EFFECT OF RATOONING ON DIFFERENT VARITIES OF BORO RICE UNDER VARYING CUTTING HEIGHT

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CERTIFICATE

This is to certify that the research work entitled , **"EFFECT OF RATOONING ON DIFFERENT VARIETIES OF BORO RICE UNDER VARYING CUTTING HEIGHT"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University , Dhaka, in partial fulfilment for the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY,** embodies the results of a piece of bona-fide research work successfully carried out by **MD. SAIFUL ISLAM** bearing Registration No. 08-3251 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:

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Prof. Dr. Md. Jafar Ullah

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DEDICATED TO
MY
BELOVED PARENTS

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ABSTRACT

An experiment was carried out at the Agronomy Field, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2009 to July 2010 to study the effect of variety and cutting height of main crop plants on the performance of ratoon *boro* rice. Four cutting heights were (0,15,30 and 45 cm) and four varieties (BRRI hybrid dhan-1, BRRI dhan28, BRRI dhan36 and BRRI dhan45) were tested. Variety had significant effect on almost all the crop characters like plant height, total number of tillers per hill, number of effective tillers per hill, number of non-effective tillers per hill, panicle length, days to panicle initiation, number of grains per panicle, number of sterile spikelets per panicle, total number of spikelets per panicle, days to maturity, 1000-grain weight, grain weight per hill, grain yield, straw yield, and harvest index in the ratoon crop. BRRI dhan28, BRRI dhan36 showed greater ratoon yields (1.8 t/ha and 1.79t/ha). Likewise cutting height also had significant effect on plant height, number of effective tillers per hill, number of non-effective tillers per hill, panicle length, days to panicle initiation, number of sterile spikelets per panicle, total number of spikelets per panicle, 1000-grain weight, grain yield, straw yield and harvest index. Cutting height 0f 30 to 45 cm showed higher yields (1.7-1.69 t/ha).Grain yield was highest at 30 cm cutting height of BRRI dhan28 and the second highest grain yield were at 30 cm cutting height of BRRI dhan36. All of the crop characters in the ratoon crop were significantly affected by the interaction of variety and cutting height of main crop.

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LIST OF SOME COMMONLY USED ABBREVIATION

ABBREVIATION	FULL MEANING
AEZ	Agro-Ecological Zone
BRRI	Bangladesh Rice Research Institute
IRRI	International Rice Research Institute
V	Variety
CH	Cutting Height
Cm	Centimeter
°C	Degree Celsius
CV	Co – efficient Variation
RCBD	Randomized Complete Block Design
DMRT	Duncan's Multiple Range Test
SD	Standard Deviation
df	Degree of Freedom
et al	and others
etc	Etcetra
eg	For example
ie	That is
g	Gram(s)
SAU	Sher-e-Bangla Agricultural University
PH	Concentrate of H^+
J	Journal
Sci	Science
Agric	Agriculture
Agril	Agricultural

CHAPTER I
INTRODUCTION

CHAPTER I

INTRODUCTION

Maximizing crop production per unit area per unit time is a burning question for crop intensification in densely populated areas of tropical Asia, where rice is the staple food. Under irrigated conditions, three successive rice crops can be grown within one year by adapting suitable short duration rice cultivars. But in the rainfed areas, which cover about two-thirds of the total rice area of Asia, the cropping intensity is minimum (Krishnamurthty, 1979) and the land remains fallow after the monsoon season. Soil moisture is the most limiting factor in intensifying rice cropping in drought areas. Here ratooning of rice may offer a great potential for increased productivity because of its short growth duration (Bahar and De Datta, 1977).

Ratooning means the production of a second crop from the stubble through regeneration of new tillers from the base and nodes of the harvested plant of the previous crops. Therefore, the benefit in ratooning lies in the facts of avoiding of elaborate land preparation, saving of seed and planting costs (Zandstra and Samson, 1979), economic use of machineries, high water use efficiency (Prashar, 1970) and considerable saving in cropping time as it has the advantage of reduced growth duration (Haque and Coffman, 1980). Its growth duration is short, generally, within two months. The ratoon crop of rice can extract moisture and nutrients from deeper soil layers by the already established root system and it may be harvested before the onset of drought.

On an average, ratoon rice can give a yield roughly equivalent to 40-50% of that of the main crop, with 40% reduction in crop duration (Samson, 1980). Faris (1984) mentioned that production of irrigated ratoon rice in Brazil covered 30% of that of the first crop and in some other countries the corresponding figure was 50%. Ratoon yield is generally less than the main crop but in some cases of higher yield have also been reported (Santhi *et al.*, 1993). Prashar (1969) reported a ratoon yield which exceeded the main crop yield by 11.2-58%. Roy (1959) found that the ratoon crop yield was increased by 117% which was more than double of the main crop. Reddy *et al.,* (1979) reported that the ratoon crop of Intan rice variety yielded 140% of its main crop yield in Karnataka.

Ratooning is a natural phenomenon in grass family (*Gramineae*) which is basically a varietal character and it differs among cultivars (Reddy and Power, 1959 ; Chatterjee *et al.,* 1982).

The success of the ratoon crop is best assured with proper pre-ratoon crop (mother crop) management. The initial nutrition of ratoon tiller depends much on the carbohydrate left in the stubbles of main crop. Therefore, much care is needed from the seedling to harvest stage of main crop for the management of ratoon crop. Satisfactory yield of ratoon rice depends on cultivars, seasonal requirements, cutting height, planting date, spacing, growth duration, date of harvest, water and fertilizer management, pest management and so on. Although ratoonability is a varietal characteristic, manipulation of cultural practices can enhance a good ratoon crop of rice (Quddus, 1981).

In the U.S.A 50% of the rice crop is ratooned (Flinchum and Evatt, 1972). In India, Colombia, Thailand, Taiwan, the Philippines and China, the possibility of growing rice ratoon has been successful (Plucknett *et al.,* 1970).However the non-acceptance of rice ratooning for large scale commercial farming in tropical Asia seems to be due to its low yield potential and vulnerability to pests and diseases (Mahadevappa, 1979). If grain yield of the ratoon crop alone is considered, it may be seen discouraging. But, if consideration is given to the time factor to express yield, ratoon cultures are found to be very encouraging (Quddus and Pendleton, 1990). The field duration of a ratoon crop is less than 50% of the main crop, even when early varieties are employed. The cost of production is very low (Mohan *et al.,* 2000).

The possibilities of increased yield from ratoon cropping in the Philippines have been investigated (Zandstra and Samson, 1979; Parago, 1963; Nadal and

Carangal, 1979; Haque, 1975). The available information suggests that the yield of ratoon rice can be increased substantially by improved cultural and management practices (Bahar and De Datta, 1977). The biophysical factors controlling the main crop yields also seem to have great influence on the ratoon productivity. Although the yield contributing factors like plant height, leaf area, leaf canopy, panicle length, growth duration, etc. are largely governed by genetic makeup of the plant, cultural manipulation still can alter the microenvironment to a considerable extent which eventually can have a large bearing on the productivity (Duncan, 1969; Watson, 1968; Yoshida, 1972). In general, the low yield obtained from a ratoon crop is believed to be mainly due to a reduction in number of productive tillers and shorter duration. For increased ratoon yields, these constraints need to be overcome.

Under Bangladesh context, there is potential for rice ratooning from the stubble of born rice with residual soil moisture and monsoon rain. In this country, crop intensification through rice ratooning constitutes one of the important options for the farmers in achieving food security. Here rice crops may be grown thrice in a year as *aus, aman* and *boro*. But, it is not always possible to accommodate three crops in a year through conventional rice culture. Under this context, ratooning may play a very significant role with its very short growth duration, usually taking only 35 to 60% of the time required for the main crop (Jones, 1985). Ratooning thus helps in adding extra yield. Boro is harvested in April-May and farmer transplant aman in August keeping land fallow in between. So at this fallow period a ratoon crop can easily be harvested. Moreover, in rice based cropping pattern when T. *aman* is grown late after *boro* rice, crops like mustard, pea etc., whose optimum sowing time is the first week of November, cannot be accommodated. Because T. *aman* is harvested only after mid November. In such a situation ratoon cropping of *boro* rice can ensure three crops in a year as well as crops like mustard, lentil, pea etc. can also be accommodated in the pattern. As it is simple and an effective way of increasing food production in the total crop programme, the Chinese government has stressed the need for the use of improved cultivation practices of ratoon rice (Yang, 1940). In Bangladesh, however, ratooning of rice is not yet practised whereas in some advanced countries of the world like, USA, China, Japan, India, Philippnies, Domenican Republic etc., its advantages are realized and it has been practiced by the farmers (Bollich *et al.,* 1991). It is thought that in Bangladesh too rice ratooning might play a significant role in increasing total crop production trend. However, information is still not enough with regard to ratooning. The farmers are also not familiar with the production technology of rice ratoon cropping. Though the Bangladesh Rice Research Institute has been developing high yielding varieties of rice, it has extended little effort towards the development of varieties having high ratoonability. The high yielding variety of rice have a high potentiality of ratoon cropping (Alim, 1974) The present study was, therefore, undertaken to find out the effect of variety and cutting height on ratoonability of some HYV*boro* rice. However, though in general, the yield in ratoon crop was comparatively less than that in main crop, experimental evidences revealed that ratoon crop would be advantageous in areas where a single crop of rice was cultivated and where the soil had sufficient moisture to sustain the ratoon crop (Gupta and Mitra, 1948). Ratoon crop was also advantageous in that two good crops could be obtained in two seasons from the same land with a considerable saving in time, cost of production, water requirement and machinery use (Balasubramanian *et al.,* 1970; Prashar, 1969; Ramaswami and Haws, 1970; Evans, 1957).

CHAPTER II
REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Ratooning of rice has been reported to be a practical means of increasing rice production (Mohan *et al.* 2000). In Bangladesh context only a few studies on rice rationing are available and it has not yet attracted the attention of researchers. In some other countries of the world, it is being practiced to some extent. A great volume of work has been done all over the world especially in Japan, U.S.A., Thailand, China, Taiwan and India on this system of rice culture. Some of those works that are pertinent to the present study are reviewed here.

2.1 Effect of variety

Ratooning is thought to be a varietal character and possibly there is a great scope to enhance ratoonability through varietal selection. Tang (2002) in a study using 37 cultivars as crop materials found that yield and yield components of ratoon crops of hybrid rice were better than those of conventional cultivars. The author also observed that the number of panicles per plant, spikelets per panicle and the number of grains per panicle were the important factors that affected the yield of ratoon crop of rice. Plant height and panicle length had significantly negative correlation with yields.

Lin *et al. (2001)* studied the morphological and functional differences of root systems among the three ratooning rice varieties, Shanyouming 86, Teyou 70 and Shanyou 63, and their correlation were studied. The results showed that Shanyourning 86 had the most flourishing root systems and yields of this variety was the highest both in the main and ratoon crop season. In Shanyou 63, root quantity, function and yield were the second highest at both crop seasons. Teyou 70 had a flourishing root system in the first season, dropped sharply after the maturing period and as a result, its yield was high in the main crop and low in the ratoon crop. The relationship between the content of the soluble carbohydrate during the harvest of the main crop and their ratoonability in hybrid rice was studied by Cheng *et al.* (2001). During the harvest of the main crop, the soluble carbohydrate content of the tillering stem and stem sheath was not correlated with their ratoonability in hybrid rice, but the soluble carbohydrate content of the main stem was interrelated. During the harvest of the main crop, significant positive correlations among the total soluble carbohydrate content of the main stem and stem sheath and their ratoonability in hybrid rice were observed.

Xu *et al.* (2000) conducted an experiment with thirty-three hybrid rice combinations to study the relationship between ratio of grain to leaf area and ratoonability during 1995 to 1998. The result showed significant negative correlations between the ratio of grain to leaf area and the ratoonability of the main crop. The ratooning ability of varieties could be changed under the ratio of grain to leaf area. The reason was that there were significant positive correlations between dry weight of maternal stems and the ratoonability, and significant negative correlations between the ratio of grain to leaf area and dry weight of the maternal stems. Significant positive correlations between the number of grains per panicle among varieties and the ratio of grain to leaf area of main crop were observed. There were significant negative correlations between the number of grains per panicle of main crop and the yield of the ratoon rice.

Chen *et al.* (2000) conducted an experiment with two-line rice hybrid Peiliangyou 500 and Shanyou 63 that were ratooned after growing as a middle-season crop. Total yield of the main and ratoon crop of Peiliangyou 500 was 12.08 t /ha, which was 37.5% higher than yield of the control cultivar Shanyou 63.

Shi and Shi (1997a) conducted an experiment to determine the benefits of ratoon cultivation in rice. In trials during 1992-96, authors found that the main crop yielded 7.60-9.46 t/ha and the ratoon crop yielded 3.10-6.24 t/ha.

Balasubramanian and Krishnasamy (1997) conducted field experiments during *kharif* (monsoon) and *rabi* (winter) seasons at Tamil Nadu Agricultural University where rice varieties ADT 36, ASD 16, CO 37 and PMK 1 were given 75, 100 or 125 kg N/ha and cut at 20 or 30 cm height with a view to ratooning. In the main crop, ADT 36 gave the highest grain yield, whereas in the ratoon crop, yield was highest in CO 37 (2.56 and 2.61 t/ha in *kharif and rabi,* respectively) followed by PMK 1. Growth and yield attributes were influenced by cultivars and nitrogen whereas, stubble height was found to have no effect on ratoon yield. Per day productivity was the highest (32.5 and 30.0 kg/ha in *kharif* and *rabi,* respectively) in variety C037. The cost benefit ratio was maximum in variety CO 37.

Andrade (1995) conducted an experiment with 4 short rice cultivars which were cut at maturity to soil level or to a height of 10 cm or 30 cm and observed that grain yield of re-growth ranged from an average of 0.99 t to 1.65 t/ha when cut to a height of 30 cm and 0 cm, respectively.

Reddy (1995) conducted two separate experiments, using 135 varieties in the first and 6 high yielding varieties in the second and observed that yield of ratoon crops ranged from 0 to 2.05 t/ha. The author also mentioned that variety Acc 1981 gave the highest ratoon yield. Main crop and ratoon crop yields and yield components of rice varieties Wantok, Tambu, Niupela and Senis grown in Papua New Guinea were evaluated and it was found that grain yield in the main crop was highest (8.5t/ha vs. 6.9-7.3 t/ha in other cultivars) in variety Senis, while in the ratoon crop yield was highest in Tambu (3.9 t/ha) followed by Wantok (3.3 t/ha) and it was lowest in Senis

(1.7 t/ha) (Sajjad, 1994).

Bollich *et al.* (1993) gave a trial with five varieties and found that among the varieties the average number of days to heading for Texmont was 82, compared with 81, 87, 90 and 92 days for Maybelle, Skybonnet, Gulfmont and Lemont, respectively. Overall yields of Texmont, were 7.34 t/ha, compared with 7.37, 7.32, 7.02, 6.46, 6.09 and 5.91 for Gulfmont, Maybelle, Lemont, Skybonnet, Labelle and Tebonnet respectively. Texmont performed superior ratoonability with ratoon yields ranging from 2.45 to 2.72 t/ha.

Srinivasan and Purushothaman (1993) reported that the ratoon crop of variety Bhavani performed better than Ponni with regard to growth, yield attributes and grain yield. Ratoon grain yield produced by Bhavani was 2.75 t/ha which was 50.2% of the main crop yield whereas the ratoon grain yield produced by Ponni was 1.75 t/ha which was 38% of the main crop yield. Sutaryo(1993) conducted an experiment with six F1 hybrids and a control (Dodokan) and reported that ratoon yields ranged from 14 to 22% of the main crop and hybrids of V20A with IR25912, IR64 and 1R28178 gave the highest ratoon yields of 1.3, 1.1 and 1.3 t/ha, respectively. In an experiment Zhang (1991) observed that hybrid rice ratoon crops yield was 17% more than conventional rice ratoon crops.

