REFERENCE ONLY

EFFECT OF SPACING AND NITROGEN FERTILIZER LEVEL ON THE YIELD AND QUALITY OF SOME VARIETIES OF AROMATIC RICE

2

A Thesis

By

MD. SHAFIQUL ISLAM SIKDAR
Examination Roll No. 1
Registration No. 16465
Session : 1988-89
Semester : July-December 2001

হাজী মোহাম্মদ দানেশ বিজ্ঞান ও প্রযুক্তি বিশ্ববিদ্যালয়
দিনাজপুর।

MASTER OF SCIENCE (M.S.)

IN

AGRONOMY

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তারিখ .....

Department of Agronomy
Bangladesh Agricultural University
Mymensingh

November 2001

ইস্যু করা হয় না

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Submitted to the Department of Agronomy
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MD. SHAFIQUL ISLAM SIKDAR
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Session : 1988-89
Semester : July-December 2001

Approved as to the style and content by :

Masood Ahmed

Professor Dr. Masood Ahmed
Supervisor

Professor Dr. S. M. Altaf Hossain
Co-supervisor

Masood Ahmed

Professor Dr. Masood Ahmed
Chairman
Examination Committee
and Head
Department of Agronomy
Bangladesh Agricultural University
Mymensingh

November 2001

DEDICATED
TO MY
BELOVED MOTHER
AND
DEPARTED SOUL OF
MY FATHER

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ABSTRACT

An experiment was carried out to investigate the effect of spacing and nitrogen level on yield and quality of some varieties of aromatic rice at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from July to December 2000. The experiment included three varieties namely, Kalizira, Badshabhog and Tulshimala, four different spacing namely, 8 cm×25 cm, 12 cm × 25 cm, 16 cm × 25 cm and 20 cm × 25 cm and three nitrogen level viz., 40, 60 and 80 kg ha^{-1}. The experiment was laid out in a split-split plot design with three replications. Except only few parameters, the yield, yield contributing characters, qualitative characters and soil properties were significantly influenced by spacing and nitrogen level in all varieties of aromatic rice. Yield increased with increasing spacing and nitrogen level up to certain limit of all varieties along with the improvement of yield contributing characters. Badshabhog was found significantly superior to Kalizira and Tulshimala with respect to number of grains $panicle^{-1}$, 1000-grain weight, grain yield, and harvest index. Among four spacings, the highest grain yield (2.84 t ha^{-1}) was obtained from spacing (16 cm × 25 cm). Among three nitrogen levels, significantly highest grain yield (2.85 t ha^{-1}) was obtained from 60kg N ha^{-1}. The effect of interaction of spacing and nitrogen, variety and spacing and variety, spacing and nitrogen level was not significant. The effect of spacing and nitrogen level on different qualitative characters viz., nitrogen content (%), nitrogen uptake (kg ha^{-1}), protein (%), germination (%), vigour index were significant in all varieties of aromatic rice. All the qualitative characters (except aroma and cooking time) were found to increase significantly with the increasing from 8 cm × 25 cm spacing to 16 cm × 25 cm and 40 to 80 kg N ha^{-1}, respectively. Most of the interaction effect was not significant. Post harvest soil analysis that the organic matter depleted and mining occurred in the case of exchangeable K and available P. The level of total N did not decrease due to nitrogen application.

CHAPTER I

INTRODUCTION

Globally, rice is the second most important crop to wheat in terms of area but as food rice is important since it provides more calorie than any other cereals. About 40% of the world's population consume rice as a major source of calorie (Banik, 1999). Among the major rice growing countries of the world, Bangladesh ranks third in respect of growing area and fourth in production (Huke and Huke, 1990). Here rice is cultivated in 10.26 million hectares having the average yield 1.79 t ha^{-1} with the production of 19.9 million metric tons (BBS, 1999). In the year 2002, the food grain requirement of the country will be 25 million metric tons. Rice, the staple food of the country is cultivated in the 76% of the arable land (BBS, 1999). It plays a vital role to the Bangladesh economy as it contributes about 50% of the total agricultural value added and engages over 65% of the total agricultural labour force. Besides, rice production continues to be one of the important sources of livelihood accounting for 76% of people's average calorie intake and 66% of protein intake (BBS, 1996).

In Bangladesh, more than four thousand land races of rice are adopted in different parts of this country. Some of these have some good quality i.e. fineness, aroma, taste and protein content (Kaul *et al.*, 1982). The productivity is very low (Chander and Jitendra, 1996). But the aromatic fine quality rice has more demand both in internal and external trade markets. For example, Basmati (aromatic) rice has extremely high demand in the world and it occupies a unique place in the world rice market (Sood, 1978). Aromatic rice such as Kalizira, Tulshimala, Badshabhog are the most highly valued rice commodity in Bangladesh

Agricultural Trade Market, having small grain pleasant aroma. Aromatic rice is used in many ways by the people like *polau, khir, finny, jarda* etc. Fine rice has high market value, because of high price and taste of this rice. Its export can bring a considerable amount of foreign exchange for the nation.

The yield of the rice is very low in Bangladesh comparing to that of the countries in the world. The reasons for such low yield are mainly associated with cultural technologies. Among the cultural technologies spacing and N-fertilization are the important ones.

Improper spacing reduced yields up to 20-30%. (IRRI, 1967). The optimum spacing ensures the plants to grow in their both aerial and under ground parts through efficient utilization of solar radiation and nutrients. If any reason, the production of number of tillers hill^{-1} is affected by spacing. As the tiller production in aromatic rice is very low and most of them are low yielding (Gangaiak and Prasad, 1999). So it is essential to determine suitable spacing for the aromatic rice varieties to maximize their yield.

Rice plant depends solely upon soil and applied source of nitrogen for maximum yield. Nitrogen plays a key role in supporting plant activity and increasing the rice yield (BRRI, 1997). Nitrogen is the key element in the production of rice and gives by far the largest response. It is also a fact that improper use of nitrogenous fertilizer, instead of giving yield advantage, may reduce the same. Again different varieties may have varying responses to N-fertilizer depending on their agronomic traits. Many workers have reported a significant response of rice to nitrogen in different soils in Bangladesh (Bhuiyan *et al.,* 1989, Hossain *et al.,* 1989 and Islam *et al.,* 1990).

For maximizing the yield, manipulation of cultural techniques like spacing and N-fertilizer are essential and the selection of suitable combination of spacing and optimum N-fertilizer is the most important factor for maximizing rice production. For aromatic rice, the information is limited on spacing and N-fertilizer combination.

Cultivation of aromatic rice is becoming popular due to its remunerative prices and huge-export potentiality (Gangaiak and Prasad, 1999). Aromatic varieties of rice are preferred by some consumers despite of their higher price and lower yield (Ratho, 1984). It is, therefore, necessary to improve its cultural practices like spacing and nitrogen level. A study was undertaken keeping the above view in mind with the following objectives :

i. to evaluate the performance of some common aromatic rice varieties, and
ii. to find out the effect of nitrogen level and spacing of aromatic rice varieties on the growth and yield.

CHAPTER II

REVIEW OF LITERATURE

Sufficient information regarding the variety of aromatic rice with spacing and N-fertilization are meagre in the world literature. In this chapter an approach has been made to review some of available information related to the study. A short review of some pertinent available information is given below:

2.1 Effect of rice variety on yield and other crop character

A BRRI (2000) reported that the performance of three proposed varieties BR 4384-2B-2-2-4, BR 4384-2B-2-2-6 and BR 4384-2B-2-2-HR3 was tested along with two standard check and one local check in 11 locations in T. Aman. Kataribhog and Khashani were used as standard check and Chinking, Basmati, Kalizira, Philippine Katari, Chinigura. Chiniatop and Bashful as local checks. In Sonagazi and Bogra Sadar, the yield performance of the proposed varieties were excellent with more than 4.0 t ha^{-1} yield. Hence, about 30% higher yield was obtained from the proposed varieties over the checks.

B BRRI (1999) reported that three proposed fine grain aromatic rice varieties viz., Khaskani, Basmati-D and Kataribhog were tested along with two check varieties at four locations each in the project and out reach area. BR5 was used as a standard check and Kalizira, Khirkon and Khirshapati as local checks. Khaskani gave the highest mean yield of 2.81 and 2.75 t ha^{-1} in the 144 and 148 days, respectively, whereas the mean yield of Basmati-D (2.34 t ha^{-1}) and

Kataribhog (2.04 t ha^{-1}) could not exceed of standard check BR5 (2.66 t ha^{-1}) in the project areas. But in the out reach area, the mean yield of Basmati-D (2.32 t ha^{-1}) and Kataribhog (2.32 t ha^{-1}) was similar to BR5 (2.4 t ha^{-1}).

C Dwivedi (1997) reported that Kamini, RP615, Harbans, Basmati, Kasturi and Sugandha varieties of fine rice produced 2.43, 1.94, 1.92, 2.01 and 2.56 t ha^{-1}, respectively.

D BRRI (1995) studied varietal performances of BR4, BR10, BR11, BR22, BR23 and BR25 varieties including two local checks Challish and Nizersail transplanted at 20 cm $\times$ 20 cm spacing with 2-3 seedling $hill^{-1}$. The results indicated that BR4, BR10, BR11, Challish and Nizersail produced yields of 4.38, 3.12, 3.12, 3.12 and 2.7t ha^{-1}, respectively. Challish variety earlier than all other varieties.

E BRRI (1994) studied the performance of BR14, Pajam, and BR5. BR14 (3.75 t ha^{-1}) produced the highest yield while BR5 (2.61 t ha^{-1}) produced the lowest one. BINA (1993) evaluated the performance of four varieties/advanced lines IRATOM 24, BR14, BINA13 and BINA19. It was found that varieties/advanced lines differed significantly for plant height, number of non-bearing tillers, panicle length, sterile spikelets $panicle^{-1}$. Results showed that grain yield did not differ significantly.

F Chowdhury *et al.* (1993) stated that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. number of productive tillers $hill^{-1}$, length of panicle, 1000-grain weight, grain and

straw yields. On the other hand, Pajam produced significantly taller plants, higher number of total spikelets panicle^{-1}, grains panicle^{-1} and unfilled spikelets panicle^{-1}. BRRI (1994) reported that Tulsimala produced the highest number of spikelets panicle^{-1} and BR1 produced the lowest number of spikelets panicle^{-1}.

BRRI (1991) reported that the number of effective tillers produced by some transplant aman rice ranged from 7 to 14 and it significantly differed from variety to variety. In local varieties, namely, Haloi, Tilockachari, Nizersail and Latishail, the number of effective tillers hill^{-1} were 9.7, 9.3, 10.8 and 9.0, respectively.

Alim *et al.* (1962) tested five fine rice cultivars namely, Badshabhog, Basmati, Hatisail and Radhunipagal for five years and found that Basmati showed the best performance followed by Gobindhabhog and Badshabhog. They also reported that Badshabhog yielded 2.6 t ha^{-1} and each of Daudkhani (another fine rice cultivars) and Hatisail yielded 2.69 t ha^{-1}. The authors further reported about a cross between Daudkhani and Indrasail which resulted an average yield of 2.87 t ha^{-1}.

2.2 Effect of spacing on the yield and yield components

BRRI (2000) reported that effect of plant density at various nitrogen level was studied to find out whether the loss of crop production in less fertile soils could be overcome by increasing plant density. Plant spacing corresponding to the plant densities 40 cm × 20 cm, 25 cm × 20 cm, 25 cm × 10 cm and 20 cm × 10 cm. were assigned in a plot receiving either 100, 150, 200 or 250 kg N ha^{-1}. N-application beyond 100 kg ha^{-1} did not increase the number of panicles plant^{-1} or unite area^{-1}. Grain yield increased with the increase of plant density up to

20 hills m^{-2} further increase of plant density increased the transplanting cost by the at least 65%. The trend in yield increase due to increase in plant density was not affected by N doses.

BRRI (1999) reported that BR varieties were grown in different Regional Research Stations at 10 × 10 spacing and 30 × 30 spacing using normal cultural practices. The grain yield, straw yield, total biomass, leaf area index specific leaf weight and harvest index were recorded. Yield varied for 2.23 t ha^{-1} in closer spacing with an average of 3.04 t ha^{-1}. Where as the yield varied from 2.27 to 4.89 t ha^{-1} in wider spacing with an average of 3.83 t ha^{-1}. Most of varieties gave higher grain yield in wider spacing.

Chandra *et al.* (1997) conducted an experiment on 12 Basmati rice varieties at Cuttack in wet season during 1991 and 1992 at 20 cm × 15 cm and 15 cm × 15 cm spacings and varieties were Basmati-370. Kapurthak Basmati, Rasbir Basmati, Dheharun Basmati, IET11347, IET8579, Pusa615, Gaurav, cv. II. Dubraj, Kalimuch and Madhuri. The closer spacing 15 cm × 15 cm gave 10-12% higher yields of rough rice.

Azad *et al.* (1995) stated that rice seedlings were transplanted at 20 cm × 10 cm, 25 cm × 15 cm or 30 cm × 20 cm spacings. Grain yield decreased by the widest plant spacing.

BRRI (1995) carried out an experiment on local variety Kumragair at 25 cm × 15 cm, 25c m × 30 cm and 25 cm × 45 cm spacing. The results revealed that panicle production and grain yield differed significantly with spacing.

Hegazy *et al.* (1995) conducted an experiment on rice planted in 15 cm × 15 cm, 20cm × 20 cm or 25 cm × 25 cm rows. The yield was the highest at the 20 cm × 20cm row spacing. Grain yield was not significantly affected by the plant density.

Padmajarao (1995) reported that rice cv. Basmati 370 and IET 8580 were transplanted at 20 cm × 20 cm, 20 cm × 15 cm or 20 cm × 10 cm spacing (25, 33 and 50 plants m^{-2}, respectively) with given 0-80 kg N ha^{-1}. Grain yield increased with N application and was highest at the closest planting spacing. At high density grain number was highest with 40 kg N ha^{-1} and the closest plant spacing.

Budhar *et al.* (1993) reported that rice cv. IR64 transplanted at row spacing of 15 cm × 20 cm, 12.5 cm × 10 cm or 10 cm × 10 cm gave grain yield of 4.33, 4.92 and 4.88 t ha^{-1}, respectively. Om *et al.* (1993) carried out a field experiment on Basmati-370 rice during the Kharif (Monsoon) season of 1987 at Kaul at 15, 22.5 or 30 cm × 15 cm spacing gave grain yields of 4.08, 3.91 and 3.63 t ha^{-1}, respectively.

Gupta and Sharma (1991) found that 10 cm × 10 cm and 15 cm × 15 cm spacing, produced more grain yields (2.86 and 2.82 t ha^{-1}, respectively) than 15 cm × 10 cm and 20 cm × 10 cm spacing. IR35 gave higher yield than JR353.

Rao *et al.* (1990) observed that grain yield was the highest at 20 cm × 10 cm spacing and decreased with closer spacing due to few filled spikelets $panicle^{-1}$ and lower panicle weight and yield was also found to be decreased at wider spacing despite of slightly higher panicle weight. Chandra and Manna (1987) stated that rice yield was the highest at a spacing of 20 cm × 15 cm than at 15 cm × 15 cm or 25 cm × 20 cm.

2.3 Effect of nitrogen on yield and other crop characters

Chopra and Chopra (2000) reported that studied the effect of row spacing and nitrogen levels on seed yield and seed quality of Pusa Basmati-1 scented rice (*Oryza sativa* L.). Row spacing did not influence on yield attributes but seed and straw yields increased linearly up to 80 kg N ha^{-1} and there after a marginal reduction in seed yield was observed at 120 kg N ha^{-1}. However, straw yield increased upto the highest level of N. Seed quality in terms of germination was neither affected by row spacing nor by N level. The response of seed yield to N-level was quadratic. The maximum response was observed at 40 kg N ha^{-1} and there after it decreased with the increased in N levels.

Dutta *et al.* (1999) reported that Basmati an introduced variety of rice in Bangladesh was grown at two locations for investigation of intensity of aroma at different levels of nitrogen application (0, 25, 50 kg N ha^{-1}). The intensity of aroma in Basmati was found higher with the application of nitrogen 25 kg N ha^{-1} at Mymensingh and Rangpur, 50 kg N ha^{-1} did not show any additional benefit regarding aroma synthesis over 25 kg N ha^{-1}.

Behera (1998) reported that nitrogen had marked effect on yield of scented rice. Grain and straw yield increased significantly at each successive levels of N. Grain yield increased with increase of N rate upto 90 kg N ha^{-1} and further increase in N increased the yield marginally.

Choudhuri *et al.* (1998) conducted a field experiment on 3 rice cultivars in 1993-96 in Maharashtra by applying 25-100 kg N ha^{-1} or no fertilizers or 12 t ha^{1} farm yard manure. They observed that the grain yield was the highest with

applying 100 kg N ha^{-1}. Haryana Basmati, Kasturi and Pusa Basmati produced mean grain yields of 2.46, 2.38 and 2.26 t ha^{-1}, respectively.

Application of nitrogen significantly increased in growth, yield attributes, grain and straw yields as well as harvest index with 60kg N ha^{-1} (Dwivedi, 1997).

Li-zhilin *et al.* (1997) reported that in aromatic rice by applying nitrogen plant height increased significantly in Basmti-370 compared with other cultivars (cv. Ratna, HKR-228) due to N application.

Maqsood *et al.* (1997) carried out an experiment at Faisalabad during 1994 and 1995 on rice cv. Basmati-385 by applying 0 - 100 kg N ha^{-1} and found that yield was increased with increasing N rate in both the years.

Singh *et al.* (1997) found that Pusa Basmati was significantly superior to Kasturi for panicles $hill^{-1}$, rechille $panicle^{-1}$, weight of panicle, grains $panicle^{-1}$ and also gave 0.16 t ha^{-1} more grain yield that of Kasturi (3.31 t ha^{-1}). They found significantly linear increase in grain yield up to 100 kg N ha^{-1} beyond which the yields of the both varieties declined and applying 100 kg N ha^{-1} gave 1.55, 0.25 and 0.65 t ha^{-1} more grain yield than those of 0, 50 and 150 kg N ha^{-1}, respectively. They also observed that Pusa Basmati-1 gave higher yield at the rate of 100 and 150 kg N ha^{-1}, that Kasturi at lower level i.e. control and 50 kg N ha^{-1}.

Application of 120 kg N ha^{-1} resulted in significant increase in effective tillers m^{-2}, grains $panicle^{-1}$ and grain yield compared to 60 kg N ha^{-1} when scented rice was grown in IARI, Farm Delhi, in India (Chander and Jitendra, 1996).

BRRI (1996) evaluated the N-response pattern of four rice cultivars of transplant aman rice viz., Nizersail, BR22, Pajam and BR25, with applied six levels (0, 30, 60, 90, 120 and 150 kg ha^{-1}) of nitrogen. It was found that in N control treatment, BR22 yielded highest (3.8 t ha^{-1}) followed by Pajam and BR25 (3.4 t ha^{-1}) Nizersail yielded lowest (3.1 t ha^{-1}). All the varieties responded significantly to applied N at 30 kg ha^{-1}. The increased in the N-level from 30 kg ha^{-1} did not bring any significant yield benefit except BR22, other varieties showed a decreasing trend of yield beyond 60 kg ha^{-1}. Unlike grain yield and the straw yield increased significantly upto 120 kg N ha^{-1}.

Kumar *et al.* (1996) used five level of nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}) in four scented varieties of rice and found that Taraori Basmati gave highest yield (3 t ha^{-1}) than other varieties like Haryana Basmati-1, Pusa Basmati-1 and Kasturi. They also found that 60 kg N ha^{-1} was the optimum rate for scented rice cultivation.

Rao *et al.* (1993) found that the highest grain yield was given in the wet season by local variety Badshabhog (3.21 t ha^{-1}) and in other varieties (cv. Kasturi, Ranbir Basmati and IET8579) mean yield varied from 2.22-2.58 t ha^{-1}. They also found that response of grain yield to N application in the wet season was upto 60 kg ha^{-1} and in the dry season upto 90 kg ha^{-1}.

Ali *et al.* (1992) conducted an experiment during the 1989 - 90 dry season on fine rice cv. 4048 and applied 100 kg N ha^{-1} in 2 (basal and 30 days after transplanting) or 3 (Basal, 30 and 60 days after transplanting) applications and observed that 1000 grain weight and per cent head rice recovery were higher when N was applied in 3 splits.

Kalita and Sharma (1992) stated that increased number of filled grains panicles^{-1} were recorded from higher levels of N. The nitrogen rates of 60 and 40 kg ha^{-1} were at par and significantly superior to the other levels of nitrogen.

Bisht *et al.* (1991) observed the performance of the newly released varieties of Pusa Basmait-1, Kasturi and HKR-228 and compared with the local control. Basmati-370 was applied at 60, 90 and 120 kg N ha^{-1} in 3 splits : $\frac{1}{2}$basal, $\frac{1}{4}$at tillering stage and $\frac{1}{4}$at 1 week before panicle initiation. They found that the Basmati varieties Pusa Basmati-1 and Kasturi, showed no differential response to N but had higher yields than the control. They also found that Kasturi (3.3 t ha^{-1}) and HKR-228 (3.4 t ha^{-1}) produced almost similar yields which were significantly higher than those of Pusa Basmati-1 (3 t ha^{-1}) and N response was significant upto 90 kg N ha^{-1}.

