SOURCE-SINK RELATIONSHIP AND YIELD PERFORMANCE OF HYBRID RICE VARIETIES IN BORO SEASON

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CERTIFICATE

This is to certify that the thesis entitled **'Source-Sink Relationship and Yield Performance of Hybrid Rice Varieties in Boro Season'** submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Agricultural Botany**, embodies the result of a piece of bonafide research work carried out by **Mahjuba Akter**, Registration No. **08-02745** 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, received during the course of this investigation has been duly acknowledged.

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ABSTRACT

The experiment was conducted in the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, to study the source-sink relationship and its impact on the yield performance of hybrid rice varieties in *Boro* season. The experiment was laid out in Randomized Complete Block Design with three replications. Five hybrid (BRRI hybrid dhan3, Heera 4, Sonarbangla 3, Moyna, Jagoron) and two inbred rice varieties (BRRI dhan28 and BRRI dhan45) were used as test crop. The studied varieties exhibited variation in plant height, tillers hill^{-1}, leaf area index, total dry matter hill^{-1}, shoot dry matter at pre-anthesis and maturity period, changes in shoot dry matter, shoot reserve translocation, total spikelets panicle^{-1}, spikelets fertility, weight of 1000 grains, biological yield and harvest index. All the studied hybrid varieties exhibited superiority in respect of growth characters, yield and yield attributes over the inbred varieties. Highest shoot reserve translocation (15.58%) was observed in Heera 4, while the lowest value (9.59%) was found in BRRI dhan28. At heading Heera 4 maintained highest ratio of spikelets no. to LA (0.31 cm^{-2}) and yield sink to LA (14.09 mg cm^{-2}), while the lowest ratio of spikelets no. to LA (0.22 cm^{-2}) and yield sink to LA (11.09 mg cm^{-2}) were observed in BRRI dhan28. Heera 4 (83.19%) accumulated significantly highest percentage of dry matter from current photosynthate in grain, while BRRI dhan45 showed the lowest value (75.79%). Heera 4 provided the highest grain yield (7.80 t ha^{-1}) which was closely followed by Jagoron (7.08 t ha^{-1}). While BRRI dhan28 showed the lowest grain yield (4.23 t ha^{-1}) closely followed by BRRI dhan45 (4.55 t ha^{-1}). These results suggested that Heera 4 had the superiority over the test varieties in respect of post heading photosynthetic assimilation per unit leaf area and grain yield.

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centimeter
Cont'd	=	Continued
cv.	=	Cultivar
DAT	=	Days after transplanting
^{o}C	=	Degree Centigrade
DF	=	Degree of freedom
EC	=	Emulsifiable Concentrate
et al.	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram
HI	=	Harvest Index
Hr	=	Hour
IRRI	=	International Rice Research institute
Kg	=	Kilogram
LV	=	Local variety
LSD	=	Least significant difference
M	=	Meter
m^2	=	Square meter
mm	=	Millimeter
viz.	=	Namely
N	=	Nitrogen
ns	=	Non significant
%	=	Per cent
$CV_{\%}$	=	Percentage of Coefficient of Variance
P	=	Phosphorus
K	=	Potassium
ppm	=	Parts per million
SAU	=	Sher-e- Bangla Agricultural University
S	=	Sulphur
Zn	=	Zinc

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa*) belongs to the family Gramineae, is the staple food for at least 62.8% of total planet inhabitants and it contributes on an average 20% of apparent caloric intake of the world population and 30% of population in Asian countries. This caloric contribution varies from 29.5% for China to 72.0% for Bangladesh (Calpe and Prakash, 2007). Around ninety per cent of rice is grown and consumed in south and southeast Asia, the highly populated area (Catling, 1992). It is the staple food for more than two billion people in Asia (Hien *et al.*, 2006). Rice is the most important food grain in the world. It is the most important cereal crop in the developing world (Khush, 1987). Ninety percent of rice is grown and consumed in Asia (Anon., 1997; Luh, 1991). Rice feeds more than a half of the people in the world (David, 1989).

The population of Bangladesh is increasing at an alarming rate and the cultivable land is reducing due to urbanization and industrialization resulting in more shortage of food. The population of Bangladesh will increase to 173 million in 2020 which is 31 percent higher than the present level (FAO, 1998). Population growth demands a continuous increase in rice production in Bangladesh. Production of rice has to be increased by at least 60% to meet up food requirement of the increasing population by the year 2020 (Masum, 2009). As it is not possible to have horizontal expansion of rice area, rice yield unit^{-1} area should be increased to meet this ever-increasing demand of food in the country. As the population rises, so the demand for rice yields of the crop are leveling out. The current level of annual rice production of around 545 million tons could be increased to about 700 million tons to feed an additional 650 million rice eaters by 2025 using less land indeed the great challenge in Asia (Dawe, 2003). A study showed that most Asian countries will not be able to feed their projected populations without irreversibly degrading their land resources, even with high levels of management input (Beinroth *et al.*, 2001).

The geographical, climatic and edaphic conditions of Bangladesh are favorable for year round rice cultivation. However, the national average yield (2.34 t ha^{-1}) is very low compared to that of other rice growing countries as the average rice yield in China is about 6.3 t ha^{-1}, Japan is 6.6 t ha^{-1} and Korea is 6.3 t ha^{-1} (FAO, 2002). Bangladesh is one of the poor countries of the world due to its dense population and threatened by floods and storms and different types of natural calamities in different season. In Bangladesh rice occupies 10.58 million hectares of land which is about 77 percent of the cultivated area (BBS, 2009). About 75% of the total cropped area and more than 80% of the total irrigated area of Bangladesh is planted to rice (Hossain and Deb, 2003) and there are three diverse growing seasons of rice namely *Aus*, *Aman* and *Boro*. Hybrid rice has been introduced in Bangladesh through BRRI, IRRI and different seed companies. Rice yield can be increased in many ways of them developing new high yielding variety and by adopting proper agronomic management practices to the hybrid varieties to achieve their potential yield is important. Hybrids are generally more vigorous and larger in size than the parent stock. The young seedlings produce long roots and broad leaves that enable them to take up more nutrients thus, produce more grains. Zhende (1988) stated that hybrid rice has high tillering capacity. During vegetative growth, hybrid rice accumulates more dry matter in the early and middle growth stages which results in more spikelets $panicle^{-1}$. They have bigger panicles and more spikelets $panicle^{-1}$. Several hybrid varieties had been developed and released up to the present. Different varieties perform differently in a particular environment. Janaiah and Hossain (2000) reported that although farmers got about 16% yield advantage in the cultivation of hybrids compared to the popularly grown inbred varieties, the yield gains were not stable. For developing the high yielding varieties, Japan initiated first breeding program in 1981 (Wang, 2001). IRRI also started super rice breeding program to give up to 30% more rice yield (13-15 t ha^{-1}) than the current modern high yielding plant types (IRRI, 1993). It has great potentiality for food security of poor countries where arable land is scarce populations is expanding and labour is cheap. Hybrid rice technology has been introduced in Bangladesh during the last ten years (Masum, 2009). In our country BRRI has started breeding program for the development of super high yielding varieties with large panicles and high yield potentialities.