Path analysis was used by Liu *et al.* (1992) to assess the relationship between ratoonability of inter subspecific hybrids between indica, japonica and javanica varieties and some agronomic characters of the parents. Days of heading and number of effective panicles showed the greatest direct effect on the ratoon ability of the hybrids while number of grains per panicle indirectly affected ratoonability via number or effective panicles.

Mathew (1992) reported that among the 15 rice cultivars tested, 8 cultivars showed potentiality for ratooning, producing ratoon grain yields in the range 0.62 varieties IET9862, IET9573 and IET9190 produced the highest yields of >1.0 t/ha.

Tan (1990) conducted an experiment with 24 hybrids and breeding lines in order to observe the differences in ratoonability among them and found that most of the hybrids had good ratoonability of which Dyou 10, Shanyou 66 and Minghui 63 produced higher ratoon tillers per hill. Palchamy *et al.* (1990) reported that among 3 varieties Bhavani had a significantly higher ratoon grain yield, stem thickness and stubble carbohydrate content than Ponni and IR20 in both seasons.

Mahadevappa (1988) found that varieties differed widely in ratoonability, type of tillers produced, growth period duration, grain quality and yield. Resistance to virus diseases was rare among ratoon varieties, although varieties like Intan, Mingolo and an Intan mutant were found to have resistance to some extent.

Li and Chen (1988) conducted experiments to study the inheritance of ratoonability in rice varieties. Short-duration Shu-Fong 1(11), a high rationing variety, and Ai-Nan-Zao, a non-ratooning variety, were used as tester parents in 3 reciprocal crosses with Hon-Mei-Zao (short duration) and Tai-Guao-Dao-Xuan and Shong-Zao-Xian 26 (medium duration). These varieties are characterized by different ratoonability. Estimates of narrow-sense heritability for ratoonability varied greatly with the genetic background of the parents.

Prakash and Prakash (1988) planted 23 mid-season and late genotypes and found that the main crop yielded from 2.02 to 4.73 t/ha. When the main crop was cut 15 cm above the ground, the number of tillers produced was highest (up to 30.2) in genotypes, which had higher main crop yields. The ratoon crop yield ranged from 0.1 in Pushpa to 1.81 t/ha in IET7431. In terms of the ratoon crop yield as a percentage of the main crop yield, BPT2685 was the best with 1.61 t/ha (71.24%).

Chauhan *et al.* (1988) observed that of 24 advanced photoperiod insensitive summer rice genotypes ratooned by cutting the stems 15 cm above the ground, only 10 showed regeneration and RP 1664-4661-693-1333 had the greatest ratoonability with 94.9% hill regeneration.

Chauhan (1988) conducted an experiment to evaluate ratoonability and found that out of 57 hybrids and 5 standard varieties, 14 hybrids and IR 56 performed consistently well. The author also found that hybrid involving the line IR 1965734-2-2-3-3A/IR36 had the highest regeneration capacity, vigorous ratoons, and the highest number of tillers and panicles/m^2, possibly as a result of dominant genes in the line.

Rosamma *et al.* (1988) compared the grain weight and germination of main and ratoon crops of 5 rice varieties and observed varietal differences for both traits. The authors also observed that the highest 1000-grain weight was found in Jaya {28g (main crop), 24g (ratoon crop)}. Palchamy ans Purushothaman (1988) assessed grain yield in main and ratoon crops in 10 early and mid season varieties and noticed that ratoon crop yields ranged from 0.43 t/ha (variety Ponni) to 2.20 t/ha (variety Bhavani).

Prakash *et al.* (1988) in a study with 23 mid-season and late genotypes observed that the number of tillers produced was highest in genotypes, which had high main crop yields. The authors also noticed that the ratoon crop yield ranged from 0.1 in Pushpa to 1.81 t/ha in IE1743I and in terms of ratoon crop yield as a percentage of the main crop yield, BPT2685 was the best with 1.61 t/ha (71.24%).

Qiu (1987) conducted an experiment to evaluate the ratoonability of 28 varieties in a greenhouse by cutting mature plants to a height of 15 cm and found that 1829, IR30, 1843 and 1864 had relatively high ratoonability, and 13 varieties had intermediate ratoonability.

Singh *et al.* (1987) showed that ten out of 24 breeding lines had ratoonability and it varied from 59.4 to 94.9%. The author also showed that ratoon grain yield ranged from 0.8 to 1.7 t/ha and the line 1664-4461-693-1333 gave the highest ratoon grain yield.

Maurya (1987) carried out an experiment by harvesting the main rice crop taking only the panicles and found that in the ratoon crop the number of effective tillers, number of grains, 1000-grain weight and grain yield ranged from 14-16 per plant, 81-90 per panicle 15.8-17.7 g and 2.0 -2.7 t/ha, respectively, depending on varieties.

Amorin-Neto *et al.* (1986) conducted an experiment with 10 varieties and lines of irrigated rice and observed that variety P 899 gave the greatest ratoon and total yields. Palchamy (1986) showed that rice variety Bhavani and Vaigai gave ratoon yield of 4.85 and 3.29 t/ha respectively. In a trial by Basavaraju (1986) with rice varieties Mawgala., CT1451 and Halobbalu (5317) found that ratoon crop yields were highest in variety Mangala and lowest in Halubbalu.

Chang *et al.* (1985) carried out an experiment with 163 varieties to assess the variation in ratoonability and showed that ratoonability varied from 0% to 122.9%.

The authors also noticed that the indica varieties had an overall higher ratoonability (29%) than the japonica varicties (19.5%). Chauhan *et al.* (1985) observed that ratoon rice crop grain yields varied considerably from 3.3 t/ha IRRI with variety IR2058-78-1-3-2-3 to 8.7 t/ha in Ehiopia with variety IR8, Japonica 1300, 0.5-0.7 t/ha in Malagasy. Singh *et al.*, (1984) carried out an experiment to determine the ratoonability of 7 varieties and found that C8585 and NC 1626 ratoons yielded 32 and 24% respectively of the main crop. The authors also observed that variety NC 1626 yielded the highest overall when the yields of the main crop and ratoon crops were totalled.

Chauhan *et al.* (1983) evaluated hybrid rice for ratoonability and found that, out of 57 hybrids and 5 control varieties, hybrid ratoons were more vigorous than control variety IR56. Hybrid IR 19657-34-2-2-3-3A/IR36 produced the highest number of tillers and panicles (515 m^2 and 423 m^2, respectively). They concluded that cultural management as well as genetic background affected ratoonability.

Gurumurthy (1983) conducted an experiment with 3 medium duration cultivars and found that Bhavani gave the highest grain yield in the ratoon crop and IR 20 the lowest, although 1820 had given the highest yield in the planted crop. Karunakaran *et al.* (1983) conducted experiment with 20 rice varieties to assess the ratoon performance and found that main crop grain yield ranged from 3.2 to 4.9 t ha^{-1} while ratoon crop yields varied from 0.1 to 0.5 t/ha. The authors also found that varietal differences in ratoon grain yields were significant and out of which five IRRI lines were promising.

Nayak *et al.* (1983) worked with 9 cultivars grown as main crop in the wet and dry season and as a ratoon crop after the dry season crop and found that ratoon yield of IET 3629 was 12% higher than its main crop yield in wet season. Bollich *et al.* (1981) reported that the grain yield of the semidwarf rice variety Bellemont was 5.80 t/ha in the main crop and 0.65 t/ha in the ratoon crop.

Das (1982) conducted an experiment with 89 semi dwarf photo-insensitive varieties and found that C3819 gave the highest yields (main and ratoon crops combined) and CR220-66 had the highest ratoonability. IRRI (1979) reported that a ratoon crop of transplanted rice variety IR32 yielded 2.3 t/ha when the main crop was cut low. The author also mentioned that a ratoon crop of variety 1R36 yielded 0.4-1.1 t ha^{-1} that had small panicles and 30% of the hills did not ratoon. The same author further noticed that in 1R38 and 1R32, an average of 12% of the hills did not produce ratoons.

Saran *et al.* (1969) in a study in North Bihar observed differential behaviour in the ratoonability of some photoperiod insensitive rice cultivars. In this study authors used the cultivar Taichung Native-1 and other four-indica varieties including the cultivar T_{21}. In the main crop Taichung Native-1 gave the highest yield but in the racoon crop T_{21} outyielded the other cultivars.

Prashar (1969) in an experiment evaluated the yield potentials of Dawn, Nato, Blue bonnet, Belle patna, IRS, and IR8 varities of rice in main and ratoon crops. The varieties IR8 and IR5 significantly out yielded the other varieties, averaging 8.05 t/ha and 6.88 t/ha respectively. Several characters measured, differed according to variety including ratoon yield, which exceeded main crop yield by 11.2 to 58% and in general, showed the same inter-varietal differences as for the main crop, ratoon maturation period, which was 17 to 32 days less than that of main crop and water use efficiency of the ratoon crop, which was 13.5-28% higher than that of the main crop.

Hsieh *et al.* (1964) from their experiments recommended that there were inter-varietal differences in capacity for regrowth and yield. Evatt and Beachell (1960) from their investigation reported that the practical means of increasing rice yield could be extended by using early maturing varieties (109-132 days from sowing to maturity). The authors obtained yields of 1.68 to 2.24 t/ha from ratoon crops.

Evatt (1958) and Kai-chu (1958) from their investigations recommended that quick maturing cultivars of early to medium type were most suitable for ratooning.

Szokolay (1956) reported that the various rice varieties showed different ratoonability. The author experimented with three varieties of rice, namely, Century patna No.2, Swazi No.1 and Swazi No.2, and obtained 3.06, 1.50, and 3.30 t/ha ratoon yield, respectively.

Ratoon yield is generally less than the yield of main crop. Gupta and Mitra (1948) at Nagina, India observed ratoonability of rice. The yield obtained from main crop was 2.85 t/ha and that of ratoon crop under irrigated condition was 2.51 t/ha or 9% of the main crop and under non-irrigated condition only 8.17 t/ha or about 3% of the main crop. Evans (1957), Garica (1962), Ganguly and Raiwani (1954) Kaichu (1958), Ramaswami and Haws (1970), Saran and Prashad (1952), however, obtained a ratoon crop of 3 to 80% of the main crop. This variation of the yield performance of the ratoon crop, however, might be due to the variation in environmental condition, variety, clipping height, cultural practices and other unforeseen factors such as damages of grains by birds and rats. Yang (1940) quantified the losses due to insects and birds.

Though ratoon yield is generally less than the main crop yield, cases of higher yield have also been reported. Prashar (1969) reported a ratoon yield that exceeded main crop yield by 11.2-58%. Roy (1959) found that the ratoon yield was increased by 117% that was more than double of main crop.

2.2 Effect of environment, cutting age and height

To produce a successful and uniform ratoon crop, it is essential to harvest the main crop at the proper time. The best time to harvest is when the main crop is fully ripe and the tillers of the ratoon crop have just begun to grow (Szokolay, 1956). Development of the ratoon crop begins soon after the main crop is ripe and in the case of delayed harvesting of the main crop, the tillers, which come up from the first crops straw, are damaged. Timely harvesting of the main crop should be done when the rice stalks are still green and should be finished in one day to obtain uniform ratoon tillers (Balasubramainian *et al.* 1970; Grist, 1965; Parago, 1963; and Saran and Prashad, 1952).

Xiong, *et al.* (1991) conducted an experiment to see the effect of different time of harvest of the main crop by harvesting it at 22, 25, 28, 31 and 34 days after main crop heading on the performance of ratoon crop and reported that cutting the main crop 34 days after heading when axillary buds began sprouting, resulted in the highest yield in the ratoon crop.

In an experiment in Japan, it was observed that Ratoon weight was higher when the second crop was exposed to higher light intensity and and warmer environments. Temperature had a significant effect on ratoon height but sunlight did not. The ratoon plants in the 30°C environment did not grow further after the 20th day, because heading was observed on the 20th day for this temperature environment. Percentage of ratoon tillers was earlier and maximum at 30°C and in the sunlight environment. Foliage of ratoon plants seemed to contribute to the growth of ratoon plants in 30°C under sunlight. The percentage of ratoon tillers seemed to be the most useful trait of ratoon plants.

The stage of maturity of the main crop at harvest affected ratooning (Haque, 1975; Votong, 1975; Yang, 1958). The best harvesting time for good ratooning was when the culms were still green (Parago, 1963; Saran and Prasad, 1952), before the crop fully matured (Balasubramanian, 1970; Nagai, 1958), or at full maturity when the shoots had just begun to grow (Szokolay, 1956). Delaying main-crop harvest to 44-56 days after flowering reduced ratoon crop growth duration (Votong, 1975). Harvesting at 30, 35, 40 and 45 days after main crop flowering did not significantly affect ratoon yields (Haque, 1975; Reddy *et al.* 1979).

Siddique (1995) showed that the optimum harvesting time of the main crop was at its physiological maturity for better performance of ratoon crop. Wang *et al.* (1995) harvested main crop of hybrid rice in different dates and showed that if cut before booting stage then regrowth was done by leaf production, but when cut after panicle emergence stage then regrowth was occurred by tiller production and if cut between these two dates then regrowth was done by both leaf and tiller production. The author also reported that the highest grain and protein yields were given by cutting between panicle emergence and grain filling stage.

Siddique (1995) reported that yield of ratoon crop increased with the increase in cutting height of the main crop, the optimum being ranged from 15 to 20 cm above the ground level.

Andrade *et al.* (1988) conducted an experiment to see the effect of cutting height of 10, 20 or 30 cm above ground level on the yield and grain quality of ratoon crop of 10 rice varieties and found that 10 cm cutting height reduced the ratooning ability of all varieties and the best ratoon crop in terms of yield and quality occurred with a cutting height of 30 cm.

According to Evatt (1958), Evatt and Beachell (1960), and Pena and Plucknett (1972) harvesting the main crop close to the ground level delayed the maturity of the ratoon crop, but the crop was uniform in growth. In Texas, Evatt (1966) found that harvest heights of 4 and 10 inches (10.16 and 25.4 cm respectively) from the ground level delayed maturity 2 to 3 weeks, respectively, when compared with regular harvesting height (about 43.18 cm).

Hodge and Evatt (1969) reported that cutting height of 17 to 18 inches (43.18 to 45.72 cm) from ground level was satisfactory for all varieties. Although the plant maturity was uneven at this cutting height, the crop would become ready for harvest sooner than at lower cutting heights.

Prashar (1970a) observed that increasing cutting heights from the ground level to 12 cm high, increased tillering of the ratoon crop.

Bahar and De Datta (1977) also found ratooning performance wasbetter in a 15cm cutting height.

Saran and Prashad (1952) conducted an experiment at Sabour in India, using aus rice *cv.* CH-10 to determine the effect of 4 different cutting heights on the yield of subsequent ratoon crop. The best ratoon crop yield was 31% of the yield of the main crop, when the main crop was harvested at a cutting height of 35.65 cm. Cutting height influences tillering capacity and yield of the ratoon crop (Prashar, 1970a; Escalada and Plucknett, 1977; Bahar and De Datta, 1977; Hsieh and Young, 1959).

Balasubramanian *et al.* (1970) reported that the tillers which developed from the axillary buds of the upper nodes produced very short spare panicles compared to basal tillers. Similar results were also obtained by Dishman (1961) in Texas. To overcome this problem, Parago (1963) suggested that the main crop should be cut close to the ground level to avoid the growth of undesired tillers coming from the nodes.

Zandstra and Samson, 1979 reported that ratoon tillers depended on the carbohydrates left in the stubble and roots after harvesting the main crop. It is generally assumed that the higher the cutting, the higher is the amount of accumulated carbohydrate which helps tiller development.

