

EFFECT OF NITROGEN LEVELS ON THE YIELD PERFORMANCE OF AROMATIC RICE VARIETIES

A THESIS

BY

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ABSTRACT

A field experiment was conducted to evaluate the effect of different nitrogen levels on the yield performance of three aromatic rice varieties in transplanted aman (monsoon) season. The rice varieties included are Morichshile, Kachra and Raniselute and five nitrogen levels 0, 30, 60, 90 and 120 kg N ha⁻¹ formed the treatment variables. The experiment was laid out in a Factorial Randomized Complete Block Design (RCBD) with three replications. All the yield contributing characters differed significantly due to variety. Morichsail produced the maximum number of grains per panicle (76.35). Among the varieties, Morichsail gave the maximum grain yield (2.69 t ha⁻¹). Different nitrogen rates also significantly affected the aromatic rice varieties. Plant height, total tiller, unfilled grain panicle⁻¹ and biological yield increased with the nitrogen application. Panicle length, effective tillers panicle⁻¹, 1000-grain weight, grain yield and harvest index were significantly increased up to 60 kg N ha⁻¹ and thereafter decreased. The combination of varieties and nitrogen rates significantly affected panicle length, filled grain panicle⁻¹ and grain yield of aromatic rice. It was observed that interaction of the variety Morichsail and 60 kg N ha⁻¹ gave the highest panicle length, filled grain panicle⁻¹ and grain yield.

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Chapter I

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than three billion people is over half of the world's total population (FAO, 2004). Rice contributes 91.1% of the total grain production and covers 74% of the total calorie intake for the people of Bangladesh (MOA, 2001).

In Bangladesh, more than four thousand land races of rice are adopted in different parts of this country. Some of these are unique for quality traits including fineness, aroma, taste and protein contents (Kaul *et al.*, 1982). Aromatic rice as reported by Singh *et al.* (2000), had 15 times more 2-acetyl-1-pyrroline content than non-aromatic rice (0.14 and 0.009 ppm, respectively). Aromatic rice is an important commodity in international trade having small grain with pleasant aroma. Among the rice varieties, aromatic rice is popular in Asia and gained wider acceptance in Europe and the United States because of its aroma, flavor and texture. Aromatic varieties fetch higher price in rice market than non- aromatic ones. Demand for aromatic rices in recent years has increased to a great extent for both internal consumption and export (Das and Baqui, 2000).

Islam *et al.* (1996) observed that the yield of aromatic rice was low (1.5-2.0 t ha⁻¹) but its high price and low cost of cultivation generated higher profit margins compared to other varieties. Most of aromatic rice varieties in Bangladesh are traditional type, photoperiod sensitive and are grown during transplanted aman season in the rainfed lowland ecosystem. Aromatic rice of Bangladesh on account of its high export potential and taste; better eating quality like polau, khir, firny, paesh, chiram khoi, birany, etc. has high demand. Basmati rice of India and Pakistan is well known in the world market whereas Bangladeshi aromatic rice is virtually unknown due to insufficient production and lack of storage trade linkage (Das and Baqui, 2000). In the near future, there is a possibility that Bangladesh may export aromatic

rice, but the competition in terms of quality and price would be very stiff in the world market (World Bank, 1995).

Fertilizer is now one of the expensive inputs for crop production in Bangladesh. Rice plants depend solely upon soil and applied source of N for higher yield. N plays a key role supporting plants physiological activity and increasing the rice yield (BRRI, 1997). Among the nutrients rice plants absorbs a large amount of N to produce higher grain yield (Murayama, 1979). Nitrogen is the most important limiting nutrient in rice production and has heavy system losses when applied as inorganic sources in paddled field (Fillery *et al.*, 1984). Nitrogen has a positive influence on the production of effective tillers per plant, yield and yield attributes (Jashim *et al.*, 1984; BRRI, 1990). Rashid *et al.* (1996) reported that nitrogen is deficient in almost all the soils of Bangladesh. Therefore, the importance of increased amount of nitrogen fertilizer use in Bangladesh to get higher yield. It is also evident that the yield of rice is affected very much if correct dose is not applied (Ahsan, 1996). Among many factors deficiency of nitrogen is now considered as the main reason of low yield of rice in saline region of Bangladesh (Ghose, 2003). It is also fact that improper use of nitrogenous fertilizer, instead of giving yield advantage, may reduce the same. Almost every farmer has tendency to apply excess of N fertilizer which are costly to get a desirable yield of Aman rice (Saleque *et al.*, 2004), but imbalance use of N fertilizer causes harm to the crop and decreases grain yield. 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 N in different soils in Bangladesh (Bhuiya *et al.*, 1998; Islam *et al.*, 1990).

A suitable combination of variety and rate of nitrogen is necessary for better yield (BRRI, 1990). Proper dose of nitrogen can improve the yield of aromatic rice. Information on the

varietal performance of aromatic rice and nitrogen response are sporadic and scattered. So, research is necessary to find out appropriate variety and optimum rate of nitrogen to obtain satisfactory yield from aromatic rice.

Therefore, the present study was undertaken to fulfill the following objective-

- To determine the response of different aromatic rice varieties to various levels of nitrogen.
- To determine the yield potential of selected varieties.

Thakur (1991) obtained the highest plant height when 40%, 30% and 30% N were applied as basal, at maximum tillering and panicle initiation stages, respectively. Islam (1978) observed that S application along with urea-N, increased plant height. Talukder (1973) reported that plant height increased with increasing rates of urea-N application. Wagh and Throat (1988) found that N application rate had significant effect on plant height.

Reduction in plant height has often been cited as the most important factor in determining the nitrogen responsiveness and higher yields of the modern rice varieties. The shorter culm means lower respiration loss by culm and therefore improved the net grains in the photosynthesis respiration balance (IRRI, 1977). Intermediate plant height when planted in areas of less dependable water control give more stable yields than short statured varieties. However, increase in plant height normally results in decrease in resistance to lodging. Intermediate tall varieties produce moderately high stable yields about 4 t ha⁻¹ at any modern levels of nitrogen (IRRI, 1976).

In a field trial Singh and Singh (1986) found that plant height increased with increasing rates of nitrogen from 0 to 120 kg N ha⁻¹ applied as urea or urea super granules. Reddy *et al.* (1988) and Oh *et al.* (1990) noted the positive effect of nitrogen on plant height in rice. Taller plants were produced by higher amount of nitrogen applications. Plant height decreased significantly with the reduction in the amount of nitrogen top dressing (Bhuiyan *et al.*, 1990). Idris and Matin (1990) noted that plant height increased up to 120 kg N /ha compared to control and thereafter decreased at 140 kg N ha⁻¹. The highest plant height was recorded from 80 kg N ha⁻¹ and lowest one from control. Sharma (1995) stated that a basal nitrogen application increased the plant height significantly.

Hussain and Sharma (1991) reported that application of nitrogen up to 140 kg ha^{-1} increased plant height. At 80 kg and 10 kg N ha^{-1} the variation in plant height was non-significant. The highest plant height was obtained from 120 kg N ha^{-1} and the lowest one from the control. Dahatonde (1995) concluded that N fertilizer significantly enhanced the plant height. Awan *et al.* (1984) found that the higher doses of N application increased the plant height and number of panicles m^{-2} . Singh and Sharma (1987) found that the higher N application increased the plant height.

Number of total tillers hill⁻¹

Tillering of rice plant is strongly influenced by nitrogen supply (IRRI, 1968). Hossain *et al.* (2008) observed that number of tillers was also significantly affected by nitrogen levels, where 120 kg N ha^{-1} produced the highest number of tillers.

Dixit and Singh (1980) observed that increasing rate of nitrogen application increased number of tillers per plant. Ram *et al.* (1984) recorded that N application increased the number of tillers hill⁻¹. Reddy *et al.* (1988) concluded that application of 120 kg N ha^{-1} to rice increased paddy yield, plant height, root length and number of tillers hill⁻¹.

Jasim *et al.* (1984) reported that nitrogen application increased the number of tillers hill⁻¹. Final tiller number per hill was a linear function of the maximum tiller at booting stage (Khanam, 1994). Hossain *et al.* (1989) observed that the number of tillers hill⁻¹ increased upto 16.4 hill^{-1} with increasing nitrogen rate in rice cv. Basmati. Idris and Matin (1990) found that maximum tillers hill⁻¹ was produced by 140 kg N ha^{-1} which was statistically identical

with 60, 80, 100 and 120 kg N ha⁻¹. The minimum tillers hill⁻¹ was produced from the control.

Tillering is positively correlated with nitrogen content of the plants (BRRI; 1990). Jasim *et al.* (1984) and Dixit and Singh (1979) reported that N application increased the number of tillers hill⁻¹. Kamal *et al.* (1988) observed a positive trend of response from all the plant characters including tillering due to increasing doses of NPK. Sulphur application along with urea-N increased fertile tillers, i.e., panicle number hill⁻¹ (Islam, 1978). Productive tiller hill⁻¹, grains per panicle, yield and straw yield significantly increased with increasing nitrogen fertilizer up to 150 kg ha⁻¹ but seed size had no significant difference between the nitrogen fertilizer rates (Rao *et al.*, 1980).

Sahrawat *et al.* (1999) observed that nitrogen level significantly affected tiller number. Kumar *et al.* (1995) stated that an increased N level from 80 to 120 kg ha⁻¹ significantly increased total tillers hill⁻¹. Mirza and Reddy (1989) also found from 0 to 120 kg ha⁻¹ in three split dressings increased number of tillers hill⁻¹.

Dubey *et al.* (1991) reported that application of 90 kg N ha⁻¹ resulted in higher number of productive tillers hill⁻¹. Pandey *et al.* (1991) concluded that higher grain yield from the increase in nitrogen level-might be attributable to increase in the productive tillers hill⁻¹.

BINA (1996) stated that the effect of different levels of nitrogen was significant only for number of tillers hill⁻¹, productive tillers hill⁻¹, straw yield and crop duration. The highest number of total and productive tillers hill⁻¹ was obtained from the highest level (120 kg ha⁻¹)

of N application. Chandra and Pandey (1996) found that application of 120 kg ha^{-1} resulted in significant increase in number of productive tillers hill^{-1} compared to 60 kg N ha^{-1} . Islam *et al.* (1996) reported that number of effective tillers hill^{-1} increased with top dressing nitrogen.

Dry matter production

Rajarithinnam and Balasubramaniyan (1999) found that N levels significantly influenced the dry matter production. Kumar *et al.* (1995) reported that an increase in N level significantly increased the dry matter accumulation of rice.

Panicle

Islam *et al.* (2008) reported that plant height, panicle length, no of grains panicle^{-1} and sterile spikelets panicle^{-1} were significantly affected by N application. Salahuddin *et al.* (2009) also reported that panicle length increased with the increase of nitrogen rate upto 150 kg N ha^{-1} and thereafter declined. The longest panicle (24.50 cm) was observed when 150 kg N ha^{-1} was applied and the shortest (18.15 cm) from control. Nitrogen nutrient takes part in panicle formation as well as panicle elongation and for this reason, panicle length increased with the increase of N-fertilization upto 150 kg/ha . Hossain *et al.* (2008) found the longest panicle (23.19 cm) from 60 kg N ha^{-1} , which was followed by 90 Kg N ha^{-1} . Sadaphal *et al.* (1981) carried out an experiment with three levels of nitrogen (40, 80, 120 kg ha^{-1}) along with different methods of nitrogen application and found that 120 kg ha^{-1} produced the highest panicle length and 40 kg ha^{-1} had the lowest.

