9	1464.3	1410.6	2287.4	3192.8	2740.1	4157.5	3662.9	3910.2
D_1N_2	230.9	391.1	311.0	1396.3	1487.0	1441.7	2347.9	3132.3	2740.1	4108.1	3760.9	3934.5
D_1N_3	230.9	451.1	341.0	1385.2	1427.0	1406.1	2309.6	3112.9	2711.2	4157.5	3761.0	3959.3
D_1N_4	281.4	451.1	366.2	1345.9	1464.3	1405.1	2249.1	3143.9	2696.5	4162.4	3711.9	3937.1
D_2N_1	192.3	484.2	338.2	1340.3	2135.6	1737.9	2442.5	2124.7	2283.6	3506.4	3662.7	3584.6
D_2N_2	212.2	453.7	332.9	1373.3	2129.0	1751.2	2389.6	2163.4	2276.5	3453.2	3788.1	3620.7
D_2N_3	232.1	453.7	342.9	1300.5	2166.1	1733.3	2442.5	2124.7	2283.6	3405.3	3662.7	3534.0
D_2N_4	212.2	484.2	348.2	1320.4	2135.6	1728.0	2491.0	2124.7	2307.8	3380.8	3726.2	3553.5
D_3N_1	257.1	252.6	254.8	1421.5	1567.8	1494.6	2848.7	2140.7	2494.7	3470.5	3395.6	3433.1
D_3N_2	257.1	252.6	254.8	1395.6	1567.8	1481.7	2757.9	2220.8	2489.3	3587.2	3277.1	3432.2
D_3N_3	257.1	252.6	254.8	1421.5	1567.8	1494.6	2848.7	2220.8	2534.7	3554.1	3315.6	3434.8
D_3N_4	257.1	252.6	254.8	1395.6	1567.8	1481.7	2926.6	2220.8	2573.7	3510.7	3377.2	3443.9
D × N												
S.Em (±)	24.8	21.9	16.6	25.9	14.5	14.9	50.2	42.7	33.0	52.4	52.9	37.2
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D												
S.Em (±)	22.4	22.2	15.8	24.9	15.1	14.6	48.2	37.7	30.6	46.6	52.0	34.9
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.2.5 (contd.)

Effect of planting time and nutrient management on heliothermal units at different phenophases of Radhatilak rice

Treatment	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (°C hour)			50% flowering to Milk (°C hour)			Milk to Dough (°C hour)			Dough to Maturity (°C hour)			Sowing to Maturity (°C hour)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time															
D_1	4082.4	3105.6	3594.0	1609.2	901.3	1255.2	937.7	1119.5	1028.6	981.2	1173.2	1077.2	15686.6	15066.0	15376.3
D_2	4433.8	2788.4	3611.1	1220.9	892.3	1056.6	954.3	1321.4	1137.8	926.8	911.1	918.9	14959.4	14368.0	14663.7
D_3	3865.9	2664.7	3265.3	881.1	1226.4	1053.7	1080.3	1036.1	1058.2	773.7	804.4	789.0	14642.8	13094.0	13868.4
S.Em (±)	45.3	21.3	25.0	30.9	17.5	17.7	24.6	11.6	13.6	6.2	18.9	10.0	12.1	15.9	10.0
C.D. at 5%	178.0	83.6	81.7	121.2	68.8	57.9	96.7	45.4	44.4	24.4	74.3	32.5	47.4	62.5	32.6
Nutrient management															
N_1	4124.2	2899.9	3512.1	1192.3	971.2	1081.7	1017.3	1169.1	1093.2	891.9	988.3	940.1	15079.8	14206.9	14643.3
N_2	4160.6	2835.7	3498.1	1187.0	1021.8	1104.4	1004.1	1153.3	1078.7	901.9	934.4	918.2	15090.0	14153.0	14621.5
N_3	4108.5	2855.7	3482.1	1266.7	1024.9	1145.8	975.2	1155.8	1065.5	907.8	964.9	936.4	15111.9	14173.3	14642.6
N_4	4116.2	2820.2	3468.2	1302.3	1008.8	1155.6	966.4	1157.7	1062.1	874.0	963.8	918.9	15103.2	14170.7	14637.0
S.Em (±)	27.8	23.3	18.1	28.6	26.1	19.4	23.3	17.1	14.5	19.9	17.3	13.2	24.1	17.9	15.0
C.D. at 5%	NS	NS	NS	85.0	NS	55.6	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect															
D_1N_1	4067.3	3138.7	3603.0	1612.5	863.3	1237.9	933.7	1119.5	1026.6	988.1	1238.0	1113.0	15684.9	15130.8	15407.8
D_1N_2	4123.3	3097.9	3610.6	1558.8	904.2	1231.5	965.9	1119.5	1042.7	960.6	1162.8	1061.7	15691.9	15055.6	15373.7
D_1N_3	4077.3	3097.6	3587.4	1602.5	923.7	1263.1	917.3	1119.5	1018.4	988.1	1162.8	1075.4	15684.9	15055.6	15370.2
D_1N_4	4061.4	3088.1	3574.8	1662.9	913.9	1288.4	933.7	1119.5	1026.6	988.1	1129.3	1058.7	15684.9	15022.1	15353.5
D_2N_1	4411.3	2843.3	3627.3	1185.6	849.6	1017.6	954.3	1365.6	1159.9	942.5	911.1	926.8	14975.0	14376.9	14676.0
D_2N_2	4464.5	2701.7	3583.1	1185.6	911.8	1048.7	954.3	1318.0	1136.1	942.5	875.6	909.0	14975.0	14341.3	14658.2
D_2N_3	4416.6	2843.3	3629.9	1281.4	944.8	1113.1	916.6	1270.4	1093.5	948.8	911.1	929.9	14943.7	14376.9	14660.3
D_2N_4	4442.9	2765.2	3604.1	1231.1	863.0	1047.1	992.0	1331.5	1161.7	873.4	946.5	909.9	14943.7	14376.9	14660.3
D_3N_1	3893.9	2717.7	3305.8	778.8	1200.6	989.7	1163.8	1022.3	1093.1	745.1	815.8	780.5	14579.5	13113.1	13846.3
D_3N_2	3893.9	2707.4	3300.7	816.5	1249.3	1032.9	1092.2	1022.3	1057.3	802.7	764.8	783.8	14603.2	13062.1	13832.6
D_3N_3	3831.6	2626.3	3228.9	916.1	1206.2	1061.2	1091.7	1077.5	1084.6	786.4	820.9	803.7	14707.2	13087.6	13897.4
D_3N_4	3844.3	2607.3	3225.8	1012.9	1249.3	1131.1	973.6	1022.3	997.9	760.4	815.8	788.1	14681.2	13113.1	13897.1
D × N															
S.Em (±)	48.2	40.4	31.4	49.5	45.2	33.5	40.3	29.7	25.0	34.4	30.0	22.8	41.8	31.0	26.0
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D															
S.Em (±)	61.6	40.9	37.0	52.9	42.9	34.0	42.7	28.2	25.6	30.5	32.1	22.1	38.1	31.3	24.7
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.2.6

Effect of planting time and nutrient management on photothermal units at different phenophases of Radhatilak rice

Treatment	Vegetative stage											
	Sowing to Emergence (°C hour)			Emergence to 4th leaf emergence (°C hour)			4th leaf emergence to Active tillering (°C hour)			Active tillering to Panicle initiation (°C hour)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time												
D_1	1067.9	1028.3	1048.1	4721.8	4777.6	4749.7	7427.3	7596.1	7511.7	9988.0	9953.1	9970.6
D_2	847.8	1037.6	942.7	4530.3	4530.6	4530.5	6698.8	6592.3	6645.5	8018.1	8352.6	8185.3
D_3	701.0	783.4	742.2	4115.2	4247.1	4181.2	6494.9	6037.1	6266.0	7340.7	7479.3	7410.0
S.Em (±)	13.1	23.4	13.4	19.6	16.6	12.8	24.0	28.2	18.5	26.7	43.7	25.6
C.D. at 5%	51.4	92.0	43.8	76.8	65.2	41.8	94.3	110.9	60.4	104.7	171.5	83.5
Nutrient management												
N_1	857.2	973.0	915.1	4504.0	4518.2	4511.1	6840.4	6696.5	6768.5	8437.4	8590.6	8514.0
N_2	857.1	910.5	883.8	4479.4	4520.3	4499.8	6837.0	6798.7	6817.9	8437.8	8604.7	8521.2
N_3	887.2	942.6	914.9	4420.1	4517.1	4468.6	6894.3	6747.4	6820.9	8462.4	8543.6	8503.0
N_4	887.4	973.0	930.2	4419.6	4518.2	4468.9	6922.9	6724.6	6823.7	8458.1	8641.0	8549.5
S.Em (±)	37.0	28.2	23.3	38.6	22.0	22.2	51.6	51.4	36.4	63.8	55.5	42.3
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect												
D_1N_1	1113.3	1052.4	1082.8	4757.2	4800.8	4779.0	7346.4	7662.8	7504.6	10025.9	9859.8	9942.9
D_1N_2	1022.4	956.1	989.3	4767.2	4802.5	4784.9	7507.6	7574.6	7541.1	9945.6	10042.6	9994.1
D_1N_3	1022.4	1052.4	1037.4	4686.4	4706.3	4696.3	7508.1	7575.5	7541.8	10025.9	9958.8	9992.3
D_1N_4	1113.3	1052.4	1082.8	4676.4	4800.8	4738.6	7347.0	7571.4	7459.2	9954.6	9951.2	9952.9
D_2N_1	757.4	1083.2	920.3	4598.6	4506.7	4552.6	6699.9	6521.4	6610.6	8160.2	8335.5	8247.9
D_2N_2	847.8	992.0	919.9	4596.6	4511.2	4553.9	6611.4	6740.7	6676.1	8076.4	8379.8	8228.1
D_2N_3	938.1	992.0	965.1	4417.8	4597.9	4507.8	6699.9	6585.8	6642.9	7921.0	8271.1	8096.0
D_2N_4	847.8	1083.2	965.5	4508.2	4506.7	4507.5	6783.9	6521.4	6652.6	7914.7	8423.9	8169.3
D_3N_1	701.0	783.4	742.2	4156.3	4247.1	4201.7	6475.0	5905.4	6190.2	7126.1	7576.5	7351.3
D_3N_2	701.0	783.4	742.2	4074.2	4247.1	4160.7	6391.9	6080.9	6236.4	7291.3	7391.8	7341.5
D_3N_3	701.0	783.4	742.2	4156.3	4247.1	4201.7	6475.0	6080.9	6278.0	7440.2	7401.0	7420.6
D_3N_4	701.0	783.4	742.2	4074.2	4247.1	4160.7	6637.7	6080.9	6359.3	7505.1	7547.7	7526.4
D × N												
S.Em (±)	64.0	48.9	40.3	66.9	38.0	38.5	89.3	89.0	63.0	110.5	96.2	73.2
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D												
S.Em (±)	57.0	48.4	37.4	61.2	36.9	35.7	81.0	82.1	57.7	99.3	94.0	68.4
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.2.6 (contd.)

Effect of planting time and nutrient management on photothermal units at different phenophases of Radhatilak rice

Treatment	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (°C hour)			50% flowering to Milk (°C hour)			Milk to Dough (°C hour)			Dough to Maturity (°C hour)			Sowing to Maturity (°C hour)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time															
D_1	7434.6	7186.9	7310.7	1990.9	2042.8	2016.9	2003.9	1879.5	1941.7	1437.3	1468.6	1453.0	36072.5	35932.8	36002.7
D_2	7221.3	6889.1	7055.2	1833.0	1684.9	1759.0	1869.5	1699.5	1784.5	1461.5	1264.7	1363.1	32480.2	32051.4	32265.8
D_3	6352.3	6350.2	6351.3	1554.0	1599.5	1576.8	1661.0	1351.9	1506.4	1036.5	1314.5	1175.5	29255.6	29163.0	29209.3
S.Em (±)	45.1	35.6	28.7	29.9	20.0	18.0	32.0	18.3	18.4	8.4	24.2	12.8	15.9	20.5	13.0
C.D. at 5%	177.2	139.8	93.7	117.4	78.5	58.7	125.7	71.7	60.1	33.1	95.1	41.8	62.4	80.4	42.3
Nutrient management															
N_1	6983.2	6884.7	6933.9	1779.5	1723.6	1751.6	1868.4	1653.5	1760.9	1309.3	1381.6	1345.5	32579.5	32421.8	32500.7
N_2	7033.7	6784.3	6909.0	1791.4	1789.1	1790.3	1838.5	1632.5	1735.5	1316.1	1309.4	1312.8	32590.9	32349.6	32470.2
N_3	6990.7	6826.4	6908.5	1777.4	1798.9	1788.1	1860.1	1650.3	1755.2	1332.9	1352.5	1342.7	32626.3	32378.9	32502.6
N_4	7003.3	6739.6	6871.5	1822.3	1791.2	1806.8	1812.1	1638.1	1725.1	1288.7	1353.6	1321.2	32614.5	32379.3	32496.9
S.Em (±)	37.3	35.5	25.8	27.8	34.6	22.2	23.9	31.7	19.8	29.9	22.6	18.7	36.9	23.7	21.9
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect															
D_1N_1	7396.9	7220.7	7308.8	1990.1	2003.3	1996.7	1991.6	1864.4	1928.0	1451.5	1544.3	1497.9	36072.9	36008.5	36040.7
D_1N_2	7464.5	7214.8	7339.7	1925.0	2009.2	1967.1	2044.0	1864.4	1954.2	1394.8	1456.7	1425.8	36071.2	35920.9	35996.1
D_1N_3	7397.4	7164.0	7280.7	1989.6	2082.6	2036.1	1988.2	1924.7	1956.4	1451.5	1456.7	1454.1	36072.9	35920.9	35996.9
D_1N_4	7479.5	7148.0	7313.7	2059.1	2076.0	2067.5	1991.6	1864.4	1928.0	1451.5	1416.7	1434.1	36072.9	35880.9	35976.9
D_2N_1	7146.1	6989.0	7067.6	1799.7	1603.4	1701.5	1857.0	1758.3	1807.6	1481.6	1265.6	1373.6	32500.4	32063.1	32281.7
D_2N_2	7229.9	6745.0	6987.5	1851.8	1733.6	1792.7	1804.8	1695.3	1750.0	1481.6	1218.7	1350.2	32500.4	32016.2	32258.3
D_2N_3	7262.6	6989.0	7125.8	1819.0	1729.3	1774.2	1911.7	1632.3	1772.0	1489.9	1265.6	1377.7	32460.1	32063.1	32261.6
D_2N_4	7246.6	6833.4	7040.0	1861.7	1673.2	1767.4	1904.5	1712.1	1808.3	1392.8	1309.2	1351.0	32460.1	32063.1	32261.6
D_3N_1	6406.5	6444.4	6425.5	1548.9	1564.1	1556.5	1756.5	1337.9	1547.2	994.8	1334.9	1164.9	29165.2	29193.8	29179.5
D_3N_2	6406.5	6393.2	6399.9	1597.4	1624.5	1611.0	1666.7	1337.9	1502.3	1071.9	1252.8	1162.3	29201.0	29111.7	29156.3
D_3N_3	6312.1	6326.0	6319.1	1523.4	1584.9	1554.2	1680.4	1394.0	1537.2	1057.2	1335.3	1196.3	29345.8	29152.8	29249.3
D_3N_4	6284.0	6237.3	6260.6	1546.3	1624.5	1585.4	1540.2	1337.9	1439.0	1021.9	1334.9	1178.4	29310.5	29193.8	29252.1
D × N															
S.Em (±)	64.7	61.5	44.6	48.2	60.0	38.5	41.4	54.9	34.4	51.8	39.1	32.4	63.9	41.1	38.0
C.D. at 5%	NS	NS	NS	NS	NS	NS	48.1	NS	NS	NS	NS	NS	NS	NS	NS
N × D															
S.Em (±)	71.9	64.1	48.2	51.3	55.6	37.8	48.1	50.9	35.0	45.6	41.6	30.9	57.6	41.1	35.4
C.D. at 5%	NS	NS	NS	NS	NS	NS	163.3	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

indica type rice crop, namely Radhatilak in the experiment. The early (2nd week of July), mid (4thweek of July) and late (2nd week of August) planted Radhatilak rice initiated flowering at average day lengths of 11.61, 11.51 and 11.40 hour, respectively at Kalyani, West Bengal.

Radhatilak rice planted on 2nd week of July (D_1) recorded the highest total summed PTU of 36002.7°C hour, which was 3736.9 and 6793.4°C hour greater over 4th week of July (D_2) and 2nd week of August (D_3) plantings, respectively (Table 4.2.6).

4.2.2.4.2 Effect of nutrient management

No significant effect due to nutrient management was noted on photothermal units at all phenophases of Radhatilak paddy during both the years of experimentation (Table 4.2.6).

4.2.2.4.3 Interaction effect between planting time and nutrient management

The non-significant interaction effects on summed PTU at different phenophases were noted during both the years of study, excluding milk to dough stage during 2012 only (Table 4.2.6).

4.2.3 Growth attributes

4.2.3.1 Plant height

The height of Radhatilak rice plants was increased rapidly during the period from 28 to 84 DAT and thereafter slowly due to exertion of panicles in the investigation (Table 4.2.7). Mean pooled plant height of Radhatilak rice, averaged over either of three planting times or four nutrient management practices, was 66.6, 107.9, 124.6 and 133.6 cm at 28, 56, 84 DAT and harvest, respectively.

4.2.3.1.1 Effect of planting time

There was gradual reduction in plant height of Radhatilak rice with delay in planting from 2nd week of July (D_1) to 2nd week of August (D_3) at 28, 56, 84 DAT and at harvest during both 2012 and 2013 in the investigation (Table 4.2.7). Thus, Radhatilak rice planted on 2nd week of July (D_1) recorded the highest plant height at harvest (137.4 cm) compared to late plantings in 4th week of July (133.8 cm) and 2nd week of August (129.6 cm) in the study. Similarly, Dhiman *et al.* (1995) and Paliwal *et al.* (1996) reported that early planted (mid or late July) rice crop usually produced taller

Table 4.2.7

Effect of planting time and nutrient management on plant height at different growth stages of Radhatilak rice

Treatment	Vegetative stage											
	28 DAT			56 DAT			84 DAT			At harvest		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time												
D_1	71.2	64.6	67.9	110.3	112.3	111.3	130.8	127.5	129.2	134.2	140.6	137.4
D_2	69.7	66.0	67.9	106.5	110.3	108.4	125.4	124.4	124.9	129.8	137.8	133.8
D_3	63.9	63.9	63.9	102.3	105.7	104.0	120.0	119.4	119.7	125.4	133.9	129.6
S.Em (±)	0.46	0.54	0.35	0.27	1.78	0.90	0.97	1.80	1.02	0.66	0.76	0.50
C.D. at 5%	1.79	NS	1.15	1.06	NS	2.93	3.81	NS	3.33	2.58	2.99	1.64
Nutrient management												
N_1	74.6	66.6	70.6	108.8	110.4	109.6	127.6	126.3	126.9	132.5	140.0	136.2
N_2	68.4	66.5	67.5	107.4	113.0	110.2	125.4	125.6	125.5	131.4	138.4	134.9
N_3	64.9	63.5	64.2	105.8	109.2	107.5	124.4	121.0	122.7	128.2	136.7	132.4
N_4	65.1	62.7	63.9	103.5	105.1	104.3	124.4	122.0	123.2	127.0	134.6	130.8
S.Em (±)	1.05	1.03	0.74	1.49	1.62	1.10	0.86	1.44	0.84	0.98	1.14	0.75
C.D. at 5%	3.13	3.05	2.11	NS	4.83	3.16	NS	4.26	2.40	2.90	3.38	2.15
Interaction effect												
D_1N_1	77.7	66.5	72.1	114.0	114.1	114.1	131.9	131.8	131.9	134.8	144.1	139.4
D_1N_2	70.6	68.0	69.3	109.0	115.9	112.5	130.0	129.5	129.7	135.3	141.5	138.4
D_1N_3	68.6	62.9	65.8	111.1	112.3	111.7	131.0	122.3	126.6	133.3	139.7	136.5
D_1N_4	67.7	60.9	64.3	107.1	106.6	106.9	130.4	126.4	128.4	133.3	137.2	135.2
D_2N_1	75.3	68.5	71.9	108.1	111.5	109.8	129.3	126.5	127.9	131.8	138.9	135.4
D_2N_2	70.7	67.6	69.2	107.3	110.9	109.1	126.5	125.1	125.8	128.8	139.6	134.2
D_2N_3	66.1	63.5	64.8	106.3	110.6	108.4	122.2	123.5	122.9	130.0	137.3	133.6
D_2N_4	66.6	64.5	65.6	104.3	108.4	106.4	123.7	122.5	123.1	128.6	135.3	131.9
D_3N_1	70.8	64.8	67.8	104.3	105.6	105.0	121.4	120.7	121.0	130.9	137.0	133.9
D_3N_2	63.9	63.8	63.9	105.9	112.3	109.1	119.6	122.3	121.0	130.3	134.1	132.2
D_3N_3	59.9	64.2	62.1	99.9	104.8	102.4	119.9	117.3	118.6	121.3	133.0	127.2
D_3N_4	60.9	62.6	61.8	99.2	100.2	99.7	119.1	117.1	118.1	119.2	131.3	125.3
D × N												
S.Em (±)	1.83	1.78	1.28	2.58	2.81	1.91	1.48	2.49	1.45	1.69	1.97	1.30
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.61	NS	NS
N × D												
S.Em (±)	1.65	1.63	1.16	2.25	3.02	1.88	1.61	2.80	1.62	1.61	1.87	1.23
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	5.03	NS	NS

DAT = Days after transplanting; NS = Not significant

plants compared to late planted ones (early or late August) in separate experiments at two different locations, in India.

The correlation studies between thermal indices and plant height of Radhatilak rice showed that both GDD and PTU during vegetative stage (emergence to panicle initiation) and reproductive stage (panicle initiation to 50% flowering) had positive effect ($P<0.01$) on plant height but HTU showed positive ($P<0.01$) and negative ($P<0.05$) influence on plant height during sowing to 4th leaf emergence and panicle initiation to 50% flowering stage, respectively (Table 4.2.21, 4.2.22 and 4.2.23) similar types of correlation for Gobindabhog paddy was reported by Mahata (2014)

4.2.3.1.2 Effect of nutrient management

Plant height of Radhatilak paddy varied significantly among nutrient management practices throughout the cropping period during both 2012 and 2013, except at 56 and 84 DAT in first year of investigation (Table 4.2.7). Based on pooled data, the highest plant height was recorded with inorganic nutrient management @ 50:25:25 of $N:P_2O_5:K_2O$ kg ha^{-1} (N_1), while the lowest height was noted with organic sources of nutrients (N_4) in the study.

4.2.3.1.3 Interaction effect between planting time and nutrient management

There was no significant interaction effect between planting time and nutrient management on the plant height of Radhatilak rice throughout the cropping period during both the years of investigation, except at harvest during 2012 only (Table 4.2.7).

4.2.3.2 TIllering pattern

The number of tillers m^{-2} was increased upto 56 DAT (*i.e.* upto panicle initiation stage) irrespective of planting time and nutrient management, and declined thereafter (Table 4.2.8, Plate 4.2.17), mainly due to death or withering of some late or unproductive tillers as suggested by Matsushima (1957) and Ishizuka and Tanaka (1963).

4.2.3.2.1 Effect of planting time

There was significant variation among three planting periods for number of tillers m^{-2} of Radhatilak paddy at 56 DAT for both the years and at 84 DAT for 2012 and pooled values in the experiment (Table 4.2.8).

Table 4.2.8

Effect of planting time and nutrient management on tillering pattern at different growth stages of Radhatilak rice

Treatment	Number of tillers m^{-2}								
	28 DAT			56 DAT			84 DAT		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	345.1	306.0	325.6	398.1	375.1	386.6	359.0	330.0	344.5
D_2	338.1	311.8	324.9	390.4	341.8	366.1	333.6	305.7	319.7
D_3	307.6	296.7	302.1	339.9	337.8	338.8	321.6	296.7	309.1
S.Em (±)	10.88	7.20	6.52	7.02	5.95	4.60	4.52	9.61	5.31
C.D. at 5%	NS	NS	NS	27.56	23.36	15.00	17.75	NS	17.32
Nutrient management									
N_1	344.7	324.6	334.7	385.4	358.0	371.7	340.2	313.0	326.6
N_2	334.8	311.4	323.1	380.7	348.2	364.4	343.8	317.5	330.6
N_3	326.9	283.4	305.2	373.3	348.5	360.9	338.3	309.4	323.8
N_4	314.7	299.8	307.3	365.2	351.5	358.3	330.0	303.4	316.7
S.Em (±)	8.19	5.39	4.90	6.18	4.76	3.90	5.78	6.51	4.35
C.D. at 5%	NS	16.02	14.06	NS	NS	NS	NS	NS	NS
Interaction effect									
D_1N_1	342.1	331.5	336.8	398.5	384.3	391.4	346.1	316.8	331.5
D_1N_2	349.7	308.0	328.9	403.6	366.7	385.1	366.7	328.5	347.6
D_1N_3	342.1	285.3	313.7	406.5	366.7	386.6	374.3	346.1	360.2
D_1N_4	346.5	299.2	322.9	383.9	382.7	383.3	349.1	328.5	338.8
D_2N_1	371.2	349.1	360.1	404.7	354.0	379.3	347.3	323.9	335.6
D_2N_2	319.1	328.5	323.8	382.4	336.0	359.2	353.2	310.0	331.6
D_2N_3	335.5	276.9	306.2	386.7	344.4	365.5	312.9	300.4	306.7
D_2N_4	326.7	292.5	309.6	387.9	332.7	360.3	320.9	288.7	304.8
D_3N_1	320.8	293.3	307.1	353.1	335.6	344.3	327.1	298.3	312.7
D_3N_2	335.5	297.6	316.5	356.0	342.0	349.0	311.5	313.9	312.7
D_3N_3	303.2	288.0	295.6	326.7	334.4	330.5	327.7	281.6	304.7
D_3N_4	270.9	307.7	289.3	323.7	339.1	331.4	320.0	292.9	306.5
D × N									
S.Em (±)	14.19	9.34	8.49	10.70	8.24	6.75	10.02	11.27	7.54
C.D. at 5%	NS	27.75	NS	NS	NS	NS	NS	NS	21.63
				N × D					
S.Em (±)	16.41	10.83	9.83	11.62	9.29	7.44	9.78	13.70	8.42
C.D. at 5%	NS	36.74	NS	NS	NS	NS	NS	NS	26.79

DAT = Days after transplanting; NS = Not significant

Radhatilak rice planted on 2nd week of July (D_1) usually produced the highest number of tillers in 1m^{-2} area compared to delayed plantings (4th week of July and 2nd week of August) at all three stages of observation like 28, 56 and 84 DAT.