Escalada and Plucknett, 1977 found that the very short stubble left on the ground at low cutting, height supplies insufficient food reserves for dormant buds to grow and develop rapidly to the reproductive stage and fully utilize the available sunlight and moisture. Cutting height was found to influence tillering capacity and grain yield of the ratoon crop (Prashar, 1970a; Escalada and Plucknett, 1977; Ramos and Dittrich, 1981).
However, there have been reports that the yield of the ratoon crop was significantly higher when the main crop was cut at ground level than at 4.8 to 20 cm height (Prashar, 1970a; Pena and Plucknett, 1972).Schikawa (1964), observed that cutting height of stubbles had no influence on the yield of ratoon crop.

Saran *et al*. (1969), on the other hand, found that increased cutting height had a positive effect on yield.

Saran and Prasad, 1952 reported that cutting the main crop close to the ground level produced low ratoon yield compared to that at higher level and the best cut was 14 inches (35.56 cm) above the ground level.

It was reported by Oh and Sunarzo (1969) in South Kalimantan of Indonesia that the panicle cutting by ani-ani (a common practice in Indonesia by small hand knife) produced more ratoon compared to methods in which the stalks were cut. Also, a cutting height at 15 cm above the ground level produced a significantly higher ratoon yield than the one cutting at 1 cm height- A recent study conducted by Samson (1980) at IRRI showed that the grain yield of a ratoon crop was higher from a 15 cm than from a 3 cm cutting height of the first crop.

Ratoon crops produced more panicles per hill, filled spikelets per panicle, and higher 100-grain weight at 3cm and 5cm cutting heights than at 15cm, but grain yields were less because low cutting resulted in more missing hills (Bahar and De Datta, 1977; Chaterjee et al., 1982; Quddus, 1981; Samson, 1980). In studies with cultivar Intan in Karnataka, Reddy *et al.*, (1979) showed that cutting the plants at 8, 13 and I 8cm did not affect ratoon yield.

Stubble height determines the number of buds available for re-growth. The effect of cutting height on ratoon vigor varies: some varieties ratooned from high nodes, others produced basal ratoons that are unaffected by cutting height (Volkova and Smetanin, 1971). In a field trial, Mochizuki (2000) found that grain yield of ratooned rice cv. Koshihikari and Yumitsukushi was highest with the higher cutting height.

Balasubramanian and Krishnasamy (1997) reported that cutting height had no significant influence on ratoon rice. Sahoo and Lenka (1992) carried out an experiment to see the effect of cutting the main crop cv. Savitni at 10 or 20 cm height on yield of a ratoon crop and found that ratoon yield was higher when the main crop was cut at 10 cm stubble height.

Jones (1986) showed that cutting height had a significant effect on maturity, height and yield of ratoon crop. On the other hand, Ishikawa (1964) reported that cutting height of the main crop did not affect the ratoon crop yield.

Amorim *et al.* (1986) conducted an experiment with 10 varieties and lines of irrigated rice by cutting the main crop to a height of 10, 20 and 30 cm and observed that grain yield ranged from 218 to 857, 157 to 750 and 315 to 1714 kg/ha, respectively. Other experimental reports showed that clipping height of the primary crop had effects on the maturity period and yield of the ratoon crop (Evatt 1958; Evatt and Beachell 1960; Jones, 1993).

Prashar (1970a) showed that the height of cutting of the main crop affected the yield of the ratoon. The ratoon yield was significantly, higher when the main crop was cut at ground level than that cut at 4.8 and 12 cm height. The number of tillers per plant at different stages of growth revealed that the absolute number was greatest with the lowest cut. The yield of plant cut at ground level to 4 cm height was significantly higher than the plants cut higher. The increase in yield was due to increase in the number of tillers per plant and maturity period.

Crop duration increased with lower clipping than with higher clipping (Quddus, 1981; Jones, 1993). Studies on rice ratooning showed that the cutting height of the main crop affects the maturity period and yield of the main crop (Pena and Plucknett, 1972; Jones 1986).

Haque (1975) reported that cutting the main crop at 25 cm above the ground and harvesting 5 days before full maturity gave the best results for evaluation of ratoonability.

IRRI (1975) showed the effects of different cutting heights on the yield of IR28. Four cutting heights used were at ground level, 5, 15 and 20 cm. The optimum cutting height in relation to grain yield production was found to be 15 or 20 cm above ground level. The different clipping heights also influenced the number of missing hills. The percentage of missing hills was low when the cutting height was 15 cm (12%) and 20 cm (5%) but it reached as high as 37% when the cutting height was 5 cm. The percentage of missing hills was significantly lower when the cutting height was 15 or 20cm as compared with a cutting height of 5 cm. Thus, lowering the cutting height from 15 to 5 cm increased the percentage of missing hills by 24% and prolonged growth duration by 13 days. The ground level cutting reduced the stand of the ratoon crop when the water was maintained at 5 to 7cm.

IRRI (1975) also reported from another experiment in the same year that cutting the main crop at 15 and 20 cm above ground level produced a significantly higher grain yield in the ratoon crop than the crop was cut at 5 cm. Ratoons were not produced on the majority of the hills when the main crop was cut at ground level and 5 to 7 cm water was maintained. More tillers were produced in the ratoon crop when the cutting height was 15 or 20 cm.

Review of literature cited and discussed above revealed that cutting height influenced the different crop characters of ratoon rice. Because, rice ratooning depends on the ability of dormant buds on the stubble of the first crop to remain viable, the buds may be at different stages of development (Nair and Sahadevan, 1961) or similar in length (Chauhan *et al*., 1985). Tiller regenerated from higher nodes formed more quickly, grew faster, and matured earlier (Prashar, 1970b).

In contrast the panicles from ratoons coming from lower nodes produced more grains per panicle than those from upper nodes, but it caused lower fertility percentage. Panicles from upper nodes contributed more to ratoon grain yields than those from lower nodes (Sun *et al*. 1988).

In the light above review of the past findings, it is evident that the times of harvest and cutting height have great influence on ratooning in rice. Since all the previous studies did not agree fully on the issue it was felt essential to obtain more clear and definite idea further.

CHAPTER III
MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

An experiment was conducted at the Agronomy Field, Sher-e- Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2009 to July 2010.

3.1Experimental Site

The experimental field was located at 90^{0} 22' E longitude and 23^{0} 41' N latitude at an altitude of 8.6 meters above the sea level. The land was located at 28 Agro-ecological zones (AEZ 28) of "Madhupur Tract"(Appendix I).

3.2 Soil

The soil of the experimental site was well drained and medium high .The physical and chemical properties of soil of the experimental site were examined prior to experimentation from 0-15 cm depth. The soil was loam in texture having soil P^{H} ranging from 5.46 to 5.61. Organic matter content was very low (0.82%).(Appendix II).

3.3 Climate

The climate is subtropical with low temperature and minimum rainfall during December to March. (Appendix III).

3.4 Treatments of the experiment

The experiment consisted of the following treatments:

Factor A: Variety

i. BRRI hybrid dhan-1

ii. BRRI dhan28

iii. BRRI dhan36 and

iv. BRRI dhan45

Factor B: Cutting height

i. 0 (zero) cm

ii. 15 cm

iii. 30 cm and

iv. 45 cm

3.5 Design and layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each replication was then divided into sixteen unit plots where in four cutting heights were distributed at random. Therefore, the total number of plots was 48 (16 × 3). The area of unit plot was 3 square meter (2 m x 1.5 m). The distance maintained between plots was one meter (1 m) and between replications was 1 m.

3.6 Main crop

3.6.1 Description of the variety

The varieties were BRRI hybrid dhan 1, BRRI dhan28, BRRI dhan36 and BRRI dhan45. They were released only for *boro* season by BRRI. Brief descriptions of these varieties are given as below.

BRRI hybriddhan-1: IR69690H genetic line was invented by crossing between IR58025 and BR827-35-2-1-1R. The station number of BRRI hybrid dhan1 is BRH1. After field trials at different regions of Bangladesh, at last in 2001 it was released by the name BRRI hybriddhan-1 and recommended for *boro* season. Stem and leaves are erect and green. Plant height ranged 110 cm. Ripen grain is golden in colour. Rice is medium fine, transparent and white. BRRI hybriddhan-1 can be successfully cultivated in the land which is affected by early flood or where aus rice is cultivated after *boro* rice. Life duration ranged 155 days. Average yield ranges 8.5 t/ha.

BRRI dhan28: In 1978, BR601-3-3-4-2-5 genetic line was invented by crossing between BR6 (IR28) and Purbachi. The station number of BRRI dhan28 is BR28. After field trials at different regions of Bangladesh, at last in 1994, it was released by the name BRRI dhan28 and recommended for *boro* season. Stem and leaves are erect and green. Plant height ranged 85 to 90 cm. 1000-grain weight is 21.8 g. Ripen grain is fade golden in colour. Rice is medium fine and white. BRRI dhan28 can be successfully cultivated in the land which is affected by early flood or where aus rice is cultivated after bozo rice. Life duration ranged 135 to 140 days. Average yield ranges 4.5 to 5.0 t/ha. It is more diseases resistant to blast than Chandina. Besides, this is less susceptible to insect attack (BRRI, 1995).

BRRI dhan36: IR54791-19-2-3 genetic line was invented by crossing between IR64 and IR 35293-125-3-2-3. The station number of BRRI dhan36 is BR36. After field trials at different regions of Bangladesh, at last in 1998, it was released by the name BRRI dhan36 and recommended for *boro* season. Plant height ranged 90 cm. 1000-grain weight is 21.8 g. Ripen grain is fade golden in colour. BRRI dhan36 is cold tolerant in nature. The few seedlings are died due to chilling temperature. Rice is fine and slender. Life duration ranged 140 days. Average yield ranges 5.0 t/ha.

BRRI dhan45: BR5778-21-2-3 genetic line was invented by crossing between BR2 and TETEP. The station number of BRRI dhan45 is BR45. After field trials at different regions of Bangladesh, at last in 2005 it was released by the name BRRI dhan45 and recommended for *boro* season. Stem and leaves are erect and green. BRRI dhan45 is resistant to blast. Plant height ranged 100 cm. Ripen grain is fade golden in colour. Rice is medium fine and white. Life duration ranged 145 days. Average yield ranges 6.5 t/ha.

3.6.2 Collection of seed

Seed of BRRI hybrid-1, BRRI dhan28, BRRI dhan36 and BRRI dhan45 were collected from BRRI Joydebpur, Gazipur.

3.6.3 Sprouting of seed

The seeds were dipped in water in bucket for 24 hours. The seeds were then taken out of water and kept thickly in gunny bags. The seeds started sprouting after 24 hours and completed sprouting within 48 hours and became suitable for sowing in the nursery bed by 72 hours.

3.6.4 Preparation of nursery bed

A piece of high land was selected in the Agronomy Field of Sher-e-Bangla Agricultural University, Dhaka for raising seedlings. The land was puddle with country plough, cleaned and leveled thoroughly with ladder to get a well puddle and leveled seedbed. Then the sprouted seeds were sown in the prepared nursery beds on 29 November 2009.

3.6.5 Land preparation

The land was opened in a water saturated condition with power tiller. The land was then prepared by repeated ploughing and cross ploughing with power triller. For breaking clods and leveling of the land, triller ladder was used. The weeds and stubble were removed and the land was then laid out according to the design adopted. The layout was completed after making ails, drains and channels.

3.6.6 Fertilizer application

For inbreed variety, the field was fertilized with urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate @ 250, 125, 80, 70 and 10 kg/ha in order to supply nitrogen, phosphorus, potassium, sulphur and zinc, respectively. Urea was applied in three times, during land preparation, after first weeding and after second weeding.

For hybrid variety, the field was fertilized with urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate @ 300, 200, 200, 50 and 12 kg/ha in order to supply nitrogen, phosphorus, potassium, sulphur and zinc, respectively except urea, the whole amount of other fertilizers were applied before final land preparation. Urea was top dressed in three equal splits at 15, 30 and 50 days after transplanting.

3.6.7 Uprooting of seedlings and transplanting

The seedlings were uprooted from the nursery bed early in the morning on 30 December 2009 with due care so as to avoid injury and kept on soft mud in shade to avoid mechanical injury to the roots. Transplanting was done with 42 day old seedlings in the main field.

3.6.8 Gap filling

Seedlings in some hills died off and these were replaced by the healthy ones from the same source on 18 January 2010.

3.6.9 Water management

The crop was irrigated three times during the whole growth period in order to maintain a constant water level in the field. Water was drained off the plots prior to the top dressing of urea and the plots were again irrigated after the application of urea. Excess water was drained out during the heavy rainfall. The field was finally drained out before 15 days of harvest to enhance maturity.

3.6.10 Weeding

Crops were infested with different weeds. Weeding was done two times by hand pulling on 28 January and 27 February 2010.

3.6.11 Plant protection measures

The crop was infested by the stem borer at the vegetative phase and rice bug, which were successfully controlled by application of Furadan 5 G @ 0.010 kg/ha mixed with 40g urea on 18 March 2010 and Malataf @ 454 ml/acre (25 ml/10L water) on 15 April 2010, respectively.

3.6.12 General observation

The field was observed frequently to notice any change in plant characters but the general condition of the crop was good from transplanting to harvesting.

3.6.13 Harvesting

Harvesting was done at physiological maturity of the main crops and cutting height of them was maintained according to the experimental treatment.

3.7 Ratoon crop

3.7.1 Cultural management

After 7 days of harvesting of the main crop the field was hand weeded and urea was top dressed at the rate of 50 g per plot (120 kg/ha). It was then mixed thoroughly with soil by a weeder. No irrigation was given as there was enough rainfall during the growing period of the ratoon crop whereas drainage was made as and when required. No plant protection measure was taken due to lack of disease infection and insect attack.

3.7.2 Sampling, harvesting and processing

Ten hills from each plot were randomly selected, uprooted and properly tagged before harvesting for recording the necessary data on crop characters. The crop of each plot was harvested at the ground level at full maturity when 80% of the grains turned golden yellow.

3.7.3 Data collection

Data on the following yield and yield contributing characters were collected:

i) Plant height (cm)

ii) Total number of tillers /hill

iii) Number of effective tillers/ hill

iv) Number of non- effective tillers/ hill

v) Days to panicle initiation

vi) Panicle length (cm)

vii) Number of total grains/ panicle

viii) Number of sterile spikelets/ panicle

ix) Total number of spikelets/ panicle

x) Days to maturity

xi) 1000-grain weight (g)

xii) Grain weight per hill

xiii) Grain yield (t/ ha)

xiv) Straw yield (t/ha) and

xv)Harvest index (%)

3.7.4 Procedure of data collection

A brief outline of data collection given procedure is given below.

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

Total number of tillers per hill: Tillers which had at least one leaf visible were counted. It included both effective and non-effective tillers.

Number of effective tillers per hill: The panicle which had at least one grain was considered as effective tiller.

Number of non-effective tillers hill: The panicle which had no grain was regarded as non-effective tiller.

Panicle length: Panicle length was recorded from the neck-node of the rachis to the tip of each panicle.

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

Number of sterile spikelets per panicle: Spikelet lacking any food material inside was considered as sterile spikelet and such spikelets present on the each panicle were counted.

Total number of spikelets per panicle: It included both grains per panicle and sterile spikelets per panicle.

1000-grain weight: One thousand clean dried grains were counted from the sun dried seed stock obtained from the ten sample plants of each plot and their weight was taken by using an electric balance.

Grain yield: Grains obtained from central 1 m^2 area of each unit plot were sun dried and weighed carefully. The grain yield was eventually converted to t/ ha.

Straw yield: Straw obtained from central 1 m^2 area of each unit plot including the straw of ten sample hills of respective unit plot was dried in the sun, weighed and finally converted to t /ha.

Harvest index (%): Harvest index is the ratio of economic yield to biological yield and was calculated with the following formula (Gardner *et al.*, 1985).