Singh and Singh (1984) observed that number of panicles m^{-2} and grains panicle^{-1} , panicle length were all significantly higher at 75 kg N ha^{-1} than in the control plots. The additional increase in panicle m^{-2} and grains panicle^{-1} was also significant when the rate of application

was increased from 75 to 150 kg N ha⁻¹. Sharma and Mishra (1986) recorded the maximum length of panicle and maximum number of tillers hill⁻¹ from the highest nitrogen dose.

Rafey *et al.* (1989) showed that increasing N levels increased panicle length, number of grains panicle⁻¹ and 1000-grains weight significantly. Sharma and Mittra (1989) noted the pronounced effect of N on yield attributing traits. Plants receiving high N doses produced long and heavy panicles.

Idris and Matin (1990) concluded that the rate of nitrogen application influenced panicle length positively. The highest panicle length was recorded from 60 kg N ha⁻¹ and the lowest from control. Azad *et al.* (1995) stated that panicle length increased significantly with the increasing level of nitrogen from 0 to 75 kg ha⁻¹.

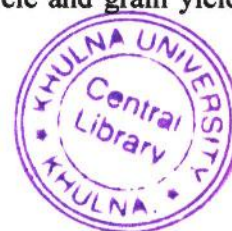
At Bangladesh Agricultural University, Mymensingh, Akanda *et al.* (1986) found that nitrogen application in three doses such as 20 kg at basal, 40 kg at active tillering and 20 kg at panicle initiation gave the highest number of panicles hill⁻¹.

Mondal *et al.* (1987) reported that increasing rates of N from 40 to 160 kg N ha⁻¹ increased the number of panicles per unit area. Dixit and Singh (1979) found that the increased nitrogen application increased the productive tillers per plant and panicle length. when the number of productive tillers per m² was increased with increasing the number of fully formed spikelets per panicle was decreased. Further, panicles per hill, seed size spikelets per panicle, and grain yield increased with increasing fertilizer rates (Pandey and Rao, 1991). Jahan (2005) carried out an investigation at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna. Local aman rice variety Jataibalam was tested against 4

different levels of nitrogen and observed that 60 kg ha⁻¹ produced higher plant height and panicle length.

Awan *et al.* (1984) found that the higher dose of N application increased the plant height and number of panicles per m². An investigation at BRRI revealed that the yield increases with the increasing rate of applied N and this was fairly related with the increasing number of panicles per unit area (BRRI, 1989).

Sing and Sharma (1987) found that plant height, panicle number per hill, straw yield and grain yield increased with increasing nitrogen doses. Similar results were obtained by Kehinde and Fagade (1987) that plant height, tiller number, panicle number per hill and grain yield increased with increasing nitrogen fertilizer. Further reported by Maurya and Yadav (1987) that plant height, panicle number per m², filled spikelets per panicle and grain yield increased with increasing nitrogen fertilizer doses.



Number of grains per panicle

Salahuddin *et al.* (2009) carried out an experiment during July-December 2001 at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh and observed that the highest number of grains panicle⁻¹ (109.79) was obtained at 150 kg N ha⁻¹, which was significantly different from other N levels. Nitrogen helped in proper filling of seeds which resulted higher plump seeds and thus the number of grains panicle⁻¹. The lowest number of grains panicle⁻¹ (99.41) was obtained from 0 kg N ha⁻¹.

Refey *et al.* (1989) observed that filled grains panicle⁻¹ increased with increasing rates of nitrogen from 0 to 60 kg N ha⁻¹. The maximum filled grains panicle⁻¹ was produced by 60 kg

N ha⁻¹ and the minimum from the control treatment. Kim *et al.* (1990) observed that high dose of nitrogen gave increased number of panicles and spikelets panicle⁻¹. Hussain and Sharma (1991) reported that application of nitrogen increased grain number panicle⁻¹. The highest number of grains panicle⁻¹ was produced by 80 kg N ha⁻¹ and the lowest was produced by the control treatment.

Nazimi *et al.* (1995) described that rice crop were strongly influenced by urea at 46 kg N ha⁻¹ which decreased unfilled grains panicle⁻¹ and on the other hand, increased filled grains panicle⁻¹.

Anrade and Amorim Neto (1996) concluded that increasing rates of applied N increased plant height, panicle per m², grains panicle⁻¹ and grain yield significantly. Chandra and Pandey (1996) stated that a significant increase in grains per panicle, tillers per m² and the grain yield were from application of 120 kg N ha⁻¹ compared to 60 kg N ha⁻¹.

There was almost a liner response of grain yield to applied nitrogen. Panicle number per m² spikelets per panicle, filled spikelets per panicle and grain yield were linear response to nitrogen application. Lin and Lin (1983) raised two rice cultivars treated with 80, 120 or 160 kg N ha⁻¹. They found that higher nitrogen levels resulted in the higher tiller number per unit area.

Tiller number, panicle number per hill and grain yield increased with increasing nitrogen fertilizer rates (Ramasamy and Sennaiyan, 1985; Hussain *et al.*, 1989; Salam, 1989; Kandasamy and Palaniappon, 1990; Peeran and Anandan, 1983; Bacon and Lewin, 1990; Rao *et al.*, 1980; Lin and Lin, 1983)

Penar and Avila (1983) reported that the increasing rates of N fertilizers generally increased the number of panicles per m², number of grains panicle⁻¹ and also the plant height. Jashim *et al.* (1984) observed that N application increased the number of tiller hill⁻¹, panicles m⁻² and

and plant height. Grain yield was positively related with panicle number, which was increased with increasing levels of applied N (BRRI, 1979). Kuo (1971) reported that increasing N up to 35 kg ha⁻¹ increased grain yield mainly through increasing panicle length and number of filled grains per panicle. Huo (1988) found that high N application reduced grain number per panicle due to lodging. Time of N application may also influence grains per panicle.

Many researchers reported that the number of filled grain per m² increased significantly with the increasing level of nitrogen application (Singh and Singh, 1984). In order to obtain a high grain yield, a heavy dressing of nitrogen, phosphate and potassium to the field is a requisite more than anything. Different from phosphate or potassium, even a small amount of excess nitrogenous fertilizer lowers the percentage of ripened grains. Yoshida and Parao (1976) reported that the decreased in the number of filled grains under over-luxuriant growth conditions is proved to be important factors. After heading, nitrogen contributes to carbohydrate production. In most cases, as the amount of nitrogen which can be absorbed during the ripening period is very small compared to the nitrogen required for grains, a large amount of nitrogen is translocated from leaves to grains with the advance of ripening. The percentage of ripened grains generally tends to decrease with the increase in the number of grains.

Weight of 1000-grains

Awan *et al.* (1984) found that weight of 1000-grains increased by the application of higher dose of nitrogen fertilizer. Mondal *et al.* (1987) observed that increasing rates of N from 40 to 160 kg ha⁻¹ increased the 1000-grains weight.

Bhuiya *et al.* (1998) carried out an experiment with rice cv. BR 10 and reported that application of nitrogen 0-61 kg N ha⁻¹ increased the weight of 1000-grains and then the weight of 1000-grains decreased at the rate of 86 kg N ha⁻¹. The weight of 1000-grains was the highest at 60 kg N ha⁻¹ and the lowest at 0 kg N ha⁻¹. Rafey *et al.* (1989) found that application of nitrogen 0-60 kg ha⁻¹ increased 1000-grains weight linearly. The highest weight of 1000-grains was obtained from 60 kg N ha⁻¹ and the lowest from the control.

Islam *et al.* (1990) reported that there was an increasing trend in the weight of 1000-grains with an increase in the levels of nitrogen up to 80 kg N ha⁻¹. A high nitrogen supply is reported to decrease the 1000 grain weight. Lawal and Lawal (2002) observed that application of fertilizer up to 80 kg N ha⁻¹ significantly increased number of ear bearing tillers per m² and grain yield.

Timing of urea application in split doses increased the grain yield as a result of increased spikelet number per panicle (Dixit and Singh, 1979).

The percentage of filled spikelets is determined by yield contributing factor and it is highly affected by variety, nitrogen management, soil and climate (Yoshida and Parao, 1976). Mondal *et al.* (1987) found that increasing rates of N from 40-160 kg/ha increased filled grain percentage. The amount and time of N application significantly influences and controls the grain size. The 1000-grain weight of the coarse cv. IR8 was significantly higher than those of fine cv. Basmati and those were influenced by the higher levels of nitrogen (Fateh *et al.*, 1978).

A high nitrogen supply tends to decrease the number of filled spikelets and the 1000- grain weight. Awan *et al.* (1984) found that 1000-grain weight increased by the application of higher dose of nitrogen fertilizer. Mondal *et al.* (1987) observed that increasing rates of N from 40-160 kg ha⁻¹ increased the 1000-grain weight.

Grain yield

Salahuddin *et al.* (2009) reported that grain yield of T. Aman rice increased gradually with the increasing levels of nitrogen upto 150 kg N ha⁻¹, but at higher rates (200 kg ha⁻¹), grain yield tended to decrease. The highest grain yield (4.91 t ha⁻¹) was obtained at 150 kg N ha⁻¹ and the lowest (3.31 t ha⁻¹) from 0 kg N ha⁻¹.

A field experiment was conducted by Hossain *et al.* (2008) to evaluate the effect of different nitrogen levels on the performance of four aromatic rice varieties. The result showed that all the yield components were significantly increased up to 90 kg ha⁻¹. Nonetheless, maximum grain yield (3.62 t ha⁻¹) was observed from 60 kg ha⁻¹.

Sikder *et al.* (2008) conducted experiment with three aromatic rice cultivars viz., Kalizira, Badshabhog and Tulshimala. Among three N levels, 80 kg ha⁻¹ performs the best to quality of aromatic rice. Jahan (2005) carried an investigation at the field laboratory of Agrotechnology Discipline, Khulna University, Khulna. Local aman rice variety Jatai was tested against 4 different levels of nitrogen. Highest grain yield also found from 40 kg ha⁻¹.

Reddy (1986) in a field experiment with 5 rice cultivars observed of all 5 rice cultivars increased by the application of increasing rate of N from 0 to 120 kg N ha⁻¹. Mondal *et al.* (1987) reported that increasing rates of N from 40 to 160 kg N/ha increased the number of panicles per unit area and also increased the grain and straw yields.

Idris and Matin (1990) observed that grain yield increased gradually with an increase in N and was maximum at 120 kg N ha⁻¹. Dahatonde (1992) conducted a field trail with four rice

cultivars and nitrogen was applied from 0 to 120 kg N ha⁻¹ and reported that yield increased up to 120 kg N ha⁻¹.

Bhale and Salunke (1996) concluded that grain yield increased linearly up to 120 kg N ha⁻¹. Chandra and Pandey (1996) noted that application of 120 kg N ha⁻¹ gave significant increase in grain yield compared with 60 kg N ha⁻¹. Application of nitrogen significantly increased in growth, yield attributes, grain and straw yields as well as harvest index with 60 kg N ha⁻¹ (Dwivedi, 1997). Singh *et al.* (1997) also concluded that grain yield increased with up to 60 kg ha⁻¹.

Lawal and Lawal (2002) observed that 1000-grains weight and grain weight per panicle responded to N up to 120 kg N ha⁻¹.

Chowdhury *et al.* (1998) conducted experiment with three rice cultivars Haryana, Basmati, Kasturi and Pusa Basmati giving 0-100 kg N ha⁻¹ and found that mean grain yields was the highest (2.90 t ha⁻¹) with 100 kg N.

Medhi *et al.* (1996) observed that addition of N, regardless of source increased grain yield significantly. The highest grain yield was recorded with 60 kg N ha⁻¹ from prilled urea. Kumar *et al.* (1995) stated that grain yield increased with increased levels of nitrogen. The increase in grain yield @ 160 kg N ha⁻¹ over the control was 42.0 %.

Adhikary and Rahman (1996) observed significant effect of various doses of nitrogen on the grain yield of rice. They recorded the highest grain yield (4.52 t ha⁻¹) from 100 kg N ha⁻¹.