4.2.3.2.2 Effect of nutrient management

The effect of nutrient management on production of tiller m^{-2} was found significant at 28 DAT during second year and pooled values in the investigation (Table 4.2.8).

4.2.3.2.3 Interaction effect between planting time and nutrient management

There was no significant interaction effect of planting time and nutrient management on tiller production of Radhatilak rice throughout the cropping period during both the years of investigation, except 28 DAT during 2013 and at 84 DAT for pooled over two years (Table 4.2.8).

4.2.3.3 Leaf area index

The foliage growth of rice in terms of LAI was increased consistently upto 84 DAT (*i.e.* flowering stage) and declined thereafter due to drying and withering of lower leaves during the ripening phase (Table 4.2.9). Mean value of pooled LAI, averaged over planting times or nutrient management, was 1.69, 3.40, 4.49 and 2.71 at 28, 56 and 84 DAT, and maturity stage, respectively.

4.2.3.3.1 Effect of planting time

There was no definite steady trend of LAI values with the advancement of crop age among three planting times in the study. Radhatilak rice planted on 2nd week of July (D_1) usually recorded the highest LAI values throughout the cropping period compared to other two late plantings (D_2 and D_3) during both 2012 and 2013, excluding at 28 DAT in first year (Table 4.2.9).

4.2.3.3.2 Effect of nutrient management

The significant variation in LAI values due to nutrient management practices was observed throughout the cropping period, except at 84 DAT during 2013 only in the study (Table 4.2.9). Sole applications of chemical fertilizers @ 50:25:25 kg ha^{-1} (N_1) usually resulted in highest LAI values at all four stages of observation, being mostly on par with integrated nutrient dose (50% RD as inorganic + 50% RD as organic), but sole organic sources (N_4) might have slow and less effect toward the foliage growth of Radhatilak paddy in the experiment.

Table 4.2.9

Effect of planting time and nutrient management on LAI at different growth stages of Radhatilak rice during *kharif* season

Treatment	Leaf area index (LAI)											
	28 DAT			56 DAT			84 DAT			At harvest		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time												
D_1	1.67	1.70	1.68	3.56	3.35	3.46	4.70	4.56	4.63	2.72	2.84	2.78
D_2	1.84	1.68	1.76	3.54	3.27	3.40	4.54	4.36	4.45	2.66	2.79	2.73
D_3	1.68	1.56	1.62	3.43	3.23	3.33	4.43	4.32	4.38	2.58	2.63	2.61
S.Em (±)	0.05	0.01	0.03	0.05	0.09	0.05	0.07	0.07	0.05	0.03	0.06	0.04
C.D. at 5%	NS	0.05	0.08	NS	NS	NS	NS	NS	0.17	NS	NS	0.11
Nutrient management												
N_1	1.86	1.79	1.83	3.71	3.42	3.57	4.78	4.57	4.68	2.79	2.90	2.84
N_2	1.87	1.72	1.80	3.63	3.36	3.49	4.54	4.40	4.47	2.66	2.84	2.75
N_3	1.58	1.58	1.58	3.41	3.30	3.35	4.64	4.45	4.55	2.69	2.68	2.69
N_4	1.60	1.48	1.54	3.28	3.05	3.17	4.27	4.23	4.25	2.47	2.58	2.53
S.Em (±)	0.05	0.07	0.04	0.11	0.09	0.07	0.11	0.12	0.08	0.07	0.07	0.05
C.D. at 5%	0.15	0.21	0.12	0.33	0.28	0.21	0.33	NS	0.23	0.22	0.22	0.15
Interaction effect												
D_1N_1	1.80	1.82	1.81	3.78	3.42	3.60	4.79	4.72	4.76	2.93	2.94	2.94
D_1N_2	1.94	1.88	1.91	3.67	3.52	3.60	4.64	4.65	4.64	2.76	2.90	2.83
D_1N_3	1.48	1.66	1.57	3.44	3.30	3.37	4.86	4.54	4.70	2.68	2.84	2.76
D_1N_4	1.45	1.43	1.44	3.35	3.16	3.26	4.53	4.34	4.43	2.49	2.66	2.58
D_2N_1	1.92	1.81	1.86	3.68	3.36	3.52	4.83	4.50	4.67	2.77	2.99	2.88
D_2N_2	1.97	1.69	1.83	3.70	3.19	3.45	4.51	4.31	4.41	2.74	2.90	2.82
D_2N_3	1.69	1.60	1.64	3.51	3.52	3.52	4.60	4.35	4.47	2.66	2.63	2.64
D_2N_4	1.80	1.60	1.70	3.26	3.00	3.13	4.20	4.28	4.24	2.49	2.62	2.56
D_3N_1	1.87	1.75	1.81	3.68	3.47	3.58	4.71	4.49	4.60	2.68	2.76	2.72
D_3N_2	1.71	1.60	1.66	3.51	3.37	3.44	4.47	4.25	4.36	2.49	2.72	2.60
D_3N_3	1.56	1.46	1.51	3.29	3.07	3.18	4.47	4.47	4.47	2.74	2.58	2.66
D_3N_4	1.56	1.41	1.49	3.23	3.00	3.12	4.07	4.08	4.08	2.43	2.46	2.45
D × N												
S.Em (±)	0.09	0.12	0.07	0.19	0.16	0.13	0.19	0.20	0.14	0.13	0.13	0.09
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D												
S.Em (±)	0.09	0.11	0.07	0.18	0.17	0.12	0.18	0.19	0.13	0.12	0.13	0.09
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

4.2.3.3.3 Interaction effect between planting time and nutrient management

Planting time × nutrient management effects on LAI were not significant at 28, 56, 84 DAT and harvest during both the years of investigation (Table 4.2.9).

4.2.3.4 Dry matter accumulation

There was steady increasing trend in accumulation of aerial dry matter in Radhatilak rice plants with the advancement of crop growth upto harvest (Table 4.2.10).

4.2.3.4.1 Effect of planting time

The dry matter production m^{-2} in Radhatilak rice was not significantly influenced by planting times from 28 DAT to harvest during both the years, excluding at 84 DAT for 2013 and pooled over two years (Table 4.2.10).

4.2.3.4.2 Effect of nutrient management

The diverse combinations of nutrient sources in the study had significant effect on dry matter yield of Radhatilak paddy at all four stages of observation during first year, while at 56 DAT only during second year (Table 4.2.10). Perusal of data revealed that Radhatilak plants when nourished with chemical fertilizers (N_1) could produce maximum dry matter in unit area compared to either integrated (N_2 and N_3) or organic nutrient management (N_4) in the investigation.

4.2.3.4.3 Interaction effect between planting time and nutrient management

The dry matter yield m^{-2} was not significantly influenced by the interaction effect of planting times and nutrient management at 28, 56, 84 DAT and harvest during both 2012 and 2013 (Table 4.2.10).

4.2.3.5 Crop growth rate (CGR)

CGR, irrespective of planting time or nutritional treatments, decreased from 28–56 DAT to 56–84 DAT; while it showed slight improvement in the next phase *i.e.* from 56–84 DAT to 84–112 DAT (Table 4.2.11).

Table 4.2.10

Effect of planting time and nutrient management on total dry matter production at different growth stages of Radhatilak rice

Treatment	Total dry matter production (g m^{-2})											
	28 DAT			56 DAT			84 DAT			At harvest		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time												
D_1	150.1	142.7	146.4	355.2	344.9	350.1	490.9	508.8	499.9	637.7	664.5	651.1
D_2	159.0	140.1	149.6	357.4	330.9	344.1	475.2	491.1	483.2	632.1	651.5	641.8
D_3	142.6	135.0	138.8	344.8	330.2	337.5	467.8	479.4	473.6	612.1	636.4	624.2
S.Em (±)	6.90	2.66	3.70	5.08	7.68	4.60	5.59	4.64	3.63	9.84	10.71	7.27
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	18.20	11.84	NS	NS	NS
Nutrient management												
N_1	161.9	153.6	157.7	374.6	352.7	363.6	500.7	515.0	507.8	653.7	671.6	662.7
N_2	159.9	144.5	152.2	369.5	346.0	357.8	474.6	492.7	483.7	635.5	665.2	650.3
N_3	142.4	136.1	139.2	340.7	326.8	333.8	487.3	484.3	485.8	625.9	639.5	632.7
N_4	138.1	122.9	130.5	325.1	315.8	320.5	449.3	480.3	464.8	594.0	627.0	610.5
S.Em (±)	5.49	11.52	6.38	10.53	8.11	6.65	11.11	11.75	8.09	11.26	12.23	8.31
C.D. at 5%	16.31	NS	18.29	31.28	24.10	19.06	32.99	NS	23.19	33.45	NS	23.84
Interaction effect												
D_1N_1	157.8	154.6	156.2	380.4	351.5	365.9	499.4	534.8	517.1	680.0	678.8	679.4
D_1N_2	166.1	152.9	159.5	372.0	361.7	366.8	479.6	520.0	499.8	661.3	676.9	669.1
D_1N_3	143.9	146.2	145.1	337.9	339.5	338.7	509.9	493.0	501.4	621.8	663.5	642.7
D_1N_4	132.5	117.1	124.8	330.5	327.0	328.8	474.8	487.4	481.1	587.8	638.9	613.3
D_2N_1	165.7	155.1	160.4	374.9	350.5	362.7	507.2	508.6	507.9	651.4	678.8	665.1
D_2N_2	172.7	139.8	156.3	376.9	327.6	352.3	475.4	482.0	478.7	639.6	669.0	654.3
D_2N_3	147.0	136.5	141.7	355.7	335.3	345.5	480.0	487.9	484.0	630.2	627.9	629.1
D_2N_4	150.7	129.0	139.8	322.2	310.1	316.1	438.2	485.9	462.1	607.0	630.5	618.8
D_3N_1	162.1	151.2	156.6	368.5	356.0	362.3	495.4	501.7	498.6	629.7	657.1	643.4
D_3N_2	141.0	140.8	140.9	359.6	348.7	354.2	468.8	476.1	472.4	605.6	649.7	627.6
D_3N_3	136.2	125.5	130.8	328.6	305.6	317.1	472.0	472.0	472.0	625.8	627.0	626.4
D_3N_4	131.0	122.6	126.8	322.6	310.4	316.5	434.9	467.7	451.3	587.3	611.7	599.5
D × N												
S.Em (±)	9.51	19.95	11.05	18.24	14.05	11.51	19.24	20.36	14.00	19.50	21.19	14.40
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D												
S.Em (±)	10.75	17.48	10.26	16.59	14.39	10.98	17.57	18.23	12.66	19.54	21.25	14.43
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

4.2.3.5.1 Effect of planting time

Planting time had no significant effect on CGR of Radhatilak paddy at three different phases (28–56 DAT, 56–84 DAT and 84–112 DAT) in the study during 2012, 2013 and pooled values (Table 4.2.11)

4.2.3.5.2 Effect of nutrient management

The variations in CGR values at four weeks intervals due to nutrient management practices were not significant during both the years of investigation (Table 4.2.11).

4.2.3.5.3 Interaction effect between planting time and nutrient management

The interaction effect of planting time and nutrient management on CGR was non-significant throughout the cropping period in 2012 and 2013 (Table 4.2.11).

4.2.3.6 Net assimilation rate (NAR)

4.2.1.6.1 Effect if planting time

The pooled values of NAR at all three phases of four weeks duration (28–56 DAT, 56–84 DAT and 84–112 DAT) were significantly influenced due to planting times in the study, along with between 84–112 DAT during 2013 only (Table 4.2.12).

4.2.3.6.2 Effect of nutrient management

NAR, irrespective of nutrition-based treatments, decreased from 28–56 DAT to 56–84 DAT followed by slight improvement between 56–84 DAT and 84–112 DAT during both the years of investigation (Table 4.2.12).

4.2.3.6.3 Interaction effect between planting time and nutrient management

The interaction of planting times and nutrient managements had no significant effect on NAR at 28–56, 56–84 and 84–112 DAT for 2012, 2013 and pooled values in the study (Table 4.2.12).

4.2.4 Yield components and associated characters

4.2.4.2 Panicle length

4.2.4.2.1 Effect of planting time

Planting time had no significant effect on panicle length of Radhatilak rice in both the years of investigation (Table 4.2.13).

Table 4.2.11

Effect of planting time and nutrient management on Crop growth rate at different growth stages of Radhatilak rice

Treatment	Crop growth rate (g m^{-2} day^{-1})								
	28-56 DAT			56-84 DAT			84-112 DAT		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	7.33	7.22	7.27	4.85	5.85	5.35	5.24	5.56	5.40
D_2	7.09	6.81	6.95	4.21	5.72	4.96	5.60	5.73	5.67
D_3	7.22	6.97	7.10	4.39	5.33	4.86	5.15	5.61	5.38
S.Em (±)	0.37	0.35	0.25	0.21	0.42	0.23	0.49	0.53	0.36
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management									
N_1	7.60	7.11	7.35	4.50	5.80	5.15	5.47	5.59	5.53
N_2	7.48	7.20	7.34	3.75	5.24	4.50	5.75	6.16	5.95
N_3	7.08	6.81	6.95	5.24	5.63	5.43	4.95	5.54	5.25
N_4	6.68	6.89	6.79	4.43	5.88	5.16	5.17	5.24	5.20
S.Em (±)	0.41	0.43	0.30	0.60	0.55	0.41	0.51	0.60	0.39
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect									
D_1N_1	7.95	7.03	7.49	4.25	6.55	5.40	6.45	5.14	5.80
D_1N_2	7.35	7.46	7.41	3.85	5.65	4.75	6.49	5.60	6.05
D_1N_3	6.93	6.90	6.91	6.14	5.48	5.81	4.00	6.09	5.04
D_1N_4	7.07	7.50	7.28	5.15	5.73	5.44	4.04	5.41	4.72
D_2N_1	7.47	6.98	7.23	4.72	5.65	5.19	5.15	6.08	5.62
D_2N_2	7.29	6.71	7.00	3.52	5.51	4.52	5.86	6.68	6.27
D_2N_3	7.46	7.10	7.28	4.44	5.45	4.95	5.36	5.00	5.18
D_2N_4	6.12	6.47	6.30	4.14	6.28	5.21	6.03	5.16	5.60
D_3N_1	7.37	7.32	7.34	4.53	5.20	4.87	4.80	5.55	5.17
D_3N_2	7.81	7.43	7.62	3.90	4.55	4.22	4.89	6.20	5.54
D_3N_3	6.87	6.43	6.65	5.12	5.94	5.53	5.49	5.54	5.51
D_3N_4	6.84	6.71	6.78	4.01	5.62	4.81	5.44	5.14	5.29
D × N									
S.Em (±)	0.71	0.75	0.52	1.04	0.95	0.71	0.88	1.03	0.68
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D									
S.Em (±)	0.72	0.73	0.51	0.93	0.93	0.66	0.91	1.04	0.69
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

Table 4.2.12

Effect of planting time and nutrient management on net assimilation rate at different growth stages of Radhatilak rice

Treatment	Net assimilation rate (g m^{-2} day^{-1})								
	28-56 DAT			56-84 DAT			84-112 DAT		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	0.40	0.41	0.41	0.24	0.26	0.25	0.28	0.28	0.28
D_2	0.39	0.42	0.40	0.25	0.26	0.26	0.29	0.29	0.29
D_3	0.41	0.44	0.43	0.26	0.27	0.26	0.29	0.29	0.29
S.Em (±)	0.005	0.007	0.004	0.003	0.004	0.003	0.003	0.002	0.002
C.D. at 5%	NS	NS	0.014	NS	NS	0.008	NS	0.008	0.006
Nutrient management									
N_1	0.37	0.40	0.39	0.24	0.25	0.25	0.27	0.27	0.27
N_2	0.38	0.41	0.39	0.25	0.26	0.25	0.29	0.28	0.28
N_3	0.42	0.43	0.43	0.25	0.26	0.26	0.28	0.29	0.28
N_4	0.43	0.46	0.45	0.27	0.28	0.27	0.31	0.30	0.30
S.Em (±)	0.010	0.010	0.007	0.005	0.005	0.003	0.006	0.006	0.004
C.D. at 5%	0.029	0.029	0.020	0.013	0.014	0.009	0.018	0.017	0.012
Interaction effect									
D_1N_1	0.38	0.40	0.39	0.23	0.25	0.24	0.26	0.27	0.27
D_1N_2	0.37	0.38	0.38	0.24	0.25	0.24	0.28	0.27	0.27
D_1N_3	0.43	0.42	0.43	0.24	0.26	0.25	0.27	0.28	0.28
D_1N_4	0.44	0.46	0.45	0.26	0.27	0.26	0.29	0.29	0.29
D_2N_1	0.37	0.40	0.39	0.24	0.26	0.25	0.27	0.27	0.27
D_2N_2	0.36	0.43	0.39	0.24	0.27	0.26	0.28	0.28	0.28
D_2N_3	0.40	0.41	0.41	0.25	0.26	0.25	0.28	0.29	0.29
D_2N_4	0.41	0.45	0.43	0.27	0.28	0.27	0.31	0.30	0.30
D_3N_1	0.38	0.40	0.39	0.24	0.25	0.25	0.28	0.28	0.28
D_3N_2	0.40	0.42	0.41	0.25	0.26	0.26	0.30	0.29	0.29
D_3N_3	0.43	0.46	0.45	0.26	0.27	0.26	0.28	0.29	0.29
D_3N_4	0.44	0.48	0.46	0.28	0.29	0.28	0.32	0.31	0.31
D × N									
S.Em (±)	0.017	0.017	0.012	0.008	0.008	0.006	0.010	0.010	0.007
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D									
S.Em (±)	0.016	0.016	0.011	0.008	0.008	0.006	0.010	0.009	0.006
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

4.2.4.2.2 Effect of nutrient management

There was no significant influence of nutrient management on panicle length of Radhatilak rice during both 2012 and 2013 in the study (Table 4.1.13)

4.2.4.2.3 Interaction effect between planting time and nutrient management

Planting time × nutrient management effect on panicle length was not found significant during 2012, 2013 and pooled values (Table 4.2.13).

4.2.4.2 Number of panicles m^{-2}

The number of panicles of Radhatilak rice in 1 m^{-2} area for all three planting times and four nutrient management practices were greater in 2012 than those in 2013, which followed the same trend of tillering pattern between two consecutive years of study (Table 4.2.8 and 4.2.13).

4.2.4.2.1 Effect of planting time

Mean number of panicles m^{-2}, pooled over two years, was 335.9, 306.1 and 290.9 with Radhatilak rice planted on 2nd week of July (D_1), 4th week of July (D_2), and 2nd week of August (D_3), respectively (Table 4.2.13), which indicated successive reduction in number of panicles in 1 m^{-2} area with delay in planting from 2nd week of July (D_1) 2nd week of August (D_3) in the investigation (Table 4.2.13).

The thermal indices like GDD. HTU and PTU showed significant positive impact ($P<0.01$) on number of panicles in unit area during both panicle determination (active tillering to panicle initiation) and panicle development (panicle initiation to 50% flowering) stage in the experiment (Table 4.2.20, 4.2.21 and 4.2.22)

4.2.4.2.2 Effect of nutrient management

The number of panicles m^{-2} of Radhatilak rice varied significantly among four nutrient management practices for pooled values only (Table 4.2.13). Integrated supply of nutrients (50% RD as inorganic + 50% RD as mustard cake) resulted in maximum number of panicles in 1 m^{-2} area, while organic sources of nutrients (N_4) led to the production of lowest number of effective tillers m^{-2} during both 2012, 2013 and pooled over two years in the experiment.

Table 4.2.13

Effect of planting time and nutrient management on yield components of Radhatilak rice during *kharif* season

Treatment	Yield components											
	Panicle length (cm)			No. of panicles m^{-2}			No. of filled grains $panicle^{-1}$			1000 grain weight (g)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time												
D_1	23.5	25.3	24.4	344.4	327.4	335.9	134.7	132.8	133.7	11.28	11.27	11.28
D_2	24.1	25.8	25.0	318.1	294.1	306.1	129.5	131.4	130.4	11.26	11.28	11.27
D_3	23.1	25.7	24.4	294.4	287.4	290.9	116.5	125.3	120.9	11.21	11.23	11.22
S.Em (±)	0.46	0.66	0.40	9.72	6.87	5.95	4.14	2.15	2.33	0.027	0.037	0.023
C.D. at 5%	NS	NS	NS	NS	26.99	19.42	NS	NS	7.613	NS	NS	NS
Nutrient management												
N_1	23.6	25.9	24.8	321.8	304.2	313.0	127.0	138.3	132.6	11.26	11.25	11.26
N_2	23.7	25.7	24.7	334.9	308.1	321.5	127.5	130.5	129.0	11.25	11.28	11.26
N_3	23.7	25.5	24.6	309.5	305.2	307.3	126.2	128.1	127.2	11.27	11.24	11.25
N_4	23.3	25.2	24.3	309.7	294.3	302.0	126.8	122.4	124.6	11.23	11.27	11.25
S.Em (±)	0.490	0.346	0.300	7.35	4.66	4.35	3.86	3.34	2.55	0.024	0.057	0.031
C.D. at 5%	NS	NS	NS	NS	NS	12.48	NS	9.92	NS	NS	NS	NS
Interaction effect												
D_1N_1	23.6	25.9	24.8	318.5	325.9	322.2	132.2	139.8	136.0	11.30	11.33	11.32
D_1N_2	23.4	25.6	24.5	333.3	328.9	331.1	137.3	133.4	135.4	11.28	11.31	11.30
D_1N_3	23.6	25.0	24.3	360.0	340.7	350.3	134.4	131.4	132.9	11.31	11.16	11.24
D_1N_4	23.5	24.6	24.0	365.9	314.0	340.0	134.9	126.4	130.6	11.25	11.28	11.26
D_2N_1	23.9	26.1	25.0	322.9	311.1	317.0	134.6	138.5	136.6	11.27	11.17	11.22
D_2N_2	24.8	25.8	25.3	351.1	290.3	320.7	128.9	134.9	131.9	11.28	11.25	11.26
D_2N_3	24.1	25.9	25.0	318.5	290.3	304.4	125.5	129.2	127.3	11.26	11.33	11.30
D_2N_4	23.6	25.5	24.5	280.0	284.4	282.2	128.9	122.9	125.9	11.22	11.35	11.28
D_3N_1	23.5	25.7	24.6	324.0	275.5	299.8	114.2	136.4	125.3	11.20	11.26	11.23
D_3N_2	22.9	25.9	24.4	320.3	305.2	312.8	116.4	123.1	119.8	11.19	11.27	11.23
D_3N_3	23.4	25.6	24.5	250.0	284.4	267.2	118.7	123.8	121.2	11.22	11.23	11.23
D_3N_4	22.8	25.6	24.2	283.3	284.4	283.9	116.7	117.8	117.3	11.22	11.18	11.20
D × N												
S.Em (±)	0.85	0.60	0.52	12.73	8.08	7.54	6.684	5.781	4.418	0.042	0.099	0.054
C.D. at 5%	NS	NS	NS	37.83	NS	21.62	NS	NS	NS	NS	NS	NS
N × D												
S.Em (±)	0.87	0.84	0.60	14.70	9.81	8.84	7.12	5.45	4.48	0.046	0.093	0.052
C.D. at 5%	NS	NS	NS	49.82	NS	28.02	NS	NS	NS	NS	NS	NS

NS = Not significant

4.2.4.2.3 Interaction effect between planting time and nutrient management

The interaction effect between planting time and nutrient management on number of panicles m^{-2} was significant in 2012 and pooled over two years (Table 4.2.13).

4.2.4.3 Number of filled grains panicle^{-1}

4.2.4.3.1 Effect of planting time

Radhatilak rice planted on 2nd week of July (D_1) recorded the highest number of filled grains (133.72) panicle^{-1} compared to either of mid (4th week of July) or late plantings (2nd week of August) during both the years of study (Table 4.2.13; Plate 4.2.9).

The positive correlations ($P<0.01$) of GDD and PTU with the number of filled grains panicle^{-1} during grain development (50% flowering to dough) and ripening (dough to maturity) stages, and HTU during dough to maturity stage only indicated that both air temperature and day length had positive influence on grain filling (*i.e.* translocation of photosynthates to sink) and development, while bright sunshine hour favoured the ripening of Radhatilak rice grain towards the maturity (Table 4.2.13)

4.2.4.3.2 Effect of nutrient management

There was progressive improvement in number of filled grains panicle^{-1} with gradual increase in inorganic nutrient sources ($N_1>N_2>N_3>N_4$) during 2012, 2013 and pooled over 2 years (Table 4.2.13).

4.2.4.3.3 Interaction effect between planting time and nutrient management

Significant interaction effect between planting time and nutrient management on number of filled grains panicle^{-1} was not found during both the years of investigation (Table 4.2.13).