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

3.7.5 Statistical analysis

Data recorded for different parameters were compiled and tabulated in proper form for statistical analysis. Analysis of variance was done (excluding data of crop duration) with the help of computer package MSTAT. The mean differences among the treatments were adjudged by Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

CHAPTER IV
RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

Results of the present study have been presented and discussed in this chapter. The summary of analysis of variance of all the plant characters studied for the ratoon crops has been presented in Appendix IV-XI. The results of effect of variety, cutting height and effect of interaction of variety and cutting height on different crop characters have been presented in Tables 1-8. The results obtained from the study are presented and discussed hereafter under different heads.

4.1 Plant height

4.1.1 Effect of variety on the plant height of ratoon crop

Height of the rice plant is dependent on the number of internodes and their length. Height of the plant may be responsible for variety. The plant height of ratoon crop was significantly affected by the different varieties of main crop. However, numerically the tallest plants were observed when the main crop variety was BRRI hybriddhan-1, whereas the shortest plants were recorded in BRRI dhan36 (Table 1, Fig.1, Appendix IV).

4.1.2Effect of cutting height on the plant height of ratoon crop

The effect of cutting height on plant height was significant (Appendix IV). The tallest plants were obtained from the culm cutting height of 45 cm was 73.93. On the contrary, the shortest plants were produced from the 0 cm of culm cutting height (Fig2). The cutting height of 30 cm produced that type of plants which were shorter than those produced at 45 cm cutting height and taller than those produced in 15 cm cutting height. This variation might be due to more nutrients stored in 45 cm cutting height of culm than that in 15 cm for the nourishment of the subsequent plant.

4.1.3Effect of interaction of variety and cutting height on the plant height of ratoon crop

The interaction between variety and cutting height had significant effect on plant height (Table 2, fig-3 Appendix IV). Numerically, the tallest plants (80 cm) were produced when the main crop was BRRI dhan28 by maintaining 45 cm cutting height. On the other hand, the shortest plants (62.96 cm) were produced when the main crops were BRRI dhan36 with a cutting height of 15 cm (Table 2).

4.2Total number of tillers per hill

4.2.1 Effect of variety on the total number of total tillers per hill of ratoon crop

The total number of tillers per hill was highly influenced by the variety (Appendix IV). Significantly highest total number of tillers per hill was produced when the main crop was BRRI dhan28 (Table 1). The lowest total number of tillers per hill was obtained when the main crop was BRRI hybriddhan-1. Second highest tillers of variety were BRRI dhan36.

4.2.2 Effect of cutting height of main crop on the total number of tillers per hill of ratoon crop

Culm cutting height had significant effect on the total number of tillers per hill (Appendix IV). The highest total number of tillers (10.64) per hill was recorded in 30 cm and 45 cm cutting height whereas the lowest total number of tillers per hill was found in 0 cm cutting height of culm (Table 1). Total number of tillers per hill produced at 15 cm cutting height was 10.35.

4.2.3Effect of interaction of variety and cutting height on the total number of tillers per hill of ratoon crop

Total number of tillers per hill was statistically influenced by the interaction of variety and cutting height (Appendix IV). But numerically, the highest total number of tillers per hill was (11.38) found when the main crop was BRRI dhan28 with 15 cm cutting height while the lowest one was(9.52) found in the interaction of BRRI hybriddhan-1 and 15 cm cutting height (Table 5). For 0 cm cutting height all variety shows result nil.

4.3Number of effective tillers per hill

4.3.1Effect of variety on the number of effective tillers per hill of ratoon crop

A rice plant may produce a number of tillers during its early growth period but all of them are not effective, that is, they do not bear panicles. So this character is directly related to yield of rice. Number of effective tillers per hill was significantly affected by variety (Appendix VI). The highest number of effective tillers per hill was (12.40) produced when the variety was BRRI dhan28 (Table 5). The lowest number of effective tillers per hill was(11.65) observed for BRRI hybrid dhan-1. The variation in producing the number of effective tillers per hill in different variety was also observed by Siddique*et al.*, (1995).

4.3.2Effect of cutting height on the number of effective tillers per hill of ratoon crop

Culm cutting height produced highly significant effect on the number of effective tillers per hill (Appendix VI). The highest number of effective tillers per hill was (13.73)observed at 30 cm cutting height (Table 5). This might be due to more food material reservation in the longest stubble which helped in the production of more effective tillers per hill. On the other hand, the lowest number of effective tillers per hill was (5.16) produced in 15 cm cutting height. No tillers produced of 0 cm cutting height of plant.

4.3.3 Effect of interaction of variety and cutting height on the number of effective tillers per hill of ratoon crop

The number of effective tillers per hill was significant due to interaction of variety and cutting height (Appendix VI). Numerically, the highest number of dhan28 by cutting it at 45 cm culm height while the lowest one was (4.60) produced by the variety of BRRI hybrid dhan-1 when cut at 15 cm culm height (Table 6).

4.4 Number of non-effective tillers per hill

4.4.1Effect of variety on the number of non-effective tillers per hill of ratoon crop

Number of non-effective tillers per hill was significantly influenced by the variety (Table 3, Appendix V). Numerically, the lowest number of non-effective tillers per hill was (1.61)produced when the main crop variety was BRRI dhan28 whereas the highest number of non-effective tillers per hill was (1.88) produced at the variety of BRRI hybrid dhan-1.

4.4.2 Effect of cutting height on the number of non-effective tillers per hill of ratoon crop

Cutting height had highly significant effect on the number of non-effective tillers per hill (Appendix V). Numerically, the highest (4.342) number of non--effective tillers per hill was found at 15 cm cutting height and the lowest was produced in 30cm cutting height (Table 3).

4.4.3 Effect of interaction of variety and cutting height on the number of non-effective tillers per hill of ratoon crop

The number of non-effective tillers per hill was significantly affected due to the interaction effect of variety and cutting height (Appendix V). Numerically, the interaction of BRRI hybrid dhan-1 with 15 cm cutting height produced the highest number of non-effective tillers per hill 4.86 whereas BRRI dhan28 with 45 cm cutting height produced the lowest one 3.16 (Table 4).

4.5Days to panicle initiation

4.5.1Effect of variety on days to panicle initiation of ratoon crop

The panicle initiation was significantly affected by different varieties (Appendix IV). Numerically, the minimum days required for panicle initiation for the variety of BRRI dhan28. On the contrary, the maximum days required for panicle initiation for the variety of BRRI dhan36 (Table 1).

4.5.2Effect of cutting height on days to panicle initiation of ratoon crop

The panicle initiation was significantly affected by cutting height (Table 1, Appendix IV). Numerically, the minimum days (33.75 days) required to panicle initiation for 45 cm cutting height of main plant. On the contrary, the maximum days (35.80 days) required to panicle initiation for 15 cm cutting height of main crop.

4.5.3Effect of interaction of variety and cutting height on thel panicle initiation of ratoon crop

The panicle initiatio was statistically influenced by the interaction of variety and cutting height (Table 2, Appendix IV). Numerically, the minimum days required to panicle initiation for BRRI dhan28 with 45 cm cutting height and BRRI dhan28 with 30 cm cutting height of main plant(30.00). On the contrary, the maximum days required to panicle initiation for BRRI dhan36 and 15 cm cutting height of main crop(40.00).

4.6 Panicle length

4.6.1Effect of variety on the panicle length of ratoon crop

The panicle length was highly significant affected by different vareties (Appendix VI). Numerically, the longest(17.09) and shortest(14.11) panicles in the ratoon crop were produced when the main crop variety was BRRI dhan28 and BRRI hybrid dhan-1, respectively (Table 5).

4.6.2Effect of cutting height on the panicle length of ratoon crop

Culm cutting height significantly affected the panicle length in ratoon crop (Appendix VI). A cutting height at 45 cm produced the longest (16.05 cm) panicles. On the other hand, the shortest (15.02 cm) panicles were obtained from 15 cm cutting height (Table 5).

4.6.3Effect of interaction of variety and cutting height on the panicle length of ratoon crop

The panicle length was significantly affected by the interaction of variety and cutting height (Appendix VI). But, it was observed that numerically the longest panicle was(17.18) produced by BRRI dhan28 when cut at 30 cm. On the other hand, the shortest length was(13.80) produced when the main crop was harvested at 15 days for BRRI hybrid dhan-1 (Table 6).

4.7 Number of total grains per panicle

4.7.1 Effect of variety on the number of total grains per panicle of ratoon crop

The number of grains per panicle in the ratoon crop was significantly affected by the variety (Appendix VI). The highest number of grains per panicle was(121.80) recorded when the main crop was BRRI dhan28 (Table 5). The lowest number of grains per panicle was(93.70) observed of BRRI hybrid dhan-1.

4.7.2 Effect of cutting height on the number of total grains per panicle of ratoon crop

Culm cutting height produced not significant effect on the number of grains per panicle (Table 5, Appendix VI). The highest (103.9) number of gains per panicle was observed at 45 cm cutting height of culm and the lowest number of grains (105.4) per panicle was produced at 15 cm cutting height.

4.7.3 Effect of interaction of variety and cutting height on the number of grains per panicle of ratoon crop

The effect of interaction between variety and cutting height on the number of grains per panicle was significant (Appendix VI). Numerically, the highest number of grains per panicle was (123.8) produced by BRRI dhan28 with 15 cm cutting height and the lowest one was(91.80) produced by BRRI hybrid dhan-1 with 15 cm cutting height (Table 6).

4.8 Number of sterile spikelets per panicle / Number of unfilled grains per panicle

4.8.1 Effect of variety on the number of sterile spikelets per panicle of ratoon crop

Among the undesirable traits, number of sterile spikelets per panicle is the most important and it plays a major role in yield reduction. The effect of hybrid on the number of sterile spikelets per panicle was significant (Appendix V). Numerically, the highest number of sterile spikelets per panicle was(16.20)recorded when the main crop was BRRI hybrid dhan-1 whereas the lowest one was observed for BRRI dhan36 (Table 3).

4.8.2 Effect of cutting height on the number of sterile spikelets per panicle of ratoon crop

Culm cutting height shows significant effect on sterile spikelets per panicle (Appendix V). Numerically, the highest sterile spikelets per panicle were found at 15 cm cutting height and the lowest of that was produced in 30 cm cutting height (Table 3).

4.8.3 Effect of interaction of variety and cutting height on the number of sterile spikelets per panicle of ratoon crop

In ratoon crop, the interaction between variety and cutting height had significant effect on the number of sterile spikelets per panicle (Appendix V). Apparently, the highest number of sterile spikelets per panicle was (39.20) produced from the interaction of BRRI hybrid dhan-1 and 15 cm cutting height whereas the lowest one was (23.40) recorded from the interaction of BRRI dhan36 of 30 cm cutting height (Table 4).

4.9 Total number of spikelets per panicle / Number of filled grains per panicle

4.9.1 Effect of variety on the total number of spikelets per panicle of ratoon crop

Hybrid differed significantly in respect of total number of spikelets per panicle (Appendix VII). BRRI dhan28 produced the highest total number of spikelets per panicle(94.63) in the ratoon crop (Table 7). In the ratoon crop the lowest total number of spikelets per panicle was (57.07) observed when the main crop was BRRI hybrid dhan-1.

4.9.2 Effect of cutting height on the total number of spikelets per panicle of ratoon crop

Culm cutting height produced significant effect on the total number of spikelets per panicle (Appendix VII). The highest (76.25) number of spikelets per panicle was observed at 45 cm cutting height of culm and the lowest (71.75) one was produced at 15 cm cutting height (Table 7). Total number of spikelets per panicle produced in the cutting height of 30 cm was higher than that produced in 15 cm cutting height and lower than that produced in 45 cm cutting height.

4.9.3 Effect of interaction of variety and cutting height on the total number of spikelets per panicle of ratoon crop

The effect of interaction between variety and cutting height on the total number of spikelets per panicle was significant (Appendix VII). Numerically, the highest total number of spikelets per panicle was(96.00) produced when the main crop was BRRI dhan28 at a height of 30 cm and the lowest one was (52.60) produced for BRRI hybrid dhan-1with 15 cm cutting height (Table 8).

4.10 Days to maturity

4.10.1 Effect of variety on days to maturity of ratoon crop

Hybrid differed significantly in respect of days to maturity of ratoon crop (Appendix IV). BRRI dhan36 required the maximum days to maturity in the ratoon crop (Table 1). In the ratoon crop the minimum days required to maturity takes by BRRI dhan28.

4.10.2 Effect of cutting height on days to maturity of ratoon crop

Cutting height differed not significantly in respect of days to maturity of ratoon crop (Table 1, Appendix IV). The maximum days to maturity in the ratoon crop required at the 15 cm cutting height and the minimum days required to maturity at the 45 cm cutting height.

4.10.3 Effect of interaction of variety and cutting height on days to maturity of ratoon crop

The effect of interaction between variety and cutting height on the days to maturity was significant (Appendix IV). Numerically, the maximum days(69.00) to maturity required when the main crop was BRRI dhan36 at a height of 15 cm and the minimum days(60.00) to maturity required when the main crop was BRRI dhan28 lowest with 30 cm and 45 cm of cutting height (Table 2).

4.11. 1000-grain weight

4.11.1 Effect of variety on the 1000-grain weight of ratoon crop

In the present study 1000-grain weight was significantly affected by the variety of main crop (Appendix VII). Numerically, the highest 1000- grain weight was(24.27) observed when the main crop was BRRI dhan36 whereas the lowest 1000-grain weight was (22.98) recorded in BRRI dhan28 (Table 7).

4.11.2 Effect of cutting height on the 1000-grain weight of ratoon crop

Culm cutting height exerted significant effect on 1000-grain weight (Appendix VII). The 1000-grain weight produced at culm cutting height of 30 cm was numerically greatest and that produced at 15 cm cutting height of culm was numerically the smallest (Table 7).

4.11.3 Effect of interaction of variety and cutting height on the 1000-grain weight of ratoon crop

The effect of interaction between variety and cutting heights on 1000-grain weight was significant (Appendix VII). Apparently, the highest 1000-grain weight was found in the interaction of BRRI dhan36 and 30 cm cutting height and the lowest 1000-grain weight was found in the interaction of BRRI dhan28 and 15 cm cutting height (Table 8).

4.12 Grain weight per hill

4.12.1 Effect of variety on the grain weight per hill

In this study, the grain weight per hill was significantly affected by the variety of rice (Table 7, Appendix VII). The highest grain weight per hill (14.97 g/hill) was produced when the main crop was BRRI dhan28, it might be due to production of highest number of effective tiller per hill and highest number of grains per panicle. The second highest yield (13.41 g/hill) was produced when main crop was BRRI dhan36.

4.12.2 Effect of cutting height on grain weight per hill

The culm cutting height produced a significant effect on the grain weight per hill (Table 7, Appendix VII). The highest grain weight per hill (12.84 g/hill) was obtained from 30 cm cutting height while the lowest grain yield (9.895g/hill) was produced from 15 cm cutting height. Grain weight per hill produced in 45 cm cutting height was in between to that produced in these two cutting heights. The highest grain yield at 30 cm culm height might be due to more accumulation of food materials into grains from comparatively vigorous plants.

4.12.3 Effect of interaction of variety and cutting height on the grain weight per hill

The interaction between variety and cutting height had no significant effect on grain yield (Table 8, Appendix VII). Apparently, the highest grain weight per hill (16.57 g/hill) was produced when the main crop was BRRI dhan28 by cutting them at a height of 30 cm and the lowest grain yield (6.190 g/hill) was produced by BRRI hybriddhan-1 at a height of 15 cm.