Raju *et al.* (1990) observed that Jeeraga Samba gave the highest grain yield (3.51 t ha^{-1}) while the highest grain yield of all 3.85 t ha^{-1} was achieved by Basmati 217 at a nitrogen application of 120 kg N ha^{-1}. Sarker *et al.* (1990) applied 0, 30, 60 and 90 kg N ha^{-1} sowing and obtained average paddy yield of 1.83, 2.14, 2.10 and 2.22 t ha^{-1}, respectively.

Hossain *et al.* (1989) conducted a field trail on cv. Basmati-370 in Faisalabad applying 0, 30, 60, 120 or 150 kg N ha^{-1} as single or in equal split applications at sowing and at panicle initiation. They found that grain yields were highest with 90 kg N ha^{-1} as a single application (3.7 t ha^{-1}) and 150 kg N ha^{-1} in split applications (3.9 t ha^{-1}). They also found that number of tillers hill^{-1} and straw yield increased with increasing nitrogen rate upto 16.4 and 9.1 t ha^{-1}, respectively with a single application and 16.6 and 8.3 t ha^{-1} also with split applications.

2.4. Effect of spacing, nitrogen and variety on qualitative characters of aromatic rice

Dutta *et al.* (1998) analyzed for their physio-chemical characteristics of grain such as analyses of length, breadth, length-breadth (L/B) ratio of kernels, 1000 kernel weight (TKW), protein and starch contents and length breadth, aroma of the grain of seven varieties of aromatic and non aromatic rice. The results revealed that wide variation existed in L/B ratio, TKW and aroma among the aroma types although most aromatic rice were classified as bold and small types, Basmati and Kataribhog were classified as extra long and slender types with less aroma in contrast to Kaligira, Badshabhog and BR5 with intense aroma. Protein and starch contents varied among the aromatic and non-aromatic fine rice and demonstrated that protein content of the most of fine and aromatic rice were comparable to that of modern rice.

Zhilin *et al.* (1997) showed that N application increased N content and uptake of rice. They observed that N content decreased during panicle initiation and heading.

Yun *et al.* (1996) observed the effects of different N rates on rice and reported that increasing N rate increased N in plant.

Kundu (1996) conducted an experiment in which N uptake by rice grain were 37.93-41.70 kg ha^{-1} and those by rice straw were 16.25-23.85kg ha^{-1} in three different rice varieties (BR9, BR20, BR21) during transplanted aman season.

Uppal and Shidul (1995) stated that grain elongation ratio of rice upon cooking showed increasing trend with increase in nitrogen application to the crop.

Mean kernel elongation ratio was significantly higher at higher dose (140 kg N ha^{-1}) of nitrogen application as compared to the control and also showed that protein content rice increased with increasing levels of nitrogen up to 120kg N ha^{-1}. But protein content decreased with higher dose of nitrogen, which was not desirable because rice with low dose nitrogen content tended to cook sticky. Grain elongation ratio of rice upon cooking showed negligible increasing trend with higher application of nitrogen under the Punjab conditions.

BRRI (1992) observed that among twelve aromatic rice varieties protein content (%) varied from 6.5 to 9.0. BRRI (1992) also reported that nitrogen fertilizer influenced protein content of rice and varies with variety. At BRRI farm, grain protein of some of the transplant aman varieties (Pajam, BR11, BR4 and BR10) was tested with respect to nitrogen fertilization. It was reported that grain yield and protein content increased with application of nitrogen fertilizer.

Jakhro (1986) observed that N uptake increased with increasing rates of N fertilizers upto a certain limit. Increasing N rates increased total N content and uptake both in the grain and straw. Nitrogen content and uptake by rice increased significantly with increasing rates of urea application (Kadu *et al.,* 1991).

From the above discussion it is evident that rice yield responds to spacing and nitrogen level up to a certain level above that yield and yield contributing characters are adversely affected. Aromatic rice also has differential responses to spacing and nitrogen level in respect of its parameters. The literate suggested having a better understanding on the response of aromatic rice varieties to spacing and nitrogen level for its economic production.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agronomy Field Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh, during the period from July to December 2000.

3.1 Description of the experimental site

3.1.1 Location

The experimental field was located at $24^0 75'$ N latitude and $90^0 50'$ E longitude at an attitude of 18 m above from sea level. The land was medium high belonging to the Sonatala soil series of non calcareous dark grey flood plain soil type under the Old Brahmaputra Floodplain of Agro-Ecological Zone # 9 (UNDP and FAO, 1988).

3.1.2 Soil

The soils of this series are predominantly silty loam and more or less neutral in reaction. The organic matter and K contents of the soil are low and P is medium. Its general fertility level was also low. The soil characteristics of the experimental field are shown in Appendix Ia -Ic.

3.1.3 Climate

The experimental area has sub-tropical climate. Usually the rainfall is heavy during *Kharif* season and scanty in *Rabi* season. The atmospheric temperature increases as the season proceeds towards *Kharif* season. The weather condition such as monthly mean rainfall (mm), mean temperature (%), bright sunshine hours

(day^{-1}) and humidity (%) are presented in Appendix III (July to December), respectively. The data were collected from the Weather Yard, Department of Irrigation and Water Management, BAU (BAU, 2000).

3.2 Planting material

Three varieties of fine rice were taken as experimental crop. They were Kalizira, Badshbhog and Tulshimala. Kalizira is an indigenous variety. It is a taller cultivar and produced lower number of tillers and longer panicle. Grains are small, fine and black in colour. However, this rice genotype is characterized by its sensory properties like aroma, size and taste. Badshabhog is another local scented variety of fine rice and the grain is yellow, its grain is small and Tulshimata is also scented variety of fine rice and the grain is blackish. Its grain is also small.

3.3 Treatment

Three factors were included in the experiment namely, variety, spacing and nitrogen level. The treatment were designated as follows :

Factor-A

Variety : Three

i) Kalizira (V_1)

ii) Badshbhog (V_2)

iii) Tulshimala (V_3)

Factor-B

Spacing : Four

i) 8 cm x 25 cm (S_1)

ii) 12 cm x 25 cm (S_2)

iii) 16 cm x 25 cm (S_3)

iv) 20 cm x 25 cm (S_4)

Factor-C

Level of nitrogen : Three

i) 40 kg ha^{-1} (N_1)

ii) 60 kg ha^{-1} (N_2)

iii) 80 kg ha^{-1} (N_3)

3.4 Experimental design

The experiment was laid out in a split-split plot design with three replications accommodating variety of aromatic rice in main plot, spacing in split plot and level of nitrogen in spilt-split plot. All the treatments were randomly allocated in the experimental plots. Each replication was first divided into three main plots. Each main plot was sub-divided into four sub plots. Again each sub plot was splited into three unit plots. The plot size was 4.0 m × 2.5 m. The spaces between replications, between main plots and between sub plots were separated by 1.5, 0.75 and 0.5 m, respectively. There were 108 (3 × 4 × 3 × 3) plots in the experiment.

3.5 Conduction of experiment

3.5.1 Collection of seed

The experimental seeds were collected from the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh.

3.5.2 Raising of seedling

Seedlings were raised in well prepared seedbed at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. Before sowing in the nursery, seeds were water soaked for 24 hrs and then these were kept in gunny

bags in dark condition. After sprouting the seeds were sown in the wet seedbed on July 2000. Due care was taken to see that there was no infestation of pests and diseases and no damage by birds.

3.5.3 Land preparation

The land was first opened in early August 2000. Firstly, two ploughings were given with a tractor mounted disc plough. After a few days the land was further ploughed and cross ploughed with the country plough followed by laddering to get a good puddled condition. Weeds and stubbles were removed from the field prior to transplanting of seedlings. The bounds around individual plot were made firm enough to control water movement between plots. The layout of the experiment in the field was done according to the experimental design adopted.

3.5.4 Fertilizer application

The whole amount of triple super phosphate (60 kg P_2O_5 ha^{-1}), muriate of potash (40 kg K_2O ha^{-1}), gypsum (15 kg S ha^{-1}) and zinc sulphate (5 kg Zn ha^{-1})were applied at final land preparation. Fertilizers were applied before a day of transplanting. The nitrogen was applied in the form of urea as experimental specification. One third of urea was applied 15 days after transplanting (DAT) and the rests were applied in two equal installments at 35 and 55 DAT.

3.5.5 Uprooting of seedling

The seedbeds were made wet by applications of water both in the morning and in the evening on the previous days of uprooting the seedlings. Seedlings were uprooted carefully without causing any injury to the roots and were kept in shade.

3.5.6 Layout of experiment

The experiment was laid out on 12 August 2000 according to the experimental design. The accommodation of variety, spacing and nitrogen level was main plot, subplot and unit plot, respectively.

3.5.7 Transplanting

Thirty six day old seedlings of three aromatic rice varieties were transplanted with 3 seedlings hill^{-1} on 13 August 2000.

3.5.8 Intercultural operation

The experimental field was frequently observed to see if insects and diseases damaged the plants. The experimental field was weeded thrice on 15, 35 and 55 DAT to keep the weed competition at a minimum level. Top dressing of urea was done on the days previously mentioned. The crop was irrigated during growth period when necessary. There was no pest infestation during the growth period of the crop.

3.5.9 Harvesting

Maturity of crops was determined when 90% of the seeds became golden yellow in colour. The crop was harvested at full maturity on 12 December 2000 and the yields of both grain and straw were recorded after thoroughly drying in sun. Harvesting was done plot wise and was tagged for proper identification for further processing.

3.5.10 Processing

After harvest, grains were threshed, cleaned and sun dried to record the grain yield plot^{-1}. The grain was adjusted to 14% moisture content. The straw was also

sun dried to record the straw yield plot^{-1}. Grain and straw yield plot^{-1} were converted to t ha^{-1}.

3.6 Collection of data before harvest

The data of the crop were collected as follows :

3.6.1 Soil sample collection

Initial soil samples were collected randomly from each unit plot at a depth of 0-15 cm before final land preparation and the samples were mixed to make a bulk sample. The bulk sample was air dried, ground and sieved to remove unwanted materials and then preserved in polythene bags for future laboratory studies. For post harvest analysis, soil samples were also collected similarly from each unit plot.

3.6.2 Plant sampling

Five hills (Excluding border hills) from each plot were selected randomly and tagged just after transplanting for measuring counting tillers at 20 day intervals from 20 DAT to 80 DAT.

3.6.3 Tiller counting

Tillers were counted from the selected hills at 20 day intervals beginning 20 from DAT to 80 DAT.

3.7 Collection of data at harvest

3.7.1 Soil sample collection after harvest

For post harvest analysis, soil samples were collected from each unit plot.

3.7.2 Data were recorded on the following crop characters

i) Plant height (cm)

ii) Number of total tillers hill^{-1}.

iii) Number of effective tillers hill^{-1}.

iv) Number of non-effective tillers hill^{-1}.

v) Length of panicle (cm).

vi) Number of grains panicle^{-1}

vii) Number of sterile spikelets panicle^{-1}.

viii) 1000-grain weight (g)

ix) Grain yield (t ha^{-1})

x) Straw yield (t ha^{-1})

xi) Biological yield (t ha^{-1})

xii) Harvest index (%)

Data on individual plant parameters (i-viii) were recorded from selected hills of each plot, those on grain yield, straw yield, biological yield and harvest index were recorded from the whole plot at harvest, and qualitative characters were recorded from selected grain and straw.

3.7.3 Qualitative characters

3.7.3.1 Seed and Grain

i) Nitrogen content (%)

ii) Nitrogen uptake (kg ha^{-1})

iii) Protein content (%)

iv) Germination (%)

v) Vigour index

vi) Aroma (Numerically)

vii) Cooking time (min)

3.7.3.2 Straw

i) Nitrogen content (%)

(ii) Nitrogen uptake (kg ha^{-1})

3.8 Procedure of Recording Data

A brief outline of the data recording procedure is given below :

3.8.1 Yield and yield contributing characters

i. Plant height at harvest (cm)

Plant height was measured from the ground level to the top of the longest panicle.

ii. Number of total tillers $hill^{-1}$

Tillers that had at least one leaf visible area counted. It included both effective and non- effective tillers.

iii. Number of effective tillers $hill^{-1}$

The panicles that had at least one grain were considered as effective tillers.

iv. Number of non-effective tillers $hill^{-1}$

The panicles, which had no grain, were regarded as non-effective tillers.

v. Panicle length (cm)

Panicle length was recorded from the basal node of the rachis to the apex of each panicle.

vi. Number of grains $panicle^{-1}$

Presence of any food material in the spikelet was considered as grain and total number of grains present on each panicle are counted.

vii. Number of sterile spikelets panicle^{-1}

Spikelets lacked any food material inside was considered as unfilled spikelet and such spikelets present on the each panicle were counted.

viii. 1000-grain weight (g)

One thousand clean dried grains were counted from the seed stock obtained from five sample plants of each plot and weighted by using an electrical balance.

ix. Grain yield (t ha^{-1})

Grains obtained from each unit plot were suns dried and weighed carefully. The dry weight of grains of selected plants was added to the respective unit plot to record the final grain yield plot^{-1}. The grain yield was finally converted to t ha^{-1}.

x. Straw yield (t ha^{-1})

Straw obtained from each unit plot including the straw of sample plants of respective unit plot was dried in sun and weighed to record the final straw yield plot^{-1} and finally converted to t ha^{-1}.

xi. Biological yield (t ha^{-1})

Grain yield and straw yield were altogether regarded as biological yield. The biological yield was calculated with the following formula :

Biological yield = Grain yield + Straw yield.

xii. Harvest index (%)

It denotes the ratio of economic yield to biological yield and was calculated with the following formula (Gardner *et al.*, 1985)

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

3.8.2 Qualitative characters measurement of aromatic rice

3.8.2.1 Determination of nitrogen content of grain and straw

Grain and straw samples from each plot were taken and separately oven dried at 65^0C over night to grind in a grinding machine. Proximately 10 g of samples were preserved separately in polythene bags for chemical analysis to determine total nitrogen content. Chemical analysis was done by Micro-kjeldahl method (AOAC, 1980) at Laboratory of Crop Physiology Division of Bangladesh Institute of Nuclear Agriculture, Mymensingh.

The required sample (0.1 g) was digested by 3 ml concentrated H_2SO_4 in presence of digestion tablet with 2 glass beads in a 75 ml kjeldahl flask. Sample mixture heated at one hour at 370^0C temperature in a preheated heater. Then flask was cooled at room temperature. Digest diluted to 75 ml distilled water by inversion. For performing distillation 10 ml of the diluted sample mixture was taken in Buchi Distillation unit with 10ml of 40% NaOH. The distillate was collected in 10 ml 2% boric acid containing 2 drops of indicator. The collected distillate in boric acid was tritrated with 0.01N HCl. A blank was done simultaneously to avoid the nitrogen either already present in chemicals or atmospheric N absorbed during digestion. The N percentage was collected by the following formula with the help of titration value

$$\text{Nitrogen} = \frac{0.14 \times \text{Normality of HCl } (0.01) \times 75 \times 100 \times V}{10W\,(g)}$$

$$= 0.105 \frac{V}{W\,(g)}$$

Where,

V = Final volume of HCl.

W = Weight of sample (g)

3.8.2.2 Determination of nitrogen uptake of grain and straw

After determination of N in both rice grain and straw, nitrogen uptake by both rice grain and straw and total nitrogen uptake were determined by the following formula

$$\text{Nitrogen uptake by grain (kg ha}^{-1}) = \frac{\%\text{ N in grain} \times \text{Grain yield (kg ha}^{-1})}{100}$$

$$\text{Nitrogen uptake by straw (kg ha}^{-1}) = \frac{\%\text{ N in straw} \times \text{Straw yield (kg ha}^{-1})}{100}$$

3.8.2.3 Determination of protein content of grain

Protein content of the grain was determined by multiplying the nitrogen content of grain by 5.95 (Anonymous, 1980). The result was expressed in percentage.

3.8.2.4 Determination of germination

Germination test was performed from 28 August to 12 October 2001 at the Agronomy Laboratory, Bangladesh Agricultural University, Mymensingh. For germination test, seeds were placed on the Petridish in and uniform layer of moist sand and covered to depth of 2 cm with sand which was left loose at a laboratory temperature. Hundred seeds were placed on a Petridish from each plot. Adequate moisture was maintained in a germination media. The number of normal seedlings was first count after 7 days and final count after 15 days. This procedure following the rules and procedures of ISTA (ISTA, 1976).

CHAPTER IV

RESULTS AND DISCUSSION

The results of the study on the effects of nitrogen levels and spacing on the yield of three varieties of aromatic rice have been presented and discussed in this chapter.

4.1 Yield and Yield Contributing Characters

4.1.1 Plant height

4.1.1.1 Effect of variety

From the experimental results it was found that plant height at harvest was significantly influenced by variety (Appendix IIa). It was observed that Tulshimala produced the tallest plant (151.02 cm) which was followed by Kalizira (148.96 cm) and Badshabhog (141.33 cm) (Table 1). It was evident that plant height significantly differed from variety to variety. This result was in agreement with that of BINA (1993).

4.1.1.2 Effect of spacing

Plant spacing significantly affected by plant height (Appendix IIa). There was a direct relationship between plant spacing and height of the plant. It showed that widest spacing (20 cm × 25 cm) produced the tallest plant (152.03 cm) and closest spacing (8 cm × 25 cm) produced shortest plant height (141.37 cm) (Table 2). It might be due to absorption of more light, and food material in wider spacing that facilitated for maximizing plant height. This result was similar to that with Shirakawa *et al.* (1992) who reported that plant height increased with deceased plant population.

Table 1. Effect of variety on yield and yield contributing characters of aromatic rice

Variety	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Non-effective tillers hill^{-1} (no)	Panicle length (cm)	Grains panicle^{-1} (no)	Sterile spikelets panicle^{-1} (no)	1000-grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
Kalizira	148.96 b	8.65 b	6.20 b	2.43 a	22.46	111.30 c	25.94	11.14 c	8.62 b	26.99 b
Badshabhog	141.33 c	8.75 a	6.38 a	2.37 b	23.23	132.70 a	21.96	12.18 a	9.72 a	29.76 a
Tulshimala	151.02 a	8.31 c	6.38 a	1.93 c	22.33	123.70 b	23.46	11.99 b	9.61 a	27.14 b
Sx	0.4806	0.0241	0.0169	0.0773	-	1.0126	-	0.0321	0.0463	0.0120
Level of significance	0.01	0.01	0.01	0.05	NS	0.01	NS	0.01	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test (DMRT)

NS = Not significant

Table 2. Effect of spacing on yield and yield contributing characters of aromatic rice

Spacing (cm × cm)	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Non-effective tillers hill^{-1} (no)	Panicle length (cm)	Grains panicle^{-1} (no)	Sterile spikelets panicle^{-1} (no)	1000-grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
8 × 25	141.37 d	6.91 d	4.43 d	2.48	21.54 c	115.73 c	24.92	11.56 c	9.47 b	24.28 c
12 × 25	146.37 c	7.82 c	5.85 c	1.97	21.78 c	121.65 b	24.31	11.73 b	9.53 a	28.95 b
16 × 25	148.64 b	9.04 b	7.01 b	2.03	22.64 b	127.86 a	21.95	11.93 a	9.44 c	30.08 a
20 × 25	152.03 a	10.51 a	7.99 a	2.52	23.42 a	130.27 a	23.98	11.85 a	8.83 d	28.88 b
Sx	0.5318	0.0255	0.0251	-	0.1858	1.8012	0.6652	0.0370	0.0560	0.0104
Level of significance	0.01	0.01	0.01	NS	0.01	0.01	0.0.5	0.01	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

4.1.1.3 Effect of nitrogen level

Plant height was significantly affected by nitrogen level (Appendix IIa). Plant height increased with the increasing rates of nitrogen. The tallest plant (150.33 cm) was observed at 80 kg N ha^{-1} and shortest plant height (141.57 cm) was observed at 40 kg N ha^{-1} (Table 3). Similar finding was reported by Li-Zhilin (1997) who stated that plant height increased significantly due to nitrogen application. The increase in plant height due to application of increased level of nitrogen might be associated with stimulating effect of nitrogen on various physiological processes including cell division and cell elongation of the plant.

4.1.1.4 Effect of interaction of variety and spacing

The interaction effect between variety and spacing on plant height was insignificant (Appendix IIa). Although not significant the tallest plant (155.87 cm) was obtained from V_3S_4 and shortest plant (141.60 cm) was found from V_2S_1 (Table 4).

4.1.1.5 Effect of interaction of variety and nitrogen level

There was no significant effect between variety and nitrogen level (Appendix IIa). However, the apparently tallest plant (156.59 cm) was produced from the interaction between Tulshimala and 80 kg N ha^{-1} (V_3N_4) and shortest plant (134.61 cm) was produced from interaction of Badshabhog and 40 kg N ha^{-1} V_2N_1 (Table 5).