4.2.4.4 1000 grain weight

4.2.4.4.2 Effect of planting time

Planting of Radhatilak paddy at three different times (2nd week of July, 4th week of July and 2nd week of August) did not register any significant variation in test weight of grains during 2012, 2013 and pooled over two years in the investigation (Table 4.2.13).

4.2.4.4.2 Effect of nutrient management

The varied combination of sources of nutrients had no significant effect on 1000 grain weight of grains of Radhatilak paddy during both the years of study (Table 4.2.13)

4.2.4.4.3 Interaction effect between planting time and nutrient management

No significant interaction between planting time and nutrient management on test weight of grain was noted during both first and second year of experiment (Table 4.2.13).

4.2.5 Yield and lodging

4.2.5.1 Grain yield

4.2.5.1.1 Effect of planting time

Grain yield, an end product of interaction among yield components, differed significantly among planting times during both the years of investigation (Table 4.2.14; Fig. 4.2.2; Plate 4.2.18). The grain yield of early (2^{nd} week of July) and mid (4^{th} week of July) planting times were at par, which declined for further delay in planting during 2^{nd} week of August (D_3). Radhatilak rice planted on 2^{nd} week of July (D_1) produced the highest pooled grain yield (3.00 t ha^{-1}), which was 2.94 and 12.78% greater over planting in 4^{th} week of July (D_2) 2^{nd} week of August (D_3), respectively. Similar types of findings for Gobindabhog paddy was reported by Mahata (2014), wherein planting on July 25 resulted in highest grain yield (3.02 t ha^{-1}) compared to early (July 10) or late plantings (August 10 and 25) at Kalyani West Bengal.

The correlation studies between thermal indices and grain yield revealed that GDD and PTU had positive influence ($P<0.05$ or $P<0.01$) throughout the cropping period, but HTU showed positive impact ($r = 0.235^*$ and $r = 0.378^*$) on economic yield during active tillering to panicle initiation and dough to maturity stage, respectively (Table 4.2.20, 4.2.21 and 4.2.22).

4.2.5.1.2 Effect of nutrient management

The nutrient combination-based treatments in the study significantly influenced the grain yield of Radhatilak paddy for 2012 and pooled values over two years (Table 4.2.14). Sole application of chemical fertilizers (N_1) or integrated nutrient management (50% RD inorganic + 50% RD organic) resulted in the similar non-significant grain

Table 4.2.14

Effect of planting time and nutrient management on grain yield, straw yield, harvest index and lodging of Radhatilak rice

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Harvest index			Lodging (score)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time												
D_1	3.07	2.93	3.00	5.43	5.95	5.69	0.36	0.33	0.35	3.17	3.67	3.42
D_2	3.02	2.86	2.94	5.33	5.43	5.38	0.36	0.34	0.35	2.33	2.33	2.33
D_3	2.63	2.69	2.66	4.84	5.03	4.93	0.35	0.35	0.35	2.00	2.33	2.17
S.Em (±)	0.03	0.03	0.02	0.056	0.094	0.055	0.004	0.004	0.003	0.565	0.674	0.440
C.D. at 5%	0.10	0.12	0.06	0.220	0.371	0.179	NS	NS	NS	NS	NS	NS
Nutrient management												
N_1	2.98	2.95	2.97	5.69	5.76	5.72	0.34	0.34	0.34	3.22	3.00	3.11
N_2	3.07	2.84	2.96	5.50	5.57	5.53	0.36	0.34	0.35	3.00	3.00	3.00
N_3	2.90	2.79	2.85	5.02	5.38	5.20	0.37	0.34	0.36	2.11	2.56	2.33
N_4	2.66	2.71	2.69	4.60	5.17	4.88	0.36	0.34	0.35	1.67	2.56	2.11
S.Em (±)	0.03	0.07	0.04	0.107	0.096	0.072	0.005	0.008	0.005	0.454	0.525	0.347
C.D. at 5%	0.09	NS	0.10	0.317	0.287	0.206	0.016	NS	NS	NS	NS	NS
Interaction effect												
D_1N_1	3.10	3.07	3.09	6.10	6.23	6.17	0.34	0.33	0.34	3.67	4.33	4.00
D_1N_2	3.25	2.92	3.09	5.73	6.10	5.92	0.36	0.32	0.34	3.67	4.33	4.00
D_1N_3	3.05	2.94	3.00	5.13	5.87	5.50	0.37	0.33	0.35	3.00	3.00	3.00
D_1N_4	2.86	2.79	2.83	4.77	5.60	5.18	0.38	0.33	0.36	2.33	3.00	2.67
D_2N_1	3.00	2.97	2.99	5.73	5.73	5.73	0.34	0.34	0.34	3.00	2.33	2.67
D_2N_2	3.11	2.82	2.97	5.60	5.50	5.55	0.36	0.34	0.35	3.00	2.33	2.67
D_2N_3	3.01	2.85	2.93	5.30	5.33	5.32	0.36	0.35	0.36	1.67	2.33	2.00
D_2N_4	2.93	2.80	2.87	4.70	5.13	4.92	0.38	0.35	0.37	1.67	2.33	2.00
D_3N_1	2.83	2.82	2.82	5.23	5.30	5.27	0.35	0.35	0.35	3.00	2.33	2.67
D_3N_2	2.84	2.79	2.82	5.17	5.10	5.13	0.36	0.35	0.36	2.33	2.33	2.33
D_3N_3	2.65	2.59	2.62	4.63	4.93	4.78	0.36	0.35	0.36	1.67	2.33	2.00
D_3N_4	2.19	2.54	2.37	4.33	4.77	4.55	0.33	0.35	0.34	1.00	2.33	1.67
D × N												
S.Em (±)	0.05	0.11	0.06	0.185	0.167	0.125	0.009	0.013	0.008	0.79	0.91	0.60
C.D. at 5%	0.15	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D												
S.Em (±)	0.05	0.10	0.06	0.17	0.17	0.12	0.009	0.012	0.007	0.88	1.04	0.68
C.D. at 5%	0.17	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

yields of Radhatilak rice, while increment in dose of organic manures (N_3 and N_4) showed lower economic yields probably due to slow release of nutrients from organic sources compared to straight fertilizes in the investigation.

4.2.5.1.3 Interaction effect between planting time and nutrient management

Planting time × nutrient management interaction effect on grain yield was found significant during 2012 only in 2-year experiment (Table 4.2.14). Based on pooled data, Radhatilak rice planted in 2nd week of July (D_1) along with either fertilizer-based treatment (N_1) or integrated nutrient management (N_2) produced the highest grain yield (3.14 t ha^{-1}) at Kalyani, West Bengal.

4.2.5.2 Straw yield

Straw yield of Radhatilak rice, irrespective of planting times and nutrient management practices, was slightly greater during 2013 than 2012 (Table 4.2.14), which might be due to better growth and development of the crop, being quantified in terms of plant height (Table 4.2.7), tiller production (Table 4.2.8) and leaf growth (Table 4.2.9) during second year than first year in the study.

4.2.5.2.1 Effect of planting time

Straw yield, an index of vegetative growth, was found to differ significantly among three planting times during first year, second year and pooled for two years in the investigation (Table 4.2.14). The highest and lowest straw yields were recorded with the crop planted on 2nd week of July (5.43 and 5.95 t ha^{-1}) and 2nd week of August (4.84 and 5.03 t ha^{-1}), respectively during both 2012 and 2013.

4.2.5.2.2 Effect of nutrient management

The inorganic nutrient management (N_1) of Radhatilak paddy resulted in 1.09 and 0.59 t ha^{-1} greater straw yield over organic nutrient management (N_4) during 2012 and 2013 respectively (Table 4.2.14). However, integrated nutrient management (N_2 and N_3) showed intermediate effect on straw yield during both the years of study.

4.2.5.2.3 Interaction effect between planting time and nutrient management

The effect of interaction between planting time and nutrient management on straw yield was not significant during both the years of investigation (Table 4.2.14).

4.2.5.3 Harvest index

4.2.5.3.1 Effect of planting time

The harvest index of Radhatilak rice was not influenced by planting times during both 2012 and 2013 in the experiment (Table 4.2.14).

4.2.5.3.2 Effect of nutrient management

The variation in dose of nutrient sources did not affect significantly the harvest index of Radhatilak rice during 2013 and pooled over two years of (Table 4.2.14), while significant difference was noted in the first year.

4.2.5.3.3 Interaction effect between planting time and nutrient management

There was no significant effect of planting time and nutrient management on harvest index during both the years of investigation (Table 4.2.14).

4.2.5.4 Lodging

The lodging scores assigned with both main and sub-plot treatments indicated that most (>50%) of Radhatilak plants had a general tendency to lodge down slightly (score 3.00) at hard dough stage in the study.

4.2.5.4.2 Effect of planting time

The lodging tendency of Radhatilak paddy at hard dough stage was not significantly influenced due to variation in planting times (Table 4.2.14). Mean lodging score, pooled over two years, was found to decrease from 3.42 (D_1) to 2.17 (D_3) with delay in planting from 2nd week of July (D_1) to 2nd week of August (D_3) probably due to successive reduction in plant height in later planted crop compared to two earlier planted ones (Table 4.2.7) in the study.

4.2.5.4.2 Effect of nutrient management

With increment in inorganic nutrient sources (N_1>N_2>N_3) from organic nutrient management (N_4), the plants of Radhatilak paddy became more susceptible to lodging at hard dough stage, but the differences in lodging scores were not significant during 2012, 2013 and pooled values in the experiment (Table 4.2.14).

4.2.5.4.3 Interaction effect between planting time and nutrient management

The interaction effect between planting time and nutrient management on lodging of Radhatilak paddy was not found significant during both the years of investigation (Table 4.2.14).

4.2.6 Grain quality

4.2.6.1 Milling quality

4.2.6.1.1 Hulling

4.2.6.1.1.1 Effect of planting time

The differences in brown rice content due to varied planting times were not significant during both 2012 and 2013 in the study (Table 4.2.15).

4.2.6.1.1.2 Effect of nutrient management

The variation in dose of nutrient sources could not affect the hulling recovery of Radhatilak rice during both the years of experimentation (Table 4.2.15).

4.2.6.1.1.3 Interaction effect between planting time and nutrient management

The interaction effect between planting time and nutrient management with regard to hulling recovery of Radhatilak rice was not found significant during both 2012 and 2013 (Table 4.2.15).

4.2.6.1.2 Milling

4.2.6.1.2.1 Effect of planting time

Like hulling recovery, similar trend of non-significant variation in milling recovery due to three planting times was also noted in the experiment (Table 4.2.15).

4.2.6.1.2.2 Effect of nutrient management

Nutrient management practices could not affect the milling yield of Radhatilak rice in the study during both the years of investigation (Table 4.2.15).

4.2.6.1.2.3 Interaction effect between planting time and nutrient management

No significant interaction effect of planting time and nutrient management was found on milling recovery of Radhatilak rice during both 2012 and 2013 (Table 4.2.15).

Table 4.2.15

Effect of planting time and nutrient management on milling quality of Radhatilak rice during *kharif* season

Treatment	Milling quality								
	Hulling (%)			Milling (%)			Head rice recovery (%)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	77.3	77.3	77.3	69.9	71.2	70.6	61.0	62.6	61.8
D_2	77.0	77.1	77.0	69.3	70.9	70.1	61.4	63.0	62.2
D_3	76.8	77.3	77.0	69.2	71.3	70.2	61.1	63.1	62.1
S.Em (±)	0.18	0.06	0.09	0.37	0.24	0.22	0.31	0.26	0.20
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management									
N_1	77.0	77.3	77.2	69.8	70.7	70.3	60.7	62.1	61.4
N_2	77.3	77.3	77.3	69.4	71.0	70.2	60.7	63.4	62.1
N_3	77.0	77.2	77.1	69.2	71.2	70.2	61.5	62.8	62.1
N_4	76.7	77.2	77.0	69.4	71.6	70.5	61.7	63.3	62.5
S.Em (±)	0.21	0.28	0.17	0.36	0.26	0.22	0.31	0.44	0.27
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	0.78
Interaction effect									
D_1N_1	77.2	77.5	77.3	70.2	70.5	70.3	60.1	62.3	61.2
D_1N_2	77.4	77.3	77.3	69.6	71.5	70.5	61.0	63.2	62.1
D_1N_3	77.7	77.1	77.4	70.2	71.3	70.7	61.3	62.3	61.8
D_1N_4	76.9	77.4	77.2	69.6	71.6	70.6	61.5	62.8	62.1
D_2N_1	77.2	77.3	77.2	69.5	70.5	70.0	60.9	61.5	61.2
D_2N_2	77.4	77.4	77.4	69.7	70.9	70.3	60.5	63.7	62.1
D_2N_3	76.7	77.3	77.0	68.4	70.8	69.6	61.6	63.4	62.5
D_2N_4	76.5	76.5	76.5	69.5	71.3	70.4	62.7	63.2	62.9
D_3N_1	76.6	77.2	76.9	69.9	71.0	70.4	61.1	62.4	61.8
D_3N_2	77.1	77.1	77.1	68.9	70.7	69.8	60.7	63.3	62.0
D_3N_3	76.5	77.0	76.8	69.1	71.4	70.3	61.4	62.8	62.1
D_3N_4	76.7	77.7	77.2	68.9	71.9	70.4	61.0	63.8	62.4
D × N									
S.Em (±)	0.36	0.49	0.30	0.62	0.45	0.38	0.54	0.77	0.47
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D									
S.Em (±)	0.36	0.42	0.28	0.65	0.46	0.40	0.56	0.71	0.45
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

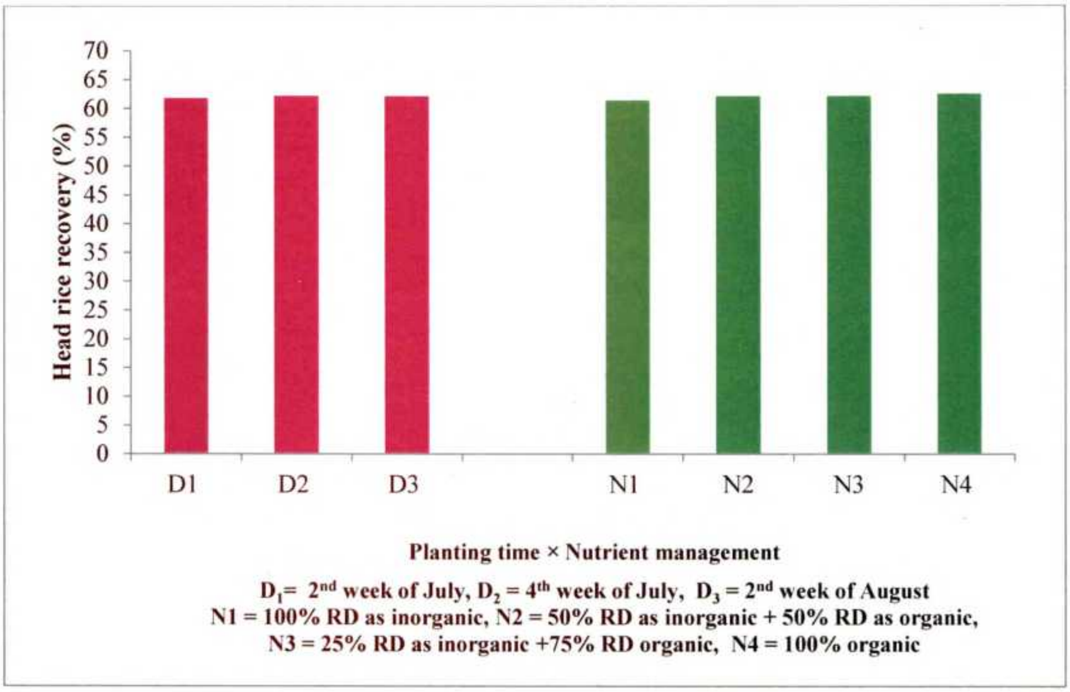


Fig. 4.2.3: Effect of planting time and nutrient management on head rice recovery (%) of Radhatilak rice during *kharif* season (pooled over two years)

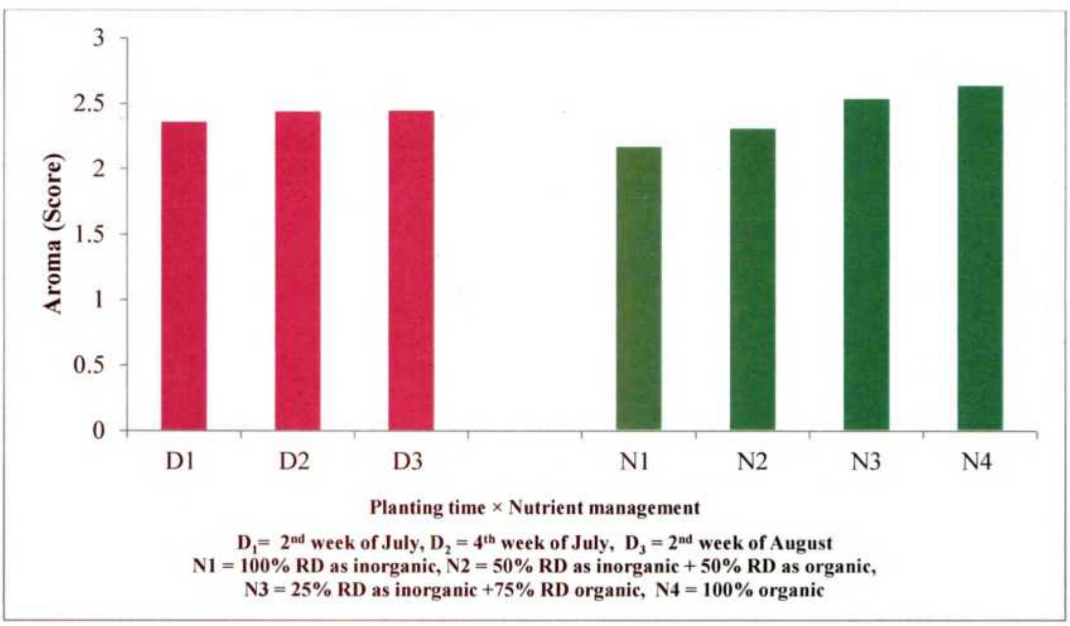


Fig. 4.2.4: Effect of planting time and nutrient management on aroma (score) of Radhatilak rice during *kharif* season (pooled over two years)

4.2.6.1.3 Head rice

4.2.6.1.3.1 Effect of planting time

Planting time had no significant effect on head rice yield (%) of Radhatilak rice during both the years of study (Table 4.2.15). However, the positive correlation of HTU (r = 0.321**) with head rice recovery of Radhatilak rice during milk to dough stage indicated that bright sunshine hour favoured the development-cum-compaction of rice grain, thereby making them less prone to breakage during milling (Table 4.2.15 and Fig. 4.2.3).

4.2.6.1.3.2 Effect of nutrient management

The head rice recovery of Radhatilak rice was influenced by nutrient management for pooled over two years only (Table 4.2.15) the use of organic manure @ 25% RD (N_2), 50% RD (N_3) and 100% RD (N_4) progressively improved HRR (%) over chemical-potassium -based nutrient management (N_1) during *kharif* season.

4.2.6.1.3.3 Interaction effect between planting time and nutrient management

Planting time × nutrient management interaction effect on head rice content (%) of Radhatilak rice was not significant in the experiment (Table 4.2.15).

4.2.6.2 Physical properties of grain

4.2.6.2.1 Kernel length

4.2.6.2.1.1 Effect of planting time

Kernel length, being a genetical character, did not differ significantly among three planting times during *kharif* season of both 2012 and 2013 (Table 4.2.16).

4.2.6.2.1.2 Effect of nutrient management

There was no significant difference in kernel length due to variation in nutrient doses during both 2012 and 2013 (Table 4.2.16).

Table 4.2.16

Effect of planting time and nutrient management on physical properties of grains of Radhatilak rice during *kharif* season

Treatment	Physical properties of grain								
	Kernel length (mm)			Kernel breadth (mm)			L / B ratio		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	4.01	4.05	4.03	1.95	2.00	1.98	2.06	2.03	2.04
D_2	4.00	4.05	4.02	1.97	1.99	1.98	2.04	2.03	2.04
D_3	4.02	4.05	4.03	1.96	2.00	1.98	2.05	2.03	2.04
S.Em (±)	0.006	0.008	0.005	0.004	0.006	0.004	0.006	0.004	0.004
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management									
N_1	4.01	4.04	4.03	1.96	1.99	1.98	2.05	2.03	2.04
N_2	4.01	4.06	4.03	1.97	1.99	1.98	2.04	2.04	2.04
N_3	4.00	4.04	4.02	1.93	1.99	1.96	2.07	2.03	2.05
N_4	4.01	4.06	4.03	1.98	2.01	1.99	2.03	2.02	2.02
S.Em (±)	0.013	0.017	0.011	0.009	0.011	0.007	0.010	0.013	0.008
C.D. at 5%	NS	NS	NS	0.027	NS	0.020	0.030	NS	NS
Interaction effect									
D_1N_1	4.00	4.05	4.03	1.95	2.00	1.98	2.05	2.03	2.04
D_1N_2	4.00	4.04	4.02	1.97	2.00	1.98	2.04	2.02	2.03
D_1N_3	4.00	4.04	4.02	1.92	1.98	1.95	2.09	2.04	2.07
D_1N_4	4.02	4.07	4.05	1.97	2.02	1.99	2.04	2.02	2.03
D_2N_1	4.00	4.05	4.03	1.98	1.98	1.98	2.02	2.05	2.03
D_2N_2	4.02	4.05	4.04	1.97	2.00	1.98	2.05	2.03	2.04
D_2N_3	3.99	4.02	4.00	1.93	1.98	1.96	2.06	2.03	2.05
D_2N_4	3.99	4.05	4.02	1.98	2.00	1.99	2.01	2.03	2.02
D_3N_1	4.02	4.02	4.02	1.95	2.00	1.98	2.06	2.01	2.04
D_3N_2	4.00	4.09	4.05	1.97	1.97	1.97	2.04	2.08	2.06
D_3N_3	4.02	4.05	4.04	1.95	2.02	1.98	2.06	2.01	2.04
D_3N_4	4.02	4.05	4.04	1.98	2.02	2.00	2.03	2.01	2.02
D × N									
S.Em (±)	0.023	0.029	0.018	0.016	0.019	0.012	0.018	0.022	0.014
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D									
S.Em (±)	0.021	0.026	0.017	0.014	0.017	0.011	0.016	0.019	0.013
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

4.2.6.2.1.3 Interaction effect between planting time and nutrient management

The interaction effect between planting time and nutrient management towards kernel length was not significant during both 2012 and 2013 (Table 4.2.16).

4.2.6.2.2 Kernel breadth

4.2.6.2.2.1 Effect of planting time

The breadth of Radhatilak rice kernel was not significantly influenced by three planting periods during *kharif* season of both 2012 and 2013 (Table 4.2.16),

4.2.6.2.2.2 Effect of nutrient management

4.2.6.2.2.3 Interaction effect between planting time and nutrient management

No significant interaction effect on kernel breadth was found in the investigation (Table 4.2.16).

4.2.6.2.3 L / B ratio

4.2.6.2.3.1 Effect of planting time

Like kernel length and breadth, L / B ratio was not affected due to three planting times during *kharif* season of 2012 and 2013 (Table 4.2.16).

4.2.6.2.3.2 Effect of nutrient management

L / B ratio of Radhatilak rice remained unaffected due to four nutrient management practices adopted in the study during 2013 and pooled over two years, excluding first year of investigation (Table 4.2.16).

4.2.6.2.3.3 Interaction effect between planting time and nutrient management

The L / B ratio of rice kernel was not significantly influenced by four levels of nutrient combinations used in the experiment during both 2012 and 2013 (Table 4.2.16).

4.2.6.2.4 Kernel type, colour and chalkiness

4.2.6.2.4.2 Effect of planting time

All the kernels of Radhatilak rice obtained from the plots assigned for different planting times belonged to short bold (SB) category, based on their respective length and L/B ratio during both the years of investigation (Table 4.2.17). The colour of rice

Table 4.2.17

Effect of planting time and nutrient management on physical properties of grains of Radhatilak rice during *kharif* season

Treatment	Physical properties of grain					
	Kernel type		Chalkiness		Kernel colour	
	2012	2013	2012	2013	2012	2013
Planting time						
D_1	SB	SB	Absent	Absent	White	White
D_2	SB	SB	Absent	Absent	White	White
D_3	SB	SB	Absent	Absent	White	White
Nutrient management						
N_1	SB	SB	Absent	Absent	White	White
N_2	SB	SB	Absent	Absent	White	White
N_3	SB	SB	Absent	Absent	White	White
N_4						
Interaction effect						
D_1N_1	SB	SB	Absent	Absent	White	White
D_1N_2	SB	SB	Absent	Absent	White	White
D_1N_3	SB	SB	Absent	Absent	White	White
D_1N_4	SB	SB	Absent	Absent	White	White
D_2N_1	SB	SB	Absent	Absent	White	White
D_2N_2	SB	SB	Absent	Absent	White	White
D_2N_3	SB	SB	Absent	Absent	White	White
D_2N_4	SB	SB	Absent	Absent	White	White
D_3N_1	SB	SB	Absent	Absent	White	White
D_3N_2	SB	SB	Absent	Absent	White	White
D_3N_3	SB	SB	Absent	Absent	White	White
D_3N_4	SB	SB	Absent	Absent	White	White

kernel was white irrespective of planting time during *kharif* season and chalkiness in grain was usually absent, excluding a few exceptions as observed in the laboratory (Plate 4.2.11).

4.2.6.2.4.2 Effect of nutrient management

Four levels of nutrient management for Radhatilak paddy could not affect the kernel shape or type, colour and abdominal white during both 2012 and 2013 (Table 4.2.17).

4.2.6.2.4.3 Interaction effect between planting time and nutrient management

The non-significant interaction effect revealed that Radhatilak rice had short bold type, white and non-chalky kernels irrespective of planting time and nutrient management adopted in the study (Table 4.2.17).

