IMPROVEMENT OF PRODUCTION AND STORAGE SYSTEM FOR GOBINDABHOG RICE IN WEST BENGAL

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in
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By

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This is to certify that the work recorded in the thesis entitled **"IMPROVEMENT OF PRODUCTION AND STORAGE SYSTEM FOR GOBINDABHOG RICE IN WEST BENGAL"** submitted by **Sri Dibyendu Mahata**, 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.

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Dedicated to

My Late Grandfather

and

My Parents

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(Dibyendu Mahata)

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LIST OF ABBREVIATIONS

Abbreviation		Full Form
&	:	And
^{0}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 hector
Temp.	:	Temperature

ABSTRACT

A comprehensive study on "Improvement of production and storage system for Gobindabhog rice in West Bengal" comprising two field and one laboratory experiments was done at Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India during the period of 2010-2012.

Gobindabhog rice planted on July 10 took 152.0 days to maturity, which was reduced by 8.2 days for July 25, 13.3 days for August 10 and 19.7 days for August 25 planting in the study. Mean summed GDD of Gobindabhog rice from sowing to emergence, 4^{th} leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 69.5, 423.0, 970.7, 1506.2, 2134.1, 2313.4, 2467.6 and 2607.6 ^{0}C, respectively. Based on pooled values for total summed GDD, HTU and PTU, four planting dates could be arranged as July 10 (2885.1^{0}C, 16194.2^{0}C hour and 35641.1^{0}C hour) > July 25 (2695.7^{0}C, 15988.1^{0}C hour and 32730.2^{0}C hour) > August 10 (2519.6^{0}C, 15464.2^{0}C hour and 30319.0^{0}C hours) > August 25 (2329.8^{0}C, 14567.7^{0}C hour and 27701.0^{0}C hours).

Plant height, tiller production and LAI were increased consistently with the advancement of crop growth upto panicle exertion, panicle initiation (*i.e.* 56 DAT) and flowering (*i.e.* 84 DAT) stage, respectively. Mean light extinction co-efficient (k), pooled over two years, were 0.43, 0.30, 0.35 and 0.50 at 28, 56, 84 DAT and at harvest, respectively. Gobindabhog rice planted on July 25 produced the highest grain yield (3.02 t ha^{-1}), which was 4.13, 14.39 and 17.51% greater over August 10, August 25 and July 10, respectively. Among treatment combinations, the crop planted on July 25 with spacing of 20 cm × 10 cm resulted in highest grain yield (3.08 t ha^{-1}), being at par with 3.02 t ha^{-1} (July 25 planted with 15 cm × 15 cm). Based on correlation studies with the thermal indices, the regression model for grain yield ($Y = -1.348 + 0.001^{**} HTU_{PI-F} - 0.001^{**} HTU_{S-E} + 0.001^{**} HTU_{E-4L} + 0.001^{**} PTU_{D-M} + 0.001^{*} PTU_{Mi-D} - 0.011^{*} GDD_{D-M}$) accounted for 71% variation in 1% level of significance.

Gobindabhog rice had short bold type, white kernels, rarely with chalkiness. The kernel length, breadth L / B ratio and alkali value of Gobindabhog rice remained

unaffected due to variation in planting time and spacing during *kharif* season. Gobindabhog rice planted on July 25 resulted in highest amylose (18.08%) and protein content (7.48%) compared to earlier (July 10) or later (August 10 and August 25) plantings. The intensity of aroma was slightly improved with delay in planting from July 10 to August 25, but Gobindabhog rice usually had intermediate gelatinization temperature and medium-strong aroma.

The use of FYM and mustard cake in either of dose resulted in taller plants, greater tiller production and higher LAI over unfertilized control. Similarly, application of $N_{40}P_{20}K_{20}$ kg ha^{-1} improved the growth and yield attributes of Gobindabhog rice over $N_{20}P_{10}K_{10}$ kg ha^{-1} and $N_{30}P_{15}K_{15}$ kg ha^{-1}.

The integrated dose of FYM @ 5.0 t ha^{-1} + $N_{40}P_{20}K_{20}$ kg ha^{-1} applied to Gobindabhog rice during *kharif* season resulted in greater grain yield (3.01 t ha^{-1}), better grain quality like 62.4% head rice recovery, 18.39% amylose, 7.75% protein and medium-strong aroma (score 2.50), and higher net return (Rs. 29110.00), B:C ratio (2.05) along with better soil residual status (+8.04% N, +27.84% P and –5.58% K).

The physical properties of grain (*viz.* kernel length, kernel breadth, L / B ratio, shape, colour, etc.) and protein content did not differ significantly among five storage containers during the ageing or storage period. The average aroma score over containers after 2-month storage (score 2.53 ± 0.18) declined 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 containers, earthen pot performed best for greater head rice recovery (62.1%), amylose (18.15%), protein (7.35%) and aroma (score 2.13) after 6-month storage period in West Bengal.

Chapter 1

INTRODUCTION

1. INTRODUCTION

Aromatic rice occupies a prime position in Indian society and culture since time immemorial (Ahuja *et. al.*, 1995). It is categorized in two types: (i) Basmati and (ii) non-Basmati, with specific distinctions in terms of grains quality features and geographical areas of cultivation. Basmati, the long-grains ones, are traditionally cultivated at the foothills of Himalayans in north states (*viz.* Punjub, Haryana, Uttaranchal, Uttar Pradesh, Himachal Pradesh, etc.); while short and medium-grain non-Basmati scented rices are grown in small pockets of the native areas in different parts of the country (Nene, 1998).

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-ueses like cooked table rice, bhog (rice intermixed with pulses), *payash* (desert), *polao*, *pistak* or *pitha* (home-made cake), *chira* (parched or flattened rice).

Gobindabhog, a short-grain scented rice, is a native cultivar of lower gangetic plains in Bengal, which is traditionally cultivated for about 400–500 years. Major quality features of Gobindabhog are: golden-yellow coloured grain, kernel length 3.97 mm, L / B ratio 2.04, short bold type kernel, amylose 17.9%, protein 7.2%, elongation ratio 1.77, alkali spreading value 3.7 and medium-strong aroma (Ghosh *et. al.*, 2012).

At present, it is cultivated in about 30,000–35, 000 ha land with an average production of 90,000 – 1, 00,000 tonnes paddy every year. Its cultivation is mainly concentrated in Burdwan (Raina I, Raina II and Khadaghos blocks), Bankura (Indus and Kotolpur blocks), Hoogly (Arambagh blocks), Nadia (Chakdah and Haringhata blocks) districts of South Bengal, along with sporadic cultivation in Murshidabad, Birbhum and North 24 Parganas districts of the state. Although it is very popular in domestic market for a long period, but it is also marketed in southern states of the country (*viz.* Karnataka, Tamilnadu, Kerala, etc.) during last two decades. In addition, the Standing Committee on Commerce, Parliament of India recommended the export of Gobindabhog rice during 2011 (Rajya Sabha, 2011) based on a

Proposal submitted by the RKVY Project on ' Bengal Aromatic Rice' of Bidhan Chandra Krishi Viswavidyalaya, West Bengal. It is much potential for international trade especially in the countries like Bangaladesh, U.K., Brazil, etc. Thus, Gobindabhog variety needs proper research and extension strategy for expansion of area, enhancement of productivity and improvement of quality in future.

Farmers in native areas produce Gobindabhog rice mostly for sale of their produce to the rice mills for earning money at a time, and sometimes a small portion for their family use. They cultivate the variety usually with low inputs following traditional practices intermixed with a few modern technologies in recent times during *kharif* season. They also use locally available storage containers for post-harvest storage of paddy at their own level. So, there is a need and scope for optimization or up-gradation of crop management practices including sowing or planting time, spacing, nutrient and pest management, etc. along with storage methods through well-planned research modules.

Among various cultivation practices, appropriate sowing or planting time, optimum planting geometry and integrated nutrient management are key factors to enhance the productivity upto a sustained level as well as for restoration of soil fertility in Gobindabhog rice-based crop sequence. Gobindabhog, 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 due to having correlations between weather factors and yield and quality parameters, including a few approaches for development of meteorology-based regression models especially for aromatic rice (Banerjee, 2011). Spacing determines the plant population in unit area thereby influencing the input-use-efficiency and yield of the crop. The combination of both planting time and spacing at optimum level may be helpful to the farmers to enhance the productivity during accommodation of Gobindabhog rice crop in multiple crop sequence within their limited land resources.

The nutrition of Gobindabhog, an indigenous tall *indica* rice, traditionally by organic manures can be refined or upgraded for better yield and quality. Banerjee *et. al.,* (2013) suggest the combined use of FYM and mustard cake @ 50% RDN each, equivalent to 50 kg N ha^{-1} for greater yield and B:C ratio of Gobindabhog rice in West Bengal. The variation in nutrient management (100% N and 50% N inorganic and 100% organic) differ significantly ($P < 0.05$) for protein content, but had no influence on apparent amylose and mineral content (with few exceptions) in non-waxy rice in USA (Champagne *et. al.*, 2007). In the background, the standardization of integrated nutrient monument system using locally available organic manures may result in increased yield and superior quality of Gobindabhog 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, but structural changes do 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 10-month storage period (Ilyas *et al.*, 1983). However, no such storage based study on Gobindabhog or such short-grained non-Basmati aromatic rice has not been made till date. Therefore, standardization of storage methods is an important area of present-day research for sustenance of quality including aroma for a longer period.

Keeping these in view, a total of three investigations were undertaken for up-gradation of production technology and storage methods of Gobindabhog rice with the following objectives:

i. To study the effect of planting time and spacing on growth, yield and quality Gobindabhog rice during *kharif* season

ii. To standardize the use of FYM or mustard cake in combination with chemical fertilizers for improvement of grain yield and quality of Gobindabhog rice

iii. To find out the effect of storage containers on grain quality of Gobindabhog rice at different storage periods

Chapter 2

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

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

The phenological development of Gobindabhog paddy could be summarized as: 72.5 days (vegetative), 37.8 days (reproductive), 31.2 days (ripening) and 141.5 days (life cycle) (Banerjee, 2011).

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 *et al.*, 2004).

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^{0}C for seedling emergence and establishment, 25-28^{0}C for rooting, 31^{0}C for leaf elongation, 25-31^{0}C for tillering, 30-35^{0}C for anthesis and 20-25^{0}C for ripening (Yoshida, 1981).

The growing degree days, heliothermal units and photothermal units for entire life cycle of Gobindabhog paddy were recorded as 2664.6^{0}C, 15055.7^{0}C hour and 32695.5^{0}C hour, respectively (Banerjee, 2011).

2.1.2.1 Effect of planting date

Delayed planting at 23 February increased the GDD (2080 *vs.* 2046^{0}C), and HTU (18505 *vs.* 17806^{0}C hour) and PTU (25172 *vs.* 24192^{0}C hour) of scented rice varieties than early planting (2 February) during dry (*boro*) season in West Bengal (Ghosh *et al.*, 2004).

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 increased plant height were the characteristics of rice plant during vegetative and reproductive stage, respectively (Yoshida, 1981).

2.2.1.1 Effect of planting date

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 higher plant height in earlier planting on 15 July than in delayed planting on 25 July and 5 August.

Escuro (1961) reported that for each of the planting dates, plant height was correlated positively and significantly with number of days required to heading and the best time of transplanting of rice crop for balanced vegetative, reproductive growth and maximum seed production appear to be earliest part of the season.

2.2.1.2. Effect of spacing

The plant height of 'Basmati 370' at harvest was highest (154.9 cm) at closer spacing (15 cm × 15 cm) than wider spacings of 22.5 cm × 15 cm (152.7 cm) and 30 cm × 15 cm (150.8 cm) at Kaul, India (Om *et al.*, 1993).

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 Effect of planting date

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.

2.2.2.2 Effect of spacing

Shah *et al.* (1991) reported that more tillers per m^{-2} produced with closer spacing of 10 cm × 10 cm than with wider spacing of 15 cm × 15 cm Similar results was also recorded by Kanungo and Roul (1994).

Patra and Nayak (2001) found that widely spaced rice crop (20 cm × 10 cm) produced significantly greater number of effective tillers $hill^{-1}$ (8.95) than the crops planted with 15 cm × 10 cm (7.41) and 10 cm × 10 cm (6.15) spacing at Orissa, India.

2.2.2.3 Effect of nutrient management

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 Effect of planting date

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 *et al.*, 2004).

2.2.3.2 Effect of spacing

A plant spacing of 30 cm × 30 cm gave significantly higher LAI at both 30 and 60 DAS for three aromatic rice varieties (*viz.* Pusa Basmati 1, Pusa Sugandh 5 and Pusa Sugandh 3) than 25 cm × 25 cm, because wider spacing produced more leaves with greater size during *kharif* season at New Delhi (Singh *et al.*, 2012).

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.* (2004) 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.

Sharma *et al.* (2008) reported that LAI at dough stage of a dwarf scented rice was 4.71 and 4.93 in plots treated with FYM and vermicompost, respectively.

2.2.4 Light interception

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

2.2.4.1 Effect of planting date

The values of light transmission ratio (LTR) for scented rice varities decreased linearly from 28 DAT (45.1 - 55.8%) to 70 DAT (14.3 - 23.9%) and thereafter increased due to senescence of leaves at ripening phase. 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 *et al.*, 2004).

2.2.4.2 Effect of spacing

According to Sheih (1977) the distribution of light within rice stand is more even with increasing LAI during this period. After LAI reached the maximum, the LTR went to the lowest value and was about same independent of the planting density, especially after booting, owing to the enlargement of leaves and the spreading of plant form.

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 Effect of planting date

Reddy and Reddy (1994) reported that maximum dry matter accumulation per m2 and per hill was recorded when planting was done on 29 August which was significantly higher than that of the crop planted on 30 July and 14 August.

2.2.5.2 Effect of spacing

Padmaja and Reddy (1998) concluded that hybrid rice 'APHR 2' transplanted at a closer spacing of 15 cm × 15 cm produced significantly higher dry matter (814 g m^{-2}) than transplanted with comparatively wider spacing of 20 cm × 15 cm at all the growth stages from a field study at Hyderabad.

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 (1988) 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 Effect of planting date

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 in different dates of planting at later stage of crop growth.

2.2.6.2 Effect 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 Pest-disease incidence and management

2.3.1 Insect-disease incidence

The incidence of insects and diseases in rice field varied depending on season, weather, variety, etc. A survey-based study in Rewa district in Madhya Pradesh revealed the incidence of 12 insect-pests, of which 8 were either regular or sporadic ones in the following order : Gundhi bug > White backed plant hopper > Grass hopper > Stem borer > Rice hispa > Army worm > Horned caterpillar > Rice case worm (Mishra *et al.*, 2010).

The population of gundhi bug (*Leptocorisa acuta*) in Gobindabhog rice field was revealed as 6.52 and 3.35 hill^{-1} at 13 and 15 WAT, respectively. The minimum temperature (21.70C for 2008 and 22.50c for 2009) prevailing during the period from pre-flowering to soft dough stage had positive ($P < 0.05$) influence on gundhi bug population in West Bengal (Banerjee, 2011).

The susceptibility of Gobindabhog rice to brown spot caused by *Drechslera oryzae* increased progressively with the advancement of growth or age including severe infestation at flowering and maturity stages (Banerjee, 2011).

2.3.1.1 Effect of planting date

According to Wang *et al.* (2008) the greatest disease incidence in rice was observed in the earliest sown plants and substantial control could be achieved by delay in planting from late May to mid-June. In an experiments where different proportions of infected plants were established (by inoculation or varying the sowing date), average yield losses were 0.8% for every 1% increase in disease incidence.

2.3.1.2 Effect of spacing

According to Rautaray (2007) planting geometry of skipping one row after every three rows with 15 cm × 15 cm spacing resulted in highest grain yield. Grain yields were similar with the next best planting geometry of 20 cm × 15 cm. Incidence of sheath rot disease (34.4%) and also its severity in terms of chaff number per panicle (41.4) were less under the skip row arrangement.

2.3.2 Weed density

2.3.2.1 Effect of planting date

Weed seedling emergence (infestation) was affected by date of planting in an inconsistent manner, a higher number of weed species were encountered in plots established on the first planting date (2 July) while plots established on the last date of planting (13 August) had the least number of weed species. Date of planting and weed control practice significantly affected maize grain yield and 100-seed weight, grain yield declined with delay in planting date. Maize growth likely contributes to the crop having a distinct competitive advantage over weeds when planted in early July, compared with late July and August plantings (Kolo *et al.*, 2012).

2.3.2.2 Effect of spacing

Hossain *et al.* (2003) reported that the highest weed density (61.67) was produced in the shorter cultivar Sonar Bangla 1 with widest density 25 cm × 35 cm and the lowest weed density (13.0) was obtained in the tallest cultivar Nezershail grown under closer spacing 10 cm × 15 cm in Bangladesh.

Payman and Singh (2008) reported that increasing seed rate from 40 to 60 kg ha^{-1} and row spacing from 15 to 20 cm, respectively, did not influence the reduction of total weed population and weed dry matter at 90 DAS and at maturity, respectively at Ludhiana, India.

2.4 Yield components and yield

2.4.1 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).

2.4.1.1 Effect of planting date

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 $panicle^{-1}$.

2.4.1.2 Effect of spacing

The number of panicles m^{-2} was significantly higher in closer spacing (25 cm × 25 cm) than wider spacing (30 cm × 30 cm) for three scented rice varieties, but panicle weight and number of filled grains $panicle^{-1}$ remained unaffected by planting density (Singh *et. al.*, 2012).

2.4.1.3 Effect of nutrient management

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).

2.4.2 Yield

2.4.2.1 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).

2.4.2.1.1 Effect of planting date

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.

2.4.2.1.2 Effect of spacing

A spacing of 25 cm × 25 cm produced 19.5% higher grain yield (3.71 - 3.86 *vs.*2.99 - 3.12 t ha^{-1}) than 30 cm × 30 cm for three scented rice varieties (viz. Pusa Basmati 1, Pusa Sugandh 5 and Pusa Sugandh 3) during *kharif* season at New Delhi (Singh *et al.*, 2012).

2.4.2.1.3 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.*, 2004). 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 (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).

2.4.2.2 Straw yield

2.4.2.2.1 Effect of planting date

According to Chaudhary *et al.* (2011) significantly highest straw yield (5.71 t ha^{-1}) was obtained from earliest planting date 5 July where lowest straw yield (4.86 t ha^{-1}) was recorded with delay planting date 4 August at Pusa, Bihar, India.

2.4.2.2.2 Effect of spacing

According to Hossian *et al.* (2003), the highest grain (4.69 t ha^{-1}) and straw yield (5.72 t ha^{-1}) were recorded with spacing of 15 cm x 25 cm, while the lowest grain (3.22 t ha^{-1}) and straw yield (4.40 t ha^{-1}) were noted with the planting density of 25 cm x 35 cm.

2.4.2.2.3 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).

Ravi and Srivastava (1997) reported that combined application of vermicompost and inorganic fertilizers recorded significantly higher plant height, effective tillers per hill, seed and straw yield of rice, compared to application of inorganic fertilizer alone.

Bhadoria and Prakash (2002) studied the effect of application of vermicompost in combination with different organic sources (*viz.* FYM, city waste, oil cake) on growth and yield of rice. It was inferred that vermicompost applied along with FYM recorded higher grain and straw yield of rice.

2.4.2.3 Harvest index

2.4.2.3.1 Effect of planting date

The harvest index was significantly increased in 15 July planting by 0.79 per cent than the 14 August planting but was comparable to 30 July planting) which might be due to higher mortality per cent of tillers in late planted crop than the early planted crop which may result reduced in grain ratio total biological yield (Yadav, 2007).

2.4.2.3.2 Effect of spacing

Singh *et al.*, (2012) reported that a spacing of 25 cm × 25 cm recorded significantly higher harvest index (mean 39.9%) than wider spacing of 30 cm × 30 cm (mean 38.7%) for three aromatic rice varieties at New Delhi.

2.4.2.3.3 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).

2.4.3 Lodging

2.4.3.1 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).

2.5 Grain quality

2.5.1 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).

The hulling, milling and head rice recovery of Gobindabhog rice was reported as 76.0, 70.0 and 63.7%, respectively (Banerjee, 2011).

2.5.1.1 Effect of planting date

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 planting 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 ka^{-1}) based on a study between eight cultivars and seven planting dates for 3 years.

2.5.1.2 Effect of nutrient management

The hulling (77%), 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 (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).

2.5.1.3 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).

2.5.2 Physical properties of grains

2.5.2.1 Length, breadth and L/B ratio

2.5.2.1.1 Effect of planting date

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.

2.5.2.1.2 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) was unaffected due to inorganic or integrated nutrient management in Bihar (Chaudhury *et al.*, 2011).

2.5.2.2 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).

2.5.2.2.1 Effect of planting date

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

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).

2.5.3 Cooking quality

2.5.3.1 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).

2.5.3.1.1 Effect of planting date

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.*, 2004). 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 (Chaudhury *et al.*, 2011).

2.5.3.1.2 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).

2.5.3.1.4 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^{0}C) and warehouse (40 ± 50^{0}C) condition for 10-month post harvest storage, respectively (Kanlayakrit and Maweang, 2013).

2.5.3.2 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 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 profundly affected by the cropping season and crop management practices (Gomez, 1979).

2.5.3.2.1 Effect of planting date

The protein content of rice (*cv.* Kashmir Basmati) was unaffected due to variation in 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).

2.5.3.2.2 Effect of spacing

Shivay and Singh (2003) reported that planting geometry (20 cm × 15 cm, 25 cm × 12 cm and 30 cm × 10 cm) did not significantly influence protein content in grain.

2.5.3.2.3 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).

2.5.3.2.4 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 in the bin, but it increased with storage (8.5 - 8.8%) over initial sample (8.4%) (Ilyas *et al.*, 1983).

2.5.3.3 Alkali spreading value

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, basically the range of temperature, wherein at least 90% of the starch granules swelled irreversibly in hot water. Final gelatinization temperature ranged between 55 - 79^{0}C, which could be classified as-low (55 - 69^{0}C), intermediate (70 - 74^{0}C) and high (74 - 79^{0}C).

2.5.3.3.1 Effect of planting date

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

2.5.3.3.2 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).

2.5.3.3.3 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).

2.5.4 Processing quality

2.5.4.1 Kernel elongation

Rice kernel absorbed water during cooking and increased in length, breadth and volume (Sood *et al.*, 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 environment, especially temperature at the time of ripening (dela Cruz *et al.*, 1989) as well as by ageing and pre-soaking before cooking.

2.5.4.1.1 Effect of planting date

Elongation ratio increased significantly with late transplanting in each of the variety tested (Dhaliwal *et al.*, 1986).

2.5.4.1.2 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 on grain elongation ratio (Ghosh *et al.*, 2004a). However, longer kernel length after cooking in Pusa Basmati 1 was reported with application of compost @ 10 t ha^{-1} (Sing *et al.*, 2000a).

2.5.4.1.3 Effect of storage container and time

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

2.5.4.2 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.* (1983b) reported over 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.*, 1983a).

2.5.4.2.1 Effect of planting date

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).

2.5.4.2.2 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).

2.5.4.2.3 Effect of storage container and time

2-acytyl-1-pyrroline, a'popcorn' like flavour compound decreased in aromatic rice (*cv.* Khao Dawk Mali 105) during post-harvest storage, but its concentration did not change 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 el.*, 2005).

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

2.6.1 Nutrient uptake

2.6.1.1 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.

2.6.2 Residual fertility status

2.6.2.1 Effect of nutrient management

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

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). Although the application of *Azolla* either alone or in conjunction with urea showed a positive N balance in soil, but greater availability of residual P was observed in *Azolla* applied plots of two Basmati rice varieties (*viz.* Basmati 370 and Pusa Basmati 1) in West Bengal (Ghosh *et.al.*, 2004).

2.7 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 2010 and 2011 at 'C' Block Farm of Bidhan Chandra Krishi Viswavidyalaya (B.C.K.V.), Kalyani, Nadia, West Bengal, India (Plate 3.1) and a storage study was done during 2010-11 and 2011-12 at Rice Laboratory, Department of Agronomy, BCKV, Mohanpur, Nadia, West Bengal, India. 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°57' N latitude and 88°20' E longitude and at an elevation of 7.8 m above mean sea level, so, it is within the agro-climatic region, namely New Alluvial Zone of West Bengal. The crop seasons of the humid sub-tropical climatic zone 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 to May. Again, it starts to decline from mid-October reaching the minimum about 10^{0}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 with greater cloudy days during the monsoon months i.e. from July to October.

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

The month wise maximum and minimum temperature during the cropping period was found to vary between 12.2 and 34.3^{0}C during 2010 and 13.4 and 33.2^{0}C during 2011. The rainfall received during *kharif* season of 2010 and 2011 were 826.4 mm and 1720.3 mm, respectively. The monthly rainfall ranged between 0.7 mm

Plate 3.1: 'C' Block Farm, B.C.K.V., Kalyani, Nadia

Plate 3.2: Seedbed for different dates of sowing

Plate 3.3: Transplanting of seedlings in main field

Plate 3.4: Observations on growth parameters in experimental plots

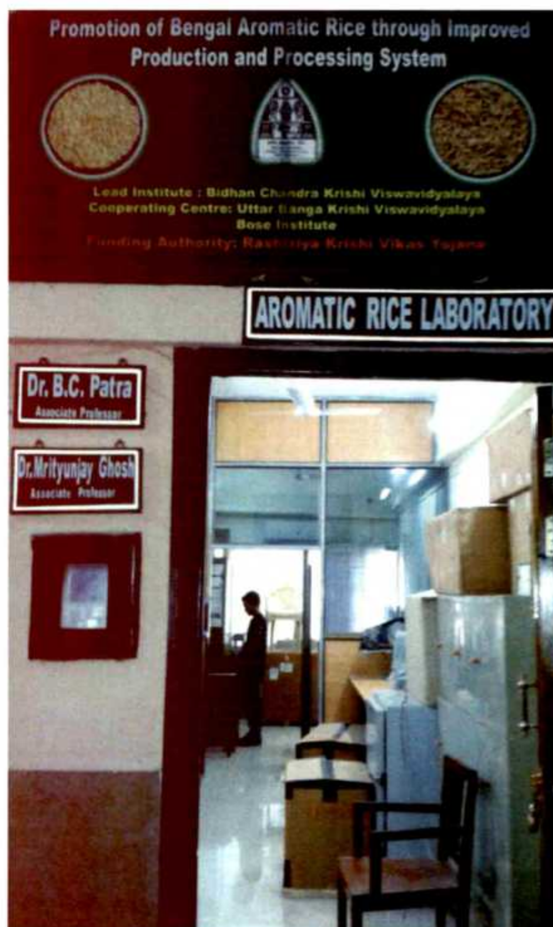

Plate 3.5: Rice Laboratory, B.C.K.V., West Bengal, India

Field activities and laboratory work on Gobindabhog Rice at B.C.K.V. West Bengal, India

(November) and 280.5 mm (September) during 2010; and 0.0 mm (December) and 646.8 mm (August) during 2011. The monthly average maximum relative humidity was greater than 91% during the period of experimentation in both 2010 and 2011, with a range between 91.6 and 96.4% for the first year and 93.0 and 97.0% for the second year of study; while minimum relative humidity varied between 53.1 and 76.5% during 2010 and between 56.0 and 83.0% during 2011. The bright sunshine hour was lower in high rainfall months mainly due to cloudy days and it ranged between 5.1 (June) and 7.5 hours (November) during 2010, and between 3.3 (August) and 8.2 hours (October) during 2011.

Table 3.1

Meteorological data pertaining to the periods of experimentation (2010 and 2011)

Month	Rainfall (mm)	Temperature (^{0}C)		Relative humidity (%)		Bright sunshine (hour)
		Maximum	Minimum	Maximum	Minimum	
2010						
June	137.8	34.3	26.8	91.6	70.9	5.1
July	128.9	33.1	26.6	92.9	73.3	5.8
August	169.8	33.0	26.7	94.8	74.8	5.6
September	280.5	32.7	25.9	96.4	76.5	5.9
October	89.2	32.5	24.3	94.2	69.4	6.4
November	0.7	30.9	19.9	92.0	55.4	7.5
December	19.5	25.3	12.2	94.4	53.1	6.8
2011						
June	308.6	33.2	26.5	93.5	74.5	4.5
July	407.7	32.2	26.3	94.3	76.8	5.3
August	646.8	30.9	26.1	97.0	83.0	3.3
September	288.3	31.4	25.8	96.0	81.0	4.3
October	60.9	33.0	24.2	93.0	62.0	8.2
November	8.0	30.0	18.1	93.0	56.0	7.4
December	0.0	25.3	13.4	95.0	58.0	6.1

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

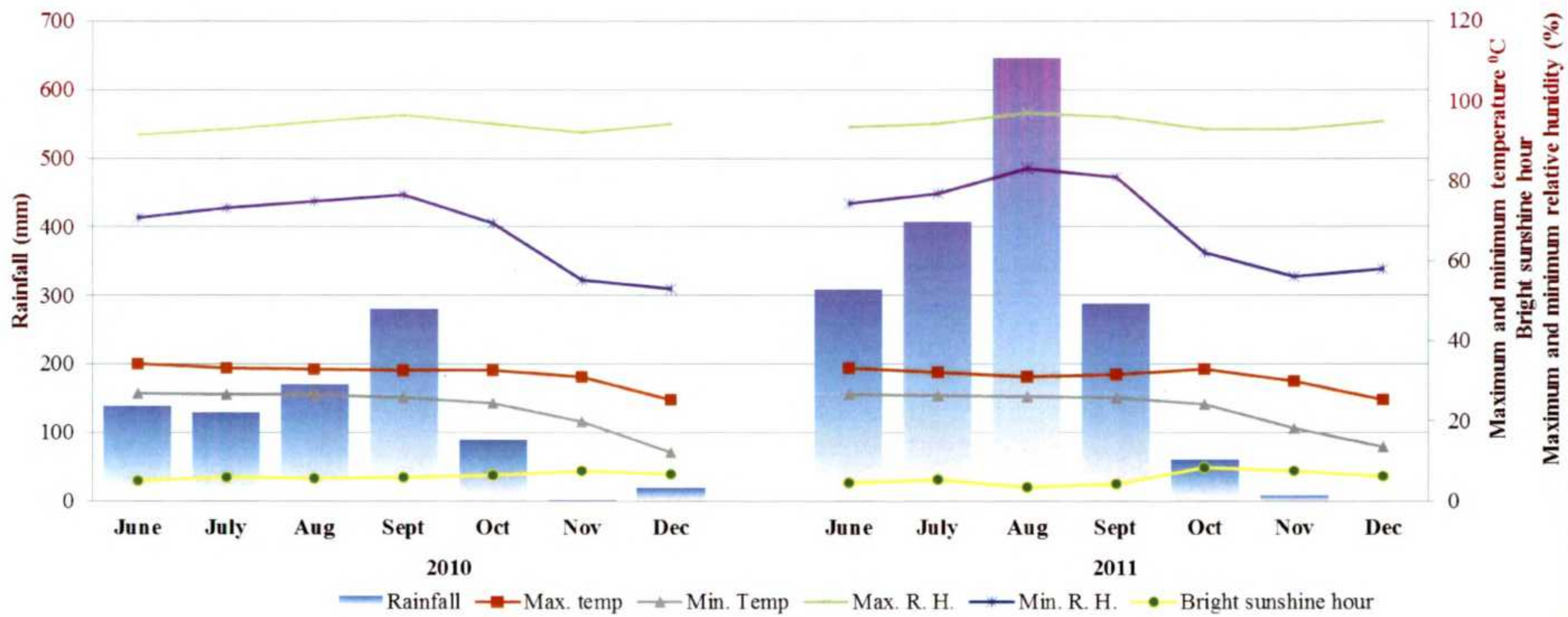

Fig. 3.1: Meteorological conditions pertaining to the periods of experimentaion (2010 and 2011)

Table 3.2

Meteorological data during storage period at Mohanpur (2011 and 2012)

Month	Temperature (^0C)		Relative humidity (%)	
	Maximum	Minimum	Maximum	Minimum
2011				
January	24.4	8.42	96.8	45.9
February	28.9	13.3	96.0	39.5
March	32.1	18.2	88.4	46.7
April	33.9	28.1	96.0	59.0
May	34.0	24.5	94.7	69.6
June	33.3	27.7	96.6	77.7
2012				
January	24.0	12.7	94.7	62.5
February	29.0	14.2	93.2	41.6
March	33.8	19.5	91.7	37.5
April	35.0	22.9	94.6	56.9
May	36.4	26.1	89.3	61.7
June	35.3	27.2	92.5	75.0

[Source: Department of Agricultural Meteorology and Physics, Faculty of Agriculture, BCKV, Mohanpur, W.B., India]

3.3 Soil

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

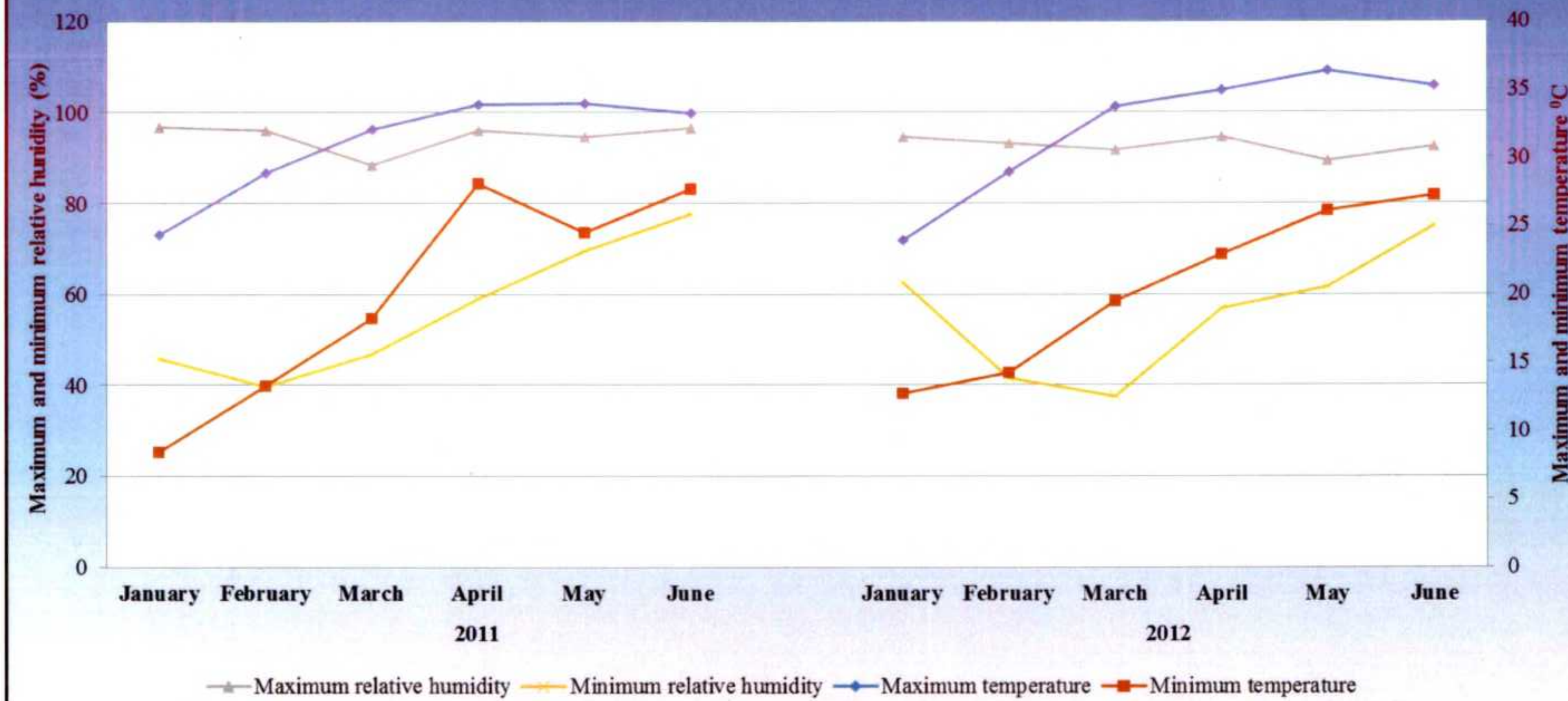

Fig. 3.2: Meteorological conditions during the storage periods at Mohanpur, West Bengal (2011 and 2012)

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 (%)	38.78	
	Silt (%)	35.10	
	Clay (%)	26.12	
2	Soil texture	Loam	USDA system (Brady, 1996)
3	Soil pH	6.8	Blackman's pH meter method (Jackson,1973)
4	Organic carbon (%)	0.61	Walkley and Black method (Jackson, 1973)
5	Available nitrogen	287.3	Macro Kjeldahl method (Jackson, 1973)
6	C: N ratio	11.5	
7	Available phosphorus (kg ha^{-1})	48.5	Olsen's method (Jackson, 1973)
8	Available potassium (kg ha^{-1})	234.7	Flame photometric method (Jackson, 1973)

3.4 Previous cropping history

Paddy cultivation was generally practised during both *kharif* (wet) and *boro* (dry) season in last 10 years. Some indigenous aromatic rice cultivars were grown under organic management system during *kharif* season (June – November) in two preceding years of 2008 and 2009.

3.5 Experimental details

3.5.1 Experiment No.1

Effect of planting date and spacing on phenology, growth, pest dynamics, yield and quality of Gobindabhog rice during *Kharif* season

First experiment was conducted to study the effect of planting date and spacing on phenology, growth, pest dynamics, yield and quality of Gobindabhog rice during *kharif* season of 2010 and 2011 in New Alluvial Zone of West Bengal. The experiment was laid out in a split-plot design with 3 replications, where 4 planting dates were allocated in main plots and 3 spacings in sub-plots. 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	Particular
Main plot	D_1	10 July
4 Planting dates	D_2	25 July
	D_3	10 August
	D_4	25 August
Sub-plot	S_1	20 cm × 10 cm (50 hills m^{-2})
3 Spacings	S_2	15 cm × 15 cm (44 hills m^{-2})
	S_3	20 cm × 15 cm (33 hills m^{-2})

Gobindabhog rice seedlings at the age of 24-25 days old (i.e. 4-5 leaf stage) were transplanted using 2-3 seedlings $hill^{-1}$ with 3 spacings in 4 m × 3 m plots at from different planting periods during both the years of study. A uniform fertilizer dose consisting of farm yard manure (FYM) @ 5 t ha^{-1} and $N_{30}\,P_{15}\,K_{15}$ kg ha^{-1} was applied to all the experimental units; of which full FYM, ¼ N, full P_2O_5 and ½ K_2O were given as basal; while ½ N as first top dressing at 3 weeks after transplanting (WAT); and rest ¼ N and ½ K_2O as second top dressing at 6 WAT.

3.5.2 Experiment No. 2

Standardization of FYM and mustard cake with inorganic fertilizers on growth, yield, quality and nutrient uptake of Gobindabhog rice

The second field study was conducted during wet (*kharif*) season of 2010 and 2011 to standardize the use of FYM or mustard cake along with chemical

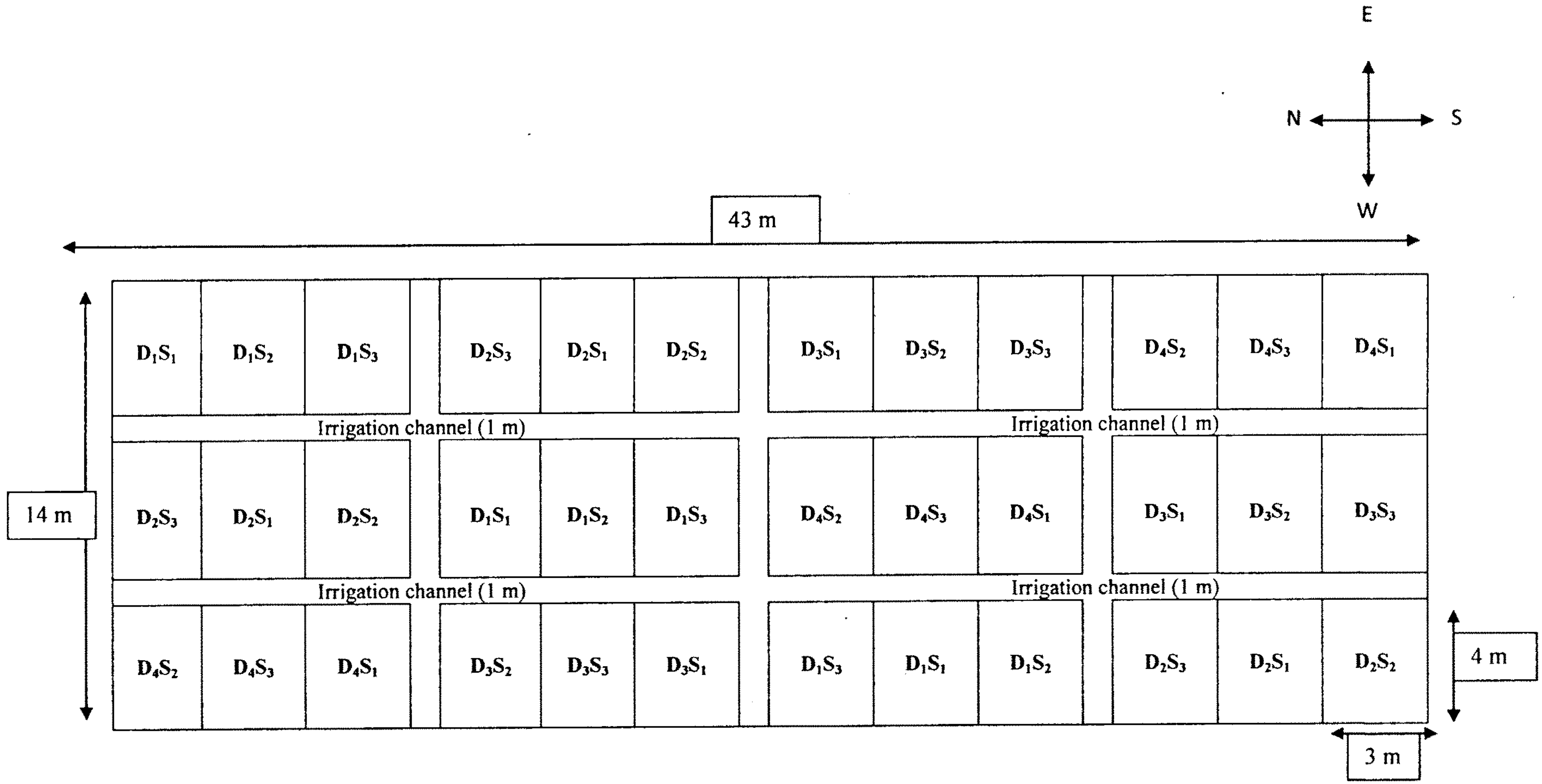

Fig. 3.1: Lay out of Experiment No. 1

fertilizers for Gobindabhog rice towards greater yield, superior quality and better soil health. The field experiment was laid out in a split-plot design consisting of 5 treatments of organic manures (FYM and mustard cake) in main plots and 3 inorganic fertilizer doses 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 Experiments No. 2

Treatment	Code	Particular
Main plot 5 levels of organic manures including control	O_1	Control
	O_2	FYM @ 2.5 t ha^{-1}
	O_3	FYM @ 5 t ha^{-1}
	O_4	Mustard Cake 0.25 t ha^{-1}
	O_5	Mustard Cake 0.50 t ha^{-1}
Sub-plot 3 doses of inorganic fertilizers	F_1	N_{20} P_{10} K_{10} kg ha^{-1}
	F_2	N_{30} P_{15} K_{15} kg ha^{-1}
	F_3	N_{40} P_{20} K_{20} kg ha^{-1}

Gobindabhog 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 plots.

The organic manures (viz. FYM and mustard cake) and chemical fertilizers (viz. urea for N, single super phosphate for P_2O_5 and muriate of potash for K_2O) were applied to the plots as per treatment combinations in the study. The application time schedule could be summarized as: the entire quantity of organic manures along with ¼ N, full P_2O_5 and ½ K_2O as basal, while ½ N as 1st top dressing at 3 WAT and rest ¼ N and ½ K_2O as 2nd top dressing at 6 WAT. The laboratory analyses of different manure samples before conducting of the experiment in each year revealed 0.40 and 0.45% N, 0.20 and 0.15% P_2O_5, and 0.45 and 0.50% K_2O in FYM; while

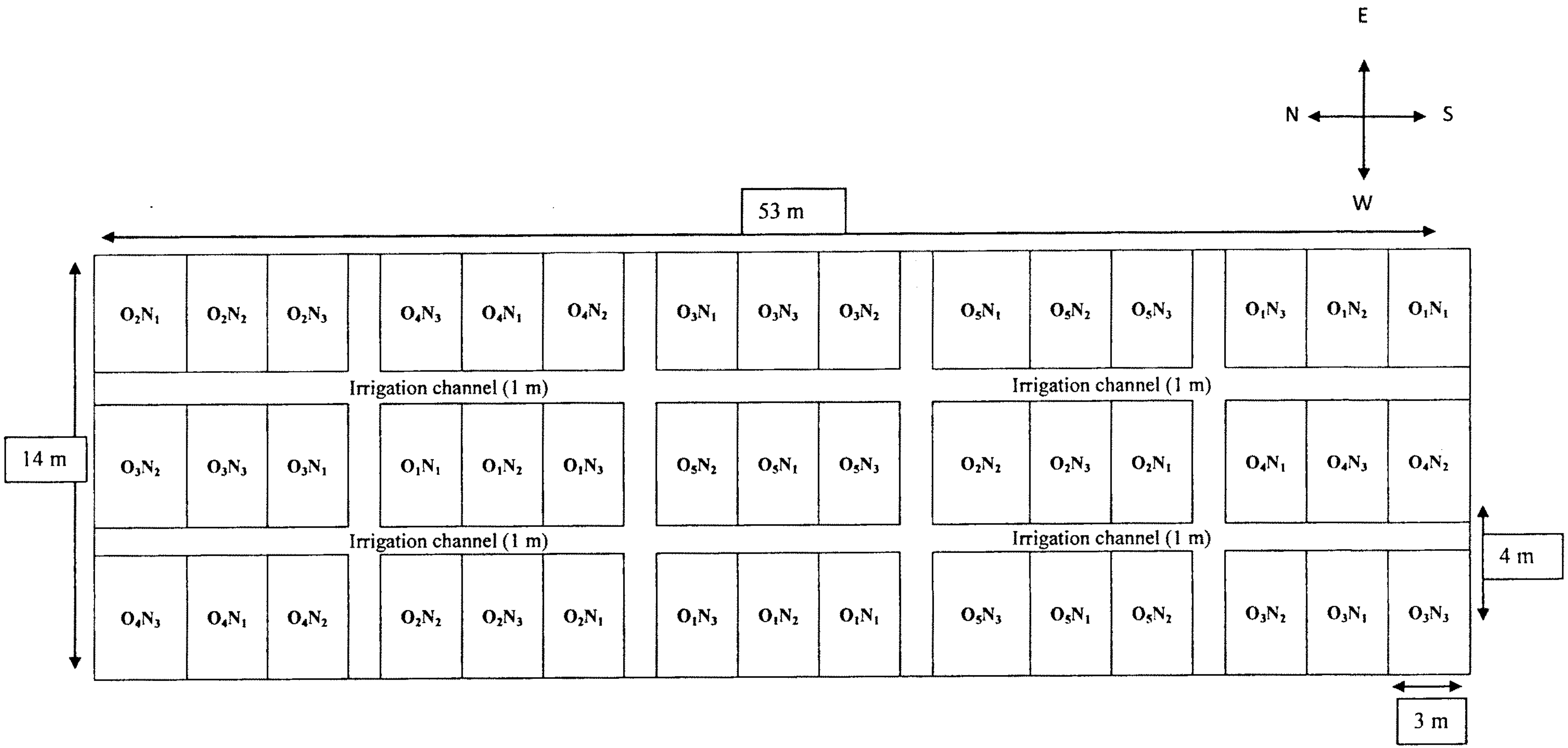

Fig. 3.2: Lay out of Experiment No. 2

4.50 and 4.60% N, 1.40 and 1.35% P_2O_5, and 1.00 and 1.10% K_2O in mustard cake during first and second year of experimentation, respectively.

3.5.3 Experiment No. 3

Effect of storage containers on quality of Gobindabhog rice during different storage periods

The effect of storage containers on quality of Gobindabhog rice during different storage periods was tested in completely randomized design (C.R.D.) with 4 replications at Rice Laboratory, Department of Agronomy, B.C.K.V., Mohanpur, Nadia during 2011 and 2012. Details of the treatments used in the study are described in Table 3.6., and Plate 3.6, 3.7, 3.8, 3.9 and 3.10.

Table 3.6

Details of treatments of Experiment No. 3

Treatment	Code	Particular
5 Storage containers	C_1	Gunny bag (Jute made) [capacity 100 kg, weight 1.02 kg]
	C_2	Polythene bag [capacity 50 kg, thickness 130-160 gsm]
	C_3	Cloth bag (Markin cloth made) [locally available]
	C_4	Earthen pot (Locally made) [locally available]
	C_5	Galvinalized iron (GI) bin [sheet thickness 0.50 mm]

3.6 Collection of seed

The seeds of Gobindabhog rice was collected from RKVY Project on "Promotion *of Bengal aromatic rice through improved production and processing system*", Department of Agronomy, B.C.K.V., during May, 2010.

Plate 3.6: Gunny (Jute-made) bag [capacity 100 kg, weight 1.02 kg]

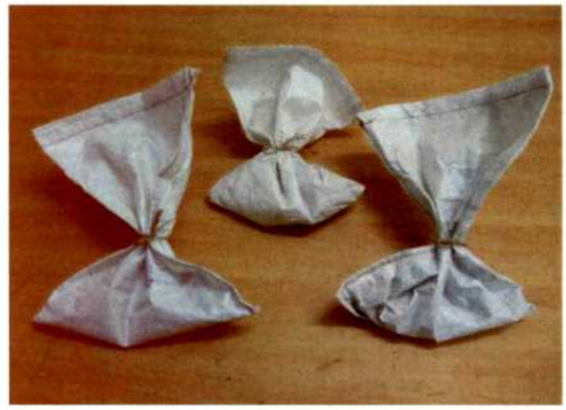

Plate 3.7: Polythene bag [capacity 50 kg, thickness 130-160 gsm]

Plate 3.8: Cloth bag (Markin cloth made) [locally available]

Plate 3.9: Earthen pot [locally available]

Plate 3.10: Galvanized Iron Bin (GI), [sheet thickness 0.50 mm]

Plate 3.11: Laboratory work at B.C.K.V., West Bengal, India

Storage containers used in Experiment No. 3 at Aromatic Rice Laboratory, B.C.K.V., Mohanpur, Nadia, West Bengal, India

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 3.7.

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 were broadcast in the nursery beds as per sowing time schedule in two experiments. 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 uprooting of the seedlings (Plate 3.2).

3.7.3 Land preparation and layout

The field was ploughed twice under dry condition by a tractor and thereafter in standing water condition by a power-tiller so that proper pudding could be made.

The lay out of the two field experiments as per treatments and replication were made separately and the plots were demarcated by earthen bunds, then they were thoroughly leveled and water was filled in.

3.7.4 Transplanting

24-25 days old Gobindabhog rice seedlings @ 2-3 $hill^{-1}$ were transplanted at a spacing of 20 cm × 10 cm, 15 cm × 15 cm and 20 cm × 15 cm in Experiment No. 1, while 15 cm x 15 cm in Experiment No. 2 at a shallow depth (3-4 cm) in puddled field during *kharif* season (Plate 3.3).

3.7.5 Nutrient management

Nutrient management practices for two field experiments were different. Although uniform integrated nutrient dose as stated earlier was applied in the first investigation, but organic manure and inorganic fertilizers in different combinations as per treatment schedule were given in the second experiment.