However, many investigators reported that greater biomass accumulation before heading and higher shoot reserve translocation are the decisive factors of higher yield in hybrids (Jeng et al., 2006). On the other hand, several scientists reported that hybrid rice had higher productivity after heading but the more dry matter in vegetative organ at heading contributes little to the grain due to poor transportation and remobilization of stored assimilates (Yang *et al.*, 2002). Slow senescence and more strong photosynthetic capability of flag leaf, higher LAI at grain filling period and higher post heading-CGR are the pre-requisites for higher yield in hybrid rice (Tang *et al.*, 2010). Hybrid rice had higher productivity after heading but translocation of assimilates was inefficient (Yan *et al.*, 2001). Yang *et al.*, 2007 reported that remobilization was poor in hybrid and super hybrid rice varieties. So, the available information on source activities, shoot reserve remobilization, and its influence on the yield formation of hybrid rice varieties are controversial. Therefore, it is imperative to clarify the controversy on source-sink relation in hybrid rice varieties. In this situation, clear information on the source-sink relation in hybrid rice would help to obtain desirable (sustainable) grain yield through the manipulation of agronomic cultural management practices.Under these circumstances, my research work was designed to evaluate source-sink relationship and yield performance of hybrid rice varieties in *Boro* season.

Objectives

i) to investigate the source use efficiency of hybrid rice at pre-heading and post heading stages in *Boro* season.

ii) to compare the yield performance of hybrid and inbred rice varieties in *Boro* season.

CHAPTER II

REVIEW OF LITERATURE

Rice is the staple food and around ninety per cent of rice is grown and consumed in south and Southeast Asia, the highly populated area. Bangladesh produces hybrid rice varieties and most of them have excellent production and eating quality for regular consumption. Most of the rice varieties have been imported from China and some also developed in Bangladesh. Very limited research works related to yield and quality analysis of hybrid rice have been carried out in home and abroad. The research work so far done in Bangladesh is not adequate and conclusive. Variety itself is the genetical factor which contributes a lot for producing yield and yield components. Different researcher reported the effect of rice varieties on yield contributing component and grain yield. However, some of the important and informative works and research findings related to the yield and quality of hybrid, so far been done at home and abroad, reviewed in this chapter under the following heads-

2.1 Plant height

Bhuiyan *et al.* (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of plant growth and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on plant height at maturity. Two field experiments were conducted by Salem *et al.* (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons to study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101. The results indicated that Sakha 101 variety surpassed than other varieties in terms of plant height. A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, Kafr-El sheikh governorate, Egypt rice season for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 were evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties in terms of plant height. Masum *et al*. (2008) found that plant height of rice affected by varieties in Aman season where Nizershail produced the taller plant height than BRRI dhan 44 at different days after transplanting (DAT). Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and observed that Mukti gave the longest plant compared to the others. Chen-Liang *et al*. (2000) showed that the cross between Peiai 64s and the new plant type lines had longest plant height. Xu and Li (1998) observed that the maintainer lines were generally shorter than restorer line. Munoz *et al.* (1996) noted that IR8025A hybrid rice cultivar produced 16% longer plant than the commercial variety Oryzica Yacu-9. BINA (1993) evaluated the performance of four rice varieties (IRAATOM 24, BR14, BINA13 and BINA19). It was found that varieties differed significantly in respect of plant height. BRRI (1991) observed the plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in the *Boro* season. Hosain and Alam (1991) found that the plant height in modern rice varieties BR3, BR11, BR14 and Pajam were 90.4, 94.5, 81.3 and 100.7 cm, respectively. Miah *et al*. (1990) conducted an experiment were rice cv. Nizersail and mutant lines Mut. NSI and Mut. NSS were planted and found that plant height were greater in Mut. NSI than Nizersail. Shamsuddin *et al*. (1988) conducted a field trial with nine different rice varieties and observed that plant height differed significantly among the varieties tested. Sawant *et al*. (1986) conducted an experiment with the new rice lines R-73-1-1, R-711 and the traditional cv. Ratna and reported that the traditional cv. Ratna was the shortest.

2.2 Tillering pattern

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of tillers, number of productive tillers. RGBU010A X SL8R is therefore recommended as planting material among hybrid rice varieties because it produced more productive tillers. A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, kafr- El sheikh governorate, Egypt for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 were evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties in consideration of effective and total tillers hill^{-1}. Masum *et al*. (2008) stated that number of total tillers hill^{-1} was significantly influenced by cultivars at all stages of crop growth. Nizersail was achieved maximum (25.63) tiller at 45 DAT, then with advancement to age it declined up to maturity, whereas in the case of BRRI dhan44, maximum (18.92) tiller production was observed around panicle initiation stage at 60 DAT. Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and observed that Mukti gave the highest tillers hill^{-1} compared to the others. Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers. They observed that CNHR2 produced more number of productive tillers (413.4/m^2) than other tested varieties. Ahmed *et al*. (1998) obtained 11 better maintainer lines with good maintainability for corresponding CMS lines in an evaluation program of 64 maintainers with respective CMS lines from different countries and recorded differences for number of effective tillers. Devaraju *et al*. (1998) in a study with two rice hybrids, Karnataka Rice Hybrid 1 (KRHI) and Karnataka Rice Hybrid-2 (KRH2), using HYV IR20 as the check, found that IR20, the tiller number was higher than that of KRH2. Islam (1995) in an experiment with four rice cultivars *viz*. BR10, BR11, BR22 and BR23 found that the highest number of non bearing tillers hill^{-1} was produced by cultivar BR11 and the lowest number by BR10. Chowdhury *et al*. (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i. e. number of productive tillers hill^{-1}. BINA (1993) conducted an experiment with four varieties/advance lines (IRATOM24, BR14, BINA13 and BINA19) and reported significant variation in number of non-bearing tillers hill^{-1}. Hossain and Alam (1991) also found that the growth characters like total tillers hill^{-1} differed significantly among BR3, BR11, Pajam and Jaguli varieties in the *Boro* srason. Idris and Matin (1990) stated that number of total tillers hill^{-1} was identical among the six varieties studied.