4.2.6.3 Cooking quality and nutritional quality

4.2.6.3.1 Amylose content

Mean amylose content in Radhatilak rice grain, based on pooled values either with planting times or with nutrient management practices, was ±18.66%, which indicated that the variety belonged to low (9–20%) amylose group, but very close to lower range of intermediate (20–25%) amylose content category (Table 4.2.18 and Fig. 4.2.4).

4.2.6.3.1.1 Effect of planting time

Amylose content in grain was significantly influenced by three planting times during 2012, 2013 and pooled over two years in the investigation (Table 4.2.18). Radhatilak rice planted during 2nd week of July (D_1) recorded the highest amylose content (19.69 and 18.11%) for the both the years; but the lowest amylose content was noted with the crop planted on 2nd week of August (19.05%) during first year and with the crop planted on 4th week of July (17.51%) during second year of the experiment. Thus, planting of Radhatilak paddy in 2nd week July (D_1) might result in greater amylose content in grain compared to late plantings during *kharif* season in New Alluvial Zone of West Bengal. Similar reduction in amylose content in rice grain (cv. Rajendra Suwasini) with delay in planting from July 5 (24.96%) to August 4 (23.93%) in Bihar, India was reported by Chowdhury *et al.* (2011).

Table 4.2.18

Effect of planting time and nutrient management on cooking and nutritional quality of grains of Radhatilak rice

Treatment	Cooking and nutritional quality of grain								
	Amylose content (%)			Protein content (%)			Alkali value (score)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	19.69	18.11	18.90	7.06	7.07	7.06	3.58	3.58	3.58
D_2	19.55	17.51	18.53	7.12	7.20	7.16	3.67	3.58	3.63
D_3	19.05	18.05	18.55	6.71	7.51	7.11	3.33	3.25	3.29
S.Em (±)	0.22	0.27	0.17	0.12	0.22	0.12	0.13	0.24	0.14
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management									
N_1	17.65	17.13	17.39	7.33	7.61	7.47	3.78	3.56	3.67
N_2	19.65	17.80	18.72	7.14	7.52	7.33	3.44	3.78	3.61
N_3	19.75	17.96	18.86	6.76	7.21	6.99	3.44	3.33	3.39
N_4	20.67	18.67	19.67	6.62	6.69	6.66	3.44	3.22	3.33
S.Em (±)	0.41	0.48	0.32	0.126	0.324	0.174	0.24	0.18	0.15
C.D. at 5%	1.22	NS	0.91	0.373	NS	0.498	NS	NS	NS
Interaction effect									
D_1N_1	17.75	17.26	17.51	7.46	7.54	7.50	4.00	3.67	3.83
D_1N_2	20.16	17.64	18.90	7.11	7.04	7.08	3.67	3.67	3.67
D_1N_3	19.66	18.37	19.02	6.91	6.75	6.83	3.33	3.67	3.50
D_1N_4	21.18	19.17	20.17	6.75	6.94	6.85	3.33	3.33	3.33
D_2N_1	17.85	16.89	17.37	7.40	7.17	7.29	4.33	3.67	4.00
D_2N_2	20.16	16.89	18.52	7.22	7.54	7.38	3.33	4.00	3.67
D_2N_3	20.24	17.34	18.79	6.98	7.74	7.36	3.33	3.33	3.33
D_2N_4	19.96	18.94	19.45	6.88	6.35	6.62	3.67	3.33	3.50
D_3N_1	17.35	17.23	17.29	7.14	8.13	7.63	3.00	3.33	3.17
D_3N_2	18.63	18.87	18.75	7.07	8.00	7.54	3.33	3.67	3.50
D_3N_3	19.34	18.18	18.76	6.40	7.14	6.77	3.67	3.00	3.33
D_3N_4	20.87	17.91	19.39	6.24	6.78	6.51	3.33	3.00	3.17
D × N									
S.Em (±)	0.71	0.84	0.55	0.22	0.56	0.30	0.42	0.31	0.26
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D									
S.Em (±)	0.66	0.77	0.51	0.22	0.53	0.29	0.39	0.36	0.26
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

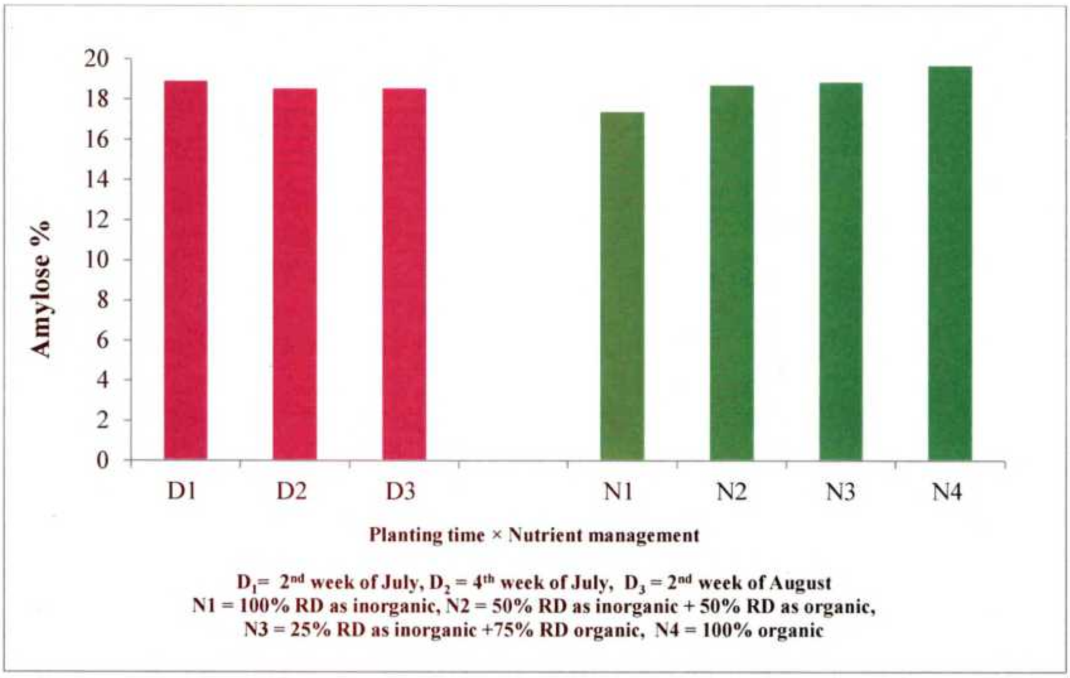


Fig. 4.2.5: Effect of planting time and nutrient management on amylose % of Radhatilak rice during *kharif* season (pooled over two years)

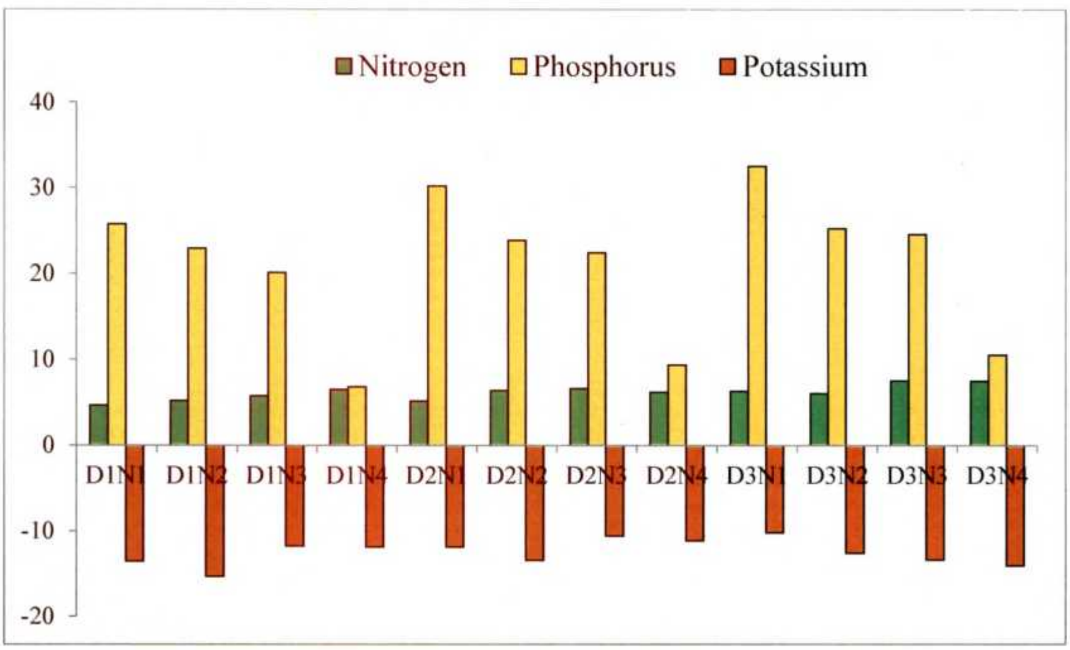


Fig. 4.2.6: Effect of planting time and nutrient management on residual fertility status of Radhatilak rice during *kharif* season (pooled over two years)

The positive influence of GDD (r = 0.240*) during milk to dough stage along with positive (r = 0.319**) and negetative (r = -0.427**) impact of HTU during 50% flowering to milk and milk to dough stage, respectively on amylose content of Radhatilak rice indicated complex relationship among air temperature and bright sunshine hour during ripening period and amylose content in the study (Table 4.2.20 and 4.2.21).

4.2.6.3.1.2 Effect of nutrient management

There was a general significant improving trend in amylose content of Radhatilak rice with the increment in organic sources of nutrients by substitution of chemical fertilizers during 2012, 2013 and pooled over two years of experiment (Table 4.2.18). Thus, organiv nutrient management (25% RD FYM + 75% RD mustard cake) could improve the flakiness of cooked rice due to higher amylose content compared to integrated (N_2 and N_3) or chemical-fertilizer based nutrition of Radhatilak rice at Kalyani, West Bengal.

4.2.6.3.1.3 Interaction effect between planting time and nutrient management

There was significant interaction effect between planting time and nutrient management toward the amylose content of Radhatilak rice grain during both the years of investigation (Table 4.2.18).

4.2.6.3.2 Protein content

4.2.6.3.2.1 Effect of planting time

Planting time could not influence the protein content of Radhatilak rice grain during both the years of investigation (Table 4.2.18).

4.2.6.3.2.2 Effect of nutrient management

There was gradual decrease in grain protein content of Radhatilak rice with increment in organic sources nutrients and the differences among the treatments were significant during 2012 and pooled values in the study (Table 4.2.18). Perusal of data revealed that sole application of chemical fertilizers (N_1) might result in greater protein synthesis compared to either integrated (N_2 and N_3) or sole organic nutrient sources (N_4) in the investigation.

4.2.6.3.2.3 Interaction effect between planting time and nutrient management

Planting time × nutrient management interaction effect on protein content in grain was not significant during both 2012 and 2013 (Table 4.2.18).

4.2.6.3.3 Alkali value or Gelatinization temperature

4.2.6.3.3.1 Effect of planting time

Although there was a steady decrease in alkali value of Radhatilak rice grain with delay in planting time from D_1 to D_3 but the differences was significant for pooled values only (Table 4.2.18; Plate 4.2.12). Thus, gelatinization temperature showed an increasing trend between intermediate (score 4.0) and high-intermediate (score 3.0) with delay in planting from early July to the end of August during *kharif* season.

4.2.6.3.3.2 Effect of nutrient management

Nutrient management practices did not have any significant influence on alkali value of Radhatilak rice during both 2012 and 2013 in the experiment (Table 4.2.18).

4.2.6.3.3.3 Interaction effect between planting time and nutrient management

There was no significant effect between planting time and nutrient management with regard to alkali value of Radhatilak rice during both the years of investigation (Table 4.2.18).

4.2.6.4 Processing quality

4.2.6.4.2 Kernel length after cooking (KLAC)

4.2.6.4.2.1 Effect of planting time

With delay in planting from 2nd week of July (D_1) to 2nd week of August (D_3), the KLAC of Radhatilak rice was found to decrease steadily (7.46 to 7.35 mm for pooled values), and the differences were significant for 2012 and pooled over two years (Table 4.2.19).

4.2.6.4.2.2 Effect of nutrient management

The length of cooked kernel of Radhatilak rice was significantly influenced by nutrient management-based treatments during first year only in the 2-year study (Table 4.2.19).

Table 4.2.19

Effect of planting time and nutrient management on processing quality of grains of Radhatilak rice during *kharif* season

Treatment	Processing quality								
	Kernel length after cooking (mm)			Elongation ratio			Aroma (score)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	7.46	7.46	7.46	1.86	1.84	1.85	2.34	2.38	2.36
D_2	7.32	7.41	7.36	1.83	1.83	1.83	2.44	2.40	2.42
D_3	7.30	7.40	7.35	1.82	1.83	1.82	2.45	2.43	2.44
S.Em (±)	0.02	0.03	0.02	0.006	0.006	0.004	0.03	0.03	0.02
C.D. at 5%	0.09	NS	0.06	0.025	NS	0.014	NS	NS	0.06
Nutrient management									
N_1	7.39	7.41	7.40	1.84	1.83	1.84	2.19	2.30	2.24
N_2	7.42	7.44	7.43	1.85	1.83	1.84	2.31	2.37	2.34
N_3	7.31	7.41	7.36	1.83	1.84	1.83	2.53	2.47	2.50
N_4	7.31	7.44	7.38	1.82	1.84	1.83	2.61	2.47	2.54
S.Em (±)	0.03	0.04	0.02	0.011	0.013	0.008	0.05	0.06	0.04
C.D. at 5%	0.09	NS	NS	NS	NS	NS	0.14	NS	0.11
Interaction effect									
D_1N_1	7.52	7.45	7.48	1.88	1.84	1.86	2.10	2.30	2.20
D_1N_2	7.50	7.48	7.49	1.87	1.85	1.86	2.20	2.40	2.30
D_1N_3	7.42	7.45	7.43	1.85	1.85	1.85	2.50	2.40	2.45
D_1N_4	7.40	7.47	7.43	1.84	1.84	1.84	2.57	2.40	2.48
D_2N_1	7.33	7.38	7.36	1.83	1.82	1.83	2.20	2.30	2.25
D_2N_2	7.38	7.42	7.40	1.84	1.83	1.83	2.37	2.30	2.33
D_2N_3	7.32	7.40	7.36	1.84	1.84	1.84	2.53	2.50	2.52
D_2N_4	7.23	7.45	7.34	1.81	1.84	1.83	2.67	2.50	2.58
D_3N_1	7.33	7.40	7.37	1.82	1.84	1.83	2.27	2.30	2.28
D_3N_2	7.37	7.43	7.40	1.84	1.82	1.83	2.37	2.40	2.38
D_3N_3	7.20	7.38	7.29	1.79	1.82	1.81	2.57	2.50	2.53
D_3N_4	7.30	7.40	7.35	1.81	1.83	1.82	2.60	2.50	2.55
D × N									
S.Em (±)	0.05	0.06	0.04	0.019	0.022	0.014	0.08	0.10	0.07
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.24	NS	0.19
N × D									
S.Em (±)	0.05	0.06	0.04	0.017	0.020	0.013	0.08	0.09	0.06
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.24	NS	0.20

NS = Not significant

4.2.6.4.2.3 Interaction effect between planting time and nutrient management

The effect of interaction between planting time and nutrient management on cooked kernel length was not significant during both the years of experimentation (Table 4.2.19).

4.2.6.4.2 Elongation ratio

4.2.6.4.2.1 Effect of planting time

The elongation ratio of Radhatilak rice was found to vary significantly among three planting times for 2012 and pooled values (Table 4.2.19). The maximum ER was noted with the kernels or grains obtained from the crop planted on 2nd week of July (D_1) during both 2012 (1.86) and 2013 (1.84) compared to late planted ones (D_2 and D_3) in the study.

4.2.6.4.2.2 Effect of nutrient management

The variation in combination of nutrient sources could not affect the elongation ratio of Radhatilak rice kernel during both the years of experiment (Table 4.2.19).

4.2.6.4.2.3 Interaction effect between planting time and nutrient management

There was no significant difference in interaction effect between planting time and nutrient management on kernel elongation ratio during both 2012 and 2013 (Table 4.2.19).

4.2.6.4.3 Aroma

The aroma scores noted with different treatments in the study indicated that Radhatilak rice generally had medium-strong aroma during *kharif* season of 2012 and 2013 at Kalyani, West Bengal, India (Table 4.2.19 Fig. 4.2.5).

4.2.6.4.3.1 Effect of planting time

Although planting time did not affect the aroma of Radhatilak rice during both 2012 and 2013 in the investigation, with exception for pooled values (Table 4.2.19; Fig. 4.2.5), but the intensity of aroma was slightly improved for delayed plantings during 4th week of July and 2nd week of August (D_2 and D_3) compared to early planting in 2nd week of July (D_1). The maximum aroma score (2.45) for the grains of the crop planted on 2nd week of August (D_3) could be due to low day-night temperature (30.21/16.03 °C) compared to plantings on 2nd week of July (30.94 / 19.91 °C) during grain filling and ripening period of Radhatilak rice.

Table 4.2.20

Correlations between GDD at different growth stages with yield associated and grain quality parameters of Radhatilak rice

Parameter	GDD_{S-E}	GDD_{E-4L}	GDD_{4L-AT}	GDD_{AT-PI}	GDD_{PI-F}	GDD_{F-Mi}	GDD_{Mi-D}	GDD_{D-M}
Plant height (cm)	0.493**	0.626**	0.247*	0.409**	0.462**	0.396**	0.233*	0.511**
Panicle length (cm)	0.263*	0.148	-0.179	0.026	-0.125	-0.045	-0.334**	0.206
No. of Panicles m^{-2}	0.246*	0.424**	0.481**	0.503**	0.525**	0.467**	0.469**	0.363**
No. of Filled grains $panicle^{-1}$	0.359**	0.502**	0.309**	0.379**	0.394**	0.317**	0.316**	0.421**
1000 grain weight (g)	0.109	0.236*	0.159	0.184	0.176	0.169	0.106	0.107
Grain yield (t ha^{-1})	0.401**	0.475**	0.213	0.360**	0.519**	0.296*	0.337**	0.429**
Straw yield (t ha^{-1})	0.380**	0.578**	0.481**	0.533**	0.448**	0.414**	0.364**	0.399**
Lodging (score)	0.202	0.293*	0.307**	0.352**	0.237*	0.266*	0.199	0.248*

GDD_{S-E} = GDD (sowing to emergence); GDD_{E-4L} = GDD (emergence to4[th] leaf emergence); GDD_{4L-AT} = GDD (4[th] leaf emergence to active tillering); GDD_{AT-PI} = GDD (active tillering to panicle initiation); GDD_{PI-F} = GDD (panicle initiation to 50% flowering); GDD_{F-Mi} = GDD (50% flowering to milk); GDD_{Mi-D} = GDD (milk to dough); GDD_{D-M} = GDD (dough to maturity) : Sample size: n = 72; r value = 0.232* and 0.302** at 5% and 1% level of significance, respectively.

Parameter	GDD_{S-E}	GDD_{E-4L}	GDD_{4L-AT}	GDD_{AT-PI}	GDD_{PI-F}	GDD_{F-Mi}	GDD_{Mi-D}	GDD_{D-M}
Hulling (%)	0.118	0.204	0.167	0.197	0.106	0.073	0.002	0.265*
Milling (%)	0.199	0.200	0.065	0.179	-0.176	0.121	-0.289*	0.181
Head rice recovery (%)	0.111	-0.004	-0.137	-0.070	-0.233*	0.008	-0.365**	0.037
Kernel length (mm)	0.008	0.014	-0.066	-0.006	-0.222	-0.108	-0.288*	-0.019
Kernel breadth (mm)	-0.017	0.141	-0.123	-0.038	-0.248*	-0.113	-0.310**	0.074
Amylose (%)	-0.074	-0.030	0.119	0.096	0.208	0.088	0.240*	0.045
Protein (%)	-0.013	0.108	-0.104	-0.050	-0.029	0.032	-0.198	0.119
Alkali value (score)	0.075	0.274*	0.123	0.170	0.171	0.204	0.198	0.037
Kernel length after cooking (mm)	0.399**	0.399**	0.224	0.468**	0.212	0.353**	0.088	0.186
Elongation ratio	0.341**	0.334**	0.225	0.400**	0.308**	0.368**	0.232*	0.189
Aroma (score)	-0.151	-0.174	-0.119	-0.170	-0.157	-0.072	-0.127	-0.134

GDD_{S-E} = GDD (sowing to emergence); GDD_{E-4L} = GDD (emergence to4[th] leaf emergence); GDD_{4L-AT} = GDD (4[th] leaf emergence to active tillering); GDD_{AT-PI} = GDD (active tillering to panicle initiation); GDD_{PI-F} = GDD (panicle initiation to 50 % flowering); GDD_{F-Mi} = GDD (50 % flowering to milk); GDD_{MI-D} = GDD (milk to dough); GDD_{D-M} = GDD (dough to maturity) : Sample size: n = 72; r value = 0.232* and 0.302** at 5% and 1% level of significance, respectively

Table 4.2.21

Correlations between HTU at different growth stages with yield associated and grain quality parameters of Radhatilak rice

Parameter	HTU_{S-E}	HTU_{E-4L}	HTU_{4L-AT}	HTU_{AT-PI}	HTU_{PI-F}	HTU_{F-Mi}	HTU_{Mi-D}	HTU_{D-M}
Plant height (cm)	0.504**	0.356**	-0.095	0.152	-0.299*	-0.119	0.363**	0.561**
Panicle length (cm)	0.452**	0.443**	-0.172	-0.142	-0.581**	-0.200	0.370**	0.173
No. of Panicles m^{-2}	-0.060	-0.290*	0.127	0.437**	0.335**	0.281*	-0.280*	0.401**
No. of Filled grains $panicle^{-1}$	0.198	0.079	-0.065	0.221	-0.015	0.197	0.033	0.380**
1000 grain weight (g)	0.043	0.086	-0.053	0.161	-0.020	0.096	0.031	0.112
Grain yield ($t\ ha^{-1}$)	0.200	0.107	-0.155	0.235*	0.032	0.098	0.107	0.378**
Straw yield ($t\ ha^{-1}$)	0.352**	0.057	0.218	0.304**	-0.065	-0.094	0.146	0.585**
Lodging (score)	0.124	-0.085	0.165	0.238*	-0.009	0.013	-0.029	0.346**

HTU_{S-E} = HTU (sowing to emergence); HTU_{E-4L} = HTU (emergence to4th leaf emergence); HTU_{4L-AT} = HTU (4th leaf emergence to active tillering); HTU_{AT-PI} = HTU (active tillering to panicle initiation); HTU_{PI-F} = HTU (panicle initiation to 50% flowering); HTU_{F-Mi} = HTU (50% flowering to milk); HTU_{Mi-D} = HTU (milk to dough); HTU_{D-M} = HTU (dough to maturity)
Sample size: n = 72; r value = 0.232* and 0.302** at 5% and 1% level of significance, respectively

Parameter	HTU_{S-E}	HTU_{E-4L}	HTU_{4L-AT}	HTU_{AT-PI}	HTU_{PI-F}	HTU_{F-Mi}	HTU_{Mi-D}	HTU_{D-M}
Hulling (%)	0.076	0.054	-0.009	0.108	-0.132	0.094	-0.054	0.237*
Milling (%)	0.390**	0.357**	0.000	-0.027	-0.657**	-0.120	0.311**	0.251*
Head rice recovery (%)	0.354**	0.405**	0-.086	-0.248*	-0.592**	-0.179	0.321**	0.056
Kernel length (mm)	0.278*	0.296*	0.032	-0.126	-0.491**	-0.263*	0.302**	0.093
Kernel breadth (mm)	0.329**	0.294*	0.072	-0.246*	-0.515**	-0.312**	0.319**	0.128
Amylose (%)	-0.363**	-0.401**	0.022	0.153	0.479**	0.319**	-0.427**	-0.061
Protein (%)	-0.019	0.118	-0.177	-0.116	-0.176	0.031	0.049	-0.012
Alkali value (score)	0.019	0.030	-0.009	0.162	0.091	0.045	0.033	0.072
Kernel length after cooking (mm)	0.299*	0.124	-0.058	0.390**	-0.266*	0.178	0.050	0.280*
Elongation ratio	0.099	-0.061	-0.076	0.395**	0.045	0.309**	-0.135	0.195
Aroma (score)	-0.052	0.039	-0.047	-0.157	-0.045	0.030	0.007	-0.186

HTU_{S-E} = HTU (sowing to emergence); HTU_{E-4L} = HTU (emergence to4th leaf emergence); HTU_{4L-AT} = HTU (4th leaf emergence to active tillering); HTU_{AT-PI} = HTU (active tillering to panicle initiation); HTU_{PI-F} = HTU (panicle initiation to 50% flowering); HTU_{F-Mi} = HTU (50% flowering to milk); HTU_{Mi-D} = HTU (milk to dough); HTU_{D-M} = HTU (dough to maturity)
Sample size: n = 72; r value = 0.232* and 0.302** at 5% and 1% level of significance, respectively

Table 4.2.22

Correlations between PTU at different growth stages with yield associated and grain quality parameters of Radhatilak rice

Parameter	PTU_{S-E}	PTU_{E-4L}	PTU_{4L-AT}	PTU_{AT-PI}	PTU_{PI-F}	PTU_{F-Mi}	PTU_{Mi-D}	PTU_{D-M}
Plant height (cm)	0.502**	0.611**	0.302**	0.422**	0.490**	0.417**	0.270*	0.533**
Panicle length (cm)	0.251*	0.107	-0.146	0.026	-0.101	-0.034	-0.307**	0.205
No. of Panicles m^{-2}	0.265*	0.468**	0.498**	0.506**	0.530**	0.473**	0.480**	0.381**
No. of Filled grains $panicle^{-1}$	0.370**	0.498**	0.337**	0.385**	0.410**	0.332**	0.335**	0.433**
1000 grain weight (g)	0.116	0.234*	0.170	0.186	0.183	0.173	0.116	0.116
Grain yield (t ha^{-1})	0.411**	0.477**	0.259*	0.370**	0.524**	0.313**	0.357**	0.443**
Straw yield (t ha^{-1})	0.395**	0.595**	0.508**	0.539**	0.475**	0.434**	0.391**	0.426**
Lodging (score)	0.211	0.317**	0.320**	0.353**	0.255*	0.274*	0.215	0.262*

PTU_{S-E} = PTU (sowing to emergence); PTU_{E-4L} = PTU (emergence to4th leaf emergence); PTU_{4L-AT} = PTU (4th leaf emergence to active tillering); PTU_{AT-PI} = PTU (active tillering to panicle initiation); PTU_{PI-F} = PTU (panicle initiation to 50% flowering); PTU_{F-Mi} = PTU (50% flowering to milk); PTU_{Mi-D} = PTU (milk to dough); PTU_{D-M} = PTU (dough to maturity)
Sample size: n = 72; r value = 0.232* and 0.302** at 5% and 1% level of significance, respectively

Parameter	PTU_{S-E}	PTU_{E-4L}	PTU_{4L-AT}	PTU_{AT-PI}	PTU_{PI-F}	PTU_{F-MI}	PTU_{MI-D}	PTU_{D-M}
Hulling (%)	0.122	0.205	0.174	0.196	0.118	0.083	0.018	0.266*
Milling (%)	0.193	0.183	0.082	0.177	-0.132	0.129	-0.257*	0.189
Head rice recovery (%)	0.100	-0.026	-0.124	-0.068	-0.205	0.009	-0.343**	0.040
Kernel length (mm)	0.001	-0.004	-0.061	-0.008	-0.197	-0.100	-0.271*	-0.014
Kernel breadth (mm)	-0.022	0.088	-0.112	-0.040	-0.220	-0.104	-0.290*	0.073
Amylose (%)	-0.064	0.004	0.114	0.094	0.188	0.083	0.228	0.041
Protein (%)	-0.014	0.073	-0.089	-0.046	-0.024	0.031	-0.185	0.115
Alkali value (score)	0.084	0.260*	0.136	0.172	0.178	0.205	0.203	0.049
Kernel length after cooking (mm)	0.402**	0.413**	0.265*	0.465**	0.241*	0.361**	0.117	0.209
Elongation ratio	0.348**	0.356**	0.258*	0.399**	0.320**	0.370**	0.247*	0.205
Aroma (score)	-0.153	-0.177	-0.131	-0.171	-0.159	-0.079	-0.132	-0.140

PTU_{S-E} = PTU (sowing to emergence); PTU_{E-4L} = PTU (emergence to4th leaf emergence); PTU_{4L-AT} = PTU (4th leaf emergence to active tillering); PTU_{AT-PI} = PTU (active tillering to panicle initiation); PTU_{PI-F} = PTU (panicle initiation to 50% flowering); PTU_{F-Mi}= PTU (50% flowering to milk)PTU_{Mi-D} = PTU (milk to dough); PTU_{D-M} = PTU (dough to maturity)
Sample size: n = 72; r value = 0.232* and 0.302** at 5% and 1% level of significance, respectively

Similarly, low temperature (<20 °C) during grain filling period (Dutta *et al.* 1999) as well as cooler temperature (25 °C day / 21 °C night) during crop maturity (Juliano, 1972 and Mann, 1987) favoured better of retention aroma in Basmati rice.