Table 3.7
Schedule of field operations during the periods of experimentation

Sl. No.	Particular	Experiment No. 1								Experiment No. 2	
		2010				2011				2010	2011
1	Seed bed preparation	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4		
	1st ploughing (Power tiller)	05.06.10	20.06.10	04.07.10	18.07.10	04.06.11	17.06.11	30.06.11	15.07.11	20.06.10	18.06.11
	2nd ploughing (Power tiller)	15.06.10	29.06.10	15.07.10	28.07.10	11.06.11	26.06.11	10.07.11	25.07.11	29.06.10	29.06.11
	Lay out	15.06.10	29.06.10	15.07.10	28.07.10	11.06.11	26.06.11	10.07.11	25.07.11	29.06.10	30.06.11
2.	Sowing of seeds in nursery beds	16.06.2010 (D_1) 30.06.2010 (D_2) 16.07.2010 (D_3) 30.07.2010 (D_4)				12.06.2011 (D_1) 27.06.2011 (D2) 12.07.2011 (D3) 27.07.2011-(D_4)				30.06.2010	30.06.2011
3.	Land preparation	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4		
	1st ploughing (Tractor)	25.06.10	10.07.10	24.07.10	09.08.10	21.06.11	10.07.11	20.07.11	06.08.11	10.07.10	12.07.11
	2nd Ploughing (Tractor)	03.07.10	18.07.10	02.08.10	17.08.10	29.06.11	15.07.11	28.07.11	14.08.11	18.07.10	18.07.11
	3rd Ploughing (Power tiller)	09.07.10	24.07.10	09.08.10	24.08.10	05.07.11	21.07.11	05.08.11	20.08.11	24.07.10	25.07.11
	Lay out	09.07.10	24.07.10	09.08.10	24.08.10	05.07.11	21.07.11	05.08.11	20.08.11	24.07.10	25.07.11
4.	Transplanting of seedling	10.07.2010 (D_1) 25.07.2010 (D_2) 10.08.2010 (D_3) 25.08.2010 (D_4)				06.07.2011 (D_1) 22.07.2011 (D_2) 06.08.2011 (D_3) 21.08.2011 (D_4)				25.07.2010	25.07.2011
5.	Nutrient management	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4		
	Basal	09.07.10	24.07.10	09.08.10	24.08.10	05.07.11	21.07.11	05.08.11	20.08.11	24.07.10	24.07.11
	1st top dressing	01.08.10	16.08.10	29.08.10	15.09.10	26.07.11	12.08.11	26.08.11	10.09.11	16.08.10	16.08.11
	2nd top dressing	23.08.10	07.09.10	20.09.10	06.10.10	16.08.11	03.09.11	16.09.11	01.10.11	07.09.10	07.09.11
6.	Intercultural operation	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4		
	1st hand weeding	29.07.10	14.08.10	27.08.10	10.09.10	24.07.11	10.08.11	24.08.11	08.09.11	14.08.10	14.08.11
	2nd hand weeding	21.08.10	04.09.10	11.09.10	25.09.10	14.08.11	02.09.11	14.09.11	28.09.11	04.09.10	04.09.11
7	Irrigation	As and when required									
8	Harvesting	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4		
		20.11.10	26.11.10	05.12.10	15.12.10	22.11.11	27.11.11	06.12.11	15.12.11	19.11.10	20.11.11

3.7.6 Weed Control

Hand weeding twice at 3 and 6 WAT was done to remove the weeds from all the plots in 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 for continuation upto flowering. Thereafter, it was reduced to 2-3 cm upto 2 weeks prior to maturity. The water requirement of indegenous Gobindabhog rice was met mainly 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. The optimum time of harvesting of Gobindabhog rice was determined, when 80% of the panicles with 80% grains in each panicle were matured. Then the produce was dried in the sun for 2-3 days and it was threshed with a pedal thresher at threshing floor in the farm. After proper cleaning and drying, the grains and straws of each net plot were weighed separately and the yield was calculated in terms of t ha^{-1}.

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):

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

where $T_{max.}$ and $T_{min.}$ were the maximum and minimum air temperature of a day, T_b was the base temperature (10^0C for rice) and n was the number of days to attain a phenophase.

The degree days for different phenophases of Gobindabhog rice were calculated, which were summed up from sowing to maturity of the crop.

3.8.2 Heliothermal units (HTU)

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

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

The heliothermal units for different phenological stages of Gobindabhog rice 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):

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

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 Plant height

Five plants randomly selected in each plot were tagged at early vegetative stage. The height of such five plants in 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 of the crop.

3.9.2 Tiller counting

The number of tillers of five tagged plants in each plot was recorded at 28, 56 and 84 DAT, which were converted into number of tillers m^{-2} area (Plate 3.4).

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 ± 1^0C for about 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 leaves and green foliage / laminae. Since leaf area index appeared to be the area of green surface $unit^{-1}$ area of land surface, so, it was calculated by using the following formula (Watson, 1958).

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

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 the dry weight gained by the plants in unit area land per unit time, which was calculated by the following formula:

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

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) was 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):

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{Log_e L_2 - Log_e L_1}{L_2 - L_1} \text{ g m}^{-2} \text{ day}^{-1}$$

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 by a lux meter (Lutron make, Model LX 101, Thailand) by keeping the sensor at the top of the canopy of 5 tagged plants and at base or ground surface in each experiment unit at 28, 56, 84 DAT. Then, light transmission ratio (LTR) 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):

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

where, I and I_0 were the light intensity 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 calculating weed density

To count the weed population in different plots, weeds samples were collected from 1 m^2 area of randomly selected places in each plot at 3 WAT, 6 WAT and 9 WAT (weeks after transplanting). Different categories of weeds (*viz*. grass, sedge and broad leaved) in each plot were counted separately to determine the category-wise total weed population in 1 m^2 area.

3.12 Methods of scoring pest-disease incidence

Five randomly selected hills were tagged in each plot for recording incidence of insect and disease at respective infestation stages during cropping season.

3.12.1 Disease incidence

3.12.1.1 Brown spot (*Drechslera oryzae*) and Blast (*Pyricularia Oryzae*)

The infestation of brown spot and blast was estimated by the percentage of leaf area affected or disease symptoms (small, oval or circular and dark brown spots with light yellow halo around the outer edge for brown spot; while diamond-shaped with a grey or white center in blast) at 28, 56 and 84 DAT. Then, the leaf area affected values (%) were compared with the disease severity scale (IRRI, 1996) (Table 3.8).

Table 3.8

Disease severity scale for brown spot and blast

Scale	Severity (leaf area affected)
0	No incidence
1	Affected leaf area less than 1%
2	1-3% of the leaf area affected
3	4-5% of the leaf area affected
4	6-10% of the leaf area affected
5	11-15% of the leaf area affected
6	16-25% of the leaf area affected
7	26-50% of the leaf area affected
8	51-75% of the leaf area affected
9	Affected leaf area above 76%

In the context, it was also noted that there were some blast lesions (*Pyricularia oryzae*) intermingled with brown spot ones on rice leaves, which could not separately be identified or considered in the study.

3.12.2 Insect incidence

3.12.2.1 Gundhi bug (*Leptocorisa acuta*)

The incidence of gundhi bug, i.e. the number of gundhi bug hill^{-1} was recorded at 84 and 112 DAT.

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

3.13.1 Panicle length

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

3.13.2 Number of panicles unit^{-1} area

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

3.13.3 Number of filled grains panicle^{-1}

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

3.13.4 Test weight of grain

250 well-filled grains were collected from the produce of each plot and the weight was taken on a digital Precision Balance (Afcoset make, Model FX 200G, India). The weight was then multiplied by 4 to determine 1000 grain weight.

3.13.5 Grain yield

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

3.13.6 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}.

3.13.7 Harvest index (HI)

Harvest index was calculated by the following formula:

$$HI (\%) = \frac{\text{Economic (grain) yield}}{\text{Biological (grain + straw) yield}} \times 100$$

3.13.8 Lodging

The rating of lodging of plants was done at hard dough stage following the scale mentioned in Standard Evaluation System for Rice (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

3.14 Methods of determining quality characteristics of grain

At first, the impurities and foreign matters like other crop seeds, straw, chaff, sand, stones, mudpieces, 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 in 'Aromatic Rice Laboratory' at Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India (Plate 3.5).

3.14.1 Milling quality

100 g clean paddy sample was dehulled with a Rice Sheller (Indosaw make, Model 6700, India) and the weight of brown rice was taken. Then the brown rice was milled or polished for 12 seconds with a Rice Miller / Polisher (Indosaw make, Model 6704, India) to remove the bran and embryo and 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 taken.

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

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

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

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

3.14.2 Physical properties of grain

3.14.2.1 Length, breadth and L / B ratio

10 whole milled rice kernels from each sample were placed lengthwise and breadthwise separately on graph paper and the total length as well as the total 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 following formula:

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

3.14.2.2 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

3.14.2.3 Kernel colour

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

3.14.2.4 Chalkiness

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

3.14.3 Cooking and nutritional quality

3.14.3.1 Amylose content

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

3.14.3.2 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).

3.14.3.3 Alkali spreading value / Gelatinization temperature

Gelatinization temperature of rice was estimated by alkali digestibility test (Little *et. al.*, 1958).Ten 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 30^0C). Kernel appearance and disintegration of endosperm after incubation were visually rated on a 7 - point numerical spreading scale (Table 3.11).

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

3.14.4 Processing quality

3.14.4.1 Kernel elongation

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

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

3.14.4.2 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 5 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

3.15 Methods of chemical analyses

3.15.1 Soil analyses for total nitrogen, available phosphorus and available potassium

Soil Samples were collected from about 15 cm depth before transplanting (one composite sample) as well as from 5 randomly selected places of each plot at 28, 56 and 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	Total nitrogen (%)	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, Model No. 1689, India)	Jackson, 1973
3	Available potassium (kg ha^{-1})	Flame-photometric method (Flamephotometer, Chemito make, Model FP 102, India)	Jackson, 1973

3.15.2 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 nutrients 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, SL. No. 1689, India)	Jackson, 1973
3	Total potassium (%)	Flame photometer method using the extract obtained from tri-acid mixture (Flamephotometer, Chemito make, Model FP 102, India)	Jackson, 1973

3.16 Economic analysis

Total cost of cultivation ha^{-1} in Experiment No. 2 was calculated considering the expenditure on total land preparation, seed, transplanting, weeding, harvesting, threshing, etc. along with different types of organic manures (*viz.* FYM and mustard cake) and inorganic fertilizers (*viz.* urea, single super phosphate and muriate of potash) depending upon the particulars of treatments in the study. Gross return was determined by the values of grain and straw of Gobindabhog rice 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 Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal and local markets during the periods of experimentation.

3.17 Methods of statistical analyses

The data collected as described earlier were subjected to statistical analyses by the analysis of variance (ANOVA) method suitable for split-plot design and completely randomized design (C.R.D) in the investigation (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 as well as to compute the critical difference (C.D.) at 5% level of significance.

The values obtained regarding insect and disease incidence in the field were transformed into square root and angular values as applicable for respective statistical analyses.

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

All statistical analyses were done using SPSS (version 10.0, 1990) on a desktop P.C.

Chapter 4

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1 Experiment No. 1

Effect of planting date and spacing on phenology, growth, pest dynamics, yield and quality of Gobindabhog rice during *Kharif* season

4.1.1 Phenology and growth environment

4.1.1.1 Phenological development and duration

Rice had 3 major growth stages: (i) vegetative, (ii) reproductive and (iii) ripening in its life cycle. A total of eight phenophases was studied in the experiment; of which four stages (*viz.* sowing to emergence, emergence to 4^{th} leaf emergence, 4^{th} leaf emergence to active tillering and active tillering to panicle initiation) were under vegetative stage, one (panicle initiation to 50% flowering) under reproductive stage and three (*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 4^{th} leaf emergence) in seedbed and rest six phases in the main field.

4.1.1.1.1 Effect of planting date

Mean daily air temperature at all phenophases of Gobindabhog paddy was usually higher in the first year than the second year of investigation (Table 4.1.1), which accelerated the rate of development of the crop and reduced the length of phenophases and life duration in 2010 compared to 2011 (Table 4.1.2; Plate 4.1).

Gobindabhog rice planted on four different planting dates, *i.e.* July 10 (D_1), July 25 (D_2), August 10 (D_3) and August 25 (D_4) took 152.0, 143.8, 138.7 and 132.7 days, respectively to maturity, which indicated reduction in life duration by 8.2 days for July 25, 13.3 days for August 10 and 19.7 days for August 25 planting compare to earlier one (July 10) in the study (Table 4.1.2; Fig. 4.1). It was mainly due to the difference in time required for vegetative and reproductive stage owing to variability in planting dates, as the number of days for ripening phase was more or less same.

Table 4.1.1

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

Treatment	Vegetative stage															
	Sowing to Emergence								Emergence to 4th leaf emergence							
	D_1		D_2		D_3		D_4		D_1		D_2		D_3		D_4	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Average maximum temperature (°C)	33.0	31.4	32.4	30.7	34.0	32.9	31.1	35.0	32.9	30.8	33.4	32.1	32.5	32.6	33.1	30.0
Average minimum temperature (°C)	26.8	26.7	26.7	26.3	27.2	27.0	25.8	27.4	26.6	25.8	26.7	26.3	26.2	26.5	26.4	25.8
Mean daily temperature (°C)	29.9	29.0	29.5	28.5	30.6	30.0	28.5	31.2	29.7	28.3	30.1	29.2	29.3	29.6	29.8	27.9
Average bright sunshine hour day^{-1}	5.4	2.8	5.4	0.7	4.9	4.8	4.6	9.8	4.9	1.7	6.1	4.4	5.7	5.4	5.8	1.2
Total rainfall (mm)	0.2	25.2	8.2	29.0	1.5	17.2	79.3	0.0	58.2	280.1	49.4	207.3	178.5	378.1	62.4	547.3

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

Treatment	Vegetative stage															
	4th leaf emergence to Active tillering (°C)								Active tillering to Panicle initiation							
	D_1		D_2		D_3		D_4		D_1		D_2		D_3		D_4	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Average maximum temperature (°C)	32.8	32.5	32.9	31.0	33.3	30.6	33.0	32.0	33.4	30.7	32.9	31.8	32.6	31.2	32.1	32.4
Average minimum temperature (°C)	26.5	26.6	26.4	26.0	26.6	25.9	26.6	26.4	26.7	25.9	26.6	26.3	24.5	25.8	25.2	25.4
Mean daily temperature (°C)	29.7	29.6	29.6	28.5	30.0	28.2	29.8	29.2	30.0	28.3	29.7	29.1	28.6	28.5	28.7	28.9
Average bright sunshine hour day^{-1}	5.4	5.1	5.6	3.6	5.8	3.4	5.9	5.4	6.2	3.9	5.6	5.1	6.7	3.9	5.2	5.8
Total rainfall (mm)	209.7	548.1	198.4	747.1	92.1	614.6	176.0	138.7	93.5	501.3	214.2	159.2	89.2	287.1	194.4	249.4

Table 4.1.1 (contd.)

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

Treatment	Reproductive stage								Ripening stage							
	Panicle initiation to 50% flowering (^{0}C)								50% flowering to Milk							
	D_1		D_2		D_3		D_4		D_1		D_2		D_3		D_4	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Average maximum temperature (°C)	32.4	32.8	32.6	32.9	32.6	33.1	32.2	31.8	33.3	31.7	32.0	31.3	30.9	30.7	32.0	29.6
Average minimum temperature (°C)	25.5	25.7	25.1	25.5	24.5	24.1	22.9	21.9	24.9	23.5	23.1	21.5	20.8	18.9	21.2	19.2
Mean daily temperature (°C)	28.9	29.2	28.8	29.2	28.6	28.6	27.6	26.8	29.1	27.6	27.6	26.4	25.8	24.8	26.6	24.4
Average bright sunshine hour day^{-1}	5.4	6.2	6.1	6.7	6.7	8.3	7.3	7.9	7.3	7.2	6.3	8.0	7.4	7.7	7.3	6.0
Total rainfall (mm)	333.3	262.3	198.9	230.5	89.2	60.9	28.9	60.6	27.0	60.6	0.0	59.0	0.7	0.0	0.0	8.0

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

Treatment	Ripening stage															
	Milk to Dough								Dough to Maturity							
	D_1		D_2		D_3		D_4		D_1		D_2		D_3		D_4	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Average maximum temperature (°C)	30.8	30.7	31.3	30.6	32.0	29.6	30.1	29.2	32.2	30.6	31.8	29.9	30.1	29.2	25.4	28.7
Average minimum temperature (°C)	21.2	19.2	20.4	19.0	21.2	19.2	17.9	15.8	20.7	19.4	21.1	19.3	17.9	15.8	15.8	16.2
Mean daily temperature (°C)	26.0	24.9	25.9	24.8	26.6	24.4	24.0	22.5	26.4	25.0	26.5	24.6	24.0	22.5	20.6	22.5
Average bright sunshine hour day^{-1}	6.9	7.7	8.4	7.7	7.3	6.0	7.7	8.1	8.7	7.4	7.2	6.3	7.7	8.1	4.1	7.0
Total rainfall (mm)	0.7	0.0	0.7	0.0	0.0	8.0	0.0	0.0	0.0	8.0	0.0	8.0	0.0	0.0	19.5	0.0

Table 4.1.2

Effect of planting date and spacing on phenological development of Gobindabhog rice during *kharif* season

Treatment	Vegetative stage											
	Sowing to Emergence (days)			Emergence to 4th leaf emergence (days)			4th leaf emergence to Active tillering (days)			Active tillering to Panicle initiation (days)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date												
D_1	4.0	4.0	4.0	18.0	19.0	18.5	28.6	30.7	29.6	30.6	31.0	30.8
D_2	3.3	3.7	3.5	18.0	18.3	18.2	27.8	29.2	28.5	27.7	28.3	28.0
D_3	3.0	3.7	3.3	17.7	18.0	17.8	27.1	28.7	27.9	24.6	27.2	25.9
D_4	3.0	3.0	3.0	17.0	18.0	17.5	25.4	26.7	26.1	23.9	25.3	24.6
S.Em (±)	0.10	0.12	0.08	0.10	0.10	0.07	0.18	0.12	0.11	0.22	0.17	0.14
C.D. at 5%	0.33	0.43	0.24	0.33	0.33	0.21	0.64	0.43	0.34	0.74	0.58	0.42
Spacing												
S_1	3.3	3.6	3.5	17.7	18.3	18.0	27.4	28.9	28.2	26.9	28.1	27.5
S_2	3.3	3.6	3.5	17.7	18.3	18.0	27.3	28.8	28.0	26.4	27.8	27.1
S_3	3.3	3.6	3.5	17.7	18.3	18.0	27.0	28.7	27.8	26.7	28.0	27.3
S.Em (±)	0.08	0.16	0.09	0.08	0.08	0.06	0.15	0.13	0.10	0.16	0.14	0.10
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect												
D_1S_1	4.0	4.0	4.0	18.0	19.0	18.5	29.0	30.3	29.7	30.7	31.0	30.8
D_1S_2	4.0	4.0	4.0	18.0	19.0	18.5	28.7	31.0	29.8	30.3	31.3	30.8
D_1S_3	4.0	4.0	4.0	18.0	19.0	18.5	28.0	30.7	29.3	30.7	30.7	30.7
D_2S_1	3.3	3.7	3.5	18.0	18.3	18.2	27.7	29.3	28.5	28.0	28.3	28.2
D_2S_2	3.3	3.7	3.5	18.0	18.3	18.2	28.0	29.0	28.5	27.3	28.0	27.7
D_2S_3	3.3	3.7	3.5	18.0	18.3	18.2	27.7	29.3	28.5	27.7	28.7	28.2
D_3S_1	3.0	3.7	3.3	17.7	18.0	17.8	27.3	29.0	28.2	25.0	27.3	26.2
D_3S_2	3.0	3.7	3.3	17.7	18.0	17.8	27.0	28.7	27.8	24.3	27.0	25.7
D_3S_3	3.0	3.7	3.3	17.7	18.0	17.8	27.0	28.3	27.7	24.3	27.3	25.8
D_4S_1	3.0	3.0	3.0	17.0	18.0	17.5	25.7	27.0	26.3	24.0	25.7	24.8
D_4S_2	3.0	3.0	3.0	17.0	18.0	17.5	25.3	26.7	26.0	23.7	25.0	24.3
D_4S_3	3.0	3.0	3.0	17.0	18.0	17.5	25.3	26.3	25.8	24.0	25.3	24.7
D × S												
S.Em (±)	0.17	0.31	0.18	0.17	0.17	0.12	0.30	0.25	0.20	0.31	0.28	0.21
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × D												
S.Em (±)	0.17	0.28	0.23	0.17	0.17	0.17	0.31	0.24	0.28	0.33	0.28	0.31
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.1.2 (contd.)

Effect of planting date and spacing on phenological development of Gobindabhog rice during *kharif* season

Treatment	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (days)			50% flowering to Milk (days)			Milk to Dough (days)			Dough to Maturity (days)			Sowing to Maturity (days)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date															
D_1	36.4	38.4	37.4	11.2	11.2	11.2	10.3	10.3	10.3	10.1	10.1	10.1	149.2	154.8	152.0
D_2	34.2	34.8	34.5	10.9	10.9	10.9	10.1	10.1	10.1	10.1	10.1	10.1	142.1	145.4	143.8
D_3	33.3	33.4	33.4	10.4	10.4	10.4	10.0	10.1	10.1	9.9	9.9	9.9	136.0	141.4	138.7
D_4	31.2	31.9	31.6	10.1	10.0	10.1	10.0	10.0	10.0	9.2	9.9	9.6	129.9	134.8	132.3
S.Em (±)	0.11	0.25	0.14	0.17	0.15	0.11	0.20	0.18	0.13	0.16	0.12	0.10	0.57	0.31	0.32
C.D. at 5%	0.37	0.88	0.43	0.59	0.53	0.35	NS	NS	NS	0.55	NS	0.30	1.98	1.07	1.00
Spacing															
S_1	33.8	34.8	34.3	10.7	10.7	10.7	10.1	10.1	10.1	9.9	9.9	9.9	139.8	144.4	142.1
S_2	33.8	34.6	34.2	10.7	10.7	10.7	10.1	10.2	10.1	9.9	10.1	10.0	139.2	144.1	141.6
S_3	33.8	34.5	34.2	10.7	10.6	10.6	10.2	10.2	10.2	9.7	10.0	9.8	139.0	143.8	141.4
S.Em (±)	0.16	0.14	0.10	0.13	0.12	0.09	0.15	0.07	0.08	0.14	0.10	0.09	0.44	0.25	0.25
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect															
D_1S_1	36.7	38.7	37.7	11.3	11.3	11.3	10.3	10.3	10.3	10.3	10.0	10.2	150.3	154.7	152.5
D_1S_2	36.3	38.3	37.3	11.0	11.3	11.2	10.3	10.3	10.3	10.0	10.3	10.2	148.7	155.7	152.2
D_1S_3	36.3	38.3	37.3	11.3	11.0	11.2	10.3	10.3	10.3	10.0	10.0	10.0	148.7	154.0	151.3
D_2S_1	34.0	35.3	34.7	11.0	10.7	10.8	10.0	10.0	10.0	10.0	10.3	10.2	142.0	146.0	144.0
D_2S_2	34.0	35.0	34.5	11.0	11.0	11.0	10.0	10.0	10.0	10.3	10.0	10.2	142.0	145.0	143.5
D_2S_3	34.7	34.0	34.3	10.7	11.0	10.8	10.3	10.3	10.3	10.0	10.0	10.0	142.3	145.3	143.8
D_3S_1	33.0	33.3	33.2	10.3	10.7	10.5	10.0	10.0	10.0	10.0	9.7	9.8	136.3	141.7	139.0
D_3S_2	33.7	33.3	33.5	10.3	10.3	10.3	10.0	10.3	10.2	10.0	10.0	10.0	136.0	141.3	138.7
D_3S_3	33.3	33.7	33.5	10.7	10.3	10.5	10.0	10.0	10.0	9.7	10.0	9.8	135.7	141.3	138.5
D_4S_1	31.3	32.0	31.7	10.0	10.0	10.0	10.0	10.0	10.0	9.3	9.7	9.5	130.3	135.3	132.8
D_4S_2	31.3	31.7	31.5	10.3	10.0	10.2	10.0	10.0	10.0	9.3	10.0	9.7	130.0	134.3	132.2
D_4S_3	31.0	32.0	31.5	10.0	10.0	10.0	10.0	10.0	10.0	9.0	10.0	9.5	129.3	134.7	132.0
D × S															
S.Em (±)	0.31	0.28	0.21	0.25	0.24	0.17	0.30	0.14	0.17	0.28	0.19	0.17	0.88	0.51	0.51
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × D															
S.Em (±)	0.28	0.34	0.31	0.27	0.25	0.26	0.32	0.21	0.27	0.28	0.20	0.24	0.92	0.52	0.75
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Mean days of Gobindabhog rice, pooled over two years and averaged over four planting dates, from sowing to emergence, 4^{th} leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 3.5, 21.5, 49.5, 76.8, 111.0, 121.7, 131.8 and 141.7 days, respectively; which could be summarized as 76.8 days for vegetative, 34.2 days for reproductive and 30.7 days for ripening phase of the crop in the study.

4.1.1.1.2 Effect of spacing

There was no significant difference in length of phenophages as well as in duration of Gobindabhog rice due to variation in spacing (20 cm × 10 cm, 15 cm × 15 cm and 20 cm × 15 cm) adopted in the study (Table 4.1.2).

4.1.1.1.3 Interaction effect between planting date and spacing

There interaction effect between planting date and spacing did not show any significant influence on attainment of phenophages and life cycle of Gobindabhog rice during both the years of investigation (Table 4.1.2).

4.1.1.2 Growing degree days (GDD)

4.1.1.2.1 Effect of planting date

Mean air temperature for entire life cycle of Gobindabhog paddy varied among planting date as: D_1 (28.71, and 27.74 ^{0}C), D_2 (28.46 and 27.54 ^{0}C), D_3 (27.94 and 27.08 ^{0}C) and D_4 (26.95 and 26.68 ^{0}C) during 2010 and 2011 (Table 4.1.1), which indicated that mean temperature of total life duration decreased slowly with delay in sowing or planting during *kharif* season.

The summed growing degree days of Gobindabhog rice for entire life cycle pooled over two years was reduced by 594.9 ^{0}C for delay in planting from July 10 (2926.5 ^{0}C) to August 25 (2331.6 ^{0}C) in the study (Table 4.1.3; Fig. 4.2).

The variation in sowing or planting time resulted in difference in summed GDD during vegetative, reproductive and ripening phases for pooled values as: July 10 (1633.8, 714.1 and 537.2 ^{0}C), July 25 (1530.9, 653.3 and 511.4 ^{0}C), August 10 (1464.1, 602.8 and 452.7 ^{0}C) and August 25 (1395.7, 541.4 and 392.7 ^{0}C).

Table 4.1.3

Effect of planting date and spacing on growing degree days at different phenophases of Gobindabhog rice during *kharif* season

Treatment	Vegetative stage											
	Sowing to Emergence (days)			Emergence to 4th leaf emergence (days)			4th leaf emergence to Active tillering (days)			Active tillering to Panicle initiation (days)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date												
D_1	79.7	77.1	78.4	355.3	367.1	361.2	568.2	588.5	578.4	614.7	616.9	615.8
D_2	64.9	67.6	66.2	373.8	350.7	362.2	534.8	570.2	552.5	547.3	552.8	550.0
D_3	61.9	73.1	67.5	341.8	345.1	343.4	528.2	570.6	549.4	473.4	534.3	503.8
D_4	55.4	76.0	65.7	336.4	357.9	347.1	503.8	517.2	510.5	451.0	493.9	472.4
S.Em (±)	1.90	2.99	1.77	2.69	1.71	1.59	6.28	2.70	3.42	4.00	4.14	2.88
C.D. at 5%	6.56	NS	5.46	9.30	5.93	4.91	21.74	9.33	10.53	13.84	14.33	8.87
Spacing												
S_1	65.4	73.5	69.5	351.8	355.3	353.5	536.4	564.0	550.2	526.8	551.0	538.9
S_2	65.4	73.3	69.4	351.8	355.1	353.4	534.8	562.2	548.5	515.7	549.2	532.4
S_3	65.4	73.5	69.5	351.8	355.2	353.5	530.1	558.6	544.4	522.3	548.3	535.3
S.Em (±)	1.64	3.37	1.87	2.15	1.54	1.32	3.12	2.44	1.98	2.60	3.00	1.99
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	7.80	NS	NS
Interaction effect												
D_1S_1	79.7	77.4	78.5	355.3	367.0	361.1	570.5	581.7	576.1	621.4	617.9	619.7
D_1S_2	79.7	76.7	78.2	355.3	367.2	361.2	570.2	595.6	582.9	608.2	621.6	614.9
D_1S_3	79.7	77.4	78.5	355.3	367.0	361.1	564.0	588.4	576.2	614.5	611.3	612.9
D_2S_1	64.9	67.6	66.2	373.8	351.1	362.4	532.6	572.9	552.7	553.6	552.4	553.0
D_2S_2	64.9	67.6	66.2	373.8	350.0	361.9	539.4	565.7	552.5	540.3	553.1	546.7
D_2S_3	64.9	67.6	66.2	373.8	351.0	362.4	532.6	572.1	552.3	547.8	553.0	550.4
D_3S_1	61.9	73.1	67.5	341.8	345.1	343.4	532.7	576.9	554.8	479.9	534.8	507.4
D_3S_2	61.9	73.1	67.5	341.8	345.1	343.4	525.8	570.6	548.2	466.7	534.3	500.5
D_3S_3	61.9	73.1	67.5	341.8	345.1	343.4	526.0	564.2	545.1	473.5	533.7	503.6
D_4S_1	55.4	76.0	65.7	336.4	357.9	347.1	509.7	524.5	517.1	452.3	498.9	475.6
D_4S_2	55.4	76.0	65.7	336.4	357.9	347.1	503.8	517.2	510.5	447.4	487.8	467.6
D_4S_3	55.4	76.0	65.7	336.4	357.9	347.1	498.0	509.9	503.9	453.3	495.1	474.2
D × S												
S.Em (±)	3.28	6.74	3.75	4.31	3.07	2.65	6.23	4.88	3.96	5.20	6.00	3.97
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	7.80	NS	NS
S × D												
S.Em (±)	3.28	6.26	5.00	4.43	3.04	3.80	8.08	4.81	6.65	5.83	6.42	6.13
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	7.80	NS	NS

NS = Not significant

Table 4.1.3 (contd.)

Effect of planting date and spacing on growing degree days at different phenophases of Gobindabhog rice during *kharif* season

Treatment	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (days)			50% flowering to Milk (days)			Milk to Dough (days)			Dough to Maturity (days)			Sowing to Maturity (days)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date															
D_1	686.4	741.8	714.1	216.2	188.3	202.2	175.8	162.0	168.9	162.1	170.2	166.1	2858.3	2911.9	2885.1
D_2	642.2	664.4	653.3	198.1	167.1	182.6	160.7	165.3	163.0	166.8	164.8	165.8	2688.5	2702.9	2695.7
D_3	623.4	582.3	602.8	164.4	171.8	168.1	161.7	158.2	160.0	144.0	105.2	124.6	2498.7	2540.5	2519.6
D_4	549.5	533.3	541.4	167.2	161.2	164.2	143.9	106.0	124.9	99.4	107.7	103.6	2306.4	2353.2	2329.8
S.Em (±)	2.51	5.02	2.80	2.99	2.69	2.01	2.34	2.52	1.72	0.89	1.99	1.09	9.15	4.46	5.09
C.D. at 5%	8.68	17.36	8.64	10.36	9.30	6.20	8.10	8.73	5.30	3.09	6.90	3.37	31.66	15.42	15.68
Spacing															
S_1	623.4	632.4	627.9	186.3	172.8	179.6	159.6	146.8	153.2	142.8	135.3	139.1	2592.4	2631.1	2611.8
S_2	625.5	631.4	628.4	186.8	172.4	179.6	160.9	148.6	154.7	145.6	138.7	142.1	2586.4	2630.9	2608.6
S_3	627.2	627.6	627.4	186.2	171.1	178.6	161.1	148.2	154.7	140.9	136.9	138.9	2585.0	2619.4	2602.2
S.Em (±)	3.00	2.36	1.91	2.10	1.99	1.45	2.78	1.09	1.50	1.37	1.52	1.02	7.32	2.82	3.92
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	8.45	NS
Interaction effect															
D_1S_1	689.9	745.3	717.6	217.9	190.5	204.2	173.1	161.9	167.5	163.2	168.5	165.8	2870.9	2910.2	2890.5
D_1S_2	684.4	740.8	712.6	212.4	187.8	200.1	177.9	163.5	170.7	161.4	175.0	168.2	2849.3	2928.2	2888.7
D_1S_3	684.8	739.3	712.1	218.2	186.4	202.3	176.6	160.5	168.6	161.7	167.2	164.4	2854.7	2897.3	2876.0
D_2S_1	638.2	673.8	656.0	199.5	167.5	183.5	162.3	164.3	163.3	164.8	165.9	165.3	2689.5	2715.3	2702.4
D_2S_2	637.7	670.1	653.9	201.3	168.8	185.0	157.2	163.4	160.3	170.2	163.6	166.9	2684.6	2702.3	2693.4
D_2S_3	650.7	649.3	650.0	193.4	164.9	179.1	162.8	168.2	165.5	165.5	164.9	165.2	2691.3	2691.0	2691.1
D_3S_1	615.8	578.8	597.3	162.6	175.5	169.0	160.0	154.5	157.2	143.9	103.2	123.5	2498.4	2541.8	2520.1
D_3S_2	630.5	580.6	605.6	162.6	170.0	166.3	165.1	161.8	163.4	149.3	106.5	127.9	2503.6	2541.8	2522.7
D_3S_3	623.9	587.5	605.7	168.1	170.0	169.0	160.0	158.5	159.2	138.9	106.0	122.4	2494.0	2538.0	2516.0
D_4S_1	549.7	531.7	540.7	165.4	157.7	161.5	143.0	106.6	124.8	99.1	103.9	101.5	2310.9	2357.1	2334.0
D_4S_2	549.4	534.1	541.7	171.0	163.0	167.0	143.4	105.7	124.6	101.4	109.7	105.5	2308.1	2351.2	2329.7
D_4S_3	549.4	534.1	541.7	165.1	163.0	164.0	145.1	105.7	125.4	97.7	109.7	103.7	2300.2	2351.2	2325.7
D × S															
S.Em (±)	6.00	4.71	3.82	4.19	3.99	2.89	5.57	2.18	2.99	2.73	3.05	2.05	14.64	5.64	7.84
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	8.45	NS
S × D															
S.Em (±)	5.50	6.32	5.93	4.55	4.22	4.39	5.11	3.09	4.22	2.41	3.19	2.82	15.05	6.41	11.57
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	8.45	NS

NS = Not significant

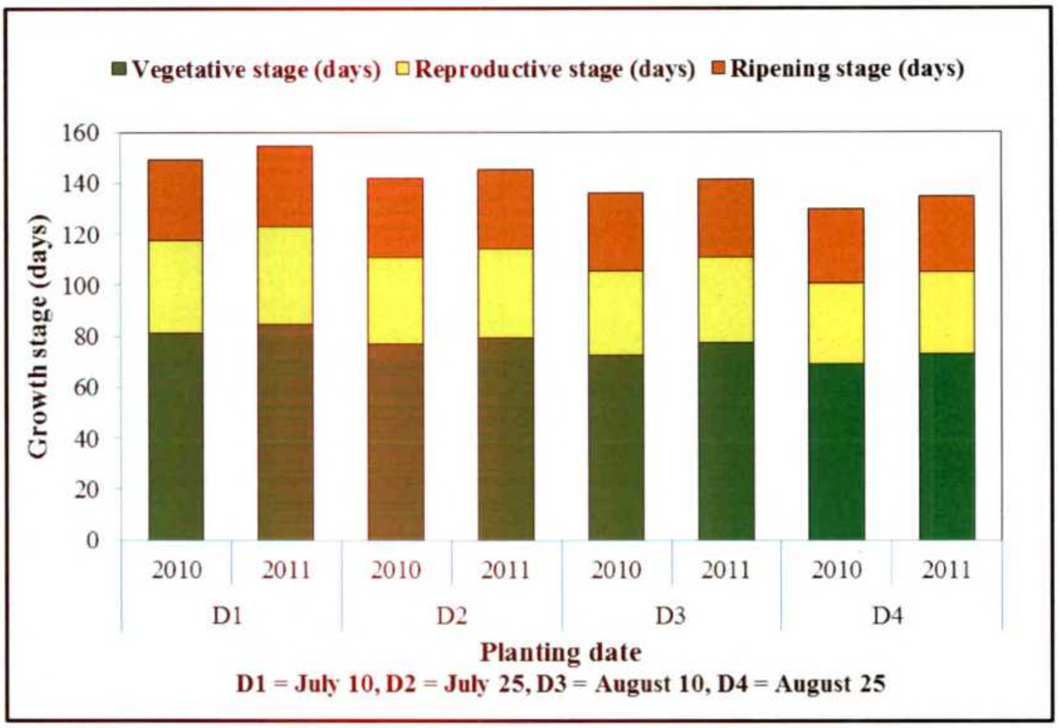

Fig. 4.1: Effect of planting date on phenological development of Gobindabhogrice during *kharif* season of 2010 and 2011 (Mean of two years)

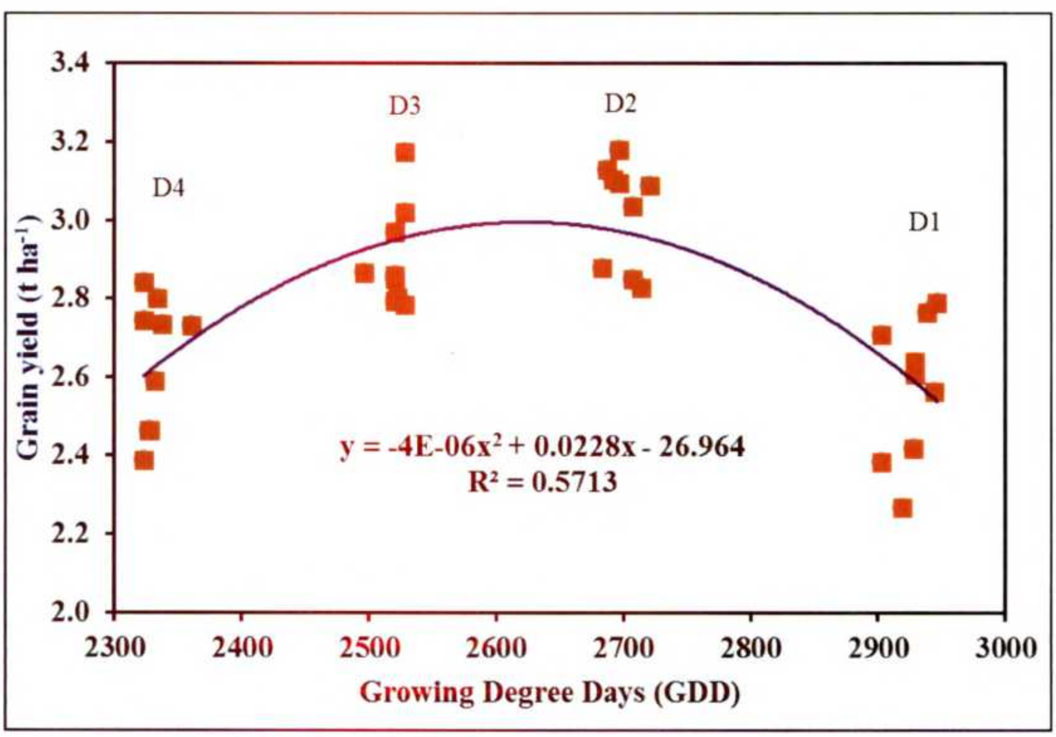

Fig. 4.2: Effect of planting date on heat use efficiency of Gobindabhog rice during *kharif* season (Pooled over two years)

Mean summed GDD of Gobindabhog rice from sowing to emergence, 4^{th} leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 69.5, 423.0, 970.7, 1506.2, 2134.1, 2313.4, 2467.6 and 2607.6 ^{0}C, respectively. Banerjee (2011) reported similar GDD values of the reproductive stages for the same variety at Kalyani, West Bengal.

4.1.1.2.2 Effect of spacing

Spacing had no significant influence on accumulation of GDD at different phenophases of Gobindabhog rice during both the years of experiment, excluding at active tillering to panicle initiation during 2010 and entire life cycle for 2011 only (Table 4.1.3).

4.1.1.2.3 Interaction effect between planting date and spacing

Planting date × spacing interaction effect on accumulated GDD at various phenophases was found non-significant in either of the years of investigation, except for the life cycle during 2011 (Table 4.1.3).

4.1.1.3 Heliothermal units (HTU)

4.1.1.3.1 Effect of planting date

Mean bright sunshine hour for entire life cycle of Gobindabhog paddy varied among planting dates as: D_1 (6.28 and 5.25 hours), D_2 (6.34 and 5.31 hours), D_3 (6.53 and 5.25 hours) and D_4 (5.99 and 6.40 hours) during 2010 and 2011 (Table 4.1.4), which indicated an increasing trend in average sunny hours for total life duration with delay in sowing or planting during *kharif* season.

The variation in mean daily temperature and bright sunshine hour among four sowing or planting dates resulted in significant variation in summed heliothermal units at different phenophases of Gobindabhog paddy during *kharif* season of both 2010 and 2011, excluding at 4^{th} leaf emergence to active tillering for 2010 only (Table 4.1.4).

Based on pooled values for total summed HTU, four planting dates could be arranged as: D_1 (16194.2 ^{0}C hour) > D_2 (15988.1 ^{0}C hour) > D_3 (15464.2 ^{0}C hour) > D_4 (14567.7 ^{0}C hour).

Table 4.1.4

Effect of planting date and spacing on heliothermal units at different phenophases of Gobindabhog rice during *kharif* season

Treatment	Vegetative stage											
	Sowing to Emergence (days)			Emergence to 4th leaf emergence (days)			4th leaf emergence to Active tillering (days)			Active tillering to Panicle initiation (days)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date												
D_1	463.6	270.0	366.8	1774.7	560.4	1167.5	3095.8	3391.5	3243.6	3754.5	2359.4	3057.0
D_2	322.8	27.9	175.4	2257.3	1622.5	1939.9	3130.3	2920.1	3025.2	3157.4	2454.8	2806.1
D_3	304.0	339.4	321.7	1950.8	2085.6	2018.2	3024.1	2103.9	2564.0	2585.4	2957.4	2771.4
D_4	260.2	754.5	507.4	1958.2	1427.6	1692.9	3057.3	2235.0	2646.1	2491.2	2696.4	2593.8
S.Em (±)	14.41	18.19	11.60	15.95	11.27	9.77	40.45	15.92	21.74	19.40	17.31	13.00
C.D. at 5%	49.85	62.96	35.75	55.20	39.01	30.09	NS	55.11	66.98	67.14	59.91	40.06
Spacing												
S_1	337.7	348.0	342.8	1985.2	1427.9	1706.6	3084.2	2682.5	2883.3	3026.2	2633.3	2829.7
S_2	337.7	348.0	342.8	1985.2	1416.3	1700.7	3074.7	2670.3	2872.5	2964.0	2594.9	2779.5
S_3	337.7	348.0	342.8	1985.2	1427.9	1706.6	3071.7	2635.1	2853.4	3001.2	2622.8	2812.0
S.Em (±)	12.48	17.22	10.63	12.89	9.79	8.09	18.60	22.37	14.55	24.44	23.64	17.00
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect												
D_1S_1	463.6	270.0	366.8	1774.7	572.3	1173.5	3109.2	3371.3	3240.3	3781.1	2360.1	3070.6
D_1S_2	463.6	270.0	366.8	1774.7	536.4	1155.6	3111.1	3431.7	3271.4	3707.9	2358.0	3033.0
D_1S_3	463.6	270.0	366.8	1774.7	572.3	1173.5	3067.2	3371.3	3219.3	3774.6	2360.1	3067.3
D_2S_1	322.8	27.9	175.4	2257.3	1626.1	1941.7	3118.5	2938.3	3028.4	3181.1	2431.2	2806.2
D_2S_2	322.8	27.9	175.4	2257.3	1615.4	1936.3	3153.9	2910.4	3032.1	3122.7	2426.8	2774.7
D_2S_3	322.8	27.9	175.4	2257.3	1626.1	1941.7	3118.5	2911.6	3015.1	3168.3	2506.2	2837.3
D_3S_1	304.0	339.4	321.7	1950.8	2085.6	2018.2	3047.6	2142.2	2594.9	2615.0	2970.4	2792.7
D_3S_2	304.0	339.4	321.7	1950.8	2085.6	2018.2	2976.7	2103.9	2540.3	2554.5	2957.4	2756.0
D_3S_3	304.0	339.4	321.7	1950.8	2085.6	2018.2	3047.9	2065.6	2556.8	2586.6	2944.4	2765.5
D_4S_1	260.2	754.5	507.4	1958.2	1427.6	1692.9	3061.4	2278.0	2669.7	2527.5	2771.5	2649.5
D_4S_2	260.2	754.5	507.4	1958.2	1427.6	1692.9	3057.3	2235.0	2646.1	2471.1	2637.3	2554.2
D_4S_3	260.2	754.5	507.4	1958.2	1427.6	1692.9	3053.2	2191.9	2622.5	2475.2	2680.3	2577.8
D × S												
S.Em (±)	24.95	34.45	21.27	25.78	19.57	16.18	37.20	44.75	29.10	48.88	47.28	34.00
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × D												
S.Em (±)	24.95	33.50	29.54	26.41	19.56	23.24	50.59	39.86	45.54	44.38	42.31	43.35
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.1.4 (contd.)

Effect of planting date and spacing on heliothermal units at different phenophases of Gobindabhog rice during *kharif* season

Treatment	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (days)			50% flowering to Milk (days)			Milk to Dough (days)			Dough to Maturity (days)			Sowing to Maturity (days)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date															
D_1	3749.3	4474.5	4111.9	1536.0	1762.4	1649.2	1085.8	1333.3	1209.6	1465.2	1311.9	1388.6	16924.9	15463.4	16194.2
D_2	3872.5	4320.8	4096.7	1382.6	1634.7	1508.6	1205.5	1231.1	1218.3	1294.1	1141.8	1218.0	16622.5	15353.8	15988.1
D_3	4204.2	4564.1	4384.1	1231.7	1193.3	1212.5	1313.3	1120.3	1216.8	1030.4	920.5	975.4	15643.8	15284.6	15464.2
D_4	3894.9	4697.0	4296.0	1323.0	1073.8	1198.4	1026.0	933.1	979.6	509.1	798.2	653.6	14519.9	14615.5	14567.7
S.Em (±)	25.49	47.53	26.97	34.91	23.12	20.94	32.43	21.17	19.36	27.60	22.23	17.72	61.17	30.17	34.10
C.D. at 5%	88.21	164.48	83.09	120.82	80.00	64.51	112.22	73.26	59.67	95.51	76.93	54.60	211.68	104.39	105.08
Spacing															
S_1	3941.3	4512.2	4226.8	1350.9	1432.7	1391.8	1168.0	1130.0	1149.0	1077.8	1029.5	1053.6	15971.2	15196.0	15583.6
S_2	3924.3	4545.7	4235.0	1374.1	1416.0	1395.1	1151.7	1153.4	1152.6	1085.6	1058.6	1072.1	15897.5	15203.1	15550.3
S_3	3925.0	4484.4	4204.7	1380.0	1399.5	1389.7	1153.2	1180.0	1166.6	1060.6	1041.2	1050.9	15914.6	15138.9	15526.7
S.Em (±)	33.75	27.93	21.90	21.00	17.88	13.79	27.78	14.44	15.65	22.86	22.35	15.99	42.86	19.88	23.62
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	59.59	NS
Interaction effect															
D_1S_1	3770.8	4458.2	4114.5	1553.7	1785.8	1669.8	1111.0	1312.9	1211.9	1510.9	1324.2	1417.6	17075.1	15454.7	16264.9
D_1S_2	3727.5	4555.6	4141.5	1484.8	1763.9	1624.4	1078.7	1319.4	1199.0	1445.3	1325.6	1385.4	16793.5	15560.6	16177.0
D_1S_3	3749.5	4409.9	4079.7	1569.5	1737.5	1653.5	1067.8	1367.8	1217.8	1439.4	1286.1	1362.7	16906.2	15374.9	16140.6
D_2S_1	3860.6	4413.2	4136.9	1362.3	1642.0	1502.1	1220.2	1176.2	1198.2	1300.4	1136.2	1218.3	16623.2	15391.2	16007.2
D_2S_2	3814.7	4350.0	4082.4	1443.7	1650.9	1547.3	1165.1	1213.9	1189.5	1328.3	1158.4	1243.3	16608.4	15353.8	15981.1
D_2S_3	3942.2	4199.2	4070.7	1341.8	1611.3	1476.5	1231.3	1303.3	1267.3	1253.7	1130.8	1192.2	16635.9	15316.5	15976.2
D_3S_1	4187.6	4537.1	4362.4	1210.0	1224.2	1217.1	1309.6	1096.5	1203.1	1026.5	900.3	963.4	15651.1	15295.8	15473.4
D_3S_2	4257.4	4552.0	4404.7	1209.8	1177.9	1193.9	1333.4	1147.8	1240.6	1054.6	931.7	993.2	15641.3	15295.8	15468.5
D_3S_3	4167.6	4603.3	4385.4	1275.2	1177.9	1226.6	1297.0	1116.5	1206.7	1010.0	929.5	969.7	15639.0	15262.2	15450.6
D_4S_1	3946.2	4640.4	4293.3	1277.5	1078.9	1178.2	1031.3	934.4	982.8	473.4	757.1	615.3	14535.6	14642.3	14589.0
D_4S_2	3897.8	4725.3	4311.6	1358.2	1071.2	1214.7	1029.9	932.5	981.2	514.4	818.7	666.5	14547.0	14602.1	14574.5
D_4S_3	3840.9	4725.3	4283.1	1333.4	1071.2	1202.3	1016.8	932.5	974.7	539.4	818.7	679.0	14477.2	14602.1	14539.6
D × S															
S.Em (±)	67.49	55.87	43.81	42.00	35.77	27.58	55.55	28.89	31.31	45.72	44.70	31.97	85.71	39.75	47.24
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	59.59	NS
S × D															
S.Em (±)	60.72	65.88	63.35	48.94	37.25	43.49	55.76	31.69	45.35	46.43	42.74	44.62	92.95	44.31	72.81
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	59.59	NS

NS = Not significant

4.1.1.3.2 Effect of spacing

Spacing had no significant influence on accumulated HTU at different phenophases of Gobindabhog paddy in the study during both 2010 and 2011, except for life cycle during second year (Table 4.1.4).

4.1.1.3.3 Interaction effect between planting date and spacing

There was no significant interaction effect between planting date and spacing on accumulation of HTU at all phenophases during both the years of investigation, except for life cycle during 2011 only (Table 4.1.4).

4.1.1.4 Photothermal units (PTU)

4.1.1.4.1 Effect of planting date

Although temperature governed the onset of different phenophases of rice, but day length had the influence on photothermal requirements of the crop.

Gobindabhog rice planted on July 10 (D_1) recorded the highest total summed PTU of 35641.1^{0}C hours, which was 2910.9, 5321.8 and 7940.1^{0}C hour greater over July 25 (D_2), August 10 (D_3) and August 25 (D_4) plantings, respectively (Table 4.1.5). This could be explained by the fact that both temperature and day length showed a linear decreasing trend after autumnal equinox (23 September) and thus, the late planted crops (D_2, D_3 and D_4) received lower temperature and day length during late vegetative, reproductive and ripening phases compared to early planted crop (D_1).

4.1.1.4.2 Effect of spacing

No significant effect due to spacing was noted on photothermal units at all phenophases of Gobindabhog paddy during both the years of experimentation, except for life cycle in 2011 only (Table 4.1.5).

4.1.1.4.3 Interaction effect between planting date and spacing

The non-significant interaction effects on summed PTU at different phenophases were noted during both the years of study, excluding reproductive stage (panicle initiation to 50% flowering) in both 2010 and 2011 (Table 4.1.5).

Table 4.1.5

Effect of planting date and spacing on photothermal units at different phenophases of Gobindabhog rice during *kharif* season

Treatment	Vegetative stage											
	Sowing to Emergence (days)			Emergence to 4th leaf emergence (days)			4th leaf emergence to Active tillering (days)			Active tillering to Panicle initiation (days)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date												
D_1	1064.3	1025.4	1044.8	4716.6	4884.7	4800.7	7329.2	7600.4	7464.8	7648.0	7677.6	7662.8
D_2	858.2	897.5	877.9	4713.0	4505.4	4609.2	6911.3	7253.0	7082.2	6723.7	6826.3	6775.0
D_3	802.3	951.8	877.1	4378.7	4436.9	4407.8	6589.7	7132.9	6861.3	5705.2	6460.3	6082.8
D_4	705.6	971.9	838.8	4233.5	4518.4	4375.9	6184.9	6359.6	6272.2	5373.8	5889.7	5631.7
S.Em (±)	25.02	38.89	23.12	22.51	46.61	25.88	70.26	33.00	38.81	49.08	54.56	36.70
C.D. at 5%	86.59	NS	71.24	77.88	161.28	79.74	243.12	114.20	119.59	169.85	188.81	113.07
Spacing												
S_1	857.6	962.3	910.0	4510.4	4587.2	4548.8	6764.5	7114.4	6939.5	6431.0	6723.4	6577.2
S_2	857.6	960.3	909.0	4510.4	4584.6	4547.5	6767.4	7094.8	6931.1	6297.3	6703.2	6500.3
S_3	857.6	962.3	910.0	4510.4	4587.2	4548.8	6729.4	7050.2	6889.8	6359.6	6713.8	6536.7
S.Em (±)	21.67	44.05	24.54	19.61	20.95	14.35	34.80	30.69	23.20	29.34	35.47	23.02
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	87.96	NS	NS
Interaction effect												
D_1S_1	1064.3	1028.1	1046.2	4716.6	4883.8	4800.2	7275.3	7513.6	7394.5	7729.2	7692.9	7711.0
D_1S_2	1064.3	1020.0	1042.1	4716.6	4886.5	4801.6	7353.7	7689.6	7521.6	7568.1	7731.3	7649.7
D_1S_3	1064.3	1028.1	1046.2	4716.6	4883.8	4800.2	7358.5	7597.9	7478.2	7646.8	7608.6	7627.7
D_2S_1	858.2	897.5	877.9	4713.0	4509.9	4611.4	6881.8	7284.8	7083.3	6801.6	6791.0	6796.3
D_2S_2	858.2	897.5	877.9	4713.0	4496.5	4604.8	6970.4	7197.2	7083.8	6638.1	6803.6	6720.8
D_2S_3	858.2	897.5	877.9	4713.0	4509.9	4611.4	6881.8	7277.2	7079.5	6731.2	6884.4	6807.8
D_3S_1	802.3	951.8	877.1	4378.7	4436.9	4407.8	6645.1	7211.3	6928.2	5806.4	6464.3	6135.4
D_3S_2	802.3	951.8	877.1	4378.7	4436.9	4407.8	6560.6	7132.9	6846.7	5651.5	6460.3	6055.9
D_3S_3	802.3	951.8	877.1	4378.7	4436.9	4407.8	6563.4	7054.4	6808.9	5657.9	6456.2	6057.0
D_4S_1	705.6	971.9	838.8	4233.5	4518.4	4375.9	6255.8	6448.0	6351.9	5386.9	5945.4	5666.1
D_4S_2	705.6	971.9	838.8	4233.5	4518.4	4375.9	6184.9	6359.6	6272.2	5331.7	5817.7	5574.7
D_4S_3	705.6	971.9	838.8	4233.5	4518.4	4375.9	6113.9	6271.3	6192.6	5402.6	5906.0	5654.3
D × S												
S.Em (±)	43.34	88.10	49.09	39.22	41.90	28.69	69.60	61.39	46.40	58.68	70.95	46.04
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × D												
S.Em (±)	43.34	81.77	65.44	39.14	57.81	49.37	90.36	60.01	76.70	68.59	79.58	74.29
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.1.5 (contd.)