2.3 Dry matter

In order to evaluate the response to planting date in rice hybrids Line dry method of working, was carried out by Shaloie *et al*. (2014) at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Hybrid rice Hb2 and Hb1 was used in the sub plots. Results showed traits were significantly affected in terms of dry matter and mentioned trait was more in hybrid Hb_2 than Hb_1. Masum *et al*. (2008) found that total dry matter production differed due to varieties. Total dry matter of BRRI dhan 44 Nizershail significantly varied at different sampling dates. Xie *et al.* (2007) found that Shanyou-63 variety gave the higher yield (12 t/ha) compared to Xieyou46 variety (10 t/ha). Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (*viz.* Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (*viz.* KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety. Amin *et al*. (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety did.

Son *et al*. (1998) reported that dry matter production of four inbred lines of rice (low-tillering large panicle type), YR15965ACP33, YR17104ACP5, YR16510-B-B-B-9, and YR16512-B-B-B-10, and cv. Namcheonbyeo and Daesanbyeo, were evaluated at plant densities of 10 to 300 plants m^{-2} and reported that dry matter production of low-tillering large panicle type rice was lower than that of Namcheonbyeo, regardless of plant density

2.4 Panicle length, filled & unfilled grains panicle^{-1}, 1000-grains weight and straw and grain yield

An experiment was conducted by Hosain *et al*. (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season (March to July 2010) to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). Hybrid varieties Heera2 (3.03 t ha^{-1}) and Aloron (2.77 t ha^{-1}) gave the higher spikelet sterility. Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of filled and unfilled grains, length of panicle and yield. RGBU010A X SL8R is therefore recommended as planting material among hybrid rice varieties because it produced longer panicles and heavy seeds. In the absence of this variety, RGBU02A X SL8R, RGBU003A X SL8R and RGBU0132A X SL8R may also be used as planting material. In order to evaluate the response to planting date in rice hybrids Line dry method of working, was carried out by Shaloie *et al*. (2014) at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Hybrid rice Hb2 and Hb1 was used in the sub plots. Results showed traits were significantly affected in terms of panicle length, fertility percentage, and mentioned traits was more in hybrid Hb_2 than Hb_1. Forty five aromatic rice genotypes were evaluated by Kaniz Fatema *et al*. (2011) to assess the genetic variability and diversity on the basis of nine characters. Significant variations were observed among the genotypes for all the characters. Thousand grain weight have been found to contribute maximum towards genetic diversity in 45 genotypes of aromatic rice. Two field experiments were conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons to study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101. The results indicated that Sakha 101 variety surpassed than other varieties in terms of 1000 seeds weight. A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, kafr- El sheikh governorate, Egypt in 2008 rice season for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 were evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties for studied characters except for number of days to panicle initiation and heading date. Wang *et al*. (2006) studied the effects of plant density and row spacing (equal row spacing and one seedling hill^{-1}, equal row spacing and 3 seedlings hill^{-1}, wide-narrow row spacing and one seedling hill^{-1}, and wide-narrow row spacing and 3 seedlings hill^{-1} on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27%. Myung (2005) worked with four different panicle types of rice varieties and observed that the primary rachis branches (PRBs) panicle^{-1} and grains were more on Sindongjinbyeo and Iksan467 varieties, but secondary rachis branches (SRBs) were fewer than in Dongjin1 and Saegyehwa varieties. Obulamma *et al.* (2004) recorded hybrid APHR 2 significantly higher grain yield than hybrid DRRH 1. The increased grain yield was due to increase in number of panicles m^{-2} and number of filled grain panicle^{-1} in hybrid APHR 2 than hybrid DRRH 1. Guilani *et al*. (2003) studied on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran, during 1997. They observed that grain number panicle^{-1} was not significantly different among cultivars. The highest grain number panicle^{-1} was obtained with Anboori. Grain fertility percentages were different among cultivars. Among cultivars, LD183 had the highest grain weight. Ahmed *et al*. (1997) conducted an experiment to compare the grain yield and yield components of seven modern rice varieties (BR4, BR5, BR10, BR11, BR22, BR23, and BR25) and a local improved variety, Nizersail. The fertilizer dose was 60-60-40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively for all the varieties and found that percent filled grain was the highest in Nizersail followed by BR25 and the lowest in BR11 and BR23. BRRI (1994) studied the performance of BR14, BR5, Pajam, and Tulsimala and reported that Tulsimala produced the highest number of filled grains panicle^{-1} and BR14 the lowest. BINA (1993) evaluated the performance of four varieties IRATOM 24, BR14, BINA13 and BINA19. They found that varieties differed significantly on panicle legth and sterile spikelets panicle^{-1}. It was also reported that varieties BINA13 and BINA19 each had better morphological characters like more grains panicle^{-1} compared to their better parents which contributed to yield improvement in these hybrid lines of rice. BRRI (1991) also reported that the filled grains panicle^{-1} of different modern varieties were 95-100 in BR3, 125 in BR4 , 120-130 in BR22 and 110-120 in BR23 when they were cultivated in the *Aman* season. Idris and Matin (1990) also observed that panicle length differed among the six rice varieties and it was longer in IR20 than in indigenous high yielding varieties. Singh and Gangwer (1989) conducted an experiment with rice cultivars C-14-8, CR-10009, IET-5656 and IET-6314 and reported that grain number panicle^{-1}, 1000-grain weight were higher for C-14-8 than those of any other three varieties. Rafey *et al*. (1989) carried out an experiment with three different rice cultivars and reported that weight of 1000 grain differed among the cultivars studied. Shamsuddin *et al*. (1988) also observed that panicle number hill^{-1} and 1000-grain weight differed significantly among the varieties. Kamal *et al*. (1988) evaluated BR3, IR20, and Pajam2 and found that number of grain panicle^{-1} were 107.6, 123.0 and 170.9 respectively, for the varieties. Costa and Hoque (1986) studied during *kharif* season, 1985 at Tangail FSR site, Palima, Bangladesh with five different varieties of T. *aman* BR4, BR10, BR11. Nizersail and Indrasail. Significant differences were observed in panicle length and number of unfilled grains panicle^{-1} among the varieties tested. Kanfany *et al*. (2014) conducted an experiment by at the Africa Rice Sahel Regional Station during two wet seasons with the aim of assessing the performances of introduced hybrid cultivars along with an inbred check cultivar under low input fertilizer levels. There were significant cultivar effects for all traits. The grain yield of rice hybrids (bred by the International Rice Research Institute) was not significantly higher than that of the check cultivar widely grown in Senegal. An experiment was conducted by Hosain *et al*. (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season (March to July 2010) to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). BRRI dhan48 produced the highest grain yield (3.51 t ha^{-1}). Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on yield. RGBU010A X SL8R is therefore recommended as planting material among hybrid rice varieties because it produced favorable yield. Samonte *et al*. (2011) reported that the two elite lines recommended for release are high yielding in Texas. RU0703190 is also very early maturing conventional long grain rice. The high yield potential of these new releases will impact grain production of rice farmers and their income. The germination and seedling cold tolerant donors that were identified will be useful in developing variety for early plantings. Tabien and Samonte (2007) observed that several elite lines at the multi-state trials had high yield potential relative to the check varieties and these can be released as new varieties after series of yield trials. With improved yield, the new varieties are expected to increase rice production. The elite lines generated are also potential germplasm for rice improvement projects. The initial effort to identify high biomass rice will enhance the development of dedicated feedstock for bioenergy production. Swain *et al*. (2006) reported that the control cultivar IR64, with high translocation efficiency and 1000-grain weight and lowest spikelet sterility recorded a grain yield of 5.6 t ha^{-1} that was statistically similar to the hybrid line PA6201. Molla (2001) reported that Pro-Agro6201 (hybrid) had a significant higher yield than IET4786 (HYV), due to more mature panicles m^{-2}, higher number of filled grains $panicle^{-1}$ and greater seed weight. Patel (2000) studied the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36 did. The mean yield increased with Kranti over IR36 was 7.1 and 10.0% for grain and straw, respectively. Julfiquar *et al*. (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during *Boro* season. It was reported that five hybrids (IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. Two hybrids out yielded the check variety of same duration yielded by more than 1 t ha^{-1}. Rajendra *et al*. (1998) carried out an experiment with hybrid rice cv. Pusa 834 and Pusa HR3 and observed that mean grain yields of Pusa 834 and Pusa HR3 were 3.3 t ha^{-1} and 5.6 t ha^{-1}, respectively. BRRI (1997) reported that three modern upland rice varieties namely, BR20, BR21, BR24 was suitable for high rainfall belts of Bangladesh. Under proper management, the grain yield was 3.5 ton for BR20, 3.0 ton ha^{-1} for BR21 and 3.5 ton ha^{-1} for BR24. Nematzadeh *et al*. (1997) reported that local high quality rice cultivars Hassan Sarai and Sang-Tarom were crossed with improved high yielding cultivars Amol 3, PND160-2-1 and RNR1446 in all possible combinations and released in 1996 under the name Nemat, which gave an average grain yield of 8 t ha^{-1}, twice as much as local cultivars. BRRI (1995) conducted an experiment to find out varietal performances of BR4, BR10, BR11, BR22, BR23 and BR25 varieties including two local check Challish and Nizersail, produced yields of 4.38, 3.18, 3.12, 3.12 and 2.70 5 t ha^{-1}, respectively. Chowdhury *et al*. (1995) studied seven varieties of rice, of which three were native (Maloti, Nizersail and