Table 3. Effect of nitrogen level on yield and yield contributing characters of aromatic rice

Nitrogen level (kg ha^{-1})	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Non-effective tillers hill^{-1} (no)	Panicle length (cm)	Grains panicle^{-1} (no)	Sterile spikelets panicle^{-1} (no)	1000-grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
40	141.57 c	8.21	6.19 b	2.02 b	21.41 c	124.67 b	22.86 b	11.70	8.98 b	28.95 a
60	147.42 b	8.93	6.78 a	2.15 b	23.20 a	130.15 a	20.37 c	11.81	9.23 a	30.87 a
80	152.33 a	8.57	6.00 b	2.57 a	22.42 b	116.81 c	28.13 a	11.78	9.43 a	25.23 b
Sx	1.5851	-	0.1561	0.1083	0.1927	1.4635	0.6556	-	0.1607	0.4068
Level of significance	0.01	NS	0.01	0.01	0.01	0.01	0.01	NS	0.05	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

Table 4. Effect of interaction of variety and spacing on yield and yield contributing characters of aromatic rice

Interaction (Variety × Spacing)	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Non-effective tillers hill^{-1} (no)	Panicle length (cm)	Grains panicle^{-1} (no)	Sterile spikelets panicle^{-1} (no)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1S_1	143.92	6.97 i	4.23	2.8	21.51	109.23	25.92	11.07	2.03	6.78	8.81	23.04 g
V_1S_2	147.31	7.43 h	5.76	2.0	21.66	112.00	26.52	11.09	2.45	6.38	8.83	27.75 de
V_1S_3	149.61	9.40 c	6.89	2.62	22.78	119.68	25.19	11.20	2.50	6.19	8.69	28.76 d
V_1S_4	154.99	10.79 a	7.93	3.10	23.92	120.20	26.13	11.17	2.31	5.84	8.15	28.34 d
V_2S_1	145.88	7.00 i	4.54	2.43	21.69	121.66	23.07	11.86	2.66	7.36	10.02	26.55 f
V_2S_2	141.60	8.21 f	5.89	2.32	21.63	131.28	24.16	12.16	3.02	6.85	9.87	30.59 b
V_2S_3	142.64	9.00 d	9.09	1.92	22.57	137.01	19.75	12.38	3.12	6.71	9.83	31.74 a
V_2S_4	145.22	10.78 a	8.01	2.70	23.05	144.74	20.87	12.28	2.82	6.35	9.17	30.75 b
V_3S_1	144.31	6.76 j	4.52	2.24	21.44	116.30	25.76	11.74	2.21	7.38	9.58	23.06 g
V_3S_2	150.20	7.82 g	5.91	1.82	22.04	121.67	22.25	11.94	2.80	7.08	9.88	28.34 d
V_3S_3	153.68	8.72 c	7.06	1.65	22.57	126.88	20.91	12.20	2.91	6.90	9.81	29.66 c
V_3S_4	155.89	9.96b	8.03	1.93	23.28	129.89	24.93	12.08	2.53	6.66	9.19	27.53 e
Sx	-	0.4472	-	-	-	-	-	-	-	-	-	0.2214
Level of significance	NS	0.01	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test
NS = Not significant

Table 5. Effect of interaction of variety and nitrogen level on yield and yield contributing characters of aromatic rice

Interaction (Variety × Nitrogen level)	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Non-effective tillers hill^{-1} (no)	Panicle length (cm)	Grains panicle^{-1} (no)	Sterile spikelets panicle^{-1} (no)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1N_1	144.38	8.12	6.11	2.47	21.20	115.64	25.86	11.09	2.31	5.97	8.28	27.95
V_1N_2	149.02	8.94	6.70	2.24	23.75	119.79	22.23	11.17	2.54	6.21	8.75	29.02
V_1N_3	153.47	8.89	5.80	3.17	22.44	110.39	29.74	11.13	2.12	6.72	8.84	23.98
V_2N_1	134.61	8.49	6.22	2.31	21.49	134.78	20.42	12.08	2.93	6.50	9.43	31.07
V_2N_2	142.48	9.15	6.84	2.20	22.89	139.41	18.47	12.20	3.11	6.85	9.96	31.22
V_2N_3	146.92	8.60	6.08	2.51	22.36	123.83	27.00	12.23	2.68	7.10	9.78	27.40
V_3N_1	145.72	8.01	6.23	1.77	21.58	123.59	22.32	11.92	2.59	6.67	9.26	27.94
V_3N_2	150.75	8.69	6.81	1.81	22.95	131.25	20.41	12.06	2.92	6.99	9.91	29.46
V_3N_3	156.59	8.24	6.10	2.13	22.46	116.21	27.66	11.99	2.35	7.34	9.69	24.25
Sx	-	-	-	-	-	-	-	-	-	-	-	-
Level of significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

4.1.1.6 Effect of interaction of spacing and nitrogen level

Interaction of spacing and nitrogen level had no significant effect on plant height at harvest (Appendix IIa). Moreover, the tallest plant (157.69 cm) was obtained in S_4N_3 and shortest plant (140.73 cm) was found in S_1N_1 (Table 6).

4.1.1.7 Effect of interaction of variety, spacing and nitrogen

Interaction of variety, spacing and nitrogen was not significant. The tallest plant height (162.80 cm) was produced from interaction of $V_3S_4N_3$ and the shortest plant was found in $V_2S_1N_1$ (Table 7).

4.1.2 Total tillers hill^{-1}

4.1.1.2 Effect of variety

Tiller production on variety had significant effect at 20 DAT and 60 DAT whereas variety had no significant effect on tiller production at 40 DAT and 80 DAT (Appendix IIb).

Tiller production was increased with the advancement of time up to 60 DAT (Fig. 1) and the number was reduced after 60 DAT. The reduction of total tillers hill^{-1} was due to death and drying of some weak tillers at 80 DAT. Naher (1995) observed a similar pattern of tiller production.

It was observed that Kalizira produced the highest number of total tillers hill^{-1} at about all the DAT except 20 DAT compared to Badshabhog and Tulshimala (Appendix IV). At harvest, the result indicated that Badshabhog produced the highest number of total tillers hill^{-1} (8.75) and Tulshimala produced the lower number of total tillers (8.31) which was indicated earlier (Table 1). Variable effect of variety on number of total tillers hill^{-1} was also reported by

Table 6. Effect of interaction of nitrogen level and spacing on yield and yield contributing characters aromatic rice

Interaction (Spacing × Nitrogen level)	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Non-effective tillers hill^{-1} (no)	Panicle length (cm)	Grains panicle^{-1} (no)	Sterile spikelets panicle^{-1} (no)	1000-grain weihgt (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1N_1	138.48	6.69	4.27	2.60	20.91	116.51	25.22 b-e	11.47	2.23 fg	6.84	9.07	24.58
S_1N_2	140.91	7.46	4.90	2.41	22.17	119.04	22.33 def	11.56	2.48 e	7.11	9.59	25.86
S_1N_3	144.73	6.58	4.13	2.45	21.55	111.64	27.20 abc	11.63	2.19 g	7.57	9.76	22.43
S_2N_1	140.43	7.46	5.78	2.02	21.11	122.22	22.32 def	11.67	2.74 c	6.52	9.26	29.58
S_2N_2	146.07	8.35	6.33	1.92	22.47	125.69	19.81 fg	11.79	3.04 b	6.80	9.84	30.90
S_2N_3	152.62	7.65	5.46	2.19	21.74	117.03	30.80 a	11.73	2.49 e	6.99	9.48	26.26
S_3N_1	142.35	8.82	6.86	2.07	21.82	128.59	19.83 fg	11.88	2.83 c	6.25	9.08	31.16
S_3N_2	149.31	9.14	7.49	1.66	23.38	138.25	17.79 g	11.98	3.18 a	6.58	9.76	32.58
S_3N_3	154.27	9.15	6.70	2.45	22.73	116.73	28.23 ab	11.93	2.52 e	6.97	9.49	26.55
S_4N_1	145.03	8.85	7.85	2.05	21.81	131.37	24.08 cde	11.78	2.60 de	5.93	8.53	30.48
S_4N_2	153.38	10.77	8.42	2.34	24.77	137.62	21.55 efg	11.91	2.71 cd	6.25	8.96	30.24
S_4N_3	157.69	10.92	7.69	3.34	23.67	121.84	26.30 bcd	11.84	2.34 f	6.67	9.01	25.97
Sx	-	-	-	-	-	-	1.3112	-	0.0447	-	-	-
Level of significance	NS	NS	NS	NS	NS	NS	0.05	NS	0.01	NS	NS	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test
NS = Not significant

Table 7. Effect of interactions of variety, spacing and nitrogen level on yield and yield contributing characters of aromatic rice

Interactions (Variety × Spacing × Nitrogen level)	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Non-effective tillers hill^{-1} (no)	Panicle length (cm)	Grains panicle^{-1} (no)	Sterile spikelets panicle^{-1} (no)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
$V_1S_1N_1$	141.59	6.47	4.07	2.56	21.00	109.63	27.84	11.04	2.00	6.43	8.42	23.66
$V_1S_1N_2$	144.37	7.45	4.79	2.66	21.97	111.44	26.56	11.10	2.14	6.65	8.79	24.34
$V_1S_1N_3$	145.79	7.01	3.85	3.16	21.56	106.62	23.37	11.07	1.96	7.27	9.23	21.23
$V_1S_2N_1$	143.26	7.27	5.87	2.40	21.3	112.74	27.89	11.05	2.41	6.05	8.46	28.48
$V_1S_2N_2$	145.69	8.01	6.21	1.80	22.44	112.52	21.33	11.15	2.76	6.33	9.09	30.36
$V_1S_2N_3$	153.00	7.03	5.22	1.81	21.51	110.74	30.34	11.09	2.19	6.77	8.96	24.44
$V_1S_3N_1$	144.50	9.22	6.76	2.80	21.74	148.40	23.00	11.16	2.48	5.88	8.36	29.66
$V_1S_3N_2$	148.91	9.29	7.43	1.86	23.61	129.33	18.03	11.24	2.82	6.14	8.96	31.47
$V_1S_3N_3$	155.44	9.69	6.49	3.20	23.00	111.31	34.55	11.21	2.21	6.57	8.78	25.17
$V_1S_4N_1$	148.20	9.53	7.77	2.13	21.05	121.82	24.70	11.12	2.37	5.53	7.89	30.00
$V_1S_4N_2$	157.11	11.01	8.38	2.63	27.01	125.88	23.00	11.22	2.43	5.73	8.16	29.77
$V_1S_4N_3$	159.67	11.85	7.65	4.53	23.71	112.90	30.70	11.18	2.13	6.27	8.40	25.35
$V_2S_1N_1$	131.39	6.93	4.37	2.93	20.98	122.02	23.47	11.69	2.60	7.07	9.67	26.88
$V_2S_1N_2$	134.22	7.77	5.01	2.30	22.37	124.37	20.57	11.80	2.81	7.32	10.13	27.73
$V_2S_1N_3$	142.05	6.32	4.26	2.06	21.74	118.61	25.17	12.09	2.58	7.71	10.29	25.06
$V_2S_2N_1$	133.73	7.85	5.72	2.13	21.00	132.36	20.66	12.11	3.09	6.75	9.85	31.37
$V_2S_2N_2$	144.12	8.49	6.37	2.12	22.33	137.09	21.09	12.22	3.24	7.01	10.25	31.60
$V_2S_2N_3$	146.96	8.30	5.59	2.71	21.57	124.40	30.73	12.17	3.75	6.80	10.20	26.96
$V_2S_3N_1$	135.50	3.59	6.93	1.66	21.80	142.45	16.74	12.34	3.18	6.30	9.44	33.61
$V_2S_3N_2$	144.35	9.48	7.58	1.93	23.32	147.56	13.41	12.43	3.44	6.71	10.15	33.89
$V_2S_3N_3$	148.06	8.94	6.78	2.16	22.61	121.03	29.12	12.39	2.74	7.14	9.88	27.73

Table 7: (Contd.)

Table 7. (Contd.)

Interactions (Variety × Spacing × Nitrogen level)	Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Non-effective tillers hill^{-1} (no)	Panicle length (cm)	Grains panicle^{-1} (no)	Sterile spikelets panicle^{-1} (no)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
$V_2S_4N_1$	137.82	10.62	7.89	2.53	22.04	142.29	20.82	12.21	2.86	5.91	8.77	32.61
$V_2S_4N_2$	147.23	10.89	8.43	5.46	23.56	148.62	18.80	12.36	2.95	6.39	9.34	31.58
$V_2S_4N_3$	150.60	10.84	7.71	3.13	23.55	131.31	23.00	12.28	2.65	6.75	9.40	28.19
$V_3S_1N_1$	142.45	6.69	4.37	2.32	20.77	117.89	24.36	11.68	2.10	7.02	9.12	23.02
$V_3S_1N_2$	144.14	7.17	4.91	2.26	22.19	121.32	19.86	11.80	2.51	7.36	9.87	25.43
$V_3S_1N_3$	146.35	6.42	4.29	2.13	21.36	109.70	33.05	11.75	2.02	7.73	9.75	20.71
$V_3S_2N_1$	144.31	7.28	5.75	1.53	21.31	121.56	18.40	11.86	2.74	6.77	9.51	28.81
$V_3S_2N_2$	148.40	8.55	6.41	1.86	22.65	127.48	17.01	12.02	2.12	7.06	10.18	30.64
$V_3S_2N_3$	157.90	7.64	5.58	2.06	22.16	115.97	31.34	11.94	2.55	7.41	9.96	25.60
$V_3S_3N_1$	147.05	8.67	6.91	1.76	21.92	124.92	19.76	12.14	2.82	6.57	9.39	30.03
$V_3S_3N_2$	154.67	8.66	7.46	1.20	23.11	137.86	21.93	12.27	3.30	6.91	10.21	32.32
$V_3S_3N_3$	159.32	8.83	6.83	2.00	22.59	117.86	21.04	12.20	2.61	7.22	9.83	26.55
$V_3S_4N_1$	149.08	9.40	7.90	1.49	22.35	129.99	26.74	12.01	2.59	6.35	8.94	28.97
$V_3S_4N_2$	155.80	10.41	8.47	1.94	23.76	138.38	22.85	12.17	2.75	6.63	9.38	29.31
$V_3S_4N_3$	162.8	10.08	7.72	2.36	23.75	121.32	25.21	12.08	2.25	7.00	9.25	24.32
Sx	-	-	-	-	-	-	-	-	-	-	-	-
Level of significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test
NS = Not significant

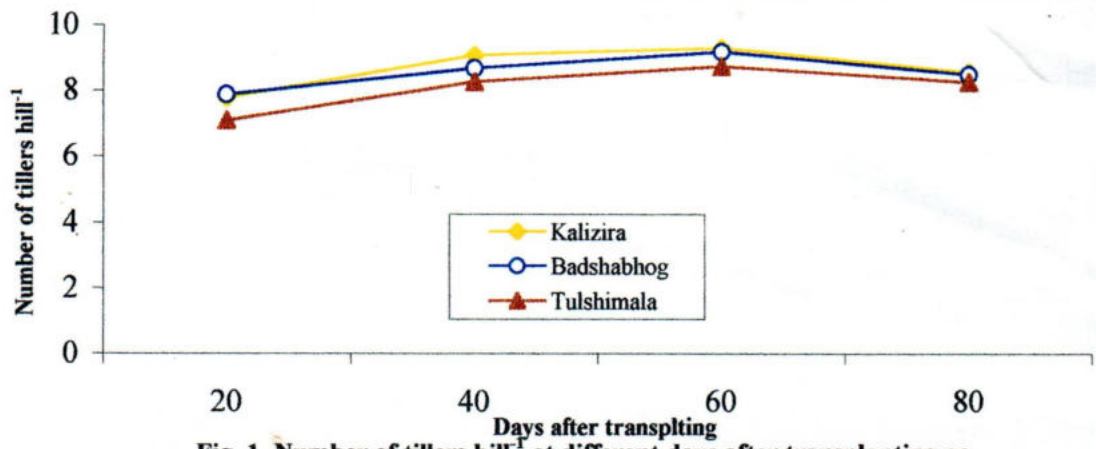

Fig. 1. Number of tillers hill^{-1} at different days after transplanting as influenced by variety.

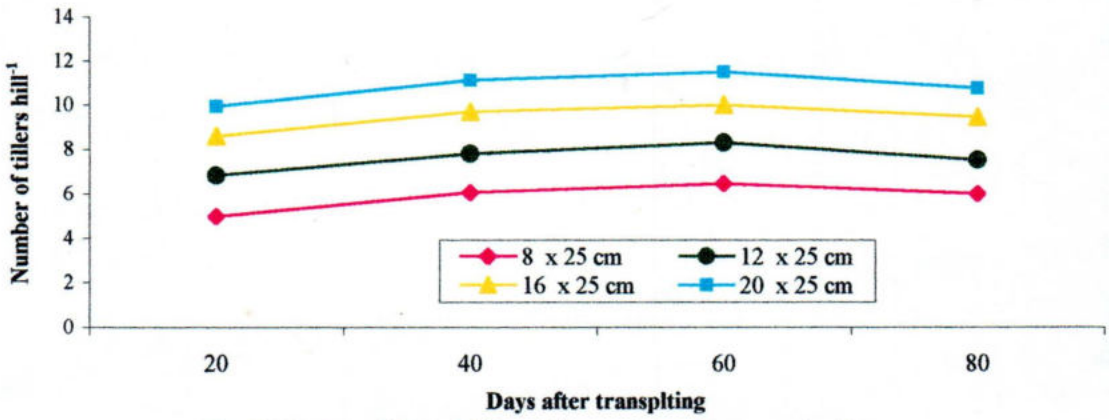

Fig. 2. Number of tillers hill^{-1} at different days after transplanting as influenced by spacing.

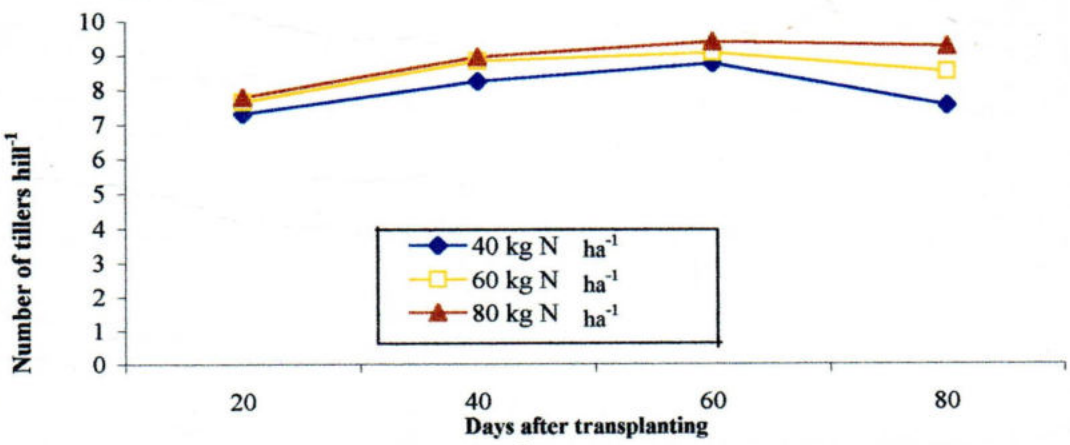

Fig. 3. Number of tillers hill^{-1} at different days after transplanting as influenced by N level.

Hossain *et al.* (1989) who noticed that number of total tiller hill^{-1} differed among the varieties. The variation in number of total tillers hill^{-1} might be due to the varietal characteristics.

4.1.2.2 Effect of spacing

Spacing significantly influenced number of total tillers of aromatic rice at the all DAT (Appendix IIb). Tillering habit of aromatic rice at different spacing are presented in Appendix V which showed that total tillers hill^{-1} differed significantly in all the stages of growth. At 20 cm × 25 cm spacing produced the highest total tillers hill^{-1} and closest spacing (8 cm × 25 cm) the lowest number of total tillers hill^{-1} were produced at all the DAT (Fig. 2).

Like variety, spacing had a significant influence on total tillers production at harvest (Appendix IIa). Table 2 shows that the highest total tillers hill^{-1} (10.51) was produced at widest spacing (20 cm × 25 cm) and lowest total tiller hill^{-1} (6.91) was produced at closest spacing (8 cm × 25 cm). The trend of total tillers hill^{-1} increased with closest (8 cm × 25 cm) to widest (20 cm × 25 cm). A similar result was obtained by Mohammad *et al.* (1987), who reported that number of total tillers hill^{-1} decreased with decrease of spacing.

4.1.2.3 Effect of nitrogen level

Nitrogen level influenced significantly on total tillers hill^{-1} in all varieties at all DAT (Appendix IIb). It was observed that number of total tillers hill^{-1} increased up to 60 DAT an thereafter decreased (Fig. 3). Number of total tillers hill^{-1} increased with increasing level of nitrogen and the highest number of total tillers hill^{-1} produced in all the stages with highest (80 kg N ha^{-1}) nitrogen level (Appendix VI). The progressive improvement in the formation of tillers with

nitrogen level in the present experiment might be due to increased availability of nitrogen, which enhanced tillering. That increasing application of nitrogen in rice, increased the number of total tillers hill^{-1} from 0 to 80 kg N ha^{-1} was also reported by Reddy (1986) in experiment conducted elsewhere.