Effect of planting date and spacing on photothermal units at different phenophases of Gobindabhog rice during *kharif* season

Treatment	Reproductive stage			Ripening stage									Life cycle		
	Panicle initiation to 50% flowering (days)			50% flowering to Milk (days)			Milk to Dough (days)			Dough to Maturity (days)			Sowing to Maturity (days)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date															
D_1	8206.0	8856.8	8531.4	2508.6	2179.5	2344.1	1972.4	1848.2	1910.3	1848.6	1915.8	1882.2	35293.8	35988.4	35641.1
D_2	7311.1	7867.9	7589.5	2279.1	1921.8	2100.4	1805.2	1875.4	1840.3	1866.9	1844.4	1855.7	32468.4	32991.9	32730.2
D_3	7284.9	6792.0	7038.4	1866.9	1946.0	1906.5	1850.1	1767.9	1809.0	1514.9	1158.3	1336.6	29992.6	30646.0	30319.3
D_4	6329.1	6136.7	6232.9	1871.8	1803.2	1837.5	1588.2	1168.6	1378.4	1082.2	1184.9	1133.5	27369.0	28032.9	27701.0
S.Em (±)	99.53	58.77	57.79	34.20	31.00	23.08	27.65	28.77	19.95	29.43	22.25	18.45	98.64	49.48	55.18
C.D. at 5%	344.40	203.37	178.07	118.33	107.26	71.11	95.69	99.55	61.47	101.84	77.00	56.84	341.35	171.22	170.02
Spacing															
S_1	7256.0	7434.7	7345.3	2129.6	1970.3	2049.9	1798.4	1652.2	1725.3	1574.9	1514.2	1544.6	31322.5	31958.8	31640.6
S_2	7214.1	7424.3	7319.2	2136.0	1965.9	2050.9	1798.2	1672.8	1735.5	1591.1	1540.9	1566.0	31172.2	31946.9	31559.5
S_3	7378.2	7381.0	7379.6	2129.1	1951.7	2040.4	1815.4	1670.0	1742.7	1568.4	1522.4	1545.4	31348.2	31838.8	31593.5
S.Em (±)	56.53	27.92	31.52	23.96	22.94	16.58	28.57	12.41	15.57	19.54	15.46	12.46	73.85	31.27	40.10
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	93.74	NS
Interaction effect															
D_1S_1	8242.1	8900.9	8571.5	2526.8	2206.2	2366.5	1978.9	1847.5	1913.2	1901.6	1896.5	1899.0	35434.9	35969.5	35702.2
D_1S_2	8185.7	8838.9	8512.3	2465.6	2172.8	2319.2	1976.7	1863.9	1920.3	1820.7	1967.3	1894.0	35151.4	36170.2	35660.8
D_1S_3	8190.2	8830.6	8510.4	2533.3	2159.7	2346.5	1961.7	1833.2	1897.5	1823.6	1883.7	1853.7	35295.0	35825.5	35560.3
D_2S_1	7262.6	7976.6	7619.6	2295.7	1925.7	2110.7	1786.5	1862.2	1824.4	1844.5	1854.9	1849.7	32443.9	33102.6	32773.2
D_2S_2	6971.5	7937.3	7454.4	2316.7	1941.5	2129.1	1783.3	1853.9	1818.6	1904.9	1831.9	1868.4	32155.9	32959.6	32557.7
D_2S_3	7699.2	7689.9	7694.6	2224.9	1898.1	2061.5	1845.9	1909.9	1877.9	1851.2	1846.6	1848.9	32805.5	32913.5	32859.5
D_3S_1	7191.2	6748.5	6969.8	1845.3	1986.5	1915.9	1849.9	1725.0	1787.5	1475.0	1135.6	1305.3	29993.9	30659.9	30326.9
D_3S_2	7369.7	6772.5	7071.1	1846.6	1925.8	1886.2	1849.5	1807.6	1828.5	1535.2	1172.2	1353.7	29993.9	30659.9	30326.9
D_3S_3	7293.8	6854.9	7074.4	1908.8	1925.8	1917.3	1850.8	1771.0	1810.9	1534.5	1167.0	1350.8	29990.1	30618.2	30304.1
D_4S_1	6328.1	6112.7	6220.4	1850.7	1762.7	1806.7	1578.2	1174.1	1376.2	1078.5	1170.0	1124.3	27417.3	28103.1	27760.2
D_4S_2	6329.7	6148.6	6239.2	1915.1	1823.5	1869.3	1583.4	1165.8	1374.6	1103.7	1192.3	1148.0	27387.5	27997.8	27692.7
D_4S_3	6329.7	6148.6	6239.2	1849.5	1823.5	1836.5	1603.0	1165.8	1384.4	1064.3	1192.3	1128.3	27302.1	27997.8	27650.0
D × S															
S.Em (±)	113.06	55.83	63.05	47.91	45.88	33.17	57.13	24.83	31.15	39.07	30.93	24.92	147.70	62.53	80.20
C.D. at 5%	338.97	167.38	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × D															
S.Em (±)	135.75	74.38	109.45	51.96	48.62	50.32	54.23	35.19	45.71	43.40	33.66	38.84	155.80	71.10	121.10
C.D. at 5%	440.72	244.46	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

4.1.2 Growth attributes

4.1.2.1 Plant height

Plant height of Gobindabhog rice was increased rapidly during the period from 28 days after transplanting (DAT) to 84 DAT and thereafter slowly due to exertion of panicles during both the years of experimentation (Table 4.1.6). Mean pooled plant height of Gobindabhog rice, averaged over either of four planting dates or three spacings, was 49.4, 87.6, 119.8 and 132.0 cm at 28, 56, 84 DAT and harvest, respectively.

4.1.2.1.1 Effect of planting date

Gobindabhog rice crop planted on July 10 (D_1) produced taller plants, which decreased with delay in plantings on July 25 (D_2), August 10 (D_3) and August 25 (D_4) at 56 DAT, 84 DAT and at harvest, except 28 DAT during both the years of investigation (Table 4.1.6; Plate 4.2). Thus, Gobindabhog rice planted on July 10 (D_1) recorded the highest plant height at harvest (136.9 cm) than July 25 (132.4 cm), August 10 (131.0 cm) and August 25 (127.8 cm) plantings in the study.

The correlation studies between thermal indices and plant height of Gobindabhog rice showed that both GDD and PTU during 4^{th} leaf emergence to flowering had positive effect ($P < 0.01$) on plant height, but HTU had negative ($P < 0.05$) and positive ($P < 0.01$) influence on plant height during active tillering to panicle initiation and panicle initiation to flowering stage, respectively (Table 4.1.24)

Based on significant correlations between agro-meteorological units at different growth stages and plant height, the regression model for plant height of Gobindabhog paddy was developed ($Y = 28.422 - 0.002^{**} HTU_{S-E} + 0.001^{*} HTU_{4L-AT}$), with 9.7% variation at 1% level of significance (Table 4.1.27)

4.1.2.1.2 Effect of spacing

Plant height was not significantly influenced by three types planting density (*viz.* 20 cm × 10 cm, 15 cm × 15 cm and 20 cm × 15 cm) adopted in the experiment at all stages of observation during both 2010 and 2011 (Table 4.1.6).

Table 4.1.6

Effect of planting date and spacing on plant height at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Plant height (cm)											
	28 DAT			56 DAT			84 DAT			At harvest		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date												
D_1	47.5	49.2	48.4	86.9	94.7	90.8	119.7	129.0	124.3	130.7	143.1	136.9
D_2	46.9	51.0	48.9	84.8	89.4	87.1	116.4	125.4	120.9	126.0	138.9	132.4
D_3	45.3	53.7	49.5	82.7	90.3	86.5	114.8	122.5	118.6	125.4	136.5	131.0
D_4	46.8	55.1	50.9	82.1	89.7	85.9	110.5	120.0	115.3	122.7	133.0	127.8
S.Em (±)	0.65	0.43	0.39	0.75	0.37	0.42	0.57	0.88	0.52	0.88	0.87	0.62
C.D. at 5%	NS	1.48	1.20	2.60	1.30	1.29	1.96	3.05	1.61	3.06	3.02	1.91
Spacing												
S_1	46.4	52.0	49.2	84.9	90.7	87.8	115.0	123.8	119.4	126.0	138.0	132.0
S_2	46.7	52.5	49.6	83.8	91.1	87.4	115.8	124.9	120.4	126.6	137.9	132.3
S_3	46.7	52.2	49.5	83.8	91.3	87.5	115.3	123.9	119.6	125.9	137.8	131.8
S.Em (±)	0.36	0.43	0.28	0.44	0.76	0.44	0.56	0.88	0.52	0.58	0.77	0.48
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect												
D_1S_1	47.2	47.5	47.4	87.1	95.2	91.2	118.6	127.4	123.0	130.1	143.4	136.7
D_1S_2	47.3	49.3	48.3	87.7	93.9	90.8	120.5	129.3	124.9	131.7	142.7	137.2
D_1S_3	48.0	50.7	49.4	86.0	95.0	90.5	120.0	130.3	125.1	130.4	143.3	136.8
D_2S_1	46.5	51.8	49.2	86.9	89.5	88.2	115.9	123.7	119.8	125.0	139.3	132.1
D_2S_2	46.5	50.7	48.6	83.9	88.7	86.3	116.4	125.1	120.8	126.9	138.7	132.8
D_2S_3	47.7	50.4	49.1	83.7	89.9	86.8	117.0	127.4	122.2	125.9	138.9	132.4
$D_3 S_1$	45.3	53.1	49.2	83.1	89.1	86.1	115.3	124.6	119.9	127.0	136.9	132.0
D_3S_2	45.4	54.3	49.8	82.2	91.1	86.7	114.8	122.9	118.8	124.8	136.7	130.8
D_3S_3	45.1	53.6	49.3	82.8	90.5	86.7	114.2	119.9	117.1	124.5	135.7	130.1
D_4S_1	46.7	55.5	51.1	82.5	88.9	85.7	110.3	119.6	115.0	122.1	132.5	127.3
D_4S_2	47.7	55.7	51.7	81.3	90.5	85.9	111.5	122.5	117.0	123.1	133.3	128.2
D_4S_3	45.9	54.2	50.1	82.5	89.6	86.1	109.8	117.9	113.9	122.9	133.1	128.0
D × S												
S.Em (±)	0.72	0.85	0.56	0.89	1.52	0.88	1.12	1.75	1.04	1.17	1.54	0.97
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × D												
S.Em (±)	0.88	0.82	0.85	1.04	1.30	1.18	1.07	1.68	1.41	1.30	1.53	1.42
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

4.1.2.1.3 Interaction effect between planting date and spacing

There was no significant interaction effect between planting date and spacing on the plant height of Gobindabhog rice throughout the cropping period during both the years of investigation (Table 4.1.6).

4.1.2.2 TIllering pattern

The number of tillers m^{-2} was increased upto 56 DAT (i.e. upto panicle initiation stage) irrespective of planting date and spacing and declined thereafter (Table 4.1.7), mainly due to death or withering of some late or unproductive tillers as suggested by Matsushima (1957) and Ishizuka and Tanaka (1963).

4.1.2.2.1 Effect of planting date

Gobindabhog rice planted on August 10 (D3) produced the highest number of tillers m^{-2} compared to earlier to plantings dates (July10 and July 25) as well as late planting (August 25) at all three stages of observation like 24, 56 and 84 DAT (Table 4.1.7).

4.1.2.2.2 Effect of spacing

Closer spacing (20 cm × 10 cm) of Gobindabhog rice resulted in significantly greater number of tiller m^{-2} like 239.3, 353.8 and 320.8 at 28, 56 and 84 DAT, respectively than wider spacings of 15 cm × 15 cm (S_2) and 20 cm × 15 cm (S_3) (Table 4.1.7), which might be due to more number of hills per unit area (50 hills m^{-2}) than wider spacings with accommodation of 44 hills m^{-2} (S_2) and 33 hills m^{-2} (S_3) in the study.

4.1.2.2.3 Interaction effect between planting date and spacing

There was no significant interaction effect on tiller production of Gobindabhog rice at 28, 56 and 84 DAT during both the years of investigation, except 56 DAT during 2010 only (Table 4.1.7).

4.1.2.3 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 4.1.8). Mean LAI, pooled over two

Table 4.1.7

Effect of planting date and spacing on tillering pattern at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Number of tillers m^{-2}								
	28 DAT			56 DAT			84 DAT		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date									
D_1	218.8	204.9	211.8	299.9	346.7	323.3	274.3	290.2	282.2
D_2	229.0	214.6	221.8	317.7	354.9	336.3	287.6	325.8	306.7
D_3	243.3	220.3	231.8	315.8	359.2	337.5	300.3	332.4	316.4
D_4	233.9	224.0	229.0	306.7	339.1	322.9	284.7	306.9	295.8
S.Em (±)	2.89	4.85	2.82	5.58	8.51	5.09	4.90	10.63	5.85
C.D. at 5%	10.00	16.77	NS	NS	NS	NS	16.96	NS	18.04
Spacing									
S_1	257.2	221.5	239.3	349.3	358.4	353.8	319.3	322.3	320.8
S_2	229.1	224.9	227.0	310.3	359.6	335.0	292.3	328.7	310.5
S_3	207.5	201.5	204.5	270.5	331.9	301.2	248.7	290.5	269.6
S.Em (±)	5.43	4.22	3.44	3.64	14.06	7.26	4.00	8.54	4.72
C.D. at 5%	16.29	12.65	9.91	10.92	NS	20.92	12.01	25.60	13.58
Interaction effect									
D_1S_1	230.7	207.6	219.1	333.0	368.0	350.5	305.0	305.9	305.4
D_1S_2	225.6	209.1	217.4	300.8	358.1	329.5	285.2	310.7	297.9
D_1S_3	200.0	198.0	199.0	266.0	314.0	290.0	232.7	254.0	243.3
D_2S_1	243.0	229.1	236.1	353.0	358.4	355.7	316.0	335.7	325.9
D_2S_2	230.0	216.8	223.4	312.0	362.4	337.2	288.8	337.6	313.2
D_2S_3	214.0	198.0	206.0	288.0	344.0	316.0	258.0	304.0	281.0
D_3S_1	276.0	220.0	248.0	345.0	366.0	355.5	329.0	336.8	332.9
D_3S_2	240.0	234.8	237.4	332.4	367.0	349.7	310.0	344.4	327.2
D_3S_3	214.0	206.0	210.0	270.0	344.7	307.3	262.0	316.0	289.0
D_4S_1	279.0	229.2	254.1	366.0	341.3	353.7	327.0	310.7	318.8
D_4S_2	220.8	238.8	229.8	296.0	351.0	323.5	285.1	322.0	303.5
D_4S_3	202.0	204.0	203.0	258.0	324.9	291.5	242.0	288.0	265.0
D × S									
S.Em (±)	10.87	8.44	6.88	7.29	28.13	14.53	8.01	17.08	9.43
C.D. at 5%	NS	NS	NS	21.85	NS	NS	NS	NS	NS
S × D									
S.Em (±)	9.33	8.42	8.89	8.16	24.49	18.25	8.17	17.54	13.68
C.D. at 5%	NS	NS	NS	26.22	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

Table 4.1.8

Effect of planting date and spacing on LAI at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Leaf area index (LAI)											
	28 DAT			56 DAT			84 DAT			At harvest		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date												
D_1	1.74	1.69	1.72	3.39	3.82	3.60	4.52	4.70	4.61	2.59	2.82	2.70
D_2	1.77	1.73	1.75	3.68	3.86	3.77	4.66	4.89	4.78	2.67	2.91	2.79
D_3	1.87	1.74	1.80	3.71	3.88	3.80	4.73	4.95	4.84	2.72	2.90	2.81
D_4	1.84	1.76	1.80	3.43	3.62	3.52	4.35	4.64	4.49	2.49	2.68	2.58
S.Em (±)	0.009	0.003	0.005	0.023	0.010	0.013	0.032	0.008	0.017	0.012	0.004	0.006
C.D. at 5%	0.03	0.01	0.01	0.08	0.04	0.04	0.11	0.03	0.05	0.04	0.01	0.02
Spacing												
S_1	1.82	1.73	1.78	3.63	3.86	3.75	4.60	4.78	4.69	2.66	2.82	2.74
S_2	1.82	1.74	1.78	3.56	3.84	3.70	4.58	4.89	4.73	2.62	2.88	2.75
S_3	1.77	1.72	1.75	3.46	3.69	3.58	4.52	4.71	4.61	2.58	2.77	2.67
S.Em (±)	0.006	0.003	0.004	0.017	0.008	0.009	0.020	0.007	0.011	0.010	0.003	0.005
C.D. at 5%	0.02	0.01	0.01	0.05	0.02	0.03	0.06	0.02	0.03	0.03	0.01	0.01
Interaction effect												
D_1S_1	1.76	1.69	1.72	3.39	3.93	3.66	4.51	4.72	4.62	2.65	2.82	2.74
D_1S_2	1.76	1.70	1.73	3.41	3.93	3.67	4.61	4.81	4.71	2.59	2.86	2.72
D_1S_3	1.69	1.69	1.69	3.36	3.59	3.48	4.45	4.58	4.51	2.52	2.78	2.65
D_2S_1	1.81	1.76	1.78	3.72	3.86	3.79	4.82	4.99	4.90	2.60	2.89	2.74
D_2S_2	1.80	1.74	1.77	3.76	3.91	3.83	4.62	4.93	4.78	2.60	2.97	2.79
D_2S_3	1.71	1.71	1.71	3.57	3.82	3.70	4.55	4.74	4.65	2.80	2.86	2.83
D_3S_1	1.88	1.74	1.81	3.77	3.92	3.85	4.65	4.85	4.75	2.79	2.88	2.84
D_3S_2	1.88	1.74	1.81	3.71	3.89	3.80	4.69	5.05	4.87	2.78	2.92	2.85
D_3S_3	1.85	1.73	1.79	3.65	3.83	3.74	4.85	4.94	4.89	2.59	2.88	2.73
D_4S_1	1.84	1.75	1.80	3.66	3.72	3.69	4.44	4.57	4.50	2.58	2.68	2.63
D_4S_2	1.85	1.77	1.81	3.36	3.62	3.49	4.40	4.76	4.58	2.50	2.78	2.64
D_4S_3	1.84	1.77	1.81	3.27	3.52	3.40	4.22	4.58	4.40	2.39	2.58	2.49
D × S												
S.Em (±)	0.013	0.006	0.007	0.033	0.016	0.018	0.041	0.014	0.022	0.020	0.005	0.010
C.D. at 5%	0.04	0.02	0.02	0.10	0.05	0.05	0.12	0.04	0.06	0.06	0.02	0.03
S × D												
S.Em (±)	0.014	0.006	0.011	0.036	0.016	0.028	0.046	0.014	0.034	0.021	0.006	0.015
C.D. at 5%	0.04	0.02	0.03	0.11	0.05	0.08	0.15	0.04	0.10	0.07	0.02	0.05

DAT = Days after transplanting; NS = Not significant

years and averaged over planting dates, was 1.77, 3.67, 4.68 and 2.72 at 28, 56 and 84 DAT, and harvesting stage, respectively.

4.1.2.3.1 Effect of planting date

There was no definite steady trend of LAI values with the advancement of crop age among four planting dates in the study; where Gobindabhog rice planted on August10 (D_3) usually recorded highest LAI values throughout the cropping period compared to early or late planting during both 2010 and 2011(Table 4.1.8).

4.1.2.3.2 Effect of spacing

The planting geometry had significant effect on foliage growth of Gobindabhog rice grown during *kharif* season of 2010 and 2011 (Table 4.1.8), medium spacing (15 cm × 15 cm) generally resulted in highest LAI values throughout the cropping period followed by close spacing (20 cm × 10 cm) and wide (20 cm × 15 cm) spacings adopted in the experiment.

4.1.2.3.3 Interaction effect between planting date and spacing

Planting date × spacing effects on LAI were significant at all dates of taking observation in the study (Table 4.1.8).

4.1.2.4 Light transmission ratio (LTR)

The average pooled LTR either of four planting dates or three spacings, was 47.8, 32.2, 19.9 and 25.9% at 28, 56, 84 and at harvest, respectively; which showed that the light interception by the crop canopy was decreased upto 84 DAT and increased thereafter (Table 4.1.9; Fig. 4.3). This trend of light transmission might be due to foliage growth, tiller production, panicle exertion, etc. upto 84 DAT (*i.e.* heading stage), and senescence of leaves, death of unproductive tillers, etc. during ripening phase. Ghosh *et al.* (2004) reported similar type of light interception between 28 and 70 DAT, with moderate increase thereafter for scented rice varieties during *boro* (dry) season in West Bengal.

4.1.2.4.1 Effect of planting date

Excluding 28 and 84 DAT, light interception differed significantly at 56 DAT for 2010 and pooled values; while at harvest for pooled values only (Table 4.1.9).

Table 4.1.9

Effect of planting date and spacing on light interception at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Light interception (%)											
	28 DAT			56 DAT			84 DAT			At harvest		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date												
D_1	46.8	50.4	48.6	34.0	30.3	32.2	21.9	18.4	20.1	26.6	25.1	25.9
D_2	47.4	49.3	48.4	32.5	30.9	31.7	20.6	18.4	19.5	26.5	24.8	25.7
D_3	46.5	49.1	47.8	32.9	30.9	31.9	20.8	17.9	19.4	25.7	24.2	25.0
D_4	45.2	47.9	46.5	34.8	31.3	33.0	21.8	19.5	20.7	27.8	25.8	26.8
S.Em (±)	0.53	0.84	0.50	0.14	0.47	0.24	0.52	0.51	0.37	0.41	0.31	0.26
C.D. at 5%	NS	NS	NS	0.47	NS	0.75	NS	NS	NS	NS	NS	0.79
Spacing												
S_1	45.9	48.0	46.9	33.0	30.2	31.6	21.2	18.1	19.7	26.3	24.1	25.2
S_2	47.0	49.4	48.2	33.1	30.5	31.8	21.0	18.2	19.6	26.4	24.7	25.5
S_3	46.6	50.0	48.3	34.6	31.9	33.2	21.6	19.4	20.5	27.4	26.2	26.8
S.Em (±)	0.25	0.30	0.19	0.39	0.39	0.28	0.32	0.30	0.22	0.28	0.27	0.19
C.D. at 5%	0.73	0.90	0.56	1.16	1.18	0.80	NS	0.91	0.63	0.82	0.82	0.56
Interaction effect												
D_1S_1	45.0	49.4	47.2	33.4	28.9	31.2	21.8	17.1	19.5	26.5	24.4	25.5
D_1S_2	47.5	50.6	49.1	32.7	29.3	31.0	22.7	17.2	19.9	25.7	25.2	25.4
D_1S_3	47.8	51.2	49.5	35.9	32.8	34.3	21.0	20.9	21.0	27.7	25.8	26.7
D_2S_1	47.6	47.1	47.3	32.1	28.8	30.5	20.0	17.7	18.8	26.8	24.1	25.5
D_2S_2	48.3	49.9	49.1	32.5	31.6	32.1	20.5	19.1	19.8	26.5	24.5	25.5
D_2S_3	46.4	50.9	48.7	32.9	32.3	32.6	21.3	18.5	19.9	26.2	25.9	26.0
D_3S_1	46.4	48.4	47.4	32.8	31.6	32.2	21.4	18.1	19.7	24.5	23.5	24.0
D_3S_2	46.6	49.4	48.0	32.2	30.1	31.2	19.9	17.5	18.7	25.6	23.5	24.6
D_3S_3	46.4	49.5	47.9	33.8	31.0	32.4	21.1	18.3	19.7	27.1	25.6	26.3
D_4S_1	44.5	47.2	45.9	33.5	31.4	32.5	21.6	19.6	20.6	27.4	24.6	26.0
D_4S_2	45.5	47.9	46.7	35.0	31.0	33.0	21.0	19.1	20.1	27.7	25.3	26.5
D_4S_3	45.6	48.5	47.1	35.8	31.5	33.6	22.9	19.9	21.4	28.4	27.4	27.9
D × S												
S.Em (±)	0.49	0.60	0.39	0.77	0.79	0.55	0.64	0.60	0.44	0.55	0.55	0.39
C.D. at 5%	1.47	NS	NS	NS	2.36	1.59	NS	1.81	NS	NS	NS	NS
S × D												
S.Em (±)	0.66	0.98	0.83	0.65	0.80	0.72	0.74	0.71	0.72	0.61	0.54	0.58
C.D. at 5%	2.18	NS	NS	NS	2.51	2.13	NS	2.30	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

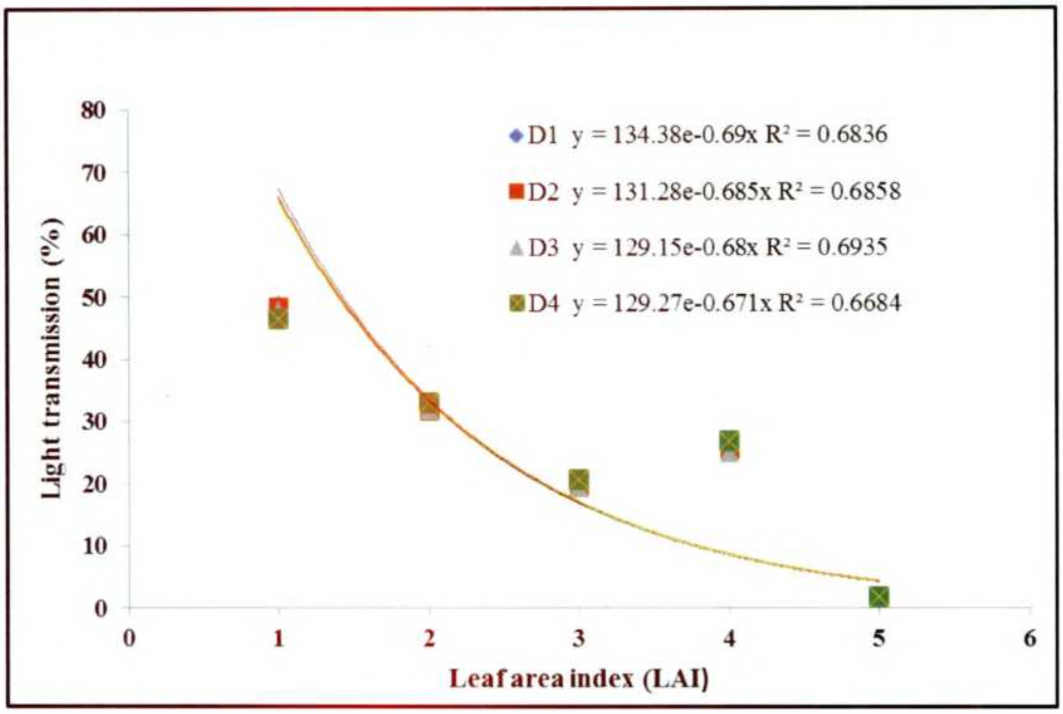

Fig. 4.3: Effect of planting date on relationship between LTR and LAI of Gobindabhog rice during *kharif* season (Pooled over two years)

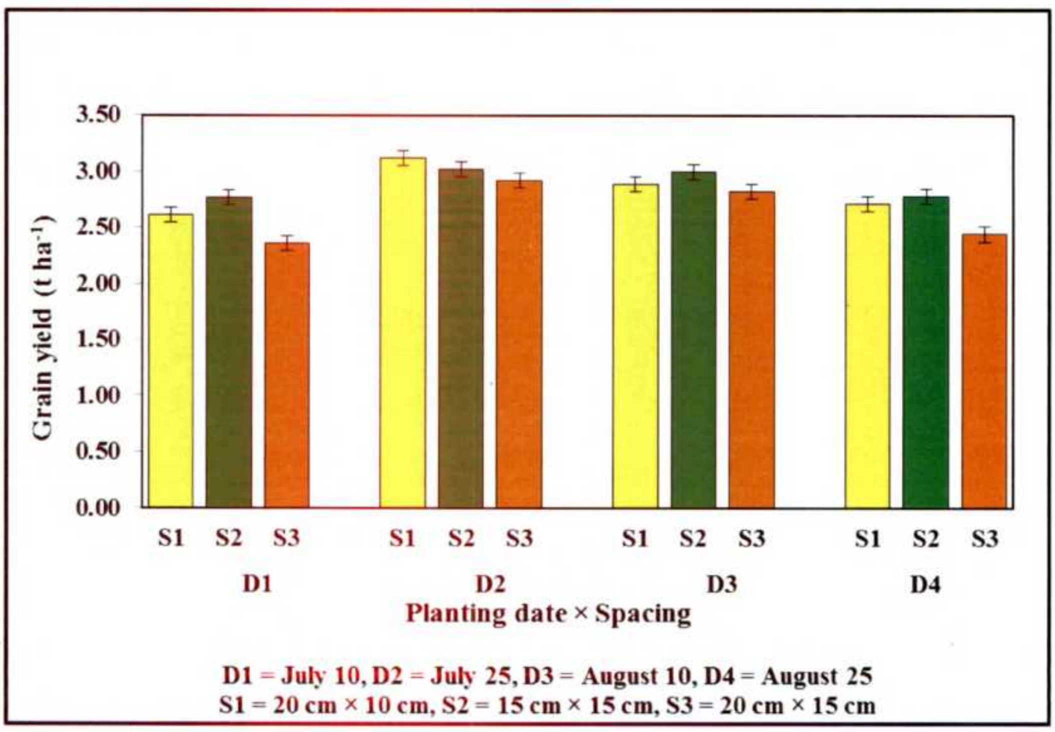

Fig. 4.4: Interaction effect between planting date and spacing on grain yield of Gobindabhog rice during *kharif* season (pooled over two years)

Gobindabhog rice planted very late (*i.e.* 25 August) usually gave rise to greater LTR values probably due to less foliage coverage in terms of LAI at 56, 84 DAT and at harvest compared to earlier three plantings between July 10 (D_1) and August 10 (D_3) in the investigation.

4.1.2.4.2 Effect of spacing

Spacing had significant effect on light interception in Gobindabhog rice field throughout the cropping period except at 84 DAT during 2010 only (Table 4.1.9), The LTR values within plants under two closer spacings (20 cm × 10 cm) and (15 cm × 15 cm), usually being at par, were significantly lower than wide plant density (20 cm × 15 cm) during mid and late phases of life cycle. The variation in LTR values among three plant densities, in general, showed inverse relationship with their respective LAI values because of the influence of foliage growth on penetration of light at ground level.

4.1.2.4.3 Interaction effect between planting date and spacing

The interaction effect between planting date and spacing on light transmission ratio was significant at 28 DAT for 2010, 56 DAT for 2011 and pooled values and 84 DAT for 2011 in the study (Table 4.1.9).

4.1.2.5 Light extinction co-efficient (k)

The average pooled k values, either of planting dates or of spacing, were 0.43, 0.30, 0.35 and 0.50 at 28, 56, 84 DAT and at harvest, respectively (Table 4.1.10), which showed a declining trend between active tillering (28 DAT) and panicle initiation stage (56 DAT), and thereafter an increasing trend toward the maturity. Banerjee (2011) reported similar k values of Gobindabhog rice like 0.40, 0.31, 0.33 and 0.54 at 28, 56, 84 DAT and at harvest, respectively.

4.1.2.5.1 Effect of planting date

The significant influence of planting time on light extinction coefficient (k) of Gobindabhog rice was noted at 56 DAT during 2010; at 56 DAT and harvest during 2011; and at 28, 56 DAT and harvest for pooled values in the investigation (Table 4.1.10). There was no definite trend of variation in k values among four planting dates at all stages of observation for both the years of experimentation.

Table 4.1.10

Effect of planting date and spacing on light extinction co-efficient at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Light extinction co-efficient (k)											
	28 DAT			56 DAT			84 DAT			At harvest		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date												
D_1	0.43	0.42	0.43	0.31	0.32	0.31	0.34	0.36	0.35	0.51	0.49	0.50
D_2	0.41	0.42	0.42	0.29	0.29	0.29	0.34	0.35	0.34	0.50	0.48	0.49
D_3	0.42	0.41	0.42	0.28	0.28	0.28	0.33	0.35	0.34	0.50	0.49	0.49
D_4	0.44	0.44	0.44	0.32	0.31	0.32	0.35	0.35	0.35	0.51	0.51	0.51
S.Em (±)	0.006	0.006	0.004	0.002	0.003	0.002	0.006	0.006	0.004	0.004	0.005	0.003
C.D. at 5%	NS	NS	0.01	0.01	0.01	0.01	NS	NS	NS	NS	0.02	0.01
Spacing												
S_1	0.43	0.44	0.44	0.30	0.30	0.30	0.34	0.36	0.35	0.50	0.51	0.50
S_2	0.42	0.41	0.42	0.30	0.30	0.30	0.34	0.35	0.35	0.51	0.49	0.50
S_3	0.42	0.41	0.42	0.30	0.29	0.29	0.34	0.35	0.34	0.50	0.48	0.49
S.Em (±)	0.003	0.003	0.002	0.003	0.006	0.003	0.004	0.003	0.003	0.004	0.004	0.003
C.D. at 5%	0.01	0.01	0.01	NS	NS	NS	NS	NS	NS	NS	0.01	NS
Interaction effect												
D_1S_1	0.45	0.44	0.44	0.31	0.32	0.31	0.34	0.37	0.36	0.50	0.50	0.50
D_1S_2	0.42	0.42	0.42	0.32	0.32	0.32	0.32	0.37	0.34	0.53	0.48	0.50
D_1S_3	0.41	0.42	0.41	0.31	0.31	0.31	0.35	0.34	0.35	0.51	0.49	0.50
D_2S_1	0.41	0.45	0.43	0.29	0.31	0.30	0.33	0.35	0.34	0.51	0.49	0.50
D_2S_2	0.40	0.42	0.41	0.29	0.28	0.28	0.34	0.34	0.34	0.51	0.47	0.49
D_2S_3	0.42	0.41	0.41	0.29	0.27	0.28	0.34	0.36	0.35	0.48	0.47	0.48
D_3S_1	0.42	0.42	0.42	0.28	0.27	0.28	0.33	0.35	0.34	0.50	0.50	0.50
D_3S_2	0.42	0.40	0.41	0.28	0.29	0.28	0.35	0.35	0.35	0.49	0.50	0.49
D_3S_3	0.43	0.40	0.42	0.27	0.28	0.27	0.32	0.34	0.33	0.51	0.47	0.49
D_4S_1	0.45	0.46	0.46	0.32	0.31	0.32	0.35	0.36	0.35	0.50	0.52	0.51
D_4S_2	0.43	0.41	0.42	0.32	0.32	0.32	0.36	0.35	0.35	0.51	0.49	0.50
D_4S_3	0.43	0.43	0.43	0.32	0.31	0.31	0.35	0.35	0.35	0.53	0.50	0.51
D × S												
S.Em (±)	0.005	0.007	0.004	0.006	0.013	0.007	0.008	0.007	0.005	0.009	0.008	0.006
C.D. at 5%	0.02	NS	0.01	NS	NS	NS	NS	NS	NS	0.03	NS	NS
S × D												
S.Em (±)	0.007	0.008	0.007	0.005	0.011	0.008	0.009	0.008	0.008	0.008	0.008	0.008
C.D. at 5%	0.02	NS	0.02	NS	NS	NS	NS	NS	NS	0.02	NS	NS

DAT = Days after transplanting; NS = Not significant

4.1.2.5.2 Effect of spacing

The value of k was significantly influenced due to planting density at 28 DAT (*i.e.* active tillering stage) for both years as well as at harvest during 2011 only, excluding any effect at 56 and 84 DAT in the study (Table 4.1.10). Close spacing (20 cm × 10 cm) usually recorded greater or similar k values compared to two wide spacings of 15 cm × 15 cm (S_2) and 20 cm × 15 cm (S_3) throughout the cropping period.

4.1.2.5.3 Interaction effect between planting date and spacing

There was mostly non-significant interaction effect on light extinction coefficient throughout the cropping period in the study, excluding significant influence at 28 DAT for 2010 and pooled values; and at harvest for 2010 only (Table 4.1.10).

4.1.3 Weed, disease and insect incidence

4.1.3.1 Weed density

4.1.3.1.1 Grass

Gobingdabog rice grown in puddled field with standing water condition resulted in less grass density, where common grasses are: (i) *Leersia hexandra*, (ii) *Echinochloa formosensis* (iii) *Echinochloa crusgalli* (iv) *Echinochloa colona* (v) *Paspalum distichum etc.* Mean values of grases m^{-2} was 13.70, 12.68 and 13.73 at 3, 6 and 9 WAT, respectively for pooled values in Gobindabhog rice.

4.1.3.1.1.1 Effect of planting date

The density of grasses varied significantly among four planting dates at 3 WAT during 2010 and pooled values, but remained unaffected during mid (6 WAT) and mid-late (9 WAT) stage of crop growth for both the years of study (Table 4.1.11).

4.1.3.1.1.2 Effect of spacing

Spacing had significant interaction influence on population of grasses in 1 m^{-2} area at all 3 stages of observation during both 2010 and 2011 (Table 4.1.11) because it affected athe crop weed competition particularly at early and mid-early stages.

Table 4.1.11

Effect of planting date and spacing on density of grass weed at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Number of Grass m^{-2}								
	3 WAT			6 WAT			9 WAT		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date									
D_1	14.4 (3.79)	14.3 (3.77)	14.4 (3.78)	13.9 (3.71)	11.9 (3.42)	12.9 (3.56)	13.2 (3.60)	13.2 (3.60)	13.2 (3.60)
D_2	11.9 (3.42)	13.0 (3.58)	12.4 (3.50)	11.8 (3.41)	11.9 (3.44)	11.8 (3.42)	13.1 (3.59)	12.9 (3.56)	13.0 (3.57)
D_3	13.1 (3.61)	13.3 (3.63)	13.2 (3.62)	12.6 (3.53)	11.7 (3.39)	12.1 (3.46)	13.9 (3.69)	13.3 (3.61)	13.6 (3.65)
D_4	15.2 (3.89)	14.4 (3.78)	14.8 (3.84)	14.7 (3.80)	13.2 (3.62)	13.9 (3.71)	14.6 (3.77)	15.6 (3.91)	15.1 (3.84)
S.Em (±)	0.36	0.34	0.25	0.98	0.94	0.68	0.98	1.13	0.75
C.D. at 5%	1.24	NS	0.76	NS	NS	NS	NS	NS	NS
Spacing									
S_1	11.3 (3.34)	11.1 (3.32)	11.2 (3.33)	11.0 (3.3)	9.6 (3.09)	10.3 (3.19)	11.1 (3.31)	10.7 (3.24)	10.9 (3.28)
S_2	13.1 (3.61)	13.1 (3.61)	13.1 (3.61)	12.9 (3.57)	12.3 (3.49)	12.6 (3.53)	13.7 (3.66)	13.5 (3.64)	13.6 (3.65)
S_3	16.7 (4.08)	17.2 (4.14)	16.9 (4.11)	15.8 (3.96)	14.7 (3.82)	15.2 (3.89)	16.3 (4.02)	17.1 (4.12)	16.7 (4.07)
S.Em (±)	0.50	0.42	0.32	0.49	0.40	0.32	0.48	0.66	0.41
C.D. at 5%	1.49	1.26	0.93	1.48	1.21	0.92	1.44	1.98	1.18
Interaction effect									
D_1S_1	12.0 (3.46)	11.7 (3.41)	11.8 (3.43)	11.3 (3.36)	8.3 (2.87)	9.8 (3.11)	10.0 (3.16)	10.0 (3.15)	10.0 (3.16)
D_1S_2	14.0 (3.74)	14.0 (3.74)	14.0 (3.74)	13.7 (3.69)	12.3 (3.51)	13.0 (3.60)	12.7 (3.54)	12.3 (3.50)	12.5 (3.52)
D_1S_3	17.3 (4.16)	17.3 (4.16)	17.3 (4.16)	16.7 (4.08)	15.0 (3.87)	15.8 (3.98)	17.0 (4.11)	17.3 (4.15)	17.2 (4.13)
D_2S_1	9.7 (3.08)	10.3 (3.20)	10.0 (3.14)	9.0 (2.99)	10.3 (3.21)	9.7 (3.10)	10.0 (3.14)	10.3 (3.21)	10.2 (3.18)
D_2S_2	11.0 (3.31)	12.3 (3.50)	11.7 (3.41)	11.7 (3.41)	11.7 (3.41)	11.7 (3.41)	13.3 (3.64)	13.0 (3.56)	13.2 (3.60)
D_2S_3	15.0 (3.87)	16.3 (4.04)	15.7 (3.96)	14.7 (3.83)	13.7 (3.69)	14.2 (3.76)	16.0 (3.99)	15.3 (3.90)	15.7 (3.94)
D_3S_1	10.7 (3.26)	11.0 (3.31)	10.8 (3.29)	11.0 (3.31)	9.3 (3.05)	10.2 (3.18)	12.7 (3.52)	10.3 (3.18)	11.5 (3.35)
D_3S_2	12.7 (3.56)	11.3 (3.36)	12.0 (3.46)	11.3 (3.36)	11.3 (3.34)	11.3 (3.35)	13.3 (3.60)	12.7 (3.54)	13.0 (3.57)
D_3S_3	16.0 (4.00)	17.7 (4.20)	16.8 (4.10)	15.3 (3.91)	14.3 (3.78)	14.8 (3.85)	15.7 (3.94)	17.0 (4.11)	16.3 (4.03)
D_4S_1	12.7 (3.56)	11.3 (3.36)	12.0 (3.46)	12.7 (3.55)	10.3 (3.21)	11.5 (3.38)	11.7 (3.40)	12.0 (3.44)	11.8 (3.42)
D_4S_2	14.7 (3.82)	14.7 (3.83)	14.7 (3.82)	15.0 (3.84)	13.7 (3.68)	14.3 (3.76)	15.3 (3.86)	16.0 (3.97)	15.7 (3.92)
D_4S_3	18.3 (4.28)	17.3 (4.16)	17.8 (4.22)	16.3 (4.02)	15.7 (3.96)	16.0 (3.99)	16.7 (4.06)	18.7 (4.32)	17.7 (4.19)
D × S									
S.Em (±)	0.99	0.84	0.65	0.99	0.81	0.64	0.96	1.32	0.82
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × D									
S.Em (±)	0.88	0.76	0.83	1.27	1.15	1.21	1.25	1.56	1.42
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

Figures in parentheses are square root transformed values; WAT = Week after transplanting; NS = Not significant

Close spacing (20 cm × 10 cm), 50 hills m^{-2} resulted in lowest population of grasses in Gobindabhog rice field at 3, 6 and 9 WAT compared to wider spacings of 15 cm × 15 cm (44 hills m^{-2}) and 20 cm × 15 cm (33 hills m^{-2}).

4.1.3.1.1.3 Interaction effect between planting date and spacing

No significant effect between planting date and spacing on population of grasses was found through out the cropping period during both the year of investigation (Table 4.1.11)

4.1.3.1.2 Sedge

The common sedges infested the experimental plot of Gobindabhog rice included : (i) *Fimbristylis dichotoma* (ii) *Cyperus rotundus* (iii) *Cyperus difformis* etc. Mean number of sedges of in 1 m^{-2} area of Gobindabhog rice field was 14.00, 11.58 and 11.58 at 3, 6 and 9 WAT, respectively, indicated that sedge density was initially higher at early tillering stage (3 WAT) and declined therefore slightly including a steady phase upto 9 WAT in the investigation (Table 4.1.12).

4.1.3.1.2.1 Effect of planting date

Planting date could register to significant effect on population of sedges in experimental field at 3 WAT only during 2010 and pooled values; but the variations among the planting date at mid-early (6 WAT) and mid (9 WAT) stage of crop growth was found non-significant (Table 4.1.12).

4.1.3.1.2.2 Effect of spacing

Among three plant densities tested in the study, close spacing (20 cm × 10 cm, 50 hills m^{-2}) recorded minimum number of sedges in 1 m^2 area through out the vegetative and early reproductive period upto 9 WAT, while wide spacing (20 cm × 10 cm, 33 hills m^{-2}) favoured the population and growth of sedges as noted with highest values during the period of observation (3 to 9 WAT) in both 2010 and 2011 (Table 4.1.12).

Table 4.1.12

Effect of planting date and spacing on density of sedge weed at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Number of Sedge / m^{-2}								
	3 WAT			6 WAT			9 WAT		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date									
D_1	18.2 (4.26)	12.0 (3.44)	15.1 (3.85)	12.0 (3.44)	11.2 (3.34)	11.6 (3.39)	11.4 (3.36)	10.8 (3.26)	11.1 (3.31)
D_2	13.8 (3.70)	11.0 (3.29)	12.4 (3.50)	11.6 (3.37)	11.9 (3.43)	11.7 (3.40)	10.6 (3.24)	11.8 (3.42)	11.2 (3.33)
D_3	13.2 (3.61)	11.1 (3.31)	12.2 (3.46)	11.4 (3.36)	11.0 (3.30)	11.2 (3.33)	11.6 (3.39)	12.0 (3.46)	11.8 (3.43)
D_4	18.7 (4.31)	14.0 (3.72)	16.3 (4.01)	11.7 (3.41)	12.0 (3.43)	11.8 (3.42)	12.2 (3.47)	12.1 (3.46)	12.2 (3.47)
S.Em (±)	0.50	0.73	0.44	0.56	0.81	0.49	0.45	0.46	0.32
C.D. at 5%	1.74	NS	1.36	NS	NS	NS	NS	NS	NS
Spacing									
S_1	13.3 (3.62)	10.3 (3.19)	11.8 (3.40)	10.5 (3.22)	10.4 (3.22)	10.5 (3.22)	9.7 (3.10)	10.6 (3.24)	10.1 (3.17)
S_2	15.9 (3.97)	11.7 (3.39)	13.8 (3.68)	10.6 (3.24)	10.4 (3.21)	10.5 (3.23)	10.8 (3.29)	10.4 (3.22)	10.6 (3.25)
S_3	18.8 (4.32)	14.2 (3.75)	16.5 (4.03)	13.9 (3.72)	13.8 (3.69)	13.8 (3.70)	13.8 (3.71)	14.0 (3.74)	13.9 (3.72)
S.Em (±)	0.53	0.60	0.40	0.67	0.67	0.47	0.39	0.43	0.29
C.D. at 5%	1.58	1.80	1.15	2.00	2.00	1.36	1.18	1.30	0.84
Interaction effect									
D_1S_1	15.3 (3.91)	9.3 (3.05)	12.3 (3.48)	10.0 (3.15)	10.3 (3.21)	10.2 (3.18)	8.7 (2.94)	9.7 (3.11)	9.2 (3.02)
D_1S_2	18.7 (4.32)	13.3 (3.64)	16.0 (3.98)	10.3 (3.20)	9.7 (3.11)	10.0 (3.15)	11.3 (3.37)	8.7 (2.94)	10.0 (3.15)
D_1S_3	20.7 (4.54)	13.3 (3.64)	17.0 (4.09)	15.7 (3.95)	13.7 (3.70)	14.7 (3.83)	14.3 (3.78)	14.0 (3.74)	14.2 (3.76)
D_2S_1	12.0 (3.46)	10.0 (3.15)	11.0 (3.31)	9.3 (3.03)	10.7 (3.26)	10.0 (3.14)	8.7 (2.94)	11.3 (3.35)	10.0 (3.14)
D_2S_2	13.3 (3.65)	10.3 (3.19)	11.8 (3.42)	11.0 (3.30)	11.0 (3.30)	11.0 (3.30)	10.7 (3.27)	10.3 (3.21)	10.5 (3.24)
D_2S_3	16.0 (4.00)	12.7 (3.54)	14.3 (3.77)	14.3 (3.78)	14.0 (3.72)	14.2 (3.75)	12.3 (3.51)	13.7 (3.69)	13.0 (3.6)
$D_3 S_1$	10.3 (3.18)	10.7 (3.27)	10.5 (3.22)	9.7 (3.10)	11.7 (3.41)	10.7 (3.26)	10.7 (3.26)	10.7 (3.27)	10.7 (3.26)
D_3S_2	13.3 (3.65)	8.7 (2.94)	11.0 (3.29)	11.3 (3.36)	10.0 (3.14)	10.7 (3.25)	11.3 (3.36)	12.3 (3.51)	11.8 (3.43)
D_3S_3	16.0 (4.00)	14.0 (3.74)	15.0 (3.87)	13.3 (3.62)	11.3 (3.34)	12.3 (3.48)	12.7 (3.56)	13.0 (3.60)	12.8 (3.58)
D_4S_1	15.3 (3.91)	11.0 (3.30)	13.2 (3.61)	13.0 (3.61)	9.0 (2.99)	11.0 (3.30)	10.7 (3.26)	10.7 (3.25)	10.7 (3.26)
D_4S_2	18.3 (4.28)	14.3 (3.78)	16.3 (4.03)	9.7 (3.11)	11.0 (3.30)	10.3 (3.20)	10.0 (3.16)	10.3 (3.21)	10.2 (3.19)
D_4S_3	22.3 (4.72)	16.7 (4.08)	19.5 (4.4)	12.3 (3.51)	16.0 (3.99)	14.2 (3.75)	16.0 (4.00)	15.3 (3.92)	15.7 (3.96)
D × S									
S.Em (±)	1.05	1.20	0.80	1.34	1.34	0.94	0.79	0.87	0.59
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	1.69
S × D									
S.Em (±)	1.00	1.22	1.11	1.23	1.36	1.29	0.79	0.84	0.82
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	2.38

Figures in parentheses are square root transformed values; WAT = Week after transplanting; NS = Not significant

4.1.3.1.2.3 Interaction effect between planting date and spacing

Interaction effect between planting date and spacing on sedge density at 3, 6 and 9 WAT was found non significant excluding at 9 WAT for pooled values only in the experiment (Table 4.1.12).

4.1.3.1.3 Broadleaf

Major broad leaf weeds, which infested the experimental rice field at Kalyani Nadia were: (i) *Luduigia parviflora,*(ii) *Ammania baccifera,*(iii*) Oldenlandia corymbos* (iv) *Alternanthera philoxeroides* (v) *Marsilea quadrifolia,*(vi) *Lindernia ciliata,* (vii) *Eclipta alba,* etc. Mean number of broad leaf weeds m^{-2} was recorded as 14.70, 12.65 and 14.29 at 3, 6 and 9 WAT rspectively for pooled values of investigation (Table 4.1.13).

4.1.3.1.3.1 Effect of planting date

With delay in planting from July 10 (D_1) to August 25 (D_4) the population of broad laeaf weed in 1 m^2 area decreased steadly including some exceptions during both the year of investigation; but the differences were significant at 3 WAT and 6 WAT for pooled values only (Table 4.1.13).

Although the broad leaf population irrespective of planting dates was higher in 2010 at 3 and 9 WAT than 2011, but surprisingly the opposite trend between two years was noted at 6 WAT.

4.1.3.1.3.2 Effect of spacing

The broad leaf weeds in greater population grew better in widely spaced plots (20 cm × 15 cm) of Gobindabhog compared to close spacing of 15 cm × 15 cm (S_2) and 20 cm × 10 cm (S_1) during both 2010 and 2011(Table 4.1.13).

4.1.3.1.3.3 Interaction effect between planting date and spacing

Planting date into spacing effect on density of weeds in Gobindabhog rice field was found significant at 9 WAT only for 2011 and pooled values in the study (Table 4.1.13).