4.13 Grain yield

4.13.1 Effect of variety on the grain yield of ratoon crop

Grain yield is the ultimate objective of rice cultivation. The yield of rice is mainly dependent on the yield contributing characters like, number of effective tillers per hill, number of grains per panicle, weight of individual grains or thousand grain weights. In this study, the grain yield was significantly affected by the variety of rice (Figure 1, Appendix VII). The highest grain yield (1.816 t/ha) was produced when the main crop was BRRI dhan28, it might be due to production of highest number of effective tiller per hill and highest number of grains per panicle. The second highest yield (1.787 t/ha) was produced when main crop was BRRI dhan36.

4.13.2 Effect of cutting height on grain yield of ratoon crop

The culm cutting height produced a significant effect on the grain yield of ratoon crop (Figure 2, Appendix VII). The highest grain yield was obtained from 30 cm cutting height while the lowest grain yield was produced from 15 cm cutting height. Grain yield produced in 45 cm cutting height was in between to that produced in these two cutting heights. The highest grain yield at 30 cm culm height might be due to more accumulation of food materials into grains from comparatively vigorous plants. Haque (1975) also reported that cutting the main crop at 25 cm above the ground level produced the highest yield in ratoon crop.

4.13.3 Effect of interaction of variety and cutting height on the grain yield of ratoon crop

The interaction between variety and cutting height had no significant effect on grain yield (Figure 3). Apparently, the highest grain yield (2.209 t/ha) was produced when the main crop was BRRI dhan28 by cutting them at a height of 30 cm and the lowest grain yield (0.825 t/ha) was produced by BRRI hybriddhan-1 at a height of 15 cm.

4.14 Straw yield

4.14.1 Effect of variety on the straw yield of ratoon crop

The straw yield was significantly influenced by variety (Table 3, Appendix V). The lowest (2.54 t/ha) straw yield in the ratoon crop was produced when the main crop was BRRI dhan45. The highest (3.94 t/ha) straw yield in the ratoon crop was produced when the main crop was BRRI dhan28.

4.14.2 Effect of cutting height on straw yield of ratoon crop

Straw yield differed significantly due to cutting height of culm (Appendix V). Results indicated that the highest straw yield was produced from 45 cm culm cutting height and the lowest straw yield was recorded at 15 cm culm cutting height (Table 3). The reason for the production of highest straw yield at 45 cm cutting height was its production of tallest plants and highest total number of tillers per hill. The straw yield produced in case of 30 cm cutting height was intermediate between, and significantly dissimilar to, that produced in other two cutting heights.

4.14.3 Effect of interaction of variety and cutting height on the straw yield of ratoon crop

Significant response was observed in straw yield due to the interaction effect of variety and cutting height (Appendix V). Apparently, the highest straw yield was(4.08) found in the variety BRRI dhan28 with 45 cm cutting height while the lowest one was(2.39) found in the variety BRRI dhan45 with 15 cm cutting height (Table 4).

4.15 Harvest index

4.15.1 Effect of variety on the harvest index of ratoon crop

Harvest index, the ratio of economic yield to the biological yield, is a measure of the efficiency of conversion of photosynthates into economic yield (Gautom and Sharma, 1989). In general, grain yield is the economic yield in case of rice while both grain and straw yields together refer to the biological yield. In this study the harvest index was significantly affected by the hybrid (Appendix V). Numerically, the highest harvest index was recorded from the variety BRRI dhan36 whereas the lowest harvest index was produced when the main crop variety was BRRI hybrid dhan-1 (Table 3).

4.15.2 Effect of cutting height on the harvest index of ratoon crop

Culm cutting height exerted significant effect on harvest index (Appendix V). Numerically, the highest (35.92) harvest index was found at 30 cm cutting height of culm and the lowest harvest index was produced with 15 cm cutting height of culm (Table 3).

4.15.3 Effect of interaction of variety and cutting height on the harvest index of ratoon crop

Harvest index was significantly affected by the interaction of variety and culm cutting height (Appendix V). Results indicated that numerically the highest harvest index was (40.40) obtained when the main crop variety was BRRI dhan36 by maintaining a cutting height of 45 cm and the lowest harvest index was(25.36) found when the main crop variety was BRRI hybrid dhan-1 by maintaining a cutting height of 15 cm (Table 4).

Table 1: Effect of cutting height and varaity on phenological and morphological characters of ratoon crop in boro rice

Treatments	Days to panicle emergence		Days to maturity		Plant height (cm)		Total number of tillers/hill	
	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop
Cutting height								
C0	0		0		0		0	
C15	35.80a		64.95		67.11b		10.35	
C30	33.83b		36.90		72.43a		10.64	
C45	33.75b		36.75		73.93a		1064	
F-test	*		NS		**		NS	
SD	0.50		0.44		0.64		0.13	
Variety								
BRRI hybrid-1	35.77b	86.00a	65.60b	116.00a	73.30b	100.10a	9.52c	13.53b
BRRI dhan28	30.50d	70.00d	60.10d	100.00d	77.40a	88.70b	11.38a	14.01ab
BRRI dhan36	37.97a	81.00b	65.77a	111.00b	66.00c	78.90c	11.14a	15.06a
BRRI dhan45	33.60c	75.00c	63.33c	105.00c	68.00c	85.20b	10.14b	11.54c
F-test	**	**	**	**	**	**	**	**
SD	0.57	1.41	0.51	0.99	0.74	1.37	0.11	0.42
CV(%)	4.99	4.14	2.39	3.21	3.12	2.70	3.66	2.70

In a column, figures bearing same letter(s) do not differ significantly at P< = 0.05 by DMRT; *,** indicate significance at 5 and 1 % respectively. NS = non significant, Ratoon crop was not successful at 0 cm cutting height. Values under ratoon crop indicate from days of cutting while those of the main crop from days after sowing.

Table 2. Interaction effect of variety and cutting height on phonological and morphological characters of ratoon crop in boro rice

Interaction (Variety × cutting height)	Days to panicle initiation	Days to maturity	Plant height (cm)	Number of total tillers hill^{-1}
$V_1 \times C_0$	---	---	---	---
$V_1 \times C_{15}$	37.20 ab	66.50 abc	68.03 de	9.460 d
$V_1 \times C_{30}$	35.10 bc	65.30 bcd	74.80 b	9.600 cd
$V_1 \times C_{45}$	35.00 bc	65.00 bcd	76.96 ab	9.500 d
$V_2 \times C_0$	---	---	---	---
$V_2 \times C_{15}$	31.50 de	60.30 ef	73.33 bc	11.45 a
$V_2 \times C_{30}$	30.00 e	60.00 f	78.80 a	11.33 a
$V_2 \times C_{45}$	30.00 e	60.00 f	80.00 a	11.36 a
$V_3 \times C_0$	---	---	---	---
$V_3 \times C_{15}$	40.00 a	69.00 a	62.96 f	10.60 b
$V_3 \times C_{30}$	36.90 ab	67.30 ab	66.86 def	11.40 a
$V_3 \times C_{45}$	37.00 ab	67.00 ab	68.18 de	11.41 a
$V_4 \times C_0$	---	---	---	---
$V_4 \times C_{15}$	34.50 bcd	64.00 cd	64.13 ef	9.910 bcd
$V_4 \times C_{30}$	33.30 cd	63.00 de	69.26 d	10.21 bc
$V_4 \times C_{45}$	33.00 cde	63.00 de	70.60 cd	10.30 bc
F-test	*	*	*	*
SD	0.99	0.885	1.28	0.22
CV (%)	4.99	2.39	3.12	3.66

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; *, indicates significance at 5% level of probability; ---: Ratoon crop was not developed at 0 cm height cutting. V_1 = BRRI hybriddhan-1, V_2 = BRRI dhan28, V_3 = BRRI dhan36, V_4 = BRRI dhan45, C_0 = Cutting height 0 cm, C_{15} = Cutting height 15 cm, C_{30} = Cutting height 30 cm and C_{45} = Cutting height 45 c

Table 3. Effect of cutting height and variety on crop characters of ratoon crop in boro rice

Treatment	Number of non-effective tillers $hill^{-1}$		Number of unfilled grains $panicle^{-1}$		Straw weight ($t\ ha^{-1}$)		Harvest index (%)	
Cutting height from base (cm)	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop
C0	0		0		0		0	
C15	4.342 a		32.10a		2.81b		31.70b	
C30	3.582 b		28.60b		3.03a		35.92	
C45	3.590 b		29.48b		3.12a		34.88a	
F-test	**		**		**		**	
SD	0.052		0.664		0.057		0.595	
Variety								
BRRI hybrid-1	4.357a	1.88a	36.67a	16.2a	2.65bc	6.62ab	28.55b	44.52b
BRRI dhan28	3.610b	1.61ab	27.17c	11.00b	3.94a	6.18b	33.51c	48.94ab
BRRI dhan36	3.667b	1.33b	24.70d	9.80b	2.82b	7.03a	38.66a	51.70a
BRRI dhan45	3.720b	0.76c	31.70b	11.1b	2.54c	5.59c	35.95b	47.75ab
F-test	**	**	**	**	**	**	**	**
SD	0.060	0.10	0.767	0.53	0.066	0.167	0.687	1.37
CV(%)	4.70	12.46	7.65	7.63	6.57	4.56	6.03	4.94

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; ** indicate significance at 1% level of probability, respectively;
---: Ratoon crop was not developed at 0 cm height cutting;

Table 4. Interaction effect of variety and cutting height on crop characters of ratoon crop in boro rice

Interaction (Variety × cutting height)	Number of non-effective tillers hill^{-1}	Number of unfilled grains panicle^{-1}	Straw weight (t ha^{-1})	Harvest index (%)
$V_1 \times C_0$	---	---	-----	---
$V_1 \times C_{15}$	4.860 a	39.20 a	2.43 c	25.36 e
$V_1 \times C_{30}$	4.110 c	34.60 bc	2.67 bc	30.81 cd
$V_1 \times C_{45}$	4.100 c	36.20 ab	2.86 b	29.47 d
$V_2 \times C_0$	---	---	---	---
$V_2 \times C_{15}$	4.450 b	30.40 c	3.74 a	31.42 cd
$V_2 \times C_{30}$	3.220 ef	26.10 d	4.02 a	35.47 b
$V_2 \times C_{45}$	3.160 f	25.00 d	4.08 a	33.63 bc
$V_3 \times C_0$	---	---	---	---
$V_3 \times C_{15}$	4.100 c	25.60 d	2.69 bc	35.46 b
$V_3 \times C_{30}$	3.400 def	23.40 d	2.85 b	40.13 a
$V_3 \times C_{45}$	3.500 de	25.10 d	2.91 b	40.40 a
$V_4 \times C_0$	---	---	---	---
$V_4 \times C_{15}$	3.960 c	33.20 bc	2.39 c	34.55 bc
$V_4 \times C_{30}$	3.600 d	30.30 c	2.59 bc	37.28 ab
$V_4 \times C_{45}$	3.600 d	31.60 c	2.63 bc	36.03 b
F-test	**	*	*	*
SD	0.104	1.328	0.113	1.189
CV (%)	4.70	7.65	6.57	6.03

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; *, ** indicate significance at 5% and 1% level of probability, respectively; ---: Ratoon crop was not developed at 0 cm height cutting. V_1 = BRRI hybriddhan-1, V_2 = BRRI dhan28, V_3 = BRRI dhan36, V_4 = BRRI dhan45, C_0 = Cutting height 0 cm, C_{15} = Cutting height 15 cm, C_{30} = Cutting height 30 cm and C_{45} = Cutting height 45 cm.

Table 5. Effect of cutting height and variety on yield attributes in ratoon crop of boro rice

Treatment	Number of total tillers hill^{-1}		Number of effective tillers hill^{-1}		Number of total grains panicle^{-1}		Panicle length (cm)	
Cutting height from base (cm)	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop
C0	0		0		0		0	
C15	10.35		6.012 b		103.9		15.42 b	
C30	10.64		7.052 a		105.4		16.02 a	
C45	10.64		7.052 a		105.7		16.05 a	
F-test	NS		**		NS		**	
SD	0.111		0.090		1.053		0.139	
Variety								
BRRI hybrid-1	9.520c	13.5b	5.163c	11.65bc	93.70c	134.4b	14.51d	23.77a
BRRI dhan28	11.38a	14.0ab	7.770a	12.40ab	121.8a	137.0ab	17.09a	21.68bc
BRRI dhan36	11.14a	15.1b	7.470a	13.73a	109.3b	145.7a	16.46b	22.68ab
BRRI dhan45	10.14b	11.4c	6.420b	10.69c	95.10c	128.0	15.27c	20.92c
F-test	**	**	**	**	**	**	**	**
SD	0.129	0.42	0.104	0.45	1.215	1.215	0.161	0.47
CV(%)	3.66	5.45	4.65	6.52	3.47	3.47	3.05	3.68

In a column, figures bearing same letter(s) do not differ significantly at P< = 0.05 by DMRT; *,** indicate significance at 5 and 1 % respectively. NS = non significant, Ratoon crop was not successful at 0 cm cutting height.

Table 6. Interaction effect of variety and cutting height on yield attributes and yield of ratoon crop in boro rice

Interaction (Variety × cutting height)	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Number of total grains panicle^{-1}	Panicle length (cm)
$V_1 \times C_0$	---	---	---	---
$V_1 \times C_{15}$	9.460 d	4.600 d	91.80 c	13.80 e
$V_1 \times C_{30}$	9.600 cd	5.490 c	93.20 c	14.83 d
$V_1 \times C_{45}$	9.500 d	5.400 c	96.10 c	14.90 d
$V_2 \times C_0$	---	---	---	---
$V_2 \times C_{15}$	11.45 a	7.000 b	123.8 a	17.00 a
$V_2 \times C_{30}$	11.33 a	8.110 a	122.1 a	17.18 a
$V_2 \times C_{45}$	11.36 a	8.200 a	119.4 a	17.10 a
$V_3 \times C_0$	---	---	----	---
$V_3 \times C_{15}$	10.60 b	6.500 b	106.3 b	16.01 bc
$V_3 \times C_{30}$	11.40 a	8.000 a	109.6 b	16.65 ab
$V_3 \times C_{45}$	11.41 a	7.910 a	112.1 b	16.71 ab
$V_4 \times C_0$	---	---	---	---
$V_4 \times C_{15}$	9.910 bcd	5.950 c	93.50 c	14.88 d
$V_4 \times C_{30}$	10.21 bc	6.610 b	96.70 c	15.43 cd
$V_4 \times C_{45}$	10.30 bc	6.700 b	95.10 c	15.50 cd
F-test	*	*	*	*
SD	0.223	0.180	2.11	0.278
CV (%)	3.66	4.65	3.47	3.05

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; *, indicates significance at 5% level of probability; ---: Ratoon crop was not developed at 0 cm height cutting. V_1 = BRRI hybriddhan-1, V_2 = BRRI dhan28, V_3 = BRRI dhan36, V_4 = BRRI dhan45, C_0 = Cutting height 0 cm, C_{15} = Cutting height 15 cm, C_{30} = Cutting height 30 cm and C_{45} = Cutting height 45 cm.

Table 7. Effect of cutting height and variety on yield attributes and yield in ratoon crop of boro rice

Treatment	Number of filled grains panicle $^{-1}$		1000-grain weight (g)		Grain weight hill^{-1} (g)	
Cutting height from base (cm)	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop	Main crop
C0	0		0		0	
C15	71.75 b		20.76 b		9.895 b	
C30	76.80 a		21.55 a		12.84 a	
C45	76.25 a		21.13ab		12.60 a	
F-test	**		*		**	
SD	0.866		0.181		0.118	
Variety						
BRRI hybrid-1	57.07d	118.2b	21.49a	23.39a	8.027d	32.21bc
BRRI dhan28	94.63a	126.0ab	19.92b	22.98a	14.97a	35.90b
BRRI dhan36	84.63b	135.9a	21.86a	24.27a	13.41b	45.29a
BRRI dhan45	63.40c	116.9b	21.31a	23.13a	10.70c	30.96c
F-test	**	**	**	NS	**	**
SD	1.00	4.01	0.209	0.428	0.136	1.37
CV(%)	4.00	5.59	2.96	3.17	3.46	6.60

DMRT; *, ** indicate significance at 5% and 1% level of probability, respectively;
: Ratoon crop was not developed at 0 cm cutting height.