¹followed by 120 kg N ha⁻¹ (4.46 t ha⁻¹), 80 kg N ha⁻¹ (14.40 t ha⁻¹) and 40 kg N ha⁻¹ (3.41 t ha⁻¹), respectively.

Dahatonde (1995) noticed that grain yield increased with N application up to 100 kg N ha⁻¹ and was not significantly affected by the P and K application. Rahman (1992) obtained the highest grain yield of 6.7 t ha⁻¹ from 100 kg N ha⁻¹ and 4.8 t ha⁻¹ with control.

Mongia (1992) showed that application of urea in 3 splits (50% basal + 25% tillering + 25% floral initiation stages) gave the highest yields with 60 kg N ha⁻¹. BRRI (1997) reported that both grain and straw yield of rice increased significantly with 80 kg N ha⁻¹. Application of nitrogen from 120 to 160 kg N ha⁻¹ significantly reduced the yield which was assumed to be due to excessive vegetative growth followed by lodging after flowering.

Hussain and Sharma (1991) disclosed that the grain yield of rice increased significantly up to the application of 80 kg N ha⁻¹ and thereafter declined. Islam *et al.* (1990) observed that the grain yield of rice increased significantly up to 80 kg N ha⁻¹ and thereafter the yield response were not found so up to 120 kg N ha⁻¹.

Mishra *et al.* (1973) stated that application of increasing N rates 0, 30 and 60 kg ha⁻¹ on the 7 rice cultivars increased the average paddy yield 3.46, 4.84 and 5.34 t ha⁻¹, respectively. Yield was not further increased with 90 kg N ha⁻¹. There was no significant difference among the yields of the cultivars. The interaction between cultivars and nitrogen rates was significant.

A considerable number of research indicated the positive response of rice to nitrogen fertilization (Pandey and Sinha, 1971). In general, grain yield increases with nitrogen addition upto a certain level. Dixit and Singh (1979) showed that 80 kg N ha⁻¹ increased rice

yield from 218 t/ha to 4.19 t/ha. Higher doses of N produced higher amount of straw and grain (Awan *et al.*, 1984). Grain yields increases with increasing nitrogen fertilizer up to a level and then decreased (Singh and Pillai, 1991; IRRI, 1986).

Nitrogen fertilization have influence on grain yield which increased gradually with an increase in N levels and was maximum at 120 kg N ha⁻¹. These results indicated that increasing rates of N increased grain yield (Sawant *et al.*, 1986). Similar results were noted by Talukder (1973). However, Islam *et al.* (1990) observed that the effect of 40, 80, and 120 kg N ha⁻¹ on grain yield was statistically identical. N application time and number of splitting may have effect on grain yield. Wagh and Throat (1988) reported that 50+30+10+10 kg N/ha applied at 8 days after transplanting, maximum tillering, primodial initiation and flowering gave the highest yield. Number of splitting of urea-N may have effect on grain yield. Milam *et al.* (1986) observed that 3 split applications of urea-N yielded higher than pre-plant incorporation. Singh *et al.* (1997) reported that the paddy yield continuously increased by added N from 0-150 kg ha⁻¹.

Effects of nitrogen on biological yield and harvest index

Hossain *et al.* (2008) conducted an experiment with four aromatic rice cultivars BRRI dhan38, Kalizira, Badshabhog and Tulshimala giving 0-120 kg N ha⁻¹. Application of 120 kg N ha⁻¹ showed the highest biological yield and lowest harvest index. Harvest index was the highest with 60 kg N ha⁻¹. This result showed that harvest index negatively correlated with biological yield.

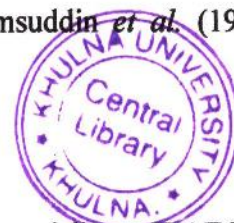
Prasad (1981) found that the increasing rate of nitrogen application 0 to 120 and 200 kg ha⁻¹ increased biological yield and decreased harvest index. Park (1987) observed that high N rates tend to increase biological yield and decreased harvest index. Harvest index of rice tends to be lower as total dry matter production increases (Machlis *et al.*, 1972).

Effect of variety

Variety may have variable effect on different plant characters of rice. Hossain *et al.* (2008) conducted an experiment with four aromatic rice varieties which included BRRI dhan38, Kalizira, Badshabhog and Tulshimala. Results revealed that plant height of different varieties was significantly different. Maximum plant height was found from the variety Tulsimala which significantly differed from the other varieties. While the lowest plant height was observed in the variety BRRI dhan38.

Islam (2007) evaluated the performance of six aromatic rice varieties *cv.* Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog. The highest plant height was found in the variety Morichsail and lowest was recorded from the variety Khaskani.

Sawant *et al.* (1986) conducted an experiment with the new rice *cv.* R-73-I-1, R-711 and the traditional *cv.* Ratna and reported that the traditional *cv.* Ratna was the shortest. Anonymous (1993) showed that plant height differed among the varieties. Shamsuddin *et al.* (1988) observed that plant height differed significantly among the varieties.



Anonymous (1993) evaluated the performance of four varieties/advanced lines, IRATOM, BR 14, BINA 13 and BINA 19 and noticed that varieties/advanced lines differed significantly for plant height. Anonymous (1998) reported that the highest plant height was obtained from Kataribhog (153 cm) followed by Khaskani (143 cm), BR4384 28-2-2-4 (130 cm), 8R4384-28-2-2-6 (125 cm) and BR4384-28-2-2-2HR3 (125 cm). Om *et al.* (1998) found taller plants, more productive tillers in ORI 161 than in PMS2A x IR31802. Huang *et al.* (1999) observed that two hybrid rice lines had a plant height of about 115.80 cm and a culm height of 105.40 cm with thick and erect V-shaped leaves of deep green color.

varieties viz. Hong12A/Tianjin 1244, Hong21A/Tianjin1244, Hong264A/Tianjin 1244 and observed that grains panicle⁻¹ was 186 .2 , 139 .2 and 205 .7, respectively.

Parvin *et al.* (2006) conducted an experiment with three rice varieties viz, Jotai, Basfulbalam and Raniselute and observed that the number of filled grains panicle⁻¹ was highly significant due to effect of variety. Basfulbalam produced the highest number of filled grains panicle⁻¹ (138.20). The lowest number of filled grains panicle⁻¹ (88.27) was produced by variety Raniselute. Raniselute produced the highest percentage (90%) of filled grains panicle⁻¹ whereas Jotai and Bashfulbalam produced 84% and 82% filled grains panicle⁻¹, respectively. Islam (2007) carried out an experiment with six aromatic rice varieties cv.Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog and reported that variety had significant effect on panicle length and filled grains per panicle.

1000-Grain weight

Weight of 1000 grains may be influenced by variety. Shamsuddin *et al.* (1988) reported that 1000-grain weight of nine rice cultivars ranged from 21.1 g to 31.4 g. Chowdhury and Ghosh (1978) carried out a number of field trials with sixty two fine and scented rice cultivars and observed that 1000-grain weight was highly variable ranging from 9.0 to 23.0 g, but 1000-grain weight was identical in BR3, BR 8 and IR 8 varieties. Rafey *et al.* (1989) conducted an experiment with three different rice cultivars and reported that weight of 1000-grains differed among the cultivars studied.

Singh and Gangwer (1989) studied with rice cv. C-14-8, CR-1009, IET- 565 and IET-1614 and found that 1000-grain weight was highest for C-14-8 among the four varieties. Anonymous (1998) found that 1000-grain weight of some aromatic rice varieties ranged from

12-20 g and it significantly differed from variety to variety. Three advanced lines 8R4384-2B-2-2-4, 8R4384-28-2-2-6 and BR4384-28-2-2-HR3 and two local varieties namely Kataribhog and Khaskani produced 1000-grain weight 20, 16.5, 16.2, 15 and 12 g, respectively. Anonymous (1998) further reported that 1000-grain weight was 24, 22, 25, 20, 23, 18 and 17 g in Kuicha binni, Leda Sinni, Chandan binni, Dudh methi, Maraka binni and Nizershail and one HYV, BR 25, respectively.

Islam *et al.* (2007) carried out an experiment with six aromatic rice varieties *cv.* Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog and found the highest 1000-grain weight from Raniselute which was statistically similar with Kachra and Morichsail.

Grain Yield

Different workers reported the effect of rice varieties on rice grain yield. Hossain *et al.* (2008) carried out an experiment with four aromatic rice varieties included BRRI dhan38, Kalizira, Badshabhog and Tulshimala. The highest grain yield (4.00 t ha⁻¹) was achieved from BRRI dhan38, the lowest grain yield was obtained from Kalizira. The biological yield was significantly affected by variety. The highest biological yield (9.47 t ha⁻¹) was obtained from Badshabhog. While the lowest biological yield (8.82 t ha⁻¹) was achieved from Kalizira.

Parvin *et al.* (2006) conducted an experiment with three rice varieties *viz.* Jotai, Basfulbalam and Raniselute and observed that variety Jotai produced the highest grain yield (4.21 t ha⁻¹). The lowest grain yield (2.70 t ha⁻¹) was obtained from Raniselute.

Idris and Matin (1990) reported that the rice varieties BAU 29, BAU 92, BAU 110, BAU 128, BR2 and BR8 gave different yield values. Kamal *et al.* (1988) found that among three rice

varieties BR3 produced the highest yield and Pajam 2 yielded the lowest. Cho and Han (1985) reported that grain yields of cv. IR7161-33-2-3-3 and RPKN-Z were 6-10 t ha⁻¹ and 5-8 t ha⁻¹, respectively.

Grain yield of rice is determined by panicle numbers unit area⁻¹, spikelet number panicle⁻¹, and filled grains panicle⁻¹ and 1000-grain weight. The number of spikelets unit area⁻¹ is highly correlated with grain yield (Shimizu, 1964). Filled spikelet is an important yield contributing factor and it is highly affected by such factor as climate, soil, variety and nitrogen fertilization (Yoshida and Parao, 1976). Dwivedi (1997) reported variable yields from 1.92 to 2.56 t ha⁻¹ produced by five aromatic rice varieties viz. Kamini, RP615, Harbans, Basmati, Kasturi and Sugandha.

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. Islam (2007) evaluated the performance of six aromatic rice varieties cv. Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog. The highest grain yield (2.53 t ha⁻¹) was found in the variety Morichsail and lowest (1.38 t ha⁻¹) was recorded from the variety Kalizira.

Rao *et al.* (1993) found that the highest grain yield was given in the wet seasons by local variety Badshabhog (3.21 t ha⁻¹) and in other varieties (cv. Kasturi, Ranbir, Basmati and IET-8579) mean yield varied from 2.22-2.58 t ha⁻¹. Rajendra *et al.* (1997) carried out an experiment with hybrid rice cv. Pusa 834 and Pusa HR 3 and observed that mean yields of Pusa 834 and Pusa HR 3 were 3.3 and 5.6 t ha⁻¹, respectively.

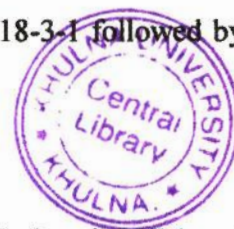
Anonymous (1999) tested that three proposed fine grain aromatic rice varieties viz. Khaskani, Basmati D and Kataribhog along with two check varieties at four locations each in the project and outreach area. BR 5 was used as a standard check and Kalijira, Khirkon and Khirshapati as local checks. Khaskani 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 BR 5 (2.66 t ha⁻¹) in the project area but the outreach area, the mean yield of Basmati D (2.32 t ha⁻¹) and Kataribhog (2.32 t ha⁻¹) was similar to BR 5 (2.4 t ha⁻¹).