Chandrashail) and four were improved (BR3, BR11, Pasam and Mala). Straw and grain yields were recorded and found that both the grain and straw yields were higher in the improved than the native varieties. Liu (1995) conducted a field trial with new indica hybrid rice You 92 and found an average yield of 7.5 t ha^{-1} which was 10% higher than that of standard hybrid Shanyou 64. In field experiments at Gazipur rice cv. BR11 (weakly photosensitive), BR22, BR23 and Nizersail (strongly photosensitive) were sown at various intervals from July to September and transplanted from August to October. Among the cv. BR22 gave the highest grain yield from most of the sowing dates for both of the years (Ali *et al*., 1993). Chowdhury *et al*. (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i. e. grain yield straw yield. Suprihatno and Sutaryo (1992) conducted an experiment with seven IRRI hybrids and 13 Indonesian hybrids using IR64 and way-seputih. They observed that TR64 was highest yielding, significantly out yielding IR64616H, IR64618, IR64610H and IR62829A/IR54 which in turn out yielded way-seputih. Chandra *et al*. (1992) reported that hybrid IR58025A out yielded the IR62829A hybrids and the three control varieties Jaya, IR36 and hybrids IR58025A x 9761-191R and IR58025A IR58025A x 1R35366-62-1-2-2-3R. Hossain and Alam (1991) studied farmers production technology in haor area and found that the grain yield of modern varieties of *Boro* rice were 2.12, 2.18, 3.17, 2.27 and 3.05 t ha^{-1}, with BR14, BR11, BR9, IR8 and BR3, respectively. In evaluation of performance of four HYV and local varieties-BR4, BR16, Rajasail and Kajalsail in *aman* season, BR4 and BR16 were found to produce more grain yield among four varieties (BRRI, 1985).