4.1.2.4 Effect of interaction of variety and spacing.

The number of total tillers hill^{-1} was not statistically influenced by the interaction of variety and spacing at all stages except 20 DAT (Appendix IIb). The highest tillers number (10.89) was obtained from V_1S_4 and lowest tillers hall^{-1} (4.35) was obtained from V_1S_1 which was statistically at par with V_3S_1 (Table 8).

The number of total tillers hill^{-1} was significantly affected by the interaction of variety and spacing at harvest (Appendix IIa). The highest tillers hill^{-1} (10.79) was produced in V_1S_4 that was statistically similar with V_2S_4. The lowest tillers hill^{-1} (6.76) was found in $V_3 S_1$ (Table 4).

4.1.2.5 Effect of interaction of variety and nitrogen level

The interaction effect of variety and nitrogen level was not significant on number of total tillers hill^{-1} at all DAT (Appendix IIb). The highest number of total tillers hill^{-1} (9.74) was obtained from the interaction of V_1S_4 at 60 DAT and the lowest number of total tillers hill^{-1} (6.88) was observed in V_3N_1 at 20 DAT (Table 9). The number of total tillers hill^{-1} was not statistically influenced by the interaction of variety and nitrogen level at harvest (Appendix IIa). The highest total tillers hill^{-1} (9.15) was produced in V_2N_2 and lowest tillers hill^{-1} (8.01) was produced in V_3S_1 (Table 5).

Table 8. Effect of interaction of variety and spacing on tiller production of aromatic rice

Interaction (Variety × Spacing)	20 DAT	40 DAT	60 DAT	80 DAT
$V_1 S_1$	4.35 g	6.16	6.48	6.04
$V_1 S_2$	6.48 f	8.09	8.28	7.46
$V_1 S_3$	9.45 bc	10.38	10.51	9.80
$V_1 S_4$	10.89 a	11.78	12.01	11.12
$V_2 S_1$	5.92 f	6.38	6.69	6.10
$V_2 S_2$	7.53 e	7.72	8.69	7.79
$V_2 S_3$	8.24 d	9.39	9.87	9.45
$V_2 S_4$	9.90 b	11.30	11.61	10.79
$V_3 S_1$	4.70 g	5.66	6.25	5.96
$V_3 S_2$	6.50 e	7.72	8.09	7.50
$V_3 S_3$	8.11 de	9.42	9.71	9.29
$V_3 S_4$	9.11 c	10.35	10.96	10.51
Sx	0.2217	-	-	-
Level of significance	0.01	NS	NS	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

DAT = Days after transplanting

Table 9. Effect of interaction of variety and nitrogen level on tiller production of aromatic rice

Interaction (Variety × Nitrogen level)	20 DAT	40 DAT	60 DAT	80 DAT
$V_1 N_1$	7.53	8.67	9.00	7.85
$V_1 N_2$	7.67	9.18	9.23	8.80
$V_1 N_3$	8.18	9.46	9.74	9.16
$V_2 N_1$	7.56	8.04	8.97	7.62
$V_2 N_2$	8.10	8.98	9.26	8.61
$V_2 N_3$	8.02	9.08	9.41	9.37
$V_3 N_1$	6.88	8.10	8.37	7.32
$V_3 N_2$	7.24	8.39	8.79	8.25
$V_3 N_3$	7.20	8.37	9.11	9.37
Sx	-	-	-	-
Level of significance	NS	NS	NS	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

DAT = Days after transplanting

4.1.2.6 Effect of interaction of spacing and nitrogen level

The interaction of spacing and nitrogen level was not significant at all DAT (Appendix IIb). The highest number of total tillers hill^{-1} (12.34) and the lowest tillers hill^{-1} (5.02) were produced in S_4N_3 and S_1N_1 at 60 DAT and 20 DAT (Table 10), respectively. The interaction of spacing and nitrogen level was not significant at harvest (Appendix IIa).

4.1.2.7 Effect of interaction of variety, spacing and nitrogen level

The effect of interaction of variety, spacing and nitrogen level was not significant on total tillers hill^{-1} at all the stages (Table 11). Their interaction effect among them was not significant on number of total tillers hill^{-1} at the harvest (Appendix IIa).

4.1.3 Effective tillers hill^{-1}

4.1.3.1 Effect of variety

Variety had significant effect on effective tillers hill^{-1} (Appendix IIa). The results indicated that Badshabhog and Tulshimala produced the higher number of effective tillers hill^{-1} (6.38). Kalizira produced the lower number of effective tillers hill^{-1} (6.20) (Table 1). The reasons for difference in producing effective tillers hill^{-1} might be due to the variation in genetic make-up of the variety that might be influenced by heredity. This was conformed by Chowdhury *et al.* (1993) and BRRI (1991) who stated that effective tillers hill^{-1} varied with variety.

4.1.3.2 Effect of spacing

Spacing had significant influence on effective tillers hill^{-1} (Appendix IIa). It was observed that widest spacing (20 cm × 25 cm) produced the highest number of

Table 10. Effect of interaction of spacing and nitrogen level on tiller production of aromatic rice

Interaction (Spacing × Nitrogen level)	20 DAT	40 DAT	60 DAT	80 DAT
$S_1 N_1$	5.02	5.90	6.33	5.48
$S_1 N_2$	5.15	6.30	6.62	5.94
$S_1 N_3$	4.79	6.00	6.47	6.68
$S_2 N_1$	6.41	7.00	7.89	6.68
$S_2 N_2$	7.02	8.32	8.58	7.61
$S_2 N_3$	7.08	8.21	8.59	8.30
$S_3 N_1$	8.52	9.53	9.97	8.65
$S_3 N_2$	8.53	9.72	9.85	9.43
$S_3 N_3$	8.76	9.94	10.27	10.46
$S_4 N_1$	9.35	10.66	10.92	9.41
$S_4 N_2$	9.97	11.05	11.32	11.25
$S_4 N_3$	10.58	11.73	12.34	11.75
Sx	-	-	-	-
Level of significance	NS	NS	NS	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

DAT = Days after transplanting

Table 11. Effect of interaction of variety, spacing and nitrogen level on tiller production of aromatic rice

Interaction (Variety × Spacing × Nitrogen level)	20 DAT	40 DAT	60 DAT	80 DAT
$V_1S_1N_1$	4.32	5.77	6.35	5.49
$V_1S_1N_2$	4.38	6.25	6.40	6.10
$V_1S_1N_3$	4.35	6.45	6.70	6.54
$V_1S_2N_1$	6.30	7.50	7.70	7.03
$V_1S_2N_2$	6.40	8.62	8.80	7.59
$V_1S_2N_3$	6.76	8.15	8.35	7.76
$V_1S_3N_1$	9.25	10.31	10.65	9.44
$V_1S_3N_2$	9.31	10.37	10.05	9.75
$V_1S_3N_3$	9.79	10.48	10.85	10.21
$V_1S_4N_1$	10.25	11.12	11.30	9.45
$V_1S_4N_2$	10.60	11.47	11.68	11.79
$V_1S_4N_3$	11.84	12.77	13.05	12.12
$V_2S_1N_1$	5.81	6.31	6.72	5.56
$V_2S_1N_2$	6.23	6.87	7.10	6.14
$V_2S_1N_3$	5.71	5.98	6.25	6.61
$V_2S_2N_1$	7.10	6.15	8.45	7.23
$V_2S_2N_2$	7.92	8.23	8.52	7.64
$V_2S_2N_3$	7.57	8.78	9.10	8.51
$V_2S_3N_1$	8.20	8.82	9.54	8.21
$V_2S_3N_2$	8.26	9.58	9.94	9.43
$V_2S_3N_3$	8.27	9.77	10.15	10.73
$V_2S_4N_1$	9.15	10.87	11.18	9.49
$V_2S_4N_2$	9.99	11.24	11.51	11.26
$V_2S_4N_3$	10.55	11.80	12.15	11.63
$V_3S_1N_1$	4.93	5.61	5.93	5.41
$V_3S_1N_2$	4.85	5.79	6.37	5.58
$V_3S_1N_3$	4.31	5.57	6.46	6.89
$V_3S_2N_1$	5.82	7.35	7.53	6.28
$V_3S_2N_2$	6.75	8.10	8.43	7.61
$V_3S_2N_3$	6.91	7.72	8.33	8.69
$V_3S_3N_1$	8.11	9.48	9.73	8.30
$V_3S_3N_2$	8.03	9.23	9.58	9.12
$V_3S_3N_3$	8.21	9.57	9.83	10.46
$V_3S_4N_1$	8.65	9.98	10.30	9.30
$V_3S_4N_2$	9.32	10.45	10.78	10.72
$V_3S_4N_3$	9.36	10.62	11.82	11.52
Sx	-	-	-	-
Level of significance	NS	NS	NS	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test
NS = Not significant
DAT = Days after transplanting

effective tillers hill^{-1} (7.99) and closest spacing (8 cm × 25 cm) produced the lowest one (4.43) (Table 3). The different responses for spacing might be due to that the wider spacing allowed more light, space and nutrients for producing higher number of effective tillers hill^{-1}. These results are supported by the results of Chander and Pundey (1996) and Mohammad *et al.* (1987).

4.1.3.3 Effect of nitrogen level

Number of effective tillers hill^{-1} was significantly affected by nitrogen level (Appendix IIa). The highest number of effective tillers hill^{-1} was obtained at 60 kg N ha^{-1} applied (Table 3). Adequacy of nitrogen probably favoured the cellular activities during formation and development which lead to increased number of effective tillers hill^{-1}. Chander and Pandey (1996) reported that application of 60 kg N ha^{-1} showed response on effective tillers production. In the present experiment with nitrogen at higher level produced identically lower effective tillers.

4.1.3.4 Effect of interaction of variety and spacing

The interaction effect of variety and spacing on effective tillers hill^{-1} was insignificant (Appendix IIa). The highest number of effective tillers hill^{-1} (8.03) was produced from V_3S_4 and the lowest effective tillers hill^{-1} (4.23) produced from V_1S_1 (Table 4).

4.1.3.5 Effect of interaction of variety and nitrogen level

The interaction effect of variety and nitrogen was not significant (Appendix IIa).

4.1.3.6 Effect of interaction of spacing and nitrogen level

The interaction effect of spacing and nitrogen level on effective tillers hill^{-1} was not significant (Appendix IIa).

4.1.3.7 Effect of interaction of variety, spacing and nitrogen level

The interaction effect of variety, spacing and nitrogen level on effective tillers hill^{-1} had no significant effect (Appendix IIa).

4.1.4 Non-effective tillers hill^{-1}

4.1.4.1 Effect of variety

The result shows that there was significant difference in number of non-effective tillers hill^{-1} among the varieties studied (Appendix IIa). All the varieties were statistically different in the respect of number of non-effective tillers hill^{-1}. Table 1 shows that production of non-effective tillers hill^{-1} differed from each other and followed in the descending to Kalizira (2.43), Badshabhog (2.37) and Tulshimala (1.93). BINA (1993) reported that number of non-effective tillers hill^{-1} was significantly influenced by variety.

4.1.4.2 Effect of spacing

The spacing did not have any significant influence on non-effective tillers hill^{-1} (Appendix IIa). The highest non-effective tillers hill^{-1} (2.52) was recorded from spacing (20 cm × 25 cm) and lowest non-effective tillers hill^{-1} (1.97) was recorded from spacing (12 cm × 25 cm) (Table 2).

4.1.4.3 Effect of nitrogen level

Different nitrogen level exerted significant influence on the production of non-effective tillers hill^{-1} at 1% level of probability (Appendix IIa). The result

shows that the number of non-effective tillers hill^{-1} ranged 2.02 to 2.57 (Table 3). The highest and lowest number of non-effective tillers hill^{-1} were produced when the crop was fertilized with 80 and 40 kg N ha^{-1}, respectively (Table 3).

4.1.4.4 Effect of interaction of variety and spacing

The interaction effect of variety and spacing was not significant on non-effective tillers hill^{-1} (Appendix IIa).

4.1.4.5 Effect of interaction of variety and nitrogen level

Number of non-effective tillers hill^{-1} was not significantly affected by the interaction of variety and nitrogen level (Appendix IIa).

4.1.4.6 Effect of interaction of spacing and nitrogen level

The effect of interaction of spacing and nitrogen level was not significant (Appendix IIa).

4.1.4.7 Effect of interaction of variety, spacing and nitrogen level

The interaction effect of variety, spacing and nitrogen level was not significant on non-effective tillers hill^{-1} (Appendix IIa).

4.1.5 Panicle length

4.1.5.1 Effect of variety

Panicle length was not affected significantly due to variety (Appendix IIa). The longest panicle (23.23 cm) was produced in Badshabhog and shortest one (22.33 cm) was produced in Tulshimala (Table 1). BINA (1993) reported that panicle length influenced due to variety. Varietal difference regarding the panicle length might be due to their differences in genetic make-up.

4.1.5.2 Effect of spacing

Panicle length was influenced significantly due to spacing (Appendix IIa). Results revealed that highest panicle length (23.42 cm) was obtained at widest spacing (20 cm × 25 cm). The shortest panicle length (21.54 cm) was obtained from the closest spacing (8 cm × 25 cm) (Table 2). It was evident from the result that the panicle length increased with increasing of spacing. This observation was in agreement with Kalita *et al.* (1997) who reported that closer spacing decreased panicle length of rice compared to wider spacing.

4.1.5.3 Effect of nitrogen level

Panicle length was influenced significantly by nitrogen level (Appendix IIa). Length of panicle followed similar pattern to that of effective tillers. Results showed that the longest panicle length (23.20 cm) was produced by 60 kg N ha^{-1} while the shortest one (21.41 cm) was obtained in 40 kg N ha^{-1} (Table 3). Azad *et al.* (1995) observed that panicle length increased significantly with increasing nitrogen level up to 75 kg N ha^{-1}. Nitrogen takes part both in panicle formation and elongation. For this reason panicle length increased with increasing of nitrogen level.

4.1.5.4 Effect of interaction of variety and spacing

The interaction of variety and spacing had no significant effect on panicle length (Appendix IIa).

4.1.5.5 Effect of interaction of variety and nitrogen level

The interaction of variety and nitrogen level did not have any significant effect on panicle length (Appendix IIa).

4.1.5.6 Effect of interaction of spacing and nitrogen level

Interaction of spacing and nitrogen level had no significant effect on panicle length (Appendix IIa).

4.1.5.7 Effect of interaction of variety, spacing and nitrogen level

Interaction of variety, spacing and nitrogen level was not significant on panicle length (Appendix IIa).

4.1.6 Grains panicle^{-1}

4.1.6.1 Effect of variety

The results revealed that the number of grains panicle^{-1} was significantly influenced by variety (Appendix IIa). Table 1 shows that Badshabhog produced statistically highest number of grains panicle^{-1} (132.70). Intermediate number (123.70) was produced in Tulshimala and lowest (115.30) was found in Kalizira. BRRI (1994) reported that the number of grains panicle^{-1} influenced significantly due to variety. In the present experiment, although not significant, Badshabhog had longer panicle which might have contributed to produce more grains panicle^{-1}.

4.1.6.2 Effect of spacing

It was observed that spacing had significant effect of grains panicle^{-1} (Appendix IIa). Table 2 shows that the widest spacing (20 cm × 25 cm) produced the highest number of grains panicle^{-1} (130.27) and the closest one (8 cm × 25 cm) produced the lowest number of grains panicle^{-1} (115.73). This result was in agreement of Kalita *et al.* (1997) who stated that the closer spacing decreased number of grains panicle^{-1}.

4.1.6.3 Effect of nitrogen level

Number of grains panicle^{-1} varied significantly due to differences in nitrogen level (Appendix IIa). Number of grains panicle^{-1}increased with the increase of N level up to 60 kg N ha^{-1} and thereafter declined. Statistically the highest number of grains panicle^{-1} (130.15) was recorded from 60 kg N ha^{-1} followed by 40 kg N ha^{-1} (124.67) and the lowest one was recorded from 80 kg N ha^{-1} (116.81) (Table 3). Adequate supply of nitrogen contributed to grain formation that probably increased the number of grains panicle^{-1}. The present results explicitly confirm similar results obtained by Behera (1998) who reported the highest number of grains panicle^{-1} from 60 kg N ha^{-1}. After treatment grains panicle^{-1} decreased due to excessive vegetative growth.

4.1.6.4 Effect of interaction of variety and spacing

The interaction of variety and spacing was not significant in respect of grains panicle^{-1} (Appendix IIa).

4.1.6.5 Effect of interaction of variety and nitrogen level

The interaction of variety and nitrogen level had no significant effect on the formation of grains panicle^{-1} (Appendix IIa).

4.1.6.6 Effect of interaction of spacing and nitrogen level

The interaction of plant spacing and nitrogen level was not found significant in respect of grains panicle^{-1} (Appendix IIa).

4.1.6.7 Effect of interaction of variety, spacing and nitrogen level

Grains panicle^{-1} showed non significant response due to interaction of variety, spacing and nitrogen level (Appendix IIa).

4.1.7 Sterile spikelets panicle^{-1}

4.1.7.1 Effect of variety

Number of sterile spikelets panicle^{-1} was not significantly affected by variety (Appendix IIa). Numerically the highest and the lowest number of sterile spiketels panicle^{-1} were obtained from Kalizira and Badshabhog, respectively (Table 1).

4.1.7.2 Effect of spacing

Among the undesirable traits, number of sterile spikelets panicle^{-1} had significant effect (Appendix IIa) and it played a vital role in yield reduction. Table 2 shows that closest spacing (8 cm × 25 cm) produced numerically highest number of sterile spiketels panicle^{-1} (24.92) and the lowest sterile spikelets panicle^{-1} (21.95) was found in the widest spacing (20 cm × 25 cm) because it received more available air, water, temperature, light than closest spacing.

4.1.7.3 Effect of nitrogen level

Number of sterile spikelets panicle^{-1} was significantly affected by nitrogen level at 1% level of probability (Appendix IIa). A significant difference in number of sterile spiketets panicle^{-1} was observed at 80 kg N ha^{-1} as compared to other level of nitrogen. The maximum number of sterile spikelets panicle^{-1} (28.13) was recorded from 80 kg N ha^{-1}. The other level of nitrogen differed in respect of sterile spikelets. The lowest number of sterile spikelets panicle^{-1} was produced at 60 kg N ha^{-1} (Table 3). The highest number of sterile spikelets panicle^{-1} at 80 kg N ha^{-1} indicated that this level of nitrogen was probably a case of over dose in respect of sterile spikelets panicle^{-1} which might lead to yield loss.

4.1.7.4 Effect of interaction of variety and spacing

The effect of interaction of variety and spacing on number of sterile spikelets panicle^{-1} was not significant (Appendix IIa).

4.1.7.5 Effect of interaction of variety and nitrogen level

The interaction of variety and nitrogen level had no significant effect on sterile spilelets panicle^{-1} (Appendix IIa).

4.1.7.6 Effect of interaction of spacing and nitrogen level

The effect of interaction of spacing and nitrogen level on number of sterile spikelets panicle^{-1} was significant (Appendix IIa). The highest number of sterile spikelets panicle^{-1} (30.80) was recorded in S_2N_3 and statistically followed by S_3N_3 (28.23), S_1N_3 (27.20) and S_4N_3. The lowest number of sterile spikelet panicle^{-1} S_3N_2 (Table 6).

4.1.7.7 Effect of interaction of variety, spacing and nitrogen level

The interaction of variety, spacing and nitrogen level did not exert significant influence on sterile spikelets panicle^{-1} (Appendix IIa).

4.1.8 Weight of 1000 grains

4.1.8.1 Effect of variety

Results revealed that 1000-grain weight significantly differed due to variety (Appendix IIa). The results expressed that the highest 1000-grain weight (12.18 g) was produced in Badshabhog might be due to its large grain size. The 1000-grain weight (11.14 g) was produced in Kalizira for its smallest stout grain. In respect of

1000-grain weight, Tulshimala performed second in position for its longer fine grains (Table 1). The variation in 1000-grain weight might be due to differences of length and breadth of the grains that were partly controlled by genetic make-up of the studied varieties. Chowdhury *et al.* (1993) also reported the similar view.

4.1.8.2 Effect of spacing

Spacing showed significant effect on 1000-grain weight (Appendix IIa). It was observed that spacing (16 cm × 25 cm) produced the highest 1000-grain weight (11.93 g) which was identical to 20 cm × 25 cm where the weight of 1000 grains was 11.85 g. However, the closest spacing (8 cm × 25 cm) produced the lowest (11.56 g) in respect of this parameter. Such variation might be due to the variations of supply of food materials, moisture and light for proper development of grain comparing closest to wider spacing but up to a certain limit (Table 2).

4.1.8.3 Effect of nitrogen level

The effect of nitrogen level on 1000-grain weight was found insignificant (Appendix IIa). It was very close to 80 kg N ha^{-1} (11.78 g) and 40 kg N ha^{-1} (11.70 g). The results were consistent with the report of Chandraskharan and Salam (1995).

4.1.8.4 Effect of interaction of variety and spacing

Interaction of variety and spacing had no significant effect on 1000-grain weight (Appendix IIa).

4.1.8.5 Effect of interaction of variety and nitrogen level

The effect of interaction of variety and nitrogen level was found to be insignificant (Appendix IIa).