Chowdhury *et al.* (1993) stated that the cultivar BR 23 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 and unfilled spikelet panicle⁻¹. Mannan (1996) conducted a field experiment with four varieties, namely BR 10, BR 11, BR 22 and BR 23 and stated that varieties have significant effect on plant height, total tillers number, length of panicle, grains panicle⁻¹, grain and straw yield. Bhowmick and Nayak (2000) found that hybrids gave higher grain and straw yield than HYVs.

Roman (1997) laid out a field experiment with rice cultivars BR 10, BR 11, BR 22, BR 23, Latisail and Nizersail and found that cultivar had a significant difference for the entire yield contributing characters. BR 11 produced the highest grain yield (5.3 t ha⁻¹) followed by BR 10 (5.13 t ha⁻¹), BR 22 (4.41 t ha⁻¹), BR 23 (4.27 t ha⁻¹) and Nizersail (4.13 t ha⁻¹). The lowest grain yield was produced by Latisail (3.24 t ha⁻¹).

Dutta (1998) carried out an experiment with two rice varieties (BR 11 and Binasail) and one mutant line (BINA 163). He noticed that plant height, total tillers hill⁻¹, length of panicle, grains panicle⁻¹ and 1000-grain weight differed significantly among the varieties.

Kamal *et al.* (1988) found that among three rice varieties BR 3 produced the highest yield and Pajam-2 yielded the lowest. Babiker (1986) reported from yield trials that grain yield was significantly influenced by rice cultivars. Anonymous (1978) found that rice cv. IR 36 was the highest yielder among the 276 rice cultivars studied. Miller (1978) found that among the 14 cultivars studied, grain yields ranged from 5.6 t ha⁻¹ to 7.7 t ha⁻¹. He also reported that grain yield was significantly influenced by rice cultivars. Kumbhar and Sonar (1978) reported the variable effect of rice varieties on grain yield. Choudhury and Bhuiyan (1991) observed that grain yield was the highest in a promising line BR-802-118-3-1 followed by BR 14, BR 3 and BR 1.



Khan (1991) conducted a green house pot experiment with rice cv. BR 6 and CSR4 and reported that yield was higher in cv. CSR 4 than BR 6. Yarosh and Lyakhovkin (1977) observed in a pot experiment that average grain yields were 10.4 and 17.5 g pot⁻¹ for the Italian cv. Redi and local cv. Krasnodarskii 424, respectively.

Harvest Index

Harvest index (HI), the ratio of the grain yield to the biological yield is positively correlated with yield. The increase in the plant height as a resultant of wet season planting or high N level resulted in a decrease in HI (Amin, 1999). The decrease in HI was greater in the tall than the short lines. Increase in growth duration increases the amount of dry matter produced,

but does not necessarily increase grain yield. Hossain *et al.* (2008) found that the highest harvest index (42.37%) was obtained from BRRI dhan38, while the lowest harvest index (36.08%) was obtained from Kalizira.

Karim *et al.* (1992) found from an experiment with Basmati-385 and breeding line-408 were grown at 118560, 160550 and 197600 plants ha⁻¹ 1000 grain weight decreased with increasing plant height. The total dry weight of a good rice crop is around 10-20 t ha⁻¹. Depending on variety, management and environments. The harvest index is about 0.3 for traditional tall varieties and 0.5 for improved short varieties (Yoshida, 1981).

Islam (2007) evaluated the performance of six aromatic rice varieties cv. Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog. The highest harvest index (36.06%) was found in the variety Khaskani and the lowest (25.48%) was recorded from the variety Kachra. Parvin *et al.* (2006) conducted an experiment with three rice varieties viz, Jotai, Basfulbalam and Raniselute and observed that Jotai produced the highest harvest index (47.71%) and the lowest harvest index (31.83%) was obtained from Raniselute.

Chapter III

MATERIALS AND METHODS

In this chapter, materials used and methods followed in carrying out the present experiment have been stated which include a short description of crop, experimental site, soil, treatment, layout, statistical design, intercultural operations, data recording, data processing and data analysis, etc.

Experimental site

The research work was conducted in 2008 during Aman season (June-December) at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna, Bangladesh.

Experimental Treatment

Three aromatic rice varieties collected from Khulna region were used as plant materials.

V₁= Morichsail.

V₂=Kachra

V₃=Raniselute

A short description of the varieties used in the experiment is as follows:

1) Marichsail

This is a local aromatic variety. It is cultivated in this region for consumption. It grows well in high land. The plant is deep green. The color of flower is white. The grain is coarse and color is golden.

2) Kachra

This is a local aromatic variety but its aroma is less than Raniselute. It is also cultivated in this region for consumption. It also grows well in high land. The plant is also deep green. The color of flower is white. The grain is also coarse and color is golden and it has awn.

3)Raniselute

This is a local aromatic variety. It is cultivated in this region extensively for consumption. It grows well in high land. The plant is deep green. The colour of flower is white. The grain is coarse and colour is golden but the two ends are black.

Four different nitrogen doses with control were used as Experimental Treatment

$$N_0 = 0 \text{ kg N ha}^{-1}$$

$$N_1 = 30 \text{ kg N ha}^{-1}$$

$$N_2 = 60 \text{ kg N ha}^{-1}$$

$$N_3 = 90 \text{ kg N ha}^{-1}$$

$$N_4 = 120 \text{ kg N ha}^{-1}$$

Design

The experiment was laid out in a Factorial Randomized Complete Block Design (RCBD) with three replications. The size of the total field was 67 m X 9.5 m divided into three (3) blocks and each block into fifteen (15) plots thus total plots were forty five (45). The plot size was 4 m X 2.5 m. The blocks were separated by 1 m wide space. The distance from plot to plot was 0.5 m.

Seed bed preparation

The seedbed was made ready by four ploughing with power tiller followed by Laddering. Pre-germinated seeds were sown on 10th July 2008. The bed was kept wet by irrigation as and when required.

Land preparation

The land of the experimental field opened by a power tiller before 15 and 10 days before transplanting. It was then ploughed sufficiently in order to make the soil nearly ready for transplanting. Weeds and stubbles were removed and the field was then divided into unit plots that were spaded one day before transplanting for intercropping the basal fertilizers.

Uprooting of seedling

Seedlings were uprooted carefully from the bed and bundled with proper care and distributed in the respective plots for transplanting.

Transplanting

Thirty day old seedlings were transplanted on 10 August 2008 in rows of 25 cm apart using 15 cm hill spacing and 3 plants per hill. Necessary gap filling was done after 7 days of transplanting.

Fertilizer application

TSP, MoP and ZnSO_4 were applied at the rate of 50 kg, 35 kg and 5 kg. Nitrogen was applied in the form of urea in two equal splits. Half is applied at 30 days after transplanting (DAT) and rest half at 50 (DAT) as per treatment.

Intercultural operations

Three hand weeding were done to check weed infestation at 25, 35 and 50 (DAT). Basudin 10G @ 16.8 kg/ha was applied to control stem borer and rice ear cutting caterpillar.

Harvest and post-harvest operation

The experimental crops were harvested at plot wise maturity in December 2008. The harvested crops were thrashed, cleaned and processed and necessary data were collected on various crop characters.

Data collection

Data on the plant height, number of total tillers per hill, effective tillers per hill, Panicle length, filled grain and unfilled grain per panicle were recorded at harvest and data on the thousand grain weight, grain yield, straw yield and biological yield were recorded after drying the grains and straw of the individual plots. The grain and straw yields per plot are expressed on per hectare basis. Five hills were selected randomly for sampling. 1 m² area was harvested from the center of the plot for grain and straw yield. After harvesting, the plants were washed thoroughly and at each sampling, the following data of yield components were recorded.

Plant height and number of total and effective tillers per hill

Plant height, number of total tiller and effective tiller per hill were recorded from randomly selected five plants. Plant height was measured from the base of plant up to the tip of the tallest leaf or panicle after anthesis and the means were calculated.

Panicle length, filled grain and unfilled grain per panicle

Panicle length of selected five hill was measured and the means were calculated. Grains of each panicle were counted and the numbers of filled and unfilled grains were separated. The counting of grains was done manually.

Thousand grain weight

Thousand clean dried grains from the seed stock of each central one square meter plot were counted separately and weighted by an electric balance and adjusted at 14% moisture content (MC) by using following formula.



$$\text{Thousand grain weight at 14\% MC} = \frac{(100 - \text{Sample MC}) \times \text{Thousand grain weight at sample MC}}{(100 - 14)}$$

Grain yield

Grain yield was measured by using a balance and converted the yield into 14% moisture by using below mentioned formula and expressed in t ha⁻¹.

$$\text{Yield (at 14\% moisture content)} = \frac{10 (100 - \text{FMC})}{(100 - 14)} \times \frac{\text{plot yield (g)}}{\text{plot area (m}^2\text{)}}$$

Straw yield

Straw yield of the harvested area of each plot was determined. Sample straw of each plot was dried in an oven at 70 °C for 48 hours and converted the sample into total straw yield and express in t ha⁻¹.

Biological yield

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

$$\text{Biological yield} = \text{Grain yield} + \text{straw yield.}$$

Harvest index (%)

It is the ratio of economic yield to biological yield and was calculated with the following formula:

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

Analysis of data

The collected data on different parameters were analyzed following analysis of variance (ANOVA) technique by using MSTAT-C program. Means were compared by Duncan's New Multiple Range (DMRT) test (Gomez and Gomez, 1984).

Chapter IV

RESULTS AND DISCUSSION

Results of the present study regarding the influence of nitrogen levels and variety and their interactions on the yield and yield components of aromatic rice have been presented in tables and figures and proper interpretation is given for easy understanding.

Effect of Variety

Plant height

Results revealed that plant height of different varieties was significantly different (Table 1). The highest plant height was found in the variety Morichsail (147.8 cm) which was statistically similar with Kachra. While, the lowest plant height was observed in the variety Raniselute (143.7 cm). Variation of plant height might be due to the differences in their genetic make-up. Shamsuddin *et al.* (1988), Hossain *et al.* (2008) and Khatun (2001) also observed variable plant heights among the varieties. Islam (2007) also found the highest plant height from Morichsail. Ghose (2003) found the lowest plant height from Raniselute among four varieties.

Total tillers hill⁻¹

Significant differences were also observed for producing total number of tillers (Table 1). Maximum number of total tillers were observed in Raniselute (9.04) which was statistically similar with Kachra. While minimum number of total tillers was observed in the variety of Morichsail (6.68). Similar results were also reported by Ramasamy *et al.* (1987) who stated that number of tillers differed due to varietal variation.

Effective tillers hill⁻¹

Variety had significant effect on effective tillers hill⁻¹ (Table 1). The highest number of effective tillers hill⁻¹ (7.17) produced by Morichsail which was statistically identical with Kachra. The lowest number of effective tillers hill⁻¹ (5.95) was observed in Raniselute. The reason of differences in effective tillers hill⁻¹ is the genetic makeup of the varieties, which is primarily influenced by heredity. This result is supported by Hossain *et al.* (2008) and Chowdhury *et al.* (1993) who stated that effective tillers hill⁻¹ varied with variety.

Panicle length

Panicle length was found to be influenced by the variety (Table 1). Panicle length recorded was the highest (23.33 cm) in the variety Morichsail which was statistically identical with Kachra. The lowest panicle length (22.23 cm) was recorded from the variety Raniselute. Similar result was also recorded by Idris and Matin (1990) and Hossain *et al.* (2008) who reported that panicle length influenced by variety. Islam *et al.* (2007) also found the highest panicle length (23.25 cm) from Morichsail. The variation as assessed might be mainly due to genetic background of the varieties. A simple linear regression using panicle length as independent variable and yield as dependent variable showed as positive relationship (Fig. 1). The value of R^2 (0.97) indicates that about 97% variation in yield could be explained by the variation in panicle length.