4.2.6.4.3.2 Effect of nutrient management

The significant improvement in aroma score of Radhatilak rice was observed with increment in organic sources of nutrients by substitution of chemical fertilizer during both the years of investigation (Table 4.2.19). The finding suggested the use of organic manure either sole or in combination with chemical fertilizers for better aroma instead of sole inorganic nutrient management system mostly practiced by the far4mers in native area of cultivation in the state.

4.2.6.4.3.3 Interaction effect between planting time and nutrient management

Planting time × nutrient management interaction effect on flavour of Radhatilak rice grain was not significant during both 2012 and 2013, indicating medium-strong aroma (2.10–2.67) irrespective of treatment combinations in the study (Table 4.2.19).

4.2.7 Nutrient uptake by the crop and fertility status of the soil

4.2.7.1 Nutrient uptake

4.2.7.1.1 Nitrogen uptake (kg ha^{-1}) by plant

The pattern of nitrogen uptake by Radhatilak rice crop, irrespective of planting time and nutrient management, showed a steady increasing trend from 28 DAT to harvest in the investigation (Table 4.2.23). The finding was consistent with increment in dry matter production by the plants with the advancement of crop growth upto maturity. Nitrogen uptake at 28 and 56 DAT, irrespective of main and sub-plot treatments, was usually higher in 2012 than in 2013; but the reverse trend between two years was noted for uptake by straw at harvest in the experiment.

4.2.7.1.1.1 Effect of planting time

N uptake of Radhatilak rice plant varied significantly among planting times at flowering (*i.e.* 84 DAT) and maturity stages during both the years of study (Table 4.2. 23). There was a decreasing trend in N uptake with delay in planting from 2nd week of July (D_1) to 2nd week of August (D_3) during 2012 and 2013.

Table 4.2.23

Effect of planting time and nutrient management on nitrogen uptake by plants at different stages of Radhatilak rice

Treatment	Nitrogen uptake (kg ha^{-1})								
	28 DAT			56 DAT			84 DAT		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	21.30	20.62	20.96	34.72	35.63	35.17	43.06	44.99	44.02
D_2	21.26	20.02	20.64	35.96	33.58	34.77	41.98	43.60	42.79
D_3	20.00	20.23	20.11	35.22	33.45	34.33	41.96	42.45	42.20
S.Em (±)	0.79	0.28	0.42	0.56	0.53	0.39	0.44	0.31	0.27
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	1.22	0.87
Nutrient management									
N_1	22.22	21.55	21.88	37.38	35.99	36.68	44.73	45.51	45.12
N_2	21.34	20.54	20.94	36.56	35.21	35.89	41.47	43.46	42.46
N_3	20.26	20.10	20.18	34.30	32.65	33.48	43.20	42.81	43.00
N_4	19.59	18.96	19.28	32.95	33.03	32.99	39.93	42.93	41.43
S.Em (±)	0.55	1.38	0.74	1.15	1.20	0.83	1.00	0.78	0.64
C.D. at 5%	1.64	NS	NS	3.40	NS	2.38	2.98	NS	1.82
Interaction effect									
D_1N_1	21.97	21.83	21.90	36.99	35.97	36.48	44.13	46.72	45.42
D_1N_2	22.42	21.40	21.91	35.96	37.08	36.52	41.14	45.77	43.46
D_1N_3	20.75	20.99	20.87	32.89	33.30	33.09	44.72	43.73	44.23
D_1N_4	20.07	18.24	19.16	33.04	36.15	34.60	42.25	43.72	42.99
D_2N_1	22.66	21.24	21.95	37.95	35.88	36.92	44.91	44.99	44.95
D_2N_2	21.54	19.47	20.51	36.91	32.93	34.92	41.70	43.34	42.52
D_2N_3	20.16	20.10	20.13	36.18	33.66	34.92	42.85	43.10	42.97
D_2N_4	20.67	19.25	19.96	32.80	31.87	32.33	38.44	42.99	40.71
D_3N_1	22.03	21.57	21.80	37.20	36.11	36.66	45.15	44.83	44.99
D_3N_2	20.06	20.75	20.41	36.82	35.63	36.22	41.55	41.27	41.41
D_3N_3	19.87	19.20	19.54	33.84	30.99	32.42	42.03	41.60	41.82
D_3N_4	18.02	19.40	18.71	33.01	31.08	32.04	39.09	42.08	40.59
				D × N					
S.Em (±)	0.96	2.39	1.29	1.98	2.08	1.44	1.74	1.35	1.10
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
				N × D					
S.Em (±)	2.84	7.10	3.69	5.90	6.18	4.12	5.16	4.01	3.16
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.2.23 (contd.)

Effect of planting time and nutrient management on nitrogen uptake by plants at different stages of Radhatilak rice

Treatment	Nitrogen uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	32.79	31.61	32.20	12.70	13.88	13.29	47.06	45.49	46.27
D_2	32.21	31.03	31.62	11.84	12.56	12.20	45.75	43.59	44.67
D_3	28.76	29.56	29.16	10.95	11.58	11.27	41.41	41.14	41.28
S.Em (±)	0.37	0.53	0.32	0.48	0.26	0.27	0.60	0.68	0.45
C.D. at 5%	1.46	NS	1.05	NS	1.00	0.88	2.35	2.67	1.48
Nutrient management									
N_1	32.38	32.54	32.46	13.55	13.45	13.50	47.44	45.99	46.72
N_2	33.82	31.11	32.46	12.49	13.16	12.83	48.01	44.27	46.14
N_3	30.96	29.70	30.33	11.21	12.18	11.69	43.87	41.87	42.87
N_4	27.87	29.60	28.73	10.09	11.90	11.00	39.66	41.50	40.58
S.Em (±)	0.54	0.79	0.48	0.37	0.46	0.30	0.74	0.86	0.57
C.D. at 5%	1.62	NS	1.37	1.11	NS	0.85	2.21	2.54	1.63
Interaction effect									
D_1N_1	33.87	33.07	33.47	16.04	15.32	15.68	51.04	48.39	49.71
D_1N_2	35.80	32.28	34.04	13.69	14.18	13.94	51.19	46.47	48.83
D_1N_3	32.02	31.06	31.54	11.22	13.72	12.47	44.93	44.78	44.85
D_1N_4	29.49	30.05	29.77	9.87	12.29	11.08	41.07	42.34	41.70
D_2N_1	32.48	33.33	32.91	12.97	13.37	13.17	47.16	46.70	46.93
D_2N_2	33.97	30.47	32.22	11.99	12.15	12.07	47.66	42.62	45.14
D_2N_3	32.22	29.78	31.00	11.96	12.11	12.03	45.88	41.89	43.88
D_2N_4	30.18	30.55	30.37	10.45	12.62	11.53	42.32	43.18	42.75
D_3N_1	30.78	31.22	31.00	11.63	11.67	11.65	44.12	42.89	43.50
D_3N_2	31.68	30.57	31.13	11.79	13.15	12.47	45.17	43.72	44.44
D_3N_3	28.65	28.25	28.45	10.45	10.70	10.57	40.79	38.95	39.87
D_3N_4	23.93	28.20	26.06	9.95	10.79	10.37	35.58	38.99	37.28
D × N									
S.Em (±)	0.94	1.37	0.83	0.65	0.80	0.51	1.29	1.48	0.98
C.D. at 5%	NS	NS	NS	1.92	NS	1.47	NS	NS	NS
N × D									
S.Em (±)	0.90	1.30	0.79	0.74	0.73	0.52	1.27	1.45	0.96
C.D. at 5%	NS	NS	NS	2.48	NS	1.64	NS	NS	NS

NS = Not significant

Besides, it was also noted that pooled N uptake by grain was usually more than double (29.16–32.20 kg ha^{-1}) compared to uptake by straw (11.27–13.29 kg ha^{-1}) of Radhatilak paddy during *kharif* season at Kalyani, West Bengal.

4.2.7.1.1.2 Effect of nutrient management

Total N uptake differed significantly among four nutrient management practices at all stages of observation during 2012 and at harvest only during 2013 (Table 4.2.23). It could be explained by the fact that the variations in N supply to plants due to different types of nutrient sources used in the study resulted in differences in growth and yield of Radhatilak rice crop. The range of variation in pooled N uptake among nutrition-based treatments was noted as: 19.3-21.9 kg ha^{-1} (28 DAT), 33.0–36.7 kg ha^{-1} (56 DAT), 41.4–45.1 kg ha^{-1} (84 DAT) and 40.6–46.7 kg ha^{-1} (at harvest) (Table 4.2.23). Mahata (2014) reported similar type of N uptake values for organic manure-based treatments of Gobindabhog rice crop at Kalyani, West Bengal.

4.2.7.1.1.3 Interaction effect between planting time and nutrient management

The interaction effect between planting time and nutrient management on total N uptake by plants was not found significant throughout the cropping period during both the years of experimentation, except for straw and total uptake during 2012 only (Table 4.2.23).

4.2.7.1.2 Phosphorus uptake (kg ha^{-1}) by plant

The P uptake in Radhatilak rice plants followed a steady increasing trend, like N uptake, with the advancement of crop age upto harvest (Table 4.2.24).

4.2.7.1.2.1 Effect of planting time

Radhatilak paddy planted during 2nd week of July (D_1) usually recorded highest P uptake throughout the cropping period compared to two late plantings (D_2 and D_3) in the study. However, significant variation in P uptake among planting times was not noted at all the stages during 2012, except for grain and total uptake at harvest (Table 4.2.24).

4.2.7.1.2.2 Effect of nutrient management

The significant variations among nutrition-based treatments toward P uptake in the study revealed that the plants of Radhatilak paddy nourished with either sole chemical fertilizer-based treatment (N_1) or integrated dose (50% RD as inorganic + 50

Table 4.2.24

Effect of planting time and nutrient management on phosphorus uptake by plants at different stage of Radhatilak rice

Treatment	Phosphorus uptake (kg ha^{-1})								
	28 DAT			56 DAT			84 DAT		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	8.90	9.18	9.04	10.54	10.80	10.67	11.85	11.73	11.79
D_2	9.27	9.06	9.17	10.54	10.40	10.47	11.67	11.35	11.51
D_3	9.01	9.00	9.00	10.32	10.39	10.36	11.62	10.99	11.31
S.Em (±)	0.15	0.03	0.07	0.09	0.09	0.06	0.05	0.08	0.05
C.D. at 5%	NS	0.11	NS	NS	NS	0.21	NS	0.33	0.16
Nutrient management									
N_1	9.33	9.36	9.35	10.78	10.89	10.84	12.04	11.76	11.90
N_2	9.38	9.34	9.36	10.74	10.74	10.74	11.85	11.41	11.63
N_3	8.74	8.93	8.84	10.30	10.36	10.33	11.66	11.27	11.46
N_4	8.79	8.68	8.74	10.06	10.12	10.09	11.31	10.99	11.15
S.Em (±)	0.12	0.21	0.12	0.15	0.10	0.09	0.10	0.16	0.10
C.D. at 5%	0.37	NS	0.35	0.43	0.30	0.25	0.30	0.49	0.28
Interaction effect									
D_1N_1	9.25	9.40	9.32	10.93	11.12	11.03	12.08	12.08	12.08
D_1N_2	9.50	9.68	9.59	10.75	11.18	10.97	11.97	11.90	11.94
D_1N_3	8.44	9.14	8.79	10.25	10.59	10.42	11.79	11.58	11.68
D_1N_4	8.43	8.50	8.46	10.24	10.29	10.27	11.55	11.36	11.46
D_2N_1	9.36	9.35	9.35	10.81	10.85	10.83	12.09	11.82	11.96
D_2N_2	9.64	9.18	9.41	10.92	10.43	10.67	11.82	11.33	11.58
D_2N_3	8.90	8.90	8.90	10.42	10.36	10.39	11.61	11.40	11.50
D_2N_4	9.20	8.80	9.00	10.01	9.94	9.98	11.16	10.85	11.00
D_3N_1	9.38	9.34	9.36	10.58	10.71	10.65	11.96	11.36	11.66
D_3N_2	9.00	9.16	9.08	10.54	10.62	10.58	11.74	11.00	11.37
D_3N_3	8.88	8.74	8.81	10.22	10.13	10.18	11.58	10.83	11.21
D_3N_4	8.76	8.75	8.75	9.94	10.11	10.03	11.22	10.76	10.99
D × N									
S.Em (±)	0.21	0.36	0.21	0.25	0.18	0.15	0.17	0.28	0.17
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D									
S.Em (±)	0.63	1.07	0.60	0.75	0.53	0.44	0.52	0.84	0.48
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.2.24 (contd.)

Effect of planting time and nutrient management on phosphorus uptake by plants at different stage of Radhatilak rice

Treatment	Phsphorus uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	9.79	9.95	9.87	4.85	5.05	4.95	14.64	14.80	14.72
D_2	9.32	9.49	9.40	4.21	4.22	4.22	13.53	13.71	13.62
D_3	8.21	8.74	8.47	4.19	3.99	4.09	12.40	12.93	12.66
S.Em (±)	0.07	0.09	0.06	0.21	0.17	0.14	0.19	0.23	0.15
C.D. at 5%	0.28	0.36	0.19	NS	0.68	0.44	0.74	0.91	0.49
Nutrient management									
N_1	9.71	10.05	9.88	5.14	4.76	4.95	14.85	15.20	15.03
N_2	9.70	9.45	9.57	4.57	4.62	4.60	14.27	14.02	14.15
N_3	8.99	9.33	9.16	4.17	4.23	4.20	13.16	13.50	13.33
N_4	8.02	8.74	8.38	3.78	4.06	3.92	11.80	12.52	12.16
S.Em (±)	0.22	0.27	0.17	0.19	0.18	0.13	0.30	0.33	0.22
C.D. at 5%	0.65	0.80	0.50	0.55	NS	0.37	0.90	0.99	0.65
Interaction effect									
D_1N_1	10.08	10.85	10.46	5.94	5.41	5.68	16.02	16.79	16.40
D_1N_2	10.53	9.86	10.19	4.67	5.23	4.95	15.19	14.53	14.86
D_1N_3	9.75	10.02	9.88	4.42	4.90	4.66	14.17	14.45	14.31
D_1N_4	8.82	9.07	8.95	4.36	4.65	4.50	13.18	13.43	13.30
D_2N_1	9.73	9.98	9.85	4.96	4.54	4.75	14.69	14.94	14.81
D_2N_2	9.92	9.53	9.72	4.53	4.34	4.44	14.45	14.06	14.25
D_2N_3	8.84	9.49	9.17	4.00	4.01	4.00	12.84	13.49	13.16
D_2N_4	8.78	8.97	8.87	3.37	4.00	3.68	12.15	12.34	12.24
D_3N_1	9.33	9.34	9.33	4.53	4.33	4.43	13.86	13.86	13.86
D_3N_2	8.65	8.96	8.81	4.53	4.29	4.41	13.18	13.49	13.33
D_3N_3	8.39	8.46	8.42	4.10	3.79	3.95	12.48	12.56	12.52
D_3N_4	6.45	8.19	7.32	3.61	3.54	3.58	10.06	11.80	10.93
D × N									
S.Em (±)	0.38	0.46	0.30	0.32	0.32	0.23	0.52	0.58	0.39
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D									
S.Em (±)	0.34	0.41	0.27	0.35	0.33	0.24	0.49	0.55	0.37
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

% RD as mustard cake) recorded significantly greater P uptake compared to N_3 and N_4 in the investigation (Table 4.2.24). The stage-wise pooled P uptake could be summarized as: 8.74–9.35 kg ha^{-1} (28 DAT), 10.09–10.84 kg ha^{-1} (56 DAT), 11.15–11.90 kg ha^{-1} (84 DAT) and 12.16–15.03 kg ha^{-1} (Harvest) (Table 4.2.24)

4.2.7.1.3.3 Interaction effect between planting time and nutrient management

There was no significant interaction effect of planting time and nutrient management on P uptake of Radhatilak paddy throughout the cropping period during both the tears of experiment (Table 4.2.24).

4.2.7.1.3 Potassium uptake (kg ha^{-1}) by plant

The increment in dry matter production with the age of Radhatilak rice resulted in steady increase of total K uptake from 28 DAT to maturity (Table 4.2.25). Unlike the relationship of N uptake in grain and straw, K uptake in grain was usually about one-third of straw uptake mainly because of low concentration and less yield of grain compared to higher K concentration and greater yield of straw in the investigation.

4.2.7.1.3.1 Effect of planting time

Although the variation in K uptake by Radhatilak rice crop was found non-significant at 28, 56 and 84 DAT during both the years but it differed significantly for grain, straw and total uptake at harvest during 2012, 2013 and pooled values in the experiment (Table 4.2.25).

4.2.7.1.3.2 Effect of nutrient management

The uptake of potassium by Radhatilak rice plants differed significantly among four nutrient management-based treatments at 84 DAT for 2012 and at harvest for both the years of study (Table 4.2.25). Based on pooled values, the range in K uptake was noted as: 15.60–17.23 kg ha^{-1} (28 DAT), 25.50–28.10 kg ha^{-1} (56 DAT), 33.92–36.64 kg ha^{-1} (84 DAT) and 39.05–46.61 kg ha^{-1} (at harvest).

4.2.7.1.3.3 Interaction effect between planting time and nutrient management

Total K uptake at all stages of observation was not significantly influenced by combined influence of planting time and nutrient management during both 2012 and 2013 in the study (Table 4.2.25).

Table 4.2.25

Effect of planting time and nutrient management on potassium uptake by plants at different stage of Radhatilak rice

Treatment	Potassium uptake (kg ha^{-1})								
	28 DAT			56 DAT			84 DAT		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	16.28	16.44	16.36	26.26	26.55	26.41	37.61	37.90	37.76
D_2	16.95	16.66	16.81	26.99	26.94	26.96	33.88	34.32	34.10
D_3	16.42	16.05	16.24	26.34	27.68	27.01	33.27	35.94	34.60
S.Em (±)	0.50	0.31	0.29	0.62	0.82	0.51	0.54	0.61	0.41
C.D. at 5%	NS	NS	NS	NS	NS	NS	2.12	2.39	1.33
Nutrient management									
N_1	17.20	17.27	17.23	27.73	28.46	28.10	36.90	36.38	36.64
N_2	17.06	16.68	16.87	27.31	27.54	27.43	34.67	37.57	36.12
N_3	16.09	16.24	16.16	25.94	26.36	26.15	35.26	35.28	35.27
N_4	15.85	15.35	15.60	25.15	25.86	25.50	32.84	35.00	33.92
S.Em (±)	0.50	0.96	0.54	0.74	0.88	0.58	0.87	0.85	0.61
C.D. at 5%	NS	NS	NS	NS	NS	1.65	2.57	2.53	1.74
Interaction effect									
D_1N_1	16.76	17.19	16.98	26.86	27.04	26.95	38.59	38.77	38.68
D_1N_2	17.32	17.12	17.22	26.55	28.11	27.33	36.95	38.84	37.89
D_1N_3	15.81	17.12	16.47	25.90	25.91	25.91	39.04	37.38	38.21
D_1N_4	15.20	14.35	14.78	25.74	25.14	25.44	35.88	36.62	36.25
D_2N_1	17.51	17.14	17.33	28.36	29.42	28.89	36.63	35.55	36.09
D_2N_2	17.81	16.35	17.08	28.29	26.37	27.33	34.09	33.84	33.96
D_2N_3	15.72	16.73	16.22	26.77	27.46	27.11	33.46	34.27	33.87
D_2N_4	16.77	16.41	16.59	24.53	24.49	24.51	31.34	33.63	32.49
D_3N_1	17.31	17.47	17.39	27.96	28.93	28.45	35.50	34.81	35.15
D_3N_2	16.05	16.57	16.31	27.10	28.15	27.62	32.97	40.02	36.50
D_3N_3	16.74	14.86	15.80	25.14	25.71	25.43	33.28	34.19	33.73
D_3N_4	15.59	15.30	15.45	25.17	27.94	26.56	31.31	34.75	33.03
				D × N					
S.Em (±)	0.87	1.67	0.94	1.28	1.53	1.00	1.50	1.48	1.05
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
				N × D					
S.Em (±)	0.90	1.48	0.87	1.27	1.55	1.00	1.41	1.42	1.00
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.2.25 (contd.)

Effect of planting time and nutrient management on potassium uptake by plants at different stage of Radhatilak rice

Treatment	Potassium uptake (kg ha^{-1})								
	Grain			Straw			Total		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Planting time									
D_1	10.54	10.39	10.47	34.57	36.97	35.77	45.11	47.36	46.24
D_2	10.55	9.83	10.19	33.23	34.28	33.76	43.78	44.10	43.94
D_3	8.52	9.25	8.89	29.62	31.77	30.69	38.14	41.02	39.58
S.Em (±)	0.13	0.30	0.16	0.41	0.58	0.35	0.39	0.72	0.41
C.D. at 5%	0.50	NS	0.53	1.62	2.26	1.16	1.53	2.84	1.34
Nutrient management									
N_1	10.21	10.72	10.46	36.09	36.21	36.15	46.30	46.93	46.61
N_2	10.57	9.79	10.18	34.39	35.20	34.79	44.95	44.98	44.97
N_3	9.84	9.85	9.85	31.05	33.62	32.33	40.89	43.47	42.18
N_4	8.87	8.93	8.90	28.36	32.34	30.35	37.23	41.27	39.25
S.Em (±)	0.21	0.40	0.23	0.73	0.57	0.46	0.66	0.64	0.46
C.D. at 5%	0.62	1.19	0.65	2.18	1.68	1.33	1.96	1.90	1.32
Interaction effect									
D_1N_1	10.62	11.48	11.05	39.56	39.38	39.47	50.18	50.86	50.52
D_1N_2	11.34	10.70	11.02	37.15	37.94	37.54	48.49	48.63	48.56
D_1N_3	10.37	10.61	10.49	31.82	35.89	33.86	42.19	46.51	44.35
D_1N_4	9.84	8.78	9.31	29.75	34.67	32.21	39.59	43.44	41.52
D_2N_1	10.70	10.88	10.79	36.75	36.02	36.39	47.45	46.90	47.17
D_2N_2	11.02	9.16	10.09	34.15	35.00	34.58	45.18	44.15	44.67
D_2N_3	10.67	9.90	10.29	32.99	33.74	33.37	43.67	43.64	43.65
D_2N_4	9.79	9.37	9.58	29.02	32.36	30.69	38.81	41.73	40.27
D_3N_1	9.31	9.80	9.56	31.96	33.23	32.60	41.27	43.02	42.15
D_3N_2	9.33	9.50	9.42	31.87	32.65	32.26	41.20	42.15	41.68
D_3N_3	8.48	9.05	8.77	28.32	31.22	29.77	36.81	40.27	38.54
D_3N_4	6.97	8.65	7.81	26.31	29.99	28.15	33.28	38.64	35.96
D × N									
S.Em (±)	0.36	0.69	0.39	1.27	0.98	0.80	1.14	1.11	0.80
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
N × D									
S.Em (±)	0.34	0.67	0.38	1.18	1.03	0.78	1.06	1.20	0.80
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

4.2.8 Residual soil fertility status in soil

4.2.8.1 Available nitrogen content in soil

There was positive N balance in soil after 2-year study, irrespective of planting time and nutrient management, over the initial N status at the commencement of experiment.