Table 8. Interaction effect of variety and cutting height on yield attributes and yield of ratoon crop in boro rice

Interaction (Variety × cutting height)	Number of filled grains panicle^{-1}	1000-grain weight (g)	Grain weight hill^{-1} (g)
$V_1 \times C_0$	---	---	---
$V_1 \times C_{15}$	52.60 f	21.45 abc	6.190 g
$V_1 \times C_{30}$	58.60 e	21.50 abc	8.920 f
$V_1 \times C_{45}$	60.00 e	21.52 abc	8.970 f
$V_2 \times C_0$	---	---	---
$V_2 \times C_{15}$	93.40 a	19.66 c	12.85 d
$V_2 \times C_{30}$	96.00 a	20.10 bc	16.57 a
$V_2 \times C_{45}$	94.50 a	20.00 bc	15.50 b
$V_3 \times C_0$	---	---	---
$V_3 \times C_{15}$	80.70 c	21.11 abc	11.07 e
$V_3 \times C_{30}$	86.20 b	22.92 a	14.35 c
$V_3 \times C_{45}$	87.00 b	21.56 abc	14.80 c
$V_4 \times C_0$	---	---	---
$V_4 \times C_{15}$	60.30 e	20.81 bc	9.470 f
$V_4 \times C_{30}$	66.40 d	21.69 ab	11.52 e
$V_4 \times C_{45}$	63.50 de	21.44 abc	11.12 e
F-test	*	*	**
SD	1.73	0.363	0.235
CV (%)	4.00	2.96	3.46

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; *, ** indicate significance at 5% and 1% level of probability, respectively; ---: Ratoon crop was not developed at 0 cm height cutting. V_1 = BRRI hybriddhan-1, V_2 = BRRI dhan28, V_3 = BRRI dhan36, V_4 = BRRI dhan45, C_0 = Cutting height 0 cm, C_{15} = Cutting height 15 cm, C_{30} = Cutting height 30 cm and C_{45} = Cutting height 45

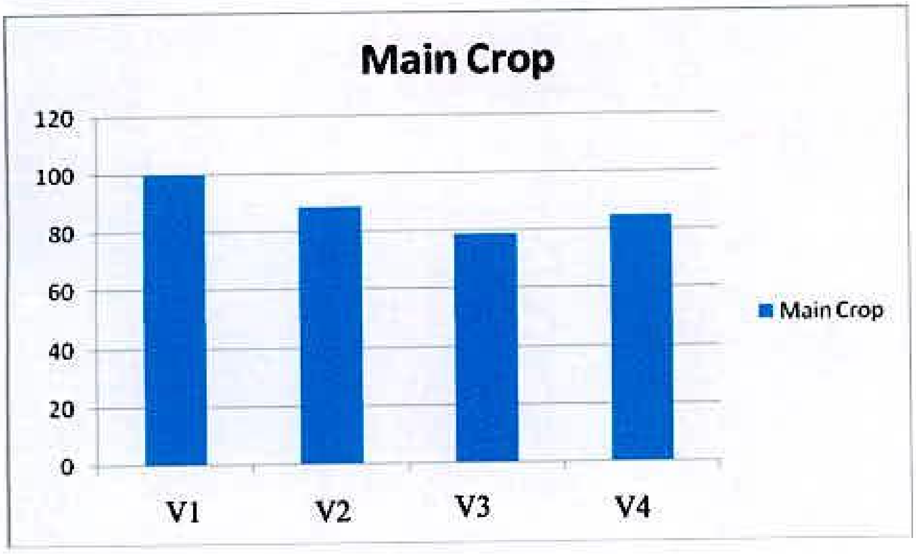


Figure 1: Plant height of main crop

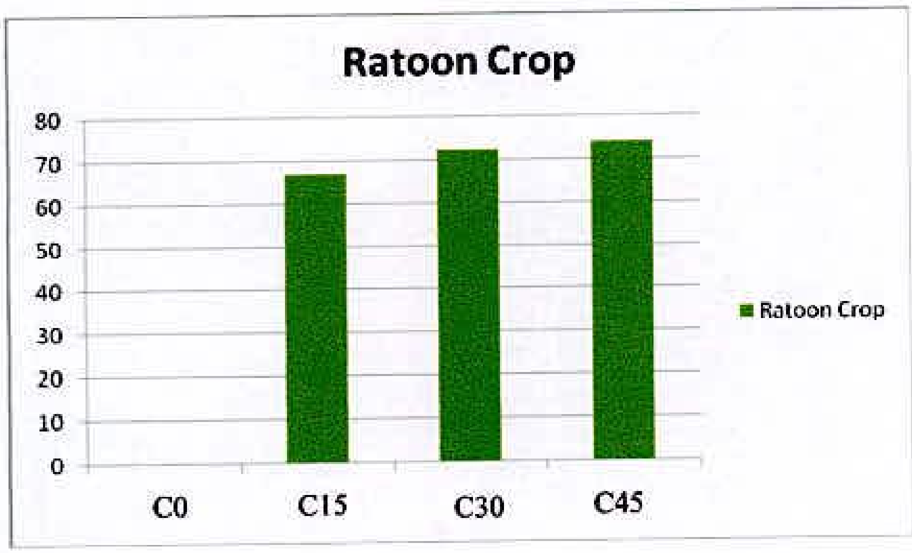


Fig.2: Plant height of ratoon crop

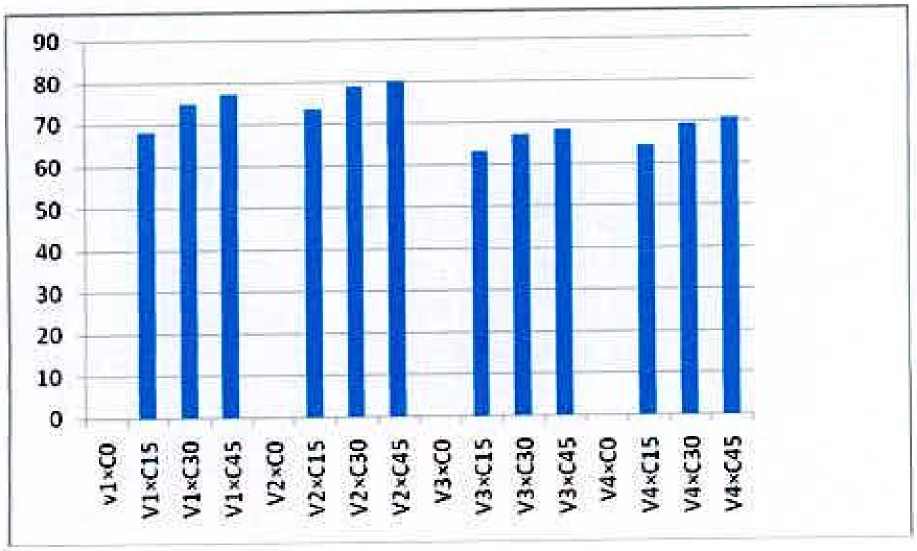


Figure 3: Interaction of main crop and ratoon crop on the basis of plant height.

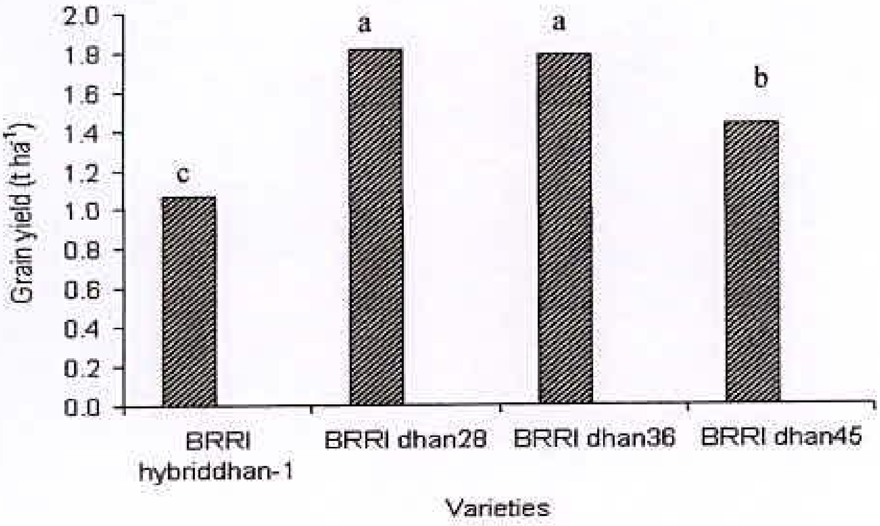


Fig. 4. Varietal variation in grain yield of boro rice.

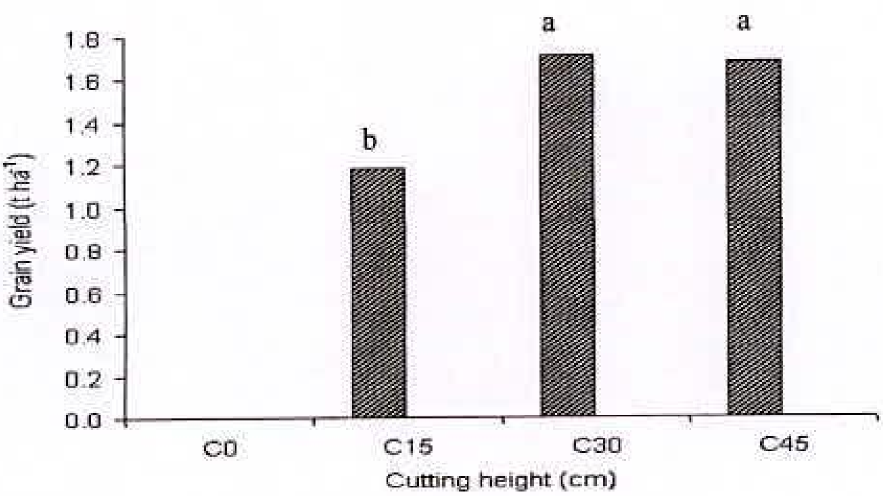


Fig. 5. Varietal variation in grain yield of boro rice.

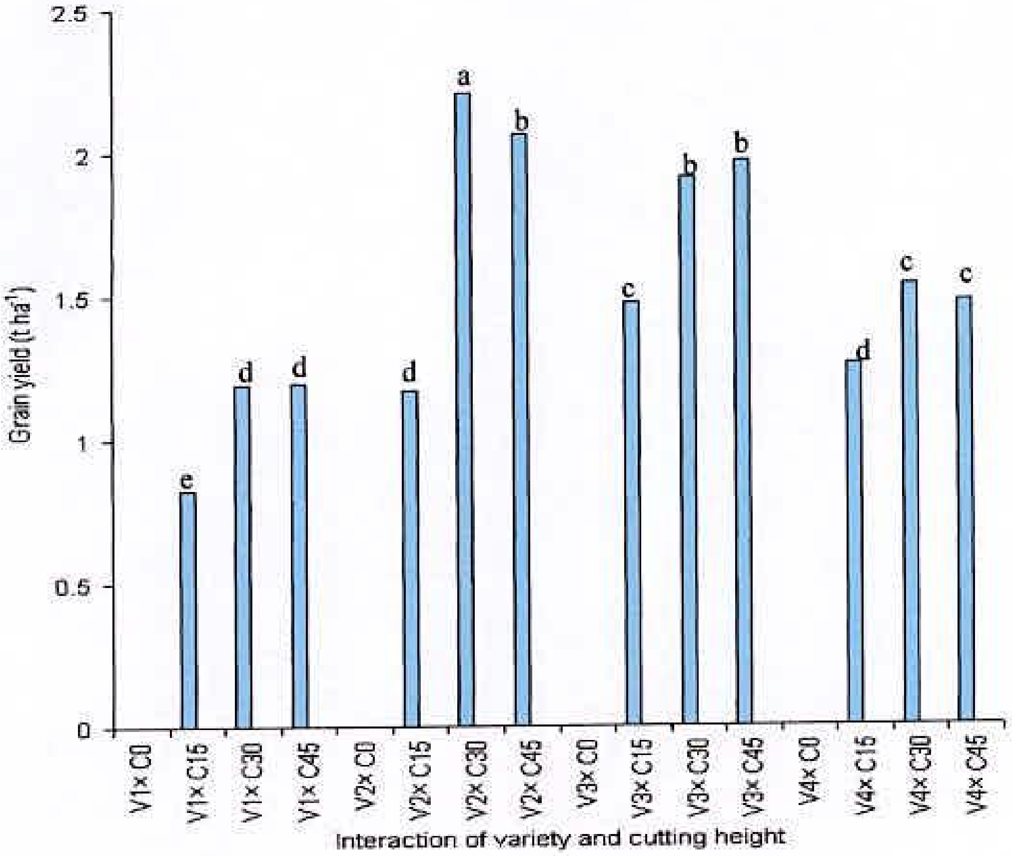


Fig. 6. Interaction of variety and cutting height on grain yield in ratoon crop of boro rice. V1 = BRRI hybriddhan-1, V2 = BRRI dhan28, V3 = BRRI dhan36 and V4 = BRRI dhan45; C0 = Cutting height 0 cm from base of main crop, C15 = Cutting height 15 cm, C30 =Cutting height 30 cm and C45 = Cutting height 45 cm.

CHAPTER V
SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The experiment was carried out at the Agronomy Field, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2009 to July 2010 with a view to studying the effects of variety and cutting height of main crop on the performance of ratoon crop of *boro* rice. The experiment was carried out in a Randomized Complete Block Design (RCBD) and was replicated thrice. The experiment included two factors which were applicable to the ratoon crop only. These were variety and cutting height. The varieties of main crop were BRRI hybriddhan-1, BRRI dhan28, BRRI dhan36 and BRRI dhan45 and the cutting heights included were 0cm, 15 cm, 30 cm and 45 cm above the ground level.

Forty-two day old seedlings of main crop varieties were transplanted on 1 January 2010 at the rate of one seedling for hybrid and three seedlings per hill for inbreed. For inbreed variety, the field was fertilized with urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate @ 250, 125, 80, 70 and 10 kg/ha in order to supply nitrogen, phosphorus, potassium, sulphur and zinc, respectively. For hybrid variety, the field was fertilized with urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate @ 300, 200, 200, 50 and 12 kg/ha in order to supply nitrogen, phosphorus, potassium, sulphur and zinc, respectively except urea, the whole amount of other fertilizers were applied before final land preparation. Urea was top dressed in three equal splits at 15, 30 and 45 days after transplanting.

The main crop was harvested in different dates leaving the culm height above the ground level according to the experimental treatment. Ratoon crop was fertilized with urea @ 300 kg/ha and 250 kg/ha for hybrid and inbreed respectively, after 7 days of harvesting main crop. Ten hills (excluding border per hills) were randomly selected from each unit plot prior to harvest for recording of necessary data on yield contributing characters of ratoon crop. Entire plot was harvested for taking grain and straw yield data.

Grain and straw yields of 10 sample plants of each plot of ratoon crop were added to those of the entire plot to calculate the yields (e.g. grain and straw) per unit plot. The data on crop characters like plant height, total number tillers per hill, number of effective tillers per hill, number of non-effective tillers per hill, per panicle length, number of grains per panicle, number of sterile spikelets per panicle, total number of spikelets per panicle, and 1000-grain weight were recorded from sample plants at maturity. Collected data were analyzed statistically and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT).