Filled grains panicle⁻¹

Number of filled grains panicle⁻¹ was found significant. Results presented in the Table 1 showed that number of filled grains panicle⁻¹ was the highest (76.35 cm) in the variety Morichsail. The lowest was recorded in the variety Raniselute which was statistically

1000-grain weight

Results revealed that 1000-grain weight of different varieties was significantly different (Table 1). The highest 1000-grain weight (32.19 g) was produced by the variety Morichsail, which was statistically similar to the variety Kachra (31.04). The lowest 1000-grain weight (29.43 g) was recorded from the variety Raniselute (29.43 g). Islam (2007) found the 1000-grain weight from the variety Raniselute which was statistically similar with the variety Kachra and Morichsail. Relationship between 1000-grain weight and grain yield was shown in the Fig. 4. The value of R^2 (0.63) indicates that more than 60% variation in yield could be explained from variation in 1000-grain weight.

Grain yield

Grain yield of rice mainly depends on the number of effective tillers per unit area, panicle length, filled grains panicle⁻¹ and 1000-grain weight. Results shown in the Table 1 revealed that the grain yield differed significantly among the varieties. Among the three varieties, Morichsail gave the highest grain yield (2.69 t ha⁻¹). The lowest grain yield (2.20 t ha⁻¹) was obtained from Raniselute which was statistically similar with Kachra. Islam (2007) also mentioned that the variety Morichsail gave the highest grain yield (2.53 t ha⁻¹) among six different aromatic rice variety. The result is also agreement with the findings of other authors that yield of aromatic rice varied from variety to variety (Hossain *et al.*, 2008; Anonymous, 1999a ; Anonymous, 2000b).

Biological yield

The varietal effect on biological yield was significant at 1% level of probability (Table 1). The highest biological yield (9.93 t ha⁻¹) was obtained from the variety Morichsail which was

statistically identical with the variety Kachra. The lowest biological yield (9.17 t ha^{-1}) was recorded from the variety Raniselute. From the result it was observed that biological yield differed due to combine effect of grain yield and straw yield. Islam (2007) and Ghose (2003) also recorded highest biological yield from the variety Kachra. A simple linear regression using biological yield as independent variable and yield as dependent variable showed as positive relationship (Fig. 5). The value of R^2 (0.97) indicates that about 97% variation in yield could be explained by the variation in biological yield.

Harvest Index

From the result presented in Table 1, it was revealed that the highest harvest index (27.27%) was recorded from the variety Morichsaile, which was statistically identical with the variety Raniselute and the lowest harvest index (24.00%) was calculated from the variety Kachra . The result have similar trend with grain yield. Hossain *et al.* (2008) reported that variety had a great influence on harvest index. Relationship between harvest index and grain yield was shown in the Fig. 6. The value of R^2 (0.99) indicates that about 99% variation in yield could be explained by the variation in harvest index.

Table 1. Effect of varieties on yield and yield attributes of aromatic rice

Varieties	Plant height(cm)	Total tiller hill ⁻¹	Effective tiller hill ⁻¹	Panicle length (cm)	Filled grains panicle ⁻¹	Unfilled grains panicle ⁻¹	1000-Grain weight (g)	Grain yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index (%)
V ₁	147.81 a	9.20 b	7.17 a	23.33 a	76.35 a	6.74 b	32.20 a	2.69 a	9.93 a	27.27 a
V ₂	146.45 ab	8.65 ab	7.04 a	22.37 a	57.38 b	9.00 a	31.04 ab	2.20 b	9.26 a	24.00 b
V ₃	143.71 b	8.03 a	5.95 b	22.23 b	54.64 b	9.77 a	29.43 b	2.22 b	9.17 b	24.42 a
Level of Significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	1.11	10.58	13.69	4.32	4.10	15.39	2.84	5.72	5.53	5.63

In a column having similar letter (s) or without letter are not significantly different whereas dissimilar letters are significantly different as per DMRT.

V₁=Morichsail, V₂=Kachra and V₃=Raniselute

Effect of Nitrogen

Plant height

Plant height increased with the increasing rates of nitrogen up to 120 kg N ha⁻¹ and it was found significantly higher from the other levels of nitrogen (Table 2). The shortest plant height (140.5 cm) was found in the control plot (without N). Nitrogen induced maximum vegetative growth with higher rates of N. The increase in plant height was due to various physiological processes including cell division and cell elongation of the plant. Similar result was found by Hossain *et al.* (2008), who found tallest plant height from 120 kg N ha⁻¹ and shortest from control. Plant height of aromatic rice varieties plotted against nitrogen doses is presented in Fig. 7. It is apparent that plant height of aromatic rice cultivars increased linearly with the nitrogen doses and about 98% ($R^2=0.98$) variation in plant height could be explained by nitrogen rate.

Total tillers hill⁻¹

Number of total tillers hill⁻¹ followed a pattern similar to that of plant height. Nitrogen dose of 120 kg ha⁻¹ produced the highest number of tillers which was statistically similar with 90 kg N ha⁻¹, 60 kg N ha⁻¹ and 30 kg N ha⁻¹. The lowest number of total tillers was found from control plot which was statistically similar with 30 kg N ha⁻¹ (Table 2). Hossain *et al.* (2008) also found highest number of total tillers hill⁻¹ from 120 kg N ha⁻¹.

Effective tillers hill⁻¹

The influence of nitrogen application on number of effective tillers hill⁻¹ was significant at 1% level (Table 2). It was found that 60 kg N ha⁻¹ produced the highest number of effective tillers hill⁻¹ (8.3) which was statistically similar with 90 kg N ha⁻¹, 30 kg N ha⁻¹ and 0 kg N

ha⁻¹. The lowest number of effective tillers/hill was found from 120 kg N ha⁻¹. This result showed that the number of effective tillers/hill increased up to 60 kg N ha⁻¹ and more than 60 kg N ha⁻¹ application decreased the number of effective tillers/hill. Hossain *et al.* (2008) also found the increasing rate of N upto 60 kg N ha⁻¹ increased number of effective tillers hill⁻¹. Regression analysis was done to quantify the relationship between effective tillers hill⁻¹ of aromatic rice varieties and applied nitrogen fertilizers (Fig. 8). The figure implied that nitrogen doses has a positive relationship with effective tillers hill⁻¹ up to 60 kg N ha⁻¹ and then the parameter decreased gradually with increasing nitrogen doses.

Panicle length (cm)

Panicle length was statistically similar in all the treatments except control (Table 2). It was observed that the longest panicle (23.54 cm) was found at 60 kg N ha⁻¹ which was followed by 90 kg N ha⁻¹ and the lowest was found from control. Idris and Matin (1990) and Hossain *et al.* (2008) also found the longest panicle form 60 kg N ha⁻¹.

Filled grains panicle⁻¹

The number of filled grains panicle⁻¹ were significantly influenced at 1% level due to different nitrogen fertilizer doses. Filled grains panicle⁻¹ ranged from 53.63-69.34 (Table 2). The highest number of filled grains panicle⁻¹ (69.34) was obtained from 30 kg N ha⁻¹ which was statistically similar with 60 kg N ha⁻¹ and the lowest number of filled grains panicle⁻¹ (53.63) was obtained from control treatment which was statistically similar to 90 kg N ha⁻¹. Similar result found by Refey *et al.* (1989) and Hossain *et al.* (2008). They obtained maximum filled grains panicle⁻¹ from 60 kg N ha⁻¹ and lowest from control.

Unfilled grains panicle⁻¹

The variation in number of unfilled grain panicle⁻¹ due to nitrogen application was found to be significant at 1% level (Table 2). The highest unfilled grains panicle⁻¹(11.13) was obtained from 120 kg N ha⁻¹ which was statistically similar with 90 kg N ha⁻¹. The minimum unfilled grains panicle⁻¹(6.13) was found from control. These results indicate that unfilled grains panicle⁻¹ increased with increasing rate of N application. Ghose (2003) also found the similar result.

1000- grain weight

Thousand grain weights were different due to different N- doses (Table 2). The highest weight (31.68g) was found from 60 kg N ha⁻¹ which was statistically similar with 30 kg N ha⁻¹, 90 kg N ha⁻¹ and 0 kg N ha⁻¹ and the lowest weight (30.21 g) was obtained from 120 kg N ha⁻¹. This result showed that application of nitrogen 0-60 kg N ha⁻¹ increased the weight of 1000-grains and then the weight of 1000-grains decreased. Bhuiya *et al.* (1998) and Rafey *et al.* (1989) also found that application of nitrogen 0-60 kg N ha⁻¹ increased 1000-grains weight linearly. Plotting 1000-grain weight of aromatic rice varieties against nitrogen levels expressed non- linear (parabolic) relationship (fig 9) . The quadratic equation for each variety obtained from the regression analysis was:

$$Y = -0.0004x^2 + 0.042x + 31.79, R^2 = 0.88 \text{ (For Morichsail)}$$

$$Y = -0.0002x^2 + 0.016x + 31.14, R^2 = 0.98 \text{ (For Kachra)}$$

$$Y = -0.0003x^2 + 0.042x + 31.79, R^2 = 0.80 \text{ (For Raniselute)}$$

The result indicated that the grain yield was increased with the increase of nitrogen application upto a certain limit . The value R^2 (0.80 to 0.98) indicated that 80 to 98% of the total variation in grain yield would be explained by the variation in applied nitrogen fertilizer.

Grain yield

Different levels of nitrogen had significant effect on grain yield (Table 2). Maximum grain yield (2.67 t ha^{-1}) was achieved from 60 kg N ha^{-1} , which was statistically identical with 60 and 30 kg N ha^{-1} . The lowest grain yield (2.08) was obtained from 120 kg N ha^{-1} . It revealed that excess N rates do not give extra benefit regarding to grain yield to aromatic rice. Further increase of N slowly decrease the yield due to excessive plant growth and crop lodging, which resulted number of non-bearing tillers hill^{-1} and sterile spikelets panicle^{-1} . Similar trend was also observed by Hossain *et al.* (2008) and Medhi *et al.* (1996). They also found highest grain yield from 60 kg N ha^{-1} . Plotting Grain yield of aromatic rice varieties against Nitrogen levels expressed non- linear (parabolic) relationship (fig 10) . The quadratic equation for each variety obtained from the regression analysis was:

$$Y = -0.0002x^2 + 0.0228x + 2.42, R^2 = 0.97 \text{ (For Morichsail)}$$

$$Y = -0.0005x^2 + 0.008x + 2.13, R^2 = 0.78 \text{ (For Kachra)}$$

$$Y = -0.0001x^2 + 0.013x + 2.08, R^2 = 0.97 \text{ (For Raniselute)}$$

The result indicated that the grain yield was increased with the increase of nitrogen application upto a certain limit . The value R^2 (0.78 to 0.97) indicated that 78 to 97% of the total variation in grain yield would be explained by the variation in applied nitrogen fertilizer.

Biological yield

Nitrogen doses showed significant effect on biological yield of rice. The highest biological yield (10.26 t ha^{-1}) was produced by 120 kg N ha^{-1} , because this rate of N produced higher grain yield as well as straw yield in this study in this study (Table 2). It was statistically identical with 90 kg N ha^{-1} (Table 2). The lowest biological yield (8.20 t ha^{-1}) was obtained from control. Hossain *et al.* (2008) also found the highest biological yield from 120 kg N ha^{-1} .

Harvest index

The effect of nitrogen level on harvest index was significant. The highest harvest index (27.57%) was obtained from 60 kg N ha⁻¹ which was statistically identical with 30 kg N ha⁻¹ and control (Table 2). The lowest harvest index (20.27%) was recorded from 120 kg N ha⁻¹. This result indicates that increasing rate of nitrogen application increased biological yield and decreased harvest index. Prasad (1981) and Park (1987) support this result. Hossain *et al* (2008) also found the highest harvest index from 60 kg N ha⁻¹ and lowest from 120 kg N ha⁻¹.