Table 4.1.13

Effect of planting date and spacing on density of broadleaf weed at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Number of Broadleaf / m^{-2}								
	3 WAT			6 WAT			9 WAT		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date									
D_1	18.2 (4.25)	15.1 (3.87)	16.7 (4.06)	13.0 (3.59)	13.7 (3.68)	13.3 (3.63)	14.1 (3.73)	13.9 (3.70)	14.0 (3.72)
D_2	15.2 (3.88)	13.9 (3.71)	14.6 (3.79)	11.8 (3.40)	13.9 (3.70)	12.8 (3.55)	15.0 (3.86)	13.2 (3.61)	14.1 (3.73)
D_3	14.4 (3.77)	13.4 (3.65)	13.9 (3.71)	12.1 (3.47)	13.0 (3.59)	12.6 (3.53)	15.4 (3.92)	14.3 (3.77)	14.9 (3.85)
D_4	14.2 (3.75)	13.0 (3.59)	13.6 (3.67)	11.3 (3.34)	12.6 (3.52)	11.9 (3.43)	14.3 (3.76)	13.6 (3.67)	13.9 (3.71)
S.Em (±)	1.10	0.55	0.61	0.35	0.49	0.30	0.78	0.51	0.47
C.D. at 5%	NS	NS	1.89	NS	NS	0.93	NS	NS	NS
Spacing									
S_1	12.1 (3.53)	12.1 (3.47)	12.3 (3.50)	10.2 (3.17)	11.2 (3.33)	10.7 (3.25)	13.3 (3.62)	12.1 (3.46)	12.7 (3.54)
S_2	15.2 (3.47)	12.7 (3.55)	13.9 (3.71)	11.4 (3.37)	12.2 (3.48)	11.8 (3.43)	13.2 (3.62)	13.2 (3.61)	13.2 (3.62)
S_3	16.8 (4.33)	16.8 (4.10)	17.8 (4.22)	14.6 (3.81)	16.5 (4.05)	15.5 (3.93)	17.8 (4.20)	16.0 (3.99)	16.9 (4.10)
S.Em (±)	0.59	0.48	0.38	0.65	0.66	0.46	0.65	0.54	0.42
C.D. at 5%	1.77	1.42	1.09	1.96	1.98	1.34	1.94	1.63	1.22
Interaction effect									
D_1S_1	15.0 (3.87)	13.3 (3.65)	14.2 (3.76)	11.0 (3.31)	10.7 (3.26)	10.8 (3.29)	11.3 (3.36)	11.0 (3.31)	11.2 (3.34)
D_1S_2	17.7 (4.20)	14.0 (3.74)	15.8 (3.97)	11.7 (3.41)	13.3 (3.65)	12.5 (3.53)	13.3 (3.65)	12.7 (3.56)	13.0 (3.60)
D_1S_3	22.0 (4.69)	18.0 (4.24)	20.0 (4.46)	16.3 (4.04)	17.0 (4.12)	16.7 (4.08)	17.7 (4.19)	18.0 (4.24)	17.8 (4.22)
D_2S_1	13.0 (3.59)	11.3 (3.37)	12.2 (3.48)	10.3 (3.17)	10.7 (3.26)	10.5 (3.21)	15.0 (3.86)	10.0 (3.15)	12.5 (3.51)
D_2S_2	15.3 (3.90)	12.7 (3.55)	14.0 (3.72)	11.0 (3.30)	13.3 (3.65)	12.2 (3.48)	13.0 (3.60)	12.7 (3.55)	12.8 (3.57)
D_2S_3	17.3 (4.16)	17.7 (4.20)	17.5 (4.18)	14.0 (3.73)	17.7 (4.18)	15.8 (3.96)	17.0 (4.11)	17.0 (4.12)	17.0 (4.11)
D_3S_1	11.3 (3.37)	12.3 (3.51)	11.8 (3.44)	11.0 (3.31)	13.0 (3.60)	12.0 (3.46)	14.0 (3.73)	12.3 (3.50)	13.2 (3.62)
D_3S_2	14.0 (3.72)	12.0 (3.45)	13.0 (3.58)	11.7 (3.41)	10.7 (3.26)	11.2 (3.34)	14.7 (3.83)	16.7 (4.07)	15.7 (3.95)
D_3S_3	18.0 (4.23)	16.0 (4.00)	17.0 (4.12)	13.7 (3.69)	15.3 (3.90)	14.5 (3.79)	17.7 (4.20)	14.0 (3.74)	15.8 (3.97)
D_4S_1	11.0 (3.87)	11.3 (3.91)	11.2 (3.89)	08.3 (3.36)	10.3 (3.65)	09.3 (3.51)	12.7 (3.63)	15.0 (4.24)	13.8 (3.94)
D_4S_2	13.7 (4.19)	12.8 (4.00)	12.8 (4.09)	11.3 (3.78)	11.3 (3.78)	11.3 (3.78)	11.7 (3.63)	10.7 (3.56)	11.2 (3.59)
D_4S_3	18.0 (4.69)	15.7 (4.43)	16.8 (4.56)	14.3 (4.16)	16.0 (4.36)	15.2 (4.26)	18.7 (4.50)	15.0 (4.23)	16.8 (4.37)
D × S									
S.Em (±)	1.18	0.95	0.76	1.31	1.32	0.93	1.29	1.09	0.84
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	3.26	2.43
S × D									
S.Em (±)	1.46	0.95	1.24	1.13	1.18	1.16	1.31	1.02	1.18
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	3.18	3.41

Figures in parentheses are square root transformed values; WAT = Week after transplanting; NS = Not significant

4.1.3.2 Disease incidence

4.1.3.2.1 Brown spot disease incidence

The susceptibility of Gobindabhog rice crop to brown spot disease caused by *Drechslera oryzae* increased progressively with the advancement of crop age from 28 DAT (*i.e.* active tillering stage) to 84 DAT (*i.e.* flowering stage). The variation in disease incidence (% of leaf area affected) at different growth stages noted in the study could generally be classified under scale 4 (6–10%) at 28 DAT, scale 5 (11–15%) at 56 DAT and scale 6 (16–25%) at 84 DAT in the investigation (Table 4.1.14).

4.1.3.2.1.1 Effect of planting date

The incidence of brown spot disease increased rapidly with delay in planting from July 10 (D_1) to August 25 during both 2010 and 2011 (Table 4.1.14).

4.1.3.2.1.2 Effect of spacing

The variation in brown spot disease incidence on Gobindabhog rice due to spacing was found non-significant at 56 and 84 DAT during both the years of experiment, except at 28 DAT during 2010 only (Table 4.1.14).

4.1.3.2.1.3 Interaction effect between planting date and spacing

The interaction effect between planting date and spacing was found significant in brown spot disease incidence at both 56 and 84 DAT for 2010 and pooled values (Table 4.1.14).

4.1.3.2.2 Blast disease incidence

The blast lesions as observed on Gobindabhog rice plants were found to increase from 28 DAT to 84 DAT during both the years of investigation (Table 4.1.15). Based on the percentage of leaf area affected, the incidence could be grouped under scale 2 (1–3%) and 3 (4–5%) at 28 DAT, scale 4 (6–10%) and 5 (11–15%) at 56 DAT, and scale 5 (11–15%) and 6 (16–25%) at 84 DAT.

4.1.3.2.2.1 Effect of planting date

The planting date had singnificant effect on incidence of blast disease in Gobindabhog rice during both 2010 and 2011 (Table 4.1.15; Plate 4.5), except at 28 DAT. Delay in planting generally provided the favorable environment for the causal organism (*Payricularia oryzae*) during vegetative and reproductive stages of Gobindabhog rice, thereby leading to greater incidence in delayed crops (D_2, D_3 and D_4) than the earlier one (D_1).

Table 4.1.14

Effect of planting date and spacing on brown spot disease incidence of Gobindabhog rice during *kharif* season

Treatment	Brown spot disease incidence (%)								
	28 DAT			56 DAT			84 DAT		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date									
D_1	7.15 (15.5)	7.77 (16.1)	7.46 (15.8)	11.2 (19.5)	12.7 (20.8)	12.0 (20.2)	19.4 (26.0)	18.1 (25.2)	18.7 (25.6)
D_2	7.40 (15.7)	7.52 (15.8)	7.46 (15.8)	14.8 (22.5)	12.8 (20.9)	13.8 (21.7)	19.9 (26.4)	21.3 (27.5)	20.6 (26.9)
D_3	8.63 (17.1)	9.00 (17.4)	8.82 (17.3)	12.8 (20.9)	13.6 (21.5)	13.2 (21.2)	20.0 (26.5)	24.5 (29.5)	22.3 (28.0)
D_4	8.39 (16.8)	9.25 (17.7)	8.82 (17.2)	13.4 (21.5)	14.4 (22.3)	13.9 (21.9)	22.4 (28.3)	24.2 (29.4)	23.3 (28.8)
S.Em (±)	0.29	0.42	0.26	0.57	0.21	0.30	0.33	1.09	0.57
C.D. at 5%	NS	NS	0.79	1.98	0.73	0.94	1.14	NS	1.75
Spacing									
S_1	8.33 (16.8)	8.51 (16.9)	8.42 (16.8)	13.1 (21.1)	12.7 (20.8)	12.9 (21.0)	20.8 (27.1)	21.7 (27.7)	21.3 (27.4)
S_2	7.49 (15.9)	8.70 (17.0)	8.09 (16.5)	13.2 (21.3)	13.6 (21.6)	13.4 (21.4)	20.4 (26.8)	22.3 (28.0)	21.3 (27.4)
S_3	7.86 (16.2)	7.96 (16.3)	7.91 (16.3)	12.9 (20.9)	13.9 (21.8)	13.4 (21.4)	20.1 (26.6)	22.1 (28.0)	21.1 (27.3)
S.Em (±)	0.28	0.30	0.21	0.30	0.46	0.27	0.27	0.56	0.31
C.D. at 5%	0.84	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect									
D_1S_1	7.77 (16.2)	7.77 (16.2)	7.77 (16.2)	11.8 (20.1)	10.4 (18.8)	11.1 (19.4)	22.6 (28.4)	19.6 (26.3)	21.1 (27.3)
D_1S_2	7.40 (15.7)	8.51 (16.9)	7.96 (16.3)	11.5 (19.8)	14.1 (22.0)	12.8 (20.9)	16.3 (23.8)	16.3 (23.8)	16.3 (23.8)
D_1S_3	6.29 (14.5)	7.03 (15.4)	6.66 (14.9)	10.4 (18.7)	13.7 (21.7)	12.0 (20.2)	19.2 (26.0)	18.5 (25.5)	18.9 (25.7)
D_2S_1	8.88 (17.3)	9.25 (17.7)	9.07 (17.5)	17.8 (24.9)	12.2 (20.4)	15.0 (22.7)	22.6 (28.4)	24.4 (29.6)	23.5 (29.0)
D_2S_2	7.40 (15.7)	6.29 (14.5)	6.85 (15.1)	15.2 (22.9)	14.8 (22.6)	15.0 (22.7)	19.6 (26.3)	20.0 (26.5)	19.8 (26.4)
D_2S_3	5.92 (14.1)	7.03 (15.3)	6.48 (14.7)	11.5 (19.8)	11.5 (19.8)	11.5 (19.8)	17.4 (24.6)	19.6 (26.3)	18.5 (25.5)
D_3S_1	8.51 (17.0)	8.51 (17.0)	8.51 (17.0)	10.0 (18.4)	13.3 (21.4)	11.7 (19.9)	16.7 (24.1)	22.2 (28.1)	19.4 (26.1)
D_3S_2	7.77 (16.2)	8.88 (17.3)	8.33 (16.7)	13.7 (21.7)	12.2 (20.4)	13.0 (21.0)	21.5 (27.6)	24.8 (29.5)	23.1 (28.5)
D_3S_3	9.62 (18.1)	9.62 (18.1)	9.62 (18.1)	14.8 (22.6)	15.2 (22.9)	15.0 (22.8)	21.8 (27.9)	26.6 (31.1)	24.2 (29.5)
D_4S_1	8.14 (16.6)	8.51 (17.0)	8.33 (16.8)	13.0 (21.1)	14.8 (22.6)	13.9 (21.8)	21.5 (27.6)	20.7 (27.1)	21.1 (27.3)
D_4S_2	7.40 (15.8)	11.1 (19.4)	9.25 (17.6)	12.6 (20.7)	13.3 (21.4)	13.0 (21.1)	24.1 (29.4)	28.1 (32.0)	26.1 (30.7)
D_4S_3	9.62 (18.1)	8.14 (16.6)	8.88 (17.3)	14.8 (22.6)	15.2 (22.9)	15.0 (22.8)	21.8 (27.9)	23.7 (29.1)	22.8 (28.5)
D × S									
S.Em (±)	1.63	1.01	0.96	1.15	1.05	0.78	1.19	1.20	0.85
C.D. at 5%	NS	NS	NS	3.44	NS	2.24	3.56	NS	2.43
S × D									
S.Em (±)	1.61	1.06	1.36	1.06	1.02	1.04	1.41	1.04	1.24
C.D. at 5%	NS	NS	NS	3.29	NS	3.16	4.57	NS	3.67

Figures in parentheses are angular transformed values; DAT = Days after transplanting; NS = Not significant

Table 4.1.15

Effect of planting date and spacing on blast disease incidence of Gobindabhog rice during *kharif* season

Treatment	Blast disease incidence (%)								
	28 DAT			56 DAT			84 DAT		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date									
D_1	3.58 (10.6)	2.84 (09.5)	3.21 (10.1)	9.00 (17.3)	7.03 (15.3)	8.02 (16.3)	13.6 (21.5)	12.8 (20.9)	13.2 (21.2)
D_2	3.58 (10.5)	3.70 (10.9)	3.64 (10.7)	10.36 (18.7)	9.87 (18.2)	10.11 (18.4)	13.8 (21.8)	15.4 (23.1)	14.6 (22.4)
D_3	3.95 (11.1)	4.69 (12.4)	4.32 (11.8)	13.81 (21.7)	12.83 (20.9)	13.32 (21.3)	16.5 (23.9)	14.9 (22.7)	15.7 (23.3)
D_4	5.18 (12.9)	4.81 (12.5)	5.00 (12.7)	14.31 (22.2)	13.81 (21.8)	14.06 (22.0)	20.1 (26.3)	18.7 (25.5)	19.4 (25.9)
S.Em (±)	0.91	0.66	0.56	0.50	0.55	0.37	1.02	0.34	0.54
C.D. at 5%	NS	NS	1.73	1.72	1.90	1.14	NS	1.17	1.66
Spacing									
S_1	4.35 (11.7)	4.26 (11.7)	4.30 (11.7)	12.21 (20.2)	12.12 (20.2)	12.16 (20.2)	18.87 (25.3)	17.11 (24.2)	17.9 (24.8)
S_2	3.15 (09.9)	3.61 (10.7)	3.38 (10.3)	11.75 (19.9)	10.55 (18.8)	11.15 (19.3)	14.80 (22.6)	15.63 (23.2)	15.2 (22.9)
S_3	4.72 (12.3)	4.16 (11.6)	4.44 (11.9)	11.66 (19.8)	9.99 (18.2)	10.82 (19.0)	14.43 (22.2)	13.69 (21.7)	14.1 (21.9)
S.Em (±)	0.81	0.50	0.48	0.57	0.53	0.39	0.59	0.60	0.42
C.D. at 5%	NS	NS	1.38	NS	1.58	NS	1.78	1.80	1.22
Interaction effect									
D_1S_1	4.44 (11.9)	3.70 (10.9)	4.07 (11.4)	6.29 (14.5)	8.14 (16.5)	7.22 (15.5)	12.2 (20.4)	11.5 (19.8)	11.8 (20.1)
D_1S_2	2.59 (09.0)	2.59 (09.0)	2.59 (09.0)	9.25 (17.7)	7.03 (15.3)	8.14 (16.5)	15.5 (23.2)	14.1 (21.9)	14.8 (22.6)
D_1S_3	3.70 (10.9)	2.22 (08.6)	2.96 (09.7)	11.47 (19.8)	5.92 (14.1)	8.70 (16.9)	13.0 (21.0)	13.0 (21.1)	13.0 (21.1)
D_2S_1	2.22 (08.4)	2.59 (09.2)	2.41 (08.8)	12.21 (20.5)	11.1 (19.4)	11.66 (19.9)	16.3 (23.8)	16.3 (23.7)	16.3 (23.7)
D_2S_2	3.33 (10.2)	3.33 (10.2)	3.33 (10.2)	10.36 (18.7)	9.99 (18.4)	10.18 (18.6)	12.2 (20.5)	15.9 (23.5)	14.1 (22.0)
D_2S_3	5.18 (12.8)	5.18 (13.1)	5.18 (12.7)	8.51 (16.8)	8.51 (16.9)	8.51 (16.8)	13.0 (21.1)	14.1 (22.0)	13.5 (21.5)
D_3S_1	5.18 (12.9)	5.55 (13.6)	5.37 (13.3)	13.32 (21.3)	12.58 (20.7)	12.95 (21.0)	17.0 (24.2)	17.0 (24.4)	17.0 (24.3)
D_3S_2	2.59 (08.9)	4.44 (12.2)	3.52 (10.5)	14.06 (21.9)	12.95 (20.9)	13.51 (21.4)	15.5 (23.2)	14.8 (22.6)	15.2 (22.9)
D_3S_3	4.07 (11.4)	4.07 (11.4)	4.07 (11.4)	14.06 (22.0)	12.95 (21.1)	13.51 (21.5)	17.0 (24.2)	13.0 (21.1)	15.0 (22.7)
D_4S_1	5.55 (13.5)	5.18 (13.1)	5.37 (13.3)	17.02 (24.3)	16.65 (24.1)	16.84 (24.2)	29.6 (32.9)	23.7 (29.1)	26.6 (31.0)
D_4S_2	4.07 (11.3)	4.07 (11.3)	4.07 (11.3)	13.32 (21.4)	12.21 (20.4)	12.77 (20.9)	15.9 (23.5)	17.8 (24.7)	16.8 (24.1)
D_4S_3	5.92 (14.0)	5.18 (13.1)	5.55 (13.6)	12.58 (20.8)	12.58 (20.8)	12.58 (20.8)	14.8 (22.4)	14.8 (22.6)	14.8 (22.5)
D × S									
S.Em (±)	1.63	1.01	0.96	1.15	1.05	0.78	1.19	1.20	0.85
C.D. at 5%	NS	NS	NS	3.44	NS	2.24	3.56	NS	2.43
S × D									
S.Em (±)	1.61	1.06	1.36	1.06	1.02	1.04	1.41	1.04	1.24
C.D. at 5%	NS	NS	NS	3.29	NS	3.16	4.57	NS	3.67

Figures in parentheses are angular transformed values; DAT = Days after transplanting; NS = Not significant

Plate 4.1: Gobindabhog rice at different planting dates in Experiment No. 1

Plate 4.2: Gobindabhog rice at vegetative and reproductive stage

Plate 4.3: Gobindabhog rice at milk and maturity stage in Experiment No. 1

Plate 4.4: Gobindabhog rice at maturity stage in Experiment No. 2

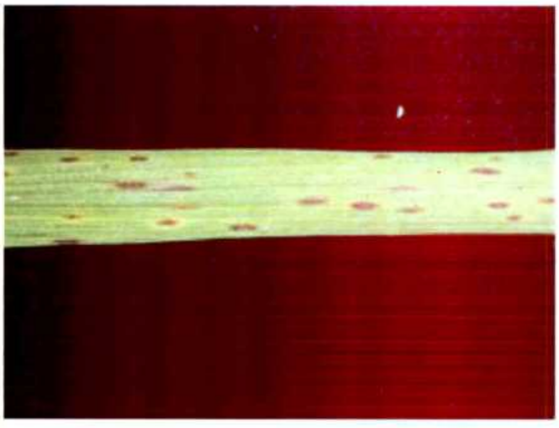

Plate 4.5: Blast disease in Gobindabhog rice leaf

Plate 4.6: Lodging of Gobindabhog rice at maturity stage

Different stages of Gobindabhog Rice in Experimental plots at B.C.K.V., Kalyani, West Bengal, India

4.1.3.2.2.2 Effect of spacing

The significant variation in blast infestation on Gobindabhog rice due to spacing was usually found at 84 DAT (i.e. flowering stage), along with a few cases at 28 and 56 DAT in the investigation. Close spacing (20 cm × 10 cm) resulted in greater blast incidence than other two wider spacings (15 cm × 15 cm and 20 cm × 15 cm) (Table 4.1.15).

4.1.3.2.2.3 Interaction effect between planting date and spacing

The interaction effect between planting date and spacing was found significant in blast disease incidence at both 56 and 84 DAT for 2010 and pooled values (Table 4.1.15).

4.1.3.3 Insect incidence

4.3.1.3.1 Gundhi bug incidence

The population of gundhi bug (*Leptocorisa acuta*) increased steadily from 84 DAT (i.e. 50 % flowering) to 112 DAT (Maturity stage) irrespective of main and sub-plot treatments, as well as years of investigation.

4.3.1.3.1.1 Effect of planting date

The population of gundhi bug per hill of gobindavhog paddy was increased from early (D_1) to mid planting (D_2) in July and there after decline gradually due to delayed planting upto August 25 (D_4) in the experiment (Table 4.1.16), but the difference were mostly non-significant, excluding at 112 DAT for pooled over two years, mean number of gundhi bug hill^{-1} of four planting dates pooled over two years was 3.10 and 4.96 during 2010 and 2011 respectively; which indicated greater incidence of gundhi bug in second year than first year.

4.3.1.3.1.2 Effect of spacing

Plant density could not show any definite effect or trend on incidence of gunghi bug during both grain development and ripening stage of Gobindabhog rice in 2010 and 2011 (Table 4.1.16).

Table 4.1.16

Effect of planting date and spacing on gundhibug incidence of Gobindabhog rice during *kharif* season

Treatment	Number of gundhibug hill^{-1}					
	84 DAT			112 DAT		
	2010	2011	Pooled	2010	2011	Pooled
Planting date						
D_1	3.00 (1.71)	2.56 (1.57)	2.78 (1.64)	5.44 (2.32)	3.89 (1.93)	4.67 (2.12)
D_2	4.44 (2.09)	2.33 (1.50)	3.39 (1.79)	6.11 (2.46)	5.00 (2.21)	5.56 (2.34)
D_3	4.11 (2.01)	2.44 (1.54)	3.28 (1.77)	5.78 (2.39)	4.56 (2.11)	5.17 (2.25)
D_4	3.67 (1.89)	2.22 (1.46)	2.94 (1.67)	5.11 (2.25)	3.78 (1.91)	4.44 (2.08)
S.Em (±)	0.33	0.21	0.19	0.27	0.33	0.21
C.D. at 5%	NS	NS	NS	NS	NS	0.65
Spacing						
S_1	3.75 (1.91)	2.42 (1.54)	3.08 (1.72)	5.33 (2.30)	5.25 (2.28)	5.29 (2.29)
S_2	3.92 (1.96)	2.17 (1.43)	3.04 (1.70)	5.67 (2.37)	3.92 (1.93)	4.79 (2.15)
S_3	3.75 (1.90)	2.58 (1.58)	3.17 (1.74)	5.83 (2.40)	3.75 (1.90)	4.79 (2.15)
S.Em (±)	0.36	0.28	0.23	0.44	0.48	0.32
C.D. at 5%	NS	NS	NS	NS	NS	NS
Interaction effect						
D_1S_1	2.67 (1.62)	2.33 (1.52)	2.50 (1.57)	5.33 (2.30)	5.33 (2.30)	5.33 (2.30)
D_1S_2	3.33 (1.82)	2.00 (1.38)	2.67 (1.60)	6.00 (2.45)	3.00 (1.69)	4.50 (2.07)
D_1S_3	3.00 (1.69)	3.33 (1.82)	3.17 (1.75)	5.00 (2.21)	3.33 (1.79)	4.17 (2.00)
D_2S_1	4.67 (2.16)	2.67 (1.62)	3.67 (1.89)	5.67 (2.37)	5.67 (2.37)	5.67 (2.37)
D_2S_2	4.67 (2.14)	2.33 (1.47)	3.50 (1.81)	6.67 (2.57)	5.00 (2.21)	5.83 (2.39)
D_2S_3	4.00 (1.96)	2.00 (1.41)	3.00 (1.69)	6.00 (2.44)	4.33 (2.07)	5.17 (2.25)
D_3S_1	4.00 (1.96)	2.67 (1.62)	3.33 (1.79)	5.33 (2.31)	5.00 (2.23)	5.17 (2.27)
D_3S_2	4.00 (2.00)	1.67 (1.27)	2.83 (1.64)	5.00 (2.23)	5.00 (2.23)	5.00 (2.23)
D_3S_3	4.33 (2.07)	3.00 (1.71)	3.67 (1.89)	7.00 (2.64)	3.67 (1.86)	5.33 (2.25)
D_4S_1	3.67 (1.90)	2.00 (1.38)	2.83 (1.64)	5.00 (2.23)	5.00 (2.23)	5.00 (2.23)
D_4S_2	3.67 (1.88)	2.67 (1.61)	3.17 (1.75)	5.00 (2.22)	2.67 (1.61)	3.83 (1.91)
D_4S_3	3.67 (1.88)	2.00 (1.38)	2.83 (1.63)	5.33 (2.30)	3.67 (1.88)	4.50 (2.09)
D × S						
S.Em (±)	0.71	0.55	0.45	0.89	0.95	0.65
C.D. at 5%	NS	NS	NS	NS	NS	NS
S.Em (±)	0.67	0.50	0.59	0.77	0.84	0.81
C.D. at 5%	NS	NS	NS	NS	NS	NS

Figures in parentheses are square root transformed values; DAT = Days after transplanting; NS = Not significant

4.3.1.3.1.3 Interaction effect between planting date and spacing

The interaction effect between planting date and spacing on incidence of gundhi bug in Gobindabhog rice plants was found non-significant at 84 and 112 DAT during both the years of investigation (Table 4.1.16).

4.1.4 Yield components and associated characters

4.1.4.1 Panicle length

4.1.4.1.1 Effect of planting date

Panicle length differed significantly among four planting dates, where longest panicle (26.3 and 26.5 cm) was recorded with the crop planted on July 25 (D_2) during 2010 and 2011, respectively (Table 4.1.17; Plate 4.7).

4.1.4.1.2 Effect of spacing

There was significant variation in panicle length of Gobindabhog rice due to three spacings adopted in the experiment, where longer panicle (26.2 cm) was noted with wide spacing (20 cm × 15cm) compared to medium (15 cm × 15cm) and close spacing (20 cm × 10 cm) during both the years of investigation (Table 4.1.17).

4.1.4.1.3 Interaction effect between planting date and spacing

Planting date × spacing effect on panicle length was evident for pooled values only, but no significant interaction was found during 2010 and 2011 (Table 4.1.17).

4.1.4.2 Number of panicles m^{-2}

The number of panicles m^{-2} for all four planting dates and three spacings of Gobindabhog rice tested in the experiment were greater in 2011 than those in 2010, which followed the same trend of tillering pattern between two years of study.

4.1.4.2.1 Effect of planting date

Mean number of panicles m^{-2}, pooled over two years, was 254.1, 282.7, 271.7 and 247.2 with Gobindabhog rice planted on July 10 (D_1), July 25 (D_2), August 10 (D_3) and August 25 (D_4), respectively (Table 4.1.17), which indicated increment in panicle production from July 10 (D_1) to July 25 (D_2) planting but successive reduction with delay in planting after July 25 (D_2) toward August 25 (D_4) in the investigation (Table 4.1.17).

Table 4.1.17

Effect of planting date and spacing on yield components of Gobindabhog 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)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date												
D_1	25.0	25.3	25.1	245.3	262.9	254.1	130.1	121.6	125.9	10.18	10.21	10.19
D_2	26.3	26.5	26.4	262.8	302.6	282.7	136.6	131.8	134.2	10.29	10.28	10.28
D_3	26.2	26.2	26.2	252.4	291.0	271.7	135.4	122.4	128.9	10.39	10.34	10.37
D_4	25.3	25.2	25.3	239.2	255.2	247.2	123.4	118.2	120.8	10.24	10.24	10.24
S.Em (±)	0.28	0.14	0.15	2.49	3.49	2.14	1.18	1.32	0.89	0.04	0.03	0.02
C.D. at 5%	0.96	0.47	0.48	8.61	12.07	6.60	4.09	4.56	2.73	0.13	NS	0.07
Spacing												
S_1	25.1	25.2	25.1	277.0	291.1	284.1	128.0	120.1	124.1	10.20	10.21	10.20
S_2	25.9	26.0	25.9	246.8	279.3	263.0	130.1	124.4	127.3	10.37	10.33	10.35
S_3	26.1	26.2	26.2	226.0	263.3	244.6	136.0	126.0	131.0	10.26	10.28	10.27
S.Em (±)	0.26	0.26	0.18	2.07	5.23	2.81	1.01	0.78	0.64	0.04	0.03	0.03
C.D. at 5%	0.79	0.77	0.53	6.21	15.67	8.10	3.02	2.35	1.84	0.13	NS	0.08
Interaction effect												
D_1S_1	23.5	24.0	23.8	272.0	269.7	270.9	125.9	119.3	122.6	10.07	10.10	10.08
D_1S_2	25.3	25.5	25.4	242.0	256.8	249.4	131.0	120.0	125.5	10.23	10.23	10.23
D_1S_3	26.2	26.3	26.3	222.0	262.1	242.1	133.5	125.6	129.6	10.23	10.30	10.27
D_2S_1	25.7	26.6	26.2	292.0	315.5	303.8	133.7	125.3	129.5	10.20	10.30	10.25
D_2S_2	26.3	26.8	26.5	262.4	306.1	284.3	133.2	133.1	133.2	10.43	10.33	10.38
D_2S_3	26.8	26.2	26.5	234.0	286.0	260.0	142.7	137.0	139.9	10.23	10.20	10.22
D_3S_1	26.1	25.7	25.9	288.0	311.8	299.9	129.7	120.1	124.9	10.33	10.23	10.28
D_3S_2	26.0	25.8	25.9	241.2	298.1	269.7	135.9	123.8	129.9	10.50	10.40	10.45
D_3S_3	26.4	27.0	26.7	228.0	263.0	245.5	140.7	123.2	132.0	10.33	10.40	10.37
D_4S_1	24.9	24.5	24.7	256.0	267.5	261.7	122.7	116.0	119.4	10.20	10.20	10.20
D_4S_2	26.0	25.9	26.0	241.6	256.0	248.8	120.5	120.7	120.6	10.30	10.33	10.32
D_4S_3	25.1	25.3	25.2	220.0	242.0	231.0	127.0	118.0	122.5	10.23	10.20	10.22
D × S												
S.Em (±)	0.53	0.52	0.37	4.14	10.46	5.62	2.02	1.57	1.28	0.09	0.06	0.05
C.D. at 5%	NS	NS	1.06	12.41	NS	NS	NS	4.69	NS	NS	NS	NS
S × D												
S.Em (±)	0.51	0.44	0.48	4.20	9.22	7.16	2.03	1.84	1.93	0.08	0.06	0.07
C.D. at 5%	NS	NS	1.43	13.26	NS	NS	NS	5.94	NS	NS	NS	NS

NS = Not significant

Plate 4.7: Panicle of Gobindabhog rice

Plate 4.8: Grains of Gobindabhog

Plate 4.9: Kernels of Gobindabhog rice

Plate 4.10: Alkali digestion test of Gobindabhog rice

Panicle, grain, kernel and alkali digestion test of Gobindabhog Rice at Rice laboratory at B.C.K.V. West Bengal, India

There were positive correlations ($P < 0.01$) of GDD and PTU with numbers of panicles m^{-2} of Gobindabhog rice at mid-vegetative stage (4^{th} leaf emergence to active tillering), while similar correlation of HTU at reproductive stage (panicle initiation to flowering) in the study (Table 4.1.24, Table 4.1.25 and Table 4.1.26).

4.1.4.2.2 Effect of spacing

Mean number of panicles m^{-2}, pooled over two years, was 284.1, 263.0 and 244.6 at 20 cm × 10 cm (S_1), 15 cm × 15 (S_2) and 20 cm × 15 cm (S_3), respectively (Table 4.1.17). So, there was successive reduction in number of panicles m^{-2} of Gobindabhog rice with widening of plant density from 20 cm × 10 cm or 50 hills m^{-2} (S_1) to 15 cm × 15 or 44 hills m^{-2} (S_2) and 20 cm × 15 cm or 33 hills m^{-2} (S_3) during both 2010 and 2011.

4.1.4.2.3 Interaction effect between planting date and spacing

The interaction effect between planting date and spacing on number of panicles m^{-2} was significant in 2010 only (Table 4.1.17).

4.1.4.3 Number of filled grains panicle^{-1}

4.1.4.3.1 Effect of planting date

Gobindabhog rice planted on July 25 (D_2) recorded highest number of filled grains panicle^{-1} (134.2) compared to either of early (July 10) or late plantings (August 10 and August 25) during both the years of study (Table 4.1.17). However, greater number filled grains panicle^{-1} irrespective of planting dates was noted during first year than the second year of experiment.

The positive correlations ($P < 0.01$) of GDD, HTU and PTU with number of filled grains panicle^{-1} at mid (milk to dough) and late (dough to maturity) ripening stage indicated that air temperature, bright sunshine period and day length had positive influence on grain filling (*i.e.* translocation of photosynthesis to the sink) and development towards maturity during *kharif* season in West Bengal (Table 4.1.24, Table 4.1.25 and Table 4.1.26).

4.1.4.3.2 Effect of spacing

A perusal of the data revealed that greater number of filled grains panicle^{-1} (131.0) was noted with wide spacing (20 cm × 15 cm) for pooled over two years than medium (15 cm × 15 cm) and close spacing (20 cm × 10 cm) in the investigation (Table 4.1.17).

4.1.4.3.3 Interaction effect between planting date and spacing

Significant interaction effect between planting date and spacing on number of filled grains panicle^{-1} was only evident during second year of investigation (Table 4.1.17).

4.1.4.4 1000 grain weight

4.1.4.4.1 Effect of planting date

The test weight of grain of Gobindabhog rice varied significantly among four planting date for 2010 and pooled values in the study (Table 4.1.17). 1000 grain weight was increased with delay in planting from July 10 (10.19 g) to August 10 (10.37 g), which declined thereafter (10.24 g).

There were negative correlations ($P < 0.01$) of GDD, HTU and PTU with 1000 grain weight during 50% flowering to milk stage in the experiment (Table 4.1.24, Table 4.1.25 and Table 4.1.26).

4.1.4.4.2 Effect of spacing

Gobindabhog rice planted with spacing of 15 cm × 15 cm (44 hills m^{-2}) recorded highest test weight (10.35 g) followed by 20 cm × 10 cm (10.27 g) and 20 cm × 10 cm (10.20 g) in the investigation (Table 4.1.17).

4.1.4.4.3 Interaction effect between planting date and spacing

No significant interaction between planting date and spacing on test weight of grain was noted during both first and second year of investigation (Table 4.1.17).

4.1.5 Yield and lodging

4.1.5.1 Grain yield

4.1.5.1.1 Effect of planting date

Grain yield, an end product of interaction among yield components, differed significantly among planting dates during both the years of investigation (Table 4.1.18; Plate 4.3 and 4.8 and Fig. 4.4). There was significant improvement in grain yield from early (July 10) to medium (July 25) planting time, which declined thereafter for further delay in planting upto August 25 (D_4). Gobindabhog rice planted on July 25 (D_2) produced the highest pooled grain yield (3.02 t ha^{-1}), which was 4.13, 14.39 and 17.51% greater over August 10 (D_3), August 10 (D_4) and July 10 (D_1) planting, respectively.

The grain yield recorded with all four planting dates in 2011 were slightly higher than those in 2010, which might be due to the combined effect of greater number of panicles m^{-2} and 1000 grain weight during second year than first year of investigation.

The correlation studies between thermal indices and grain yield revealed that GDD and PTU during mid-vegetative stage (fourth leaf emergence to active tillering stage) had positive ($P < 0.05$) influence, while negative effect during 50% flowering to milk stage. However, HTU showed negative influence ($P < 0.01$) on economic yield during vegetative stage (4^{th} leaf emergence to panicle initiation) and positive effect ($r = 0.546^{**}$) during reproductive phase (panicle initiation to 50% flowering) in the study.

The significant correlations between heat units at different stages and economic yield were identified and used to develop prediction model for grain yield as: $Y = -1.348 + 0.001^{**}\ HTU_{PI-F} - 0.001^{**}\ HTU_{S-E} + 0.001^{**}\ HTU_{E-4L} + 0.001^{**}\ PTU_{D-M} + 0.001^{*}\ PTU_{Mi-D} - 0.011^{*}\ GDD_{D-M}$, which accounted for 71% variation at 1% level of significance (Table 4.1.27). Similar type of multiple regression equation for grain yield of Gobindabhog rice using correlations with agro-meteorological parameters was developed by Banerjee (2011).

4.1.5.1.2 Effect of spacing

Planting geometry had significant influence on grain yield of Gobindabhog rice during both 2010 and 2011 (Table 4.1.18). Square planting method (15 cm × 15 cm or 44 hills m^{-2}) resulted in highest grain yield (2.89 t ha^{-1}), which was at par with

Table 4.1.18

Effect of planting date and spacing on grain yield, straw yield, harvest index and lodging of Gobindabhog rice during *kharif* season

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Harvest index			Lodging (score)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date												
D_1	2.38	2.77	2.57	4.92	5.43	5.17	0.33	0.34	0.33	4.33	5.22	4.78
D_2	2.89	3.16	3.02	5.11	5.63	5.37	0.36	0.36	0.36	4.33	5.00	4.67
D_3	2.73	3.08	2.90	5.08	5.41	5.25	0.35	0.36	0.36	4.11	5.00	4.56
D_4	2.45	2.83	2.64	4.51	5.26	4.89	0.35	0.35	0.35	3.67	4.78	4.22
S.Em (±)	0.03	0.04	0.02	0.12	0.08	0.07	0.005	0.002	0.003	0.19	0.14	0.12
C.D. at 5%	0.11	0.13	0.08	0.41	NS	0.22	0.016	0.008	0.008	NS	NS	0.37
Spacing												
S_1	2.65	3.02	2.83	5.05	5.51	5.28	0.34	0.35	0.35	4.00	4.83	4.42
S_2	2.69	3.08	2.89	5.10	5.58	5.34	0.35	0.36	0.35	4.17	5.00	4.58
S_3	2.49	2.78	2.63	4.57	5.20	4.88	0.35	0.35	0.35	4.17	5.17	4.67
S.Em (±)	0.03	0.04	0.03	0.11	0.08	0.07	0.006	0.005	0.004	0.38	0.14	0.20
C.D. at 5%	0.10	0.12	0.07	0.32	0.23	0.19	NS	NS	NS	NS	NS	NS
Interaction effect												
D_1S_1	2.45	2.76	2.61	5.04	5.46	5.25	0.33	0.34	0.33	4.33	5.00	4.67
D_1S_2	2.55	2.96	2.76	5.19	5.70	5.45	0.33	0.34	0.34	4.33	5.00	4.67
D_1S_3	2.13	2.58	2.36	4.52	5.12	4.82	0.32	0.34	0.33	4.33	5.67	5.00
D_2S_1	2.93	3.31	3.12	4.98	5.50	5.24	0.37	0.38	0.37	4.33	5.00	4.67
D_2S_2	2.83	3.21	3.02	5.30	5.81	5.55	0.35	0.36	0.35	4.33	5.00	4.67
D_2S_3	2.90	2.95	2.92	5.04	5.59	5.31	0.37	0.35	0.36	4.33	5.00	4.67
D_3S_1	2.69	3.08	2.89	5.29	5.61	5.45	0.34	0.35	0.35	3.67	5.00	4.33
D_3S_2	2.81	3.19	3.00	5.31	5.62	5.47	0.35	0.36	0.35	4.33	5.00	4.67
D_3S_3	2.68	2.96	2.82	4.64	5.00	4.82	0.37	0.37	0.37	4.33	5.00	4.67
D_4S_1	2.51	2.91	2.71	4.88	5.48	5.18	0.34	0.35	0.34	3.67	4.33	4.00
D_4S_2	2.58	2.96	2.77	4.59	5.20	4.89	0.36	0.36	0.36	3.67	5.00	4.33
D_4S_3	2.26	2.62	2.44	4.07	5.09	4.58	0.36	0.34	0.35	3.67	5.00	4.33
D × S												
S.Em (±)	0.07	0.08	0.05	0.22	0.16	0.13	0.011	0.010	0.008	0.77	0.27	0.41
C.D. at 5%	0.20	NS	0.15	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × D												
S.Em (±)	0.06	0.07	0.07	0.21	0.15	0.18	0.010	0.008	0.009	0.66	0.26	0.50
C.D. at 5%	0.20	NS	0.21	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

similar planting density (20 cm × 10 cm or 50 hills m^{-2}) but significantly greater over wide spacing (20 cm × 15 cm or 33 hills m^{-2}) adopted in the experiment.

4.1.5.1.3 Interaction effect between planting date and spacing

Planting date × spacing interaction effect on grain yield was found significant during 2010 and pooled values in the study (Table 4.1.18). Gobindabhog rice planted on July 25 with a spacing of 20 cm × 10 cm yielded highest (3.08 t ha^{-1}), which was on par with 3.02 t ha^{-1} (July 25 planting and 15 cm × 15 cm spacing) and 3.00 t ha^{-1} (August 10 planting and 15 cm × 15 cm spacing) at Kalyani, West Bengal.

4.1.5.2 Straw yield

Straw yield of Gobindabhog rice, irrespective of planting date and spacing treatments, was slightly greater during 2011 than 2010 (Table 4.1.18), which might be due to better growth and developments of the crop, being quantified in terms of plant height (Table 4.1.6), tiller production (Table 4.1.7) and leaf growth (Table 4.1.8) during second year than first year in the study.

4.1.5.2.1 Effect of planting date

Straw yield, an index of vegetative growth, was found to differ significantly among four planting dates during first year and pooled for two years in the investigation (Table 4.1.18). The highest and lowest straw yields were recorded with the crop planted on July 25 (5.11 and 5.63 t ha^{-1}) and August 25 (4.51 and 5.26 t ha^{-1}), respectively during both 2010 and 2011.

4.1.5.2.2 Effect of spacing

The non-significant variation in straw yield between the crops planted at spacing of 15 cm × 15cm (S_2) and 20 cm × 10 cm (S_1) was noted, which was probably due to near-similar planting density (44 *vs.* 50 hills m^{-2}) and both of which were significantly higher than wide spacing of 20 cm × 15 cm (S_3) in the experiment (Table 4.1.18).

4.1.5.2.3 Interaction effect between planting date and spacing

The effect of interaction between planting date and spacing on straw yield was not significant during both the years of investigation (Table 4.1.18).

4.1.5.3 Harvest index

4.1.5.3.1 Effect of planting date

The planting of Gobindabhog rice on or after July 25 (D_2) upto August 25 (D_4) resulted in significantly higher harvest index (0.35 – 0.36) over early planting on July 10 (D_1) during both the years of experimentation (Table 4.1.18).

4.1.5.3.2 Effect of spacing

Spacing had no significant influence on harvest of Gobindabhog rice during *kharif* season of both 2010 and 2011 (Table 4.1.18).

4.1.5.3.3 Interaction effect between planting date and spacing

There was no significant effect between planting date and spacing with regard to harvest index during both the years of investigation (Table 4.1.18).

4.1.5.4 Lodging

A perusal of data revealed that most (> 50%) Gobingabhog rice plants had a tendency to lodge down slightly (score 3.0) to completely (score 5.0) at hard dough stage, but the crop grown during 2011 were more susceptible to lodging, irrespective of treatments, than 2010 in the study (Table 4.1.18).

4.1.5.4.1 Effect of planting date

The lodging tendency of Gobindabhog paddy at hard dough stage was not significantly influenced due to variation in planting dates between July 10 (D_1) and August 25 (D_4) during both 2010 and 2011, except pooled over two years (Table 4.1.18; Plate 4.6). Mean lodging score was found to decrease from 4.78 (D_1) to 4.22 (D_4) with delay in planting from July 10 (D_1) to August 25 (D_4) probably due to reduction in plant height (Table 4.1.6) with the irrespective planting dates in the study.

The correlation studies revealed that temperature during vegetative stage and bright sunshine hour during ripening phase had positive ($P < 0.01$) correlation influence on lodging, probably due to favouring culm development and elongation of long-statured Gobindabhog rice (Table 4.1.24 and Table 4.1.25). Based on these, the model developed for lodging (Y = -3.840 + 0.010** GDD_{4L-AT} + 0.001* HTU_{PI-F}) accounted for 20.5% variation at 1% level of significance (Table 4.1.27).

4.1.5.4.2 Effect of spacing

With widening of planting density of Gobindabhog paddy from 20 cm × 10 cm (50 hills m^{-2}) to 20 cm × 15 cm (33 hills m^{-2}), the crop had greater tendency to lodge down at hard dough or near maturity stage, but the differences among three spacings adopted were not found significant during both 2010 and 2011 (Table 4.1.18).

4.1.5.4.3 Interaction effect between planting date and spacing

The interaction effect between planting date and spacing on lodging of Gobindabhog paddy was not found significant during both 2010 and 2011 (Table 4.1.18).

4.1.6 Grain quality

4.1.6.1 Milling quality

4.1.6.1.1 Hulling

4.1.6.1.1.1 Effect of planting date

There was, in general, a successive decreasing trend in brown rice content of Gobindabhog rice with delay planting from July 10 (78.8%) to August 25 (77.9%) during *kharif* season of both 2010 and 2011 (Table 4.1.19), but the differences were not significant in either of the years.

4.1.6.1.1.2 Effect of spacing

Spacing or planting density did not register any significant influence on brown rice recovery (%) of Gobindabhog rice tested in the investigation (Table 4.1.19).

4.1.6.1.1.3 Interaction effect between planting date and spacing

The interaction effect between planting date and spacing with regard to hulling recovery of Gobindabhog rice was not significant during both 2010 and 2011 (Table 4.1.19).

Table 4.1.19

Effect of planting date and spacing on milling quality of Gobindabhog rice during *kharif* season

Treatment	Milling quality								
	Hulling (%)			Milling (%)			Head rice recovery (%)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date									
D_1	78.4	79.2	78.8	72.7	74.0	73.4	61.6	63.0	62.3
D_2	78.4	79.0	78.7	72.8	73.2	73.0	61.9	63.6	62.7
D_3	77.8	79.0	78.4	72.3	73.0	72.6	60.5	62.8	61.7
D_4	76.9	78.8	77.9	71.1	72.8	71.9	59.5	63.0	61.2
S.Em (±)	0.71	0.48	0.43	0.51	0.48	0.35	0.24	0.40	0.23
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.83	NS	0.72
Spacing									
S_1	77.6	78.7	78.1	72.3	73.0	72.7	61.1	63.3	62.2
S_2	77.9	79.4	78.6	72.4	73.4	72.9	60.9	62.8	61.8
S_3	78.2	79.0	78.6	71.9	73.4	72.6	60.7	63.2	62.0
S.Em (±)	0.35	0.39	0.26	0.38	0.35	0.26	0.45	0.25	0.26
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect									
D_1S_1	78.4	79.3	78.8	73.2	74.2	73.7	62.3	63.5	62.9
D_1S_2	77.4	79.1	78.2	72.4	73.9	73.2	61.8	62.0	61.9
D_1S_3	79.5	79.4	79.4	72.5	74.0	73.2	60.8	63.6	62.2
D_2S_1	77.5	78.0	77.7	72.6	72.5	72.5	62.4	63.0	62.7
D_2S_2	79.2	79.4	79.3	73.2	73.8	73.5	61.8	64.5	63.1
D_2S_3	78.5	79.7	79.1	72.6	73.3	73.0	61.5	63.3	62.4
D_3S_1	77.2	79.0	78.1	72.2	73.0	72.6	60.0	62.4	61.2
D_3S_2	79.1	79.4	79.2	73.4	72.8	73.1	60.4	62.5	61.5
D_3S_3	77.1	78.6	77.9	71.2	73.2	72.2	61.2	63.3	62.3
D_4S_1	77.2	78.3	77.8	71.3	72.5	71.9	59.6	64.1	61.9
D_4S_2	75.7	79.7	77.7	70.4	73.1	71.8	59.5	62.1	60.8
D_4S_3	77.7	78.4	78.1	71.5	72.9	72.2	59.4	62.6	61.0
D × S									
S.Em (±)	0.70	0.79	0.53	0.76	0.69	0.51	0.89	0.49	0.51
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	1.48	NS
S × D									
S.Em (±)	0.91	0.80	0.86	0.80	0.74	0.77	0.77	0.57	0.68
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	1.84	NS

NS = Not significant

4.1.6.1.2 Milling

4.1.6.1.2.1 Effect of planting date

Like hulling recovery, similar trend of non-significant variation in milling recovery due to four planting dates was also noted in the experiment (Table 4.1.19).

4.1.6.1.2.2 Effect of spacing

There was no significant effect of spacing with regard to milling yield of Gobindabhog rice during both the years of investigation (Table 4.1.19).

4.1.6.1.2.3 Interaction effect between planting date and spacing

No significant interaction effect of planting date and spacing was found on milling recovery of Gobindabhog rice during both 2010 and 2011 (Table 4.1.19).

4.1.6.1.3 Head rice

4.1.6.1.3.1 Effect of planting date

Planting date had significant effect on head rice yield (%) of Gobindabhog rice during 2010 and pooled values in the study (Table 4.1.19; Plate 4.9 and Fig. 4.5). There was non-significant increase in head rice recovery from July 10 (D_1) to July 25 (D_2), which declined thereafter for two late plantings in the month of August. Gobindabhog rice planted on July 25 (D_2) recorded highest head rice recovery (62.7%), which was 0.4, 1.0 and 1.5% greater over July 10 (D_1), August 10 (D_3) and August 25 (D_4), respectively.

The positive correlations of HTU (r = 0.319**) and PTU (r = 0.268*) with head rice recovery of Gobindabhog rice during dough to maturity stage indicated that both bright sunshine hour and day length favoured the development and ripening of rice grain thereby making them less prone to breakage during milling. The multiple regression model ($Y = 64.326 + 0.014^{**}\ GDD_{AT-PI} - 0.004^{**}\ HTU_{F-Mi} - 0.002^{**}\ HTU_{4L-AT}$) developed for HRR accounted for 55.7% variation with 1% level of significance (Table 4.1.27).

4.1.6.1.3.2 Effect of spacing

Spacing had no significant influence on head rice yield of Gobindabhog rice during both the years of investigation (Table 4.1.19).

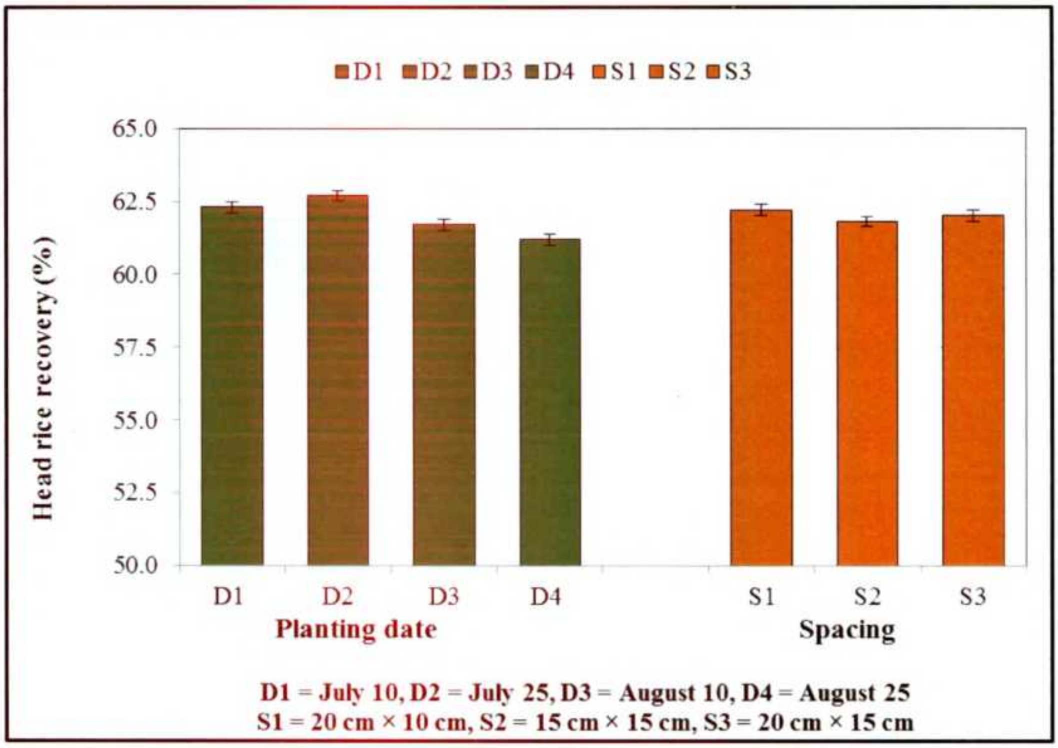

Fig. 4.5: Effect of planting date and spacing on head rice recovery (%) of Gobindabhog rice during *kharif* season (pooled over two years)

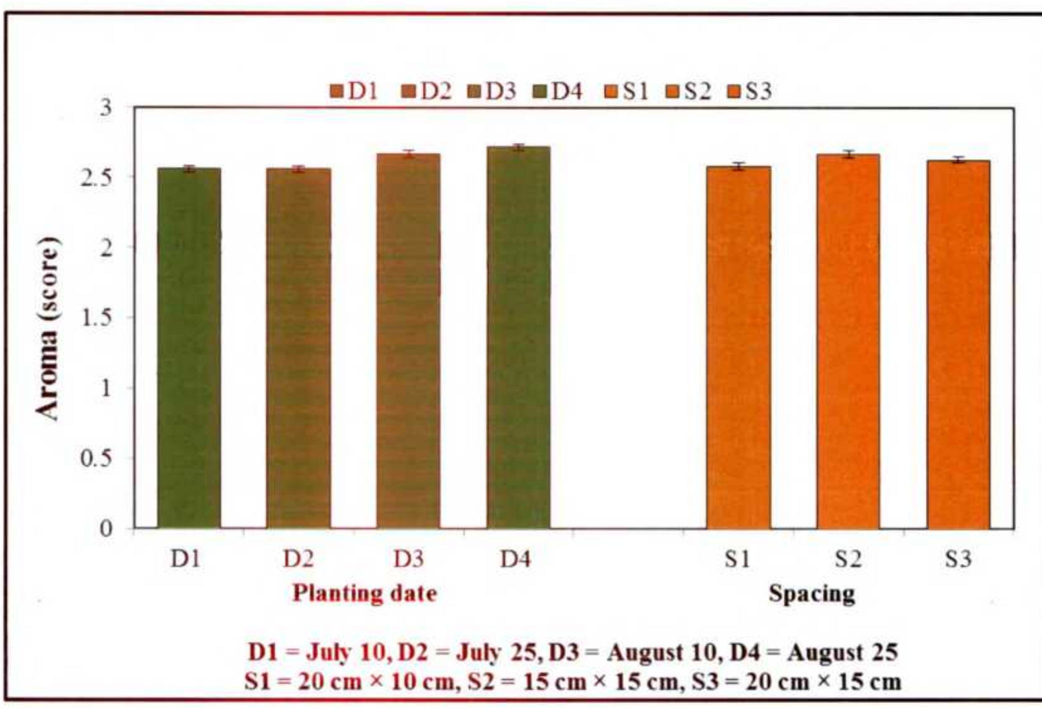

Fig. 4.6: Effect of planting date and spacing on aroma (score) of Gobindabhog rice during *kharif* season (pooled over two years)

4.1.6.1.3.3 Interaction effect between planting date and spacing

Planting date × spacing interaction effect on head rice content (%) of Gobindabhog rice was not noted in the experiment (Table 4.1.19).