Variety had highly significant effect on all yield and yield contributing characters like plant height, total number of tillers per hill, number of effective tillers per hill, number of non-effective tillers per hill, panicle length, days to panicle initiation, number of grains per panicle, number sterile spikelets per panicle, total number of spikelets per panicle, days to maturity, 1000-grain weight, grain yield and straw yield. The variety BRRI hybriddhan-1 gave the best performance in terms of number of non-effective tillers per hill and number of unfilled grains per panicle. The variety BRRI dhan28 gave the best performance in terms of plant height, number of total tillers per hill, number of effective tillers per hill, panicle length, number of filled grains per panicle, grain weight per hill and straw weight. The variety BRRI dhan36 gave the best performance in terms of days to panicle initiation, days to maturity and 1000-grain weight. Number of total tillers per hill and number of effective tillers per hill produced in variety BRRI dhan28 were statistically similar to that produced in variety BRRI dhan36.

Cutting height had significant effect on almost all yield and yield contributing characters except number of total tillers per hill, number of total grains and days to maturity. A cutting height to 15 cm above the ground level gave the best performance in terms of days to panicle initiation, number of non-effective tillers per hill, number of unfilled grains per panicle and days to maturity. A cutting height to 30 cm above the ground level gave the best performance in terms of number of total tillers per hill, number of effective tillers per hill, number of filled grains per panicles, grain weight per hill and 1000- grain weights A cutting height to 45 cm above the ground level gave the best performance in terms of plant height, panicle length, number of total grains per panicles and straw weight. The plant height, panicle length, number of effective tillers per hill, number of filled grains per panicles, grain weight per hill, straw weight and harvest index produced in the cutting height of 30 cm was statistically similar to that produced in 45 cm cutting height.

The interaction of variety and cutting height of main crop had significant effect on any of the crop characters of ratoon crop. The interaction of variety and cutting height of main crop had highly significant effect on number of non-effective tillers per hill and grain weight per hill.

Based on the present study it can be said that for ratooning in born rice under the agro-ecological conditions of the present study BRRI dhan28 may be harvested at a height of 30 cm to get best yield. If, however, it is not possible, it may be harvested with a cutting height of 45 cm.

REFERENCES

REFERENCES

Alim,A. (1974). An Introduction to Bangladesh Agriculture. Publish by M.Alim,220 Garden road,Kawran Bazar,Tejgaon-1,Dacca-8.

Amorim N. S., Oliveira, A. D., Andrade, W. D., Fernandes, G. M. B., (1986). Effect of cutting height at harvest of rice on the yield of the ratoon crop. *Pesquisa em Andamento*, Pesagro-Rio No.41. p. 5.

Andrade, W. D., Amorim, N. S., Oliveira, A. D. and Fernandes, G. M. B. (1988). Utilization of Rice ratooning by farmers Rio de Janeiro State, Brazil. In: Rice Ratooning. pp. 55-60.

Bahar, F. A. and De Datta. S. K. (1977). Prospects of increasing total rice production through ratooning. *Agron. J.* **69**: 536-540.

Balasubramanian, B., Morachan, Y. B. and Kaliappa, R. (1970). Studies on ratooning in rice. 1. Growth attributes and yield. *Madras Agric. J.* **57**(11): 565-570.

Balasubramanian, R. and Krishnasamy, S. (1997). Rice ratooning as influenced by varieties, nitrogen and cutting height. *Madras Agric. J.* **84**(8): 489-491.

Bollich, C. N., Magill, C. W., Livore, A. B., Hung, H. H., Webb, B. D., Marchetti, M. A. and Scott, J. E. (1991). Registration of 'Maybelle' rice. *Crop Sci.* **31**(4): 1090.

BRRI (Bangladesh Rice Research Institute). (1995). Adhunik Dhaner Chash (in Bengali). Bangladesh Rice Res. Inst., Joydebpur, Gazipur. Pub. No. 5. pp. 6-7, 12-13, 19-21, 23.

Chang, L. Z., Hsieh, S. C. and Pai, C. (1985). Variations in ratooning ability of rice. Bull. Taichung Dist. Agric. Improv. Sta. 11, 93-100. [Rice Abst. 10 (4): 118].

Chaterjee, B. N., Bhattacharya, S. and Debnath., P.(1982). Ratooning of rice. Oryza 19 (3/4): 226-227.

Chauhan, J. S. (1988). Use of ratooning in hybrid rice. Central Rainfed Rice Res. Sta., Bihar, India. Rice Ratooning. pp.151-154.

Chauhan, J. S. Vergara, B. S. and Lopez, F. S. S. (1985). Rice ratooning. IRRI Res. 102. Intl. Rice Res. Inst., Los Banos, Philippines.

Chauhan, J. S., Virmani, S. S., Aquino. R. R. and Vergara, B. S. (1983). Evaluation of hybrid rices for ratooning ability. IRRI, Los Banos, Laquana, Philippines Intl. Rice Res. *Newsl.*8 **(6)** : 6.

Chen, L. Y., Xiao, Y. H., Tang, W. B. and Liu, D. M., (2000). An ideal planting pattern for the adjustment of grain yield structure- middle season rice and its ratoonrice. *J. Hunan Agric. Univ.* **26**(3): 160-162. [Rice Abst. 10 (4): 118].

Cheng, J. F., Pan, X. Y., Zeng, X. C., and Liu, Y, B. (2001). A study on the physiological properties of rationing rice. II. Effect of soluble carbohydrate content during the harvest of main crop. Acta-Agriculturae-Universitatis-Jiangxiensis. **23** (20: 167-170. [CAB Abst. 2002].

Das, G. R. and Ahmed, T. (1982). Performance of semi-dwarf rice varieties as ratoon crop after summer harvest. Oryza. **19**(3/4): 159-161.

Dishman, J. C. (1961). Ratooning methods of a Texas rice farmer. *Rice J.* **64**: 22.

Duncan, W. G. (1969). Cultural manipulation for higher yields. In: Physiological aspects of crop yield. ASA and Crop Sci. Society of America. USA. PR 327-339.

Escalada, P. and Plucknett, D. L. (1977). Ratoon cropping of sorghum. III. Effect of nitrogen and cutting height on ratoon performance. *Agron. J.* **69**(3): 341-346.

Evans, L. J. C. (1957). Ratoon rice. World Crops 9 (6): 227-228.

Evatt, N. S. (1958). Stubble rice production tests. *Rice J.* **61**(6): 18-19, 40.

Evatt, N. S. (1966). High annual yields of rice in Texas through ratoon or double cropping. *Rice J.* **69** (12): 10-12, 32.

Evatt, N. S. and Beachell, H. M. (1960). Ratoon cropping of short-season rice varieties in Texas. *Intl. Rice Res, Newsl.* **9**(3): 1-4.

FAO (Food and Agricultural Organization) and UNDP (United Nations Development Programme). (1988). Land Resources Appraisal of Bangladesh for Agricultural Development. Report No. 2, Agro-ecological Regions of Bangladesh. UNDP, FAO, Rome. pp. 212- 221.

Faris, E. A. (1984). Ratoon production of irrigated rice in Minas Gerais. Present situation and prospects. Inform Agropecua rio. 10: 51,114.

Flinchum, W. T. and Evatt. N. S. (1972). The effect of 2, 4-D and nitrogen on the stubble crop rice production in Texas, Rice Res. in Texas. Consolidated PR 3105. Sept. (1972).

Ganguly, B. D. and Ralwany, L. L. (1954). Possibilities of growing ratoon crop of paddy and increasing its yield under irrigated conditions. Field crop Abst. 7 (3): 146.

Gardner, F. P. Pearce, R. B. and Mistecheel, R. L. (1985). Physiology of Crop Plants. Iowa State Univ. Press, Iowa. pp. 66.

Gautom, R. C. and Sharma, K. C. (1989). Drymatter accumulation under different planting schemes and planting densities of rice. *Indian J. Agric. Res.* **21**: 101-109.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2nd ed. John Wiley and Sons, New York. p. 680.

Grist, D. H. (1965). Rice. London. Longmans, 571p.

Gupta, P. S. and Mitra, A. K. (1948). Possibilities of increasing the yield of rice by ratooning in the United Provinces. Indian Farm. 9: 13-15.

Gurumurthy, S., Muthuknshnan, P., Trumurugan, V. and Kaliappa, R.(1983). Studies of ratoon in IR20, Bhavani and CO42 rice varieties. *Madras Agric. J.* **70**(12): 825-826.

Haque, M. M. (1975). Varietal variation and evaluation procedures for ratoonability in rice (*Oryza sativa* L.) M. S. Thesis, Univ. of the Philippines, Los Banos, Philippnies.

Haque, M. M. and Coffman, W. R. (1980). Varietal variation and evaluation procedures for ratooning ability in rice. SABRAO J. 12 (2): 113-120.

Hoeges, R. J. and Evatt. N. S. (1969). Second crop rice production. Agron. Notes 69: 21-22.

Hsieh, C. F. and Kao, S. and Chiang, G. (1964). Studies on the method of growing rice from rations. Plant Breeding Abst. 37(1): 85.

Hsieh, C. F. and Young, F. P. (1959). Studies on the cultivation of ratoon. *J. Taiwan. Agr. Res.* **8** (2): 31-32 (English summary).

IRRI (International Rice Research Institute). (1975). Annual Report for 1975. Intl. Rice Res. Inst., Los Banos, Philippines. pp. 10, 79-81 and 294-296.

Ishi Kawa, T. (1964). Studies on the ratoon rice plant in early cultivation. Bull Faculty Agric. University of Miyazaki, Japan 10(1): 72-78 (In Japanese). English summary.

Jones, B. D. (1985). The effect of plant crop cutting height on ratoon crop performance and yield. Agron. J. 79: 623-626.

Jones, B. D. (1986). Ratoon crop management. Belle Glade EREC Res. Rep. No. EV-1986-6, 61-69.

Jones, B. D. (1993). Rice ratoon response to main crop harvest cutting height. *Agron. J.* **85**(6): 1139-1142.

Kaichu, Y. (1958). A study of regeneration rice. Field Crop Abst. 12(2):111.

Karunakaran, K., Jalajakumari, M. B. and Sreedevi, P. (1983). Ratoon performance of some short- duration rive cultivars. *Intl. Rice Res. Newls.* **8** (4): 4.

Krishnamoorthy, C. H. (1979). rainfed lowland rice-problems and opportunities. In rainfed low land rice. Selective papers from the 1978 IRRI Conference, Los Banos, Laguna, Philippines. pp. 61-71.

Lin, W., Li, Y. Z. Jiang, Z. W. and Zheng, J. S. (2001). Morphologic and functional differences of root systems among rationing varieties and its correlation with yield. *Fjian J. Agric, Sci.* **16** (1): 1-4. [CAB Abst. 2002].

Liu, Y. S., Zhou, K. D., Zeng, R. Y. and Luo, (1992). Evaluation for rice rationing ability of inter subspecific hybrid and its reletion to agronomic characters of mother plant. *Chinese J. Rice Sci.* **6** (4): 151-154.

Mahadevappa, M. (1979). Ratoon cropping to increase rice production. USA, Tec. Series 26:1-23.

Mahadevappa, M. (1988). Rice ratooning practice in India. In: Rice ratooning. Intl. Rice Res. Inst. pp. 69-78.

Mahadevappa, M., Reddy, T. G. and Nagaraju. (1988). Ratoon rice research in Karnataka, India. In: Rice Ratooning. Intl. Rice Res. Inst. pp. 105-109.

Mathew, G., Alexander, D. and Dev, V. P. S. (1992). Paddy- some promising ratooners. *Orissa J. Agric. Res*: **5** (1-2): 140-141.

Maurya, D. M., Vishwakarma, D. N. and Rathi, S. P. S. (1987). Whole plant rationing technique. Intl. Rice Res. Newsl. **12** (3): 3.

Mochizuki, T., Kajihara, Y., Torikai, Y. and Nakagawa, Y. (2000). Effects of fertilizer application and cutting height on growth and yield of ratooned rice. Sci. Bull. Fac. Agric., Kyushu Univ. **54**(3-4): 115-120.

Mohan, R., Balasubramanian, N., Aruna, L. and Narayan, A. L. (2000). Economic viability of rationing rice. *Madras Agric. J.* **87**(4-6): 299-302.

Nadal, A. M. and Carangal, V. R. (1979). Performance of the main and ratoon crops of 13 advanced rice selections under dry seeded rainfed bunded conditions. *Philipp. J. Crop Sci.* **4** (2/3): 95-101.

Nagai, I. (1958). Japonica rice – its breeding and culture. Yokendo Ltd., Tokyo. 843p.

Nair, N. R. and Sahadevan, P. C. (1961). A note on vegetative propagation of cultivated rice. *Curr. Sci.* **30**: 474-476.

Oh, W. K. and Sunarzo. W. (1969). Comparison between paddy ratoons grown after stalk cutting and panicle cutting. Departemon Pertanian, Djakarta. Penungkatan Produkksi Pangan, Statement Mentan / Menpen 23 Djuli. 1958. pp. 6.

Palchamy, A., (1986). A note on the yield and duration of ratoon rice varieties. Mad*ras Agric. J.* **73** (8): 466-467.

Palchamy, A., Purushothaman, S. and Rajogopal, A. (1990). Effect of stem thichness and carbohydrate content on ratoon rice yield. *Intl. Rice Res. Newsl.* **15** (2): 10.

Parago, J. E. (1963). A review of work on rice ratooning in the Philippines. *Agric. Ind. Life* **25**(7): 8-9, 39.

Parago, J. F. (1963). Rice ratoon culture. *Agric. Ind. Life* **25(8)**: 15, 45, 47.

Pena, R. S. Dela and Plucknett, D. L. (1972). Ratoon performance of IR8 and IR22 at different cutting heights. In: Proc. 14th Rice Tech. Working Group; Univ. Calif. Davis. pp.83.

Plucknett, D. L., Everson, J. P. and Sanford, W. G. (1970). Ratoon cropping. *Adv. Agron.* **22**:285-230.

Prakash, K. S. and Prakash, B. G. (1988). Screening rice genotypes for rationing ability in the Tungabhadra river project of Karnataka. Rice Ratooning. pp. 265-269.

Prakash, K. S., Krishnamurthy, K., Panchal, Y. C. and Prakash, B. G. (1988). Production practices for ratoon rice in Tungabhadra River project. Rice Ratooning. pp. 97-103.

Prashar, C. R. K. (1969). Studies on the growth, yield and water use efficiency of rice ratoon of different varieties. Agron. Absts. Modison. P. 45.

Prashar, C. R. K. (1970)a. Some factors governing rice-ratoon yields. Plant and Soil. 32(2): 540-541.

Prashar, C. R. K. (1970)b. Paddy ratoons. *World Crops.* **22** (3): 145-147.

Qiu, B. Q. and Jin, Q. S. (1988). Ratooning ability of IR varieties in Hangzhou china. *Intl. Rice Res. Newsl.* **12**(3): 7.

Quddus, M. A. (1981). Effect of several growth regulators, shading and cultural management practices on rice ratooning. M. S. Thesis, Universities of the Philip., Los Banos, Philippines. p. 100.

Quddus, M. A. and Pendleton, J. W. (1990). Management effects on main rice crop and its ratoon. *Bangladesh Agron. J.* **3**(1 &3): 11-14.

Ramos, M. G. and Dittrich, R. C. (1981). Effect of height cutting of the main crop on rice ratooning [in Portuguese]. In: Irrigated Rice Workshop, 11 Pelotas pp.137-140.

Ramswami, C. and Haws, L. W. (1970). Successive cropping of IRS paddy with notes on ratooning. *Madras Agric. J.* **57**(11): 545-547.

Reddy, N. (1995). Varietal evaluation for rationing ability in flood irrigated rice (*Oryza sativa* L.). *Fiji Agric. J.* **47**(1-2): 1-5.

Reddy, R and Pawar, M. S. (1959). Studies on ratooning in Paddy. *Andra Agric. J.* **6**(2): 70-72.