2.5 Source-sink relationship

Jeng et al., 2006 reported that greater biomass accumulation before heading and higher shoot reserve translocation are the decisive factors of higher yield in hybrids. Yang *et al.*, 2002 reported that hybrid rice had higher productivity after heading but the more dry matter in vegetative organ at heading contributes little to the grain due to poor transportation and remobilization of stored assimilates. Tang *et al*., 2010 reported that slow senescence and more strong photosynthetic capability of flag leaf, higher LAI at grain filling period and higher post heading-CGR are the pre-requisites for higher yield in hybrid rice. Yan *et al.*, 2001 reported that hybrid rice had higher productivity after heading but translocation of assimilates was inefficient. Yang *et al.,* 2007 reported that remobilization was poor in hybrid and super hybrid rice varieties.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November, 2013 to March 2014, to study the source-sink relationship and its contribution to the yield performances of hybrid rice varieties in *Boro* season. The materials and methods which were used for conducting the experiment have been presented in this chapter. It includes a short description of the location of experimental site, soil and climate condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure.

3.1 Experimental site

The study was conducted in the experimental farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the experimental site is $23^0 74^/$N latitude and $90^0 33^/$E longitude and at an elevation of 8.4 m from sea level (Anon., 1989). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.2 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). Its top soil is clay loam in texture and olive gray with common fine to medium distinct dark yellowish brown mottles. The soil pH ranged from 6.0 to 6.6 and organic carbon content is 0.84%. Experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analysis was done by Soil Resource and Development Institute (SRDI), Dhaka. The details of the plot soil have been presented in Appendix II.

3.3 Climate of the experimental site

The experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, Dhaka and has been presented in Appendix II.

3.4 Experimental materials

Table 1. Name of rice variety

#	Rice variety	#	Rice variety
01	V_1: BRRI dhan28	02	V_2: BRRI hybrid dhan3
03	V_3: Heera 4	04	V_4: Sonarbangla 3
05	V_5: Moyna	06	V_6: Jagoron
07	V_7: BRRI dhan45		

3.5 Description of cultivars

3.5.1 BRRI dhan28

BRRI dhan28 is an early rice variety which is recommended for *Boro* season. This variety was developed by Bangladesh Rice Research Institute and approved in 1994 for cultivation. The grains are medium thin and white in color. The average plant height is 90 cm. It requires about 140 days on an average for completing its life cycle with an average grain yield of 5.5-6.0 t ha^{-1}.

3.5.2 BRRI hybrid dhan3

BRRI hybrid dhan3 was developed by Bangladesh Rice Research Institute and it was approved by National Seed Board in 2009. This early variety is recommended for *Boro* season. It can produce yield of about 9 t ha^{-1}. It is about 110 cm in height. It provides medium thick grain, non-glutinous and tasty rice. It takes 145 days for maturity. Disease, insect and pest resistance power of the variety is more or less similar to our modern inbred varieties.

3.5.3 Heera 4

It is a commercial hybrid rice variety. It was developed in China. This variety was introduced in our country by Supreme Seed Company Ltd., Bangladesh. It can produce grain yield of 10-12 t ha^{-1} in dry (*Boro*) season. It is a lodging and shattering resistant variety with low sterility, white grain, non-glutinous and tasty rice. It matures in 135 - 140 days in dry season for maturity.

3.5.4 Sonarbangla 3

This hybrid variety has been imported from China and approved by the National Seed Board of Bangladesh. The variety is recommended for the *Boro* season. The plant type is semi-dwarf (95-105 cm), growth duration is 145-150 days and its average grain yield ranges from 9 to 10 t ha^{-1}.

3.5.5 Moyna

Moyna is a high yielding hybrid rice variety. It was developed in China and marketed in Bangladesh by Lal Teer Seed Ltd. It is highly resistant variety with wide adaptability. Its grain is non sticky and white in color. Its sowing time is November to mid January. It requires about 135-140 days for maturity with an average grain yield of 6 to 7 t ha^{-1}.

3.5.6 Jagoron

It is a hybrid rice variety and developed in China. BRAC (Bangladesh Rural Advancement Committee) is the sale agent for this variety in Bangladesh. Its grain yield ranges from 8.5-9.5 t ha^{-1}, growth duration varies from 104-130 days, plant type is semi dwarf (100-120 cm) and it is suitable for irrigated soils.

3.5.7 BRRI dhan45

It is a high yielding variety of *Boro* season and was developed by Bangladesh Rice Research Institute in 2005 through crossing between BR2 and TETEP. Originally this variety has been developed from the breeding line BR5778-21-2-3 and its growth duration ranges from 140 to 145 days. This variety has long and erect flag leaf which remains slightly below the panicle. Plants are about 100 cm in height and remain green at maturity with grain yield 6-6.5 t ha^{-1}. The grains are moderately coarse and white in color.

3.6 Seed collection and sprouting

Seeds were collected from BRRI (Bangladesh Rice Research Institute), Gazipur and some were procured from respected company just 20 days ahead of the sowing of seeds in seed bed. Seeds were immersed in water in a bucket for 24 hours. Then the seeds were taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

3.7 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed according to the necessity. No fertilizer was used in the nursery bed.

3.8 Land preparation

The plot selected for conducting the experiment was opened in the second week of November 2013 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain until good tilth. Weeds and stubbles were removed and a desirable tilth of soil was obtained for transplanting seedlings. The experimental plot was partitioned into unit plots in accordance with the experimental design. Organic and inorganic manures as indicated below were mixed with the soil of each unit plot.

3.9 Design and layout

The single factor experiment was laid out in Randomized Complete Block Design with three replications. The layout of the experiment was prepared for distributing the advanced line. There were 21 plots of size 4.0 m × 2.5 m in each. Seven rice varieties were assigned randomly into 7 plots of each replication. The layout of the experiment is shown in Figure 1.

3.10 Fertilizers and manure

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MP, gypsum, zinc sulphate and borax, respectively were applied. The entire amount of TSP, MP, gypsum, zinc sulphate and borax were applied during the final preparation of plot land. Mixture of cowdung and compost was applied at the rate of 10 t ha^{-1} during 15 days before transplantation. Urea was applied in three equal installments at after recovery, tillering and before panicle initiation. The dose and method of application of fertilizers are shown in Table 2.