4.1.6.2 Physical properties of grain

4.1.6.2.1 Kernel length

4.1.6.2.1.1 Effect of planting date

Kernel length, being a genetical character, did not differ significantly among four planting dates during *kharif* season of both 2010 and 2011 (Table 4.1.20).

The non-significant correlations of GDD, HTU and PTU during the ripening stage with kernel length confirmed that kernel length remained unaffected by temperature, bright sunshine hour and day length during grain formation, development and ripening period (Table 4.1.24, Table 4.1.25 and Table 4.1.26).

4.1.6.2.1.2 Effect of spacing

There was no significant difference in kernel length due to spacing during both the years of experimentation (Table 4.1.20).

4.1.6.2.1.3 Interaction effect between planting date and spacing

The interaction effect between planting date and spacing towards kernel length was not significant during both 2010 and 2011 (Table 4.1.20).

4.1.6.2.2 Kernel breadth

4.1.6.2.2.1 Effect of planting date

The breadth of Gobindabhog rice kernel was not significantly influenced by four planting periods during *kharif* season of 2010 and 2011 (Table 4.1.20), which could be supported by non-significant correlations of GDD HTU and PTU with kernel breadth in the study (Table 4.1.24, Table 4.1.25 and Table 4.1.26).

4.1.6.2.2.2 Effect of spacing

Kernel breadth remained unaffected due to adoption of three spacings in the experiment (Table 4.1.20).

Table 4.1.20

Effect of planting date and spacing on physical properties of grains of Gobindabhog rice during *kharif* season

Treatment	Physical properties of grain								
	Kernel length (mm)			Kernel breadth (mm)			L / B ratio		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date									
D_1	3.92	4.04	3.98	1.98	2.00	1.99	1.97	2.03	2.00
D_2	3.88	3.97	3.93	1.96	1.96	1.96	1.98	2.03	2.01
D_3	3.87	4.06	3.97	1.91	2.00	1.95	2.04	2.04	2.04
D_4	3.87	4.04	3.96	1.92	1.98	1.95	2.03	2.05	2.04
S.Em (±)	0.04	0.03	0.02	0.03	0.05	0.03	0.04	0.05	0.03
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Spacing									
S_1	3.89	4.03	3.96	1.94	2.02	1.98	2.01	2.00	2.00
S_2	3.88	4.00	3.94	1.94	1.98	1.96	2.00	2.02	2.01
S_3	3.89	4.05	3.98	1.94	1.95	1.94	2.01	2.09	2.05
S.Em (±)	0.07	0.02	0.04	0.02	0.02	0.01	0.05	0.02	0.02
C.D. at 5%	NS	NS	NS	NS	0.05	NS	NS	0.05	NS
Interaction effect									
D_1S_1	3.92	4.06	3.99	2.02	2.01	2.02	1.94	2.02	1.98
D_1S_2	3.92	3.97	3.94	1.95	1.96	1.96	2.01	2.02	2.02
D_1S_3	3.92	4.10	4.01	1.98	2.01	2.00	1.97	2.04	2.01
D_2S_1	3.85	3.98	3.91	1.95	2.01	1.98	1.97	1.98	1.98
D_2S_2	3.88	3.94	3.91	1.95	1.96	1.96	2.00	2.01	2.00
D_2S_3	3.92	4.00	3.96	1.98	1.90	1.94	1.98	2.10	2.04
D_3S_1	3.95	4.09	4.02	1.92	2.03	1.97	2.06	2.02	2.04
D_3S_2	3.82	4.05	3.93	1.88	2.01	1.95	2.03	2.02	2.02
D_3S_3	3.85	4.05	3.95	1.92	1.94	1.93	2.02	2.09	2.05
D_4S_1	3.85	4.02	3.94	1.88	2.03	1.96	2.04	1.98	2.01
D_4S_2	3.88	4.06	3.97	1.98	1.99	1.99	1.96	2.05	2.00
D_4S_3	3.88	4.08	3.98	1.88	1.93	1.91	2.07	2.12	2.10
D × S									
S.Em (±)	0.14	0.05	0.08	0.05	0.03	0.03	0.09	0.03	0.05
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × D									
S.Em (±)	0.12	0.05	0.09	0.05	0.06	0.05	0.09	0.06	0.07
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

4.1.6.2.2.3 Interaction effect between planting date and spacing

No significant interaction effect on kernel breadth was found in the investigation (Table 4.1.20).

4.1.6.2.3 L / B ratio

4.1.6.2.3.1 Effect of planting date

Like kernel length and breadth, L / B ratio was not affected due to four planting dates during *kharif* season of 2010 and 2011 (Table 4.1.20).

4.1.6.2.3.2 Effect of spacing

Spacing had significant effect on L / B ratio of rice kernel during 2011 only, where the variation between 2.00 (S_1) and 2.09 (S_3) could probably be explained by any one or both of the following reasons: (i) better length-wise development and or (ii) less degree of milling of rice kernels obtained from wide spaced crop (20 cm × 15 cm, *i.e.* 33 hills m^{-2}) compared to two closer spacings of S_1 (20 cm × 10 cm) and S_2 (15 cm × 15 cm) (Table 4.1.20). However, L / B ratio of Gobindabhog rice remained unaffected due to three spacings adopted during 2010 and pooled overs two years in the investigation.

4.1.6.2.3.3 Interaction effect between planting date and spacing

Planting date × spacing interaction effect on L / B ratio was not found significant during both 2010 and 2011 (Table 4.1.20).

4.1.6.2.4 Kernel type, colour and chalkiness

4.1.6.2.4.1 Effect of planting date

Based on length and L / B ratio, the kernels of Gobindabhog rice obtained from the plots assigned for different planting dates belonged to short bold (SB) category during both the years of investigation (Table 4.1.21). The colour of rice kernel was white irrespective of plantings dates during *kharif* season and there was no chalkiness in grain, excluding a few exceptions as studied in the laboratory.

Table 4.1.21

Effect of planting date and spacing on physical properties of grains of Gobindabhog rice during *kharif* season

Treatment	Physical properties of grain					
	Kernel type		Chalkiness		Kernel colour	
	2010	2011	2010	2011	2010	2011
Planting date						
D_1	SB	SB	Absent	Absent	White	White
D_2	SB	SB	Absent	Absent	White	White
D_3	SB	SB	Absent	Absent	White	White
D_4	SB	SB	Absent	Absent	White	White
Spacing						
S_1	SB	SB	Absent	Absent	White	White
S_2	SB	SB	Absent	Absent	White	White
S_3	SB	SB	Absent	Absent	White	White
Interaction effect						
D_1S_1	SB	SB	Absent	Absent	White	White
D_1S_2	SB	SB	Absent	Absent	White	White
D_1S_3	SB	SB	Absent	Absent	White	White
D_2S_1	SB	SB	Absent	Absent	White	White
D_2S_2	SB	SB	Absent	Absent	White	White
D_2S_3	SB	SB	Absent	Absent	White	White
D_3S_1	SB	SB	Absent	Absent	White	White
D_3S_2	SB	SB	Absent	Absent	White	White
D_3S_3	SB	SB	Absent	Absent	White	White
D_4S_1	SB	SB	Absent	Absent	White	White
D_4S_2	SB	SB	Absent	Absent	White	White
D_4S_3	SB	SB	Absent	Absent	White	White

4.1.6.2.4.2 Effect of spacing

Spacing did not register any influence on variation in kernel shape or type, kernel colour and abdominal white of Gobindabhog rice during both 2010 and 2011 (Table 4.1.21).

4.1.6.2.4.3 Interaction effect between planting date and spacing

The non-significant interaction effect revealed that Gobindabhog rice had short bold type, white and non-chalky kernels irrespective of planting dates and spacings adopted in the study (Table 4.1.21).

4.1.6.3 Cooking quality and nutritional quality

4.1.6.3.1 Amylose content

Mean amylose content in Gobindabhog rice grain, among treatments in the study, was ±18.00%, which indicated that the variety belonged to low (9-20%), but very close to intermediate (20-25%) amylose content category (Table 4.1.22).

4.1.6.3.1.1 Effect of planting date

Amylose content in grain was significantly influenced by planting dates during 2010 and pooled for two years in the investigation (Table 4.1.22). Gobindabhog rice planted on July 25 (D_2) recorded highest amylose content (18.05-18.12%), being at par with August 25 (D_4) and August 10 (D_3), but the lowest amylose content (17.74-17.92 %) was noted with early planted crop on July 10 (D_1) during both the years of experimentation (Table 4.1.22). Thus, planting of Gobindabhog paddy on or after July 25 (D_2) upto August 25 (D_4) improved the amylose content in grain compared to early planting on July 10 (D_1) during *kharif* season.

The findings could be supported by low mean air temperature during ripening period for two August planted crops, *viz.* August 10 (23.25 ^{0}C) and August 25 (21.55 ^{0}C) compared to two July planted crops like July 10 (25.70 ^{0}C) and July 25 (25.55 ^{0}C) in the study, which also confirmed the negative relationship between amylose content and temperature during the ripening period (Resurrcinon *et al.* 1977), specifically in low amylose rices (Paule, 1977).

Table 4.1.22

Effect of planting date and spacing on cooking and nutritional quality of grains of Gobindabhog rice during *kharif* season

Treatment	Cooking and nutritional quality of grain								
	Amylose content (%)			Protein content (%)			Alkali value (score)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date									
D_1	17.74	17.91	17.82	7.44	7.16	7.30	3.67	3.89	3.78
D_2	18.12	18.05	18.08	7.68	7.28	7.48	3.56	3.89	3.72
D_3	18.02	17.99	18.01	7.14	7.38	7.26	3.33	3.56	3.44
D_4	18.08	18.00	18.04	7.17	7.23	7.20	3.33	3.44	3.39
S.Em (±)	0.07	0.08	0.05	0.11	0.20	0.12	0.15	0.11	0.09
C.D. at 5%	0.23	NS	0.16	0.37	NS	NS	NS	NS	0.28
Spacing									
S_1	18.02	18.03	18.02	7.35	7.23	7.29	3.50	3.75	3.63
S_2	17.99	17.98	17.98	7.31	7.18	7.25	3.42	3.67	3.54
S_3	17.96	17.97	17.96	7.40	7.38	7.39	3.50	3.67	3.58
S.Em (±)	0.05	0.05	0.03	0.22	0.15	0.13	0.20	0.15	0.13
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect									
D_1S_1	17.71	18.04	17.87	7.60	7.15	7.38	3.67	4.00	3.83
D_1S_2	17.79	17.87	17.83	7.27	6.88	7.08	3.33	3.67	3.50
D_1S_3	17.71	17.83	17.77	7.44	7.43	7.44	4.00	4.00	4.00
D_2S_1	18.09	17.99	18.04	7.50	6.88	7.19	3.67	4.00	3.83
D_2S_2	18.12	18.07	18.09	7.73	7.18	7.46	3.67	4.00	3.83
D_2S_3	18.14	18.10	18.12	7.81	7.79	7.80	3.33	3.67	3.50
D_3S_1	18.11	18.11	18.11	6.90	7.63	7.27	3.33	3.67	3.50
D_3S_2	18.04	18.01	18.02	7.16	7.54	7.35	3.33	3.67	3.50
D_3S_3	17.92	17.85	17.89	7.36	6.98	7.17	3.33	3.33	3.33
D_4S_1	18.18	17.96	18.07	7.42	7.26	7.34	3.33	3.33	3.33
D_4S_2	17.99	17.96	17.98	7.09	7.11	7.10	3.33	3.33	3.33
D_4S_3	18.07	18.09	18.08	6.99	7.32	7.15	3.33	3.67	3.50
D × S									
S.Em (±)	0.11	0.09	0.07	0.44	0.30	0.27	0.40	0.30	0.25
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × D									
S.Em (±)	0.11	0.11	0.11	0.38	0.32	0.35	0.36	0.27	0.32
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

4.1.6.3.1.2 Effect of spacing

Spacing or planting density had no significant influence on amylose content in Gobindabhog rice during both 2010 and 2011 (Table 4.1.22).

4.1.6.3.1.3 Interaction effect between planting date and spacing

There was no significant interaction effect between planting date and spacing toward the amylose content of Gobindabhog rice grain during both the years of investigation (Table 4.1.22).

4.1.6.3.2 Protein content

4.1.6.3.2.1 Effect of planting date

Protein content in Gobingdabhog rice grain was significantly influenced by four planting dates during the first year only in 2-year experiment (Table 4.1.22). The highest protein content was noted with July 25 (D_2) planted crop (7.68%) during 2010, while with August 10 (7.38%) during 2011.. Perusal of data revealed that Gobindabhog rice planted during July (D_1 and D_2) usually produced greater protein in grain than August planting (D_3 and D_4).

4.1.6.3.2.2 Effect of spacing

There was no significant influence of plant density on protein content of Gobindabog rice during both the years of experimentation (Table 4.1.22)

4.1.6.3.2.3 Interaction effect between planting date and spacing

Planting date × spacing interaction effect on protein content in grain was not significant during both 2010 and 2011 (Table 4.1.22).

4.1.6.3.3 Alkali value or Gelatinization temperature

4.1.6.3.3.1 Effect of planting date

Although there was a steady decrease in alkali value of Gobindabhog rice grain with delay in planting time from July 10 (D_1) to August 25 (D_4), but the differences was significant for pooled values only (Table 4.1.22; Plate 4.10). 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.

4.1.6.3.3.2 Effect of spacing

Spacing could not significantly influence the alkali spreading value of Gobindabhog rice during both the years of experimentation (Table 4.1.22).

4.1.6.3.3.3 Interaction effect between planting date and spacing

There was no significant effect between planting date and spacing with regard to alkali value of Gobindabhog rice during both 2010 and 2011 (Table 4.1.22).

4.1.6.4 Processing quality

4.1.6.4.1 Kernel length after cooking (KLAC)

4.1.6.4.1.1 Effect of planting date

With delay in planting from July 10 (D_1) to August 25 (D_4), the KLAC of Gobindabhog rice was found to increase steadily (6.92 to 7.34 mm), but the differences were significant for pooled over two years only (Table 4.1.23).

4.1.6.4.1.2 Effect of spacing

Spacing did not affect the length of cooked kernel of Gobindabhog rice during both the years of investigation (Table 4.1.23).

4.1.6.4.1.3 Interaction effect between planting date and spacing

The effect of interaction between planting date and spacing on cooked kernel length was not significant during both the years of experimentation (Table 4.1.23).

4.1.6.4.2 Elongation ratio

4.1.6.4.2.1 Effect of planting date

The elongation ratio of Gobindabhog rice was found to vary significantly among four planting dates for pooled values only (Table 4.1.23). The maximum ER (1.85) was noted with August 25 (D_4) planting, while minimum ER (1.74) with July 10 planting (D_1) in the investigation.

4.1.6.4.2.2 Effect of spacing

Planting density had no significant influence on elongation ratio of Gobindabhog rice kernel during both 2010 and 2011 (Table 4.1.23).

4.1.6.4.2.3 Interaction effect between planting date and spacing

There was no interaction effect between planting date and spacing on kernel elongation ratio during both the years of experimentation (Table 4.1.23).

4.1.6.4.3 Aroma

The aroma scores noted among treatments in the study indicated that Gobindabhog rice generally had medium-strong aroma during *kharif* season of both 2010 and 2011 (Table 4.1.23).

4.1.6.4.3.1 Effect of planting date

Although planting date did not affect the aroma of Gobindabhog rice in the investigation (Table 4.1.23; Fig. 4.6), but the intensity of aroma was improved for delayed plantings during August (D_3 and D_4) than plantings in July (D_1 and D_2). The maximum aroma score (2.72) for the grains of August 25 planted crop (D_4) could be due to low day-night temperature (29.17 ^{0}C / 17.68 ^{0}C) compared to July 10 (31.55 ^{0}C / 21.48 ^{0}C), July 25 (31.15 ^{0}C / 20.73 ^{0}C) and August 10 (30.42 ^{0}C / 18.97 ^{0}C) during grain filling and ripening period (Table 4.1.1).

Similarly, low temperature (< 20 ^{0}C) during grain filling period (Dutta et al. 1999) as well as cooler temperature (25 ^{0}C / 21 ^{0}C – day / night temperature) during crop maturity (Juliano, 1972 and Mann, 1987) favoured better of retention aroma in Basmati rice.

4.1.6.4.3.2 Effect of spacing

The intensity of aroma in of Gobindabhog rice grain was not influenced significantly due to three spacings adopted in the study (Table 4.1.23).

4.1.6.4.3.3 Interaction effect between planting date and spacing

Planting date × spacing interaction effect on flavour of rice grain was not significant during both 2010 and 2011, indicating medium-strong aroma (2.33 - 3.00) irrespective of treatment combinations in the study (Table 4.1.23).

Table 4.1.23

Effect of planting date and spacing on processing quality of grains of Gobindabhog rice during *kharif* season

Treatment	Processing quality								
	Kernel length after cooking (mm)			Elongation ratio			Aroma (score)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Planting date									
D_1	6.81	7.04	6.92	1.75	1.74	1.74	2.56	2.56	2.56
D_2	7.13	7.21	7.17	1.84	1.82	1.83	2.44	2.67	2.56
D_3	7.15	7.27	7.21	1.85	1.79	1.82	2.67	2.67	2.67
D_4	7.28	7.41	7.34	1.88	1.84	1.86	2.67	2.78	2.72
S.Em (±)	0.12	0.13	0.09	0.03	0.04	0.03	0.19	0.21	0.14
C.D. at 5%	NS	NS	0.28	NS	NS	0.08	NS	NS	NS
Spacing									
S_1	7.11	7.15	7.13	1.83	1.78	1.80	2.58	2.58	2.58
S_2	7.12	7.30	7.21	1.84	1.83	1.83	2.58	2.75	2.67
S_3	7.04	7.25	7.14	1.81	1.79	1.80	2.58	2.67	2.63
S.Em (±)	0.11	0.11	0.08	0.03	0.03	0.02	0.16	0.15	0.11
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect									
D_1S_1	6.85	6.99	6.92	1.75	1.72	1.74	2.67	2.67	2.67
D_1S_2	6.85	7.25	7.05	1.76	1.83	1.80	2.67	2.67	2.67
D_1S_3	6.72	6.89	6.80	1.73	1.68	1.70	2.33	2.33	2.33
D_2S_1	7.07	7.17	7.12	1.84	1.80	1.82	2.33	2.67	2.50
D_2S_2	7.04	7.23	7.14	1.81	1.84	1.83	2.33	2.67	2.50
D_2S_3	7.27	7.23	7.25	1.86	1.81	1.83	2.67	2.67	2.67
D_3S_1	7.24	7.16	7.20	1.83	1.75	1.79	2.67	2.33	2.50
D_3S_2	7.21	7.33	7.27	1.89	1.81	1.85	2.67	2.67	2.67
D_3S_3	7.01	7.33	7.17	1.82	1.81	1.81	2.67	3.00	2.83
D_4S_1	7.29	7.30	7.29	1.89	1.82	1.86	2.67	2.67	2.67
D_4S_2	7.39	7.40	7.39	1.90	1.83	1.87	2.67	3.00	2.83
D_4S_3	7.15	7.53	7.34	1.84	1.86	1.85	2.67	2.67	2.67
D × S									
S.Em (±)	0.22	0.22	0.16	0.06	0.06	0.04	0.32	0.30	0.22
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
S × D									
S.Em (±)	0.22	0.22	0.22	0.06	0.06	0.06	0.32	0.32	0.32
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.1.24

Correlations between GDD at different growth stages and yield associated parameters of Gobindabhog 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)	0.455**	0.293*	0.756**	0.610**	0.485**	0.010	0.090	0.297*
Panicle length (cm)	-0.026	-0.062	0.009	-0.142	0.002	-0.061	0.102	0.072
No. of Panicles m^{-2}	0.102	0.054	0.415**	0.184	0.104	-0.136	0.148	0.105
No. of Filled grains $panicle^{-1}$	-0.205	0.108	-0.040	0.026	0.279*	0.220	0.473**	0.473**
1000 grain weight (g)	-0.119	-0.143	-0.094	-0.277*	-0.130	-0.298*	0.032	-0.099
Grain yield ($t\ ha^{-1}$)	0.030	0.120	0.301*	0.025	0.004	-0.317**	-0.066	0.061
Straw yield ($t\ ha^{-1}$)	-0.053	0.124	0.390**	0.213	0.228	0.002	0.276*	0.317**
Lodging (score)	0.325**	0.164	0.443**	0.322**	0.224	-0.029	0.054	0.152

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-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

Correlations between GDD at different growth stages and grain quality parameters of Gobindabhog 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}
Hulling (%)	0.154	0.235*	0.363**	0.317**	0.192	0.055	0.027	0.185
Milling (%)	0.290*	0.338**	0.580**	0.549**	0.561**	0.320**	0.340**	0.530**
Head rice recovery (%)	0.366**	0.353**	0.434**	0.445**	0.240*	0.001	-0.050	0.225
Kernel length (mm)	0.261*	0.062	0.228	0.183	0.010	-0.149	-0.093	-0.070
Kernel breadth (mm)	0.160	0.268*	0.236*	0.273*	0.131	0.178	-0.097	0.048
Amylose (%)	-0.265*	0.045	-0.152	-0.262*	-0.232*	-0.110	-0.142	-0.081
Protein (%)	0.104	0.125	0.054	0.107	0.038	0.106	0.145	0.092
Alkali value (score)	0.198	0.189	0.233*	0.152	0.115	-0.118	-0.043	0.060
Kernel length after cooking (mm)	-0.284*	0.000	-0.341**	-0.289*	-0.275*	-0.208	-0.176	-0.215
Elongation ratio	-0.406**	-0.041	-0.437**	-0.356**	-0.227	-0.048	-0.078	-0.127
Aroma (score)	-0.009	-0.069	-0.123	-0.143	-0.151	-0.125	-0.084	-0.149

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-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 4.1.25

Correlations between HTU at different growth stages and yield associated parameters of Gobindabhog 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)	-0.160	-0.689**	-0.093	-0.242*	0.589**	0.475**	0.236*	0.357**
Panicle length (cm)	-0.250*	0.228	-0.087	-0.128	0.083	0.031	0.115	-0.032
No. of Panicles m^{-2}	-0.339**	0.002	-0.228	-0.141	0.318**	0.140	0.203	0.100
No. of Filled grains $panicle^{-1}$	-0.379**	0.430**	0.369**	0.236*	-0.501**	0.127	0.401**	0.370**
1000 grain weight (g)	-0.095	0.232*	-0.157	-0.149	0.113	-0.256*	0.143	-0.122
Grain yield (t ha^{-1})	-0.263*	0.010	-0.349**	-0.304**	0.546**	-0.024	0.140	0.032
Straw yield (t ha^{-1})	-0.275*	0.068	0.036	0.026	0.077	0.078	0.334**	0.320**
Lodging (score)	-0.006	-0.332**	-0.136	-0.092	0.391**	0.167	0.181	0.214

HTU_{S-E} = HTU (sowing to emergence); HTU_{E-4L} = HTU (emergence to4[th] leaf emergence); HTU_{4L-AT} = HTU (4[th] 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

Correlations between HTU at different growth stages and grain quality parameters of Gobindabhog 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}
Hulling (%)	0.018	-0.235*	-0.105	0.004	0.266*	0.136	0.107	0.264*
Milling (%)	-0.130	-0.340**	0.219	0.063	0.102	0.412**	0.429**	0.567**
Head rice recovery (%)	0.023	-0.357**	-0.232*	-0.031	0.400**	0.216	0.098	0.319**
Kernel length (mm)	0.167	-0.286*	-0.289*	-0.083	0.395**	-0.044	0.040	0.025
Kernel breadth (mm)	0.100	-0.156	-0.121	0.125	0.159	0.100	-0.160	0.189
Amylose (%)	-0.097	0.223	-0.011	-0.122	-0.073	-0.121	-0.035	-0.160
Protein (%)	0.016	0.148	-0.010	0.205	-0.081	-0.038	0.059	0.125
Alkali value (score)	-0.058	-0.193	-0.074	-0.119	0.205	0.150	0.044	0.107
Kernel length after cooking (mm)	0.081	0.131	-0.104	-0.097	-0.016	-0.247*	-0.137	-0.225
Elongation ratio	-0.038	0.301*	0.118	-0.008	-0.296*	-0.166	-0.150	-0.194
Aroma (score)	0.116	0.035	-0.100	-0.035	0.045	-0.168	-0.050	-0.135

HTU_{S-E} = HTU (sowing to emergence); HTU_{E-4L} = HTU (emergence to4[th] leaf emergence); HTU_{4L-AT} = HTU (4[th] 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 4.1.26

Correlations between PTU at different growth stages and yield associated parameters of Gobindabhog 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)	0.482**	0.480**	0.703**	0.601**	0.515**	0.051	0.122	0.327**
Panicle length (cm)	-0.021	-0.151	0.017	-0.125	-0.003	-0.057	0.107	0.048
No. of Panicles m^{-2}	0.119	0.048	0.347**	0.182	0.092	-0.114	0.158	0.107
No. of Filled grains $panicle^{-1}$	-0.157	0.062	0.079	0.059	0.245*	0.243*	0.491**	0.432**
1000 grain weight (g)	-0.131	-0.214	-0.110	-0.274*	-0.162	-0.291*	0.013	-0.143
Grain yield (t ha^{-1})	0.032	-0.006	0.237*	0.020	-0.013	0.296*	-0.040	0.062
Straw yield (t ha^{-1})	-0.021	0.126	0.377**	0.217	0.197	0.030	0.291*	0.288*
Lodging (score)	0.335**	0.277*	0.395**	0.308**	0.231	-0.007	0.044	0.177

PTU_{S-E} = PTU (sowing to emergence); PTU_{E-4L} = PTU (emergence to4[th] leaf emergence); PTU_{4L-AT} = PTU (4[th] 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

Correlations between PTU at different growth stages and grain quality parameters of Gobindabhog 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}
Hulling (%)	0.169	0.268*	0.352**	0.316**	0.146	0.073	0.073	0.206
Milling (%)	0.335**	0.534**	0.599**	0.556**	0.513**	0.353**	0.392**	0.532**
Head rice recovery (%)	0.381**	0.386**	0.429**	0.424**	0.250*	0.032	-0.034	0.268*
Kernel length (mm)	0.248*	0.102	0.176	0.158	0.028	-0.141	-0.103	-0.063
Kernel breadth (mm)	0.169	0.252*	0.233*	0.265*	0.155	0.178	-0.090	0.076
Amylose (%)	-0.272*	-0.066	-0.169	-0.249*	-0.245*	-0.121	-0.123	-0.119
Protein (%)	0.113	0.081	0.064	0.110	0.008	0.107	0.117	0.108
Alkali value (score)	0.200	0.178	0.208	0.152	0.080	-0.100	-0.005	0.089
Kernel length after cooking (mm)	-0.304**	-0.195	-0.331**	-0.298*	-0.265*	-0.220	-0.188	-0.231
Elongation ratio	-0.413**	-0.221	-0.391**	-0.346**	-0.231	-0.064	-0.080	-0.145
Aroma (score)	-0.028	-0.063	-0.150	-0.137	-0.126	-0.132	-0.083	-0.164

PTU_{S-E} = PTU (sowing to emergence); PTU_{E-4L} = PTU (emergence to4[th] leaf emergence); PTU_{4L-AT} = PTU (4[th] 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

Table 4.1.27

Multiple regression equations for prediction of yield and grain quality of Gobindabhog rice

Parameter	Equation	R^2
Plant height (cm)	$Y = 87.616 + 0.091^{**}\ GDD_{4L-AT} + 0.003^{*}\ HTU_{F-Mi} - 0.009^{**}\ HTU_{4L-AT} - 0.008^{**}\ HTU_{E-4L} - 0.011^{**}\ HTU_{S-E} + 0.095^{**}\ GDD_{E-4L}$	0.097**
Panicle length (cm)	$Y = 28.422 - 0.002^{**}\ HTU_{S-E} + 0.001^{*}\ HTU_{4L-AT}$	0.116*
No. of Panicles m^{-2}	$Y = -41.954 + 0.686^{**}\ GDD_{4L-AT} - 0.049^{**}\ PTU_{F-Mi} + 0.018^{**}\ HTU_{E-4L}$	0.352**
No. of filled grains panicle^{-1}	$Y = 93.397 + 0.010^{**}\ HTU_{E-4L} + 0.162^{**}\ GDD_{D-M} - 0.065^{**}\ GDD_{AT-PI} + 0.004^{*}\ PTU_{PI-F}$	0.633**
1000 grain weight (g)	$Y = 10.247 - 0.004^{**}\ GDD_{F-Mi} + 0.001^{**}\ HTU_{E-4L} + 0.001^{**}\ GDD_{PI-F}$	0.194**
Grain yield (t ha^{-1})	$Y = -1.348 + 0.001^{**}\ HTU_{PI-F} - 0.001^{**}\ HTU_{S-E} + 0.001^{**}\ HTU_{E-4L} + 0.001^{**}\ PTU_{D-M} + 0.001^{*}\ PTU_{Mi-D} - 0.011^{*}\ GDD_{D-M}$	0.710**
Straw yield (t ha^{-1})	$Y = 2.704 + 0.009^{**}\ GDD_{4L-AT} - 0.001^{**}\ HTU_{F-Mi} + 0.001^{**}\ HTU_{D-M} - 0.001\ PTU^{*}_{Mi-D}$	0.523**
Lodging (score)	$Y = -3.840 + 0.010^{**}\ GDD_{4L-AT} + 0.001^{*}\ HTU_{PI-F}$	0.205**
Hulling (%)	$Y = 68.066 + 0.019^{**}\ GDD_{4L-AT}$	0.132**
Milling (%)	$Y = 59.016 + 0.002^{**}\ PTU_{4L-AT}$	0.347**
Head rice recovery (%)	$Y = 64.326 + 0.014^{**}\ GDD_{AT-PI} - 0.004^{**}\ HTU_{F-Mi} - 0.002^{**}\ HTU_{4L-AT}$	0.557**
Kernel length (mm)	$Y = 3.203 + 0.001^{**}\ HTU_{PI-F}$	0.156**
Kernel breadth (mm)	$Y = 1.340 + 0.002^{*}\ GDD_{E-4L}$	0.072*
Amylose (%)	$Y = 18.450 + 0.001^{**}\ PTU_{S-E}$	0.123**
Protein (%)	$Y = 5.042 + 0.003^{**}\ HTU_{S-E} + 0.002^{**}\ HTU_{E-4L} + 0.000^{*}\ HTU_{4L-AT} - 0.002^{*}\ HTU_{AT-PI} - 0.001^{*}\ PTU_{E-4L} + 0.001^{**}\ PTU_{AT-PI}$	0.171*
Alkali value (score)	$Y = 1.264 + 0.004^{*}\ GDD_{4L-AT}$	0.054*
KLAC (mm)	$Y = 9.457 - 0.004^{**}\ GDD_{4L-AT}$	0.116**
Elongation ratio	$Y = 2.627 - 0.001^{*}\ GDD_{4L-AT} - 0.003^{*}\ GDD_{S-E}$	0.243**
Aroma (score)	$Y = 3.952 - 0.028^{*}\ GDD_{AT-PI} + 0.043^{*}\ GDD_{F-Mi} + 0.001^{*}\ HTU_{S-E} + 0.002^{*}\ PTU_{AT-PI} - 0.004^{*}\ PTU_{F-Mi} + 0.001^{*}\ PTU_{Mi-D}$	0.115*

4.2 Experiment No. 2

Standardization of organic nutrient management system for greater yield and superior quality of Gobindabhog rice along with better soil health

4.2.1 Growth attributes

4.2.1.1 Plant height

4.2.1.1.1 Effect of organic manure

Plant height of Gobindabhog rice was significantly influenced by the type and dose of organic manures throughout the cropping period during both 2010 and 2011(Table 4.2.1). All four treatments (O_2 - O_5) comprising organic manures either farm yard manure (FYM) or mustard cake (MC) produced taller plants upto harvest than unfertilized control (O_1). The final plant height, pooled over two years, could be arranged in the following order: O_4 (138.9 cm) > O_3 (136.9 cm) > O_2 (135.2 cm) > O_5 (134.6 cm) > O_1 (128.7 cm).

4.2.1.1.2 Effect of inorganic fertilizer

Plant height was significantly increased with the increment in inorganic fertilizer dose from F_1 ($N_{20}P_{10}K_{10}$ kg ha^{-1}) to F_3 ($N_{40}P_{20}K_{20}$ kg ha^{-1}) at all stages of observation during both 2010 and 2011 (Table 4.2.1).

4.2.1.1.3 Interaction effect between organic manure and inorganic fertilizer

Organic manure × inorganic fertilizer interaction effect on plant height was mostly non-significant thorough out the cropping period, excluding at 84 DAT for 2010 and pooled values, and at harvest for the pooled values in the experiment (Table 4.2.1). Gobindabhog rice treated with integrated dose of O_4N_3 (mustard cake @ 0.50 t ha^{-1} + $N_{40}P_{20}K_{20}$ kg ha^{-1}) recorded highest plant height (140.3 cm), which was on par with other two combined doses like O_2F_3 and O_4F_1.

4.2.1.2 Tillreing pattern

The tiller production in unit area at 28, 56 and 84 DAT was higher in second year than those in first year of investigation (Table 4.2.2).

4.2.1.2.1 Effect of organic manure

Table 4.2.1

Effect of organic manure and inorganic fertilizer on plant height at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Plant height (cm)											
	28 DAT			56 DAT			84 DAT			At harvest		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure												
O_1	45.1	44.0	44.5	77.9	82.2	80.0	107.3	116.2	111.8	125.6	131.8	128.7
O_2	47.1	47.8	47.5	79.6	84.5	82.1	108.2	122.0	115.1	130.6	139.8	135.2
O_3	49.1	49.4	49.3	82.8	85.8	84.3	112.0	124.3	118.1	134.1	139.7	136.9
O_4	48.3	52.8	50.5	82.8	89.2	86.0	112.8	124.8	118.8	135.2	142.5	138.9
O_5	47.3	50.7	49.0	81.6	88.1	84.9	109.3	121.7	115.5	129.9	139.3	134.6
S.Em (±)	0.48	0.58	0.38	0.88	0.56	0.52	0.98	0.89	0.66	0.92	0.83	0.62
C.D. at 5%	1.57	1.89	1.13	2.88	1.84	1.57	3.19	2.90	1.98	2.99	2.70	1.85
Inorganic fertilizer												
F_1	45.8	47.7	46.7	79.1	84.5	81.8	106.4	118.6	112.5	128.8	137.0	132.9
F_2	47.1	49.1	48.1	80.3	86.2	83.2	110.1	122.2	116.2	130.4	138.8	134.6
F_3	49.3	50.1	49.7	83.4	87.1	85.3	113.1	124.6	118.9	134.0	140.1	137.1
S.Em (±)	0.61	0.35	0.35	0.48	0.45	0.33	0.69	0.60	0.46	0.42	0.51	0.33
C.D. at 5%	1.80	1.02	1.00	1.41	1.33	0.94	2.03	1.78	1.31	1.24	1.51	0.95
Interaction effect												
O_1F_1	41.1	43.1	42.1	76.1	80.9	78.5	102.5	114.5	108.5	124.0	130.4	127.2
O_1F_2	46.3	43.9	45.1	76.6	82.7	79.6	106.1	117.1	111.6	124.7	131.7	128.2
O_1F_3	47.9	45.0	46.4	81.0	83.1	82.0	113.1	117.1	115.1	128.1	133.2	130.6
O_2F_1	46.1	44.4	45.3	78.0	81.6	79.8	106.3	118.9	112.6	127.9	139.0	133.5
O_2F_2	46.7	48.7	47.7	78.7	85.8	82.2	109.3	121.6	115.5	130.9	139.3	135.1
O_2F_3	48.5	50.3	49.4	82.3	86.2	84.2	109.0	125.5	117.3	133.1	141.2	137.1
O_3F_1	47.9	48.5	48.2	81.2	83.9	82.5	105.5	119.9	112.7	131.7	138.0	134.8
O_3F_2	48.7	49.6	49.1	83.0	85.7	84.4	113.9	126.8	120.4	133.0	140.7	136.8
O_3F_3	50.7	50.3	50.5	84.1	87.7	85.9	116.5	126.1	121.3	137.6	140.5	139.0
O_4F_1	46.9	52.5	49.7	80.7	88.5	84.6	109.1	119.9	114.5	133.8	143.1	138.4
O_4F_2	48.1	52.5	50.3	82.5	88.3	85.4	112.4	124.7	118.5	134.7	141.0	137.8
O_4F_3	49.8	53.3	51.6	85.1	90.7	87.9	116.7	129.7	123.2	137.2	143.5	140.3
O_5F_1	46.7	50.3	48.5	79.8	87.9	83.9	108.6	119.5	114.1	126.8	134.6	130.7
O_5F_2	45.7	50.5	48.1	80.6	88.3	84.5	108.9	121.0	115.0	128.6	141.1	134.9
O_5F_3	49.6	51.4	50.5	84.5	88.1	86.3	110.3	124.6	117.5	134.2	142.1	138.1
O × F												
S.Em (±)	1.36	0.78	0.78	1.07	1.01	0.73	1.54	1.35	1.02	0.94	1.15	0.74
C.D. at 5%	NS	NS	NS	NS	NS	NS	4.54	NS	2.93	NS	NS	2.12
F × O												
S.Em (±)	1.21	0.86	0.74	1.24	1.00	0.80	1.59	1.42	1.07	1.20	1.25	0.87
C.D. at 5%	NS	NS	NS	NS	NS	NS	4.88	NS	3.15	NS	NS	2.58

DAT = Days after transplanting; NS = Not significant

Table 4.2.2

Effect of organic manure and inorganic fertilizer on tillering pattern at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Number of tillers m^{-2}								
	28 DAT			56 DAT			84 DAT		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure									
O_1	209.6	225.2	217.4	285.9	314.1	300.0	273.2	299.1	286.1
O_2	232.0	273.5	252.7	308.3	334.1	321.2	281.5	306.6	294.0
O_3	250.0	276.4	263.2	327.6	345.6	336.6	300.3	321.5	310.9
O_4	260.1	280.9	270.5	346.0	355.9	351.0	320.7	334.8	327.7
O_5	256.2	272.8	264.5	345.9	374.4	360.2	311.9	344.4	328.2
S.Em (±)	2.02	1.63	1.30	2.30	3.11	1.93	2.58	3.22	2.07
C.D. at 5%	6.57	5.32	3.89	7.52	10.14	5.80	8.42	10.52	6.19
Inorganic fertilizer									
F_1	233.3	262.1	247.7	317.3	337.0	327.1	291.0	314.1	302.5
F_2	246.5	265.7	256.1	323.5	342.1	332.8	298.6	321.0	309.8
F_3	244.9	269.5	257.2	327.4	355.4	341.4	302.9	328.7	315.8
S.Em (±)	2.99	1.26	1.62	1.79	3.00	1.75	2.36	3.13	1.96
C.D. at 5%	8.81	3.72	4.63	5.27	8.86	4.99	6.97	9.22	5.60
Interaction effect									
O_1F_1	194.4	218.4	206.4	276.0	314.4	295.2	268.0	285.6	276.8
O_1F_2	216.0	226.4	221.2	285.6	309.6	297.6	270.4	305.6	288.0
O_1F_3	218.4	230.8	224.6	296.0	318.4	307.2	281.2	306.0	293.6
O_2F_1	224.8	264.0	244.4	305.6	325.6	315.6	277.6	296.0	286.8
O_2F_2	232.4	276.0	254.2	306.0	330.0	318.0	283.2	308.0	295.6
O_2F_3	238.9	280.4	259.6	313.2	346.8	330.0	283.6	315.7	299.7
O_3F_1	241.1	273.6	257.3	323.6	344.4	334.0	295.2	309.6	302.4
O_3F_2	256.6	273.6	265.1	325.6	334.0	329.8	298.0	308.4	303.2
O_3F_3	252.2	282.0	267.1	333.6	358.4	346.0	307.6	346.4	327.0
O_4F_1	250.3	278.4	264.3	345.6	352.0	348.8	310.4	332.1	321.3
O_4F_2	266.5	278.8	272.7	342.1	354.0	348.1	320.8	331.2	326.0
O_4F_3	263.6	285.6	274.6	350.4	361.6	356.0	330.8	341.1	335.9
O_5F_1	255.9	276.0	265.9	335.7	348.4	342.1	303.6	346.9	325.3
O_5F_2	261.2	273.6	267.4	358.0	382.8	370.4	320.8	352.0	336.4
O_5F_3	251.6	268.8	260.2	344.0	392.0	368.0	311.2	334.4	322.8
O × F									
S.Em (±)	6.68	2.82	3.63	4.00	6.71	3.91	5.28	6.99	4.38
C.D. at 5%	NS	8.32	NS	11.79	NS	11.17	NS	20.62	12.52
F × O									
S.Em (±)	5.82	2.82	3.23	3.99	6.30	3.73	5.03	6.55	4.13
C.D. at 5%	NS	8.61	NS	12.20	NS	11.13	NS	19.83	12.29

DAT = Days after transplanting; NS = Not significant

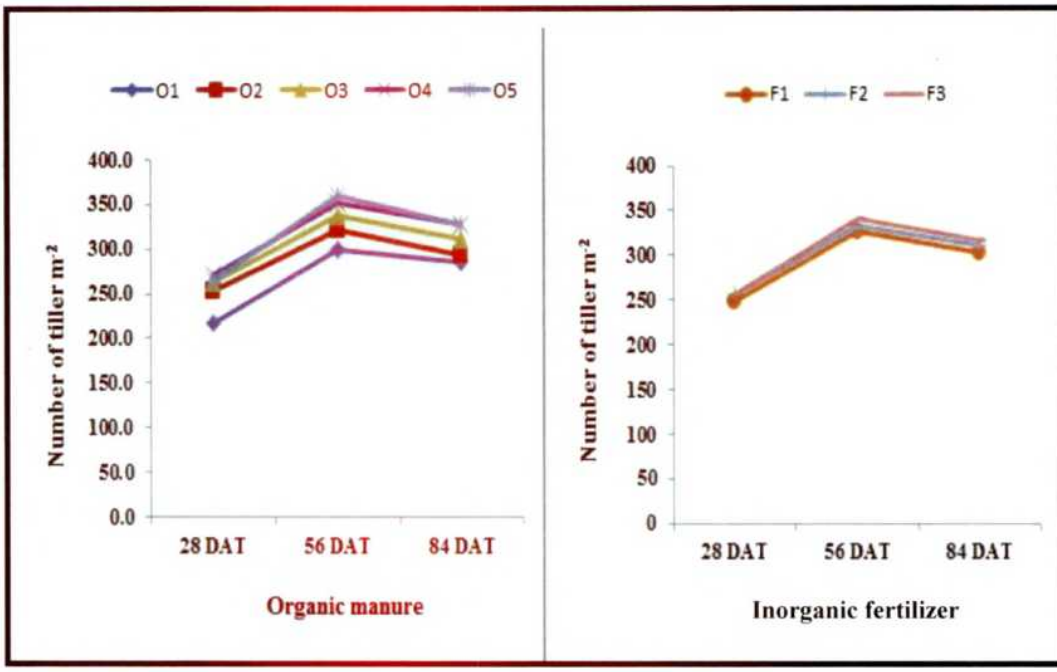

Fig. 4.7: Effect of organic manure and inorganic fertilizer on tillers m^{-2} Gobindabhog rice during *kharif* season (pooled over two years)

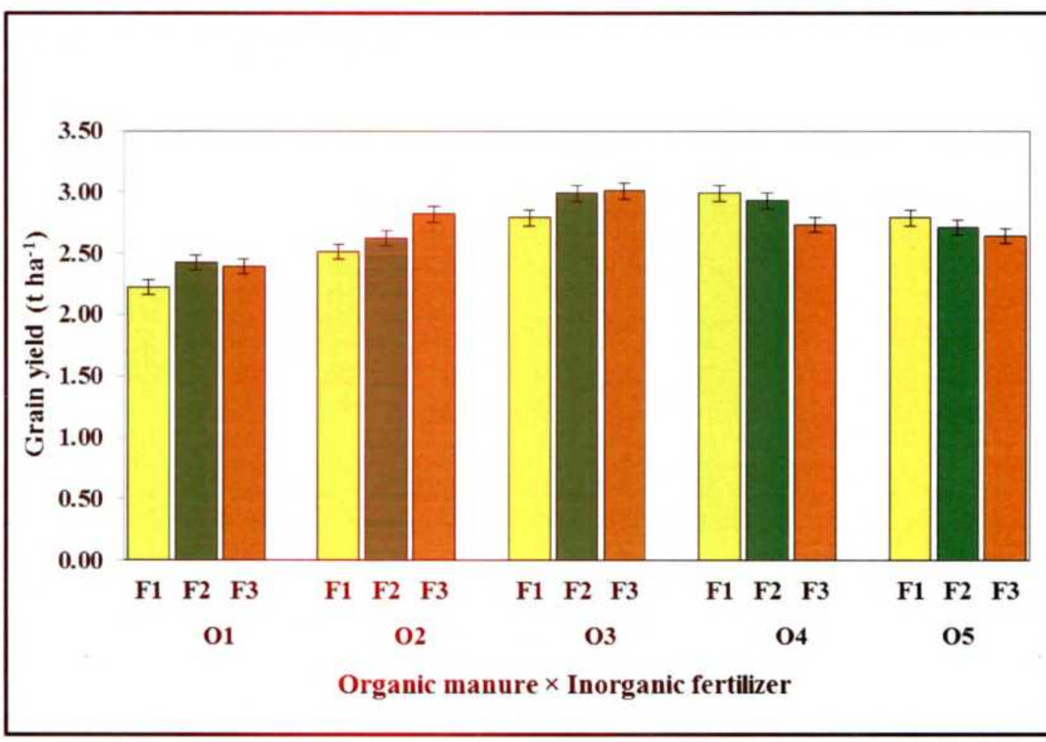

Fig. 4.8: Interaction effect between organic manure and inorganic fertilizer on grain yield of Gobindabhog rice during *kharif* season (pooled over two years)

The application of mustard cake @ 0.25 t ha^{-1} (O_4) or 0.50 t ha^{-1} (O_5) triggered the tiller production during active to maximum tillering phase compared to FYM-treated plots (O_2 and O_3). The findings could be supported by the fact that greater proportion of nitrogen from mustard cake because available for nutrition of the test crop within a short period than FYM (Table 4.2.2; Fig. 4.7).

4.2.1.2.2 Effect of inorganic fertilizer

The increase in chemical fertilizer dose from $N_{20}P_{10}K_{10}$ kg ha^{-1} (F_1) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) improved the tiller production ability of Gobindabhog rice during both the years of investigation (Table 4.2.2). The highest number of tiller m^{-2}, pooled over two years, was recorded as 257.2, 341.4 and 315.8 at 28, 56 and 84 DAT, respectively with the inorganic fertilizer dose ($N:P_2O_5:K_2O$) of 40:20:20 kg ha^{-1} (F_3).

4.2.1.2.3 Interaction effect between organic manure and inorganic fertilizer

The interaction effect between organic manure and inorganic fertilizer on tiller production of Gobindabhog rice was significant at 28 DAT for 2011, at 56 DAT for 2010 and pooled values and at 84 DAT for 2011 and pooled values in the experiment (Table 4.2.2). Perusal of data revealed that maximum tiller production was usually noted with combined doses of O_4F_3 (MC @ 0.25 t + $N_{40}P_{20}K_{20}$ kg ha^{-1}) or O_5F_2 (MC @ 0.50 t + $N_{30}P_{15}K_{15}$ kg ha^{-1}).

4.2.1.3 Leaf area index (LAI)

LAI, in either of treatments, increased progressively upto 84 DAT (*i.e.* upto pre-flowering stage) and declined thereafter due to senescence of lower leaves (Table 4.2.3).

4.2.1.3.1 Effect of organic manure

The organic manure based treatments could affect LAI of Gobindabhog rice at mid early (28 DAT) for 2010 and pooled values, and late (maturity) stage for 2011 only, indicating no influence at mid (56 DAT) and mid-late (84 DAT) stages of the crop during *kharif* season of both the years (Table 4.2.3). Although manuring of Gobindabhog paddy (O_2-O_5) improved the LAI over control (O_1) throughout the cropping period, but the FYM (O_2 and O_3) was found usually better than mustard

Table 4.2.3

Effect of organic manure and inorganic fertilizer on LAI at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Leaf area index (LAI)											
	28 DAT			56 DAT			84 DAT			At harvest		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure												
O_1	1.64	1.83	1.73	3.64	3.75	3.70	4.77	4.96	4.86	2.64	2.80	2.72
O_2	1.71	1.84	1.78	3.84	4.03	3.94	4.79	4.99	4.89	2.70	2.88	2.79
O_3	1.73	1.87	1.80	3.67	3.94	3.81	4.82	5.02	4.92	2.69	2.99	2.84
O_4	1.73	1.86	1.80	3.76	3.83	3.79	4.70	4.97	4.83	2.68	2.90	2.79
O_5	1.77	1.82	1.80	3.69	3.85	3.77	4.89	5.09	4.99	2.66	2.94	2.80
S.Em (±)	0.01	0.02	0.01	0.09	0.07	0.06	0.09	0.06	0.05	0.04	0.03	0.03
C.D. at 5%	0.04	NS	0.03	NS	NS	NS	NS	NS	NS	NS	0.11	NS
Inorganic fertilizer												
F_1	1.69	1.83	1.76	3.66	3.82	3.74	4.76	4.96	4.86	2.67	2.85	2.76
F_2	1.72	1.86	1.79	3.73	3.85	3.79	4.82	4.98	4.90	2.68	2.92	2.80
F_3	1.74	1.85	1.79	3.77	3.97	3.87	4.80	5.08	4.94	2.68	2.94	2.81
S.Em (±)	0.02	0.01	0.01	0.04	0.04	0.03	0.05	0.03	0.03	0.02	0.01	0.01
C.D. at 5%	NS	NS	NS	NS	0.12	0.08	NS	0.09	NS	NS	0.04	0.03
Interaction effect												
O_1F_1	1.62	1.82	1.72	3.58	3.63	3.60	4.72	4.85	4.79	2.60	2.76	2.68
O_1F_2	1.64	1.82	1.73	3.66	3.76	3.71	4.74	4.98	4.86	2.66	2.81	2.73
O_1F_3	1.66	1.84	1.75	3.67	3.88	3.77	4.84	5.04	4.94	2.67	2.84	2.76
O_2F_1	1.69	1.83	1.76	3.72	3.88	3.80	4.71	4.91	4.81	2.69	2.81	2.75
O_2F_2	1.70	1.87	1.79	3.82	4.09	3.95	4.82	5.01	4.91	2.68	2.90	2.79
O_2F_3	1.74	1.84	1.79	4.00	4.13	4.07	4.85	5.05	4.95	2.73	2.93	2.83
O_3F_1	1.71	1.84	1.77	3.82	3.95	3.89	4.85	5.00	4.92	2.73	2.93	2.83
O_3F_2	1.73	1.89	1.81	3.64	3.85	3.75	4.78	4.98	4.88	2.73	2.98	2.85
O_3F_3	1.74	1.89	1.81	3.56	4.03	3.79	4.84	5.09	4.97	2.62	3.05	2.83
O_4F_1	1.70	1.86	1.78	3.65	3.81	3.73	4.71	4.92	4.82	2.65	2.84	2.74
O_4F_2	1.74	1.87	1.81	3.70	3.78	3.74	4.81	4.94	4.87	2.69	2.87	2.78
O_4F_3	1.75	1.86	1.81	3.92	3.88	3.90	4.57	5.04	4.81	2.71	3.00	2.85
O_5F_1	1.72	1.82	1.77	3.56	3.83	3.70	4.80	5.11	4.95	2.68	2.91	2.80
O_5F_2	1.79	1.82	1.81	3.82	3.79	3.81	4.98	5.02	5.00	2.61	3.03	2.82
O_5F_3	1.80	1.83	1.82	3.70	3.92	3.81	4.89	5.15	5.02	2.69	2.88	2.78
O × F												
S.Em (±)	0.03	0.03	0.02	0.08	0.09	0.06	0.11	0.07	0.06	0.03	0.03	0.02
C.D. at 5%	NS	NS	NS	0.23	NS	NS	NS	NS	NS	NS	0.10	NS
F × O												
S.Em (±)	0.03	0.03	0.02	0.11	0.10	0.08	0.13	0.08	0.08	0.05	0.04	0.03
C.D. at 5%	NS	NS	NS	0.36	NS	NS	NS	NS	NS	NS	0.14	NS

DAT = Days after transplanting; NS = Not significant

cake (O_4 and O_5) toward the leaf growth of the crop in the study. However, Banerjee (2011) opined differently indicating better performance of mustard cake compared to FYM and vermicompost for LAI of Gobindabhog rice in West Bengal.