Table 2. Effect of nitrogen on yield and yield attributes of aromatic rice

Nitrogen levels	Plant height(cm)	Total tiller hill ⁻¹	Effective tiller hill ⁻¹	Panicle Length (cm)	Filled Grains Panicle ⁻¹	Un Filled Grains Panicle ⁻¹	1000-Grain weight (g)	Grain yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index (%)
N ₀	140.54 d	6.689 b	6.11 ab	21.24 b	60.94 b	6.14 c	30.54 a	2.21 bc	8.20 c	26.93 ab
N ₁	143.11 cd	7.800 ab	6.76 ab	22.95 a	69.24 a	7.49 bc	31.22 a	2.45 ab	8.91 bc	27.52 a
N ₂	146.31 bc	9.044 a	8.31 a	23.54 a	68.20 a	7.99 bc	31.68 a	2.67 a	9.67 ab	27.57 a
N ₃	148.85 ab	9.726 a	7.25 ab	23.12 a	61.94 b	9.78 ab	30.77 a	2.44 ab	10.23 a	23.85 b
N ₄	151.11 a	9.867 a	5.17 b	22.38 a	53.63 c	11.13 a	30.21 b	2.08 c	10.26 a	20.27 c
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.01
CV(%)	1.11	10.58	13.69	4.32	4.10	15.39	2.84	5.72	5.53	5.63

In a column having similar letter (s) or without letter are not significantly different whereas dissimilar letters are significantly different as per DMRT.

Where,

N₀= 0 kg N ha⁻¹

N₁= 30 kg N ha⁻¹

N₂= 60 kg N ha⁻¹

N₃= 90 kg N ha⁻¹

N₄= 120 kg N ha⁻¹

Interaction Effect of Variety and Nitrogen

The combined effect of variety and nitrogen on plant height presented in (Table 3). The tallest plant (153.28 cm) was found at harvest from Morichsail with 120 kg N ha⁻¹(V₁N₄) treatment combination and same variety with control treatment combination produced the shortest plant (141.03 cm). The Interaction effect of variety and nitrogen on total tiller was not significant at harvest (Table 3). The results showed that total tiller per hill ranged from 6.00 to 10.60. The highest and lowest total tiller per hill was observed from Morichshile with 120 kg N ha⁻¹ and Raniselute with 0 kg N ha⁻¹ treatment combinations. Ghose (2003) also observed similar trend.

All the yield attributes of aromatic rice varieties were not significantly influenced by combined effect of variety and nitrogen except panicle length, filled grain panicle⁻¹ and grain yield in this study.

The effective tiller per hill ranged from 4.5 to 8.67 (Table 3). The maximum effective tillers hill⁻¹ (8.67) was recorded from kachra with 60 kg N ha⁻¹ and the minimum effective tillers hill⁻¹ (4.5) was recorded from Raniselute with 120 N ha⁻¹ treatment combinations. Hossain *et al.* (2008) observed that effective tillers hill⁻¹ was non significant by the interaction effect of variety and nitrogen.

Length of panicle was also not significantly influenced by interaction effect of variety and nitrogen (Table 3). Length of panicle ranged from 20.12 to 24.54 cm. The maximum panicle length (24.54 cm) was recorded from Morichsail with 60 kg N ha⁻¹ and the minimum panicle length (20.12) was recorded from Raniselute with 0 kg N ha⁻¹ treatment combinations. Ghose (2003) also observed the similar result.

Filled grain panicle⁻¹ was significantly influenced by the interaction effect of variety and nitrogen (Table 3). The maximum Filled grain panicle⁻¹ (83.25) was observed from Morichsail and 60 kg N ha⁻¹ which was statistically identical with Morichsail with 30 kg N ha⁻¹ treatment combination. where variety Kachra and 120 kg N ha⁻¹ gave the lowest filled grain panicle⁻¹(46.96). Hossain *et al.* (2008) and Ghose (2003) also observed significant effect of variety and nitrogen on Filled grain panicle⁻¹

Unfilled grain panicle⁻¹ and 1000- grain weight were not significantly influenced by different treatment combination. The results showed that unfilled grain panicle⁻¹ ranged from 5.04 to 12.59 (Table 3). The highest and lowest unfilled grain panicle⁻¹ was observed from kachra with 120 kg N ha⁻¹ and Morichsail with control treatment combinations. The range of 1000-grain weight was 28.72 g to 33.24 g (Table 3). The highest 1000 grain weight observed in Morichsail with 30 kg N ha⁻¹ treatment where Raniselute with 0 kg N ha⁻¹ treatment produced lowest 1000 grain weight (28.72 g). Ghose (2003) also observed non significant effect of variety and nitrogen on unfilled grain panicle⁻¹ and 1000- grain weight.

The interaction effect of variety and nitrogen on grain yield was significant at 5% level. The grain yield ranged from 1.99 to 3.10 t ha⁻¹. The highest grain yield was observed in Morichsaile with 60 kg N ha⁻¹ treatment combination. Lowest grain yield was recorded from kachra with 120 kg N ha⁻¹ treatments combination (Table 3) which was statistically identical with Raniselute with 0 kg N ha⁻¹, Raniselute with 120 kg N ha⁻¹ treatment combination. Hossain *et al.* (2008) also observed significant effect of variety and nitrogen on grain yield.

Biological yield and harvest index were not significantly influenced by the combined effect of variety and nitrogen. It was found that Biological yield ranged from 7.94 to 10.58 t/ha.

The highest biological yield was observed in Morichsail with 90 kg N ha⁻¹ treatment. Lowest Biological yield was recorded from kachra with 0 kg N ha⁻¹ treatment combination.

The range of harvest index was 19.55 to 29.96 (Table 3). The highest harvest index was observed in Morichsail with 60 kg N ha⁻¹ treatment. Lowest harvest index was recorded from kachra with 120 kg N ha⁻¹ treatment combination respectively. Ghose (2003) also observed similar result in case of biological yield and harvest index.

Table 3. Interaction effect of varieties and nitrogen on Plant Characters and yield attributes of aromatic rice

Interaction	Plant height(cm)	Total tiller hill ⁻¹	Effective tiller hill ⁻¹	Panicle length (cm)	Filled grains panicle ⁻¹	Un filled grains panicle ⁻¹	1000-grain weight (g)	Grain yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index (%)
V ₁ N ₀	141.03	7.53	7.07	22.94 abc	74.40 b	5.04	31.77	2.46 c	8.64	28.57
V ₁ N ₁	144.55	8.33	7.40	23.94 ab	83.08 a	6.75	32.66	2.83 b	9.61	29.50
V ₁ N ₂	148.62	9.40	8.53	24.54 a	83.25 a	6.50	33.24	3.10 a	10.39	29.96
V ₁ N ₃	151.55	10.13	7.33	22.94 abc	77.17 b	6.80	32.00	2.87 b	10.58	27.13
V ₁ N ₄	153.28	10.60	5.49	22.32 abcd	63.86 cd	8.61	31.27	2.21 cde	10.43	21.20
V ₂ N ₀	141.62	6.53	5.93	20.66 cd	56.60 efg	6.25	31.12	2.13 de	7.94	26.82
V ₂ N ₁	143.32	8.13	7.60	22.98 abc	68.26 c	7.53	31.49	2.29 cd	8.68	26.35
V ₂ N ₂	146.82	9.27	8.67	22.53 abcd	62.04 de	8.32	31.46	2.46 c	9.36	26.36
V ₂ N ₃	148.90	9.98	7.49	23.02 abc	53.03 fghi	10.33	30.87	2.11 de	10.10	20.92
V ₂ N ₄	151.58	9.33	5.53	22.65 abc	46.96 i	12.59	30.24	1.99 e	10.21	19.55
V ₃ N ₀	138.97	6.00	5.33	20.12 d	51.82 ghi	7.14	28.72	2.03 e	8.01	25.41
V ₃ N ₁	141.48	6.93	5.27	21.93 bcd	56.37 efgh	8.17	29.50	2.25 cde	8.44	26.72
V ₃ N ₂	143.50	8.47	7.73	23.54 ab	59.31 def	9.15	30.34	2.44 c	9.26	26.39
V ₃ N ₃	146.10	9.07	6.93	23.41 ab	55.63 fgh	12.22	29.44	2.33 cd	10.02	23.50
V ₃ N ₄	148.48	9.67	4.50	22.16 abcd	50.07 hi	12.19	29.13	2.03 e	10.13	20.07
Level of significance	NS	NS	NS	0.01	0.01	NS	NS	0.05	NS	NS
CV (%)	1.11	10.58	13.69	4.32	4.10	15.39	2.84	5.72	5.53	5.63

In a column having similar letter (s) or without letter are not significantly different whereas dissimilar letters are significantly different as per DMRT.

Where

V₁= Morichsail, V₂= Kachra and V₃= Raniselute

and

N₀= 0 kg N ha⁻¹, N₁= 30 kg N ha⁻¹, N₂= 60 kg N ha⁻¹, N₃= 90 kg N ha⁻¹ and N₄= 120 kg N ha⁻¹

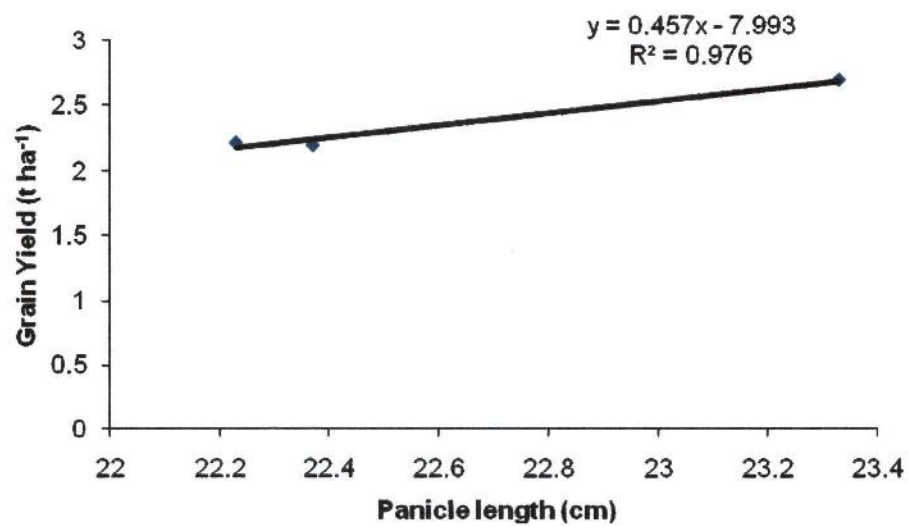


Fig. 1. Functional relationship between panicle length and grain yield in aromatic rice varieties

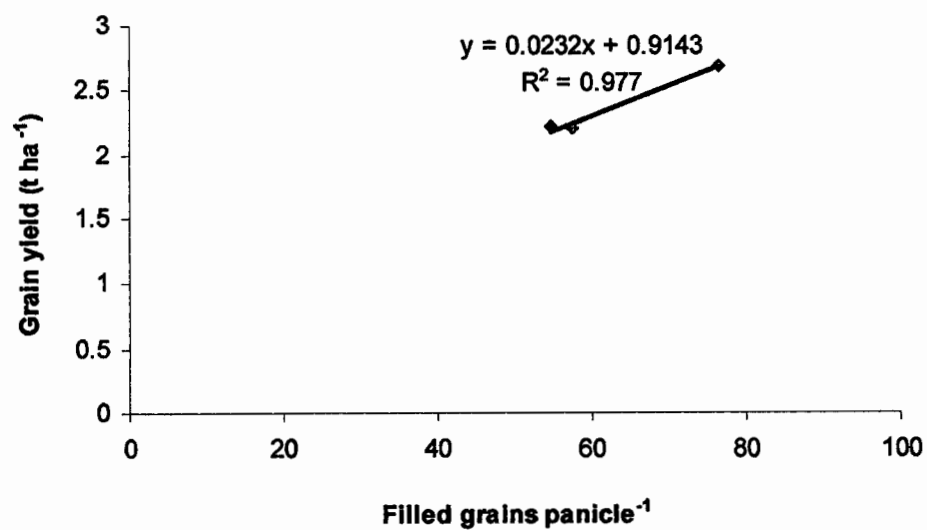


Fig. 2. Functional relationship between filled grains panicle⁻¹ and grain yield in aromatic rice varieties