4.1.8.6 Effect of interaction of spacing and nitrogen level

The interaction effect of spacing and nitrogen level was not significant on 1000-grain weight (Appendix IIa).

4.1.8.7 Effect of interactions of variety, spacing and nitrogen level

The interaction of variety, spacing and nitrogen level did not exert significant influence on 1000-grain weight (Appendix IIa).

4.1.9 Grain yield

4.1.9.1 Effect of variety

Evidently, grain yield differed significantly due to variety (Appendix IIa). The Fig. 4 and Appendix VII showed that Badshabhog performed the highest in respect of grain yield (2.90 t ha^{-1}) and lowest grain yield was obtained from Kalizira (2.32 t ha^{-1}). Tulshimala produced the intermediate yield (2.61 t ha^{-1}). BRRI (2000) and Dwivedi (1997) were also reported the similar view.

The highest grain yield (2.90 t ha^{-1}) was produced in Badshhbhog which was mostly dependent on 1000-grain weight number of effective tillers $hill^{-1}$ and panicle length, grains $panicle^{-1}$ of this variety. The results of the present experiment indicate that highest number of effective tillers $hill^{-1}$ more grains $panicle^{-1}$ as well as heavier grains produced in Badshabhog must have contributed to the highest grain yield in other variety. These variation in yield might be due to genetic make-up of the studied varieties which was primarily influenced by heredity, Kalizira produced the lowest grain yield (2.32 t ha^{-1}) because of less number of effective tillers $hill^{-1}$, the lowest number of grains $panicle^{-1}$, lower 1000-grain weight.

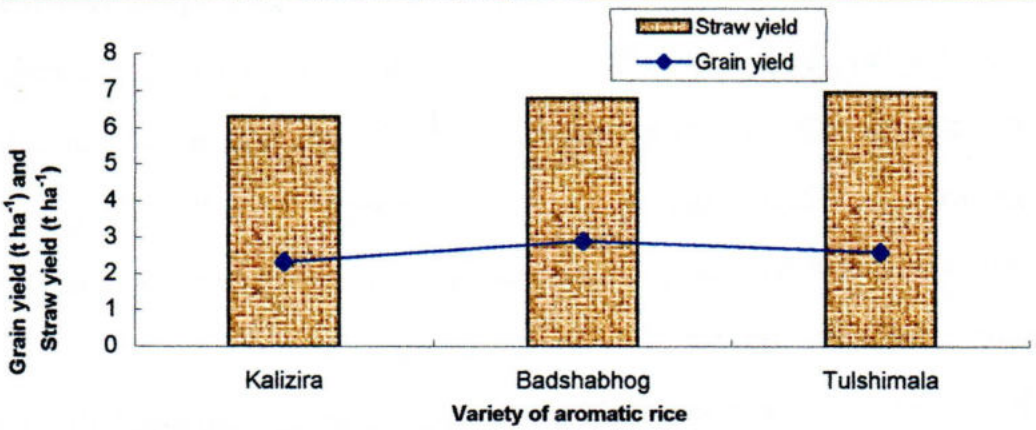

Fig. 4. Grain yield and straw yield of aromatic rice as influenced by variety

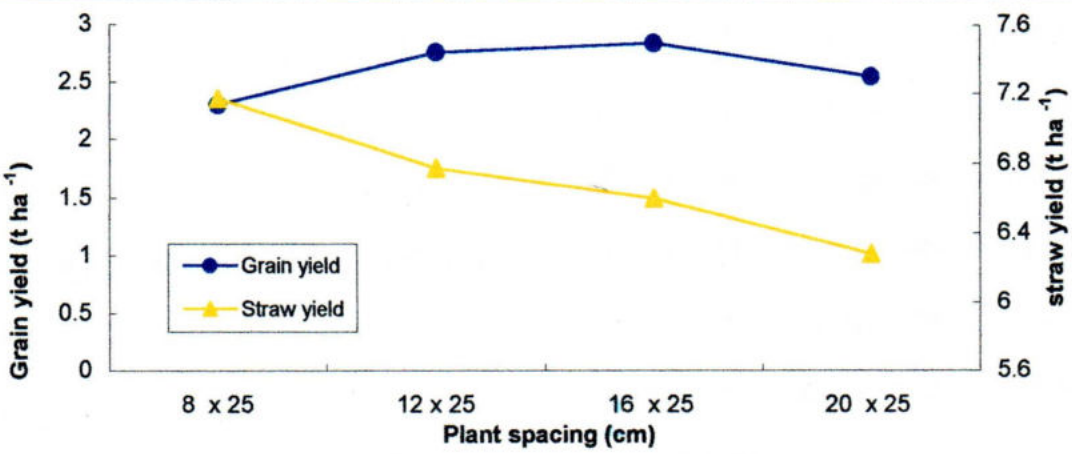

Fig. 5. Grain yield and straw yield of aromatic rice as influenced by plant spacing

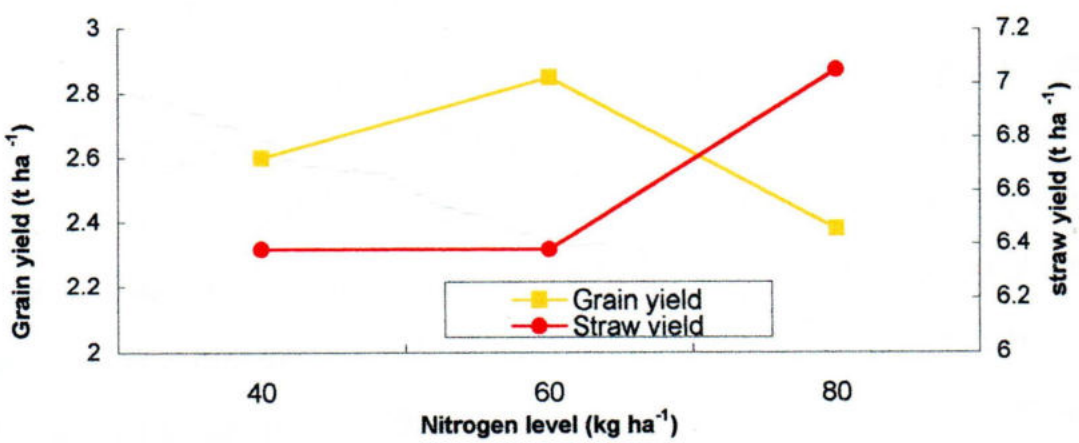

Fig. 6. Grain yield and straw yield of aromatic rice as influenced by nitrogen level

4.1.11.6 Effect of interaction of spacing and nitrogen level

The interaction effect of spacing and nitrogen level on biological yield was found non-significant. (Appendix IIa).

4.1.11.7 Effect of interaction of variety, spacing and nitrogen level

The interaction of variety, spacing and nitrogen level did not exert significant influence on biological yield (Appendix IIa).

4.1.12 Harvest index

4.1.12.1 Effect of variety

Variety exerted a significant effect on harvest index (Appendix IIa). From Table 1, it was evident that the highest harvest index (29.76%) was recorded from Badshabhog. The lowest harvest index (26.99%) was observed in Kalizira which was statistically similar with Tulshimala (27.14%). It was evident that the variety Kalizira was less efficient to translate the assimilates toward the grain. Shah *et al.* (1991) reported that variety had a great influence to harvest index. They also reported that harvest index decreased with the increase in plant height.

4.1.12.2 Effect of spacing

Spacing showed significant effect on harvest index (Appendix IIa). The result indicates that the highest harvest index (30.08%) was recorded from (16 cm × 25 cm) spacing. The second highest harvest index (28.95%) was recorded from (12 cm × 25 cm) spacing which was statistically similar with (20cm × 25 cm) spacing (28.88%). The lowest (24.28%) harvest index was observed in closest (8 cm × 25 cm) spacing (Table 2). The closest spacing produced the highest straw yield compared to that of grain yield resulting the lowest harvest index.

4.1.12.3 Effect of nitrogen level

The influence of nitrogen level on harvest index was significant at 1% level of probability (Appendix IIa). The experimental result showed that the highest harvest index (30.87%) was obtained with 60 kg N ha^{-1} which was identical to 40 kg N ha^{-1} (28.95%) and lowest harvest index was found (25.23%) with 80 kg N ha^{-1} (Table 3). With the increment of nitrogen from 40 kg N ha^{-1} to 60 kg N ha^{-1} grain yield was increased but further increase in nitrogen level produced higher straw yield which ultimately caused lower harvest index. Similar result was obtained by Dwivedi (1997).

4.1.12.4 Effect of interaction of variety and spacing

Harvest index was significantly affected by the interaction of variety and spacing at 1% level of probability (Appendix IIa). Table 4 shows that the highest harvest index (31.74%) was recorded in V_2S_3 identically followed by V_2S_4 (30.75%), V_2S_2 (30.59%), V_3S_3 (29.66%). The lowest harvest index (23.04%) was recorded in V_1S_1 which was statistically similar to V_3S_1 (23.06%).

4.1.12.5 Effect of interaction of variety and nitrogen level

Harvest index was not significantly affected by the interaction of variety and nitrogen level (Appendix IIa).

4.1.12.6 Effect of interaction of spacing and nitrogen level

The effect of interaction of spacing and nitrogen level on harvest index was not significant (Appendix IIa).

4.1.12.7 Effect of interaction of variety, spacing and nitrogen level

Interaction of variety spacing and nitrogen level did not have any significant effect on harvest index (Appendix IIa).

4.2 Effect on qualitative characters

4.2.1 Nitrogen content in grain

4.2.1.1 Effect of variety

Evidently, the varieties exhibited their differences in N content. (Appendix IIc). Table 12 shows that the highest N content of grain (1.45%) was obtained from Kalizira. The lowest N content of grain (1.43%) was recorded from Badshabhog which was statistical similar to Tulshimala (1.44%). This result was consistent to Dutta *et al.* (1998) who recorded variable N content among varieties.

4.2.1.2 Effect of spacing

Spacing had significant effect on N content (Appendix IIc). Results revealed that the highest N content (1.59%) was recorded from wider (20 cm × 25 cm) spacing and lowest N content (1.21%) was obtained from closest (8 cm × 25 cm) spacing (Appendix VIII and Fig. 7). The N content was increased with increasing of spacing. It might be due to absorption of more light, air, and food material in wider spacing that facilitated for maximizing of nitrogen content.

4.2.1.3 Effect of nitrogen level

The effect of different nitrogen level on N content was found significant at 1% level of probability (Appendix IIc). Appendix IX and fig. 8 show that grain attained maximum N content (1.58%) with 80 kg N ha^{-1} and the minimum N

Table 12. Effect of variety on qualitative characters of grain and straw of aromatic rice

Variety	Grain					Straw	
	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})	Germination (%)	Vigour index	Cooking time (min)	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})
Kalizira	1.45 a	33.92 c	86.55	27.35	14.25	0.49	31.21 c
Badsshabhog	1.43 b	41.82 a	86.87	27.58	14.20	0.49	33.43 b
Tulshimala	1.44 b	37.91 b	86.32	27.63	14.55	0.49	34.28 a
Sx	0.0031	0.1687	-	-	-	-	0.0301
Level of significance	0.01	0.01	NS	NS	NS	NS	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

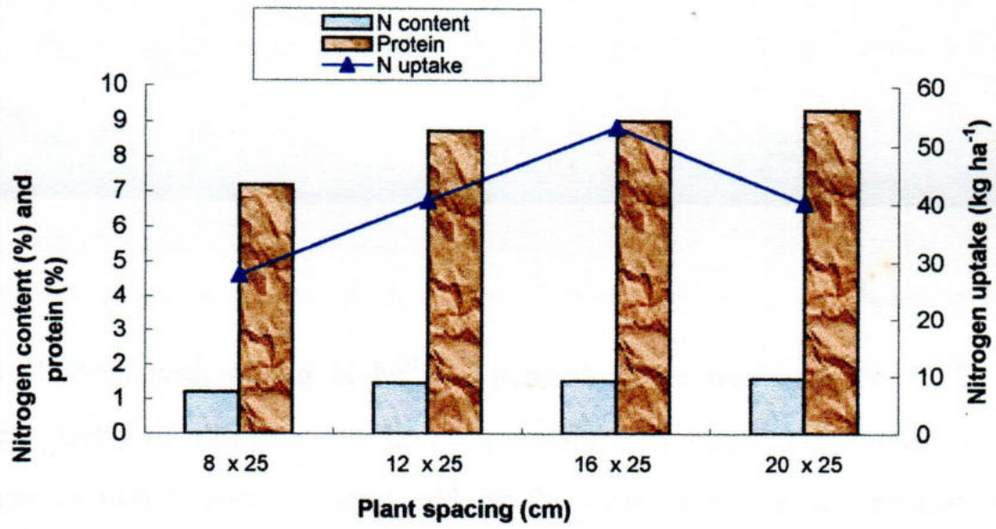

Fig. 7. Nitrogen content, nitrogen uptake and protein of aromatic rice as affected by spacing.

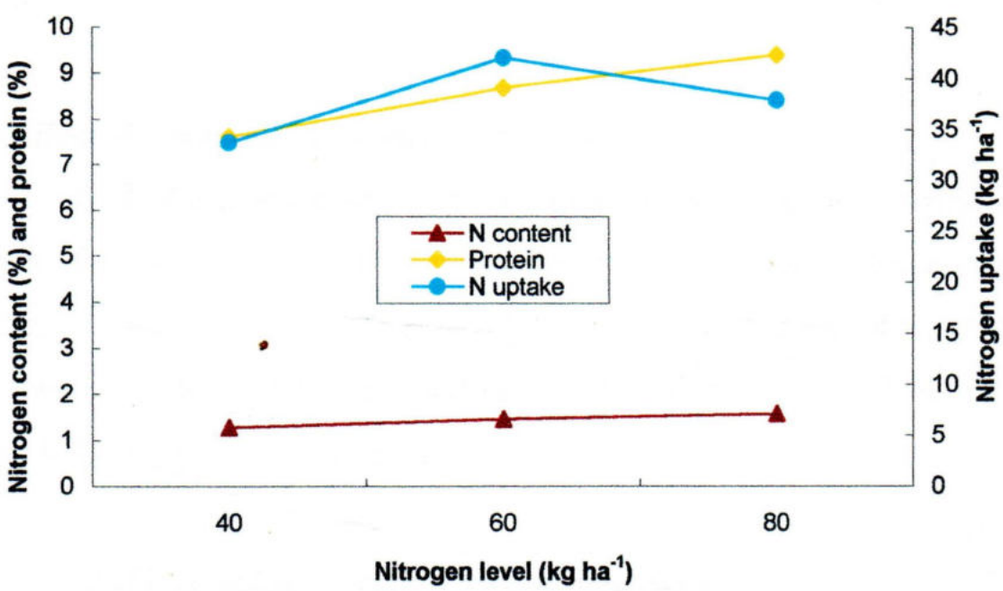

Fig. 8. Nitrogen content, nitrogen uptake and protein of aromatic rice as affected by nitrogen level

was significant (Appendix IIc). The highest N content of grain (1.67%) was obtained from S_4N_3 which was statistically similar to S_3N_3. The second lower and identical content of nitrogen was obtained from S_2N_3 and S_4N_2. The lowest N content (1.02%) was observed in S_1N_1 (Table 17).

content (1.28%) with 40 kg N ha^{-1}. In general, N content increased with the increasing levels of nitrogen. Similar result obtained by Uppal and Shidul. (1995) who reported that N content increased with the increasing level of nitrogen. The increase in N content due to application of increasing level of nitrogen might be associated with stimulating effect of nitrogen on various physiological processes including on various physiological processes including cell division and cell elongation.

4.2.1.4 Effect of interaction of variety and spacing

The effect of interaction of variety and spacing was found to be significant in respect of N content (Appendix IIc). Results presented in Table 15 shows that the highest N content (1.58%) was given by V_1S_4 and V_3S_4. The lowest (1.20%) N content was recorded from V_3S_1 identically followed by V_1S_1 (1.21%), V_2S_1 (1.21%), V_3S_2 (1.46%), V_2S_2 (1.46), V_2S_2 (1.47%).

4.2.1.5 Effect of interaction of variety and nitrogen level

Interaction of variety and nitrogen level was not significant on N content (Table 16).

4.2.1.6 Effect of interaction of spacing and nitrogen level

The interaction effect of spacing and nitrogen level on N content of grain was significant (Appendix IIc). The highest N content of grain (1.67%) was obtained from S_4N_3 which was statistically similar to S_3N_3. The second lower and identical content of nitrogen was obtained from S_2N_3 and S_4N_2. The lowest N content (1.02%) was observed in S_1N_1 (Table 17).

Table 13. Effect of spacing on qualitative characters of grain and straw of aromatic rice

Spacing (cm × cm)	Grain				Straw	
	Germination (%)	Vigour index	Aroma (numerical)	Cooking time (min)	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})
8 × 25	82.46 d	23.62 d	2.18	14.72	0.34 d	25.02 d
12 × 25	86.11 c	24.76 c	2.20	14.48	0.47 c	32.18 c
16 × 25	87.52 b	28.91 b	2.31	14.15	0.53 b	35.77 b
20 × 25	89.69 a	30.81 a	2.27	14.10	0.61 a	38.92 a
Sx	0.3608	0.1546	-	-	0.0007	0.0503
Level of significance	0.01	0.01	NS	NS	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

Table 14. Effect of nitrogen level on qualitative characters of grain and straw of aromatic rice

Nitrogen Level (kg ha^{-1})	Grain				Straw	
	Germination (%)	Vigour index	Aroma (numerical)	Cooking time (min)	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})
40	82.71 c	24.16 c	2.24	14.45	0.38 c	24.23 c
60	87.18 b	27.90 b	2.24	14.33	0.50 b	33.09 b
80	89.45 a	30.51 a	2.23	14.24	0.59 a	41.59 a
Sx	0.4568	0.3923	-	-	0.002	0.5410
Level of significance	0.01	0.01	NS	NS	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

Table 15. Effect of interaction of variety and spacing on qualitative characters of grain and straw of aromatic rice

Interaction (Variety × Spacing)	Grain							Straw	
	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})	Protein (%)	Germination (%)	Vigour index	Aroma (numerical)	Cooking time (min)	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})
$V_1 S_1$	1.21 h	24.57 h	7.23 f	82.04 d	23.22 f	3.03	14.60	0.34 h	23.46 k
$V_1 S_2$	1.46 fg	35.94 e	8.72 e	86.20 c	26.51 d	3.26	14.30	0.48 f	31.13 h
$V_1 S_3$	1.54 c	38.54 d	9.18 c	87.87b c	28.59 c	3.42	14.12	0.55 c	34.33 e
$V_1 S_4$	1.58 a	36.53 e	9.54 a	90.09 a	31.08 a	3.35	14.00	0.61 d	35.93 d
$V_2 S_1$	1.21 h	32.24 f	7.23 f	82.81 d	23.41 f	1.43	14.40	0.35 g	26.42 I
$V_2 S_2$	1.47 f	44.52 b	8.78 e	86.09 c	26.60 d	1.20	14.30	0.47 f	31.44 g
$V_2 S_3$	1.50 e	46.63 a	8.92 d	86.99 bc	29.10 c	1.25	14.13	0.52 e	35.71 d
$V_2 S_4$	1.55 b	43.89 b	9.23 c	89.99 a	31.21 a	1.25	14.00	0.62 a	34.15 b
$V_3 S_1$	1.20 I	26.55 g	7.15 f	82.55 d	24.23 e	2.07	14.17	0.34 h	25.20 j
$V_3 S_2$	1.46 g	41.06 c	8.72 e	86.05 c	27.16 d	2.13	14.83	0.47 f	33.96 f
$V_3 S_3$	1.51 d	44.05 b	9.02 d	87.71 bc	29.03 c	2.26	14.20	0.53 d	37.27 c
$V_3 S_4$	1.58 a	39.97 c	9.41 b	88.98 ab	30.12 b	2.20	14.30	0.60 b	40.67 a
Sx	0.0049	0.3853	0.032	0.6249	0.2678	-	-	0.0012	0.0871
Level of Significance	0.01	0.01	0.01	0.01	0.05	NS	NS	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

Table 16. Effect of interaction of variety and nitrogen level on qualitative characters of aromatic rice

Interaction (Variety × Nitrogen level)	Grain							Straw	
	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})	Protein (%)	Germination (%)	Vigour index	Aroma (numerical)	Cooking time (min)	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})
$V_1 N_1$	1.30	30.30	7.81	82.80	24.48	3.32	14.4	0.37 g	22.50
$V_1 N_2$	1.47	37.72	8.77	87.37	27.71	3.22	14.24	0.51 c	31.89
$V_1 N_3$	1.58	33.72	9.42	89.46	29.85	3.25	14.12	0.59 b	39.23
$V_2 N_1$	1.28	37.80	7.61	82.91	24.00	1.36	14.27	0.39 f	25.13
$V_2 N_2$	1.44	45.08	8.56	86.96	27.67	1.22	14.20	0.49 e	32.08
$V_2 N_3$	1.59	42.55	9.45	89.53	31.06	1.27	14.15	0.60 a	43.08
$V_3 N_1$	1.27	32.92	7.56	82.40	23.97	2.05	14.67	0.37 g	25.06
$V_3 N_2$	1.47	43.30	8.75	87.20	28.31	2.28	14.55	0.51 d	35.30
$V_3 N_3$	1.58	37.49	9.41	89.34	30.61	2.16	14.45	0.58 b	42.46
Sx	-	-	-	-	-	-	-	0.0034	-
Level of significance	NS	NS	NS	NS	NS	NS	NS	0.01	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test
NS = Not significant

Table 17. Effect of interaction of spacing and Nitrogen level on qualitative characters of grain and straw of aromatic rice

Interaction (Spacing × Nitrogen level)	Grain							Straw	
	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})	Protein (%)	Germination (%)	Vigour index	Aroma (numerical)	Cooking time (min)	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})
$S_1 N_1$	1.02 I	22.91h	6.06 h	80.87	21.27	2.33	14.90	0.29 k	20.52 g
$S_1 N_2$	1.20 h	29.99 g	7.14 g	82.66	24.00	2.07	14.70	0.31 j	22.75 fg
$S_1 N_3$	1.40 ef	30.55 g	8.33 e	83.85	25.57	2.14	14.56	0.42 h	31.80 d
$S_2 N_1$	1.30 g	35.82 f	7.73 f	81.75	23.68	2.10	14.60	0.36 I	23.74 efg
$S_2 N_2$	1.49 d	45.47 b	8.86 cd	86.61	26.80	2.26	14.53	0.48 f	30.70 b
$S_2 N_3$	1.61 b	40.23 cde	9.57 b	98.97	29.78	2.22	14.30	0.58 d	42.10 b
$S_3 N_1$	1.39 f	38.54 dcf	8.27 e	82.49	25.39	2.26	14.26	0.41 h	25.82 ef
$S_3 N_2$	1.54 c	49.02 a	9.16 c	88.84	29.25	2.33	14.08	0.55 e	36.40 c
$S_3 N_3$	1.65 a	41.65 cd	9.81 ab	91.24	32.07	2.34	14.10	0.64 c	45.10 ab
$S_4 N_1$	1.44 e	37.45 ef	8.56 d	85.71	26.27	2.29	14.03	0.45 g	26.86 e
$S_4 N_2$	1.60 b	43.66 bc	9.52 d	90.61	31.54	2.30	14.00	0.68 b	42.52 b
$S_4 N_3$	1.67 a	39.28 def	9.93 a	92.73	34.60	2.21	14.00	0.71 a	47.37 a
Sx	0.0154	1.1733	0.0987	-	-	-	-	0.0039	1.0819
Level of significance	0.01	0.01	0.01	NS	NS	NS	NS	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

4.2.1.7 Effect of interaction of variety, spacing and nitrogen level

The interaction effect of variety, spacing and nitrogen level was not significant on N content in grain (Table 18).