4.2.1.3.2 Effect of inorganic fertilizer

There was a general increasing trend in LAI with increment of fertilizers dose from $N_{20}P_{10}K_{10}$ (F_1) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) at all stages of observation (Table 4.2.3). Based on pooled values, the highest LAI values was usually recorded with $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) at 28 DAT (1.79), 56 DAT (3.87), 84 DAT (4.94) and at harvest (2.81).

4.2.1.3.3 Interaction effect between organic manure and inorganic fertilizer

LAI of Gobindabhog paddy was mostly unaffected by the interaction between organic manure and inorganic fertilizer during both the years of investigation, excluding at harvest during 2011 (Table 4.2.3).

4.2.1.4 Dry matter accumulation

The accumulation of dry matter in Gobindabhog rice plants was in increasing trend with the advancement of crop growth upto harvest (Table 4.2.4).

4.2.1.4.1 Effect of organic manure

The variation in type and dose of organic manure had significant effect on dry matter yield of Gobindabhog rice during the period from active tillering (28 DAT) to harvest (Table 4.2.4).

4.2.1.4.2 Effect of inorganic fertilizer

There was progressive improvement on total dry matter production unit^{-1} area with the increase in level of chemical fertilizers from $N_{20}P_{10}K_{10}$ kg ha^{-1} (F_1) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) throughout the cropping period (Table 4.2.4). This might be due to greater capability of plants to assimilate carbohydrates in the form of tiller production and better foliage growth for higher fertilizer dose ($N_{40}P_{20}K_{20}$ kg ha^{-1}) compared to two lower doses ($N_{30}P_{15}K_{15}$ kg ha^{-1} and $N_{20}P_{10}K_{10}$ kg ha^{-1}) in the study. The highest total dry matter yield, pooled over years, was recorded as 192.9, 281.5,

Table 4.2.4

Effect of organic manure and inorganic fertilizer on total dry matter production at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Total dry matter production (g m^{-2})											
	28 DAT			56 DAT			84 DAT			At harvest		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure												
O_1	165.6	177.4	171.5	234.4	258.7	246.5	396.0	420.8	408.4	481.3	488.4	484.9
O_2	175.9	189.1	182.5	267.6	274.4	271.0	426.8	455.6	441.2	518.0	527.7	522.8
O_3	184.5	192.2	188.3	275.2	287.6	281.4	432.8	470.4	451.6	537.5	567.2	552.3
O_4	184.4	193.4	188.9	273.6	290.0	281.8	449.1	472.8	460.9	526.2	566.0	546.1
O_5	190.8	193.0	191.9	279.6	307.2	293.4	443.6	481.1	462.4	525.3	558.0	541.7
S.Em (±)	3.00	1.75	1.73	3.39	3.71	2.51	2.82	3.76	2.35	2.69	3.48	2.20
C.D. at 5%	9.77	5.70	5.20	11.07	12.10	7.54	9.20	12.26	7.05	8.78	11.33	6.59
Inorganic fertilizer												
F_1	173.2	181.8	177.5	258.2	275.0	266.6	422.6	450.0	436.3	507.9	534.0	520.9
F_2	179.8	187.2	183.5	268.6	284.1	276.4	428.9	462.2	445.6	517.6	541.1	529.4
F_3	187.8	198.0	192.9	271.4	291.6	281.5	437.5	468.2	452.9	527.5	549.3	538.4
S.Em (±)	1.06	1.05	0.75	1.22	1.30	0.89	1.02	1.01	0.72	1.52	1.18	0.96
C.D. at 5%	3.13	3.11	2.14	3.61	3.82	2.55	3.02	2.99	2.06	4.50	3.49	2.76
Interaction effect												
O_1F_1	160.4	170.2	165.3	228.0	255.2	241.6	389.6	408.4	399.0	470.8	478.0	474.4
O_1F_2	165.2	176.2	170.7	234.0	258.4	246.2	395.6	422.8	409.2	479.2	490.0	484.6
O_1F_3	171.2	185.8	178.5	241.2	262.4	251.8	402.8	431.2	417.0	494.0	497.2	495.6
O_2F_1	170.4	177.8	174.1	261.6	264.0	262.8	423.6	446.0	434.8	506.3	521.1	513.7
O_2F_2	174.9	190.0	182.5	268.8	274.8	271.8	426.0	456.8	441.4	522.0	526.8	524.4
O_2F_3	182.4	199.4	190.9	272.4	284.4	278.4	430.8	464.0	447.4	525.6	535.2	530.4
O_3F_1	182.2	182.6	182.4	268.8	277.6	273.2	428.4	463.2	445.8	533.2	558.0	545.6
O_3F_2	183.2	191.0	187.1	278.4	288.4	283.4	433.2	472.8	453.0	538.8	567.6	553.2
O_3F_3	188.0	203.0	195.5	278.4	296.8	287.6	436.8	475.2	456.0	540.4	576.0	558.2
O_4F_1	172.8	185.0	178.9	265.2	282.4	273.8	436.1	466.8	451.4	511.5	561.6	536.6
O_4F_2	187.2	193.4	190.3	274.8	289.6	282.2	446.0	472.8	459.4	522.8	564.0	543.4
O_4F_3	193.2	201.8	197.5	280.8	298.0	289.4	465.2	478.8	472.0	544.4	572.4	558.4
O_5F_1	180.0	193.4	186.7	267.6	296.0	281.8	435.2	465.4	450.3	517.6	551.2	534.4
O_5F_2	188.4	185.4	186.9	287.2	309.2	298.2	443.6	486.0	464.8	525.1	557.2	541.2
O_5F_3	204.0	200.2	202.1	284.0	316.4	300.2	452.0	492.0	472.0	533.2	565.6	549.4
O × F												
S.Em (±)	2.37	2.36	1.67	2.74	2.90	1.99	2.29	2.27	1.61	3.41	2.65	2.16
C.D. at 5%	7.00	6.95	NS	NS	NS	NS	6.76	6.69	4.61	10.05	NS	NS
F × O												
S.Em (±)	3.57	2.60	2.21	4.06	4.40	3.00	3.38	4.19	2.69	3.87	4.09	2.82
C.D. at 5%	11.31	8.03	NS	NS	NS	NS	10.72	13.41	8.07	12.00	NS	NS

DAT = Days after transplanting; NS = Not significant

452.9 and 538.4 g m^{-2} with higher fertilizer dose ($N_{40}P_{20}K_{20}$ kg ha^{-1}) at 28, 56, 84 DAT and harvest, respectively.

4.2.1.4.3 Interaction effect between organic manure and inorganic fertilizer

The dry matter yield m^{-2} was significantly influenced by the combined effect of organic manures and chemical fertilizers at 28 and 84 DAT for both the years; while at harvest for 2010 only (Table 4.2.4). The integrated dose of mustard cake @ 0.5 t ha^{-1} + $N_{40}P_{20}K_{20}$ kg ha^{-1} (O_5F_3) usually produced highest dry matter in 1 m^{-2} area at mid and mid-late phase of crop growth, while the combined application of mustard cake @ 0.25 t + $N_{40}P_{20}K_{20}$ kg ha^{-1} (O_4F_3) resulted in maximum dry matter yield at late phase mainly due to better production as well as translocation of photosynthates from source to source to sink during the period.

4.2.1.5 Crop growth rate (CGR)

CGR, irrespective of nutritional treatments, increased from 28–56 DAT to 56–84 DAT; while it declined sharply from 56–84 DAT to 84–112 DAT (Table 4.2.5).

4.2.1.5.1 Effect of organic manure

There was no definite trend of variation in CGR among manure based treatments at different periods of Gobindabhog rice in the study (Table 4.2.5). Although the application of mustard cake @ 0.5 t ha^{-1} (O_5) triggered the CGR during 28-56 DAT, while lower dose of mustard cake @ 0.25 t ha^{-1} (O_4) resulted in higher CGR during 56-84 DAT and FYM @ 5.0 t ha^{-1}(O_3) favoured better CGR during 84-112 DAT during both 2010 and 2011. The findings could be explained by quick release and supply of nutrients in varied proportions from two different doses of mustard cake during 28-56 DAT and 56-84 DAT, while slow and steady release of nutrients from FYM @ 5.0 t ha^{-1} (O_3) throughout the cropping period compared to unfertilized control (O_1).

4.2.1.5.2 Effect of inorganic fertilizer

There was no definite trend of increase or decrease in CGR during three different stages of 28-56 DAT, 56-84 DAT and 84-112 DAT due to variation in doses of chemical fertilizers in the study (Table 4.2.5). The significant influence of

Table 4.2.5

Effect of organic manure and inorganic fertilizer on crop growth rate at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Crop growth rate (g m^{-2} day^{-1})								
	28-56 DAT			56-84 DAT			84-112 DAT		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure									
O_1	2.46	2.90	2.68	5.77	5.79	5.78	3.05	2.41	2.73
O_2	3.27	3.05	3.16	5.69	6.47	6.08	3.26	2.57	2.92
O_3	3.24	3.41	3.32	5.63	6.53	6.08	3.74	3.46	3.60
O_4	3.19	3.45	3.32	6.27	6.53	6.40	2.76	3.33	3.04
O_5	3.17	4.08	3.63	5.86	6.21	6.03	2.92	2.75	2.83
S.Em (±)	0.04	0.10	0.06	0.17	0.19	0.13	0.06	0.08	0.05
C.D. at 5%	0.15	0.34	0.17	NS	NS	0.38	0.20	0.27	0.15
Inorganic fertilizer									
F_1	3.04	3.33	3.18	5.87	6.25	6.06	3.05	3.00	3.02
F_2	3.17	3.46	3.32	5.72	6.36	6.04	3.17	2.82	2.99
F_3	2.99	3.34	3.16	5.93	6.31	6.12	3.21	2.89	3.05
S.Em (±)	0.03	0.06	0.03	0.05	0.06	0.04	0.05	0.04	0.03
C.D. at 5%	0.09	NS	0.09	0.14	NS	NS	NS	0.12	NS
Interaction effect									
O_1F_1	2.41	3.04	2.73	5.77	5.47	5.62	2.90	2.49	2.69
O_1F_2	2.46	2.94	2.70	5.77	5.87	5.82	2.99	2.40	2.69
O_1F_3	2.50	2.74	2.62	5.77	6.03	5.90	3.26	2.36	2.81
O_2F_1	3.26	3.08	3.17	5.79	6.50	6.14	2.95	2.68	2.82
O_2F_2	3.35	3.03	3.19	5.61	6.50	6.06	3.43	2.50	2.96
O_2F_3	3.21	3.04	3.13	5.66	6.41	6.04	3.39	2.54	2.96
O_3F_1	3.09	3.39	3.24	5.70	6.63	6.16	3.74	3.39	3.56
O_3F_2	3.40	3.48	3.44	5.53	6.59	6.06	3.77	3.39	3.58
O_3F_3	3.23	3.35	3.29	5.66	6.37	6.01	3.70	3.60	3.65
O_4F_1	3.30	3.48	3.39	6.10	6.59	6.34	2.70	3.39	3.04
O_4F_2	3.13	3.44	3.28	6.11	6.54	6.33	2.74	3.26	3.00
O_4F_3	3.13	3.44	3.28	6.59	6.46	6.52	2.83	3.34	3.09
O_5F_1	3.13	3.66	3.40	5.99	6.05	6.02	2.94	3.06	3.00
O_5F_2	3.53	4.42	3.98	5.59	6.31	5.95	2.91	2.54	2.73
O_5F_3	2.86	4.15	3.50	6.00	6.27	6.14	2.90	2.63	2.76
O × F									
S.Em (±)	0.07	0.12	0.07	0.11	0.13	0.09	0.11	0.09	0.07
C.D. at 5%	0.21	NS	0.20	NS	NS	NS	NS	NS	NS
F × O									
S.Em (±)	0.07	0.14	0.08	0.19	0.22	0.14	0.11	0.11	0.08
C.D. at 5%	0.22	NS	0.24	NS	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

inorganic fertilizer doses on CGR was found at 28-56 DAT during 2010 and pooled values, at 56-84 DAT during 2010 and at 84-112 DAT during 2011 only.

4.2.1.5.3 Interaction effect between organic manure and inorganic fertilizer

The interaction effect of organic manure and inorganic fertilizer on CGR was mostly non-significant throughout the cropping period for both the years, excluding at 28-56 DAT for 2010 and pooled values only (Table 4.2.5).

4.2.1.6 Net assimilation rate (NAR)

4.2.1.6.1 Effect of organic manure

The variation in NAR among nutritional treatments comprising organic manures (*viz.* FYM and mustard cake) mostly followed the trend observed in CGR during the period from 28 to 112 DAT in the investigation (Table 4.2.6).

4.2.1.6.2 Effect of inorganic fertilizer

The NAR of Gobindabhog paddy influenced by differed doses of chemical fertilizers developed no definite trend in variation at different periods and even between two years of study (Table 4.2.6).

4.2.1.6.3 Interaction effect between organic manure and inorganic fertilizer

The combination of organic manures and inorganic fertilizers had significant interaction effect on NAR at 28-56 DAT only for 2010, 2011 and pooled values in the study (Table 4.2.6).

4.2.2 Yield components and associated characters

4.2.2.1 Panicle length

4.2.2.1.1 Effect of organic manure

The length of panicle obtained from four nutritional treatments (O_2-O_5) comprising different types and doses of organic manures was significantly greater over than of unfertilized control (O_1) in the study (Table 4.2.7). The application of FYM @ 5 t ha^{-1} (O_3) usually recorded the maximum panicle length (25.8 and 26.0 cm) than other treatments during first and second year of investigation.

Table 4.2.6

Effect of organic manure and inorganic fertilizer on net assimilation rate at different growth stages of Gobindabhog rice during *kharif* season

Treatment	Net assimilation rate (g m^{-2} day^{-1})								
	28-56 DAT			56-84 DAT			84-112 DAT		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure									
O_1	0.98	1.09	1.03	1.39	1.34	1.36	0.73	0.56	0.64
O_2	1.24	1.09	1.17	1.33	1.44	1.38	0.76	0.57	0.66
O_3	1.26	1.23	1.24	1.34	1.47	1.40	0.89	0.78	0.83
O_4	1.22	1.26	1.24	1.49	1.49	1.49	0.66	0.76	0.71
O_5	1.21	1.50	1.36	1.38	1.40	1.39	0.69	0.62	0.65
S.Em (±)	0.02	0.03	0.02	0.06	0.06	0.04	0.01	0.02	0.01
C.D. at 5%	0.07	0.11	0.06	NS	NS	NS	0.05	0.06	0.03
Inorganic fertilizer									
F_1	1.19	1.23	1.21	1.40	1.43	1.42	0.73	0.69	0.71
F_2	1.22	1.27	1.24	1.35	1.45	1.40	0.75	0.64	0.69
F_3	1.14	1.20	1.17	1.40	1.40	1.40	0.76	0.64	0.70
S.Em (±)	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01
C.D. at 5%	0.03	NS	0.04	0.05	0.04	NS	NS	0.03	NS
Interaction effect									
O_1F_1	0.98	1.16	1.07	1.40	1.30	1.35	0.70	0.59	0.65
O_1F_2	0.98	1.10	1.04	1.38	1.36	1.37	0.72	0.55	0.63
O_1F_3	0.99	1.00	1.00	1.37	1.36	1.37	0.77	0.53	0.65
O_2F_1	1.27	1.13	1.20	1.38	1.49	1.43	0.70	0.61	0.66
O_2F_2	1.28	1.07	1.17	1.31	1.43	1.37	0.80	0.55	0.68
O_2F_3	1.19	1.07	1.13	1.28	1.40	1.34	0.77	0.56	0.66
O_3F_1	1.18	1.23	1.20	1.32	1.49	1.41	0.87	0.76	0.81
O_3F_2	1.32	1.27	1.29	1.32	1.50	1.41	0.90	0.77	0.84
O_3F_3	1.27	1.19	1.23	1.36	1.41	1.38	0.89	0.79	0.84
O_4F_1	1.29	1.28	1.29	1.47	1.52	1.49	0.65	0.78	0.71
O_4F_2	1.20	1.27	1.24	1.45	1.51	1.48	0.65	0.75	0.70
O_4F_3	1.16	1.25	1.21	1.56	1.46	1.51	0.67	0.75	0.71
O_5F_1	1.24	1.36	1.30	1.44	1.36	1.40	0.71	0.69	0.70
O_5F_2	1.32	1.65	1.48	1.28	1.44	1.36	0.67	0.58	0.62
O_5F_3	1.09	1.51	1.30	1.41	1.39	1.40	0.68	0.58	0.63
O × F									
S.Em (±)	0.03	0.05	0.03	0.04	0.03	0.02	0.03	0.03	0.02
C.D. at 5%	0.07	0.14	0.08	NS	NS	NS	NS	NS	NS
F × O									
S.Em (±)	0.03	0.05	0.03	0.06	0.06	0.04	0.03	0.03	0.02
C.D. at 5%	0.09	0.16	0.09	NS	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

Table 4.2.7

Effect of organic manure and inorganic fertilizer on yield components of Gobindabhog 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)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure												
O_1	24.7	25.4	25.0	246.5	263.7	255.1	122.5	129.8	126.1	10.27	10.26	10.26
O_2	25.6	25.7	25.7	260.5	288.6	274.6	130.8	135.8	133.3	10.49	10.41	10.45
O_3	25.8	26.0	25.9	281.8	311.6	296.7	149.1	138.0	143.6	10.42	10.32	10.37
O_4	25.6	26.0	25.8	295.7	317.3	306.5	144.7	138.3	141.5	10.52	10.40	10.46
O_5	25.0	25.5	25.2	284.8	321.5	303.1	133.6	139.4	136.5	10.26	10.38	10.32
S.Em (±)	0.10	0.10	0.07	4.01	5.01	3.21	3.46	1.86	1.97	0.03	0.05	0.03
C.D. at 5%	0.32	0.34	0.21	13.08	16.35	9.62	11.29	6.08	5.89	0.11	NS	0.09
Inorganic fertilizer												
F_1	25.2	25.7	25.4	267.8	287.1	277.4	124.1	131.9	128.0	10.35	10.29	10.32
F_2	25.3	25.8	25.6	275.4	305.0	290.2	136.4	138.7	137.6	10.42	10.41	10.42
F_3	25.5	25.6	25.6	278.4	309.6	294.0	147.9	138.2	143.0	10.40	10.36	10.38
S.Em (±)	0.06	0.05	0.04	2.668	2.728	1.908	1.88	1.70	1.27	0.04	0.04	0.03
C.D. at 5%	0.17	0.16	0.11	7.870	8.047	5.453	5.55	5.01	3.62	NS	NS	0.08
Interaction effect												
O_1F_1	24.5	25.1	24.8	238.0	254.8	246.4	105.9	119.7	112.8	10.13	10.17	10.15
O_1F_2	24.8	25.6	25.2	242.0	260.0	251.0	123.1	136.5	129.8	10.33	10.23	10.28
O_1F_3	24.9	25.4	25.2	259.6	276.4	268.0	138.3	133.1	135.7	10.33	10.37	10.35
O_2F_1	25.3	25.4	25.3	253.6	272.7	263.1	119.7	132.5	126.1	10.40	10.27	10.33
O_2F_2	25.4	25.8	25.6	261.6	295.2	278.4	132.2	138.7	135.4	10.53	10.53	10.53
O_2F_3	26.1	26.0	26.1	266.4	298.0	282.2	140.5	136.4	138.5	10.53	10.43	10.48
O_3F_1	25.6	26.0	25.8	271.2	296.8	284.0	140.1	134.1	137.1	10.37	10.30	10.33
O_3F_2	25.8	26.3	26.1	282.0	305.2	293.6	152.4	136.3	144.3	10.50	10.40	10.45
O_3F_3	25.9	25.7	25.8	292.0	332.8	312.4	154.9	143.6	149.3	10.40	10.27	10.33
O_4F_1	25.7	26.2	26.0	294.4	304.4	299.4	134.9	133.5	134.2	10.57	10.30	10.43
O_4F_2	25.8	26.0	25.9	302.8	330.8	316.8	139.4	139.5	139.5	10.50	10.50	10.50
O_4F_3	25.4	25.7	25.5	290.0	316.8	303.4	159.9	141.8	150.9	10.50	10.40	10.45
O_5F_1	24.9	25.6	25.3	281.6	306.8	294.2	120.0	139.4	129.7	10.30	10.40	10.35
O_5F_2	24.6	25.5	25.0	288.8	333.6	311.2	135.1	142.7	138.9	10.23	10.40	10.32
O_5F_3	25.4	25.5	25.5	284.0	324.0	304.0	145.8	136.1	141.0	10.23	10.33	10.28
O × F												
S.Em (±)	0.13	0.12	0.09	5.97	6.10	4.27	4.21	3.80	2.83	0.09	0.08	0.06
C.D. at 5%	0.37	0.36	0.25	NS	NS	12.19	NS	NS	NS	NS	NS	NS
F × O												
S.Em (±)	0.14	0.14	0.10	6.31	7.07	4.74	4.88	3.62	3.04	0.08	0.08	0.06
C.D. at 5%	0.44	0.45	0.30	NS	NS	14.11	NS	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

Although the panicle length of Gobindabhog rice increased steadily with the increment of inorganic fertilizers dose from $N_{20}P_{10}K_{10}$ (F_1) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) during 2010, but it increased upto $N_{30}P_{15}K_{15}$ kg ha^{-1} (F_2) and declined thereafter during 2011. Based on pooled values for 2 years both $N_{30}P_{15}K_{15}$ kg ha^{-1} (F_2) and to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) resulted in same panicle length (25.6 cm) slightly greater over $N_{20}P_{10}K_{10}$ kg ha^{-1} (F_1) (Table 4.2.7).

4.2.2.1.3 Interaction effect between organic manure and inorganic fertilizer

The interaction effect between organic manure and inorganic fertilizer on panicle length was found significant during both the years of experimentation (Table 4.2.7).

4.2.2.2 Number of panicles m^{-2}

The number of panicle m^{-2} in all nutritional treatments was greater during 2011 than their respective values during 2010 (Table 4.2.6), which is in conformity with tillering pattern observed in the study between two years of study (Table 4.2.7).

4.2.2.2.1 Effect of organic manure

Four nutritional treatments (O_2-O_5) comprising either of organic manures (*viz.* FYM and mustard cake) at two different doses recorded significantly greater number of panicles in 1 m^{-2} area over untreated control (F_1) during both 2010 and 2011 (Table 4.2.7). Perusal of data revealed that the application of mustard cake (@ 0.25 or 0.50 t ha^{-1}) was formed better than FYM (@ 2.5 or 5.0 t ha^{-1}) toward the production of Gobindabhog paddy in the experiment.

4.2.2.2.2 Effect of inorganic fertilizer

With increase in dose of inorganic fertilizer from $N_{20}P_{10}K_{10}$ kg ha^{-1} (F_1) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3), the numbers of panicles m^{-2} was progressively increased upto 278.4 and 309.6 during 2010 and 2011, respectively; but the values were on par with the respective values of $N_{30}P_{15}K_{15}$ kg ha^{-1} (F_2) during both the years of investigation. Thus, any additional supply of inorganic fertilizers beyond $N_{30}P_{15}K_{15}$ kg ha^{-1} (F_2) did not have significant influence on greater production of panicles in Gobindabhog rice during *kharif* season.

4.2.2.2.3 Interaction effect between organic manure and inorganic fertilizer

There was significant interaction effect between organic manures and inorganic fertilizers on production of panicles m^{-2} for pooled values only (Table 4.2.7).

4.2.2.3 Number of filled grains panicle^{-1}

4.2.2.3.1 Effect of organic manure

The effect of types and doses of organic manures (*viz.* FYM and mustard cake) toward the production of number of filled grains panicle^{-1} was found complex during 2-year study at Kalyani, West Bengal (Table 4.2.7). Although the application of FYM @ 5 t ha^{-1} (O_3) usually produced the highest number of filled grain panicle^{-1}, but it was at par with the use of mustard cake @ 0.25 t ha^{-1} (O_4) in the investigation.

4.2.2.3.2 Effect of inorganic fertilizer

There was progressive improvement in number of filled grains panicle^{-1} with the increment of inorganic fertilizer dose from $N_{20}P_{10}K_{10}$ (F_1) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) during 2010 and pooled overs 2 years; but the same trend was not noted during 2011 due to non-significant variation between $N_{30}P_{15}K_{15}$ (F_2) and $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3).

4.2.2.3.3 Interaction effect between organic manure and inorganic fertilizer

No significant interaction of organic manure and inorganic fertilizer for number of filled grains panicle^{-1} was found during both the years of experimentation (Table 4.2.7).

4.2.2.4 1000 grain weight

4.2.2.4.1 Effect of organic manure

Although the test weight was a genetical character, but it differed significantly among organic manures-based nutritional treatments during 2010 and pooled over two years (Table 4.2.7). The maximum 1000-grain weight was recorded with O_4 (10.52 g) and O_2 (10.41g) during 2010 and 2011, respectively; while minimum test weight was noted with O_5 and O_1 (10.26 g) during first and second years of investigation.

4.2.2.4.2 Effect of inorganic fertilizer

Although three different levels of chemical fertilizer did not differ among themselves for 1000-grain weight during 2010 and 2011; but the application of $N_{30}P_{15}K_{15}$ kg ha^{-1} (F_2) resulted in highest test weight (10.42 g), being at par with $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) for pooled over two years (Table 4.2.7).

4.2.2.4.3 Interaction effect between organic manure and inorganic fertilizer

There was no significant interaction effect on 1000-grain weight of Gobindabhog paddy during both the years of experimentation (Table 4.2.7).

4.2.3 Yield and lodging

4.2.3.1 Grain yield

4.2.3.1.1 Effect of organic manure

Manuring of Gobindabhog paddy either with FYM (O_2 and O_3) or mustard cake (O_4 and O_5) significantly improved the grain yield over unmanured control (O_1), during both the years of investigation (Table 4.2.8; Plate 4.4). The application of FYM @ 5 t ha^{-1} (O_3) resulted in highest grain yield (2.84 and 3.02 t ha^{-1}), being at par with mustard cake @ 0.25 t ha^{-1} (O_4) during 2010 and 2011. However, Banerjee (2011) reported better effect of mustard cake than FYM or vermicompost for grain yield of Gobindabhog paddy in West Bengal.

Based on pooled values, organic manure-based treatments could be arranged as: O_3 (2.93 t ha^{-1}) $\geq$ O_4 (2.88 t ha^{-1}) > O_5 (2.78 t ha^{-1}) > O_2 (2.65 t ha^{-1}) > O_1 (2.44 t ha^{-1}).

4.2.3.1.2 Effect of inorganic fertilizer

The chemical fertilizer-based treatments in the study significantly influenced the grain yield of Gobindabhog paddy for pooled values only (Table 4.2.8). The grain yield was significantly increased with increment of NPK fertilizers dose from $N_{20}P_{10}K_{10}$ kg ha^{-1} (2.69 t ha^{-1}) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (2.76 t ha^{-1}), beyond which the additional fertilization of $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) showed no significant effect toward the grain yield.

Table 4.2.8

Effect of organic manure and inorganic fertilizer on grain yield, straw yield, harvest index and lodging of Gobindabhog rice during *kharif* season

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Harvest index			Lodging (score)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure												
O_1	2.29	2.39	2.34	4.71	4.90	4.81	0.33	0.33	0.33	4.33	4.56	4.44
O_2	2.56	2.74	2.65	5.10	5.39	5.24	0.33	0.34	0.34	4.78	4.78	4.78
O_3	2.84	3.02	2.93	5.39	5.70	5.54	0.34	0.35	0.35	5.44	5.44	5.44
O_4	2.77	3.00	2.88	5.31	5.64	5.47	0.34	0.35	0.34	4.78	5.22	5.00
O_5	2.60	2.82	2.71	5.22	5.62	5.42	0.33	0.33	0.33	5.22	5.22	5.22
S.Em (±)	0.03	0.05	0.03	0.09	0.05	0.05	0.005	0.004	0.003	0.23	0.17	0.14
C.D. at 5%	0.09	0.16	0.09	0.29	0.17	0.15	NS	NS	0.010	NS	0.56	0.43
Inorganic fertilizer												
F_1	2.55	2.76	2.66	5.04	5.30	5.17	0.34	0.34	0.34	4.47	4.60	4.53
F_2	2.65	2.81	2.73	5.14	5.48	5.31	0.34	0.34	0.34	5.00	5.27	5.13
F_3	2.63	2.80	2.72	5.26	5.56	5.41	0.33	0.33	0.33	5.27	5.27	5.27
S.Em (±)	0.03	0.02	0.02	0.05	0.04	0.03	0.003	0.003	0.002	0.20	0.20	0.14
C.D. at 5%	NS	NS	0.05	0.14	0.12	0.09	NS	NS	NS	0.60	0.58	0.40
Interaction effect												
O_1F_1	2.20	2.24	2.22	4.66	4.69	4.68	0.32	0.32	0.32	3.67	3.67	3.67
O_1F_2	2.36	2.48	2.42	4.65	4.92	4.79	0.34	0.34	0.34	4.33	5.00	4.67
O_1F_3	2.32	2.46	2.39	4.83	5.09	4.96	0.32	0.33	0.33	5.00	5.00	5.00
O_2F_1	2.40	2.62	2.51	5.01	5.35	5.18	0.32	0.33	0.33	4.33	4.33	4.33
O_2F_2	2.55	2.69	2.62	5.15	5.48	5.31	0.33	0.33	0.33	5.00	5.00	5.00
O_2F_3	2.74	2.90	2.82	5.15	5.33	5.24	0.35	0.35	0.35	5.00	5.00	5.00
O_3F_1	2.66	2.92	2.79	5.26	5.55	5.41	0.34	0.34	0.34	5.00	5.00	5.00
O_3F_2	2.94	3.03	2.99	5.42	5.73	5.58	0.35	0.35	0.35	5.67	5.67	5.67
O_3F_3	2.91	3.11	3.01	5.49	5.81	5.65	0.35	0.35	0.35	5.67	5.67	5.67
O_4F_1	2.86	3.12	2.99	5.12	5.60	5.36	0.36	0.36	0.36	4.33	5.00	4.67
O_4F_2	2.81	3.05	2.93	5.32	5.57	5.44	0.35	0.35	0.35	5.00	5.00	5.00
O_4F_3	2.63	2.83	2.73	5.48	5.74	5.61	0.32	0.33	0.33	5.00	5.67	5.33
O_5F_1	2.65	2.92	2.79	5.16	5.33	5.25	0.34	0.35	0.35	5.00	5.00	5.00
O_5F_2	2.59	2.82	2.71	5.14	5.69	5.42	0.34	0.33	0.33	5.00	5.67	5.33
O_5F_3	2.55	2.72	2.64	5.36	5.83	5.60	0.32	0.32	0.32	5.67	5.00	5.33
O × F												
S.Em (±)	0.06	0.05	0.04	0.10	0.09	0.07	0.008	0.006	0.005	0.46	0.44	0.32
C.D. at 5%	0.19	0.16	0.12	NS	NS	NS	NS	0.017	0.014	NS	NS	NS
F × O												
S.Em (±)	0.06	0.07	0.04	0.12	0.09	0.08	0.008	0.007	0.005	0.44	0.40	0.30
C.D. at 5%	0.18	0.21	0.13	NS	NS	NS	NS	0.020	0.015	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

4.2.3.1.3 Interaction effect between organic manure and inorganic fertilizer

Organic manure × inorganic fertilizer interaction effect on grain yield was found significant during both 2010 and 2011 (Table 4.2.8; Fig. 4.8). Among different treatments combinations, O_3F_3 (FYM @ 5 t ha^{-1} + $N_{40}P_{20}K_{20}$ kg ha^{-1}) produced the highest grain yield (3.01 t ha^{-1}), being closely followed by O_3F_2 (FYM @ 5 t ha^{-1} + $N_{30}P_{15}K_{15}$ kg ha^{-1}), O_4F_1 (mustard cake @ 0.25 t ha^{-1} + $N_{20}P_{10}K_{10}$ kg ha^{-1}) and O_4F_2 (mustard cake @ 0.25 t ha^{-1} + $N_{30}P_{15}K_{15}$ kg ha^{-1}) in the investigation.

4.2.3.2 Straw yield

Straw yield, irrespective of main and sub-plot treatments, was higher during 2011 than the earlier year (2010) of study (Table 4.2.8).

4.2.3.2.1 Effect of organic manure

The straw yield of Gobindabhog rice differed significantly among organic manure-based treatments in the study during both 2010 and 2011 (Table 4.2.8). The treatments (O_3) comprising FYM @ 5.0 t ha^{-1} resulted in highest straw yield (5.54 t ha^{-1}), being at par with two mustard cake-based treatments (O_4 and O_5) for pooled values as well as for both the years of experimentation.

4.2.3.2.2 Effect of inorganic fertilizer

There was successive increase in straw yield with the increment of chemical fertilizer dose from $N_{20}P_{10}K_{10}$ (F_1) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3), where the highest straw yield was recorded with F_3, being at par with F_2 ($N_{30}P_{15}K_{15}$ kg ha^{-1}) during both 2010 and 2011 (Table 4.2.8).

4.2.3.2.3 Interaction effect between organic manure and inorganic fertilizer

The effect of interaction between organic manure and inorganic fertilizer on straw yield was not significant during both the years of study (Table 4.2.8).

4.2.3.3 Harvest index

4.2.3.3.1 Effect of organic manure

The perusal of data revealed that there was vary little differences in harvest index during both 2010 and 2011 (0.33-0.35) among organic manure-based treatments, which were non-significant for both the years as well as for pooled values in the investigation (Table 4.2.8).

4.2.3.3.2 Effect of inorganic fertilizer

The variation in dose in chemical fertilizer did not affect significantly the harvest index of Gobindabhog rice during both the years of experimentation (Table 4.2.8).

4.2.3.3.3 Interaction effect between organic manure and inorganic fertilizer

There was no significant effect between organic manure and inorganic fertilizer with regard to harvest index during both 2010 and 2011 (Table 4.2.8).

4.2.3.4 Lodging

The lodging scores assigned with both main and sub-plot treatments indicated that most (> 50%) of Gobindabhog plants had a general tendency to lodge down completely (score 5.00) in the study (Table 4.2.8).

4.2.3.4.1 Effect of organic manure

The lodging tendency of Gobindabhog paddy at near-maturity stage was significantly influenced by organic manure based treatments during 2011 and pooled for 2-year in the investigation (Table 4.2.8).

The application of either of organic manure (viz. FYM and mustard cake) increased the lodging tendency (4.78-5.44) over unmanured control (4.44) as well as the higher doses of organic manures (O_3 and O_5) favoured lodging compared to lower of respective manure (O_2) and cake (O_4) in the investigation (Table 4.2.8).

4.2.3.4.2 Effect of inorganic fertilizer

With increment of chemical fertilizer dose from $N_{20}P_{10}K_{10}$ (F_1) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3), the plants of Gobindabhog paddy became more susceptible to lodging at hard dough stage.

4.2.3.4.3 Interaction effect between organic manure and inorganic fertilizer

The interaction effect of organic manure and inorganic fertilizer on lodging tendency of Gobindabhog paddy was not significant during both the years of experimentation (Table 4.2.8).

4.2.4 Grain quality

4.2.4.1 Milling quality

4.2.4.1.1 Hulling

4.2.4.1.1.1 Effect of organic manure

The hulling recovery of Gobindabhog rice was significantly influenced by organic manure-based treatments during 2010 and pooled for two years in the study (Table 4.2.9). The application of mustard cake @ 0.50 t ha^{-1} (O_5) resulted in highest hulling recovery (79.4% and 79.3%) during both 2010 and 2011, while unmanured control (O_1) recorded lowest brown rice content (77.3% and 78.6%) after shelling of rice.

4.2.4.1.1.2 Effect of inorganic fertilizer

The variations in dose of chemical fertilizers could not affect the hulling recovery of Gobindabhog rice during both the years of experimentation (Table 4.2.9).

4.2.4.1.1.3 Interaction effect between organic manure and inorganic fertilizer

The interaction effect between organic manure and inorganic fertilizer toward hulling recovery was found significant during 2010 and pooled for two years (Table 4.2.9).

4.2.4.1.2 Milling

4.2.4.1.2.1 Effect of organic manure

The milling recovery of Gobindabhog rice grain was found to vary between 71.9 (O_1) and 72.9% (O_4) during 2010, and between 72.2 (O_4) and 73.4% (O_2) during 2011; but the differences were not significant in either of the year of investigation (Table 4.2.9).

4.2.4.1.2.2 Effect of inorganic fertilizer

The little differences in milling recovery due to three doses of chemical fertilizers in the study were not found significant during both 2010 and 2011 (Table 4.2.9).

Table 4.2.9

Effect of organic manure and inorganic fertilizer on milling quality of Gobindabhog rice during *kharif* season

Treatment	Milling quality								
	Hulling (%)			Milling (%)			Head rice recovery (%)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure									
O_1	77.3	78.6	77.9	71.9	72.8	72.4	61.4	61.9	61.6
O_2	78.2	79.2	78.7	72.1	73.4	72.7	61.8	62.3	62.0
O_3	78.3	79.0	78.6	72.5	73.0	72.7	61.9	62.6	62.3
O_4	78.5	77.6	78.1	72.9	72.2	72.5	61.7	63.5	62.6
O_5	79.4	79.3	79.3	72.5	72.9	72.7	61.8	62.3	62.1
S.Em (±)	0.31	0.39	0.25	0.34	0.23	0.20	0.310	0.303	0.217
C.D. at 5%	1.01	NS	0.74	NS	NS	NS	NS	0.989	NS
Inorganic fertilizer									
F_1	77.8	78.6	78.2	72.2	72.8	72.5	61.5	62.5	62.0
F_2	78.7	78.7	78.7	72.5	72.8	72.6	61.7	62.7	62.2
F_3	78.4	78.9	78.7	72.4	72.9	72.7	62.0	62.4	62.2
S.Em (±)	0.30	0.30	0.21	0.28	0.25	0.19	0.232	0.212	0.157
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect									
O_1F_1	76.8	78.0	77.4	71.8	72.4	72.1	60.6	61.7	61.1
O_1F_2	77.6	78.6	78.1	72.0	72.9	72.4	61.5	61.5	61.5
O_1F_3	77.5	79.1	78.3	71.8	73.2	72.5	62.1	62.4	62.2
O_2F_1	76.2	79.2	77.7	70.9	73.3	72.1	62.4	61.9	62.1
O_2F_2	78.2	79.0	78.6	72.2	73.2	72.7	61.0	62.4	61.7
O_2F_3	80.0	79.5	79.8	73.1	73.6	73.4	61.9	62.7	62.3
O_3F_1	78.2	78.6	78.4	73.6	72.9	73.3	61.0	62.5	61.8
O_3F_2	79.4	79.1	79.3	72.6	73.0	72.8	62.1	63.4	62.7
O_3F_3	77.3	79.2	78.3	71.2	73.1	72.1	62.8	62.0	62.4
O_4F_1	77.4	77.5	77.5	72.4	72.4	72.4	61.2	63.4	62.3
O_4F_2	78.9	77.6	78.3	72.9	72.3	72.6	62.0	63.5	62.8
O_4F_3	79.1	77.7	78.4	73.4	71.9	72.6	62.0	63.5	62.8
O_5F_1	80.5	79.7	80.1	72.3	73.1	72.7	62.5	62.8	62.7
O_5F_2	79.5	79.0	79.3	72.7	72.7	72.7	61.8	62.6	62.2
O_5F_3	78.1	79.0	78.6	72.5	72.9	72.7	61.2	61.5	61.4
O × F									
S.Em (±)	0.66	0.68	0.47	0.62	0.57	0.42	0.52	0.47	0.35
C.D. at 5%	1.95	NS	1.36	NS	NS	NS	NS	NS	NS
F × O									
S.Em (±)	0.62	0.68	0.46	0.61	0.52	0.40	0.52	0.49	0.36
C.D. at 5%	1.88	NS	1.34	NS	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

4.2.4.1.2.3 Interaction effect between organic manure and inorganic fertilizer

No significant interaction between organic manure and inorganic fertilizer was noticed toward the milling recovery during both the years of experimentation (Table 4.2.9).

4.2.4.1.3 Head rice

4.2.4.1.3.1 Effect of organic manure

Head rice recovery of Gobindabhog rice was affected significantly by organic manure-based treatments during second year only in 2-year experiment (Table 4.2.9). During 2011, the application of mustard cake @ 0.25 t ha^{-1} (D_4) resulted in highest head rice recovery (63.5%), being significantly greater over other treatments. Although manuring of Gobindabhog paddy with FYM or mustard cake at either of doses favourd the head rice yield over unmanured control (O_1), but it did not show any definite trend among manure treated plots (O_2 - O_5) in the study. Banerjee (2011) reported similar finding for Gobindabhog paddy treated with organic manures of different types and doses at the same site of West Bengal.

4.2.4.1.3.2 Effect of inorganic fertilizer

The application of N-P-K fertilizers at three different doses did not influence the head rice recovery during both the years of investigation (Table 4.2.9).

4.2.4.1.3.3 Interaction effect between organic manure and inorganic fertilizer

Organic manure × inorganic fertilizer interaction effect on head rice recovery yield of Gobindabhog rice was not significant during both 2010 and 2011 (Table 4.2.9).

4.2.4.2 Physical properties of grain

4.2.4.2.1 Kernel length

The kernel length, irrespective of main or subplot treatments, was usually longer in 2011 than 2010, probably because of either better grain filling and development and / or less degree of milling during second year compared to first year of the investigation (Table 4.2.10).

Table 4.2.10

Effect of organic manure and inorganic fertilizer on physical properties of grain of Gobindabhog rice during *kharif* season

Treatment	Physical properties of grain								
	Kernel length (mm)			Kernel breadth (mm)			L / B ratio		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure									
O_1	3.82	4.06	3.94	1.86	2.00	1.93	2.06	2.04	2.05
O_2	3.89	4.02	3.96	1.86	1.99	1.92	2.10	2.02	2.06
O_3	3.81	4.02	3.91	1.91	2.01	1.96	2.00	2.00	2.00
O_4	3.91	4.10	4.01	1.88	2.04	1.96	2.08	2.02	2.05
O_5	3.84	4.02	3.93	1.90	2.02	1.96	2.03	1.99	2.01
S.Em (±)	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.04	0.02
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Inorganic fertilizer									
F_1	3.86	4.08	3.97	1.87	2.00	1.93	2.07	2.04	2.06
F_2	3.85	4.05	3.95	1.88	2.00	1.94	2.05	2.03	2.04
F_3	3.86	4.01	3.93	1.89	2.04	1.96	2.04	1.97	2.01
S.Em (±)	0.02	0.02	0.02	0.02	0.02	0.01	0.03	0.02	0.02
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect									
O_1F_1	3.93	4.11	4.02	1.87	1.97	1.92	2.11	2.09	2.10
O_1F_2	3.80	4.06	3.93	1.83	2.01	1.92	2.07	2.03	2.05
O_1F_3	3.73	4.02	3.88	1.87	2.01	1.94	2.00	2.00	2.00
O_2F_1	3.97	4.12	4.04	1.87	1.99	1.93	2.13	2.07	2.10
O_2F_2	3.80	3.96	3.88	1.83	1.93	1.88	2.08	2.06	2.07
O_2F_3	3.90	3.99	3.95	1.87	2.06	1.96	2.09	1.94	2.02
O_3F_1	3.67	4.13	3.90	1.87	2.01	1.94	1.97	2.06	2.01
O_3F_2	3.90	4.02	3.96	1.97	2.03	2.00	1.98	1.98	1.98
O_3F_3	3.87	3.90	3.88	1.90	2.00	1.95	2.04	1.96	2.00
O_4F_1	3.93	4.14	4.04	1.87	2.01	1.94	2.11	2.06	2.08
O_4F_2	3.83	4.15	3.99	1.90	2.04	1.97	2.02	2.03	2.03
O_4F_3	3.97	4.02	3.99	1.87	2.06	1.96	2.13	1.96	2.04
O_5F_1	3.80	3.92	3.86	1.87	2.02	1.94	2.04	1.94	1.99
O_5F_2	3.90	4.03	3.97	1.87	1.99	1.93	2.09	2.03	2.06
O_5F_3	3.83	4.11	3.97	1.97	2.05	2.01	1.95	2.01	1.98
O × F									
S.Em (±)	0.05	0.05	0.03	0.04	0.04	0.03	0.06	0.05	0.04
C.D. at 5%	0.14	0.15	0.10	NS	NS	NS	NS	NS	NS
F × O									
S.Em (±)	0.05	0.05	0.04	0.04	0.04	0.03	0.05	0.05	0.04
C.D. at 5%	0.14	0.15	0.10	NS	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

4.2.4.2.1.1 Effect of organic manure

The kernel length of Gobindabhog rice, being a genetical character, remained unaffected under different organic manure-based treatments during both the years of experiment (Table 4.2.10).

4.2.4.2.1.2 Effect of inorganic fertilizer

There was no significant difference in kernel length due to variation in chemical fertilizers doses during both 2010 and 2011 (Table 4.2.10), but additional N-P-K fertilization over $N_{20}P_{10}K_{10}$ kg ha^{-1} (F_1) surprisingly reduced the kernel length in the study.

4.2.4.2.1.3 Interaction effect between organic manure and inorganic fertilizer

The interaction effect between organic manure and inorganic fertilizer toward the length of kernel of Gobindabhog rice was found significant during both the years of experimentation (Table 4.2.10).

4.2.4.2.2 Kernel breadth

4.2.4.2.2.1 Effect of organic manure

The variation in types and doses of organic manures including unmanured control could not affect the breadth of Gobindabog rice kernel during both 2010 and 2011 (Table 4.2.10).

4.2.4.2.2.2 Effect of inorganic fertilizer

The kernel breadth of Gobindabhog rice did not differ significantly among different doses of chemical fertilizers during both the years of experimentation (Table 4.2.10).

4.2.4.2.2.3 Interaction effect between organic manure and inorganic fertilizer

No significant interaction effect between organic manure and chemical fertilizer was found toward the breadth of Gobindabhog rice kernel in the investigation (Table 4.2.10).

4.2.4.2.3 L / B ratio

4.2.4.2.3.1 Effect of organic manure

With regard to L / B ratio, there was no significant effect due to five organic manure-based treatments in the study (Table 4.2.10).

4.2.4.2.3.2 Effect of inorganic fertilizer

The L / B ratio of rice kernel was not significantly influenced by three levels of chemical fertilizers used in the experiment during both 2010 and 2011 (Table 4.2.10).

4.2.4.2.3.3 Interaction effect between organic manure and inorganic fertilizer

There was no significant interaction effect between organic manure and inorganic fertilizer on L / B ratio of Gobindabhog rice during both the years of experimentation (Table 4.2.10).

4.2.4.3 Kernel type, colour and chalkiness

4.2.4.3.1 Effect of organic manure

Based on length and L / B ratio of rice kernel obtained from different organic manure treated plots, Gobindabhog rice could be placed in short bold (SB) type category (Table 4.2.11). The colour of kernel was white including the absence of chalkiness irrespective of treatments in the investigation.

4.2.4.3.2 Effect of inorganic fertilizer

The N-P-K fertilizers at different doses could not affect the kernel shape or type, colour and abdominal white during both 2010 and 2011 (Table 4.2.11).

4.2.4.3.3 Interaction effect between organic manure and inorganic fertilizer

Gobindabhog rice had short bold type, white and non-chalky kernels at any combinations of organic manure and chemical fertilizer in the experiment (Table 4.2.11).

4.2.4.4 Cooking quality and nutritional quality

4.2.4.4.1 Amylose content

4.2.4.4.1.1 Effect of organic manure

Mnauring of Gobindabhog paddy with FYM @ 5.0 t ha^{-1} (O_3), and mustard cake @ 0.25 (O_4) and 0.50 t ha^{-1} (O_5) could significantly improve the amylose content in grain over unmanured control (O_1) and FYM @ 2.5 t ha^{-1}(O_2) during both the years of study (Table 4.2.12).

Table 4.2.11

Effect of organic manure and inorganic fertilizer on physical properties of grain of Gobindabhog rice during *kharif* season

Treatment	Physical properties of grain					
	Kernel type		Chalkiness		Kernel colour	
	2010	2011	2010	2011	2010	2011
Organic manure						
O_1	SB	SB	Absent	Absent	White	White
O_2	SB	SB	Absent	Absent	White	White
O_3	SB	SB	Absent	Absent	White	White
O_4	SB	SB	Absent	Absent	White	White
O_5	SB	SB	Absent	Absent	White	White
Inorganic fertilizer						
F_1	SB	SB	Absent	Absent	White	White
F_2	SB	SB	Absent	Absent	White	White
F_3	SB	SB	Absent	Absent	White	White
Interaction effect						
O_1F_1	SB	SB	Absent	Absent	White	White
O_1F_2	SB	SB	Absent	Absent	White	White
O_1F_3	SB	SB	Absent	Absent	White	White
O_2F_1	SB	SB	Absent	Absent	White	White
O_2F_2	SB	SB	Absent	Absent	White	White
O_2F_3	SB	SB	Absent	Absent	White	White
O_3F_1	SB	SB	Absent	Absent	White	White
O_3F_2	SB	SB	Absent	Absent	White	White
O_3F_3	SB	SB	Absent	Absent	White	White
O_4F_1	SB	SB	Absent	Absent	White	White
O_4F_2	SB	SB	Absent	Absent	White	White
O_4F_3	SB	SB	Absent	Absent	White	White
O_5F_1	SB	SB	Absent	Absent	White	White
O_5F_2	SB	SB	Absent	Absent	White	White
O_5F_3	SB	SB	Absent	Absent	White	White

Table 4.2.12

Effect of organic manure and inorganic fertilizer on cooking and nutritional quality of grains of Gobindabhog rice during *kharif* season

Treatment	Cooking and nutritional quality of grain								
	Amylose content (%)			Protein content (%)			Alkali value (score)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure									
O_1	18.00	18.13	18.07	6.93	7.01	6.97	3.89	3.78	3.83
O_2	18.08	18.16	18.12	7.48	7.23	7.36	4.00	4.11	4.06
O_3	18.34	18.47	18.40	7.62	7.55	7.59	3.78	4.00	3.89
O_4	18.21	18.70	18.45	7.24	7.65	7.45	4.00	4.22	4.11
O_5	18.27	18.40	18.33	7.35	7.60	7.48	4.00	4.11	4.06
S.Em (±)	0.07	0.10	0.06	0.09	0.13	0.08	0.26	0.25	0.18
C.D. at 5%	0.23	0.31	0.18	0.29	0.43	0.24	NS	NS	NS
Inorganic fertilizer									
F_1	18.16	18.26	18.21	7.08	7.36	7.22	3.87	3.93	3.90
F_2	18.16	18.39	18.27	7.44	7.31	7.37	3.87	4.07	3.97
F_3	18.22	18.46	18.34	7.46	7.56	7.51	4.07	4.13	4.10
S.Em (±)	0.05	0.05	0.04	0.05	0.07	0.04	0.16	0.18	0.12
C.D. at 5%	NS	0.16	NS	0.14	0.20	0.12	NS	NS	NS
Interaction effect									
O_1F_1	17.99	17.95	17.97	6.96	6.78	6.87	4.00	4.00	4.00
O_1F_2	18.02	18.21	18.12	7.12	6.94	7.03	4.00	3.67	3.83
O_1F_3	17.97	18.24	18.11	6.70	7.30	7.00	3.67	3.67	3.67
O_2F_1	18.04	17.94	17.99	7.27	7.41	7.34	4.00	4.00	4.00
O_2F_2	18.02	18.31	18.16	7.37	7.11	7.24	3.67	4.00	3.83
O_2F_3	18.18	18.24	18.21	7.80	7.18	7.49	4.33	4.33	4.33
O_3F_1	18.29	18.39	18.34	7.49	7.54	7.52	3.67	3.67	3.67
O_3F_2	18.43	18.54	18.49	7.79	7.20	7.50	3.67	4.00	3.83
O_3F_3	18.30	18.47	18.39	7.59	7.91	7.75	4.00	4.33	4.17
O_4F_1	18.26	18.54	18.40	6.91	7.51	7.21	4.00	4.33	4.17
O_4F_2	18.10	18.64	18.37	7.49	7.71	7.60	3.67	4.33	4.00
O_4F_3	18.26	18.92	18.59	7.33	7.72	7.53	4.33	4.00	4.17
O_5F_1	18.19	18.50	18.35	6.77	7.55	7.16	3.67	3.67	3.67
O_5F_2	18.23	18.24	18.24	7.41	7.57	7.49	4.33	4.33	4.33
O_5F_3	18.38	18.46	18.42	7.88	7.69	7.78	4.00	4.33	4.17
O × F									
S.Em (±)	0.12	0.12	0.09	0.10	0.15	0.09	0.35	0.40	0.27
C.D. at 5%	NS	NS	NS	0.30	NS	0.26	NS	NS	NS
F × O									
S.Em (±)	0.12	0.14	0.09	0.12	0.18	0.11	0.39	0.41	0.28
C.D. at 5%	NS	NS	NS	0.38	NS	0.32	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

Thus, the observation of Prakash *et al.* (2002) for lower amylose content of Pusa Basmati in FYM treatment than commercial manures could be applicable to lower FYM dose @ 2.5 t ha^{-1} (O_2) only, excluding the explanation for positive influence of higher FYM dose @ 5.0 t ha^{-1} (O_3) on amylose content of Gobindabhog rice in the experiment. The maximum amylose content was noted with FYM @ 5.0 t ha^{-1} (18.34%) during 2010 and mustard cake @ 0.25 t ha^{-1} (18.70%) during 2011, but the lowest values were always with unmanured control (18.00 and 18.13%) during both the years of investigation.