Table 2. Dose and method of fertilizers application

Fertilizers	Dose (kg ha^{-1})	Application (%)			
		Basal	1st installment	2nd installment	3rd installment
Urea	150	--	33.33	33.33	33.33
TSP	100	100	--	--	--
MP	100	100	--	--	--
Zinc sulphate	10	100	--	--	--
Gypsum	60	100	--	--	--
Borax	10	100	--	--	--

Source: BRRI, 2012, Adhunik Dhaner Chash, Joydevpur, Gazipur

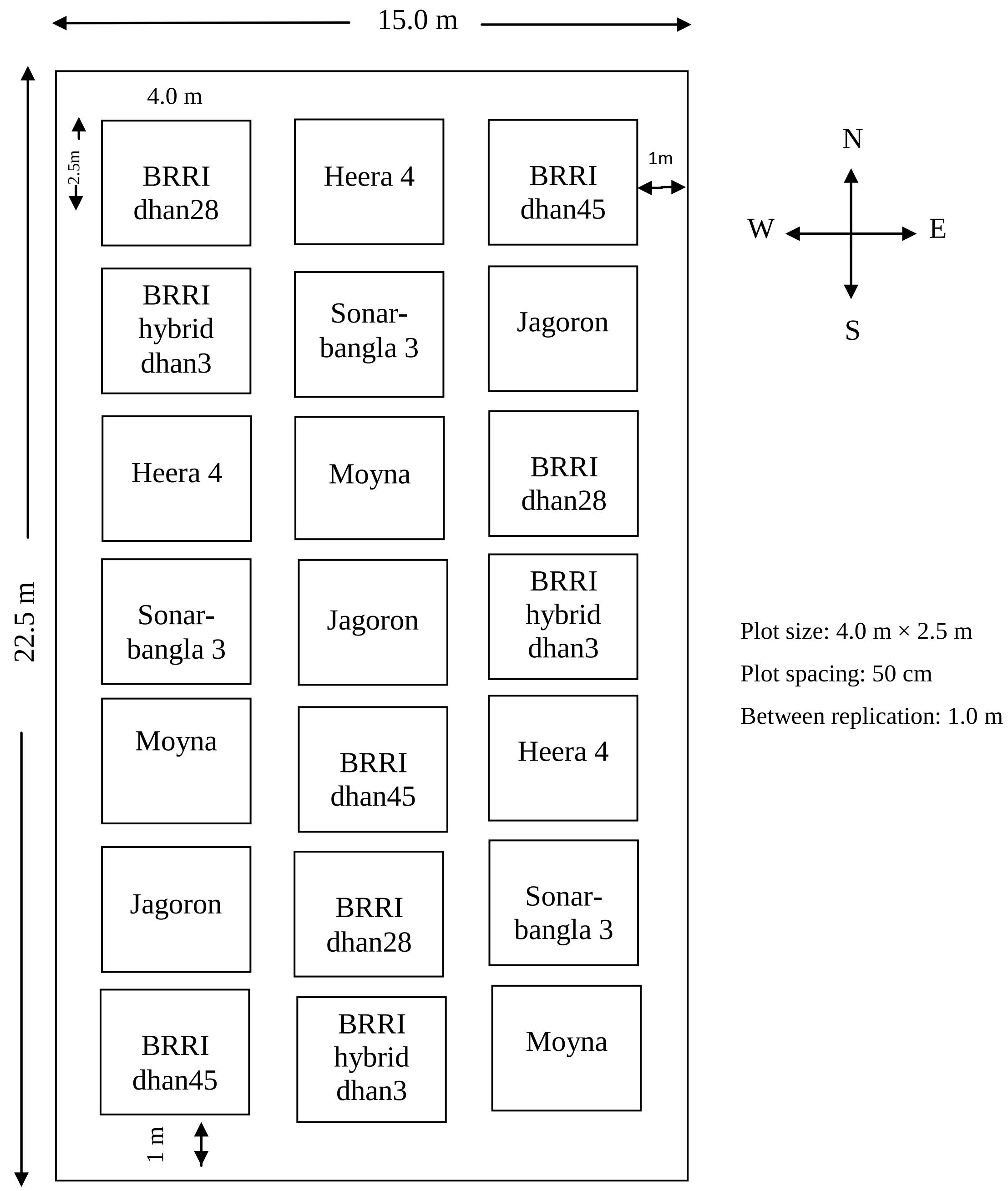

Figure 1. Layout of the experimental plot

3.11 Transplanting of seedlings

Rice seedlings were transplanted in lines each having a line to line 30 cm and plant to plant 25 cm distance in the well prepared plot at 20 November, 2013.

3.12 After care

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the rice seedlings.

3.12.1 Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water upto 6 cm in the early stages to enhance tillering and 10-12 cm in the later stage to discourage late tillering. The field was finally dried out 15 days before harvesting.

3.12.2 Gap filling

First gap filling was done for all of the plots at 10 days after transplanting (DAT).

3.12.3 Weeding

Weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at tillering stage and at panicle initiation stage by mechanical means.

3.12.4 Top dressing

After basal dose, the remaining doses of urea were top-dressed in 2 equal installments. The fertilizers were applied on both sides of seedlings rows with the soil.

3.12.5 Plant protection

Furadan 57 EC was applied at the time of final land preparation and later on other insecticides were applied as and when necessary.

3.13 Harvesting, threshing and cleaning

The rice was harvested depending upon the maturity of plant and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 14%.

3.14 Data recording

Data were recorded on physiological characters and yield components in each replication as follows-

3.14.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 30, 50, 70 and 90 DAT (Days after transplanting) and at harvest. The height was measured from the ground level to the tip of the plant of five hills and finally the average value was calculated.

3.14.2 Tillers hill^{-1}

The number of tillers hill^{-1} was recorded at the time of 30, 50, 70 and 90 DAT by counting total tillers of five respective hills and finally the average value was calculated to hill^{-1} basis.

3.14.3 Leaf area index

Leaf area index (LAI) was measured manually at the time of 30, 50, 70 and 90 DAT and at harvest. Data were recorded as the average of 05 plants selected at random the inner rows of each plots. The final data were calculated multiplying by a correction factor 0.75 as per Yoshida (1981).

3.14.4 Stem dry matter hill^{-1}

Stem dry matter hill^{-1} was recorded at 30, 50, 70 and 90 DAT and at harvest from 10 randomly collected stems hill^{-1} of each plot from inner rows leaving the boarder row. Collected stems were oven dried at 70^{0}C for 72 hours then transferred into desiecator and allowed to cool down at room temperature, final weight was taken and converted into stem dry matter content hill^{-1}.