4.2.8.1.1 Effect of planting time

With delay in planting from 2nd week of July (D_1) to 2nd week of August (D_3), the respective residual nitrogen status was slightly improved during both 2012 and 2013 in the investigation (Table 4.2.26), which might be due to greater N uptake by the earliest planted crop (D_1) compared to the late planted ones (D_2 and D_3) during *kharif* season at Kalyani, Nadia.

4.2.8.1.2 Effect of nutrient management

The variation in supply-cum-availability of N through different nutritional sources and total N uptake at harvest resulted in variation in residual N status between 340.9 (N_1) and 347.1 kg ha^{-1} (N_4) (Table 4.2.26). Thus, there was positive N balance (17.7–22.2 kg ha^{-1}) after second year for all four nutritional treatments over initial N status (330.8 kg ha^{-1}) in the investigation, but Kumari *et al.* (2010) reported an opposite trend *i.e.* loss in soil N irrespective of organic treatments in scented rice (*cv.* Birsamati) after 2-year study.

4.2.8.1.3 Interaction effect between planting time and nutrient management

Among different nutritional treatment combinations, D_1N_1 (2nd week of July planting + 50:25:25 kg ha^{-1} of $N:P_2O_5:K_2O$) and D_3N_4 (2nd week of August planting + 100% RD organic manure) recorded the lowest (337.9 kg ha^{-1}) and highest (350.4 kg ha^{-1}) residual N status in soil, respectively for pooled over two years (Table 4.2.26). The findings indicated the variation in soil N balance between +4.63 (D_1N_1) and +7.50% (D_3N_3) after 2-year study at Kalyani, West Bengal (Fig. 4.2.6).

4.2.8.2 Available phosphorous content in soil

Like soil N balance, positive P balance in soil was also noted for all mail and sub-plot treatments after 2-year study in the investigation.

Table 4.2.26

Effect of organic manure and inorganic fertilizer on residual nitrogen status after harvest of Radhatilak rice

Treatment	Available nitrogen (kg ha^{-1})																				
	2012						2013						Mean								
	Initial	Treatment		Total	Total uptake	Resi-dual status	Initial	Treatment		Total	Total uptake	Resi-dual status	Initial	Treatment		Total	Total uptake	Resi-dual status			
		Org-anic	Inorg-anic					Org-anic	Inorg-anic					Org-anic	Inorg-anic						
Planting time																					
D_1	330.8	28.1	21.9	380.8	47.1	333.7	344.5	28.1	21.9	394.5	45.5	349.0	337.7	28.1	21.9	387.7	46.3	341.4			
D_2	330.8	28.1	21.9	380.8	45.8	335.1	344.5	28.1	21.9	394.5	43.6	350.9	337.7	28.1	21.9	387.7	44.7	343.0			
D_3	330.8	28.1	21.9	380.8	41.4	339.4	344.5	28.1	21.9	394.5	41.1	353.4	337.7	28.1	21.9	387.7	41.3	346.4			
Nutrient management																					
N_1	330.8	0.0	50.0	380.8	47.4	333.4	344.5	0.0	50.0	394.5	46.0	348.5	337.7	0.0	50.0	387.7	46.7	340.9			
N_2	330.8	25.0	25.0	380.8	48.0	332.8	344.5	25.0	25.0	394.5	44.3	350.2	337.7	25.0	25.0	387.7	46.1	341.5			
N_3	330.8	37.5	12.5	380.8	43.9	336.9	344.5	37.5	12.5	394.5	41.9	352.6	337.7	37.5	12.5	387.7	42.9	344.8			
N_4	330.8	50.0	0.0	380.8	39.7	341.1	344.5	50.0	0.0	394.5	41.5	353.0	337.7	50.0	0.0	387.7	40.6	347.1			
Interaction effect																					
D_1N_1	330.8	0.0	50.0	380.8	51.0	329.8	344.5	0.0	50.0	394.5	48.4	346.1	337.7	0.0	50.0	387.7	49.7	337.9			
D_1N_2	330.8	25.0	25.0	380.8	51.2	329.6	344.5	25.0	25.0	394.5	46.5	348.0	337.7	25.0	25.0	387.7	48.8	338.8			
D_1N_3	330.8	37.5	12.5	380.8	44.9	335.9	344.5	37.5	12.5	394.5	44.8	349.7	337.7	37.5	12.5	387.7	44.9	342.8			
D_1N_4	330.8	50.0	0.0	380.8	41.1	339.7	344.5	50.0	0.0	394.5	42.3	352.2	337.7	50.0	0.0	387.7	41.7	346.0			
D_2N_1	330.8	0.0	50.0	380.8	47.2	333.6	344.5	0.0	50.0	394.5	46.7	347.8	337.7	0.0	50.0	387.7	46.9	340.7			
D_2N_2	330.8	25.0	25.0	380.8	47.7	333.1	344.5	25.0	25.0	394.5	42.6	351.9	337.7	25.0	25.0	387.7	45.1	342.5			
D_2N_3	330.8	37.5	12.5	380.8	45.9	334.9	344.5	37.5	12.5	394.5	41.9	352.6	337.7	37.5	12.5	387.7	43.9	343.8			
D_2N_4	330.8	50.0	0.0	380.8	42.3	338.5	344.5	50.0	0.0	394.5	43.2	351.3	337.7	50.0	0.0	387.7	42.8	344.9			
D_3N_1	330.8	0.0	50.0	380.8	44.1	336.7	344.5	0.0	50.0	394.5	42.9	351.6	337.7	0.0	50.0	387.7	43.5	344.2			
D_3N_2	330.8	25.0	25.0	380.8	45.2	335.6	344.5	25.0	25.0	394.5	43.7	350.8	337.7	25.0	25.0	387.7	44.4	343.2			
D_3N_3	330.8	37.5	12.5	380.8	40.8	340.0	344.5	37.5	12.5	394.5	39.0	355.6	337.7	37.5	12.5	387.7	39.9	347.8			
D_3N_4	330.8	50.0	0.0	380.8	35.6	345.2	344.5	50.0	0.0	394.5	39.0	355.5	337.7	50.0	0.0	387.7	37.3	350.4			

4.2.8.2.1 Effect of planting time

Like available N content in soil after harvest, the residual phosphorus content was also improved with delay in planting from 2nd week of July (D_1) to 2nd week of August (D_3) during both the years of investigation (Table 4.2.27). The variation in pooled P content between 49.4 (D_1) and 51.5 Kg ha^{-1} (D_3) indicated positive P balance for all planting times over initial P status (42.7 kg ha^{-1}) at the commencement of the experiment.

4.2.8.2.2 Effect of nutrient management

The greater replacement of chemical fertilizers by organic manures ($N_4>N_3>N_2$), resulted in lower residual P status in soil compared to inorganic nutrient management (N_1) of Radhatilak psddy during 2012, 2013 and pooled over two years (Table 4.2.27).

4.2.8.2.3 Interaction effect between planting time and nutrient management

The initial effect of planting time and nutrient management showed positive P balance in soil over initial was noted between +9.37 (D_2N_4) and +32.55 kg ha^{-1} (D_3N_2) at Kalyani, West Bengal (Fig. 4.2.6).

4.2.8.3 Available potassium content in soil

The residual K values recorded in main and sub-plot treatments after 2-year study indicated negative K balance compared to initial K status (239.2 kg ha^{-1}) in the experimental soil at Kalyani, West Bengal.

4.2.8.3.1 Effect of planting time

Planting time could make negligible difference in residual K balance in soil after harvesting of Radhatilak paddy during both 2012 and 2013 in the investigation (Table 4.2.28).

4.2.8.3.2 Effect of nutrient management

There was no definite trend in residual K balance in soil among from nutrient-based treatments during 2012, 2013 and pooled over two years. (Table 4.2.28).

4.2.8.3.3 Interaction effect between planting time and nutrient management

The combined effect of planting time and nutrient management on residual K status showed the variation between 193.5 (D_3N_4) and 207.2 kg ha^{-1} (D_2N_3) after 2-year study over the initial value (239.2 kg ha^{-1}) before transplanting of Radhatilak paddy in 2012 (Table 4.2.28). The finding showed negative K balance within a renge between -10.24% (D_3N_1) and -15.30% (D_1N_2) at Kalyani, West Bengal (Fig. 4.2. 28; Fig. 4.2.6).

Table 4.2.27

Effect of organic manure and inorganic fertilizer on residual phosphorus status after harvest of Radhatilak rice

Treatment	Available phosphorus (kg ha^{-1})																	
	2012						2013						Mean					
	Initial	Treatment		Total	Total uptake	Residual status	Initial	Treatment		Total	Total uptake	Residual status	Initial	Treatment		Total	Total uptake	Residual status
		Organic	Inorganic					Organic	Inorganic					Organic	Inorganic			
Planting time																		
D_1	42.7	9.1	10.9	62.7	14.6	48.1	45.5	9.1	10.9	65.5	14.8	50.7	44.1	9.1	10.9	64.1	14.7	49.4
D_2	42.7	9.1	10.9	62.7	13.5	49.2	45.5	9.1	10.9	65.5	13.7	51.8	44.1	9.1	10.9	64.1	13.6	50.5
D_3	42.7	9.1	10.9	62.7	12.4	50.3	45.5	9.1	10.9	65.5	12.9	52.6	44.1	9.1	10.9	64.1	12.7	51.5
Nutrient management																		
N_1	42.7	0.0	25.0	67.7	14.9	52.9	45.5	0.0	25.0	70.5	15.2	55.3	44.1	0.0	25.0	69.1	15.0	54.1
N_2	42.7	9.0	12.5	64.2	14.3	49.9	45.5	9.0	12.5	67.0	14.0	53.0	44.1	9.0	12.5	65.6	14.2	51.5
N_3	42.7	14.0	6.3	63.0	13.2	49.8	45.5	14.0	6.3	65.8	13.5	52.3	44.1	14.0	6.3	64.4	13.3	51.0
N_4	42.7	13.5	0.0	56.2	11.8	44.4	45.5	13.5	0.0	59.0	12.5	46.5	44.1	13.5	0.0	57.6	12.2	45.4
Interaction effect																		
D_1N_1	42.7	0.0	25.0	67.7	16.0	51.7	45.5	0.0	25.0	70.5	16.8	53.7	44.1	0.0	25.0	69.1	16.4	52.7
D_1N_2	42.7	9.0	12.5	64.2	15.2	49.0	45.5	9.0	12.5	67.0	14.5	52.5	44.1	9.0	12.5	65.6	14.9	50.7
D_1N_3	42.7	14.0	6.3	63.0	14.2	48.8	45.5	14.0	6.3	65.8	14.5	51.3	44.1	14.0	6.3	64.4	14.3	50.0
D_1N_4	42.7	13.5	0.0	56.2	13.2	43.0	45.5	13.5	0.0	59.0	13.4	45.6	44.1	13.5	0.0	57.6	13.3	44.3
D_2N_1	42.7	0.0	25.0	67.7	14.7	53.0	45.5	0.0	25.0	70.5	14.9	55.6	44.1	0.0	25.0	69.1	14.8	54.3
D_2N_2	42.7	9.0	12.5	64.2	14.5	49.8	45.5	9.0	12.5	67.0	14.1	52.9	44.1	9.0	12.5	65.6	14.3	51.4
D_2N_3	42.7	14.0	6.3	63.0	12.8	50.1	45.5	14.0	6.3	65.8	13.5	52.3	44.1	14.0	6.3	64.4	13.2	51.2
D_2N_4	42.7	13.5	0.0	56.2	12.2	44.1	45.5	13.5	0.0	59.0	12.3	46.7	44.1	13.5	0.0	57.6	12.2	45.4
D_3N_1	42.7	0.0	25.0	67.7	13.9	53.8	45.5	0.0	25.0	70.5	13.9	56.6	44.1	0.0	25.0	69.1	13.9	55.2
D_3N_2	42.7	9.0	12.5	64.2	13.2	51.0	45.5	9.0	12.5	67.0	13.5	53.5	44.1	9.0	12.5	65.6	13.3	52.3
D_3N_3	42.7	14.0	6.3	63.0	12.5	50.5	45.5	14.0	6.3	65.8	12.6	53.2	44.1	14.0	6.3	64.4	12.5	51.8
D_3N_4	42.7	13.5	0.0	56.2	10.1	46.1	45.5	13.5	0.0	59.0	11.8	47.2	44.1	13.5	0.0	57.6	10.9	46.7

Table 4.2.28

Effect of organic manure and inorganic fertilizer on residual potassium status after harvest of Radhatilak rice

Treatment	Available potassium (kg ha^{-1})																	
	2012						2013						Mean					
	Initial	Treatment		Total	Total uptake	Residual status	Initial	Treatment		Total	Total uptake	Residual status	Initial	Treatment		Total	Total uptake	Residual status
		Organic	Inorganic					Organic	Inorganic					Organic	Inorganic			
Planting time																		
D_1	239.2	11.5	10.9	261.6	45.1	216.5	232.7	11.5	10.9	255.1	47.4	207.7	236.0	11.5	10.9	258.4	46.2	212.2
D_2	239.2	11.5	10.9	261.6	43.8	217.8	232.7	11.5	10.9	255.1	44.1	211.0	236.0	11.5	10.9	258.4	43.9	214.5
D_3	239.2	11.5	10.9	261.6	38.1	223.5	232.7	11.5	10.9	255.1	41.0	214.1	236.0	11.5	10.9	258.4	39.6	218.8
Nutrient management																		
N_1	239.2	0.0	25.0	264.2	46.3	217.9	232.7	0.0	25.0	257.7	46.9	210.8	236.0	0.0	25.0	261.0	46.6	214.4
N_2	239.2	6.0	12.5	257.7	45.0	212.8	232.7	6.0	12.5	251.2	45.0	206.2	236.0	6.0	12.5	254.5	45.0	209.5
N_3	239.2	18.5	6.3	264.0	40.9	223.1	232.7	18.5	6.3	257.5	43.5	214.0	236.0	18.5	6.3	260.7	42.2	218.5
N_4	239.2	21.5	0.0	260.7	37.2	223.5	232.7	21.5	0.0	254.2	41.3	212.9	236.0	21.5	0.0	257.5	39.3	218.3
Interaction effect																		
D_1N_1	239.2	0.0	25.0	264.2	50.2	214.0	232.7	0.0	25.0	257.7	50.9	206.8	236.0	0.0	25.0	261.0	50.5	210.5
D_1N_2	239.2	6.0	12.5	257.7	48.5	209.2	232.7	6.0	12.5	251.2	48.6	202.6	236.0	6.0	12.5	254.5	48.6	205.9
D_1N_3	239.2	18.5	6.3	264.0	42.2	221.8	232.7	18.5	6.3	257.5	46.5	211.0	236.0	18.5	6.3	260.7	44.4	216.4
D_1N_4	239.2	21.5	0.0	260.7	39.6	221.1	232.7	21.5	0.0	254.2	43.4	210.8	236.0	21.5	0.0	257.5	41.5	216.0
D_2N_1	239.2	0.0	25.0	264.2	47.5	216.8	232.7	0.0	25.0	257.7	46.9	210.8	236.0	0.0	25.0	261.0	47.2	213.8
D_2N_2	239.2	6.0	12.5	257.7	45.2	212.5	232.7	6.0	12.5	251.2	44.2	207.1	236.0	6.0	12.5	254.5	44.7	209.8
D_2N_3	239.2	18.5	6.3	264.0	43.7	220.3	232.7	18.5	6.3	257.5	43.6	213.9	236.0	18.5	6.3	260.7	43.7	217.1
D_2N_4	239.2	21.5	0.0	260.7	38.8	221.9	232.7	21.5	0.0	254.2	41.7	212.5	236.0	21.5	0.0	257.5	40.3	217.2
D_3N_1	239.2	0.0	25.0	264.2	41.3	222.9	232.7	0.0	25.0	257.7	43.0	214.7	236.0	0.0	25.0	261.0	42.2	218.9
D_3N_2	239.2	6.0	12.5	257.7	41.2	216.5	232.7	6.0	12.5	251.2	42.2	209.1	236.0	6.0	12.5	254.5	41.7	212.8
D_3N_3	239.2	18.5	6.3	264.0	36.8	227.2	222.7	18.5	6.3	247.5	40.3	207.2	231.0	18.5	6.3	255.7	38.5	217.2
D_3N_4	239.2	21.5	0.0	260.7	33.3	227.4	222.7	21.5	0.0	244.2	38.6	205.6	231.0	21.5	0.0	252.5	36.0	216.5

4.2.9 Economics of production and benefit : cost ratio

4.2.9.1. Cost of cultivation

4.2.9.1.1 Effect of planting time

The common cost of cultivation of Radhatilak paddy included the cost of seedbed preparation and sowing, land preparation and transplanting of seedlings, weeding, irrigation, harvesting, threshing, etc., excluding the cost of chemical fertilizers and organic manures neededfollowing treatment schedule in the study.

The common cost of cultivation of Radhatilak paddy irrespective of planting time was calculated as Rs. 24,903.00 in 2012, Rs. 25,703.00 ha^{-1} in 2013 and Rs. 25,303.00 ha^{-1} during *kharif* for pooled over two years at Kalyani, West Bengal, India (Table 4.2.29). Likewise, the total cost of cultivation for all three planting times was Rs. 33.693.00 during first year, Rs. 35,093.00 during second year and Rs. 34,393.00 for pooled values in the investigation (Table 4.2.30).

Above all, the total cost of cultivation, was higher in second year than first year, exclusively due to price hike for seed, power-tiller charges, chemical fertilizers (Urea, Single Super Phosphate, Muriate of Potash), organic manures (FYM and mustard cake), irrigation etc. in the later year compared to the earlier one.

4.2.9.1.2 Effect of nutrient management

The mean cost variation among nutrition-based treatments was noted between Rs. 2,140.00 (N_1) and Rs. 14,250.00 ha^{-1} (N_4) (Table 4.2.30), which might be due to differences in doses, types, quantities and rates of organic manures and chemical fertilizers used in the experiment. Based on these, total cost of cultivation was increased by Rs. 12,110.00 ha^{-1} (Rs. 39,553.00 *vs.* Rs. 27,443.00 ha^{-1}) for organic nutrient management (25% RD FYM + 75% RD mustard cake) instead of sole application of chemical fertilizers (50:25:25 kg ha^{-1} of $N:P_2O_5:K_2O$) (Table 4.4.30).

Table 4.2.29

Effect of planting time and nutrient management on common cost of cultivation of Radhatilak rice during *kharif* season

Input and operation	2012	2013	Mean
Cost of Radhatilak seed (@20 kg ha^{-1})	900.00	1000.00	950.00
Preparation of seed bed, sowing of seeds and seedbed management (3 mandays)	501.00	501.00	501.00
Land preparation (Powertiller for 20 hours for 3 times ploughing in 1 ha)	4500.00	5000.00	4750.00
Transplanting of seedlings (40 mandays ha^{-1})	6680.00	6680.00	6680.00
Application of manures and inorganic fertilizers (6 mandays ha^{-1}) including transportation	1002.00	1002.00	1002.00
Weeding (20 mandays ha^{-1})	3340.00	3340.00	3340.00
Irrigation	800.00	900.00	850.00
Harvesting (20 mandays ha^{-1})	3340.00	3340.00	3340.00
Threshing and winnowing (20 mandays for 1 ha produce)	3340.00	3340.00	3340.00
Other contingent expenses	500.00	600.00	550.00
Total	24903.00	25703.00	25303.00

Cost of Radhatilak seed = Rs. 45.00 kg^{-1} (2012), Rs. 50.00 kg^{-1} (2013); Labour wages = Rs. 167.00 $manday^{-1}$ during both the years; Rate of power tiller = Rs. 225.00 $hour^{-1}$ (2012), Rs. 250.00 $hour^{-1}$ (2013)

Table 4.2.30

Effect of planting time and nutrient management on total cost of cultivation of Radhatilak rice during *kharif* season

Treatment	2012			2013			Mean		
	Common cost of cultivation (Rs. ha^{-1})	Cost of manure and fertilizer (Rs. ha^{-1})	Total cost of cultivation (Rs. ha^{-1})	Common costof cultivation (Rs. ha^{-1})	Cost of manure and fertilizer (Rs. ha^{-1})	Total cost of cultivation (Rs. ha^{-1})	Common cost of cultivation (Rs. ha^{-1})	Cost of manure and fertilizer (Rs. ha^{-1})	Total cost of cultivation (Rs. ha^{-1})
Planting time									
D_1	24903.00	8790.00	33693.00	25703.00	9390.00	35093.00	25303.00	9090.00	34393.00
D_2	24903.00	8790.00	33693.00	25703.00	9390.00	35093.00	25303.00	9090.00	34393.00
D_3	24903.00	8790.00	33693.00	25703.00	9390.00	35093.00	25303.00	9090.00	34393.00
Inorganic fertilizer									
N_1	24903.00	2100.00	27003.00	25703.00	2180.00	27883.00	25303.00	2140.00	27443.00
N_2	24903.00	9040.00	33943.00	25703.00	9580.00	35283.00	25303.00	9310.00	34613.00
N_3	24903.00	10270.00	35173.00	25703.00	11050.00	36753.00	25303.00	10660.00	35963.00
N_4	24903.00	13750.00	38653.00	25703.00	14750.00	40453.00	25303.00	14250.00	39553.00
Interaction effect									
D_1N_1	24903.00	2100.00	27003.00	25703.00	2180.00	27883.00	25303.00	2140.00	27443.00
D_1N_2	24903.00	9040.00	33943.00	25703.00	9580.00	35283.00	25303.00	9310.00	34613.00
D_1N_3	24903.00	10270.00	35173.00	25703.00	11050.00	36753.00	25303.00	10660.00	35963.00
D_1N_4	24903.00	13750.00	38653.00	25703.00	14750.00	40453.00	25303.00	14250.00	39553.00
D_2N_1	24903.00	2100.00	27003.00	25703.00	2180.00	27883.00	25303.00	2140.00	27443.00
D_2N_2	24903.00	9040.00	33943.00	25703.00	9580.00	35283.00	25303.00	9310.00	34613.00
D_2N_3	24903.00	10270.00	35173.00	25703.00	11050.00	36753.00	25303.00	10660.00	35963.00
D_2N_4	24903.00	13750.00	38653.00	25703.00	14750.00	40453.00	25303.00	14250.00	39553.00
D_3N_1	24903.00	2100.00	27003.00	25703.00	2170.00	27873.00	25303.00	2140.00	27443.00
D_3N_2	24903.00	9040.00	33943.00	25703.00	9580.00	35283.00	25303.00	9310.00	34613.00
D_3N_3	24903.00	10270.00	35173.00	25703.00	11040.00	36743.00	25303.00	10660.00	35963.00
D_3N_4	24903.00	13750.00	38653.00	25703.00	14750.00	40453.00	25303.00	14250.00	39553.00

Cost of FYM = Rs. 0.70 kg^{-1} (2012), Rs. 0.80 kg^{-1} (2013); Cost of mustard cake = Rs. 16.00 kg^{-1} (2012), Rs. 17.00 kg^{-1} (2013); Cost of Urea = Rs. 5.90 kg^{-1} (2012), Rs. 6.00 kg^{-1} (2013); Cost of Single Super Phosphate = Rs. 6.20 kg^{-1} (2012), Rs. 6.50 kg^{-1} (2013); Cost of Muriate of Potash = Rs. 11.80 kg^{-1} (2012), Rs. 12.00 kg^{-1} (2013);

4.2.9.1.3 Interaction effect

The common cost of cultivation was same for all twelve combinations of planting time and nutrient management (D_1N_1 to D_3N_4) for a particular year, which varied between two years (Rs. 24,903.00 *vs.* Rs. 25,703.00) in the study (Table 4.2.30). As the planting time could not affect the total cost of cultivations, the cost of chemical fertilizers or organic manures or both as required for different nutrition-based treatments caused variations in total cost of cultivation of Radhatilak paddy at Kalyani, West Bengal.

The total cost of cultivation averaged over two years varied between Rs. 27,443.00 (D_1N_1 or D_2N_1 or D_3N_1) and Rs. 39,553.00 ha^{-1} (D_1N_4 or D_2N_4 or D_3N_4) during *kharif* season.

4.2.9.2 Gross return, net return and B:C ratio

4.2.9.2.1 Effect of planting time

Gross return included the values of grain and straw of Radhatilak paddy as obtained from different plots under three planting periods in the study. The return from grain and straw of Radhatilak paddy in the experiment could generally be summarized in the ratio of 5:1. With delay in planting from 2nd week of July (D_1) to 2nd week of August (D_3), the pooled gross return was reduced by Rs. 7,462.00 ha^{-1} (Rs. 64,735.00 *vs.* Rs. 57,273.00 ha^{-1}) for Radhatilak rice during kharif season at Kalyani, West Bengal (Table 4.2.32).

The highest net return was obtained from the early planted crop (2nd week of July) compared to two late planted ones (4th week of July and 2nd week of August) during 2012, 2013 and pooled over two years (Table 4.2.32). The pooled net return varied between Rs. 22,880.00 (D_3) and Rs. 30,342.00 ha^{-1} (D_1), which led to B:C ratio of 1.88 (D_1), 1.83 (D_2) and 1.67 (D_3) in the study.