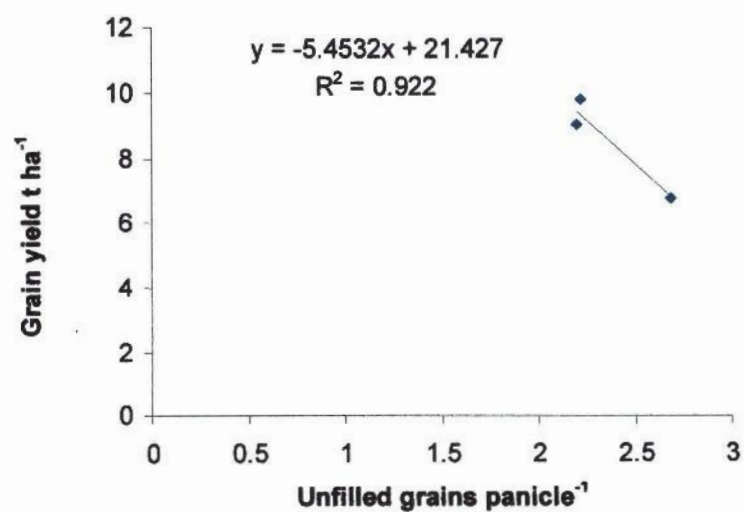


Fig. 3. Functional relationship between unfilled grains panicle⁻¹ and grain yield in aromatic rice varieties

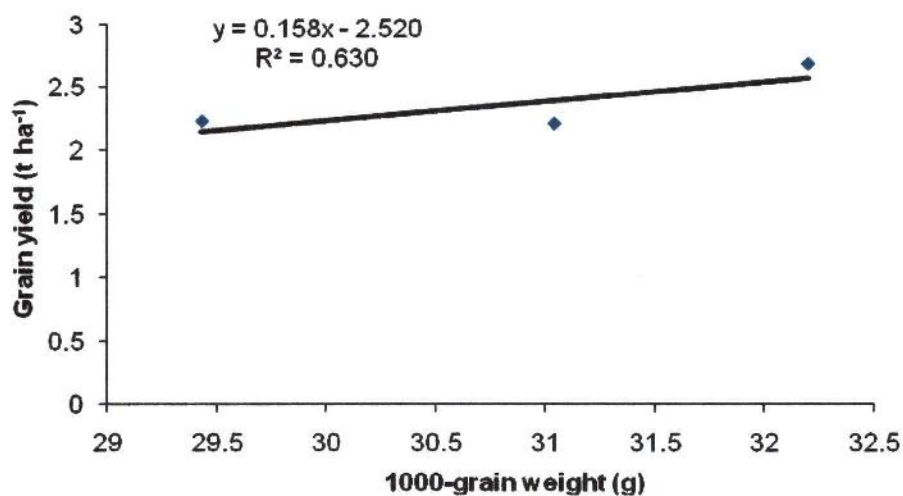


Fig. 4. Functional relationship between grain yield and 1000-grain weight among local aromatic rice varieties

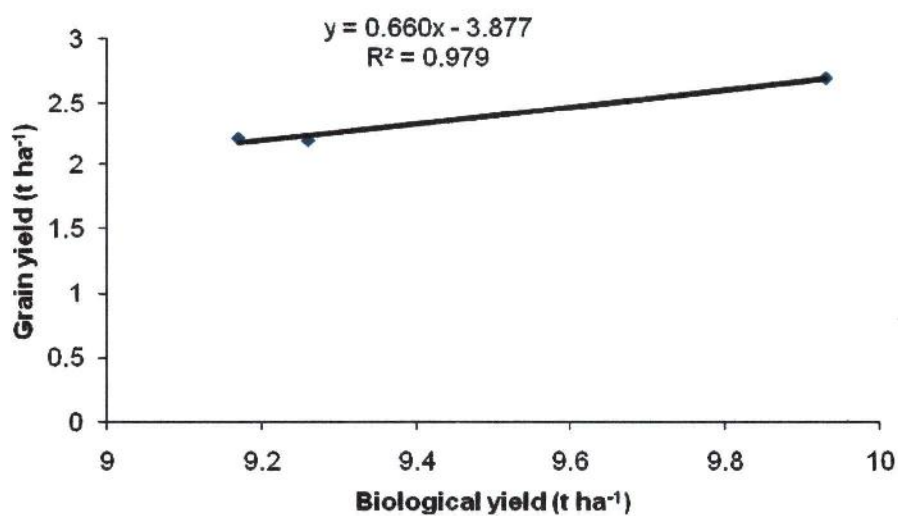


Fig. 5. Functional relationship between grain yield and biological yield weight in aromatic rice varieties

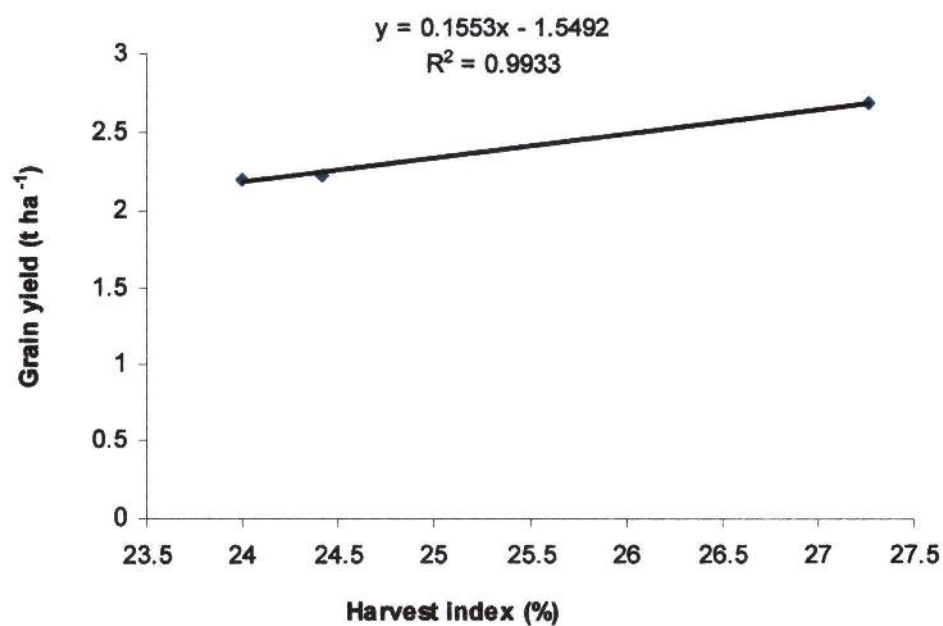


Fig. 6. Functional relationship between grain yield and harvest index in aromatic rice varieties

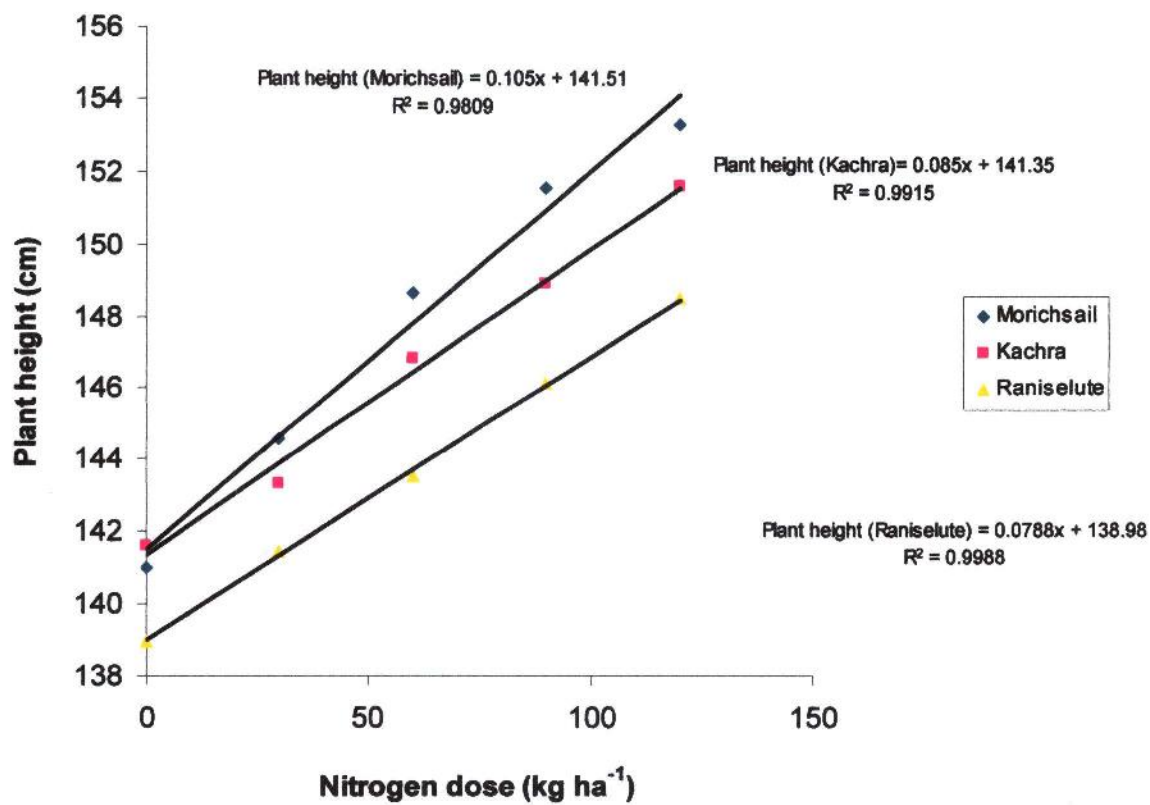


Fig. 7. Functional relationship between nitrogen dose and plant height of aromatic rice varieties