Reddy, T. G., Mahadevappa, M. and Kuldarni, K. R. (1979). Ratoon cropping of rainfed rice. *Intl. Rice Res. Newsl.* **4**(5): 25-26.

Reddy, T. G., Mahadevappa, M. and Kulkami, K. R. (1979). Rice ratoon crop management in hilly regions of Karnataka, India. *Intl. Rice Res. Newsl.* **4**(6): 22-23.

Rosamma, C.A., Karunakaran, K, Chandrika, P. and Nair, N.R. (1988). Weight germination of main and ratoon crop seeds. *Intl. Rice Res.Newsl.* **13**(4):4

Roy, S. K. (1959). Second flowering in *Oryza sativa* L. (var. indica). Nature, Land. 183(4673): 1458-1459.

Sahoo, S. and Lenka, D. (1992). Effects of fertility level, cutting height and beushan operation on ratooning of rice (*Oryza sativa* L.) *Indian J. Agric. Sci.* **62**(6): 195-396.

Sajjad, M. S. (1994). Comparative study on rationing potential of standard rice varieties of PNG. Papua New Guinea . *J. Agric. Forest. Fish.* **37**(2):19-22. [Rice Abst. 19(20):103].

Samson, B. T. (1980). Rice ratooning: effects of varietal type and some cultural management practices. M.S. Thesis, Univ. Philippines. Los Banos, Philippines.

Santhi, P., Ponnuswamy, K. and Shanmugasundaram, V. S. (1993). Economic evaluation of ratoon paddy in low lying old ayacut areas of Tamil Nadu. New-Botanist. 20: 1-4, 217-220.

Saran, A. B. and Prasad, M. (1952). Ratooning in paddy. *Current Sci.* **21(8)**: 223-224.

Saran, S., Azam, M. Q. and Sahu, S. P. (1969). A note on differential behaviour in the ratooning ability of some photoperiod insensitive rice genotypes. *J. Appl. Sci. Bihar. L* **(I): 46-48**.

Schikawa, T. (1964). Studies on the ratoon of rice plant in early cultivation of rice. B. Fac. Agric. U. Miyazaki 10: 72-78.

Shi, N. P. and Shi, N. P. (1997)a. The development of ratiooning rice and its utilization. China Rice. 4 : 14-16. [CAB Abst. 1998-2000].

Shi, N. P. and Shi, N. P. (1997)b. Hybrid Intermediate rice-ratoon rice and high yield cultivation techniques. China Rice. 5: 18-21. [CAB Abst. 1998-2000].

Siddique, S. B., Rashid, M. A. and Haldar, K. P. (1995). Effect of harvesting date and cutting height on performance of ratoon crop of BRIT *Bangladesh Rice J.* **6**(1 &2): 91-94.

Singh, B. N., Sahu, S. P., Pandey, S. S. and Chauhan, J. (1987). Possibility of a ratoon crop from photoperiod insensitive summer rice in calcareous sodic soils of nortg Bihar, India. *Intl. Rice Res. Newsl.* **12** (6): 8-9.

Smetanin, A. P. and Volkova, N. P. (1970). On ratooning characters of rice cultivar adapted to the Kuban region. Field Crop Abst. 25(2): 250.

Srinivasan, K. and Purushothaman, S. (1993). Ratooning ability of medium rice varieties. *Madras Agric. J.* **80**(10):552-555.

Sun, X. H., Zhang, J. G. and Liang, Y. J. (1988). Ratooning with rice hybrids. In: Rice Ratooning. Intl. Rice Res. Inst. pp. 155-161.

Sutaryo, B. and Suprihatno, B. (1993). Ratoon crop performance in some rice hybrids. *Intl. Rice Res. Notes.* **18** (1): 18-19.

Szokolay, G. (1956). Ratooning of rice on the Swazil and irrigation scheme. *World Crops-* **8**(2): 71-73.

Tan, Z. B. and Li, S. F. (1990). Differences in ratooning ability among rice cultivars. *Rice Res. Newsl.* **15** (1): 12.

Tang, W. B., Chen. L. Y., Xiao, Y. B. and Liu, J. F. (2002). Relationships among yield, yield components and some features of ratooing rice. J. Hunan Agric. Univ. Hanu, Changsha 410128, China. 28(1):1-3. [CAB Abst. 2002-2003].

Volkova, N. P. and Smetanin, A. K. (1971). On the ratooning characters of rice cultivar adapted to the kuban region. Field Crop Abst. 25(2): 250.

Votong, V. (1975). The effect of time of drainage and time of rewatering on the Yield of ratoon rice. MS thesis, University of Sydney, Australia.

Wang, G., Longquan, L., Bairong, W. and Pengyan, J. (1995). Studies on ratooning characters of hybrid rice and its forage and grain production pattern. Acta Agril. Zhejiangensis. 7(5): 352-354, 395.

Watson, D. J. (1968). A prospect of crop physiology. *Am.J. Appl. Biol.* **62**:1-9.

Xiong, H., Fang, W. and Tan, Z. B. (1991)- Effect of number of axillary buds and main crop cutting time on ratoon crop yield. *Intl. Rice Res. Newsl.* **16** (l)-*19*.

Xu, F. X. and Xiong, H. (2000). Relationship between ratio of grain to leaf area and ratooning ability in middle-season hybrid rice. *Chinese J. Rice Sci.***14** (4): 249-252.

Yang, K. C., Sun, S. W. and Long, C. Y. (1958). A study of regeneration in rice. Acta Agric. Sin. 9:107-133.

Yang, S. J. (1940). The cultivation of regenerate rice and its future in Human and Szechan. Field Crop Abst. 1(2): 91.

Yoshida, S. (1972). Physiological aspect of grain yield. Ann. Rev. Plant Physiology. 23:437-466.

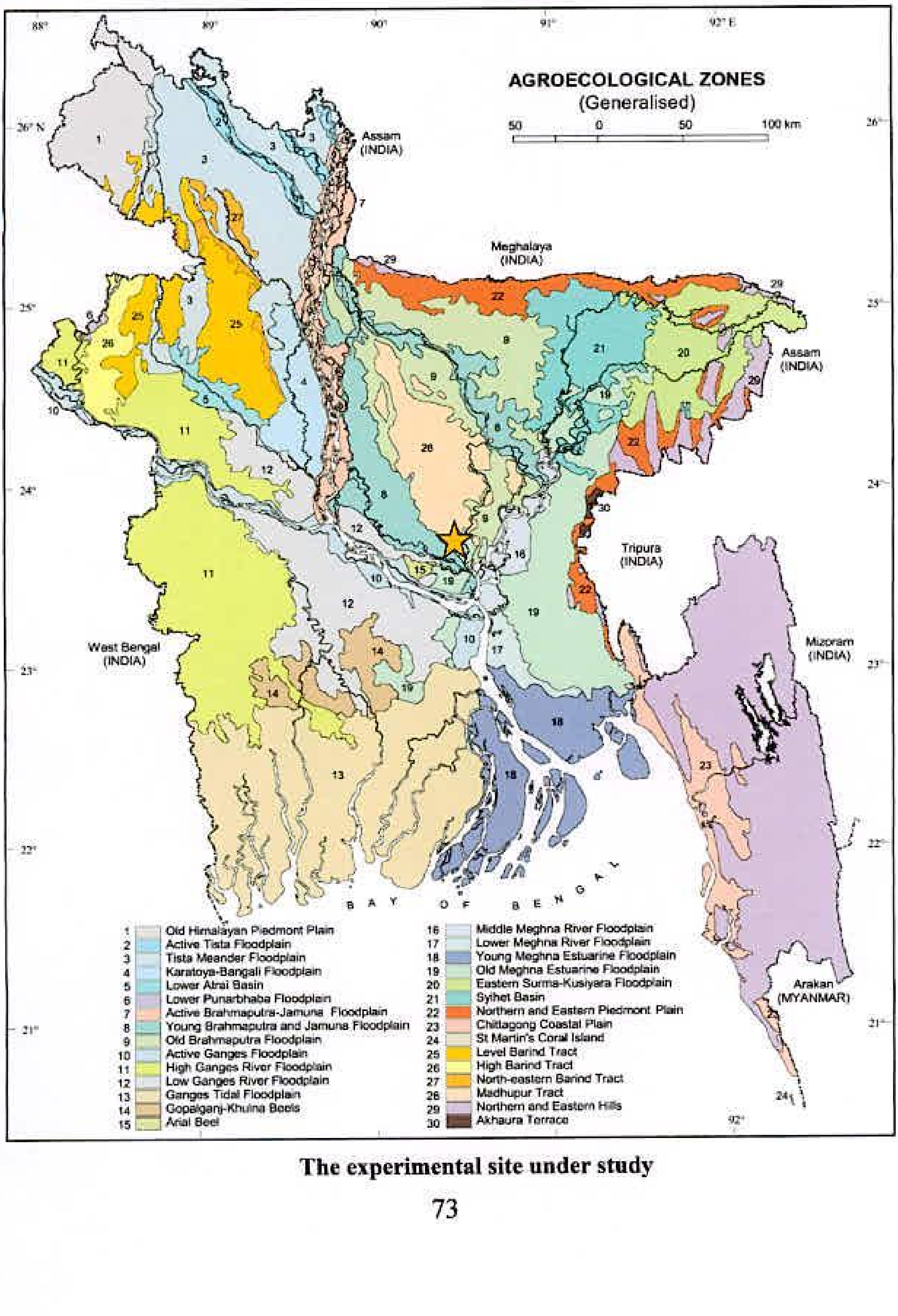
Young, F. P. (1959). Studies on the cultivation of ratoon. *J. Taiwan. Agr. Res.* **8** (2): 31-32 (English summary).

Zandstra, H. G. and Samson, B. T. (1979). Rice ratoon management. Discussion paper presented at the Intl. Rice Res. Conf. April 16-21, 1979.

Zhang, J. H. (1991). Hybrid rice ratoon exploited in sichuan, China. *Intl. Rice Res. Newsl.* **16**(5): 27-28.

APPENDICES

Appendix I. Map showing the experimental site under study



The experimental site under study

APPENDICES

Appendix II. Physical and chemical properties of soil (0-15 cm) of the experimental field

A. Physical properties of soil	
% sand (0.2-.02 mm)	21.75
% silt (0.02-.002 mm)	66.60
% clay (< 0.002 mm)	11.65
Textural class	Silty loam
Consistency	Granular
B. Chemical properties of soil	
Soil pH	6.4
Organic carbon (%)	1.30
Organic matter (%)	1.28
Total nitrogen (%)	0.11
Available phosphorus (ppm)	27
Exchangeable potassium (me/100 g soil)	0.12
Available sulphur (ppm)	9.00

Source: Soil Science Department, SAU, Dhaka-1207

Appendix III. Average monthly rainfall, air temperature, relative humidity during the experimental period between November 2009 to April 2010 at the SAU area, Dhaka-1207

Month	Monthly average air temperature (^0C)			Average rainfall (mm)	Average relative humidity (%)
	Maximum	Minimum	Average		
November	27.00	14.81	20.91	00	72.00
December	28.50	16.40	22.45	92.2	76.75
January	30.56	22.14	26.35	96.6	78.57
February	32.80	23.34	28.07	266	82.50
March	34.60	16.50	25.55	45.00	67.00
April	35.80	20.30	28.05	88.00	65.00

Source: Bangladesh Metrological Department (Climate Division) Agargaon, Dhaka-1212.

Appendix IV. Analysis of variance (mean square) on phenological and morphological characters of ratoon crop in boro rice

Source of variation	df	Days to panicle initiation	Days to maturity	Plant height (cm)	Number of total tillers hill^{-1}
Replication	2	3.00	1.47	6.750	0.21
Variety (A)	3	91.28 **	96.7 **	239.1 **	6.79 **
Cutting height (B)	2	16.22 *	5.13 ^{ns}	154.2 **	0.32 ns
A × B	6	9.62 *	3.45 *	14.986 *	0.66 *
Error	22	2.955	2.35	4.932	0.15

*, ** indicate significant at 5% and 1% level of probability, respectively;
ns = Not significant

Appendix V. Analysis of variance (mean square) on crop characters of ratoon crop in boro rice

Source of variation	df	Number of non-effective tillers $hill^{-1}$	Number of unfilled grains $panicle^{-1}$	Straw weight ($t\ ha^{-1}$)	Harvest index (%)
Replication	2	0.01	0.130	0.042	1.333
Variety (A)	3	1.09 **	250.3 **	3.778 **	166.30 **
Cutting height (B)	2	2.29 **	39.81 **	0.302 **	58.153 **
A × B	6	0.14 **	9.766 *	0.068 *	7.041 *
Error	22	0.03	5.294	0.039	4.242

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix VI. Analysis of variance (mean square) on yield attributes in ratoon crop of boro rice

Source of variation	df	Number of total tillers $hill^{-1}$	Number of effective tillers $hill^{-1}$	Number of total grains $panicle^{-1}$	Panicle length (cm)
Replication	2	0.208	0.013	0.750	0.000
Variety (A)	3	6.786 **	12.53 **	1576.8 **	12.13 **
Cutting height (B)	2	0.322 ns	4.326 **	11.617 ^{ns}	1.516 **
A × B	6	0.459 *	0.220 *	27.884 *	0.448 *
Error	22	0.149	0.097	13.295	0.232

*, ** indicate significant at 5% and 1% level of probability, respectively;
ns = Not significant

Appendix VII. Analysis of variance (mean square) on yield attributes and yield in ratoon crop of boro rice

Source of variation	df	Number of filled grains panicle $^{-1}$	1000-grain weight (g)	Grain weight hill^{-1} (g)	Grain yield (t ha^{-1})
Replication	2	14.083	0.211	0.018	0.001
Variety (A)	3	2803.2 **	6.492 **	84.27 **	1.111 **
Cutting height (B)	2	92.110 **	1.899 *	32.07 **	1.050 **
A × B	6	19.527 *	0.715 *	0.835 **	0.105 **
Error	22	8.992	0.392	0.166	0.011

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix VIII. Analysis of variance (mean square) on phenological and morphological characters of main crop in boro rice

Source of variation	df	Days to panicle initiation	Days to maturity	Plant height (cm)	Number of total tillers hill^{-1}
Replication	2	4.000	6.15	9.000	0.076
Variety	3	146.0 **	188.2 **	238.3 **	6.896 **
Error	6	6.000	4.11	5.667	0.542

** indicate significant at 1% level of probability

Appendix IX. Analysis of variance (mean square) on crop characters of main crop in boro rice

Source of variation	df	Number of non-effective tillers $hill^{-1}$	Number of unfilled grains $panicle^{-1}$	Straw weight ($t\ ha^{-1}$)	Harvest index (%)
Replication	2	0.001	0.123	0.001	1.000
Variety	3	0.689 **	24.29 **	1.142 **	26.54 *
Error	6	0.030	0.843	0.084	4.667

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix X. Analysis of variance (mean square) on yield attributes in main crop of boro rice

Source of variation	df	Number of total tillers $hill^{-1}$	Number of effective tillers $hill^{-1}$	Number of total grains $panicle^{-1}$	Panicle length (cm)
Replication	2	0.076	0.010	20.25	0.010
Variety	3	6.896 **	4.936 **	161.35 **	4.588 *
Error	6	0.542	0.623	33.58	0.670

*, ** indicate significant at 5% and 1% level of probability, respectively

Appendix XI. Analysis of variance (mean square) on yield attributes and yield in main crop of boro rice

Source of variation	df	Number of filled grains $panicle^{-1}$	1000-grain weight (g)	Grain weight $hill^{-1}$ (g)	Grain yield ($t\ ha^{-1}$)
Replication	2	12.250	0.511	1.00	0.038
Variety	3	229.41 **	0.999^{ns}	126.0 **	3.426 **
Error	6	43.250	0.551	5.67	0.088

** indicate significant at 1% level of probability; ns = Not significant