4.2.2 Nitrogen uptake in grain

4.2.2.1 Effect of variety

The results showed that there was a significant difference in nitrogen uptake among the varieties studied (Appendix IIc). Table 12 shows that the highest nitrogen uptake (41.82%) was recorded from Badshabhog which was statistically followed by Tulshimala (37.91%). The lowest nitrogen uptake in grain (33.92%) was obtained from Kalizira.

4.2.2.2 Effect of spacing

N uptake was significantly affected by spacing (Appendix IIc) Results presented in Appendix VIII and fig. 7 indicate that maximum nitrogen uptake (43.07%) was recorded from 16 cm × 25 cm spacing which was identically followed by 40.51% from 12 cm × 25 cm spacing and 40.13% from 20 cm × 25 cm. The lowest N uptake (27.82%) was obtained from closest (8 cm × 25 cm) spacing.

4.2.2.3 Effect of nitrogen level

Nitrogen uptake was significantly influenced by nitrogen level (Appendix IIc). The maximum nitrogen uptake (42.04%) was calculated at 60 kg N ha^{-1} and minimum nitrogen uptake (33.68%) was calculated at 40 kg N ha^{-1} (Appendix IX and Fig. 8).

Table 18. Effect of interaction of variety, spacing and nitrogen level on qualitative characters of grain and straw of aromatic rice

Interaction (Variety × Spacing × Nitrogen level)	Grain							Straw	
	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})	Protein (%)	Germination (%)	Vigour index	Aroma (numerical)	Cooking time (min)	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})
$V_1S_1N_1$	1.03	20.49	6.12	80.25	21.71	3.00	15.00	0.29 rs	19.29
$V_1S_1N_2$	1.20	25.89	7.19	82.29	23.41	3.01	14.50	0.31 qr	21.28
$V_1S_1N_3$	1.41	27.63	8.38	83.56	24.55	3.09	14.30	0.41 n	29.80
$V_1S_2N_1$	1.30	31.33	7.73	81.37	24.36	3.19	14.40	0.35 p	21.17
$V_1S_2N_2$	1.51	41.67	8.98	87.21	26.47	3.29	14.30	0.51i	32.28
$V_1S_2N_3$	1.56	34.82	9.46	90.01	28.69	3.29	14.20	0.59 g	39.94
$V_1S_3N_1$	1.41	34.96	8.38	82.34	25.71	3.53	14.20	0.42 n	24.69
$V_1S_3N_2$	1.56	43.99	9.28	89.59	28.29	3.29	14.16	0.58 g	35.61
$V_1S_3N_3$	1.66	36.68	9.88	91.68	31.78	3.43	14.00	0.65 f	42.70
$V_1S_4N_1$	1.46	34.45	9.01	87.23	26.17	3.58	14.00	0.45 lm	24.88
$V_1S_4N_2$	1.62	39.36	9.63	90.42	32.69	3.29	14.00	0.67 e	38.39
$V_1S_4N_3$	1.68	35.78	9.99	92.62	34.38	3.19	14.00	0.71 ab	44.51
$V_2S_1N_1$	1.04	27.04	6.18	81.02	20.61	1.00	14.50	0.31 qr	21.91
$V_2S_1N_2$	1.20	33.72	7.14	83.16	23.70	1.11	14.40	0.32 q	23.42
$V_2S_1N_3$	1.41	35.95	8.38	84.25	25.91	1.20	14.30	0.44 m	33.92
$V_2S_2N_1$	1.32	40.78	7.85	81.69	23.18	1.11	14.40	0.37 o	25.01
$V_2S_2N_2$	1.48	47.95	8.80	86.26	26.24	1.20	14.30	0.46 kl	25.93
$V_2S_2N_3$	1.63	44.82	9.69	90.31	30.39	1.30	14.20	0.59 g	43.39
$V_2S_3N_1$	1.35	43.04	8.05	82.17	25.91	1.16	14.20	0.41 n	25.83
$V_2S_3N_2$	1.50	51.60	8.92	88.12	29.21	1.30	14.10	0.52 i	34.89

Table 18: (Contd.)

Interaction (Variety × Spacing × Nitrogen level)	Grain							Straw	
	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})	Protein (%)	Germination (%)	Vigour index	Aroma (numerical)	Cooking time (min)	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})
$V_2S_3N_3$	1.65	45.21	9.81	90.69	32.18	1.30	14.10	0.65 f	46.41
$V_2S_4N_1$	1.41	40.35	8.38	86.78	26.32	1.16	14.00	0.47 jk	27.77
$V_2S_4N_2$	1.58	47.08	9.40	90.31	31.54	1.30	14.00	0.69 cd	44.09
$V_2S_4N_3$	1.67	44.25	9.93	92.87	35.78	1.30	14.00	0.72 a	48.60
$V_3S_1N_1$	1.01	21.21	6.00	81.36	21.50	2.00	15.20	0.29 s	20.35
$V_3S_1N_2$	1.21	30.37	7.19	82.54	24.91	2.09	15.20	0.32 q	23.55
$V_3S_1N_3$	1.39	28.07	8.27	83.74	26.27	2.13	15.10	0.41n	31.69
$V_3S_2N_1$	1.29	35.34	7.67	82.19	23.51	2.00	15.00	0.37 o	25.04
$V_3S_2N_2$	1.50	46.80	8.92	86.36	27.71	2.30	15.00	0.48 j	33.88
$V_3S_2N_3$	1.61	41.05	9.57	89.59	30.26	2.09	14.50	0.58 g	42.97
$V_3S_3N_1$	1.34	37.60	7.97	82.96	24.56	2.09	14.40	0.41 n	26.93
$V_3S_3N_2$	1.56	51.48	9.28	88.81	30.26	2.40	14.00	0.56 h	38.69
$V_3S_3N_3$	1.65	43.06	9.81	91.36	32.27	2.30	14.20	0.64 f	46.20
$V_3S_4N_1$	1.45	37.55	8.62	83.12	26.32	2.14	14.10	0.44 m	27.94
$V_3S_4N_2$	1.61	44.55	9.63	91.12	30.39	2.32	14.00	0.68 de	45.08
$V_3S_4N_3$	1.68	37.80	9.99	92.70	33.65	2.14	14.00	0.70 bc	49.00
Sx	-	-	-	-	-	-	-	0.0068	-
Level of significance	NS	NS	NS	NS	NS	NS	NS	0.01	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test
NS = Not significant

4.2.2.4 Effect of interaction of variety and spacing

N uptake in grain was significantly influenced by the interaction of variety and spacing (Appendix IIc). The maximum N uptake was obtained from V_2S_3 which were identically followed by V_2S_2 (44.52%), V_3S_3 (44.05%), V_2S_4 (43.89%) and V_3S_2 (41.06%). The minimum N uptake was found by V_1S_1 (24.67%) (Table 15).

4.2.2.5 Effect of interaction of variety and nitrogen level

The interaction of variety and nitrogen level was insignificant on N uptake in grain (Appendix IIc).

4.2.2.6 Effect of interaction of spacing and nitrogen level

The ANOVA indicates that the spacing and nitrogen level interact with each other in respect of N uptake of grain (Appendix IIc). The highest N uptake of grain (49.02%) was recorded from S_3N_2 which was identically followed by S_2N_2 (45.47%) S_4N_2 (43.66%), S_3N_3 (41.65%), S_2N_3 (40.23%), S_4N_3 (39.28%) and S_3N_1 (38.54%). The lowest N uptake in grain (22.91%) was obtained from S_1N_1 which was statistically at par with S_1N_2 (29.99), S_1N_2 (30.55), S_2N_2 (35.82%) and S_4N_1 (37.45%) (Table 17).

4.2.2.7 Effect of interaction of variety, spacing and nitrogen level

The interaction of variety, spacing and nitrogen level was not significant (Appendix IIc).

4.2.3 Protein in grain

4.2.3.1 Effect of variety

The variation due to variety was significant for protein (Appendix IIc). The highest percentage of protein (8.62) was recorded from Kalizira. The lowest percentage of protein (8.50) was recorded from Badshabhog which was statistically similar to Tulshimala (8.57%) (Appendix VII and Fig. 9). Differences in protein percentage due to varieties also reported by BRRI (1992) and Dutta (1998). Varietal differences regarding the percentage of protein were probably due to their differences in genetic make-up.

4.2.3.2 Effect of spacing

Protein was influenced significantly by spacing (Appendix IIc). Result revealed that protein was highest (9.34%) at widest spacing (20 cm × 25 cm) and the lowest value of protein (7.2%) was obtained from closest (8 cm × 25 cm) spacing (Appendix VIII). The trend of protein (%) increased with increasing of spacing.

4.2.3.3 Effect of nitrogen level

The effect of nitrogen level on protein content of grain was significant at 1% level (Appendix IIc). The maximum protein content (9.40%) was found when N application with 80 kg N ha^{-1}. The maximum protein content differed from other treatments. The minimum protein content (7.61%) was observed from 40 kg N ha^{-1} (Appendix IX). This finding is quite similar to the finding of Uppal and Shidul (1995) who stated that protein content of rice increased with increasing level of nitrogen up to 120 kg N ha^{-1}. This also agrees with the findings of BRRI (1992).

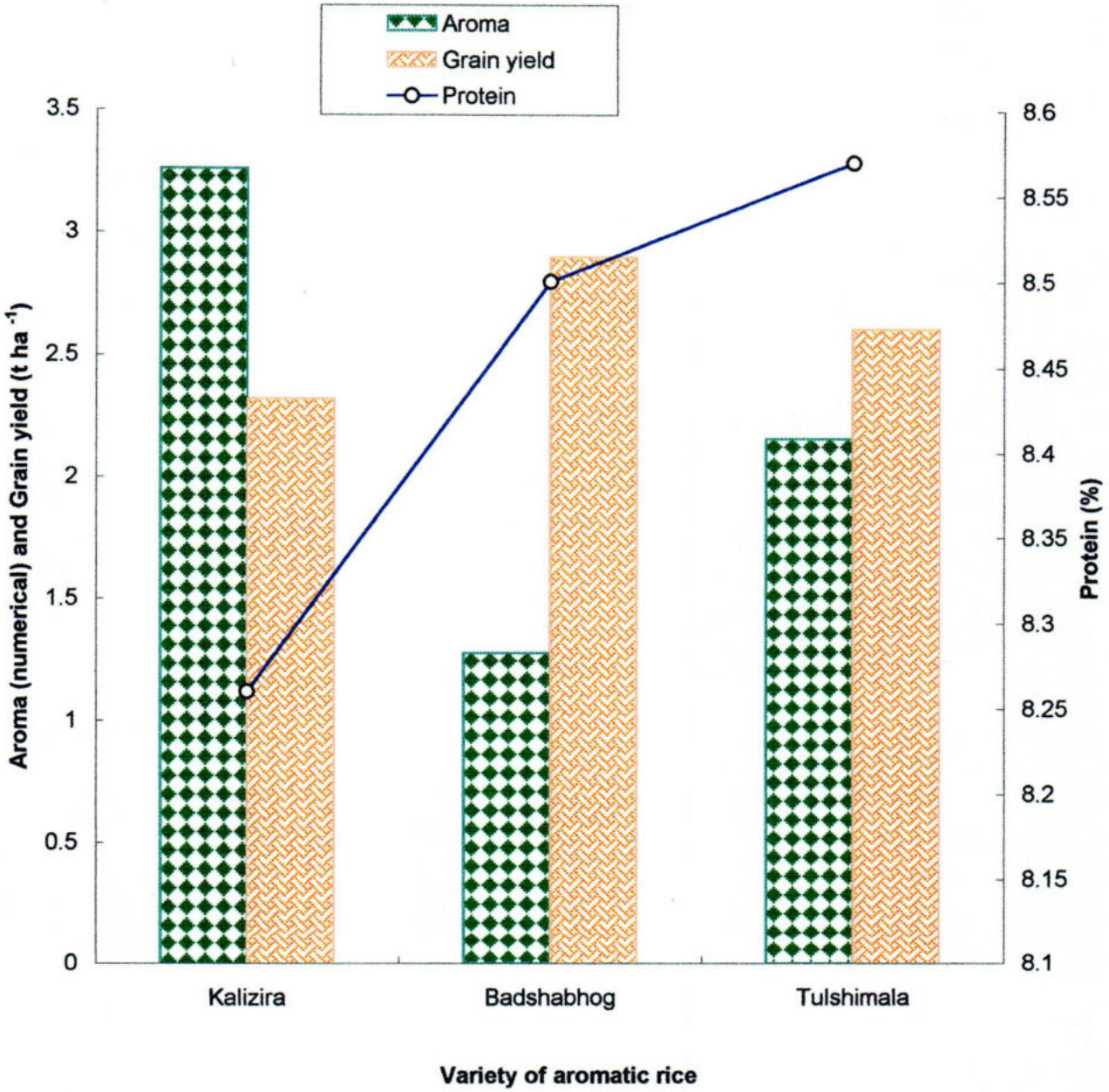

Fig. 9. Aroma, protein and grain yield of aromatic rice as influenced by variety

4.2.3.4 Effect of interaction of variety and spacing

The effect of interaction of variety and spacing was found to be significant in respect of protein content of grain (Appendix IIc). The highest percentage of protein (9.4) was recorded from V_1S_4 spacing which was statistically identically followed by V_3S_4 (9.41%), V_2S_4 (9.23%), V_1S_3 (9.18%) and V_3S_3 (9.02%). The lowest protein content (7.23%) was obtained from V_1S_1 which was statistically followed by V_1S_2 (8.72%), V_3S_2 (8.72%) and V_1S_3 (9.18%) (Table 15).

4.2.3.5 Effect of interaction of variety and nitrogen level

The interaction of variety and nitrogen level was not significant on protein content (Appendix IIc).

4.2.3.6 Effect of interaction of spacing and nitrogen level

Interaction effect of spacing and nitrogen level application on protein content of grain was significant (Appendix IIc). Table 17 shows that the maximum protein content (9.93%) was recorded form S_4N_3 which was statistically followed by S_3N_3 (9.81%). The minimum protein content (6.06%) was observed S_1N_1. The result showed that protein content significantly increased with the increasing spacing and nitrogen level.

4.2.3.7 Effect of interaction of variety, spacing and nitrogen level

The effect of interaction of variety, spacing and nitrogen level was not significant in respect of protein content (Appendix IIc).

4.2.4 Germination

4.2.4.1 Effect of variety

Germination was not significantly affected by variety (Appendix IIc). All the varieties however, had acceptable level of germination of over 86% indicates that all of them would be used as seed.

4.2.4.2 Effect of spacing

Germination rate differed significantly due to spacing (Appendix IIc). The highest result (89.69%) was obtained at widest spacing (20 cm × 25 cm). The lowest germination (82.46%) was recorded from closest (8 cm × 25 cm) spacing (Table 13). The results of the present experiment suggested that as the wider spacing enjoyed more moisture, nutrients etc, it helped to develop more food in the embryo, which possibly helped to germinate better.

4.2.4.3 Effect of nitrogen level

The influence of nitrogen level on germination had significant effect (Appendix IIc). Table 17 indicates that highest nitrogen level significantly influenced germination. The highest germination (89.45%) was recorded at 80 kg N ha^{-1} and lowest germination (82.71%) was obtained from 40 kg N ha^{-1} (Table 14). Higher rate of germination in the seed obtained from the mother plant which received higher rate of nitrogen might be due to the fact that it contained more nitrogen which might have an indirect positive effect.

4.2.4.4 Effect of interaction of variety and spacing

The interaction effect of variety and spacing was significant on germination percentage (Appendix IIc). The maximum value of germination (90.09%) which

was recorded from V_1S_4 which was statistically similar to V_2S_4 (89.99%) and V_3S_4 (88.98%). The lowest of germination (82.04%) was obtained from V_1S_1which was statistically at par V_3S_1 (82.55%), and V_2S_1 (82.81%) (Table 15).

4.2.4.5 Effect of interaction of variety and nitrogen level

The interaction of variety and nitrogen level was not significant on germination (Appendix IIc).

4.2.4.6 Effect of interaction of spacing and nitrogen level

Germination was not significantly influenced due to interaction of spacing and nitrogen level (Appendix IIc).

4.2.4.7 Effect of interaction of variety, spacing and nitrogen level

The interaction effect of variety, spacing and nitrogen level on germination was not significant (Appendix IIc).

4.2.5 Vigour index

4.2.5.1 Effect of variety

Variation in vigour index was found to be insignificant due to variety (Appendix IIc) and Table 12.

4.2.5.2 Effect of spacing

Spacing had a significant effect on vigour index (Appendix IIc). The highest value (30.81) was obtained at widest (20 cm × 25 cm) spacing and lowest 23.62% was obtained at closest (8 cm × 25 cm) spacing (Table 13). The effect of spacing on vigour index showed exactly similar trend with germination.

4.2.5.3 Effect of nitrogen level

There was a direct and significant relationship between nitrogen level and vigour index of rice seeds (Appendix IIc). The vigour index ranged from 24.16 to 30.51, respectively. The highest value was recorded at 80 kg N ha^{-1} application which was significantly different from all other N level ha^{-1} and the lowest was obtained at 40 kg N ha^{-1}. The increasing trend of vigour index was observed with increasing nitrogen level having similarity with germination (Table 14). Patel *et al.* (1991) also reported that vigour index was significantly increased with nitrogen level.

4.2.5.4 Effect of interaction of variety and spacing

The interaction effect of variety and spacing on vigour index was significant at 5% level (Appendix IIc). The highest value (31.21) was obtained at V_2S_4 which was statistically at par with V_1S_4 (31.08), The lowest value (23.22) was recorded from V_1S_1 which was statistically followed by V_1S_1 (23.41), V_1S_2 (26.51), V_2S_2 (26.60) and V_3S_2 (27.16) (Table 15).

4.2.5.5 Effect of interaction of variety and nitrogen level

The interaction effect of variety and nitrogen level on vigour index was not significant (Appendix IIc).

4.2.5.6 Effect of interaction of spacing and nitrogen level

The interaction effect of spacing and nitrogen level on vigour index was insignificant (Appendix IIc)

4.2.5.7 Effect of interaction of variety, spacing and nitrogen level

The effect of interaction of variety spacing and nitrogen level on vigour index was not significant (Appendix IIc).

4.2.6 Aroma

4.2.6.1 Effect of variety

The aroma of rice was significantly influenced by variety at 1% level of significance (Appendix IIc). The highest value (3.26) was recorded from Kalizira. The lowest value (1.28) was obtained from Badshabhog (Appendix VII and fig. 9). Varietal differences regarding aroma might be due to their difference in genetic make-up. Dutta *et al.* (1998) reported that aroma varied among the varieties.