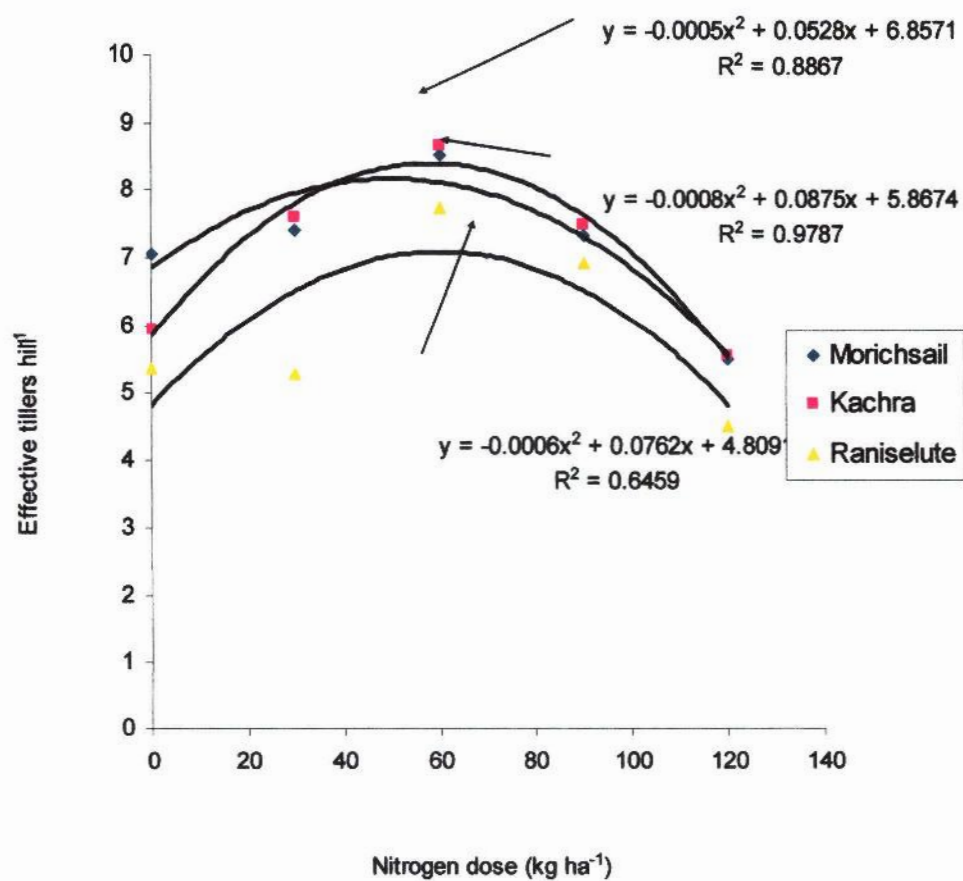


Fig. 8. Functional relationship between nitrogen dose and effective tillers hill⁻¹ of aromatic rice varieties

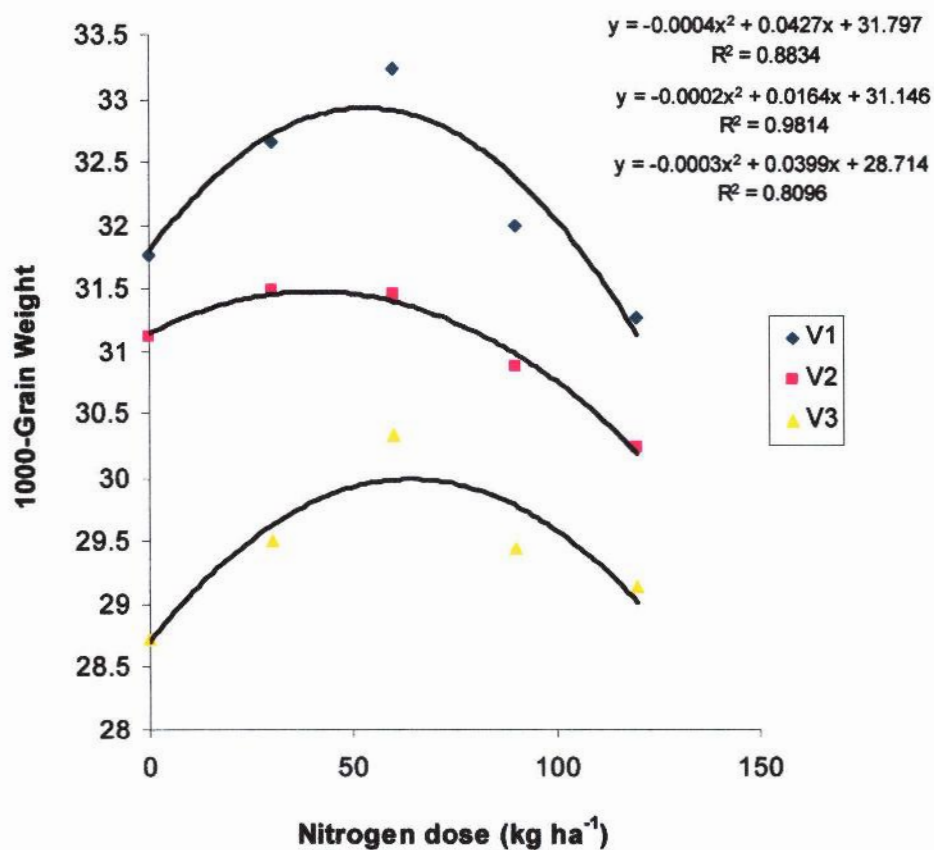


Fig. 9. Functional relationship between nitrogen dose and 1000- grain weight of aromatic rice varieties

Where

V₁= Morichsail, V₂= Kachra and V₃= Raniselute



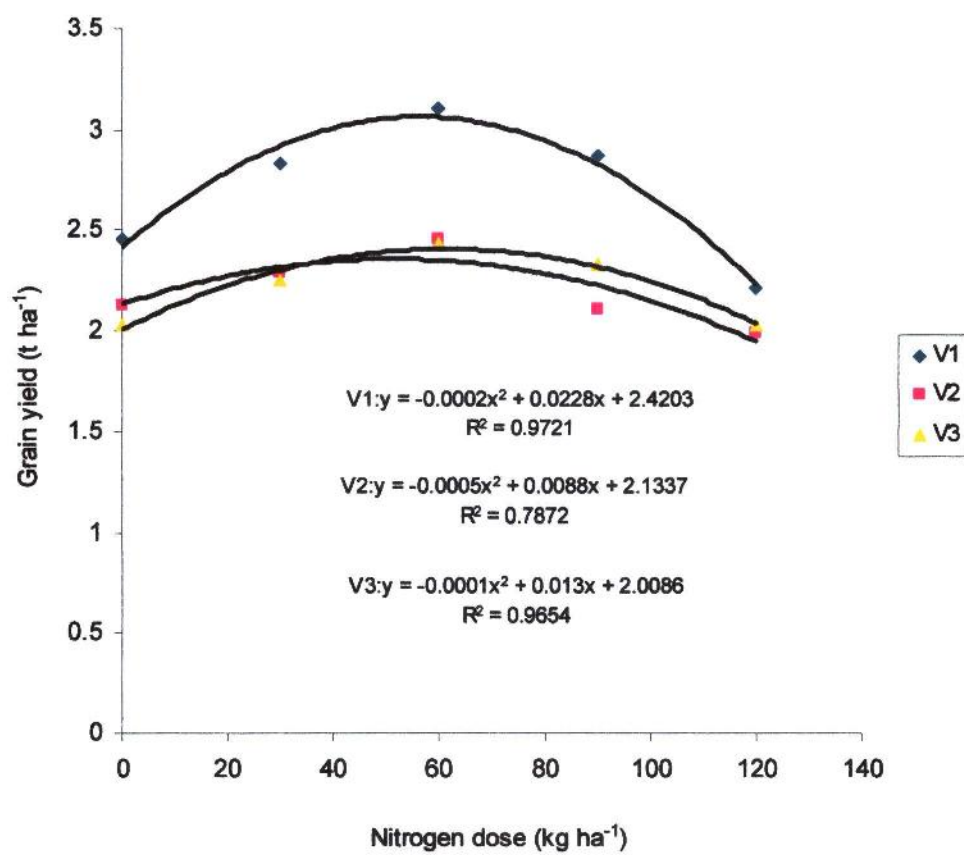


Fig. 10. Functional relationship between nitrogen dose and grain yield of aromatic rice varieties

Where

V₁= Morichsail, V₂= Kachra and V₃= Raniselute

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted during Aman season (June to December 2008) in the field Laboratory of Khulna University to evaluate the response of added N to three local aromatic rice varieties of Khulna. The experiment was laid out in a Factorial Randomized Complete Block Design with three replications. Three aromatic rice varieties viz, V_1 = Morichsail, V_2 =Kachra and V_3 = Raniselute and five levels of nitrogen viz., N_1 = 0 kg N ha⁻¹(control), N_2 = 30 kg N ha⁻¹, N_3 = 60 kg N ha⁻¹, N_4 = 90 kg N ha⁻¹ and N_5 = 120 kg N ha⁻¹ were the treatments. The total number of experimental units were $3 \times 5 \times 3 = 45$. The unit plot size was $4 \text{ m} \times 2.5 \text{ m} = 10 \text{ m}^2$. Block to block distance was 1m and plot to plot distance was maintained by 0.5m. The experimental land was fertilized with TSP, Murate of potash (MoP) and Zinc sulphate as the sources of P, K, and Zn, respectively. TSP, MoP and Zinc sulphate were applied at the rate of 50, 35, and 5 kg ha⁻¹. Nitrogenous fertilizer was applied to the plots as per treatment in the form of prilled urea (46.00 % N). All fertilizers except urea was applied and thoroughly mixed with the soil at the time of final land preparation. Nitrogen (N) treatment was applied in two equal installments, first at 30 DAT and 2nd at 50 DAT. The seedlings of rice varieties were transplanted on 10 August, 2008 at the age of 30 days, giving three seedlings per hill. Row to row and hill to hill distance were 20 cm and 15 cm, respectively. The crop was harvested at maturity in December, 2008. Data on yield and yield components were collected following standard procedure and analyzed for interpretation of the results. The effect of variety was differed significantly at 1% level. Among the three varieties, Morichsail produced the longest plant (147.81 cm), panicle (23.33 cm), the highest effective tiller hill⁻¹ (7.17), number of filled grain per panicle (76.35), grain yield (2.69 t ha⁻¹), 1000-grain weight (32.20 g), biological yield (9.93 t ha⁻¹) and harvest index (27.27 %).

On the other hand, Raniselute produced the maximum no total tiller hill⁻¹ (8.03) and highest unfilled grain per panicle (9.77). The lowest plant height (143.71 cm), panicle length (22.23cm), effective tiller hill⁻¹(5.95), filled grain panicle⁻¹(54.64), 1000-grain weight (29.43 g) and biological yield (9.17 t ha⁻¹) were obtained from the variety Raniselute. The lowest total tiller hill⁻¹(8.03) and unfilled grain per panicle (6.74) were obtained from the variety Morichsail. The lowest harvest index (24%) was found from the variety Kachra.

The effect of nitrogen on all the parameters was found significant. Among the five nitrogen treatments, application of 60 kg N ha⁻¹ produced the highest effective tillers hill⁻¹ (8.31), the longest panicle (23.54 cm), the highest 1000-grain weight (31.68 g), grain yield (2.67 t ha⁻¹) and the highest harvest index (27.57%). 30 kg N ha⁻¹ produced the highest filled grain panicle⁻¹(69.24). On the other hand, 120 kg N ha⁻¹ produced the highest plant height (151.11 cm), total tiller hill⁻¹ (9.87), the highest unfilled grains panicle⁻¹(11.13) and the highest biological yield (10.26 t ha⁻¹). Whereas the lowest plant height (140.54 cm), total tiller hill⁻¹, panicle length (21.24 cm), unfilled grain panicle⁻¹ (6.14) and biological yield (8.20 t ha⁻¹) obtained from control. Treatment N₄ produced the lowest effective tiller hill⁻¹(5.17), filled grain panicle⁻¹(53.63), 1000-grain weight (30.21 g), grain yield (2.08 t ha⁻¹) and harvest index (20.27%).

The interaction effect of variety and nitrogen was insignificant for parameters of growth and yield attributes except panicle length, filled grain panicle⁻¹ and grain yield. The highest panicle length (24.54 cm), maximum filled grain panicle⁻¹(83.25) and the highest grain yield (3.10 t ha⁻¹) was found from the variety Morichsail and 60 kg N ha⁻¹ treatment combination. The lowest panicle come from interaction of the variety Raniselute and 0 kg N ha⁻¹ and the

lowest filled grain panicle⁻¹ obtained from the variety Kachra and 120 kg N ha⁻¹ and the lowest grain yield found from the variety Kachra and 120 kg N ha⁻¹ treatment combination. Result of the present study showed that the variety Morichsail produced highest grain yield (2.69 t ha⁻¹) with 60 kg N ha⁻¹.

Chapter VI

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