3.14.5 Leaf dry matter hill^{-1}

Leaf dry matter hill^{-1} was recorded at 30, 50, 70 and 90 DAT and at harvest from 10 randomly collected leaf hill^{-1} of each plot from inner rows leaving the boarder row. Collected stems were oven dried at 70^0C for 72 hours then transferred into desiecator and allowed to cool down at room temperature, final weight was taken and converted into leaf dry matter content hill^{-1}.

3.14.6 Total dry matter hill^{-1}

Total dry matter hill^{-1} was recorded at 30, 50, 70 and 90 DAT and at harvest by adding stem dry matter and leaf dry matter hill^{-1}.

3.14.7 Shoot dry matter accumulation and its remobilization to grain

Plants from 1 m^2 were sampled from each plot at pre-anthesis and maturity. The harvested plants were separated into leaf blades (leaf), culm and sheath (stem) and panicles. Dry matter of each component was determined after drying at 72^0C for 72 hours. The shoot reserve translocation was calculated by net loss in dry weight of vegetative organs between pre-anthesis and maturity (Bonnett and Incoll, 1992) using the following:

$$\text{Shoot reserve translocation (\%)} = \frac{\text{A-M}}{\text{A}} \times 100$$

Where,

A = Total shoot dry matter at pre-anthesis, g m^{-2}

M = Total shoot dry matter at maturity, g m^{-2}

3.14.8 Days to maturity

Days to maturity were recorded by counting the number of days required to harvest in each plot.

3.14.9 Panicles hill^{-1}

The total number of panicles hill^{-1} was counted as the number of panicle bearing hill plant^{-1}. Data on effective tillers hill^{-1} were counted from 5 selected hills at harvest and average value was recorded.

3.14.10 Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tillers plant^{-1}. Data on effective tillers hill^{-1} were counted from 5 selected hills at harvest and average value was recorded.

3.14.11 Ineffective tillers hill^{-1}

The total number of non effective tillers hill^{-1} was counted as the number of no panicle bearing tillers plant^{-1}. Data on non effective tillers hill^{-1} were counted from 5 selected hills at harvest and average value was recorded.

3.14.12 Total tillers hill^{-1}

Number of total tillers hill^{-1} was counted by adding effective tillers and ineffective tillers hill^{-1}.

3.14.13 Panicle length

The length of panicle was measured with a meter scale from 10 selected panicles and the average value was recorded.

3.14.14 Filled spikelets panicle^{-1}

The total number of filled spikelets was counted randomly from selected 10 panicles of a plot on the basis of grain in the spikelet and then average number of filled spikelets panicle^{-1} was recorded.

3.14.15 Unfilled spikelets panicle^{-1}

The total number of unfilled spikelets panicle^{-1} was counted randomly from the same 10 previously selected panicles where filled grains were counted of a plot on the basis of no grain in the spikelet and then average number of unfilled spikelets panicle^{-1} was recorded.

3.14.16 Total spikelets panicle^{-1}

Number of total spikelets panicle^{-1} was counted by adding filled and unfilled spikelets panicle^{-1}.

3.5.17 Spikelets fertility

Spikelets fertility was computed using the formula:

$$\text{Spikelets fertility (\%)} = \frac{\text{Filled spikelets panicle}^{-1}}{\text{Total spikelets panicle}^{-1}} \times 100$$

3.14.18 1000 grains weight

One thousand grains were counted randomly from the total cleaned harvested grains of each individual plot and then weighed in grams and recorded.

3.14.19 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully and finally adjusted to 14% moisture basis using a digital moisture meter. The dry weight of grains of each plot from harvested area was measured and converted to t ha^{-1}.

3.14.20 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The samples of the straw of each plot were oven dried and finally converted to t ha^{-1}.

3.14.21 Biological yield

Grain yield and straw yield together were regarded as biological yield and expressed in t ha^{-1}. The biological yield was calculated with the following formula:

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

3.14.22 Harvest index

Harvest index was calculated from the grain and straw yield of rice for each plot and expressed in percentage.

$$\text{HI (\%)} = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.14.23 Source-sink relation

Ratio of spikelets number to leaf area (at heading), yield sink to leaf area (at heading) and accumulated grain dry matter from current photosynthate (GDMCPn) to average leaf area (heading to maturity) reflect source -sink relations. Ratio of spikelets number to leaf area (at heading) and yield sink to leaf area (at heading) were estimated as follows (Zhao *et al.*, 2006).

$$\text{Ratio of spikelets no to LA (cm}^{-2}\text{)} = \frac{\text{Spikelets number cm}^{-2}}{\text{LAI at heading}}$$

$$\text{Ratio of Yield sink to LA (mg cm}^{-2}\text{)} = \frac{\text{Yield sink mg cm}^{-2}}{\text{LAI at heading}}$$

Where,

$$\text{Yield sink (mg cm}^{-2}\text{)} = \frac{\text{Panicles wt. hill}^{-1}}{\text{Hill area}} \times 100$$

Ratio of accumulated grain dry matter from current photosynthate to average leaf area (heading to maturity) expresses the actual assimilate supply to grain from each unit post-heading leaf area and was calculated as follows-

Ratio of accumulated grain dry matter from current photosynthate (GDMCPn) to average leaf area,

$$\text{LA (mg cm}^{-2}\text{)} = \frac{\text{Yield sink – (panicle dry weight at heading + remobilization)}}{\text{Average LAI from heading to maturity}}$$

3.14.24 Grain dry matter percent from current photosynthate

Percentage of grain dry matter from current photosynthate (GDMCPn%) was estimated using following formula-

$$\text{GDMCPn(\%)} = \frac{\text{Yield sink-(panicle dry weight at heading + remobilization)}}{\text{Grain weight}} \times 100$$

3.15 Statistical Analysis

The data obtained for different characters were statistically analyzed using MSTAT-C software to observe the significant difference among the varieties. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the source-sink relationship and the yield performances of hybrid rice varieties in *Boro* season. The analysis of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix III-XI. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant height

Statistically significant variation was recorded for plant height for different varieties at 30, 50, 70 and 90 days after transplanting (DAT) under the present trial (Appendix III). Data revealed that at 30, 50, 70 and 90 DAT, the tallest plant heights (37.29, 56.49, 79.23 and 98.83 cm respectively) were recorded from Jagoron which were statistically similar (35.34, 55.69, 77.69 and 99.03 cm respectively) to Heera 4, whereas the shortest plant heights (29.28, 47.68, 71.12 and 87.30 cm respectively) were recorded from BRRI dhan28 (Figure. 2). Data revealed that at different days after transplanting of rice seedlings produced different plant heights due to different rice varieties that used in the present experiment. Varieties produced different plant heights on the basis of their varietal characters and also genetical influences but environmental and different management practices also influence different growth parameters as well as plant height. Khalifa (2009) reported earlier that H_1 hybrid rice variety surpassed other varieties in terms of plant height. Bhuiyan *et al*. (2014) reported earlier significant effects on plant height at maturity for different rice variety.