4.2.9.2.2 Effect of nutrient management

The gross return obtained from inorganic nutrient management (N_1) was highest (Rs. 64,235.00 ha^{-1}) for mean of two years, which was Rs. 592.00, Rs. 3,097.00 and Rs. 6,530.00 ha^{-1} greater over integrated (N_2 and N_3) and organic nutrient management system (N_4) adopted for Radhatilak paddy at Kalyani, West Bengal (Table 4.2.32).

Table 4.2.31

Effect of planting time and nutrient management on gross return of Radhatilak rice during *kharif* season

Treatment	2012			2013			Mean		
	Grain (Rs. ha^{-1})	Straw (Rs. ha^{-1})	Total (Rs. ha^{-1})	Grain (Rs. ha^{-1})	Straw (Rs. ha^{-1})	Total (Rs. ha^{-1})	Grain (Rs. ha^{-1})	Straw (Rs. ha^{-1})	Total (Rs. ha^{-1})
Planting time									
D_1	52133.00	10867.00	63000.00	54570.00	11900.00	66470.00	53352.00	11383.00	64735.00
D_2	51255.00	10667.00	61922.00	53295.00	10850.00	64145.00	52275.00	10758.00	63033.00
D_3	44682.00	9683.00	54365.00	50130.00	10050.00	60180.00	47406.00	9867.00	57273.00
Inorganic fertilizer									
N_1	50622.00	11378.00	62000.00	54960.00	11511.00	66471.00	52791.00	11444.00	64235.00
N_2	52152.00	11000.00	63152.00	53000.00	11133.00	64133.00	52576.00	11067.00	63643.00
N_3	49376.00	10044.00	59420.00	52100.00	10756.00	62856.00	50738.00	10400.00	61138.00
N_4	45277.00	9200.00	54477.00	50600.00	10333.00	60933.00	47938.00	9767.00	57705.00
Interaction effect									
D_1N_1	52757.00	12200.00	64957.00	57060.00	12467.00	69527.00	54908.00	12333.00	67241.00
D_1N_2	55193.00	11467.00	66660.00	54420.00	12200.00	66620.00	54807.00	11833.00	66640.00
D_1N_3	51907.00	10267.00	62174.00	54720.00	11733.00	66453.00	53313.00	11000.00	64313.00
D_1N_4	48677.00	9533.00	58210.00	52080.00	11200.00	63280.00	50378.00	10367.00	60745.00
D_2N_1	51057.00	11467.00	62524.00	55320.00	11467.00	66787.00	53188.00	11467.00	64655.00
D_2N_2	52927.00	11200.00	64127.00	52560.00	11000.00	63560.00	52743.00	11100.00	63843.00
D_2N_3	51170.00	10600.00	61770.00	53100.00	10667.00	63767.00	52135.00	10633.00	62768.00
D_2N_4	49867.00	9400.00	59267.00	52200.00	10267.00	62467.00	51033.00	9833.00	60866.00
D_3N_1	48053.00	10467.00	58520.00	52500.00	10600.00	63100.00	50276.67	10533.00	60809.67
D_3N_2	48336.67	10333.33	58670.00	52020.00	10200.00	62220.00	50178.00	10267.00	60445.00
D_3N_3	45050.00	9266.67	54316.67	48480.00	9867.00	58347.00	46765.00	9567.00	56332.00
D_3N_4	37286.67	8666.67	45953.34	47520.00	9533.00	57053.00	42403.00	9100.00	51503.00

Rate of grain = Rs. 1700 q^{-1} (2012), Rs. 1800 q^{-1} (2013); and Rate of straw = Rs. 200.00 q^{-1} (2012), Rs. 200.00 q^{-1} (2013)

Table 4.2.32

Effect of planting time and nutrient management on cost of cultivation, gross return, net return and B: C ratio of Radhatilak rice

Treatment	2012				2013				Mean			
	Total cost (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio	Total cost (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio	Total cost (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
Organic manure												
D_1	33693.00	63000.00	29307.00	1.87	35093.00	66470.00	31377.00	1.89	34393.00	64735.00	30342.00	1.88
D_2	33693.00	61922.00	28229.00	1.84	35093.00	64145.00	29052.00	1.83	34393.00	63033.00	28640.00	1.83
D_3	33693.00	54365.00	20672.00	1.61	35093.00	60180.00	25087.00	1.71	34393.00	57273.00	22880.00	1.67
Inorganic fertilizer												
N_1	27003.00	62000.00	34997.00	2.30	27883.00	66471.00	38588.00	2.38	27443.00	64235.00	36792.00	2.34
N_2	33943.00	63152.00	29209.00	1.86	35283.00	64133.00	28850.00	1.82	34613.00	63643.00	29030.00	1.84
N_3	35173.00	59420.00	24247.00	1.69	36753.00	62856.00	26103.00	1.71	35963.00	61138.00	25175.00	1.70
N_4	38653.00	54477.00	15824.00	1.41	40453.00	60933.00	20480.00	1.51	39553.00	57705.00	18152.00	1.46
Interaction effect												
D_1N_1	27003.00	64957.00	37954.00	2.41	27883.00	69527.00	41644.00	2.49	27443.00	67241.00	39798.00	2.45
D_1N_2	33943.00	66660.00	32717.00	1.96	35283.00	66620.00	31337.00	1.89	34613.00	66640.00	32027.00	1.93
D_1N_3	35173.00	62174.00	27001.00	1.77	36753.00	66453.00	29700.00	1.81	35963.00	64313.00	28350.00	1.79
D_1N_4	38653.00	58210.00	19557.00	1.51	40453.00	63280.00	22827.00	1.56	39553.00	60745.00	21192.00	1.54
D_2N_1	27003.00	62524.00	35521.00	2.32	27883.00	66787.00	38904.00	2.40	27443.00	64655.00	37212.00	2.36
D_2N_2	33943.00	64127.00	30184.00	1.89	35283.00	63560.00	28277.00	1.80	34613.00	63843.00	29230.00	1.84
D_2N_3	35173.00	61770.00	26597.00	1.76	36753.00	63767.00	27014.00	1.74	35963.00	62768.00	26805.00	1.75
D_2N_4	38653.00	59267.00	20614.00	1.53	40453.00	62467.00	22014.00	1.54	39553.00	60866.00	21313.00	1.54
D_3N_1	27003.00	58520.00	31517.00	2.17	27873.00	63100.00	35227.00	2.26	27443.00	60810.00	33367.00	2.22
D_3N_2	33943.00	58670.00	24727.00	1.73	35283.00	62220.00	26937.00	1.76	34613.00	60445.00	25832.00	1.75
D_3N_3	35173.00	54317.00	19144.00	1.54	36743.00	58347.00	21604.00	1.59	35963.00	56332.00	20369.00	1.57
D_3N_4	38653.00	45953.00	7300.00	1.19	40453.00	57053.00	16600.00	1.41	39553.00	51503.00	11950.00	1.30

Banerjee (2011) reported that Gobindabhog paddy under integrated nutrient management (FYM @ 50% RDN + Mustard cake @ 50% RDN) resulted in highest net return (Rs. 19,190 ha^{-1}) and greater B:C ratio (1.87) in West Bengal.

4.2.9.2.3 Interaction effect

The variations in grain and straw yields of Radhatilak paddy due to combined effect of planting time and nutrient management led to the differences in income from grain (Rs. 42,403.00 to Rs. 54,908.00 as well as straw (Rs. 9000.00 to Rs. 12,333.00 ha^{-1}) for pooled over two years (Table 4.2.31).

Planting of Radhatilak paddy during 2nd week of August (D_3) under organic nutrient management (N_4) resulted in lowest net return of Rs. 11,950.00 ha^{-1}, which could be improved upto Rs. 39,798.00 ha^{-1} under 2nd week of July planting and inorganic nutrient management (D_1N_1) in the investigation (Table 4.2.32). The findings reflected that chemical fertilizer-based nutrient management (N_1) for all three planting times resulted in B:C ratio of >2.00 (2.22–2.45), while integrated (N_2 and N_4) and organic nutrient management (N_4) had B:C ratio of <2.00 with a range between 1.30 (D_3N_4) and 1.93 (D_1N_2).

4.3 Experiment No. 3

Effect of storage containers on grain quality of Radhatilak rice

4.3.1 Storage environment

There was steady increase in maximum, minimum and mean ambient temperature from the start of storage period *i.e.* 0-month to the end of 6-month, but thereafter they showed declining trends upto the end of 9-month period in the laboratory at Kalyani, West Bengal, India (Table 4.3.1). Although the maximum, minimum and mean relative humidity were mostly in steady phase during the first 6-month period, but they were increased during the last 3-month storage time. These kinds of meteorological parameters might be due to common seasonal changes from cool and dry weather during January and February to hot and humid during May and June and then to warm and humid during August and September at the experimental site.

4.3.2 Grain quality

4.3.2.1 Milling quality

The effect of storage methods on milling quality of Radhatilak rice in terms of the percentage of brown rice, milled rice and head rice was evaluated in the experiment.

4.3.2.1.1 Hulling

After shelling of Radhatilak paddy, the brown rice content varied significantly among five containers after 3-month, 6-month and 9-month storage period during 2012-13, 2013-14 and pooled values in the study (Table 4.3.2). Grains stored in jute bag (C_3) and markin cloth bag (C_4) mostly recorded higher hulling recovery than the others, while storage in earthen pot (C_1) resulted in lowest brown rice content in the study. With the advancement of storage period from 90 days to 270 days, the hulling recovery usually showed an increasing trend irrespective of the container and year.

4.3.2.1.2 Milling

Mean milling recovery of Radhatilak rice was slightly increased from 3-month to 9-month period during both the years of investigation (Table 4.3.3). The milled rice content varied significantly among five storage containers irrespective of the storage period and year of investigation. Like hulling recovery, paddy grains stored in earthen

Table 4.3.1

Meteorological data during post-harvest storage period at B.C.K.V., Mohanpur, Nadia, West Bengal during 2012-13 and 2013-14

	Meteorological data during storage period								
	2012-2013			2013-2014			Mean		
	1 – 90 days	91 – 180 days	181 – 270 days	1 – 90 days	91 – 180 days	181 – 270 days	1 – 90 days	91 – 180 days	181 – 270 days
Maximum Temp. (^{0}C)	27.53	36.03	33.29	27.13	37.73	33.70	27.33	36.88	33.50
Minimum Temp. (^{0}C)	12.34	24.57	26.25	12.62	25.18	26.57	12.48	24.88	26.41
Mean Temp. (^{0}C)	19.94	30.30	29.77	19.87	31.45	30.13	19.91	30.88	29.95
Maximum Relative humidity (%)	92.80	89.84	95.49	85.50	87.30	95.23	89.15	88.57	95.36
Minimum Relative humidity (%)	48.32	54.97	81.21	56.76	50.17	80.13	52.54	52.57	80.67
Mean Relative humidity (%)	70.56	72.40	88.35	71.13	68.74	87.68	70.85	70.57	88.02

* **1 – 90 days** = 15th December to 14th March; **91 – 180 days** = 15th March to 14th June; **181 – 270 days** = 15th June to 14th September

Table 4.3.2

Effect of storage container on hulling recovery of Radhatilak rice during post-harvest storage period

Storage container	Hulling (%)								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	75.58	78.08	76.83	76.23	78.18	77.20	76.65	78.40	77.53
C_2	77.10	78.15	77.63	77.43	78.43	77.93	78.13	78.20	78.16
C_3	78.65	79.68	79.16	78.18	79.55	78.86	78.40	79.83	79.11
C_4	77.95	79.88	78.91	77.83	79.90	78.86	78.35	79.85	79.10
C_5	77.88	79.13	78.50	77.75	79.08	78.41	78.40	79.25	78.83
Mean	77.43	78.98	78.21	77.48	79.03	78.25	77.99	79.11	78.55
S.Em (±)	0.24	0.13	0.14	0.30	0.18	0.17	0.21	0.15	0.13
C.D. at 5%	0.70	0.36	0.39	0.85	0.51	0.50	0.59	0.43	0.36

NS = Not significant

Table 4.3.3

Effect of storage container on milling recovery of Radhatilak rice during post-harvest storage period

Storage container	Milling (%)								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	67.63	69.93	68.78	68.60	71.08	69.84	68.89	71.25	70.07
C_2	69.53	69.98	69.75	70.48	70.98	70.73	70.20	71.30	70.75
C_3	70.98	72.10	71.54	71.45	71.63	71.54	70.05	72.20	71.13
C_4	70.73	73.30	72.01	71.40	71.83	71.61	70.15	72.23	71.19
C_5	70.18	72.25	71.21	70.30	72.23	71.26	70.85	71.98	71.41
Mean	69.81	71.51	70.66	70.45	71.55	71.00	70.03	71.79	70.91
S.Em (±)	0.37	0.48	0.30	0.27	0.26	0.19	0.47	0.16	0.25
C.D. at 5%	1.05	1.36	0.86	0.77	0.74	0.53	1.33	0.47	0.71

NS = Not significant

pot (C_1) recorded the lowest milling yield throughout the storage period for both 2012-13 and 2013-14.

4.3.2.1.3 Head rice

The head rice recovery of Radhatilak rice generally showed slight increasing trend from 3-month to 9-month storage period during both first and second year of investigation (Table 4.3.4; Fig. 4.3.1), which was in conformity with Singh *et al.* (2003). This observation might be due to the ageing of the grains, which led to less breakage during milling process.

Storage containers had significant influence on head rice recovery of Radhatilak rice after 3-month, 6-month and 9-month periods for both 2012-13, 2013-14 and pooled values, except after 3-month time during 2013-14 only (Table 4.3.4). The whole grains of Radhatilak paddy stored in markin cloth bag (C_4) usually yielded the highest head rice followed by jute bag (C_3), while earthen pot (C_1) recorded lower HRR for all storage periods (90 days, 180 days and 270 days) during both the years and pooled values of the experiment. Thus, the higher HRR recorded with two porous bags (markin cloth and gunny bag) might be attributed to natural tempering of paddy grains in storage environment leading to greater hardness of grains compared to other three containers (G.I. bin, polythene bag and earthen pot) in the study. Based on pooled data for HRR after 9-month period, five storage containers could be arranged as: Markin cloth bag (62.75%) > Jute bag (62.58%). > Galvanized Iron bin (62.16%) > Polythene bag (62.14%) > Earthen pot (61.79%). On the contrary, Mahata (2014) observed that increased porosity in fibre-made bags (jute and markin cloth) caused great exposure of grains to the storage environment, which led to lower HRR of Gobindabhog rice compared to earthen pot, GI bin and polythene bag used in the investigation.

The grains stored in the second year yielded greater HRR than the first year irrespective of the storage period at Kalyani, West Bengal, India.

4.3.2.2 Physical properties of grain

4.3.2.2.1 Kernel length

Kernel length, being a genetical character, remained usually unaffected after 3 and 6-month storage in five different containers during both 2012-13 and 2013-14,

Table 4.3.4

Effect of storage container on head rice recovery of Radhatilak rice during post-harvest storage period

Storage container	Head rice recovery (%)								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	59.19	62.45	60.82	59.33	62.63	60.98	60.03	63.55	61.79
C_2	60.80	62.75	61.78	61.39	62.70	62.04	60.63	63.70	62.16
C_3	61.19	63.30	62.24	61.39	63.00	62.19	61.07	64.10	62.58
C_4	61.11	63.70	62.40	61.81	63.80	62.81	61.22	64.28	62.75
C_5	61.01	62.55	61.78	60.82	64.08	62.45	61.41	62.88	62.14
Mean	60.66	62.95	61.80	60.95	63.24	62.09	60.87	63.70	62.29
S.Em (±)	0.47	0.33	0.29	0.37	0.24	0.22	0.46	0.19	0.25
C.D. at 5%	1.34	NS	0.82	1.05	0.68	0.63	1.30	0.54	0.70

NS = Not significant

Table 4.3.5

Effect of storage container on kernel length of Radhatilak rice during post-harvest storage period

Storage container	Kernel length (mm)								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	4.06	4.10	4.08	4.08	4.10	4.09	3.98	4.11	4.04
C_2	4.06	4.10	4.08	4.08	4.10	4.09	4.03	4.10	4.07
C_3	4.06	4.10	4.08	4.01	4.09	4.05	3.98	4.10	4.04
C_4	4.06	4.09	4.07	4.08	4.10	4.09	4.03	4.11	4.07
C_5	4.05	4.10	4.07	4.02	4.11	4.06	3.98	4.10	4.04
Mean	4.06	4.09	4.08	4.05	4.10	4.08	4.00	4.10	4.05
S.Em (±)	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
C.D. at 5%	NS	NS	NS	NS	NS	0.04	0.04	NS	0.02

NS = Not significant

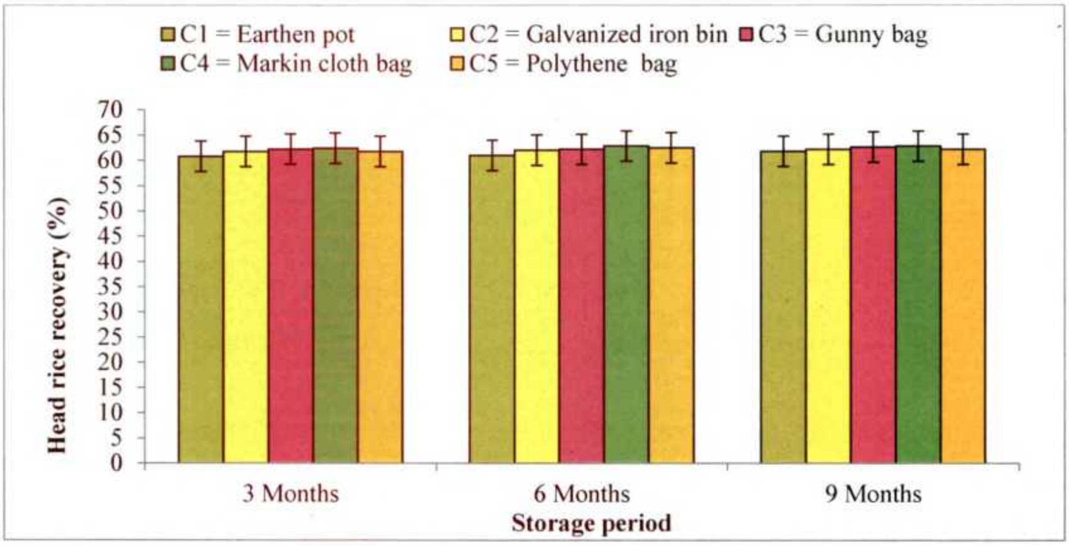


Fig. 4.3.1: Effect of storage containers on head rice recovery (%) of Radhatilak rice during post-harvest storage period (pooled over two years)

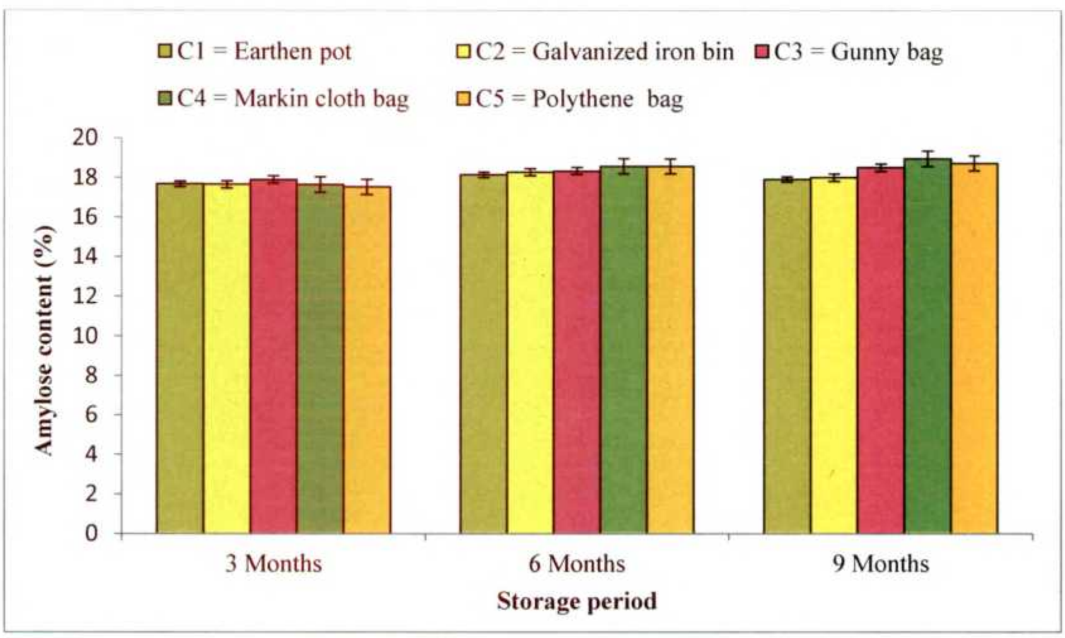


Fig. 4.3.2: Effect of storage containers on amylose (%) of Radhatilak rice during post-harvest storage period (pooled over two years)

but it varied significantly after long storage of 9-month period during first year and pooled values in the study (Table 4.3.5).

4.3.2.2.2 Kernel breadth

Storage containers did not have any influence on kernel breadth of Radhatilak rice at three different storage periods (90, 180 and 270 days) during both the years of investigation (Table 4.3.6).

4.3.2.2.3 L / B ratio

Like kernel length and breadth, L / B ratio of Radhatilak rice, did not vary among five storage containers at different post-harvest periods during both 2012-13 and 2013-14 (Table 4.3.7).

4.3.2.3 Cooking quality

4.3.2.3.1 Amylose content

The amylose content in Radhatilak rice was usually improved with the ageing of paddy grains from 3-month to 9-month period but it did not vary significantly among five containers at short, medium, and long-term storage periods during both 2012-13 and 2013-14 (Table 4.3.8; Fig. 4.3.2). Kanlayakrit and Maweag (2013) reported non-significant influence or no change in amylose content of two *thai* rice varieties during 10-month storage period at Bangkok, Thailand.

Based on pooled values for amylose content after nine month storage time, five storage containers could be arranged as: Markin cloth bag (18.97%) ≥ Polythene bag (18.74%) ≥ Jute bag (18.52%) ≥ G.I. bin (18.02%) ≥ Earthen pot (17.92%). However, Mahata (2014) reported mostly-opposite sequence of storage containers for amylose content of Gobinda

4.3.2.3.2 Protein content

The protein content in Radhatilak rice was decreased sharply with ageing of grains from 3-month to 6-month time, while reduced slowly during 6-month to 9-month period in both 2012-13 and 2013-14 (Table 4.3.9). The findings differed with Ilyas *et. al,* (1983), wherein little increase in protein content (8.5-8.8%) was noted during post-harvest storage over initial sample (8.4%) in a study at Cuttack, Odisha, India. The containers used in the study did not show any influence on protein content of Radhatilak rice irrespective of the storage period and year of investigation.

Table 4.3.6

Effect of storage container on kernel breadth of Radhatilak rice during post-harvest storage period

Storage container	Kernel breadth (mm)								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	1.98	1.95	1.96	1.94	1.94	1.94	1.94	1.91	1.93
C_2	1.98	1.96	1.97	1.97	1.96	1.97	1.98	1.94	1.96
C_3	1.96	1.96	1.96	1.98	1.96	1.97	1.93	1.94	1.93
C_4	1.96	1.95	1.96	1.98	1.95	1.97	1.94	1.91	1.93
C_5	1.95	1.96	1.96	1.97	1.95	1.96	1.96	1.94	1.95
Mean	1.97	1.96	1.96	1.97	1.95	1.96	1.95	1.93	1.94
S.Em (±)	0.02	0.01	0.01	0.02	0.01	0.01	0.03	0.01	0.01
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.3.7

Effect of storage container on L / B ratio of Radhatilak rice during post-harvest storage period

Storage container	L / B ratio								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	2.06	2.10	2.08	2.10	2.12	2.11	2.05	2.15	2.10
C_2	2.06	2.09	2.07	2.07	2.09	2.08	2.04	2.12	2.08
C_3	2.07	2.09	2.08	2.05	2.09	2.07	2.06	2.12	2.09
C_4	2.07	2.10	2.08	2.06	2.10	2.08	2.07	2.15	2.11
C_5	2.08	2.09	2.08	2.04	2.11	2.07	2.04	2.12	2.08
Mean	2.07	2.09	2.08	2.06	2.10	2.08	2.05	2.13	2.09
S.Em (±)	0.02	0.01	0.01	0.02	0.01	0.01	0.03	0.01	0.01
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.3.8

Effect of storage container on amylose content of Radhatilak rice during post-harvest storage period

Storage container	Amylose content (%)								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	18.28	17.06	17.67	18.81	17.48	18.15	18.16	17.69	17.92
C_2	17.60	17.72	17.66	18.81	17.75	18.28	18.64	17.40	18.02
C_3	18.32	17.49	17.90	18.18	18.49	18.34	18.77	18.26	18.52
C_4	17.87	17.43	17.65	19.16	18.03	18.59	19.10	18.84	18.97
C_5	17.42	17.63	17.53	18.39	18.78	18.58	18.90	18.58	18.74
Mean	17.90	17.47	17.68	18.67	18.10	18.39	18.71	18.16	18.43
S.Em (±)	0.46	0.62	0.38	0.74	0.72	0.51	0.69	0.66	0.48
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.3.9

Effect of storage container on protein cintent of Radhatilak rice during post-harvest storage period

Storage container	Protein content (%)								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	7.24	7.22	7.23	6.41	6.86	6.63	6.29	6.98	6.63
C_2	7.00	7.14	7.07	6.50	7.11	6.80	6.51	6.90	6.71
C_3	7.08	7.31	7.20	6.54	6.99	6.77	6.78	6.87	6.82
C_4	7.16	6.90	7.03	6.73	6.52	6.62	6.37	6.56	6.47
C_5	6.73	6.84	6.79	6.31	6.71	6.51	6.45	6.62	6.53
Mean	7.04	7.08	7.06	6.50	6.84	6.67	6.48	6.78	6.63
S.Em (±)	0.35	0.23	0.21	0.23	0.33	0.20	0.35	0.20	0.20
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

4.3.1.3.3 Alkali value or Gelatinization temperature

Mean container pooled alkali value was 4.08 (3-month), 3.80 (6-month) and 3.43 (9-month), which indicated a gradual decrease in alkali spreading value from short-term to long-term storage in the study (Table 4.3.10). The containers did not vary significantly among themselves for alkali value throughout the post-harvest storage period in 2012-13 and 2013-14. Above all, the milled rice of Radhatilak obtained from all samples had intermediate gelatinization temperature.