4.2.4.4.1.2 Effect of inorganic fertilizer

Although there was a general improving trend in amylose content of Gobindabhog rice with the increment in N-P-K dose of fertilizers, including significant influence during 2011 only in 2-year experiment (Table 4.2.12). During second year, the highest amylose content (18.46%) was recorded with $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) and the same pattern was also observed in 2010 and pooled values including non-significant variation in the study.

4.2.4.4.1.3 Interaction effect between organic manure and inorganic fertilizer

Organic manure × chemical fertilizer interaction effect on amylose content was not significant during both the years of experimentation (Table 4.2.12).

4.2.4.4.2 Protein content

4.2.4.4.2.1 Effect of organic manure

Although four organic manure based treatments (O_2 - O_5) improved the protein content of Gobindabhog rice grain compared to unmanured control (O_1), but the trend of variation was not consistent across the years (Table 4.2.12; Fig. 4.9). The application of FYM @ 5.0 t ha^{-1} (O_3) recorded the highest protein content during 2010 (7.62%) and for pooled values (7.59%), while mustard cake @ 0.25 t ha^{-1} (O_4) during 2011 (7.65%) in the study. There findings were partly consistent with Prakash *et al.*, (2002), wherein, FYM treatments to Pusa Basmati gave higher protein content than treatments with commercial manures and chemical fertilizers.

4.2.4.4.2.2 Effect of inorganic fertilizer

There was, in general, a steady increase in grain protein content of Gobindabhog rice with increment in chemical fertilizer level from $N_{20}P_{10}K_{10}$ (F_1) to

$N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) and the differences were significant during both the years of investigation (Table 4.2.12). The highest protein content (7.51%) noted with $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) might be due to greater N supply (40 kg ha^{-1}) leading to better protein synthesis compared to lower N doses (20 kg and 30 kg ha^{-1}) in the study.

4.2.4.4.2.3 Interaction effect between organic manure and inorganic fertilizer

The interaction effect between organic manure and inorganic fertilizer on grain protein content was significant during 2010 and pooled study of two years (Table 4.2.12).

4.2.4.4.3 Alkali value or Gelatinization temperature

4.2.4.4.3.1 Effect of organic manure

The range of variation in alkali value, being non-significant, among organic manure based treatments during both the years of study indicated that Gobindabhog rice usually had intermediate (70-74 ^{0}C) gelatinization temperature.

4.2.4.4.3.2 Effect of inorganic fertilizer

The general trend of increase in alkali value with increment of chemical fertilizer level could not be explained due to non-significant variation among the treatments during both the years of experimentation (Table 4.2.12).

4.2.4.4.3.3 Interaction effect between organic manure and inorganic fertilizer

The combination of organic manures and inorganic fertilizers in the study revealed similar range of variation in alkali value (3.67-4.33) during both 2010 and 2011, which indicated intermediate gelatinization temperature of Gobindabhog rice grain.

4.2.4.5 Processing quality

4.2.4.5.1 Kernel length after cooking (KLAC)

4.2.4.5.1.1 Effect of organic manure

The application of organic manures in either of the types and doses could not affect the kernel length after cooking during both the years of investigation (Table 4.2.13).

Table 4.2.13

Effect of organic manure and inorganic fertilizer on processing quality of grains of Gobindabhog rice during *kharif* season

Treatment	Processing quality								
	Kernel length after cooking (mm)			Elongation ratio			Aroma (score)		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure									
O_1	6.90	7.12	7.01	1.81	1.75	1.78	2.22	2.56	2.39
O_2	7.05	7.09	7.07	1.81	1.76	1.79	2.33	2.44	2.39
O_3	7.14	7.23	7.19	1.87	1.80	1.84	2.33	2.56	2.44
O_4	7.22	7.43	7.33	1.85	1.81	1.83	2.44	2.56	2.50
O_5	7.24	7.37	7.30	1.88	1.83	1.86	2.56	2.67	2.61
S.Em (±)	0.15	0.08	0.08	0.03	0.01	0.02	0.27	0.14	0.15
C.D. at 5%	NS	NS	NS	NS	0.04	0.06	NS	NS	NS
Inorganic fertilizer									
F_1	7.00	7.14	7.07	1.82	1.75	1.78	2.33	2.47	2.40
F_2	7.18	7.26	7.22	1.86	1.79	1.83	2.33	2.60	2.47
F_3	7.15	7.35	7.25	1.85	1.83	1.84	2.47	2.60	2.53
S.Em (±)	0.11	0.05	0.06	0.03	0.02	0.02	0.21	0.16	0.13
C.D. at 5%	NS	0.15	NS	NS	0.05	0.05	NS	NS	NS
Interaction effect									
O_1F_1	6.79	7.19	6.99	1.73	1.75	1.74	2.00	2.33	2.17
O_1F_2	7.02	6.92	6.97	1.85	1.71	1.78	2.00	2.67	2.33
O_1F_3	6.89	7.26	7.07	1.85	1.80	1.83	2.67	2.67	2.67
O_2F_1	7.27	6.89	7.08	1.83	1.67	1.75	2.00	2.33	2.17
O_2F_2	6.87	7.26	7.07	1.81	1.83	1.82	2.67	2.33	2.50
O_2F_3	7.01	7.12	7.07	1.80	1.78	1.79	2.33	2.67	2.50
O_3F_1	6.81	7.09	6.95	1.86	1.72	1.79	2.67	2.33	2.50
O_3F_2	7.27	7.22	7.25	1.86	1.80	1.83	2.33	3.00	2.67
O_3F_3	7.33	7.39	7.36	1.90	1.90	1.90	2.00	2.33	2.17
O_4F_1	7.24	7.46	7.35	1.84	1.80	1.82	2.67	2.67	2.67
O_4F_2	7.27	7.56	7.42	1.90	1.82	1.86	2.33	2.33	2.33
O_4F_3	7.14	7.29	7.22	1.80	1.82	1.81	2.33	2.67	2.50
O_5F_1	6.91	7.09	7.00	1.82	1.81	1.81	2.33	2.67	2.50
O_5F_2	7.44	7.32	7.38	1.91	1.82	1.86	2.33	2.67	2.50
O_5F_3	7.37	7.69	7.53	1.92	1.87	1.90	3.00	2.67	2.83
O × F									
S.Em (±)	0.25	0.12	0.14	0.06	0.04	0.04	0.46	0.36	0.29
C.D. at 5%	NS	0.35	NS	NS	NS	NS	NS	NS	NS
F × O									
S.Em (±)	0.25	0.12	0.14	0.06	0.03	0.04	0.46	0.32	0.28
C.D. at 5%	NS	0.38	NS	NS	NS	NS	NS	NS	NS

DAT = Days after transplanting; NS = Not significant

4.2.4.5.1.2 Effect of inorganic fertilizer

The length of cooked kernel of Gobindabhog rice was significantly influenced by chemical fertilizers-based treatments during second year only in the 2-year study (Table 4.2.13). During 2011, the maximum (7.35 mm) and minimum (7.14 mm) KLAC was recorded with $N_{40}P_{20}K_{20}$ (F_3) and $N_{20}P_{10}K_{10}$ kg ha^{-1} (F_1), respectively.

4.2.4.5.1.3 Interaction effect between organic manure and inorganic fertilizer

The effect of interaction between organic manure and chemical fertilizer on cooked kernel length was significant during second year of investigation (Table 4.2.13).

4.2.4.5.2 Elongation ratio

4.2.4.5.2.1 Effect of organic manure

Manuring of Gobindabhog paddy by either of FYM or mustard cake even at two different doses (O_2-O_3 and O_4-O_5) usually improved the kernel elongation ratio of Gobindabhog rice over unmanured control (O_1), but the differences were significant during 2011 and pooled for two years (Table 4.2.13) including non-significant trend across the years. On the contrary, Banerjee (2011) earlier reported no influence of organic manures on ER of Gobindabhog rice at the same site in West Bengal.

4.2.4.5.2.2 Effect of inorganic fertilizer

The application of chemical fertilizers at three different levels significantly influenced the elongation ratio of Gobindabhog rice kernel during 2011 and pooled for two years (Table 4.2.13), wherein the maximum (1.84) and minimum (1.78) ER were recorded with $N_{40}P_{20}K_{20}$ (F_3) and $N_{20}P_{10}K_{10}$ kg ha^{-1} (F_1), respectively for pooled study.

4.2.4.5.2.3 Interaction effect between organic manure and inorganic fertilizer

There was no significant interaction effect between organic manure and chemical fertilizer on elongation ratio of rice kernel during both the years of investigation (Table 4.2.13).

4.2.4.5.3 Aroma

The aroma score, irrespective of main and sub-plot treatments, in the study indicated that Gobindabhog rice had medium-strong aroma during both 2010 and 2011, including better intensity during first year than second year (Table 4.2.13).

4.2.4.5.3.1 Effect of organic manure

The intensity of aroma in Gobindabhog rice grain was slightly improved due to application of organic manures in either of types and doses (O_2 - O_5) over unmanured control (O_1), but the differences were non-significant during both the years of investigation (Table 4.2.13). The application of mustard cake @ 0.5 t ha^{-1} (O_5) resulted in production of grains with maximum aroma score (2.33 - 2.56) for 2010, 2011 and pooled study.

4.2.4.5.3.2 Effect of inorganic fertilizer

The non-significant improvement in aroma score with additional use of NPK fertilizer from $N_{20}P_{10}K_{10}$ (F_1) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) revealed medium-strong aroma in Gobindabhog rice during both the years of investigation (Table 4.2.13). Similarly, 50 kg N ha^{-1} did not show additional benefit regarding aroma synthesis in Basmati (*cv.* Pusa) over 25 kg ha^{-1} at Mymensingh, Bangladesh (Dutta *et al.*, 1999).

4.2.4.5.3.3 Interaction effect between organic manure and inorganic fertilizer

Organic manure × inorganic fertilizer interaction effect on aroma in Gobindabhog rice grain was not significant during both the years of study (Table 4.2.13)

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

4.2.5.1 Nutrient uptake

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

4.2.5.1.1.1 Effect of organic manure

The pattern of nitrogen uptake by Gobindabhog rice crop showed a steady increasing trend from 28 DAT to harvest in the investigation (Table 4.2.14). The finding was consistent with the increment of dry matter production by the plants with the advancement of crop growth upto maturity. N uptake irrespective of treatments, was usually higher in 2011 than 2010 at 28, 56 DAT and harvest, excluding the

Table 4.2.14

Effect of organic manure and inorganic fertilizer on total nitrogen uptake by plants at different stage of Gobindabhog rice during *kharif* season

Treatment	Nitrogen uptake (kg ha^{-1})														
	28 DAT			56 DAT			At harvest								
	Total			Total			Grain			Straw			Total		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure															
O_1	16.5	17.7	17.1	23.5	25.9	24.7	24.3	24.1	24.2	10.5	11.2	10.9	34.8	35.4	35.1
O_2	17.8	19.0	18.4	27.2	27.8	27.5	30.8	28.1	29.4	12.5	13.5	13.0	43.3	41.6	42.4
O_3	18.5	19.3	18.9	27.6	28.9	28.2	29.5	30.6	30.1	12.5	12.9	12.7	42.0	43.5	42.7
O_4	18.4	19.2	18.8	27.6	29.3	28.5	30.2	30.8	30.5	12.0	12.9	12.5	42.2	43.7	43.0
O_5	19.4	19.8	19.6	28.9	31.7	30.3	26.7	29.4	28.0	12.8	14.2	13.5	39.4	43.6	41.5
S.Em (±)	0.28	0.14	0.16	0.26	0.40	0.24	0.49	0.57	0.38	0.21	0.12	0.12	0.44	0.63	0.38
C.D. at 5%	0.91	0.46	0.47	0.84	1.31	0.72	1.60	1.86	1.13	0.67	0.38	0.35	1.45	2.05	1.15
Inorganic fertilizer															
F_1	17.4	18.3	17.8	26.2	27.8	27.0	26.9	28.2	27.5	11.7	12.4	12.0	38.6	40.6	39.6
F_2	18.1	18.9	18.5	27.2	28.8	28.0	28.8	28.7	28.8	12.0	13.1	12.5	40.8	41.8	41.3
F_3	18.9	19.9	19.4	27.5	29.6	28.6	29.1	28.9	29.0	12.5	13.3	12.9	41.6	42.2	41.9
S.Em (±)	0.11	0.14	0.09	0.17	0.14	0.11	0.50	0.26	0.28	0.11	0.11	0.08	0.49	0.26	0.28
C.D. at 5%	0.33	0.41	0.25	0.49	0.43	0.32	1.49	NS	0.81	0.32	0.33	0.22	1.44	0.76	0.79
Interaction effect															
O_1F_1	15.9	16.9	16.4	22.8	25.4	24.1	21.8	22.4	22.1	9.4	9.9	9.6	31.1	32.3	31.7
O_1F_2	16.8	17.9	17.3	23.7	26.1	24.9	25.5	25.2	25.4	10.4	10.8	10.6	35.9	36.0	36.0
O_1F_3	16.8	18.4	17.6	24.0	26.2	25.1	25.5	24.8	25.2	11.8	13.0	12.4	37.3	37.8	37.6
O_2F_1	17.1	17.8	17.5	27.1	27.0	27.1	27.4	26.9	27.2	12.3	13.9	13.1	39.7	40.9	40.3
O_2F_2	17.8	19.3	18.5	27.3	27.9	27.6	33.9	27.2	30.6	12.8	13.6	13.2	46.7	40.7	43.7
O_2F_3	18.5	20.0	19.3	27.3	28.5	27.9	30.9	30.2	30.6	12.5	13.0	12.7	43.4	43.2	43.3
O_3F_1	18.3	18.4	18.4	27.0	27.9	27.4	28.5	29.5	29.0	12.6	12.6	12.6	41.1	42.1	41.6
O_3F_2	18.4	19.1	18.7	27.8	28.8	28.3	30.4	31.0	30.7	12.9	13.3	13.1	43.3	44.2	43.8
O_3F_3	18.8	20.4	19.6	28.1	30.0	29.0	29.6	31.4	30.5	11.9	12.7	12.3	41.5	44.1	42.8
O_4F_1	17.3	18.6	18.0	26.6	28.3	27.5	29.7	32.1	30.9	11.5	12.6	12.1	41.3	44.7	43.0
O_4F_2	18.5	19.2	18.8	27.7	29.2	28.5	27.8	30.8	29.3	11.9	13.0	12.4	39.6	43.8	41.7
O_4F_3	19.3	20.0	19.6	28.5	30.3	29.4	33.0	29.6	31.3	12.7	13.2	12.9	45.7	42.7	44.2
O_5F_1	18.2	19.6	18.9	27.3	30.3	28.8	27.2	30.0	28.6	12.5	13.1	12.8	39.7	43.1	41.4
O_5F_2	19.1	19.0	19.0	29.5	31.8	30.7	26.5	29.5	28.0	12.2	14.7	13.5	38.7	44.3	41.5
O_5F_3	21.1	20.7	20.9	29.7	33.1	31.4	26.3	28.6	27.5	13.6	14.8	14.2	39.9	43.4	41.7
O × F															
S.Em (±)	0.25	0.31	0.20	0.37	0.32	0.25	1.13	0.59	0.64	0.25	0.25	0.17	1.09	0.58	0.62
C.D. at 5%	0.73	NS	0.56	NS	NS	0.71	3.33	1.73	1.82	0.72	0.73	0.50	3.23	1.71	1.77
F × O															
S.Em (±)	0.34	0.29	0.22	0.40	0.48	0.31	1.04	0.74	0.64	0.29	0.23	0.19	1.00	0.79	0.63
C.D. at 5%	1.08	NS	0.67	NS	NS	0.94	3.15	2.33	1.90	0.89	0.71	0.54	3.00	2.47	1.89

DAT = Days after transplanting; NS = Not significant

uptake by grains in the study. Besides, it was also noted that N uptake by grain was usually more than double (25.2-30.5 t ha^{-1}) compared to the uptake by straw (11.0-13.5 t ha^{-1}) of Gobindabhog paddy during *kharif* season.

The range of variation in N uptake among organic manure-based treatments for pooled values was noted as: 17.1-19.6 kg ha^{-1} (28 DAT), 24.7-30.3 kg ha^{-1} (56 DAT) and 35.1-43.0 kg ha^{-1} (at harvest) (Table 4.2.14). Although Gobindabhog rice plants in mustard cake applied plots (O_4 and O_5) absorbed greater N during mid-growth phase, but the plants in FYM treated plots (O_2 and O_3) became on par with O_4 and O_5 at maturity stage due to slow and steady release of nutrients from FYM throughout the cropping period. On the contrary, the plants receiving no organic manure (O_1) recorded lowest N uptake because they depended on soil inherent fertility status and chemical fertilizers only.

4.2.5.1.1.2 Effect of inorganic fertilizer

Total N uptake differed significantly among three doses of chemical fertilizers at all stages of observation during both 2010 and 2011 (Table 4.2.14). It could be explained by the fact that the variations in N supply to plants due to different levels of inorganic fertilizers resulted in differences in growth, DM yield and nutrient uptake, of Gobindabhog rice crop. With increment in dose of chemical fertilizers from $N_{20}P_{10}K_{10}$ (F_1) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3), N uptake by plants was progressively increased in the study.

4.2.5.1.1.3 Interaction effect between organic manure and inorganic fertilizer

The interaction effect between organic manure and inorganic fertilizer on total N uptake by plants was found significant throughout the cropping period during both the years of experimentation (Table 4.2.14). Among different nutrient based treatments combinations, O_4F_3 recorded highest total N uptake (44.2 kg ha^{-1}) and O_1F_1 noted lowest N uptake (31.7 kg ha^{-1}) at harvest for pooled values.

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

The P uptake in Gobindabhog rice plants followed the same increasing trend, like N uptake, with the advancement of crop age upto harvest (Table 4.2.15). On the contrary, P uptake in grain was almost half of the straw.

Table 4.2.15

Effect of organic manure and inorganic fertilizer on total phosphorus uptake by plants at different stage of Gobindabhog rice during *kharif* season

Treatment	Phosphorus uptake (kg ha^{-1})														
	28 DAT			56 DAT			At harvest								
	Total			Total			Grain			Straw			Total		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure															
O_1	6.53	7.04	6.78	9.34	10.42	9.88	7.59	8.38	7.98	4.31	4.39	4.35	11.90	12.76	12.33
O_2	6.83	7.38	7.10	10.55	10.79	10.67	8.88	9.40	9.14	6.79	7.18	6.98	15.66	16.57	16.12
O_3	7.56	7.86	7.71	11.50	12.27	11.89	10.32	11.03	10.67	5.80	6.39	6.10	16.11	17.42	16.77
O_4	7.63	8.08	7.86	11.45	12.26	11.86	10.08	10.90	10.49	4.97	5.52	5.24	15.05	16.42	15.73
O_5	7.93	8.06	7.99	11.92	13.14	12.53	9.48	10.27	9.88	4.96	5.61	5.29	14.44	15.88	15.16
S.Em (±)	0.11	0.08	0.07	0.16	0.16	0.12	0.10	0.20	0.11	0.09	0.05	0.05	0.11	0.22	0.12
C.D. at 5%	0.36	0.25	0.20	0.54	0.53	0.35	0.31	0.67	0.34	0.30	0.17	0.16	0.35	0.72	0.37
Inorganic fertilizer															
F_1	7.00	7.35	7.18	10.51	11.37	10.94	9.05	9.90	9.47	5.18	5.53	5.35	14.23	15.42	14.83
F_2	7.28	7.61	7.44	11.08	11.92	11.50	9.25	10.09	9.67	5.25	5.74	5.49	14.50	15.83	15.16
F_3	7.60	8.09	7.84	11.27	12.04	11.65	9.51	10.00	9.75	5.67	6.18	5.92	15.17	16.18	15.68
S.Em (±)	0.05	0.06	0.04	0.06	0.07	0.04	0.10	0.09	0.07	0.05	0.05	0.04	0.10	0.09	0.07
C.D. at 5%	0.14	0.17	0.11	0.17	0.19	0.13	0.29	NS	0.19	0.16	0.15	0.11	0.29	0.27	0.19
Interaction effect															
O_1F_1	6.22	6.61	6.41	8.95	10.24	9.60	6.77	7.89	7.33	2.77	2.58	2.68	9.54	10.47	10.01
O_1F_2	6.71	7.20	6.95	9.32	10.38	9.85	7.59	9.00	8.30	4.21	3.91	4.06	11.81	12.90	12.35
O_1F_3	6.65	7.31	6.98	9.74	10.63	10.18	8.42	8.24	8.33	5.93	6.67	6.30	14.35	14.91	14.63
O_2F_1	6.58	6.87	6.73	10.30	10.52	10.41	8.76	9.00	8.88	6.57	6.75	6.66	15.33	15.74	15.54
O_2F_2	6.81	7.44	7.13	10.78	11.04	10.91	8.24	9.14	8.69	6.74	7.39	7.06	14.98	16.53	15.75
O_2F_3	7.08	7.81	7.44	10.55	10.81	10.68	9.63	10.05	9.84	7.05	7.39	7.22	16.68	17.44	17.06
O_3F_1	7.47	7.42	7.45	11.16	11.71	11.43	9.63	10.79	10.21	6.92	7.74	7.33	16.54	18.52	17.53
O_3F_2	7.55	7.89	7.72	11.55	12.45	12.00	10.72	10.94	10.83	5.40	6.13	5.76	16.12	17.07	16.60
O_3F_3	7.66	8.26	7.96	11.79	12.66	12.23	10.61	11.35	10.98	5.08	5.32	5.20	15.68	16.66	16.17
O_4F_1	7.27	7.74	7.51	10.88	11.86	11.37	10.41	11.15	10.78	4.81	5.36	5.09	15.22	16.52	15.87
O_4F_2	7.61	7.99	7.80	11.55	12.21	11.88	10.24	11.13	10.69	5.00	5.65	5.33	15.25	16.78	16.01
O_4F_3	8.02	8.51	8.26	11.93	12.71	12.32	9.58	10.41	10.00	5.10	5.54	5.32	14.68	15.95	15.32
O_5F_1	7.47	8.09	7.78	11.24	12.53	11.88	9.68	10.65	10.16	4.82	5.20	5.01	14.50	15.86	15.18
O_5F_2	7.70	7.54	7.62	12.22	13.50	12.86	9.46	10.22	9.84	4.88	5.64	5.26	14.34	15.86	15.10
O_5F_3	8.61	8.54	8.57	12.32	13.39	12.85	9.30	9.95	9.62	5.17	5.99	5.58	14.47	15.93	15.20
O × F															
S.Em (±)	0.10	0.13	0.08	0.13	0.15	0.10	0.22	0.20	0.15	0.12	0.12	0.08	0.22	0.21	0.15
C.D. at 5%	0.31	0.38	0.24	0.38	NS	0.28	0.65	0.60	0.43	0.36	0.34	0.24	0.65	0.61	0.43
F × O															
S.Em (±)	0.14	0.13	0.10	0.20	0.20	0.14	0.20	0.26	0.17	0.13	0.11	0.09	0.21	0.28	0.17
C.D. at 5%	0.44	0.40	0.29	0.62	NS	0.42	0.62	0.82	0.49	0.42	0.33	0.25	0.63	0.87	0.51

DAT = Days after transplanting; NS = Not significant

4.2.5.1.2.1 Effect of organic manure

The significant variation among organic manure-based treatments toward P uptake in the study revealed that four treatments (O_2 - O_5) comprising either of organic manures (FYM or mustard cake) recorded greater P uptake over unmanured control (O_1) throughout the cropping period (Table 4.2.15). Based on total P uptake for pooled values at harvest, five organic manure-based treatments could be arranged as O_3 (16.77 kg ha^{-1}) > O_2 (16.12 kg ha^{-1}) > O_4 (15.73 kg ha^{-1}) > O_5 (15.16 kg ha^{-1}) > O_1 (12.33 kg ha^{-1}).

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

The increment in DM production with the age of Gobindabhog rice resulted in steady increase of total K uptake from 28 DAT to maturity (Table 4.2.16). Unlike the relationship of N uptake in grain and straw, K uptake in grain was much lower, usually about one-third of the straw uptake because of low K concentration and less grain yield compared to higher K concentration along with greater straw yield in the investigation.

4.2.5.1.3.1 Effect of organic manure

The uptake of potassium by Gobindabhog rice plants differed significantly among five organic manure-based treatments at 28, 56 DAT and at harvest during both 2010 and 2011 (Table 4.2.16). Based on pooled values, the range in K uptake was noted as: 14.8 – 19.4 kg ha^{-1} 28 (DAT), 26.6 – 33.8 kg ha^{-1} 56 (DAT) and 41.0 – 46.6 kg ha^{-1} (at harvest).

4.2.5.1.3.2 Effect of inorganic fertilizer

There was significant improvement in K uptake with increment in N-P-K fertilizer dose from $N_{20}P_{10}K_{10}$ (F_1) to $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) throughout the cropping period during both the years of investigation (Table 4.2.16).

4.2.5.1.3.3 Interaction effect between organic manure and inorganic fertilizer

Total K uptake at all stages of observation was significantly influenced by combined influence of organic manure and chemical fertilizer for both 2010 and 2011 in the study (Table 4.2.16).

Table 4.2.16

Effect of organic manure and inorganic fertilizer on total potassium uptake by plants at different stage of Gobindabhog rice during *kharif* season

Treatment	Potassium uptake (kg ha^{-1})														
	28 DAT			56 DAT			At harvest								
	Total			Total			Grain			Straw			Total		
	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
Organic manure															
O_1	14.9	14.7	14.8	25.3	27.9	26.6	9.24	9.71	9.47	30.1	31.4	30.8	40.0	41.9	41.0
O_2	16.3	22.4	19.4	31.9	32.6	32.2	10.26	10.45	10.35	34.7	36.2	35.5	45.7	47.5	46.6
O_3	17.1	17.8	17.4	32.2	33.5	32.9	11.48	12.20	11.84	36.0	37.8	36.9	48.3	50.9	49.6
O_4	17.1	21.3	19.2	32.8	34.7	33.8	11.28	12.19	11.73	36.1	37.7	36.9	48.2	50.8	49.5
O_5	17.8	18.0	17.9	31.0	35.2	33.1	10.67	11.56	11.12	34.6	37.0	35.8	46.0	49.4	47.7
S.Em (±)	0.28	0.18	0.17	0.40	0.42	0.29	0.12	0.20	0.12	0.57	0.40	0.35	0.54	0.50	0.37
C.D. at 5%	0.91	0.60	0.50	1.32	1.35	0.87	0.38	0.65	0.35	1.85	1.30	1.04	1.78	1.63	1.11
F_1	15.8	19.3	17.5	29.0	30.8	29.9	10.33	10.85	10.59	33.1	34.9	34.0	44.2	46.6	45.4
F_2	16.7	18.6	17.7	31.0	32.9	31.9	10.73	11.40	11.06	34.5	36.5	35.5	46.1	48.8	47.4
F_3	17.5	18.7	18.1	31.9	34.8	33.4	10.70	11.41	11.06	35.2	36.7	36.0	46.7	49.0	47.8
S.Em (±)	0.10	0.10	0.07	0.15	0.16	0.11	0.12	0.10	0.08	0.31	0.30	0.22	0.30	0.31	0.21
C.D. at 5%	0.29	0.31	0.21	0.43	0.47	0.31	0.35	0.28	0.22	0.90	0.89	0.62	0.87	0.91	0.61
Inorganic fertilizer															
O_1F_1	13.3	14.1	13.7	18.9	21.2	20.1	8.82	9.07	8.95	26.0	26.2	26.1	35.4	36.0	35.7
O_1F_2	15.4	14.6	15.0	27.8	30.9	29.3	9.45	10.06	9.75	31.6	33.4	32.5	41.7	44.2	43.0
O_1F_3	15.9	15.4	15.7	29.1	31.7	30.4	9.43	10.00	9.72	32.9	34.6	33.8	43.0	45.4	44.2
O_2F_1	15.9	21.2	18.5	31.2	31.4	31.3	9.64	8.89	9.27	34.1	36.4	35.2	44.4	46.1	45.3
O_2F_2	16.2	22.5	19.4	31.9	32.6	32.3	10.18	10.83	10.50	35.0	36.1	35.5	45.9	47.7	46.8
O_2F_3	16.9	23.7	20.3	32.5	33.9	33.2	10.97	11.61	11.29	35.0	36.2	35.6	46.8	48.7	47.7
O_3F_1	16.8	20.7	18.8	30.6	31.3	30.9	10.79	11.80	11.29	35.7	37.3	36.5	47.3	50.0	48.6
O_3F_2	17.0	15.8	16.4	33.1	34.2	33.6	11.80	12.17	11.98	36.9	39.0	37.9	49.5	52.0	50.8
O_3F_3	17.5	16.8	17.1	32.9	35.2	34.0	11.86	12.64	12.25	35.4	37.1	36.3	48.1	50.7	49.4
O_4F_1	16.1	22.3	19.2	31.8	34.1	32.9	11.60	12.62	12.11	34.9	38.1	36.5	47.3	51.7	49.5
O_4F_2	17.4	22.9	20.1	33.0	34.6	33.8	11.49	12.38	11.94	36.1	37.8	37.0	48.5	51.1	49.8
O_4F_3	18.0	18.8	18.4	33.5	35.6	34.6	10.76	11.56	11.16	37.3	37.1	37.2	48.8	49.5	49.2
O_5F_1	16.8	18.0	17.4	32.3	35.8	34.0	10.80	11.88	11.34	35.1	36.3	35.7	46.7	49.0	47.9
O_5F_2	17.5	17.4	17.5	29.0	32.1	30.5	10.72	11.56	11.14	33.2	36.3	34.7	44.7	48.7	46.7
O_5F_3	19.0	18.5	18.8	31.7	37.6	34.7	10.49	11.25	10.87	35.5	38.6	37.0	46.8	50.6	48.7
Interaction effect															
S.Em (±)	0.22	0.23	0.16	0.33	0.36	0.24	0.27	0.22	0.17	0.69	0.68	0.48	0.66	0.69	0.48
C.D. at 5%	0.66	0.68	0.46	0.96	1.05	0.69	0.78	0.64	0.49	2.02	2.00	1.38	1.96	2.03	1.37
F × O															
S.Em (±)	0.33	0.26	0.21	0.48	0.51	0.35	0.25	0.27	0.18	0.80	0.68	0.52	0.77	0.75	0.54
C.D. at 5%	1.05	0.82	0.63	1.53	1.60	1.03	0.74	0.83	0.53	2.48	2.09	1.54	2.39	2.32	1.59

NS = Not significant

4.2.6 Residual soil fertility status in soil

4.2.6.1 Available nitrogen content in soil

4.2.6.1.1 Effect of organic manure

Based on initial soil N status (287.3 kg ha^{-1}) before transplanting of Gobindabhog rice during 2010, the availability of N through different nutritional treatments and total N uptake by Gobindabhog rice at harvest resulted in variation in residual N status between 282.53 (O_1) and 300.37 kg ha^{-1} (O_5) (Table 4.2.17; Fig. 4.10). Perusal of data on residual N status after second year revealed that there was positive N balance (4.35 – 14.1 kg ha^{-1}) for four organic manure based treatments (O_2 – O_5) over initial value, excluding unmanured control (O_1) in the investigation. However, Kumari *et al.,* (2010) reported an opposite trend *i.e.* loss in soil N irrespective of organic treatments in scented rice (*cv.* Basmati) after 2-years of study.

4.2.6.1.2 Effect of inorganic fertilizer

The higher application of N in the form chemical fertilizers from 20 (F_1) to 40 kg N ha^{-1} (F_3) resulted in greater N status after harvesting of Gobindabhog rice during both 2010 and 2011 (Table 4.2.17).

4.2.6.1.3 Interaction effect between organic manure and inorganic fertilizer

Among different nutritional treatments combinations O_5F_3 (Mustard cake @ 0.50 t + $N_{40}P_{20}K_{20}$ kg ha^{-1}) and O_1F_1 (no manure + $N_{20}P_{10}K_{10}$ kg ha^{-1}) recorded the highest (309.90 and 311.60 kg ha^{-1}) and lowest (276.20 and 279.70 kg ha^{-1}) residual N status in soil, respectively during both 2010 and 2011 (Table 4.2.17).

4.2.6.2 Available phosphorous content in soil

4.2.6.2.1 Effect of organic manure

The residual P content in soil varied between 51.60 (O_1) and 57.39 kg ha^{-1} (O_3) during 2010 and between 53.13 (O_4) and 57.07 kg ha-1 (O_5) during 2011 (Table 4.2.18; Fig. 4.10), which indicated positive for all five P balance organic manure-based treatments over initial P status (48.50 kg ha^{-1}) at the commencement of experiments.

Table 4.2.17

Effect of organic manure and inorganic fertilizer on residual nitrogen status after harvest of Gobindabhog rice during *kharif* season

Treatment	Available nitrogen (kg ha^{-1})																	
	2010						2011						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			
Organic manure																		
O_1	287.30	0.00	30.00	317.30	34.77	282.53	292.00	0.00	30.00	322.00	35.37	286.63	289.65	0.00	30.00	319.65	35.07	284.58
O_2	287.30	10.00	30.00	327.30	43.27	284.03	292.00	11.25	30.00	333.25	41.60	291.65	289.65	10.63	30.00	330.28	42.43	287.84
O_3	287.30	20.00	30.00	337.30	41.97	295.33	292.00	22.50	30.00	344.50	43.47	301.03	289.65	21.25	30.00	340.90	42.72	298.18
O_4	287.30	11.25	30.00	328.55	42.20	286.35	292.00	11.50	30.00	333.50	43.73	289.77	289.65	11.38	30.00	331.03	42.97	288.06
O_5	287.30	22.50	30.00	339.80	39.43	300.37	292.00	23.00	30.00	345.00	43.60	301.40	289.65	22.75	30.00	342.40	41.52	300.88
Inorganic fertilizer																		
F_1	287.30	12.75	20.00	320.05	38.58	281.47	292.00	13.65	20.00	325.65	40.62	285.03	289.65	13.20	20.00	322.85	39.60	283.25
F_2	287.30	12.75	30.00	330.05	40.84	289.21	292.00	13.65	30.00	335.65	41.80	293.85	289.65	13.20	30.00	332.85	41.32	291.53
F_3	287.30	12.75	40.00	340.05	41.56	298.49	292.00	13.65	40.00	345.65	42.24	303.41	289.65	13.20	40.00	342.85	41.90	300.95
Interaction effect																		
O_1F_1	287.30	0.00	20.00	307.30	31.10	276.20	292.00	0.00	20.00	312.00	32.30	279.70	289.65	0.00	20.00	309.65	31.70	277.95
O_1F_2	287.30	0.00	30.00	317.30	35.90	281.40	292.00	0.00	30.00	322.00	36.00	286.00	289.65	0.00	30.00	319.65	35.95	283.70
O_1F_3	287.30	0.00	40.00	327.30	37.30	290.00	292.00	0.00	40.00	332.00	37.80	294.20	289.65	0.00	40.00	329.65	37.55	292.10
O_2F_1	287.30	10.00	20.00	317.30	39.70	277.60	292.00	11.25	20.00	323.25	40.90	282.35	289.65	10.63	20.00	320.28	40.30	279.98
O_2F_2	287.30	10.00	30.00	327.30	46.70	280.60	292.00	11.25	30.00	333.25	40.70	292.55	289.65	10.63	30.00	330.28	43.70	286.58
O_2F_3	287.30	10.00	40.00	337.30	43.40	293.90	292.00	11.25	40.00	343.25	43.20	300.05	289.65	10.63	40.00	340.28	43.30	296.98
O_3F_1	287.30	20.00	20.00	327.30	41.10	286.20	292.00	22.50	20.00	334.50	42.10	292.40	289.65	21.25	20.00	330.90	41.60	289.30
O_3F_2	287.30	20.00	30.00	337.30	43.30	294.00	292.00	22.50	30.00	344.50	44.20	300.30	289.65	21.25	30.00	340.90	43.75	297.15
O_3F_3	287.30	20.00	40.00	347.30	41.50	305.80	292.00	22.50	40.00	354.50	44.10	310.40	289.65	21.25	40.00	350.90	42.80	308.10
O_4F_1	287.30	11.25	20.00	318.55	41.30	277.25	292.00	11.50	20.00	323.50	44.70	278.80	289.65	11.38	20.00	321.03	43.00	278.03
O_4F_2	287.30	11.25	30.00	328.55	39.60	288.95	292.00	11.50	30.00	333.50	43.80	289.70	289.65	11.38	30.00	331.03	41.70	289.33
O_4F_3	287.30	11.25	40.00	338.55	45.70	292.85	292.00	11.50	40.00	343.50	42.70	300.80	289.65	11.38	40.00	341.03	44.20	296.83
O_5F_1	287.30	22.50	20.00	329.80	39.70	290.10	292.00	23.00	20.00	335.00	43.10	291.90	289.65	22.75	20.00	332.40	41.40	291.00
O_5F_2	287.30	22.50	30.00	339.80	38.70	301.10	292.00	23.00	30.00	345.00	44.30	300.70	289.65	22.75	30.00	342.40	41.50	300.90
O_5F_3	287.30	22.50	40.00	349.80	39.90	309.90	292.00	23.00	40.00	355.00	43.40	311.60	289.65	22.75	40.00	352.40	41.65	310.75

Table 4.2.18

Effect of organic manure and inorganic fertilizer on residual phosphorus status after harvest of Gobindabhog rice during *kharif* season

Treatment	Available phosphorus (kg ha^{-1})																	
	2010						2011						Mean					
	Initial	Treatment: Organic	Treatment: Inorganic	Total	Total uptake	Residual status	Initial	Treatment: Organic	Treatment: Inorganic	Total	Total uptake	Residual status	Initial	Treatment: Organic	Treatment: Inorganic	Total	Total uptake	Residual status
Organic manure																		
O_1	48.50	0.00	15.00	63.50	11.90	51.60	51.20	0.00	15.00	66.20	12.76	53.44	49.85	0.00	15.00	64.85	12.33	52.52
O_2	48.50	5.00	15.00	68.50	15.66	52.84	51.20	3.75	15.00	69.95	16.57	53.38	49.85	4.38	15.00	69.23	16.12	53.11
O_3	48.50	10.00	15.00	73.50	16.11	57.39	51.20	7.50	15.00	73.70	17.42	56.28	49.85	8.75	15.00	73.60	16.77	56.84
O_4	48.50	3.50	15.00	67.00	15.05	51.95	51.20	3.38	15.00	69.58	16.42	53.16	49.85	3.44	15.00	68.29	15.73	52.55
O_5	48.50	7.00	15.00	70.50	14.44	56.06	51.20	6.75	15.00	72.95	15.88	57.07	49.85	6.88	15.00	71.73	15.16	56.57
Inorganic fertilizer																		
F_1	48.50	5.10	10.00	63.60	14.23	49.37	51.20	4.28	10.00	65.48	15.42	50.05	49.85	4.69	10.00	64.54	14.82	49.71
F_2	48.50	5.10	15.00	68.60	14.50	54.10	51.20	4.28	15.00	70.48	15.83	54.65	49.85	4.69	15.00	69.54	15.16	54.37
F_3	48.50	5.10	20.00	73.60	15.17	58.43	51.20	4.28	20.00	75.48	16.18	59.30	49.85	4.69	20.00	74.54	15.68	58.86
Interaction effect																		
O_1F_1	48.50	0.00	10.00	58.50	9.54	48.96	51.20	0.00	10.00	61.20	10.47	50.73	49.85	0.00	10.00	59.85	10.01	49.85
O_1F_2	48.50	0.00	15.00	63.50	11.81	51.69	51.20	0.00	15.00	66.20	12.90	53.30	49.85	0.00	15.00	64.85	12.36	52.50
O_1F_3	48.50	0.00	20.00	68.50	14.35	54.15	51.20	0.00	20.00	71.20	14.91	56.29	49.85	0.00	20.00	69.85	14.63	55.22
O_2F_1	48.50	5.00	10.00	63.50	15.33	48.17	51.20	3.75	10.00	64.95	15.74	49.21	49.85	4.38	10.00	64.23	15.54	48.69
O_2F_2	48.50	5.00	15.00	68.50	14.98	53.52	51.20	3.75	15.00	69.95	16.53	53.42	49.85	4.38	15.00	69.23	15.76	53.47
O_2F_3	48.50	5.00	20.00	73.50	16.68	56.82	51.20	3.75	20.00	74.95	17.44	57.51	49.85	4.38	20.00	74.23	17.06	57.17
O_3F_1	48.50	10.00	10.00	68.50	16.54	51.96	51.20	7.50	10.00	68.70	18.52	50.18	49.85	8.75	10.00	68.60	17.53	51.07
O_3F_2	48.50	10.00	15.00	73.50	16.12	57.38	51.20	7.50	15.00	73.70	17.07	56.63	49.85	8.75	15.00	73.60	16.60	57.01
O_3F_3	48.50	10.00	20.00	78.50	15.68	62.82	51.20	7.50	20.00	78.70	16.66	62.04	49.85	8.75	20.00	78.60	16.17	62.43
O_4F_1	48.50	3.50	10.00	62.00	15.22	46.78	51.20	3.38	10.00	64.58	16.52	48.06	49.85	3.44	10.00	63.29	15.87	47.42
O_4F_2	48.50	3.50	15.00	67.00	15.25	51.75	51.20	3.38	15.00	69.58	16.78	52.80	49.85	3.44	15.00	68.29	16.02	52.27
O_4F_3	48.50	3.50	20.00	72.00	14.68	57.32	51.20	3.38	20.00	74.58	15.95	58.63	49.85	3.44	20.00	73.29	15.32	57.97
O_5F_1	48.50	7.00	10.00	65.50	14.50	51.00	51.20	6.75	10.00	67.95	15.86	52.09	49.85	6.88	10.00	66.73	15.18	51.55
O_5F_2	48.50	7.00	15.00	70.50	14.34	56.16	51.20	6.75	15.00	72.95	15.86	57.09	49.85	6.88	15.00	71.73	15.10	56.63
O_5F_3	48.50	7.00	20.00	75.50	14.47	61.03	51.20	6.75	20.00	77.95	15.93	62.02	49.85	6.88	20.00	76.73	15.20	61.53

With increment in P dose from 10 (F_1) to 20 kg ha^{-1} (F_3) through chemical fertilizers, the residual P status was steadily increased during both the years of investigation (Table 4.2.18).

4.2.6.2.3 Interaction effect between organic manure and inorganic fertilizer

The variation in available P status after harvesting of Gobindabhog rice was noted as: - 3.55 and - 6.13% (O_4F_1) to + 14.32 and + 21.17 % (O_3F_3) during 2010 and 2011 (Table 4.2.18).

4.2.6.3 Available potassium content in soil

4.2.6.3.1 Effect of organic manure

Perusal of data revealed in the variation in residual K content in plots of different organic manure-based treatments in the study indicated negative K balance in after 2-year experiment (Table 4.2.19 and Fig. 4.10).

4.2.6.3.2 Effect of inorganic fertilizer

The residual K status in soil was steadily increased with increment of inorganic fertilizers from 10 (F_1) to 20 kg ha-1 (F_3) in the investigation (Table 4.2.19).

4.2.6.3.3 Interaction effect between organic manure and inorganic fertilizer

Organic manure × chemical fertilizers effect on residual K status was found significant during both the years of experiment (Table 4.2.19).

4.2.7 Economics of production and benefit:cost ratio

4.2.7.1 Total cost of production

The common cost of cultivation for Gobindabhog paddy included cost of seed, seedbed preparation and sowing, land preparation, transplanting of seedlings, weeding, irrigation, harvesting, threshing, etc. in the study, excluding the cost of organic manures and chemical fertilizers. It was estimated as Rs. 22,248.00 ha^{-1} for 2010 and Rs. 23,128.00 ha^{-1} for 2011, with an average of Rs. 22,688.00 ha^{-1} over two year, while unmanured control (O_1) and related treatments (O_1F_1, O_1F_2 and O_1F_3) required Rs. 1232.00 ha^{-1} less due to non-application of organic manure for both the years of investigation.

Table 4.2.19

Effect of organic manure and inorganic fertilizer on residual potassium status after harvest of Gobindabhog rice during *kharif* season

Treatment	Available potassium (kg ha^{-1})																	
	2010						2011						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			
Organic manure																		
O_1	234.70	0.00	15.00	249.70	40.05	209.65	227.30	0.00	15.00	242.30	41.86	200.44	231.00	0.00	15.00	246.00	40.95	205.05
O_2	234.70	11.25	15.00	260.95	45.72	215.23	227.30	12.50	15.00	254.80	47.50	207.30	231.00	11.88	15.00	257.88	46.61	211.27
O_3	234.70	22.50	15.00	272.20	48.32	223.88	227.30	25.00	15.00	267.30	50.90	216.40	231.00	23.75	15.00	269.75	49.61	220.14
O_4	234.70	2.50	15.00	252.20	48.20	204.00	227.30	2.75	15.00	245.05	50.77	194.28	231.00	2.63	15.00	248.63	49.48	199.14
O_5	234.70	5.00	15.00	254.70	46.05	208.65	227.30	5.50	15.00	247.80	49.45	198.35	231.00	5.25	15.00	251.25	47.75	203.50
Inorganic fertilizer																		
F_1	234.70	8.25	10.00	252.95	44.24	208.71	227.30	9.15	10.00	246.45	46.55	199.90	231.00	8.70	10.00	249.70	45.39	204.31
F_2	234.70	8.25	15.00	257.95	46.06	211.89	227.30	9.15	15.00	251.45	48.76	202.69	231.00	8.70	15.00	254.70	47.41	207.29
F_3	234.70	8.25	20.00	262.95	46.70	216.25	227.30	9.15	20.00	256.45	48.97	207.48	231.00	8.70	20.00	259.70	47.84	211.86
Interaction effect																		
O_1F_1	234.70	0.00	10.00	244.70	35.43	209.27	227.30	0.00	10.00	237.30	35.97	201.33	231.00	0.00	10.00	241.00	35.70	205.30
O_1F_2	234.70	0.00	15.00	249.70	41.72	207.98	227.30	0.00	15.00	242.30	44.22	198.08	231.00	0.00	15.00	246.00	42.97	203.03
O_1F_3	234.70	0.00	20.00	254.70	42.99	211.71	227.30	0.00	20.00	247.30	45.38	201.92	231.00	0.00	20.00	251.00	44.19	206.81
O_2F_1	234.70	11.25	10.00	255.95	44.44	211.51	227.30	12.50	10.00	249.80	46.07	203.73	231.00	11.88	10.00	252.88	45.25	207.62
O_2F_2	234.70	11.25	15.00	260.95	45.92	215.03	227.30	12.50	15.00	254.80	47.74	207.06	231.00	11.88	15.00	257.88	46.83	211.04
O_2F_3	234.70	11.25	20.00	265.95	46.78	219.17	227.30	12.50	20.00	259.80	48.69	211.11	231.00	11.88	20.00	262.88	47.74	215.14
O_3F_1	234.70	22.50	10.00	267.20	47.27	219.9	227.30	25.00	10.00	262.30	50.00	212.30	231.00	23.75	10.00	264.75	48.64	216.11
O_3F_2	234.70	22.50	15.00	272.20	49.55	222.7	227.30	25.00	15.00	267.30	52.04	215.26	231.00	23.75	15.00	269.75	50.79	218.96
O_3F_3	234.70	22.50	20.00	277.20	48.14	229.1	227.30	25.00	20.00	272.30	50.67	221.63	231.00	23.75	20.00	274.75	49.41	225.34
O_4F_1	234.70	2.50	10.00	247.20	47.32	199.9	227.30	2.75	10.00	240.05	51.68	188.37	231.00	2.63	10.00	243.63	49.50	194.12
O_4F_2	234.70	2.50	15.00	252.20	48.46	203.7	227.30	2.75	15.00	245.05	51.11	193.94	231.00	2.63	15.00	248.63	49.78	198.84
O_4F_3	234.70	2.50	20.00	257.20	48.82	208.4	227.30	2.75	20.00	250.05	49.50	200.55	231.00	2.63	20.00	253.63	49.16	204.46
O_5F_1	234.70	5.00	10.00	249.70	46.71	203.0	227.30	5.50	10.00	242.80	49.03	193.77	231.00	5.25	10.00	246.25	47.87	198.38
O_5F_2	234.70	5.00	15.00	254.70	44.67	210.0	227.30	5.50	15.00	247.80	48.68	199.12	231.00	5.25	15.00	251.25	46.68	204.57
O_5F_3	234.70	5.00	20.00	259.70	46.76	212.9	227.30	5.50	20.00	252.80	50.63	202.17	231.00	5.25	20.00	256.25	48.69	207.56

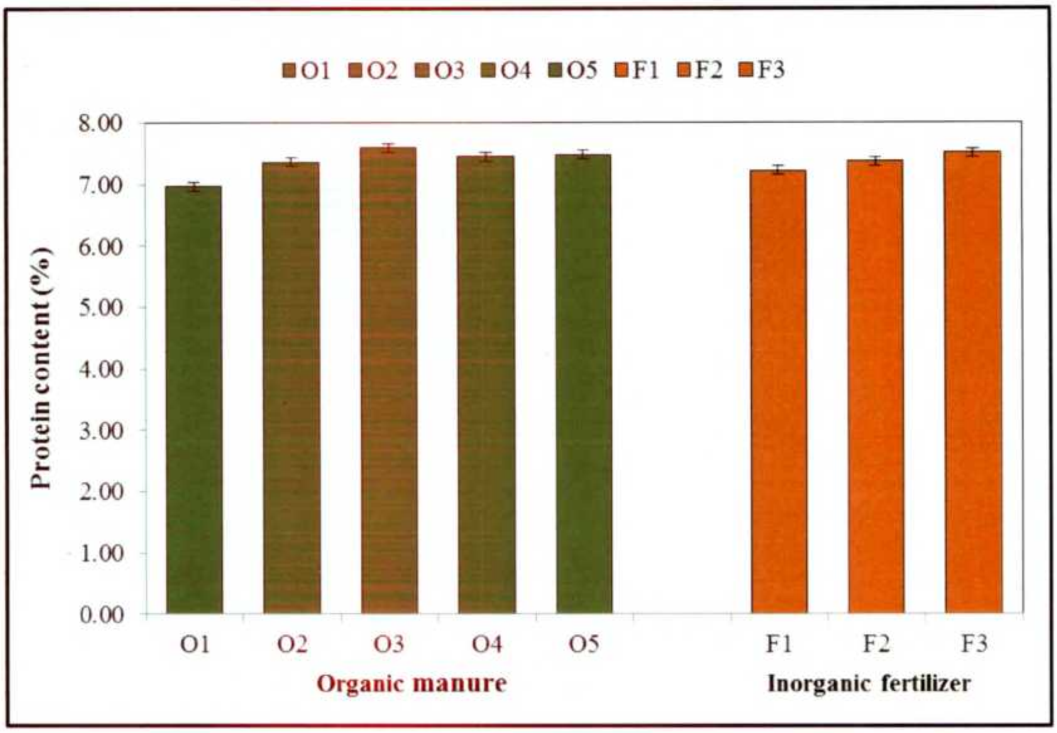

Fig. 4.9: Effect of organic manure and inorganic fertilizer on protein content (%) of Gobindabhog rice during *kharif* season (pooled over two years)

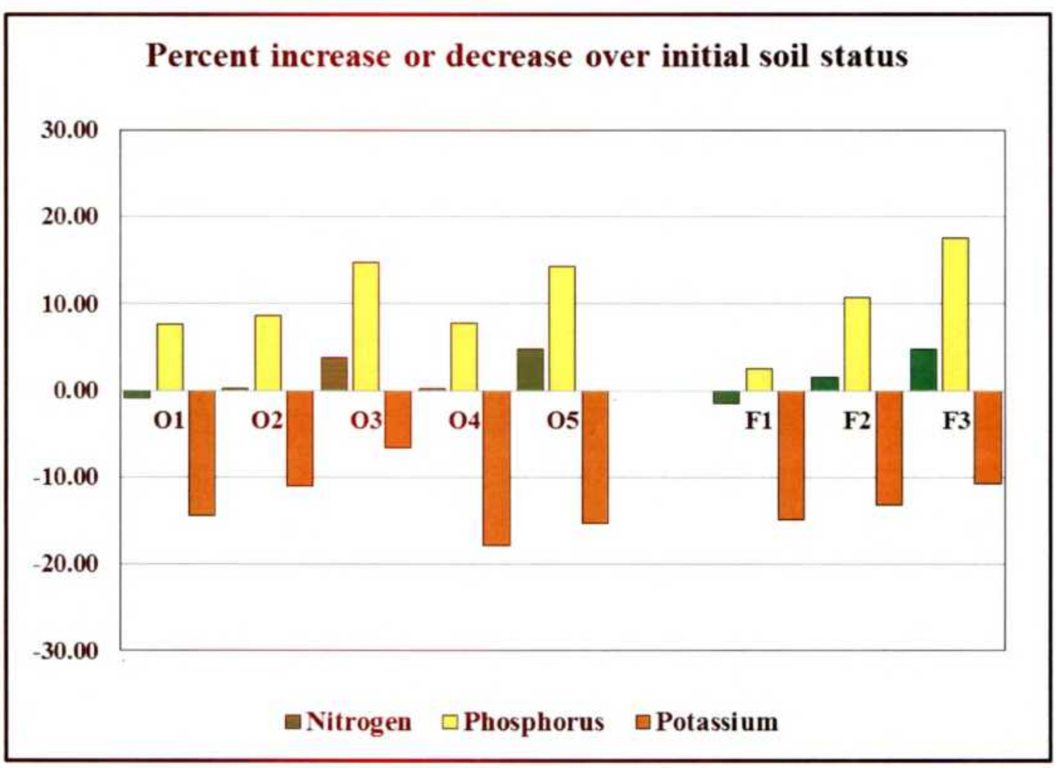

Fig. 4.10: Effect of organic manure and inorganic fertilizer on residual fertility status of Gobindabhog rice during *kharif* season (pooled over two years)

The variations in treatment cost depend on the fours, quantities and rates of organic manures and chemical fertilizers used following the treatment schedule in the study. The treatment cost due to procurement of organic manures varied greatly among Rs. 958.00 (O_1) and Rs. 7708.00 (O_5); while that for inorganic fertilizers between Rs. 3789.00 (F_1) to Rs. 4427.00 (F_3) for pooled over two years (Table 4.2.20).