4.2.6.2 Effect of spacing

Different spacing did not significantly affect on aroma (Appendix IIc).

4.2.6.3 Effect of nitrogen level

Aroma was insignificant due to different levels of nitrogen application (Appendix IIc).

4.2.6.4 Effect of interaction of variety and spacing

The interaction effect of variety and spacing was not significant (Appendix IIc).

4.2.6.5 Effect of interaction of variety and nitrogen level

The effect of interaction of variety and nitrogen level was not significant (Appendix IIc).

4.2.6.6 Effect of interaction of spacing and nitrogen level

The interaction of spacing and nitrogen level did not effect on Aroma. (Appendix IIc).

4.2.6.7 Effect of interaction of variety, spacing and nitrogen level.

The effect of interaction of variety, spacing and nitrogen level was not significant (Appendix IIc).

4.2.7 Cooking time

Results in Tables 12, 13, 14, 15, 16, 17, and 18 shows that there no significant effect of variety, or spacing or nitrogen levels even interaction effect on cooking time among the different treatments.

4.2.8 N-content of straw

4.2.8.1 Effect of variety

Nitrogen content of straw was not significantly affected due to variety. (Appendix IIc). All the varieties used had 0.49% of nitrogen (Table 12).

4.2.8.2 Effect of spacing

Nitrogen content of straw was found to be highly responsive to spacing (Appendix IIc) and had similar pattern as was found in grain. The maximum value (0.61%) was recorded from widest spacing and the minimum value (0.34%) was recorded from closest spacing (Table 13). The percentage of N-content of straw was increased with increasing of spacing.

4.2.8.3 Effect of nitrogen level

The percentage of N-content of straw was found to be highly responsive to nitrogen level. (Appendix IIc). The highest value (0.59%) was recorded when the crop was fertilized with 80 kg N ha^{-1} and the lowest value (0.38%) was recorded from 40 kg N ha^{-1} (Table 14).

4.2.8.4Effect of interaction of variety and spacing

The interaction effect of variety and spacing was significant (Appendix IIc). The highest value (0.62%) was recorded from V_2S_4 which was statistically followed by V_3S_4, V_3S_3, V_1S_3, V_3S_3 and V_2S_3. The lowest value (3.4) was recorded from V_1S_1 and V_3S_1 (Table 15).

4.2.8.5 Effect of interaction of variety and nitrogen level

Nitrogen content was significantly effected due to interaction of variety and nitrogen level (Appendix IIc). From Table 16, it is evident that the highest value (0.60%) was given by V_2N_3 which was statically followed by V_1N_3, V_3N_3, V_1N_2, V_3N_2 and V_2N_2. The lowest value (0.37%) was recorded from $V_1N_1$and V_3N_1, respectively.

4.2.8.6 Effect of interaction of spacing and nitrogen level

The effect of interaction of spacing and nitrogen level was significant (Appendix IIc). Table 17 shows that the maximum of N-content (0.71%) was recorded from S_4N_3 which was statistically identically by S_4N_2, S_3N_3, S_2N_3, N_3N_2 and S_2N_2. The minimum value (0.29) was given from S_1N_1.

4.2.8.7 The effect of interaction of variety, spacing and nitrogen level

The interaction effect of variety, spacing and nitrogen level was significant (Appendix IIc). Table 18 shows that the highest value (0.72%) was obtained from $V_2S_4N_3$ treatment.

4.2.9 Nitrogen uptake of straw

4.2.9.1 Effect of variety

The nitrogen uptake of straw was significantly affected by variety (Appendix IIc). Results presented in Table 12 indicates that maximum nitrogen uptake of straw (34.28 kg ha^{-1}) was recorded from Tulshimala followed by Badshabhog. The minimum nitrogen uptake of straw (31.21 kg ha^{-1}) was recorded from Kalizira. The variation might be due to the genetic make up of the varieties.

4.2.9.2 Effect of spacing

The N-uptake of straw was significant due to spacing. (Appendix IIc). The highest value (38.92 kg ha^{-1}) was given by widest spacing because of light, temperature and nitrogen availability. The lowest percentage of nitrogen uptake of straw (25.02 kg ha^{-1}) was recorded from closest spacing (Table 13).

4.2.9.3 Effect of nitrogen level

It is presented from Appendix IIc that nitrogen uptake of straw was significantly influenced by nitrogen level. Nitrogen uptake increased with increasing level of nitrogen. Table 14 shows that maximum nitrogen uptake of straw (41.59 kg ha^{-1}) was calculated at 80 kg N ha^{-1} and minimum one (24.23 kg ha^{-1}) was calculated at 40 kg N ha^{-1}.

4.2.9.4 Effect of interaction of variety and spacing

The interaction effect of variety and plant spacing was found significant (Appendix IIc). The highest nitrogen uptake (40.67 kg ha^{-1}) was obtained from V_3S_4 which was statistically followed by V_2S_4, V_3S_3 and V_1S_4. The lowest value of nitrogen uptake of straw (23.46 kg ha^{-1}) was obtained from S_1V_1 (Table 15).

4.2.9.5 Effect of interaction of variety and nitrogen level

The interaction effect of variety and nitrogen level was not significant (Appendix IIc).

4.2.9.6 Effect of interaction of spacing and nitrogen level

Nitrogen uptake of straw was significantly influenced by the interaction of spacing and nitrogen level (Appendix IIc). Table 17 shows that maximum nitrogen uptake of straw (47.37 kg ha^{-1}) was calculated from the interaction of widest spacing and 80 kg N ha^{-1}. The lowest one (20.52 kg ha^{-1}) was recorded in closest spacing with 40 kg N ha^{-1}. S_4N_2 gave second highest nitrogen uptake of straw 42.52 kg ha^{-1} which was statistically at par S_2N_2 (42.40 kg ha^{-1}).

4.2.9.7 Effect of interaction of variety, spacing and nitrogen level

The interaction effect of variety, spacing and nitrogen level were not significant (Appendix IIc).

4.3 Soil fertility status

Results of the properties of post harvest soil may be seen in Table 19-25, and Appendix IId, showed marked variation in the values of soil pH, organic matter (%), total nitrogen (%), available phosphorus (ppm) and exchangeable potassium (me 100 g $soil^{-1}$) as compared to the respective value of initial soil.

4.3.1 Soil pH

4.3.1.1 Effect of variety

The pH data of post harvest soil were not statistically significant due to variety (Table 19).

4.3.1.2 Effect of spacing

Spacing exerted a significant effect on pH of post harvest soil (Appendix IId). From the Table 20 it was found that the highest value (7.60) was recorded at widest spacing (S_4) and the lowest value (7.22) was at closest spacing (S_1). The increasing trend of pH value explained that the pH value increased with increasing of spacing. pH values increased from the initial in all spacing and ranged from 7.22-7.60.

4.3.1.3 Effect of nitrogen level

pH was found to be highly significant due to nitrogen level (Appendix IId). The highest value (7.69) was recorded from 80 kg N ha^{-1} and lowest value (7.20) was recorded from 40 kg N ha^{-1} (Table 21). The increasing trend of pH value explained that the pH value increased with increasing level of nitrogen.

4.3.1.4 Effect of interaction of variety and spacing

The interaction effect of variety and spacing was not significant (Table 22).

4.3.1.5 Effect of interaction of spacing and nitrogen level

The interaction effect of spacing and nitrogen level was not significant (Table 23).

Table 19. Effect of variety on the nutrient status of the post harvest soil

Variety	Soil pH	Organic matter (%)	Total nitrogen (%)	Available P (ppm)	Exchangeable K (me 100g soil^{-1})
Kalizira	7.47	1.21 ab	0.087	21.13 a	0.110 a
Badshabhog	7.39	1.19 b	0.083	19.44 c	0.098 b
Tulshimala	7.49	1.22 a	0.085	20.43 b	0.108 a
Sx	-	0.025	-	0.0312	0.000
Level of significance	NS	0.05	NS	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

Table 20. Effect of spacing on the nutrient status of the post harvest soil

Spacing (cm × cm)	Soil pH	Organic matter (%)	Total nitrogen (%)	Available P (ppm)	Exchangeable K (me 100g soil^{-1})
8 × 25	7.22 d	1.16 b	0.075 c	18.51 d	0.092 d
12 × 25	7.45 c	1.19 c	0.086 b	19.61 c	0.101 c
16 × 25	7.52 d	1.21 b	0.088 ab	21.03 b	0.108 b
16 × 25	7.60 a	1.25 a	0.093 a	22.19 a	0.120 a
Sx	0.0228	0.0028	0.0003	0.0315	0.005
Level of significance	0.01	0.01	0.01	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

Table 21. Effect of nitrogen on the nutrient status of the post harvest soil

Nitrogen level (kg ha^{-1})	Soil pH	Organic matter (%)	Total nitrogen (%)	Available P (ppm)	Exchangeable K (me 100g $soil^{-1}$)
40	7.20 c	1.15 c	0.074 b	17.13 c	0.087 c
60	7.46 b	1.20 b	0.087 a	20.50 b	0.107 b
80	7.69 a	1.27 a	0.095 a	23.38 a	0.123 a
Sx	0.0350	0.0070	0.0010	0.2322	0.0011
Level of significance	0.01	0.01	0.01	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

Table 22. Effect of interaction of variety and spacing on the nutrient status of the post harvest soil

Interaction (variety × spacing)	Soil pH	Organic matter (%)	Total nitrogen (%)	Available P (ppm)	Exchangeable K (me 100g soil^{-1})
V_1S_1	7.29	1.91 d	0.076	20.32 d	0.097 ef
V_1S_2	7.47	1.20 d	0.088	20.45 d	0.104 cde
V_1S_3	7.53	1.20 d	0.089	21.27 c	6.113 bc
V_1S_4	7.59	1.27 a	0.094	22.50 a	0.127 a
V_2S_1	7.16	1.14 g	0.073	17.35 h	0.087 f
V_2S_2	7.40	1.19 e	0.083	18.48 f	0.093 ef
V_2S_3	7.48	1.20 d	0.086	20.41 d	0.100 de
V_2S_4	7.51	1.23 c	0.090	21.53 b	0.113 bc
V_{31}	7.21	1.17 f	0.074	17.87 g	0.094 ef
V_3S_2	7.48	1.20 d	0.086	19.90 e	0.107 cd
V_3S_3	7.57	1.23 c	0.088	21.42 b	0.110 bcd
V_3S_4	7.72	1.26 b	0.094	22.55 a	0.120 ab
Sx	-	0.0049	-	0.0545	0.0009
Level of significance	NS	0.01	NS	0.01	0.05

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

Table 23. Effect of interaction of variety and nitrogen level on the nutrient status of the post harvest soil

Interaction (Variety × Nitrogen level)	Soil pH	Organic matter (%)	Total nitrogen (%)	Available P (ppm)	Exchangeable K (me 100g soil^{-1})
V_1N_1	7.17	1.15	0.076	12.16	0.090
V_1N_2	7.45	1.21	0.088	22.11	0.113
V_1N_3	7.78	1.28	0.097	24.13	0.128
V_2N_1	7.13	1.14	0.072	16.82	0.080
V_2N_2	7.43	1.19	0.086	19.18	0.100
V_2N_3	7.60	1.24	0.092	22.32	0.115
V_3N_1	7.29	1.16	0.075	17.42	0.090
V_3N_2	7.51	1.21	0.087	20.20	0.108
V_3N_3	7.68	1.28	0.095	23.69	0.125
Sx	-	-	-	-	-
Level of significance	NS	NS	NS	NS	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

4.3.1.6 Effect of interaction of variety and nitrogen level

pH value of post harvest soil was not significant due to interaction of variety and nitrogen level (Table 24).

4.3.1.7 Effect of interaction of variety, spacing and nitrogen level

The interactions effect of variety, spacing and nitrogen level were not significant (Table 25).

4.3.2 Organic matter (%)

4.3.2.1 Effect of variety

After harvest the organic matter in the soil was significantly different due to variety (Appendix IId). The highest organic matter (1.22%) was recorded from Tulshimala which was statistically identical with Kalizira (Table 19). The results of the present experiment showed that the organic matter content available due to different treatment were little below to the national average of 1.5% (BARC, 1997).

4.3.2.2 Effect of spacing

The organic matter of post harvest soil was significantly affected due to spacing (Appendix IId). The highest value of organic matter (1.25%) was obtained from widest spacing (S_4) and the lowest value (1.16%) was recorded from closest spacing (Table 20).

4.3.2.3 Effect of nitrogen level

Organic matter in the soil samples collected after harvest was significantly influenced with the application of different nitrogen level (Appendix IId). The highest organic matter contents (1.27%) was recorded when 80 kg N ha^{-1} applied and the lowest (1.15%) in the 40 kg N ha^{-1} (Table 21).

Table 24. Effect of interaction of spacing and nitrogen on the nutrient status of the post harvest soil

Interaction (Spacing × Nitrogen level)	Soil pH	Organic matter (%)	Total nitrogen (%)	Available P (ppm)	Exchangeable K (me 100g soil^{-1})
S_1N_1	6.76	1.09	0.036	14.83	0.077
S_1N_2	7.30	1.17	0.077	18.73	0.094
S_1N_3	7.61	1.23	0.084	21.97	0.107
S_2N_1	7.31	1.15	0.074	16.16	0.087
S_2N_2	7.44	1.19	0.089	19.75	0.100
S_2N_3	7.61	1.25	0.093	22.91	0.117
S_3N_1	7.31	1.16	0.076	18.13	0.087
S_3N_2	7.57	1.20	0.090	21.17	0.110
S_3N_3	7.69	1.27	0.097	23.80	0.127
S_4N_1	7.42	1.19	0.082	19.41	0.097
S_4N_2	7.55	1.24	0.091	22.34	0.123
S_4N_3	7.85	1.33	0.105	24.83	0.140
Sx	-	-	-	-	-
Level of significance	NS	NS	NS	NS	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

Table 25. Effect of interaction of variety, spacing and nitrogen level on the nutrient status of the post harvest soil

Interaction (Variety × Spacing × Nitrogen level)	Soil pH	Organic matter (%)	Total nitrogen (%)	Available P (ppm)	Exchangeable K (me 100g soil^{-1})
$V_1S_1N_1$	6.79	1.12	0.065	15.22	0.080
$V_1S_1N_2$	7.40	1.19	0.078	22.30	0.100
$V_1S_1N_3$	7.70	1.26	0.086	23.43	0.110
$V_1S_2N_1$	7.20	1.15	0.077	16.40	0.090
$V_1S_2N_2$	7.51	1.20	0.091	21.35	0.100
$V_1S_2N_3$	7.70	1.25	0.095	23.60	0.121
$V_1S_3N_1$	7.29	1.14	0.079	18.01	0.090
$V_1S_3N_2$	7.50	1.20	0.089	21.80	0.120
$V_1S_3N_3$	7.80	1.26	0.098	24.00	0.130
$V_1S_4N_1$	7.42	1.21	0.081	19.00	0.100
$V_1S_4N_2$	7.41	1.25	0.092	23.00	0.130
$V_1S_4N_3$	7.93	1.37	0.110	25.51	0.150
$V_2S_1N_1$	6.71	1.07	0.061	14.76	0.070
$V_2S_1N_2$	7.18	1.16	0.077	16.51	0.090
$V_2S_1N_3$	7.60	1.19	0.081	20.78	0.100
$V_2S_2N_1$	7.30	1.15	0.071	15.60	0.080
$V_2S_2N_2$	7.40	1.18	0.087	18.35	0.090
$V_2S_2N_3$	7.52	1.26	0.091	21.50	0.110
$V_2S_3N_1$	7.21	1.16	0.074	17.85	0.080
$V_2S_3N_2$	7.63	1.19	0.089	20.38	0.100
$V_2S_3N_3$	7.60	1.26	0.095	23.00	0.121
$V_2S_4N_1$	7.31	1.18	0.080	19.10	0.090
$V_2S_4N_2$	7.53	1.23	0.089	21.50	0.120
$V_2S_4N_3$	7.69	1.28	0.101	23.99	0.130
$V_3S_1N_1$	6.78	1.10	0.063	14.50	0.080
$V_3S_1N_2$	7.33	1.18	0.076	17.40	0.091
$V_3S_1N_3$	7.53	1.24	0.084	21.71	0.110
$V_3S_2N_1$	7.42	1.16	0.075	16.50	0.090
$V_3S_2N_2$	7.41	1.19	0.089	19.55	0.110
$V_3S_2N_3$	7.60	1.26	0.093	23.65	0.120
$V_3S_3N_1$	7.42	1.19	0.076	18.55	0.090
$V_3S_3N_2$	7.60	1.23	0.090	21.33	0.110
$V_3S_3N_3$	7.68	1.29	0.097	24.40	0.130
$V_3S_4N_1$	7.53	1.20	0.085	20.13	0.100
$V_3S_4N_2$	7.70	1.25	0.093	22.53	0.120
$V_3S_4N_3$	7.93	1.34	0.105	25.00	0.140
Sx	-	-	-	-	-
Level of significance	NS	NS	NS	NS	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test
NS = Not significant

4.3.2.4 Effect of interaction of variety and spacing

The interaction effect of variety and spacing were significant (Appendix IId). The highest value (1.27%) was recorded from the interaction of V_1S_4 and the lowest value (1.14%) was recorded from the interaction of V_2S_1 (Table 22). From that table, it was found that all treatment combinations exhibited lower organic matter content as compared to the same of initial soil.

4.3.2.5 Effect of interaction of variety and nitrogen level

The interaction effect of variety and nitrogen level was not significant (Appendix IId).

4.3.2.6 Effect of interaction of spacing and nitrogen level

The interaction effect of spacing and nitrogen level was not significant (Appendix IId).

4.3.2.7 Effect of interaction of variety, spacing and nitrogen level

The interaction effect of variety, spacing and nitrogen level were not significant (Appendix IId).

4.3.3 Total nitrogen (%)

4.3.3.1 Effect of variety

After harvest, the total nitrogen in the soil was not significantly influenced due to variety (Appendix IId).

4.3.3.2 Effect of spacing

Total nitrogen content of post harvest soil was found to be significantly influenced by spacing (Appendix IId). The maximum total nitrogen content

(0.093%) was recorded from the widest spacing (S_4) which was statistically identical with S_3. The lowest value (0.075%) was obtained from closest spacing (Table 20).

4.3.3.3 Effect of nitrogen level

Nitrogen level was found to be significant in terms of total nitrogen content in post harvest soil (Appendix IId). The highest value (0.095%) was obtained from 80 kg N ha^{-1} applied which was statistically at par with the application of 60 kg N ha^{-1}. The lowest value (0.074%) was obtained from 40 kg N ha^{-1} (Table 21). The mining of nitrogen was more intense with lower nitrogen level.

4.3.3.4 Effect of interaction of variety and spacing

The interaction effect of variety and spacing was not significant (Appendix IId).

4.3.3.5 Effect of interaction of variety nitrogen level

The interaction effect of variety and nitrogen level was not significant (Appendix IId).

4.3.3.6 Effect of interaction of spacing and nitrogen level

The interaction effect of spacing and nitrogen level on total nitrogen in post harvest soil in significant (Appendix IId).

4.3.3.7 Effect of interaction of variety, spacing and nitrogen level

The interaction effect of variety, spacing and nitrogen level were not significant (Appendix IId).

4.3.4 Available phosphorus

4.3.4.1 Effect of variety

Appendix IId indicates that available phosphorus content of soil was significant due to variety. Table 19 showed that the highest value (21.13 ppm) was recorded from Kalizira and the lowest value (19.44 ppm) was recorded from Badshabhog.

4.3.4.2 Effect of spacing

The available phosphorus in post harvest soil was significant at 1% level of probability due to spacing (Appendix IId). The maximum value (22.19 ppm) was obtained from widest spacing and the minimum value (18.51 ppm) was obtained from closest spacing (Table 20). The increasing trend of available phosphorus explained that the available phosphorus value increased with increasing spacing.

4.3.4.3 Effect of nitrogen level

The available phosphorus content of soil was significant at 1% level probability (Appendix IId). Table 21 indicated that numerically the highest value (23.38 ppm) and the lowest value (17.13 ppm) available phosphorus content were recorded against the highest (80 kg N ha^{-1}) and the lowest (40 kg N ha^{-1}) level of nitrogen, respectively.

4.3.4.4 Effect of interaction of variety and spacing

The interaction effect of variety and spacing was significant (Appendix IId). The highest value (22.55 ppm) was recorded from the interaction of V_3S_4 which was statistically at par V_1S_4. The lowest value (17.87 ppm) was obtained from V_3S_1 (Table 23).

4.3.4.5 Effect of interaction of variety and nitrogen level

The interaction of variety and nitrogen level was not significant (Appendix IId).

4.3.4.6 Effect of interaction of spacing and nitrogen level

The interaction effect of spacing and nitrogen level was not significant (Appendix IId).

4.3.4.7 Effect of interaction of variety, spacing and nitrogen level

Interaction effect of variety, spacing and nitrogen level was not significant (Appendix IId).