4.3.1.4 Processing quality

4.3.1.4.1 Kernel length after cooking

The cooked kernel length of Radhatilak rice after cooking was slightly increased with the advancement of storage periods during both 2012 - 13 and 2013 - 14. Perusal of data revealed that the grains stored in plastic bag resulted least kernel length after cooking throughout the storage period during both the years of investigation (Table 4.3.11).

4.3.1.4.2 Elongation ratio (ER)

The results on elongation ratio of Radhatilak rice stored in five different containers under 3, 6 and 9-months period indicated that there was no change in ER from 3 to 6 months storage time; while a slight increase in ER from 6 months to 9 months storage during both 2013 and 2014 (Table 4.3.12; Fig. 4.3.3). Similar kind of finding in cooked kernel elongation of *thai* paddy varieties during the ageing process was reported by Kanlayakrit and Maweag (2013).

4.3.1.4.3 Aroma

There was a steady decrease in intensity of aroma of Radhatilak rice during post-harvest storage from 3-month to 9-month period irrespective of the containers used during both the years of investigation (Table 4.3.13; Fig. 4.3.4). The average aroma score over containers after 3-month storage (score 2.00 ± 0.25) declined by 18.5% after 6-month (score 1.63 ± 0.15) and 20.2% after 9-month (score 1.32 ± 0.10). The loss in flavour during the post-harvest storage period might be due to release or volatilization of 2-acety-l-pyroline content in the grain. The finding followed the same trend of decrease in 2-acety-l-pyroline content in *thai* rice (*cv.* Khao Dawk Mali 105) with increasing storage time from 1 to 10-month period (Wongpornchai *et al.*, 2004).

Table 4.3.10

Effect of storage container on alkali value (score) of Radhatilak rice during post-harvest storage period

Storage container	Alkali value (score)								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	4.00	4.25	4.13	3.75	4.00	3.88	3.25	3.75	3.50
C_2	4.00	4.00	4.00	4.00	3.50	3.75	3.25	3.25	3.25
C_3	4.00	4.25	4.13	3.50	4.00	3.75	3.50	4.00	3.75
C_4	4.00	4.50	4.25	3.75	4.00	3.88	3.25	3.75	3.50
C_5	4.00	3.75	3.88	3.75	3.75	3.75	3.00	3.25	3.13
Mean	4.00	4.15	4.08	3.75	3.85	3.80	3.25	3.60	3.43
S.Em (±)	0.48	0.39	0.31	0.35	0.36	0.25	0.30	0.43	0.26
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.3.11

Effect of storage container on kernel length after cooking of Radhatilak rice during post-harvest storage period

Storage container	Kernel length after cooking (mm)								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	7.40	7.28	7.34	7.35	7.34	7.35	7.39	7.38	7.38
C_2	7.30	7.25	7.28	7.30	7.29	7.30	7.27	7.40	7.33
C_3	7.40	7.28	7.34	7.28	7.29	7.28	7.47	7.33	7.40
C_4	7.25	7.28	7.26	7.30	7.24	7.27	7.29	7.30	7.30
C_5	7.08	7.23	7.15	7.20	7.27	7.23	7.19	7.30	7.25
Mean	7.29	7.26	7.27	7.29	7.29	7.29	7.32	7.34	7.33
S.Em (±)	0.08	0.08	0.06	0.08	0.09	0.06	0.06	0.10	0.06
C.D. at 5%	0.21	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.3.12

Effect of storage container on elongation ratio of Radhatilak rice during post-harvest storage period

Storage container	Elongation ratio								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	1.82	1.78	1.80	1.80	1.79	1.80	1.86	1.82	1.84
C_2	1.80	1.77	1.78	1.79	1.78	1.78	1.80	1.83	1.82
C_3	1.82	1.78	1.80	1.88	1.78	1.83	1.87	1.81	1.84
C_4	1.78	1.78	1.78	1.79	1.77	1.78	1.80	1.81	1.80
C_5	1.77	1.76	1.77	1.80	1.77	1.79	1.78	1.81	1.79
Mean	1.80	1.77	1.79	1.81	1.78	1.79	1.82	1.82	1.82
S.Em (±)	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.01
C.D. at 5%	NS	NS	NS	0.05	NS	NS	0.05	NS	0.04

NS = Not significant

Table 4.3.13

Effect of storage container on aroma score of Radhatilak rice during post-harvest storage period

Storage container	Aroma (score)								
	3 Months			6 Months			9 Months		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
C_1	2.25	2.25	2.25	1.75	1.67	1.71	1.50	1.50	1.50
C_2	2.00	1.84	1.92	1.75	1.59	1.67	1.25	1.33	1.29
C_3	1.75	1.92	1.83	1.50	1.58	1.54	1.00	1.42	1.21
C_4	1.75	1.75	1.75	1.25	1.67	1.46	1.00	1.42	1.21
C_5	2.25	2.25	2.25	1.75	1.75	1.75	1.25	1.50	1.38
Mean	2.00	2.00	2.00	1.60	1.65	1.63	1.20	1.43	1.32
S.Em (±)	0.22	0.15	0.13	0.26	0.18	0.16	0.20	0.19	0.14
C.D. at 5%	NS	NS	0.38	NS	NS	NS	NS	NS	NS

NS = Not significant

Among storage containers used in the study, earthen pot (C_1) and plastic bag (C_5) could favorably inhibit the release of 2-acety-l-pyroline from the whole grains of Radhatilak rice compared to other three containers at 3, 6 and 9-month storage period in the investigation; while the loss of aroma in gunny bag (C_3) and markin cloth (C_4) bag were much faster in 90 days (score 1.83 and 1.75), 180 days (score 1.54 and 1.46) and 270 days (score 1.21 and 1.21) storage time.

Table 4.1.2 may be placed at appropriate place. Table 4.1.3 Title does not give the effect of cultivars. Text and Table need to be arranged. Discussion is meagre. Lacking in many places. Many things could have been correlated with GDD and discussed.

GDD
HTU
PTU

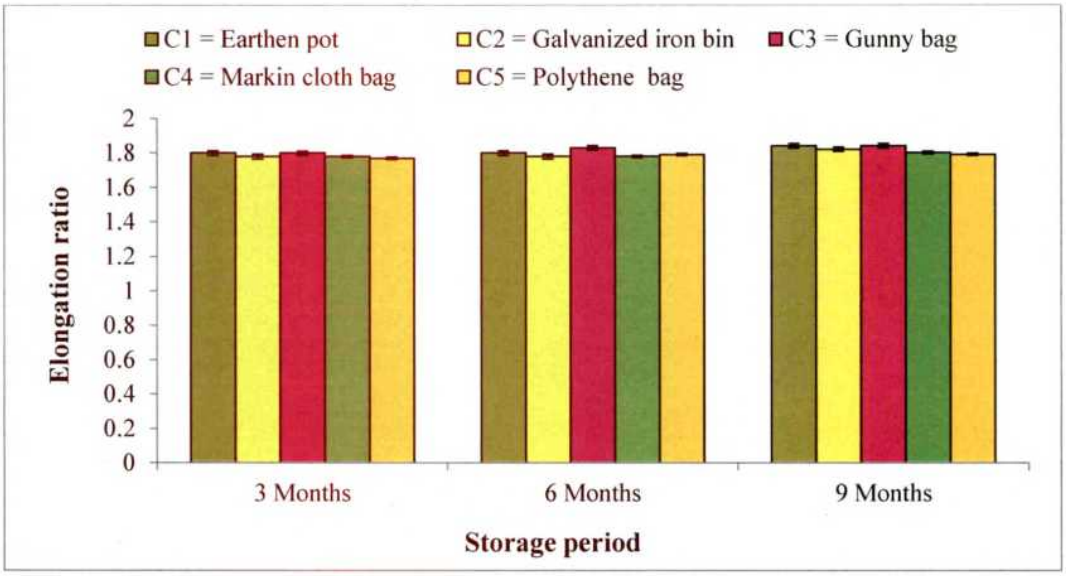


Fig. 4.3.3: Effect of storage containers on elongation ratio of Radhatilak rice during post-harvest storage period (pooled over two years)

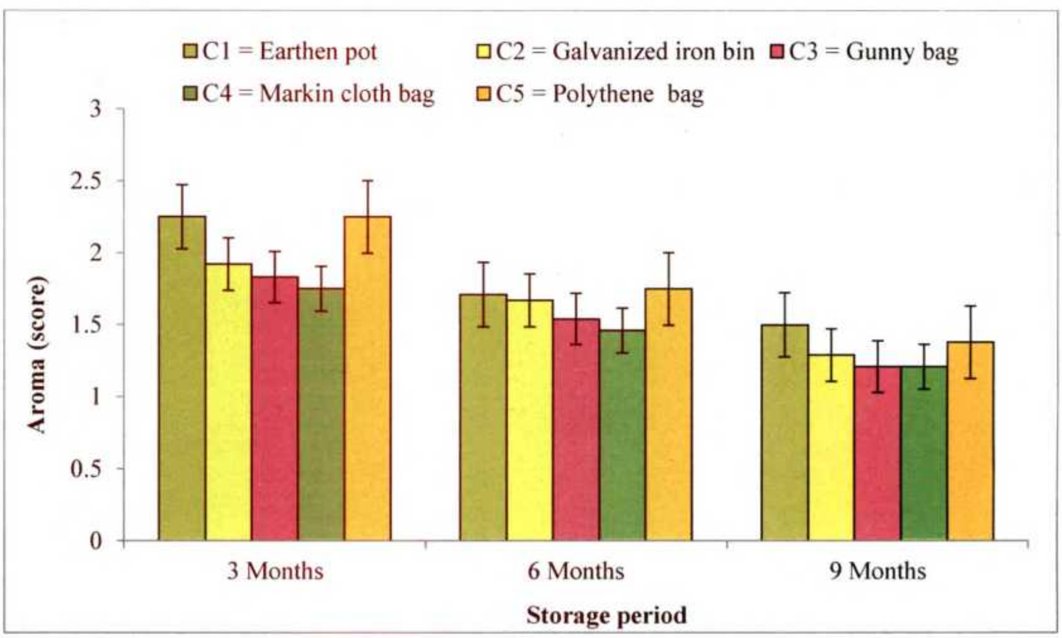


Fig. 4.3.4: Effect of storage containers on aroma (score) of Radhatilak rice during post-harvest storage period (pooled over two years)

Chapter 5

SUMMARY AND CONCLUSION

5. SUMMARY AND CONCLUSION

A comprehensive study on "Evaluation of agro-techniques and storage methods for aromatic rice landraces of West Bengal" was done at Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India during the period of 2012–2014. Two field experiments were conducted at 'C' Block Farm, Kalyani, Nadia during wet (*kharif*) season of 2012 and 2013 to evaluate the performance of fourteen scented rice cultivars as well as to standardize the agro-techniques like planting time and nutrient management system for better yield and quality of Radhatilak rice in New Alluvial Zone of West Bengal. Besides, a post-harvest storage study was made during 2012-13 and 2013-14 to identify better storage method(s) for sustenance of grain quality of Radhatilak rice at different storage periods.

The salient findings of first experiment entitled, "Evaluation of indigenous scented rice cultivars in New Alluvial Zone of West Bengal" were summarized as follow:

All fourteen aromatic rice cultivars were long duration types (>140 days), except Lal Badshabhog (medium-long duration, 136.0 days). Mean cultivar GDD from sowing to emergence 4^{th} leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 77.7, 423.3, 940.0, 1684.3, 2296.1, 2483.6, 2628.5 and 2772.5°C, respectively. Based on pooled data, the stage-wise mean cultivar duration, GDD, HTU and PTU were determined as: vegetative (86.3 days, 1684.3°C day, 7786.4°C hour and 21424.2°C hour), reproductive (31.3 days, 611.8°C day, 3650.4°C hour and 7257.3°C hour) and ripening phase (30.9 days, 476.4°C day, 3281.8°C hour 5441.6°C hour).

Plant height, tiller production and LAI were increased consistently with the advancement of crop growth upto maturity, panicle initiation (*i.e.* up to 56 DAT) and pre-flowering (*i.e.* upto 84 DAT) stage, respectively. Based as pooled values, the final plant height was found to vary between 131.0 (Kataribhog) and 148.7 cm (Lal Badshabhog) at harvest; maximum number of tillers m^{-2} between 324.0 (Kaminibhog) and 400.3 (Gobindabhog) at 56 DAT, and maximum LAI between 4.62 (Kaminibhog) and 5.09 (Kataribhog) at 84 DAT. The variation in light interception ratio among fourteen cultivars generally showed inverse relationship with their respective LAI values at different stages. Mean cultivar light extinction coefficient (k), pooled over two years, was 0.60, 0.41, 0.53 and 0.76 at 28, 56, 84 DAT and harvest, respectively.

The grain colour-based grouping of varieties might be as: gold and gold furrows on straw background (Badshabhog, Gobindabhog, Kataribhog, Sitabhog and Tulaipanji), brown spots on straw background (Kaminibhog), brown / tawny (Lal Badshabhog), purple spots / furrows on straw background (NC 324, Radhatilak and Radhunipagal) and black coloured grain (Kalojira, Kalonunia, NC 365 and Tulsimukul). Three varieties (Kalonunia, NC 365 and Tulaipanji) possessed awn at tip of the lemma, while rest eleven cultivars were awnless.

Genetic variation in yield contributing characters (*viz.* panicle length, number of panicles m^{-2}, number of filled grains $panicle^{-1}$, 1000 grain weight) and grain yield was noted among fragrant rice cultivars in the study. Panicle length was found to vary between 23.7 cm (Radhunipagal) and 28.2 cm (NC 365), while number of panicles m^{-2} between 233.7 (Kaminibhog) and 302.6 (Gobindabhog), number of filled grains $panicle^{-1}$ between 73.2 (Tulaipanji) and 142.3 (Radhunipagal) and 1000 grain weight between 10.38 (Radhunipagal) and 17.09 g (NC 365). Based on pooled grain yield, the varieties could be arranged in different categories as: >3.00 t ha^{-1} (NC 365 and Kataribhog), 2.75–3.00 t ha^{-1} (Badshabhog, Kalonunia, Radhatilak, NC 324, Kalojira and Gobindabhog), 2.50–2.75 t ha^{-1} (Radhunipagal and Tulsimukul), 2.25–2.50 t ha^{-1} (Lal Badshabhog and Kaminibhog) and 2.00–2.25 t ha^{-1} (Tulaipanji and Sitabhog). The correlation studies revealed that the yield components like number of filled grains $panicle^{-1}$ (r =0.397** and test weight (r =0.327**) had significant contributions toward the grain yield of indigenous scented rice compared to number of panicles m^{-2} in the study.

Mean cultivar pooled hulling, milling and head rice recovery were 76.9, 68.5 and 61.9%, respectively. Among fourteen varieties, nine (Badshabhog, Gobindabhog, Kalojira, Kaminibhog, Lal Badshabhog, Radhatilak, Radhunipagal, Sitabhog and Tulsimukul) were classified as short bold (SB) type, while five (Kalonunia, Kataribhog, NC 324, NC 365 and Tulaipanji) belonged to medium-slender (MS) category. Based on pooled values, amylose content was found to vary between 16.60 (Kaminibhog) and 19.03% (Sitabhog), and protein content between 6.77 (Kalojira) and 7.38% (NC 365). The variation in alkali spreading values (3.0 to 4.5) revealed that the tested cultivars had either high-intermediate or intermediate gelatinization temperature. Among fourteen cultivars, six varieties (Badshabhog, Kaminibhog, Lal, Badshabhog, Radhatilak, Radhunipagal and Sitabhog) exhibited >1.80 kernel elongation; while Radhunipagal had the highest intensity of aroma (score 2.45) followed by Gobindabhog and Kalonunia (score 2.35) in the study.

The important observations from second investigation entitled "Standardization of planting time and nutrient management system for better yield and quality of Radhatilak rice during *kharif* season" could be summarized as under:

Radhatilak paddy, being a tall-*indica* type, produced long-statured plant (138.0 cm) with late maturity (149.0 days) and few (average 10.67) well-exerted panicles plant^{-1} during *kharif* season. The colour of lemna and palea was green at anthesis, which turned to golden-yellow with reddish-purple spot at the tip during maturity. The flower was bi-sexual comprising six yellow-coloured anthers and, white feathery stigma. The white-coloured short-bold type kernels had low amylose (average 18.67%), medium gelatinization temperature and pleasant aroma.

Radhatilak rice planted at three different times, *i.e.* 2nd week of July (D_1), 4th week of July (D_2) and 2nd week of August (D_3) took 155.2, 144.7, and 138.1 days to maturity, which indicated reduction in life duration by 10.5 and 17.1 days for second (D_2) and third (D_3) plantings compared to the earliest one (D_1) in the study. Mean summed GDD for Radhatilak paddy from sowing to emergence, 4th leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 72.2, 418.9, 949.6, 1651.9, 2230.8, 2385.7, 2530.9 and 2651.8°C day, respectively. Based on pooled values for total accumulated GDD, HTU and PTU, three planting times could be arranged as: 2nd week of planting (2912.8°C day, 15376.3°C hour and 36002.7°C hour) > 4th week of July (2648.0°C day, 14663.7°C hour and 32265.8°C hour) > 2nd week of August (2431.2°C day, 13868.4°C hour and 29209.3°C hour).

The yield components (*viz.* number of panicles m^{-2}, number of filled grains panicle^{-1} and 1000 grain weight) and grain yield differed significantly among three planting times and four nutrient management practices in the investigation. Radhatilak rice planted during 2nd week of July (D_1) produced the highest pooled grain yield (3.00 t ha^{-1}), which was 2.94 and 12.78 % greater over 4th week of July (D_2) and 2nd

week of August (D_3), respectively. The correlation studies between thermal indices and grain yield revealed that GDD and PTU had positive influence ($P<0.05$ or $P<0.01$) throughout the cropping period, but HTU showed positive impact (r = 0.235* and r = 0.378*) on economic yield during active tillering to panicle initiation and dough to maturity stage, respectively. On the other hand, sole application of chemical fertilizers (N_1) or integrated nutrient management (50% RD inorganic + 50% RD mustard cake) resulted in similar non-significant grain yields of Radhatilak rice, while increment in dose of organic manures (N_3 and N_4) showed lower economic yields during *kharif* season.

The variation in planting time and nutrient management did not show any significant influence on milling quality, kernel size, shape and colour of Radhatilak rice in the experiment. Radhatilak rice planted during 2nd week of July (D_1) resulted in highest amylose content (18.90%) compared to second (D_2) and third (D_3) plantings; while organic nutrient management improved the flakiness of cooked rice due to higher amylose content (19.67%) over both integrated (N_2 and N_3) and fertilizer-based (N_1) nutrient management during *kharif* season at Kalyani, West Bengal. The intensity of aroma was improved with delay in planting from 2nd week of July (score 2.36) to 2nd week of August (score 2.44) probably due to decreasing day and night temperature (30.94/19.91°C *vs.* 30.21/16.03°C) during grain-filling and ripening period. Radhatilak rice usually had intermediate gelatinization temperature and medium-strong aroma.

Although chemical fertilizer-based nutrition (50:25:25 kg ha^{-1} of $N:P_2O_5:K_2O$) to Radhatilak paddy resulted in highest grain yield (2.97 t ha^{-1}), net return (Rs. 36,792.00 ha^{-1}) and B:C ratio (2.34); but integrated nutrient management (50% RD as inorganic + 50% RD as mustard cake) might be an alternative option for similar grain yield (2.96 t ha^{-1}), lesser lodging tendency (score 3.00), slightly-higher grain quality like head rice recovery (62.1%), amylose content (18.72%) and aroma (score 2.34) along with better residual status (+5.87% N, +24.04% P_2O_5 and -13.77% K_2O) in soil.

The findings of third experiment on "Effect of storage containers on grain quality of Radhatilak rice" during post-harvest storage period of 2012-13 2013-14 could be summarized as:

The seasonal changes in weather during 9-month post-harvest period caused differences in ambient temperature and relative humidity of the laboratory during both the years of investigation. The variation in parent material of five containers including their porosity, temperature sensitivity, etc. influenced the grain quality parameters of Radhatilak rice during different storage periods.

With the advancement of storage time from 90 to 270 days, the milling quality of Radhatilak rice (*viz.* hulling, milling and head rice recovery) generally showed slight increasing trend, including few significant changes during the post-harvest storage period. Five storage containers, with regard to pooled head rice yield after 9-month period, could be arranged as: Markin cloth bag (62.75%) > Jute bag (62.58%) > Galvanized Iron bin (62.16%) > Polythene bag (62.14%) > Earthen pot (61.79%).

The physical properties of grain (*viz.* kernel length, kernel breadth, L/B ratio, shape, etc.) of Radhatilak rice did not differ significantly among five storage containers during the ageing process at Kalyani West Bengal. On an average, the protein content and alkali value decreased steadily from 3-month to 9-month storage period, including non-significant variations among the containers in the experiment. Mean cultivar pooled amylose content was 17.67, 18.39 and 18.43% at 3-month, 6-month and 9-month storage period, respectively; which indicated slight improvement in amylose content during the ageing process in the study.

There was a steady decrease in intensity of aroma of Radhatilak rice during post-harvest storage from 3-month to 9-month period irrespective of the container used in the investigation. The average aroma score after 3-month storage (score 2.00 ± 0.25) was decreased by 18.5% after 6-month (score 1.63±0.15) and 34.0% after 9-month period (score 1.32±0.10). Among storage containers, earthen pot (C_1) performed best for retention of aroma throughout the post-harvest period. Alternately, polythene bag (C_5) could also be used considering the grain quality parameters like HRR, amylose content and aroma at short, medium and long-storage period. Two fibre-made porous bags (jute made gunny bag and markin cloth bag) appeared unfit for long-term storage of Radhatilak paddy with respect to aroma (score 1.21), even with better head rice recovery (62.58–62.75%).

Based on the findings of three investigations, two native aromatic rice landraces (Gobindabhog and Radhunipagal) might be promoted for large-scale cultivation due to medium grain yield (2.57–2.81 t ha^{-1}) highest volume expansion ratio (2.74) and medium-strong aroma (score 2.35–2.45); while medium-grained Kalonunia and NC 365, and short-grained Radhatilak could also be tried with standardization of agro-techniques in South Bengal region for better yield potentiality, amylose content and flavour. The planting of Radhatilak paddy during 2^{nd} week of July along with fertilizer-based nutrition (50:25:25 kg ha^{-1} of $N:P_2O_5:K_2O$) could be recommended due to highest grain yield (3.14 t ha^{-1}), net return (Rs. 39,798.00 ha^{-1}) and B:C ratio (2.45); but it might be better option for planting of the crop during 4^{th} week of July coupled with integrated nutrient management (50% RD inorganic + 50% RD as mustard cake) due to similar grain yield (3.02 t ha^{-1}), lesser duration (144.7 days) and lodging tendency (score 2.67), slightly-better grain quality like head rice recovery (62.1%), amylose content (18.52%) and aroma (score 2.33), and better residual soil status (+6.38% N, +23.89% P_2O_5 and -13.42% K_2O) toward the development of sustainable market potential-based cultivation system of Radhatilak rice in New Alluvial Zone of West Bengal. Among five storage containers, earthen pot performed best for medium protein content (6.63%), greater elongation ratio (1.84) and aroma (score 1.50) of Radhatilak rice after 9-month storage period in West Bengal.

Chapter 6

FUTURE SCOPE OF RESEARCH

6. FUTURE SCOPE OF RESEARCH

The present study on "Evaluation of agro-techniques and storage methods for aromatic rice landraces of West Bengal" was done during the period of 2012–2014 in New Alluvial Zone of West Bengal, India. However, there is a wide scope to undertake the future research programmes on the following aspects:

A large genetic stock of Basmati and non-Basmati aromatic rice including landraces, high-yielding and recently developed hybrid ones are available in different parts of our country. Besides some exotic long-grained scented rice varieties popular in the world market are cultivated in some Asian and South American countries. These aromatic rice cultivars having varied yield potentiality and diverse grain quality may be evaluated during both wet and dry season to find out the suitable ones in different agro-climatic zones of India.

Research works may be undertaken for standardization of cultural practices like planting dynamics, organic or integrated nutrient, weed and water management, system of rice intensification (S.R.I.), harvesting time, etc. for selected popular and potential scented rice varieties under different land situations and seasons. In addition, research on aromatic rice-based and crop sequence should be conducted to develop suitable-*cum*-profitable cropping system for specific agro-ecological conditions of the country.

Field experiments may be conducted to study the effect of locally-available organic or green manures along with estimation of efficacy of bio-pesticides against major insect-diseases-weeds to develop location-specific organic production system for selected high-value aromatic rice of the grain.

The thrust areas for future research on rice grain quality parameters include: (i) method and degree of milling, (ii) storage environment including the use of bio-pesticides, texture of cooked rice and intensity of aroma, etc. towards the improvement of consumer acceptability scores. The quantification of 2-acetyl-1-pyrroline content in grain to determine the intensity of aroma is very important especially for non-Basmati short and medium-grained scented rice of India.

A survey-based study in native areas may be done on farmers' perceptions agronomic practices, processing, storage methods, grain quality, etc. as well as for identification of socio-economic constraints, which may be helpful for formulating the future strategy for premium aromatic rice.

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