The total cost of cultivation for 1 ha of Gobindabhog paddy during *kharif* season ranged between Rs. 21,620.00 (O_1F_1) and Rs. 29,655.00 (O_5F_3) during 2010; while between Rs. 22,569.00 (O_1F_1) to Rs. 31,475.00 (O_5F_3) during 2011 (Table 4.2.21). Above all the total cultivation cost was higher during the second year than first year irrespective of treatments, exclusively due to price hike for seed, power tiller charges, irrigation, organic manures, chemical fertilizers, etc. in the latter year compared to the earlier one.

4.2.7.2 Gross return, net return and benefit:cost ratio

Gross return included the values of grain and straw of Gobindabhog paddy as obtained from different nutritional treatments in the investigation. The return from grain and straw of Gobindabhog paddy in the study summarized as the ratio of 12:1. Among treatments of organic manures, it was highest with O_3 (Rs. 55,315.00 ha^{-1}), being closely followed by O_4 (Rs. 54,448.00 ha^{-1}); while among inorganic fertilizers treatments, that was with F_2 (Rs. 51,703.00 ha^{-1}) followed by F_3 (Rs. 51,518.00 ha^{-1}) for pooled overs two years (Table 4.2.22).

The net return from three organic manure-based treatments (O_2, O_3 and O_4) was always greater than unmanured control (O_1) during both 2010 and 2011 (Table 4.2.23). Based on pooled values, it varied between Rs. 20,989.00 (O_5) and 27,919.00 (O_3) in the investigation. The lowest net return from O_5 treatments could be explained by the fact that application of mustard cake @ 0.50 t ha^{-1} could not improve the grain and straw yield over lower dose (@ 0.25 t ha^{-1}) despite the additional costs involved for the manures.

Although the unmanured control (O_1) recorded higher benefit:cost ratio (1.99) than O_2 (1.97) and O_5 (1.69) for pooled values, but with lower net return compared to O_2 indicating positive outline by application of FYM @ 2.5 t ha^{-1} over

Table 4.2.20

Effect of organic manure and inorganic fertilizer on common cost of cultivation of Gobindabhog rice during *kharif* season

Input and operation	2010	2011	Mean
Cost of Gobindabhog seed (@20 kg ha^{-1})	840.00	920.00	880.00
Preparation of seed bed, sowing of seeds and seedbed management (3 mandays)	366.00	366.00	366.00
Land preparation (Powertiller for 20 hours for 3 times ploughing in 1 ha)	4500.00	5000.00	4750.00
Transplanting of seedlings (45 mandays ha^{-1})	5490.00	5490.00	5490.00
Application of manures (6 mandays ha^{-1}) and transportation charges, excluding unmanured control	1232.00	1232.00	1232.00
Application of inorganic fertilizers (2 mandays ha^{-1})	244.00	244.00	244.00
Weeding (18 mandays ha^{-1})	2196.00	2196.00	2196.00
Irrigation	1500.00	1600.00	1550.00
Harvesting (20 mandays ha^{-1})	2440.00	2440.00	2440.00
Threshing and winnowing (20 mandays for 1 ha produce)	2440.00	2440.00	2440.00
Other contingent expenses	1000.00	1200.00	1100.00
Total	22248.00	23128.00	22688.00

Cost of Gobindabhog seed = Rs. 42.00 kg^{-1} (2010), Rs. 46.00 kg^{-1} (2011); Labour wages = Rs. 122.00 $manday^{-1}$ during both the years; Rate of power tiller = Rs. 225.00 $hour^{-1}$ (2010), Rs. 250.00 $hour^{-1}$ (2011)

Table 4.2.21

Effect of organic manure and inorganic fertilizer on total cost of cultivation of Gobindabhog rice during *kharif* season

Treatment	2010			2011			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 costof cultivation (Rs. ha^{-1})	Cost of manure and fertilizer (Rs. ha^{-1})	Total cost of cultivation (Rs. ha^{-1})
Organic manure									
O_1	21016.00	906.00	21922.00	21896.00	1010.00	22906.00	21456.00	958.00	22414.00
O_2	22248.00	2656.00	24904.00	23128.00	3010.00	26138.00	22688.00	2833.00	25521.00
O_3	22248.00	4406.00	26654.00	23128.00	5010.00	28138.00	22688.00	4708.00	27396.00
O_4	22248.00	4156.00	26404.00	23128.00	4510.00	27638.00	22688.00	4333.00	27021.00
O_5	22248.00	7406.00	29654.00	23128.00	8010.00	31138.00	22688.00	7708.00	30396.00
Inorganic fertilizer									
F_1	22248.00	3604.00	25852.00	23128.00	3973.00	27101.00	22688.00	3789.00	26477.00
F_2	22248.00	3906.00	26154.00	23128.00	4310.00	27438.00	22688.00	4108.00	26796.00
F_3	22248.00	4207.00	26455.00	23128.00	4647.00	27775.00	22688.00	4427.00	27115.00
Interaction effect									
O_1F_1	21016.00	604.00	21620.00	21896.00	673.00	22569.00	21456.00	639.00	22095.00
O_1F_2	21016.00	906.00	21922.00	21896.00	1010.00	22906.00	21456.00	958.00	22414.00
O_1F_3	21016.00	1207.00	22223.00	21896.00	1347.00	23243.00	21456.00	1277.00	22733.00
O_2F_1	22248.00	2354.00	24602.00	23128.00	2673.00	25801.00	22688.00	2514.00	25202.00
O_2F_2	22248.00	2656.00	24904.00	23128.00	3010.00	26138.00	22688.00	2833.00	25521.00
O_2F_3	22248.00	2957.00	25205.00	23128.00	3347.00	26475.00	22688.00	3152.00	25840.00
O_3F_1	22248.00	4104.00	26352.00	23128.00	4673.00	27801.00	22688.00	4389.00	27077.00
O_3F_2	22248.00	4406.00	26654.00	23128.00	5010.00	28138.00	22688.00	4708.00	27396.00
O_3F_3	22248.00	4707.00	26955.00	23128.00	5347.00	28475.00	22688.00	5027.00	27715.00
O_4F_1	22248.00	3854.00	26102.00	23128.00	4173.00	27301.00	22688.00	4014.00	26702.00
O_4F_2	22248.00	4156.00	26404.00	23128.00	4510.00	27638.00	22688.00	4333.00	27021.00
O_4F_3	22248.00	4457.00	26705.00	23128.00	4847.00	27975.00	22688.00	4652.00	27340.00
O_5F_1	22248.00	7104.00	29352.00	23128.00	7673.00	30801.00	22688.00	7389.00	30077.00
O_5F_2	22248.00	7406.00	29654.00	23128.00	8010.00	31138.00	22688.00	7708.00	30396.00
O_5F_3	22248.00	7707.00	29955.00	23128.00	8347.00	31475.00	22688.00	8027.00	30715.00

Cost of FYM = Rs. 0.70 kg^{-1} (2010), Rs. 0.80 kg^{-1} (2011); Cost of mustard cake = Rs. 13.00 kg^{-1} (2010), Rs. 14.00 kg^{-1} (2011); Cost of Urea = Rs. 5.50 kg^{-1} (2010), Rs. 6.00 kg^{-1} (2011); Cost of Single Super Phosphate = Rs. 4.50 kg^{-1} (2010), Rs. 5.00 kg^{-1} (2011); Cost of Muriate of Potash = Rs. 5.00 kg^{-1} (2010), Rs. 6.00 kg^{-1} (2011);

Table 4.2.22

Effect of organic manure and inorganic fertilizer on gross return of Gobindabhog rice during *kharif* season

Treatment	2010			2011			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})
Organic manure									
O_1	38987.00	3300.00	42287.00	43100.00	3676.00	46776.00	41043.00	3488.00	44531.00
O_2	43577.00	3572.00	47148.00	49260.00	4040.00	53300.00	46418.00	3806.00	50224.00
O_3	48223.00	3775.00	51998.00	54360.00	4273.00	58633.00	51292.00	4024.00	55315.00
O_4	47033.00	3715.00	50749.00	54000.00	4228.00	58228.00	50517.00	3971.00	54488.00
O_5	44143.00	3655.00	47798.00	50760.00	4213.00	54973.00	47452.00	3934.00	51385.00
Inorganic fertilizer									
F_1	43418.00	3531.00	46949.00	49764.00	3978.00	53742.00	46591.00	3754.00	50345.00
F_2	45050.00	3595.00	48645.00	50652.00	4109.00	54761.00	47851.00	3852.00	51703.00
F_3	44710.00	3684.00	48394.00	50472.00	4171.00	54643.00	47591.00	3927.00	51518.00
Interaction effect									
O_1F_1	37400.00	3264.00	40664.00	40380.00	3518.00	43898.00	38890.00	3391.00	42281.00
O_1F_2	40120.00	3255.00	43375.00	44640.00	3690.00	48330.00	42380.00	3473.00	45853.00
O_1F_3	39440.00	3381.00	42821.00	44280.00	3820.00	48100.00	41860.00	3601.00	45461.00
O_2F_1	40800.00	3507.00	44307.00	47160.00	4013.00	51173.00	43980.00	3760.00	47740.00
O_2F_2	43350.00	3603.00	46953.00	48420.00	4110.00	52530.00	45885.00	3856.00	49741.00
O_2F_3	46580.00	3605.00	50185.00	52200.00	3998.00	56198.00	49390.00	3801.00	53191.00
O_3F_1	45220.00	3684.00	48904.00	52560.00	4163.00	56723.00	48890.00	3923.00	52813.00
O_3F_2	49980.00	3796.00	53776.00	54540.00	4298.00	58838.00	52260.00	4047.00	56307.00
O_3F_3	49470.00	3843.00	53313.00	55980.00	4358.00	60338.00	52725.00	4100.00	56825.00
O_4F_1	48620.00	3586.00	52206.00	56160.00	4200.00	60360.00	52390.00	3893.00	56283.00
O_4F_2	47770.00	3722.00	51492.00	54900.00	4178.00	59078.00	51335.00	3950.00	55285.00
O_4F_3	44710.00	3838.00	48548.00	50940.00	4305.00	55245.00	47825.00	4072.00	51897.00
O_5F_1	45050.00	3612.00	48662.00	52560.00	3998.00	56558.00	48805.00	3805.00	52610.00
O_5F_2	44030.00	3600.00	47630.00	50760.00	4268.00	55028.00	47395.00	3934.00	51329.00
O_5F_3	43350.00	3752.00	47102.00	48960.00	4373.00	53333.00	46155.00	4062.00	50217.00

Rate of grain = Rs. 17000.00 t^{-1} (2010), Rs. 18000.00 t^{-1} (2011); and Rate of straw = Rs. 700.00 t^{-1} (2010), Rs. 750.00 t^{-1} (2011)

nonuse of organic manure (O_1) (Table 4.2.23). On the other hand, the application of $N_{30}P_{15}K_{15}$ kg ha^{-1} (F_2) resulted in highest net return (Rs. 22,492.00 ha^{-1}) and B:C ratio (1.86 and 2.00) in 2010 and 2011 than both F_1 ($N_{20}P_{10}K_{10}$ kg ha^{-1}) and F_3 ($N_{40}P_{20}K_{20}$ kg ha^{-1}). Among different nutrient combinations, the highest net return and B:C ratio was obtained from O_3F_2 (Rs. 27,123.00 ha^{-1} and 2.02) in 2010; O_4F_1 (Rs. 33,059.00 ha^{-1} and 2.21) in 2011 and O_4F_1 (Rs. 29,582.00 ha^{-1} and 2.11) for pooled over two years.

Banerjee (2011) recommended combined use of FYM @ 50% RDN + mustard cake @ 50% RDN for highest net return (Rs. 19,190.00 ha^{-1}) and greater B:C ratio (1.81) for Gobindabhog paddy at Kalyani, West Bengal. Thus, the combined doses like O_4F_1 (Rs. 29,582.00 ha^{-1} and 2.11) or O_3F_3 (Rs. 29,110.00 ha^{-1} and 2.05) or O_3F_2 (Rs. 28,911.00 ha^{-1} and 2.05) could be recommended as economically acceptable integrated nutrient management system for Gobindabhog paddy during *kharif* season in West Bengal.

Table 4.2.23

Effect of organic manure and inorganic fertilizer on cost of cultivation, gross return, net return and B: C ratio of Gobindabhog rice

Treatment	2010				2011				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												
O_1	21922.00	42287.00	20365.00	1.93	22906.00	46776.00	23870.00	2.04	22414.00	44531.00	22117.00	1.99
O_2	24904.00	47148.00	22245.00	1.89	26138.00	53300.00	27162.00	2.04	25521.00	50224.00	24703.00	1.97
O_3	26654.00	51998.00	25344.00	1.95	28138.00	58633.00	30494.00	2.08	27396.00	55315.00	27919.00	2.02
O_4	26404.00	50749.00	24345.00	1.92	27638.00	58228.00	30589.00	2.11	27021.00	54488.00	27467.00	2.01
O_5	29654.00	47798.00	18145.00	1.61	31138.00	54973.00	23834.00	1.77	30396.00	51385.00	20989.00	1.69
Inorganic fertilizer												
F_1	25852.00	46949.00	21097.00	1.82	27101.00	53742.00	26641.00	1.98	26477.00	50345.00	23869.00	1.90
F_2	26154.00	48645.00	22492.00	1.86	27438.00	54761.00	27322.00	2.00	26796.00	51703.00	24907.00	1.93
F_3	26455.00	48394.00	21938.00	1.83	27775.00	54643.00	26868.00	1.97	27115.00	51518.00	24403.00	1.90
Interaction effect												
O_1F_1	21620.00	40664.00	19045.00	1.88	22569.00	43898.00	21328.00	1.95	22095.00	42281.00	20186.00	1.91
O_1F_2	21922.00	43375.00	21453.00	1.98	22906.00	48330.00	25424.00	2.11	22414.00	45853.00	23439.00	2.04
O_1F_3	22223.00	42821.00	20598.00	1.93	23243.00	48100.00	24857.00	2.07	22733.00	45461.00	22727.00	2.00
O_2F_1	24602.00	44307.00	19705.00	1.80	25801.00	51173.00	25371.00	1.98	25202.00	47740.00	22538.00	1.89
O_2F_2	24904.00	46953.00	22049.00	1.89	26138.00	52530.00	26392.00	2.01	25521.00	49741.00	24221.00	1.95
O_2F_3	25205.00	50185.00	24980.00	1.99	26475.00	56198.00	29723.00	2.12	25840.00	53191.00	27351.00	2.06
O_3F_1	26352.00	48904.00	22553.00	1.86	27801.00	56723.00	28921.00	2.04	27077.00	52813.00	25737.00	1.95
O_3F_2	26654.00	53776.00	27123.00	2.02	28138.00	58838.00	30699.00	2.09	27396.00	56307.00	28911.00	2.05
O_3F_3	26955.00	53313.00	26358.00	1.98	28475.00	60338.00	31863.00	2.12	27715.00	56825.00	29110.00	2.05
O_4F_1	26102.00	52206.00	26105.00	2.00	27301.00	60360.00	33059.00	2.21	26702.00	56283.00	29582.00	2.11
O_4F_2	26404.00	51492.00	25088.00	1.95	27638.00	59078.00	31439.00	2.14	27021.00	55285.00	28264.00	2.04
O_4F_3	26705.00	48548.00	21843.00	1.82	27975.00	55245.00	27270.00	1.97	27340.00	51897.00	24557.00	1.90
O_5F_1	29352.00	48662.00	19310.00	1.66	30801.00	56558.00	25756.00	1.84	30077.00	52610.00	22533.00	1.75
O_5F_2	29654.00	47630.00	17977.00	1.61	31138.00	55028.00	23889.00	1.77	30396.00	51329.00	20933.00	1.69
O_5F_3	29955.00	47102.00	17147.00	1.57	31475.00	53333.00	21858.00	1.69	30715.00	50217.00	19502.00	1.63

4.3 Experiment No. 3

Effect of storage containers on quality of Gobindabhog rice

4.3.1 Moisture content

There was a steady increase in maximum, minimum and mean temperature as well as in relative humidity from the start of storage period i.e. 0-month to the end of 6-month at the laboratory in the study (Table 4.3.1). This might be due to common seasonal changes in weather from cool and dry (January and February) to hot and humid (May and June) at the experimental site.

The moisture content in paddy or rough rice stored in 5 different containers was significantly influenced after 2-month during 2011 and pooled values; after 4-month time during 2011; and after 6-month during 2012 and pooled values (Table 4.3.2). The variations in material of the containers including their temperature sensitivity, porosity, etc. influenced the moisture the content of whole paddy grains at different storage periods during both 2011 and 2012. Among storage containers earthen pot recorded lowest moisture content than four others used in the study. The grain moisture content in all five containers was usually higher in first year than second year of investigation.

Perusal of data revealed that there was a slight increasing trend in moisture content from 2-month to 6-month irrespective of the year probably due to change in mean relative humidity over two years values from 71.2 (2-month) to 82.2% (6-month) in the laboratory environment. However, Kanlayakrit and Maweang (2013) reported decline in moisture content in two *thai* rice varieties with the advancedment of storage period from 0 to 10 month period at Bangkok, Thailand.

4.3.2 Grain quality

4.3.2.1 Milling quality

The effect of the storage methods on milling quality of Gobindabhog rice samples stored as whole grains was evaluated, based on the percentage of brown rice, milled rice and head rice, as showed in Table (Table 4.3.3, 4.3.4 and 4.3.5).

Table 4.3.1

Meteorological data during post-harvest storage period at B.C.K.V., Mohanpur, Nadia, West Bengal during 2011 and 2012

	Meteorological data during storage period								
	2011			2012			Mean		
	1st and 2nd Month	3rd and 4th Month	5th and 6th Month	1st and 2nd Month	3rd and 4th Month	5th and 6th Month	1st and 2nd Month	3rd and 4th Month	5th and 6th Month
Maximum Temp. (^{0}C)	26.6	33.0	33.6	26.5	34.4	35.9	26.6	33.7	34.8
Minimum Temp. (^{0}C)	10.9	23.1	26.1	13.4	21.2	26.6	12.2	22.2	26.4
Mean Temp. (^{0}C)	18.8	28.1	29.9	20.0	27.8	31.2	19.4	28.0	30.6
Maximum Relative humidity (%)	96.4	92.2	95.6	94.0	93.2	90.9	95.2	92.7	93.3
Minimum Relative humidity (%)	42.7	52.8	73.6	52.0	47.2	68.3	47.4	50.0	71.0
Mean Relative humidity (%)	69.6	72.5	84.6	73.0	70.2	79.6	71.3	71.4	82.2

* 1st and 2nd month = January and February; 3rd and 4th month = March and April: 5th and 6th month = May and June

Table 4.3.2

Effect of storage container on moisture content in grains of Gobindabhog rice during post-harvest storage period

Storage container	Moisture content (%)								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	12.8	12.5	12.6	13.4	12.9	13.1	13.3	13.2	13.2
C_2	13.5	12.4	12.9	12.9	13.1	13.0	13.2	13.0	13.1
C_3	13.6	12.5	13.0	13.5	12.9	13.2	13.2	13.5	13.4
C_4	12.6	12.7	12.6	13.2	12.8	13.0	13.2	12.7	13.0
C_5	13.1	12.9	13.0	13.2	12.8	13.0	13.1	13.0	13.1
Mean	13.1	12.6	12.8	13.2	12.9	13.1	13.2	13.1	13.1
S.Em (±)	0.08	0.13	0.08	0.04	0.10	0.05	0.07	0.11	0.06
C.D. at 5%	0.25	NS	0.22	0.12	NS	NS	NS	0.32	0.19

NS = Not significant

4.3.2.1.1 Hulling

After shelling of Gobindabhog paddy, the brown rice content of Gobindabhog varied significantly among five containers after 2-month storage period during 2011 and pooled values, but it remained unaffected after 4-month and 6-month period during both first and second year of investigation (Table 4.3.3). With the advancement of storage period from 60 days to 180 days, the milling recovery showed a decreasing trend irrespective of container and year. The findings could be explained by the fact that the increase in mean relative humidity from 2-month (71.3%) to 6 month (78.8%) period caused slightly greater removal of husk due to softness of paddy (Table 4.3.3).

4.3.2.1.2 Milling

Mean milling recovery of Gobindabhog rice decreased slightly from 2-month to 6-month period during both 2011 and pooled values (Table 4.3.4). The milled rice content did not vary significantly among storage containers irrespective of storage period and year of investigation.

4.3.2.1.3 Head rice

The head rice recovery of Gobindabhog rice showed definite pattern of change during 2-month to 4-month storage period irrespective of containers between 2011 and 2012, but there was a little decreasing trend in HRR from 4-month to 6-month storage period during both first and second year of post-harvest storage experiment (Table 4.3.5; Fig. 4.11). The finding is in conformity with Wongponnchi *et al,* (2004), but differs Singh *et al,* (2003) wherein an trend of increasing HRR with the ageing of grains for 6-month period was noted probably due to less breakage during milling process.

Storage containers had no influence on the head rice recovery of Gobindabhog rice after 2-month period for both 2011 and 2012, but they could affect the HRR after 4-month time during 2012 and pooled values, as well as at the end of 6-month period during 2012 only (Table 4.3.5). The whole grains of Gobindabhog paddy stored in earthen pots usually yielded highest head rice compared to other containers irrespective of storage period and post-harvest year in the study. On the other hand. gunny (jute-made) bag and markin cloth bag recorded lower HRR

Table 4.3.3

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

Storage container	Hulling (%)								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	80.4	80.7	80.6	79.1	78.8	78.9	75.5	76.8	76.1
C_2	78.2	79.7	78.9	79.5	79.1	79.3	76.5	78.2	77.4
C_3	78.1	80.3	79.2	79.6	79.0	79.3	76.9	76.4	76.7
C_4	80.9	80.9	80.9	79.6	79.5	79.6	77.3	78.4	77.9
C_5	80.0	80.0	80.0	79.7	78.6	79.1	76.3	78.8	77.5
Mean	79.5	80.3	79.9	79.5	79.0	79.2	76.5	77.7	77.1
S.Em (±)	0.55	0.60	0.41	1.46	0.55	0.78	0.68	0.79	0.52
C.D. at 5%	1.62	NS	1.18	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.3.4

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

Storage container	Milling (%)								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	71.5	71.8	71.6	70.9	70.7	70.8	70.4	70.7	70.6
C_2	70.9	73.1	72.0	71.4	71.3	71.4	71.3	71.5	71.4
C_3	72.3	72.5	72.4	72.1	70.9	71.5	71.2	70.8	71.0
C_4	72.0	72.3	72.1	71.2	71.5	71.4	71.5	72.0	71.7
C_5	71.4	72.8	72.1	71.4	72.1	71.7	71.1	72.3	71.7
Mean	71.6	72.5	72.0	71.4	71.3	71.4	71.1	71.5	71.3
S.Em (±)	0.50	0.65	0.41	0.87	0.64	0.54	0.64	0.73	0.48
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

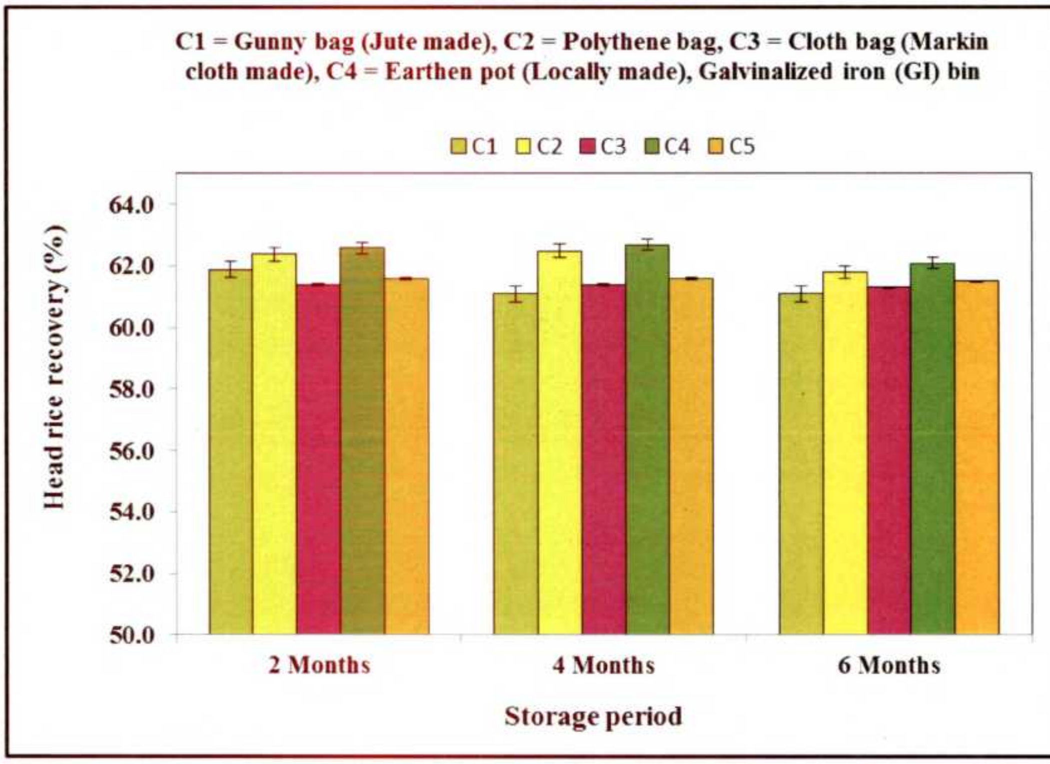

Fig. 4.11: Effect of storage containers on head rice recovery (%) of Gobindabhog rice during post-harvest storage period (pooled over two years)

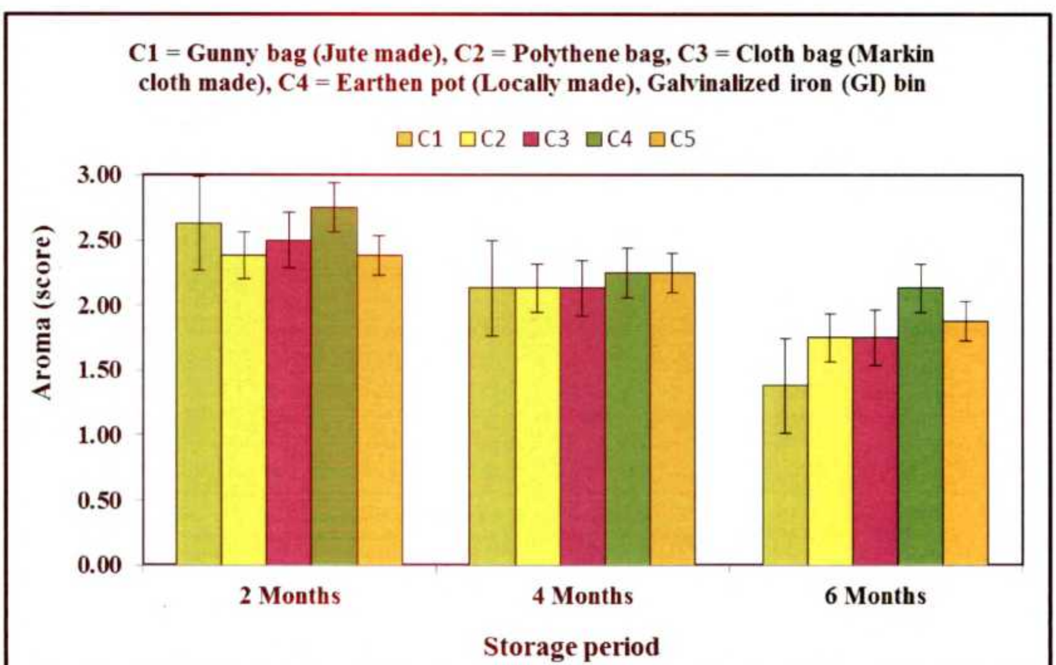

Fig. 4.12: Effect of storage containers on aroma (score) of Gobindabhog rice during post-harvest storage period (pooled over two years)

particularly for longer storage period (120 days and 180 days). This might be due to the increased porosity in two fiber-made bags (C_1 and C_3) caused greater exposure of grains than other three containers. Thus, five storage containers with respect to head rice yield after 6-month period for pooled values 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%).

4.3.2.2 Physical properties of grain

4.3.2.2.1 Kernel length

Kernel length, being a genetical character, was not significantly influenced by 5 different storage containers at 2, 4, 6-month period during both 2011 and 2012 (Table 4.3.6).

4.3.2.2.2 Kernel breadth

Storage containers did not have any influence on kernel breadth of Gobindabhog rice at three different periods (60, 120 and 180 days) of storage during both the years of investigation (Table 4.3.7).

4.3.2.2.3 L / B ratio

Like kernel length and breadth of Gobindabhog rice, L / B ratio remained unaffected due to variations in storage containers even at different storage periods during both 2011 and 2012 (Table 4.3.8).

4.3.2.3 Cooking quality

4.3.2.3.1 Amylose content

The amylose content in Gobindabhog rice slightly improved with ageing from 2-month to 4-month and declined thereafter toward 6-month period during both 2011 and 2012 (Table 4.3.9). 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, five storage containers with regard to amylose content could be arranged as: Earthen pot (18.15%) ≥ Jute bag (18.03%) ≥ Polythene bag (17.79%) ≥ G.I. bin (17.77%) ≥ Markin cloth bag (17.70%).

Table 4.3.5

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

Storage container	Head rice recovery (%)								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	61.3	62.5	61.9	61.6	60.7	61.1	61.5	60.7	61.1
C_2	60.4	64.5	62.4	62.7	62.3	62.5	61.7	61.9	61.8
C_3	60.5	62.2	61.4	61.8	61.1	61.4	62.0	60.7	61.3
C_4	62.0	63.1	62.6	62.6	62.8	62.7	61.6	62.6	62.1
C_5	61.1	62.2	61.6	61.6	61.6	61.6	60.7	62.2	61.5
Mean	61.0	62.9	62.0	62.0	61.7	61.9	61.5	61.6	61.6
S.Em (±)	0.74	0.71	0.51	0.57	0.42	0.35	0.75	0.35	0.41
C.D. at 5%	NS	NS	NS	NS	1.23	1.01	NS	1.04	NS

NS = Not significant

Table 4.3.6

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

Storage container	Kernel length (mm)								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	4.03	4.12	4.08	4.01	4.08	4.05	4.00	4.00	4.00
C_2	4.01	4.06	4.04	3.97	4.01	3.99	3.98	4.01	3.99
C_3	4.07	4.08	4.08	4.00	3.99	4.00	3.95	3.97	3.96
C_4	3.98	4.00	3.99	3.99	3.99	3.99	3.97	3.93	3.95
C_5	3.96	3.97	3.97	3.93	3.97	3.95	3.94	3.99	3.96
Mean	4.01	4.05	4.03	3.98	4.01	3.99	3.97	3.98	3.97
S.Em (±)	0.08	0.08	0.06	0.05	0.05	0.04	0.04	0.05	0.03
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 kernel breadth of Gobindabhog rice during post-harvest storage period

Storage container	Kernel breadth (mm)								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	2.00	2.01	2.00	1.97	1.96	1.96	1.95	1.97	1.96
C_2	1.97	1.98	1.97	1.97	1.97	1.97	1.97	1.99	1.98
C_3	2.04	2.01	2.03	1.96	1.96	1.96	1.94	1.92	1.93
C_4	1.96	1.99	1.97	1.93	1.96	1.95	1.95	1.99	1.97
C_5	1.98	1.94	1.96	1.95	1.98	1.96	1.94	1.96	1.95
Mean	1.99	1.98	1.99	1.96	1.97	1.96	1.95	1.97	1.96
S.Em (±)	0.05	0.02	0.03	0.04	0.03	0.02	0.04	0.03	0.02
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 L / B ratio of Gobindabhog rice during post-harvest storage period

Storage container	L / B ratio								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	2.03	2.06	2.04	2.04	2.09	2.06	2.05	2.04	2.05
C_2	2.05	2.05	2.05	2.02	2.04	2.03	2.02	2.01	2.02
C_3	1.99	2.03	2.01	2.04	2.04	2.04	2.04	2.07	2.06
C_4	2.03	2.02	2.02	2.07	2.03	2.05	2.04	1.98	2.01
C_5	2.00	2.05	2.02	2.02	2.00	2.01	2.03	2.03	2.03
Mean	2.02	2.04	2.03	2.04	2.04	2.04	2.04	2.03	2.03
S.Em (±)	0.06	0.04	0.04	0.05	0.02	0.03	0.04	0.04	0.03
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 amylose content of Gobindabhog rice during post-harvest storage period

Storage container	Amylose content (%)								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	18.09	17.99	18.04	18.16	18.12	18.14	18.13	17.93	18.03
C_2	17.73	17.88	17.80	18.02	17.75	17.88	17.74	17.85	17.79
C_3	17.97	17.65	17.81	17.78	17.77	17.78	17.59	17.81	17.70
C_4	18.33	18.14	18.23	18.43	18.28	18.35	18.30	18.01	18.15
C_5	17.85	17.72	17.78	17.90	17.97	17.93	17.78	17.75	17.77
Mean	17.99	17.87	17.93	18.06	17.98	18.02	17.91	17.87	17.89
S.Em (±)	0.16	0.15	0.11	0.18	0.09	0.10	0.15	0.12	0.10
C.D. at 5%	NS	NS	0.32	NS	0.26	0.29	0.43	NS	0.28

NS = Not significant

Table 4.3.10

Effect of storage container on protein content of Gobindabhog rice during post-harvest storage period

Storage container	Protein content (%)								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	7.75	7.29	7.52	7.59	7.18	7.38	7.30	7.29	7.29
C_2	7.38	7.31	7.34	7.36	7.26	7.31	7.24	7.16	7.20
C_3	7.48	7.31	7.39	7.27	7.14	7.20	7.38	7.31	7.34
C_4	7.35	7.28	7.31	7.49	7.41	7.45	7.41	7.29	7.35
C_5	7.62	7.31	7.46	7.31	7.32	7.31	7.16	7.22	7.19
Mean	7.51	7.30	7.41	7.40	7.26	7.33	7.30	7.25	7.27
S.Em (±)	0.41	0.29	0.25	0.08	0.07	0.05	0.25	0.15	0.14
C.D. at 5%	NS	NS	NS	NS	NS	0.15	NS	NS	NS

NS = Not significant

4.3.2.3.2 Protein content

The protein content in Gobindabhog rice stored in five different types of containers remained largely unchanged during storage from 2 to 6-month period, excluding after 4-month for pooled values only (Table 4.3.10). The finding is consistent with Kanlayakrit and Maweag (2013), but differes with Ilyas *et al.* (1983) wherein little increase in protein content (8.5 - 8.8%) was noted during storage over initial sample (8.4%) in the study at Cuttack, Odisha, India.

4.3.2.3.3 Alkali value or Gelatinization temperature

Mean containers pooled alkali value was 3.83 (2-month), 3.98 (4-month) and 4.08 (6-month), which indicated gradual increase in alkali spreading value from short-term to long-term storage in the study (Table 4.3.11). The containers did not vary among themselves for alkali value throughout the post-harvest storage period in 2011 and 2012 excluding at 4-month for pooled values only. Above all, the milled rice of Gobindabhog obtained from all samples had intermediate gelatinization temperature.

4.3.2.4 Processing quality

4.3.2.4.1 Kernel length after cooking

The cooked kernel length of Gobindabhog rice after cooking was unaffected due to variation in storage periods or containers throughout the post-harvest storage period of both 2011 and 2012. Although there was no definite trend of change in cooked kernel length among storage containers during the ageing process in the study, but the grains stored in G.I. bin (C_5) showed highest KLAC (7.23 and 7.33 mm) at short-term (2-month) storage, and grains of earthen pot (C_4) recorded highest KALC (7.53 and 7.60 mm) at mid-term (4-month) and long-term (6-month) storage in the laboratory (Table 4.3.12).

4.3.2.4.2 Elongation ratio (ER)

The results on elongation ratio of Gobindabhog rice stored in five different containers under 2, 4 and 6 month period indicated a slight increase in ER with the lengthening of storage time during both 2011 and 2012 (Table 4.3.13). Similar kind of increase in cooked kernel elongation of *thai* paddy varieties during the ageing

Table 4.3.11

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

Storage container	Alkali value (score)								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	4.25	3.75	4.00	4.25	4.25	4.25	4.50	4.00	4.25
C_2	4.25	3.50	3.88	4.00	3.75	3.88	4.25	3.75	4.00
C_3	3.50	3.50	3.50	4.00	3.50	3.75	4.00	3.75	3.88
C_4	4.00	3.75	3.88	4.25	4.00	4.13	4.25	4.00	4.13
C_5	4.00	3.75	3.88	4.00	3.75	3.88	4.25	4.00	4.13
Mean	4.00	3.65	3.83	4.10	3.85	3.98	4.25	3.90	4.08
S.Em (±)	0.27	0.27	0.19	0.16	0.23	0.14	0.23	0.24	0.17
C.D. at 5%	NS	NS	NS	NS	NS	0.41	NS	NS	NS

NS = Not significant

Table 4.3.12

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

Storage container	Kernel length after cooking (mm)								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	7.33	7.18	7.25	7.20	7.43	7.31	7.23	7.28	7.25
C_2	7.23	7.15	7.19	7.18	7.43	7.30	7.35	7.25	7.30
C_3	7.25	7.20	7.23	7.35	7.33	7.34	7.10	7.30	7.20
C_4	7.23	7.25	7.24	7.38	7.50	7.44	7.53	7.60	7.56
C_5	7.23	7.33	7.28	7.10	7.48	7.29	7.28	7.43	7.35
Mean	7.25	7.22	7.24	7.24	7.43	7.34	7.30	7.37	7.33
S.Em (±)	0.19	0.16	0.12	0.29	0.23	0.19	0.20	0.15	0.12
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.3.13

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

Storage container	Elongation ratio								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	1.81	1.74	1.78	1.79	1.82	1.81	1.81	1.82	1.81
C_2	1.81	1.77	1.79	1.81	1.85	1.83	1.85	1.81	1.83
C_3	1.78	1.77	1.77	1.84	1.83	1.84	1.80	1.84	1.82
C_4	1.82	1.81	1.81	1.85	1.88	1.86	1.90	1.94	1.92
C_5	1.81	1.83	1.82	1.81	1.88	1.85	1.85	1.86	1.85
Mean	1.81	1.78	1.80	1.82	1.85	1.84	1.84	1.85	1.85
S.Em (±)	0.04	0.05	0.03	0.07	0.05	0.05	0.05	0.05	0.04
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not significant

Table 4.3.14

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

Storage container	Aroma (score)								
	2 Months			4 Months			6 Months		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
C_1	2.50	2.75	2.63	2.00	2.25	2.13	1.00	1.75	1.38
C_2	2.25	2.50	2.38	2.00	2.25	2.13	1.50	2.00	1.75
C_3	2.25	2.75	2.50	2.00	2.25	2.13	1.75	1.75	1.75
C_4	2.75	2.75	2.75	2.00	2.50	2.25	2.00	2.25	2.13
C_5	2.25	2.50	2.38	2.25	2.25	2.25	1.75	2.00	1.88
Mean	2.40	2.65	2.53	2.05	2.30	2.18	1.60	1.95	1.78
S.Em (±)	0.26	0.27	0.19	0.46	0.26	0.26	0.20	0.27	0.17
C.D. at 5%	NS	NS	NS	NS	NS	NS	0.60	NS	0.48

NS = Not significant

process was reported by Kanlayakrit and Maweag (2013). The whole grains stored in all five containers at room temperature (25 ± 5^0C) resulted in increase in ER during first 4-month storage, but it continued upto 6-month time for earthen pot only and decreased for markin cloth during 4 to 6-month period.

4.3.2.4.3 Aroma

There was a steady decrease in intensity of aroma of Gobindabhog rice during post-harvest storage from 2-month to 6-month period irrespective of container during both the years of investigation (Table 4.3.14; Fig. 4.12). The average aroma score over containers after 2-month storage (score 2.53 ± 0.18) declined by 13.83% after 4-month (score 2.18 ± 0.06) and 29.64% after 6-month (score 1.78 ± 0.37). The loss in flavour during the post-harvest storage period was due to release or volatilization of 2-acety-l-pyroline contain in 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).

Among storage containers used in the study, earthen pot (C_4) could favorably inhibit the release of 2-acety-l-pyroline from whole grains of Gobindabhog rice compared to other four containers at 2, 4 and 6-month storage period in the investigation; while the loss of aroma in jute bags was very fast between 120 (score 2.13) and 180 days (score 1.38) storage time.

Chapter 5

SUMMARY AND CONCLUSION

5. SUMMARY AND CONCLUSION

A comprehenshive study on "Improvement of production and storage system for Gobindabhog rice in West Bengal" comprising two field and one laboratory experiments was done at Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India during the period of 2010-2012.

Two field investigations were conducted at 'C' Block Farm, Kalyani, Nadia, during wet (*kharif*) season of 2010 and 2011 to find out the optimum planting time and spacing as well as to standardize the integrated nutrient management system for better grain yield and aroma quality of Gobindabhog rie in West Bengal. Besides, the laboratory experiment was conducted at 'Aromatic rice Laboratory', Mohanpur, Nadia during 2011 and 2012 to identify better storage method(s) for sustenance of grain quality at different storage periods.

The salient findings of first experiment entitled "Effect of planting date and spacing on phenology, growth, pest dynamics, yield and quality of Gobindabhog rice during *Kharif* season" were summarized as follow:

Gobindabhog rice planted on four different dates, *i.e.* July 10 (D_1), July 25 (D_2), August 10 (D_3) and August 25 (D_4) took 152.0, 143.8, 138.7 and 132.7 days, respectively to maturity; which indicated reduction in life duration by 8.2 days for July 25, 13.3 days for August 10 and 19.7 days for August 25 planting compared to earlier one (July 10) in the study. Mean summed GDD of Gobindabhog rice from sowing to emergence, 4^{th} leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 69.5, 423.0, 970.7, 1506.2, 2134.1, 2313.4, 2467.6 and 2607.6 ^{0}C, respectively. Based on pooled values for total summed GDD, HTU and PTU, four planting dates could be arranged as July 10 (2885.1^{0}C, 16194.2^{0}C hour and 35641.1^{0}C hour) > July 25 (2695.7^{0}C, 15988.1^{0}C hour and 32730.2^{0}C hour) > August 10 (2519.6^{0}C, 15464.2^{0}C hour and 30319.0^{0}C hours) > August 25 (2329.8^{0}C, 14567.7^{0}C hour and 27701.0^{0}C hours).

Plant height, tiller production and LAI were increased consistently with the advancement of crop growth upto panicle exertion, panicle initiation (*i.e.* 56 DAT) and flowering (*i.e.* 84 DAT) stage, respectively. Based on pooled values, the final plant height was found to vary between 127.8 (August 25) and 136.9 days (July 10)) at harvest; maximum tiller production between 323.3 (July 10) and 337.5m^{-2} (August 25) at 56 DAT, and maximum LAI between 4.61 (July 10) and 4.84 (August 10) at 84 DAT. The variations in light interception generally showed inverse relationship with their respective LAI values at different stages of the crop. Mean light extinction co-efficient (k), pooled over two years, were 0.43, 0.30, 0.35 and 0.50 at 28, 56, 84 DAT and at harvest, respectively. The infestation of brown spot and blast diseases on Gobindabhog rice plant increased progressively from 3 to 9 WAT, while population of gundhi bug from 84 to 112 DAT in the study. Close spacing 20 cm × 10 cm (S_1) retarded the weed growth that led to lowest density of grass, sedge and broadleaf weeds in experimental plots compared to wider spacing of 15 cm × 15 cm (S_2) and 20 cm × 15 cm (S_3) throughout the cropping period.

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 four plating dates and three different spacings in the study. Gobindabhog rice planted on July 25 (D_2) produced the highest grain yield (3.02 t ha^{-1}), which was 4.13, 14.39 and 17.51% greater over August 10 (D_3), August 25 (D_4) and July 10 (D_1), respectively.

Besides, square planting method (15 cm × 15 cm) resulted in highest pooled grain yield (2.89 t ha^{-1}) compared to (2.83 t ha^{-1}) 20 cm × 10 cm and 20 cm × 15 cm (2.63 t ha^{-1}) in the study.

Among treatment combinations, the crop planted on July 25 with a spacing of 20 cm × 10 cm (D_2S_1) resulted in highest grain yield (3.08 t ha^{-1}), being at par with 3.02 t ha^{-1} (July 25 planted with 15 cm × 15 cm). Based on correlation studies with the thermal indices, the regression model for grain yield ($Y = -1.348 + 0.001^{**} HTU_{PI\text{-}F} - 0.001^{**} HTU_{S\text{-}E} + 0.001^{**} HTU_{E\text{-}4L} + 0.001^{**} PTU_{D\text{-}M} + 0.001^{*} PTU_{Mi\text{-}D} - 0.011^{*} GDD_{D\text{-}M}$) accounted for 71% variation in 1% level of significance.

Mean hulling, milling and head rice recovery of Gobindabhog were 78.5, 72.7 and 62.0%, respectively. The positive correlation of HTU ($r = 0.319^{*}$) and PTU ($r = 0.268^{*}$) during dough to maturity stage with head rice recovery indicated better HRR (62.7%) from July 25 (D_2) planted crop compared to other three plantings dates in the study.

Gobindabhog rice had short bold type, white kernels and rarely with chalkiness. The kernel length, breadth L / B ratio and alkali value of Gobindabhog rice remained unaffected due to variation in planting time during *kharif* season, and spacing had no influence on most of grain quality parameters in the investigation.

Gobindabhog rice planted on July 25 (D_2) resulted in highest amylose (18.08%) and protein content (7.48%) compared to earlier (D_1) or later (D_3 and D_4) plantings. The intensity of aroma was improved with delay in planting from July 10 (D_1) to August 25 (D_4) probably due to decreasing day and night temperature during grain filling and ripening period. Gobindabhog rice usually had intermediate gelatinization temperature and medium-strong aroma.

The second findings of investigation, entitled "Standardization of FYM and mustard cake with inorganic fertilizers for better yield and superior quality of Gobindabhog rice along with better soil health during *kharif* season" could be summarized as under:

The use of FYM and mustard cake in either of dose (O_2–O_5) resulted in taller plants, greater tiller production and higher LAI over unfertilized control (O_1). Similarly, application of $N_{40}P_{20}K_{20}$ kg ha^{-1} (F_3) improved the growth attributes of Gobindabhog rice over $N_{20}P_{10}K_{10}$ kg ha^{-1} (F_1) and $N_{30}P_{15}K_{15}$ kg ha^{-1} (F_2) in the study.

The combined effect of organic manure and chemical fertilizer on yield components led to the highest grain yield (3.01 t ha^{-1}) under O_3F_3 (FYM @ 5 t ha^{-1} + $N_{40}P_{20}K_{20}$ kg ha^{-1}), being closely followed by O_3F_2 and O_4F_1 (2.99 t ha^{-1}) in the investigation.

The physical properties of grain (viz. kernel length, breadth, L / B ratio, shape colour, etc.) remained unaffected due to variation in types and doses of organic manures and chemical fertilizers. However, the application of FYM @ 5.0 t ha^{-1} (O_3) or mustard cake @ 0.25 t ha^{-1} (O_4) or 0.50 t ha^{-1} (O_5) improved the amylose content (18.33 – 18.45%), protein content (7.36 – 7.59%) and aroma (score 2.28 – 2.44) over FYM @ 2.5 t ha^{-1} (O_2) or unmanured control (O_1).

The integrated dose of FYM @ 5.0 t ha^{-1} + $N_{40}P_{20}K_{20}$ kg ha^{-1} (O_3F_3) applied to Gobindabhog rice during *kharif* season resulted in grain yield (3.01 t ha^{-1}), better grain quality like 62.4% head rice recovery, 18.39% amylose, 7.75% protein and medium-strong aroma (score 2.50), and higher net return (Rs. 29110.00), B:C ratio (2.05) along with better soil residual status (+8.04% N, +27.84% P and –5.58% K).

The findings of third experiment on "Effect of storage containers on quality of Gobindabhog rice during different storage periods" during post-harvest storage period of 2011 and 2012 could be summarized as:

The change in mean relative humidity over two years from 71.2 (2-month) to 82.2% (6-month) in the laboratory experiments probably caused a slight increasing trend in moisture content in grain irrespective of storage container used in the study. The variation in material of the containers including their temperature sensitivity, porosity, etc. influenced the moisture content of whole paddy grains at different storage period during both 2011 and 2012. Among containers, earthen pot recorded lowest moisture content than other four tested in the experiment.

With the advancement of storage time from 60 days to 180 days, the milling quality of Gobindabhog rice (*viz*. hulling, milling and head rice recovery) generally showed slight declining trend, including few significant changes during the post-harvest storage period. Five storage containers, with respect to pooled head rice yield after 6-month storage period 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%).

The physical properties of grain (*viz.* kernel length, kernel breadth, L / B ratio, shape, colour, etc.) did not differ significantly among five storage containers during the ageing or storage period. On an average, the protein content in the Gobindabhog rice grain remained largely unchanged during entire 6-month storage time, but amylose content improved slightly upto 4-month, and alkali value and elongation ratio upto 6-month period including non-significant variations among the containers in the experiment.

There was a steady decrease in intensity of aroma of Gobindabhog rice during post-harvest storage from 2-month to 6-month period irrespective of container used in the study. The average aroma score over containers after 2-month storage (score 2.53 ± 0.18) declined by 13.83% after 4-month (score 2.18 ± 0.06) and

29.64% after 6-month (score 1.78 ± 0.37). Among storage containers, earthen pot performed best for retention of aroma while jut-made gunny bag appeared unfit for long-term storage of Gobindabhog paddy with respect to grain quality parameters, especially aroma.

Based on the findings in the investigation, Gobindabhog rice might be transplanted on July 25) with a spacing of 15 cm × 15 cm during *kharif* season for medium long growth duration (143.5 days), higher grain yield (3.02 t ha^{-1})and better quality (amylose 18.09%. protein 7.46%, elongation ratio 1.38 and medium-strong aroma). The integrated dose of FYM @ 5.0 t ha^{-1} + $N_{40}P_{20}K_{20}$ kg ha^{-1} (O_3F_3) could be recommended for Gobindabhog rice during *kharif* season in New Alluvial Zone for greater grain yield (3.01 t ha^{-1}), better grain quality like 62.4% head rice recovery, 18.39% amylose, 7.75% protein and medium-strong aroma (score 2.50), and higher net return (Rs. 29110.00), B:C ratio (2.05) along with better soil health. Among five storage containers, earthen pot (C_4) performed best for greater head rice recovery (62.1%), amylose (18.15%), protein (7.35%) and aroma (score 2.13) after 6-month storage period in West Bengal.

Chapter 6

FUTURE SCOPE OF RESEARCH

6. FUTURE SCOPE OF RESEARCH

The present study on "Improvement of production and storage system for Gobindabhog rice in West Bengal" was done during the period of 2010–2012 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 cultivars 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 world rice market are cultivated in some Asian and South American countries. These aromatic rice cultivars having varied yield potentiality and grain quality may be evaluated during both wet and dry season to find out the suitable ones in different agro-ecological conditions.

Research works may be undertaken for standardization of cultural practices like planting dynamics, organic or integrated nutrient, weed and water management, harvesting time, etc. for selected promising scented rice varieties under different land situations and seasons.

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

The influence of (i) degree of milling or polishing, (ii) storage periods or environments and (iii) storage materials or packets (iv) cooking methods on grain quality of popular aromatic rice should be studied toward 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 future strategy for premium aromatic rice.

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