4.3.5 Exchangeable potassium

4.3.5.1 Effect of variety

In respect of soil, exchangeable potassium content, the varieties were significantly affected (Appendix IId). Table 19 showed that the highest value (.110 me 100 g soil^{-1}) was recorded from Kalizira which was statistically at par with Tulshimala and the lowest value (0.098 me 100 g soil^{-1}) was recorded from Badshabhog.

4.3.5.2 Effect of spacing

Exchangeable potassium was significantly influenced by spacing (Appendix IId). The maximum value (0.12 me 100 g soil^{-1}) was recorded from widest spacing (S_4) and the minimum value (0.92 me 100 g soil^{-1}) was record from closest spacing (S_1) (Table 20).

4.3.5.3 Effect of nitrogen level

Exchangeable potassium was significantly differed due to nitrogen level (Appendix IId). The highest value (0.123 me 100 g soil^{-1}) was recorded from 80 kg N ha^{-1} and the lowest value (0.087 me 100 g soil^{-1}) was recorded from 40 kg N ha^{-1} (Table 21). The result showed that the exchangeable potassium increased with increasing of nitrogen level.

4.3.5.4 Effect of interaction of variety and spacing

The interaction effect of variety and spacing was significant on exchangeable potassium (Appendix IId). The highest value (0.127 me 100 g soil^{-1}) was recorded from interaction of V_1S_4 which was statistically identical to V_3S_4. The lowest value (0.87 me 100 g soil^{-1}) was recorded from interaction of V_2S_1 which was statistically at par with V_1S_1 and V_3S_1 (Table 22).

4.3.5.5 Effect of interaction of variety and nitrogen level

The interaction effect of variety and nitrogen level was insignificant (Appendix IId).

4.3.5.6 Effect of interaction of spacing and nitrogen level

The interaction effect of spacing and nitrogen level was not significant (Appendix IId).

4.3.5.7 Effect of interaction of variety, spacing and nitrogen level

The interaction of variety, spacing and nitrogen level was not significant (Appendix IId).

CHAPTER V

SUMMARY

The research work was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from July to December 2000 with a view to finding out the effect of spacing and nitrogen level on the yield and quality of some varieties of aromatic rice grains. The experimental treatments included were: (A) three varieties of transplant aromatic rice viz., Kalizira (V_1), Badshabhog (V_2) and Tulshimala (V_3), (B) four spacing viz., 8 cm × 25 cm (S_1), 12 cm × 25 cm (S_2), 16 cm × 25 cm (S_3) and 20 cm × 25 cm (S_4) and three nitrogen level viz., 40 (N_1), 60 (N_2) and 80 kg ha^{-1} (N_3) applied as urea. The experiment was laid out in a split-split plot design with three replications. The unit plot size was 10 m^2 (4.0 m × 2.5 m) and the spaces between replications, plots and between subplots were 1.5, 0.75 and 0.5 m, respectively. The land was fertilized with triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate. Urea as a source of nitrogen was applied as per experimental specification. The entire amount of TSP, MP, gypsum and zinc sulphate were applied as basal dose while urea was applied as top dressing in three equal splits at 15, 35 and 55 DAT. Seedlings were transplanting on 13 August 2000 at the rate of 3 seedling $hill^{-1}$.

Intercultural operations such as gap filling, weeding, water management and pest management was done as and when necessary. Five hills (excluding border hills) were randomly selected from each unit plot prior to harvest for recording different crop characters. Tiller number was recorded from five selected hills at 20

day intervals beginning 20 DAT to 80 DAT. After sampling the whole plots were harvested when some 90% of the seeds became golden yellow in colour. The data on different agronomic characters were recorded from the randomly selected five hills in each plot and those on grain and straw yields were recorded from the whole plot. After harvest, soil samples were taken, prepared and analysed to assess the nutrient status of the soil. The initial soil sample was also tested. Data were analysed using the "Analysis of variance" technique and mean differences were recognized by DMRT.

Number of tiller gradually increased up to 60 DAT and thereafter decreased. The tiller number significantly differed due to spacing and nitrogen levels at all growth stages of all varieties. Variety had significant influence on all the parameters (except panicle length and striate spikelets paniele^{-1}) studied. Number of tiller gradually increased up to 60 DAT and thereafter decreased, and number of tillers hill^{-1} at 20 DAT and 60 DAT varied significantly due to variety. Badshabhog produced highest number of total tillers hill^{-1} (8.75), number of effective tillers hill^{-1} (6.38), panicle length (23.23 cm), grains panicle^{-1} (132.7) and 1000-grain weight (12.18 g) as a results highest yield (2.90 t ha^{-1}) than other varieties. Tulshimala produced the second highest yield (2.61 t ha^{-1}) because of less total tillers (8.31), panicle length (22.33 cm), grain panicle^{-1} (123.7) and 1000-grain weight (11.99 g) than Badshabhog. Kalizira produced the lowest effective tillers hill^{-1} (6.20) grains panicle^{-1} (115.3) and 1000-grain weight (11.14 g), So Kalizira produced the lowest yield (2.32 t ha^{-1}).

The highest biological yield (9.72 t ha^{-1}) and harvest index (29.76%) were observed in Badshabhog which were identical with Tulshimala for which the

corresponding values were 9.61 t ha^{-1} and 27.14 t ha^{-1}, respectively. The tiller number significantly differed due to spacing and nitrogen level at all DAT. Widest spacing (20 cm × 25 cm) produced the highest number of tillers $hill^{-1}$ at all DAT.

The effect of spacing was significant on most of the parameters studied, except non-effective tillers $hill^{-1}$. Taller plant (152.03 cm), number of total tillers $hill^{-1}$ (10.51), panicle length (23.42 cm) and number of grains $panicle^{-1}$ (130.27) were found at widest spacing (20 cm × 25 cm). Shorter plant (141.37 cm), number of total tillers $hill^{-1}$ (6.91), panicle length (21.54 cm) and number of grains $panicle^{-1}$ (115.73) were obtained at closest spacing (8 cm × 25 cm). The highest grain yield (2.84 t ha^{-1}) and harvest index (30.08%) were obtained at spacing (16 cm × 25 cm).

Results showed that different nitrogen level had significant positive effect on most of the parameters studied except 1000-grain weight and total tillers $hill^{-1}$ at harvest. It was observed that number of total tillers $hill^{-1}$ increased up to 60 DAT and thereafter decreased at all DAT. Plant height increased progressively up to maturity. Tallest plant (152.33 cm), highest straw yield (7.05 t ha^{-1}) and biological yield (9.43 t ha^{-1}) were obtained at the highest nitrogen level (80 kg N ha^{-1}). Highest panicle length (23.20 cm), grains $panicle^{-1}$ (130.15), grain yield (2.85 t ha^{-1}) and harvest index (30.87%) were found from 60 kg N ha^{-1} which was identical with 80 kg N ha^{-1}.

The interaction of variety and spacing was significantly affected by total tiller number $hill^{-1}$ and harvest index but the grain yield was not significant. Interaction effect of variety and nitrogen level was not significant all the parameters. Interaction of spacing and nitrogen level was not significant on most of

the parameters but grain yield was significant. The highest grain yield (3.18 t ha^{-1}) was obtained from interaction of spacing (16 cm × 25 cm) and 60 kg N ha^{-1}. Interaction of variety, spacing and nitrogen level was not significant on the yield and other crop characters.

The effect of variety on different qualitative characters (except germination, vigour index and cooking time) in grain and straw showed significant influence. Kalizira contained highest nitrogen content (1.45%), protein content (8.62%) and aroma. The effect of spacing on different quality characters in grain and straw viz., nitrogen content, nitrogen uptake, protein content and germination were highly significant except aroma, cooking time and nitrogen uptake. All the characters were found to increase significantly with the increasing of spacing from 8 cm × 25 cm to 20 cm × 25 cm.

Qualitative characters (except cooking time and aroma) were significantly influenced by application of nitrogen levels. The qualitative characters under study both in grain and straw were significantly increased with the increasing nitrogen levels from 40 to 80 kg ha^{-1}. Most of the interaction effects were not significant. However, post-harvest analysis of the experimental soil indicated that the soil pH increased, the soil organic matter depleted and P and K mining took place. Positive balance was however, observed in the case of nitrogen where supplementation was done.

Not only yield but also desirable qualitative characters are burning issue now-a-days. The issue as mentioned above has been very correctly address in this study by finding out suitable spacing and nitrogen level on three varieties of aromatic rice at 16 cm × 25 cm and 60 kg N ha^{-1}, respectively.

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APPENDICES

Appendix Ia. Morphological characteristics of the soil

Constituents	Characteristics
Location	Field Laboratory, Department of Agronomy, BAU, Mymensingh
Soil Tract	Old Brahmaputra Alluvium
Land type	Medium high land
General soil type	Non-calcareous dark grey flood plain
Soil series	Sonatola
Agro-ecological zone	Old Brahmaputra Flood Plain (AEZ-9)
Topography	Fairly level
Soil colour	Dark grey
Drainage	Moderate

Appendix Ib. Physical properties of the initial soil (0-15 cm depth)

Constituents	Results
Particle size analysis	
Sand (%) (0.2-0.02 mm)	25
Silt (1%) (0.02-0.002 mm)	61
Clay (%) (<0.002 mm)	14
Soil textural class	Silt loam

*** Results obtained from the mechanical analysis of the initial soil sample.**

Appendix Ic. Chemical composition of the initial soil (0-15 mm depth)

Constituents	Results
Soil P^H	6.4
Organic matter (%)	1.29
Total nitrogen (%)	0.101
Available phosphorus (ppm)	26
Exchangeable potassium (me/100 g soil)	0.13

*** Results obtained from the chemical analysis of initial soil sample**

Appendix IIa: Summary of analysis of variance for yield and other crop characters of aromatic rice as influence by variety, spacing and nitrogen level at harvest

Source of Variations	Degrees of freedom	Mean Squares											
		Plant height (cm)	Total tillers hill^{-1} (no)	Effective tillers hill^{-1} (no)	Non-effective tillers hill^{-1} (no)	Panicle Length (cm)	Grains panicle^{-1} (no)	Sterile spikelets panicle^{-1} (no)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	7.906	0.050	0.114	2.425	0.909	11.426	41.790	0.037	0.001	0.075	0.067	0.430
Variety	2	937.241**	1.874**	0.380**	5.728*	0.480 NS	2725.501**	145.317 NS	11.093**	3.043**	4.768**	14.063**	87.624**
Error (a)	4	8.315	0.021	0.010	0.215	0.912	36.914	23.831	0.037	0.015	0.096	0.077	0.005
Spacing	3	540.691**	65.702**	63.402**	2.091 NS	19.813**	1152.902**	44.522 NS	0.699**	1.584**	3.698**	3.180**	177.339**
Variety × spacing	6	11.634 NS	0.917**	0.027 NS	0.670 NS	0.705 NS	31.429 NS	20.383 NS	0.075 NS	0.041 NS	0.042 NS	0.123 NS	2.565**
Error (b)	18	7.637	0.018	0.017	0.742	0.932	87.620	11.947	0.037	0.020	0.118	0.085	0.003
Nitrogen level	2	1043.542**	4.687 NS	6.107**	2.774*	28.886**	1618.327**	565.619**	0.127 NS	1.991**	4.017 NS	3.423*	228.715**
Variety × nitrogen	4	12.744 NS	0.413 NS	0.042 NS	0.423 NS	1.399 NS	47.195 NS	6.509 NS	0.012 NS	0.032 NS	0.054 NS	0.074 NS	2.085 NS
Spacing × nitrogen	6	25.3477 NS	0.887 NS	0.017 NS	0.778*	1.528 NS	97.778 NS	37.901*	0.011 NS	0.081 NS	0.049 NS	0.099 NS	4.868 NS
Variety × spacing × nitrogen	12	8.737 NS	0.462 NS	0.021 NS	0.519 NS	1.407 NS	16.804 NS	53.769**	0.009 NS	0.010 NS	0.041 NS	0.020 NS	0.579 NS
Error (c)	48	90.456	1.917	0.878	0.422	1.337	77.101	15.474	0.041	0.018	1.080	0.930	5.958
Cv (%)	-	6.47	16.15	14.81	28.31	5.17	7.09	16.53	1.73	5.12	15.49	10.33	8.73

*** = Significant at 5% level of significance**
**** = Significant at 1% level of significance**
NS = Not significant

Appendix IIb. Summary of analysis of variance for total tiller production of aromatic rice as influenced by variety, spacing and nitrogen level

Source of variations	Degrees of freedom	Means squares			
		20 DAT	40 DAT	60 DAT	80 DAT
Replication	2	0.231	1.173	2.370	0.235
Variety	2	6.673*	5.990 NS	3.245*	0.813 NS
Error (a)	4	0.598	1.258	0.361	0.126
Spacing	3	126.075**	132.447**	127.945**	119.446**
Variety × Spacing	6	4.909**	1.120 NS	0.707 NS	0.323 NS
Error (b)	18	0.442	0.906	0.962	0.189
Nitrogen	2	2.199*	5.000*	3.680*	26.274**
Variety × Nitrogen	4	0.351 NS	0.585 NS	0.143 NS	0.578 NS
Spacing × Nitrogen	6	0.980 NS	1.077 NS	1.055 NS	0.998 NS
Variety × Spacing × Nitrogen	12	0.135 NS	0.476 NS	0.291 NS	0.336 NS
Error (c)	48	0.507	1.010	0.962	2.240
Cv (%)	-	9.37	11.55	10.78	17.63

*** = Significant at 5% level of significance**

**** = Significant at 1% level of significance**

NS = Not significant

Appendix IIc: Summary of analysis of variance for the qualitative characters of grain and straw as influence by variety, spacing and nitrogen level

Source of variation	Degrees of freedom	Mean Squares								
		Grain							Straw	
		Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})	Protein (%)	Germination (%)	Vigour index	Aroma (numerical)	Cooking time (min.)	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})
Replication	2	0.001	0.380	0.027	3.303	0.219	0.215	0.267	0.000	5.577
Variety	2	0.003*	561.115**	0.153**	0.486 NS	0.816 NS	35.498**	1.298 NS	0.000**	90.206**
Error (a)	4	0.000	1.024	0.008	0.846	0.774	0.075	0.242	0.000	0.033
Spacing	3	0.694**	1261.130**	25.175**	248.688**	256.718**	0.101 NS	2.778 NS	0.348**	963.035**
Variety × spacing	6	0.002**	7.190**	0.080**	2.113 NS	2.257*	0.155 NS	0.333 NS	0.001**	10.633**
Error (b)	18	0.000	1.336	0.009	3.514	0.645	0.078	0.029	0.000	0.068
Nitrogen	2	0.828**	628.894**	28.359**	423.651**	367.421**	0.003 NS	0.393 NS	0.398**	2712.701**
Variety × nitrogen	4	0.002 NS	12.526 NS	0.106 NS	0.499 NS	3.129 NS	0.115 NS	0.018 NS	0.001**	15.897 NS
Spacing × nitrogen	6	0.009**	32.455*	0.395**	17.004 NS	6.765 NS	0.090 NS	0.059 NS	0.018**	85.144**
Varity × spacing × nitrogen	12	0.001 NS	3.161 NS	0.028 NS	2.445 NS	1.574 NS	0.109 NS	0.052 NS	0.000**	7.168 NS
Error (c)	48	0.002	12.390	0.088	7.511	5.541	0.184	0.319	0.000	10.535
Cv (%)	-	3.19	9.29	3.44	3.17	8.55	19.14	3.94	2.37	9.84

* = Significant at 5% level of significance
** = Significant at 1% level of significance
NS = Not significant

Appendix IId. Summary of analysis of variance for the nutrients status of the post harvest soil as influenced by variety, spacing and nitrogen level

Source of variations	Degrees of freedom	Means squares				
		Soil pH	Organic matter (%)	Total nitrogen (%)	Available P (ppm)	Exchangeable K (me 100 g soil^{-1})
Replication	2	0.006	0.001	0.000	0.590	0.000
Variety	2	0.108^{NS}	0.008*	0.000*	26.001**	0.001**
Error (a)	4	0.023	0.000	0.000	0.035	0.000
Spacing	3	0.726**	0.038**	0.002**	70.157**	0.004**
Variety × Spacing	6	0.021^{NS}	0.002**	0.000^{NS}	3.842**	0.000*
Error (b)	18	0.014	0.000	0.000	0.027	0.000
Nitrogen	2	2.152**	0.124**	0.004**	351.856**	0.012**
Variety × Nitrogen	4	0.043^{NS}	0.001^{NS}	0.000^{NS}	6.142^{NS}	0.000^{NS}
Spacing × Nitrogen	6	0.159^{NS}	0.001^{NS}	0.000^{NS}	1.570^{NS}	0.000^{NS}
Variety × Spacing × Nitrogen	12	0.019^{NS}	0.000^{NS}	0.000^{NS}	0.915^{NS}	0.000^{NS}
Error (c)	48	0.044	0.002	0.000	1.941	0.000
Cv (%)	-	2.82	3.49	7.18	6.85	6.40

*** = Significant at 5% level of significance**
**** = Significant at 1% level of significance**
NS = Not significant

Appendix III. Distribution of monthly temperature, relative humidity, rainfall and duration of sunshine of the experimental site during the period from June to December 2000

Month	**Air temperature (^{0}C)			**Relative humidity (%)	*Rainfall (mm)	Daily Sunshine (hr)
	Maximum	Minimum	Average			
June	31.91	25.88	28.89	87.20	479.90	3.57
July	31.72	26.54	29.13	85.58	136.40	4.43
August	31.64	26.32	28.98	88.35	292.10	3.45
September	30.54	25.43	27.99	89.93	342.40	3.31
October	31.62	23.86	27.74	86.10	171.90	6.63
November	29.70	19.09	24.40	82.37	000.00	7.93
December	26.71	13.43	20.07	77.00	000.00	7.01

*** = Monthly total**

**** = Monthly average**

Source : Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh

Appendix IV. Effect of variety on tiller production of aromatic rice

Variety	20 DAT	40 DAT	60 DAT	80 DAT
Kalizira	7.79 a	9.10	9.32 a	8.60
Badshabhog	7.89 a	8.70	9.21 a	8.53
Tulshimala	7.10 b	8.29	8.76 b	8.31
Sx	0.1289	-	0.1001	-
Level of significance	0.05	NS	0.05	NS

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

DAT = Days after transplanting

Appendix V. Effect of spacing on tiller production of aromatic rice

Spacing (cm × cm)	20 DAT	40 DAT	60 DAT	80 DAT
8 × 25	4.99 d	6.07 d	6.47 d	6.03 d
12 × 25	6.84 c	7.84 c	8.35 c	7.58 c
16 × 25	8.60 b	9.73 b	10.04 b	9.51 b
20 × 25	9.97 a	11.15 a	11.53 a	10.81 a
Sx	0.1280	0.1832	0.1888	0.0836
Level of significance	0.01	0.01	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

DAT = Days after transplanting

Appendix VI. Effect of nitrogen level on tiller production of aromatic rice

Nitrogen level (kg ha^{-1})	20 DAT	40 DAT	60 DAT	80 DAT
40	7.32 b	8.27 b	8.78 b	7.59 c
60	7.67 a	8.85 a	9.09 ab	8.56 b
80	7.80 a	8.97 a	9.42 a	9.30 a
Sx	0.1187	0.1675	0.1635	0.2495
Level of significance	0.01	0.05	0.05	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

DAT = Days after transplanting

Appendix VII. Effect of variety on grain yield, straw yield, protein and aroma of aromatic rice

Variety	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Protein (%)	Aroma (numerical)
Kalizira	2.32 c	6.30 b	8.62 a	3.26 a
Badshabhog	2.90 a	6.82 a	8.50 b	1.28 c
Tulshimala	2.61 b	7.00 a	8.57 b	2.16 b
Sx	0.0201	0.0518	0.015	0.0457
Level of significance	0.01	0.01	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

Appendix VIII. Effect of spacing on grain yield, straw yield, nitrogen content, nitrogen uptake and protein of aromatic rice

Spacing (cm × cm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})	Protein (%)
8 × 25	2.30 d	7.17 a	1.21 d	27.82 c	7.20 d
12 × 25	2.76 b	6.77 b	1.47 c	40.51 b	8.74 c
16 × 25	2.84 a	6.60 b	1.52 b	43.07 a	9.04 b
20 × 25	2.55 c	6.28 c	1.59 a	40.13 b	9.34 a
Sx	0.0272	0.0661	0.0029	0.2224	0.0185
Level of significance	0.01	0.01	0.01	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant

Appendix IX. Effect of nitrogen level on grain yield, straw yield, nitrogen content, nitrogen uptake and protein of aromatic rice

Nitrogen (kg ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Nitrogen content (%)	Nitrogen uptake (kg ha^{-1})	Protein (%)
40	2.60 b	6.38 b	1.28 c	33.68 c	7.61 c
60	2.85 a	6.38 b	1.46 b	42.04 a	8.69 b
80	2.38 c	7.05 a	1.58 a	37.93 b	9.40 a
Sx	0.0223	0.1732	0.0077	0.05863	0.0493
Level of significance	0.01	0.05	0.01	0.01	0.01

In a column, figures bearing same or no letter (s) do not differ significantly at 5% level of significance by Duncan's Multiple Range Test

NS = Not significant