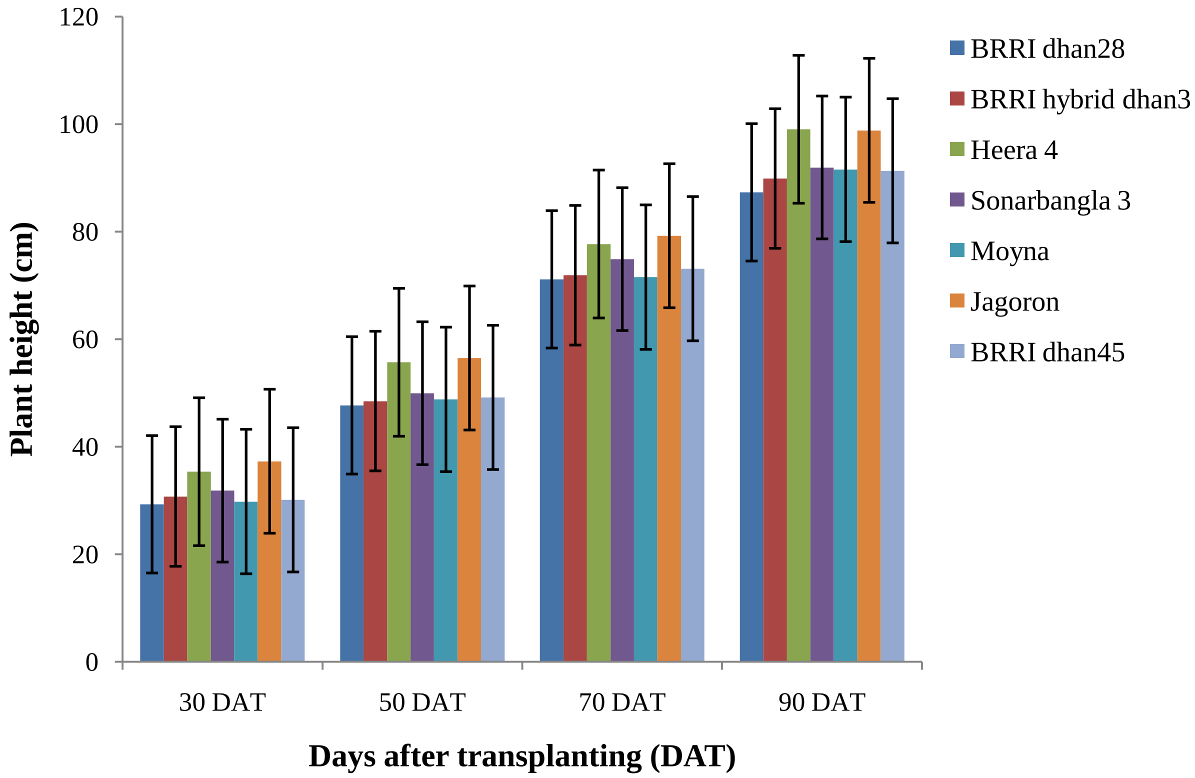

Figure 2. Plant heights at different days after transplanting (DAT) in the test rice varieties. *Vertical bar represents LSD values*

4.2 Tillers hill^{-1}

Tillers hill^{-1} showed statistically significant variation due to different varieties at 30, 50, 70, 90 days after transplanting (DAT) (Appendix IV). At 30, 50, 70 and 90 DAT, the maximum tillers hill^{-1} (6.83, 10.52, 17.31 and 19.27 respectively) were found in Heera 4 which were statistically similar (6.03, 10.12, 16.69 and 17.46 respectively) to Jagoron, while the minimum tillers hill^{-1} (4.07, 7.27, 11.07 and 14.41 respectively) were observed in BRRI dhan28 (Table 3). Bhuiyan *et al.* (2014) recommended hybrid rice varieties because it produced more productive tillers. Devaraju *et al.* (1998) also reported that Rice Hybrid-2 (KRH2) produced highest tiller number than the other varieties.

4.3 Leaf area index

Different varieties of rice varied significantly in terms of leaf area index at 30, 50, 70, 90 days after transplanting (DAT) (Appendix V). At 30, 50, 70 and 90 DAT, the highest leaf area index (0.279, 1.164, 3.48 and 5.97 respectively) was observed in Heera 4 which was statistically similar (0.257, 1.147, 3.48 and 5.68 respectively) to Jagoron and the lowest leaf area index (0.213, 0.921, 2.74 and 5.03 respectively) was found in BRRI dhan28 (Table 3). The variation in LAI could be attributed due to the changes in number of leaves and the rate of leaf expansion and abscission. The high yielding varieties possessed higher LAI values throughout the whole growth period which led to the higher biomass production and yield. The result indicated that hybrid rice produced higher LAI than the check variety and the increase in LAI with time could be attributed to increase in number of tillers consequently higher number of leaves hill^{-1}.

4.4 Stem dry matter hill^{-1}

Statistically significant variation was recorded for stem dry matter hill^{-1} for different varieties at 30, 50, 70 and 90 days after transplanting (DAT) (Appendix VI). At 30, 50, 70 and 90 DAT, the highest stem dry matter hill^{-1} (2.75, 3.95, 8.22 and 6.47 g respectively) were found in Heera 4 which were statistically similar (2.46, 3.82, 7.70 and 6.10 g respectively) to Jagoron, while the lowest stem dry matter hill^{-1} (2.02, 2.69, 5.79 and 5.12 g respectively) were attained from BRRI dhan28 (Figure 3). Similar results were also reported by Amin *et al*. (2006), Son *et al*. (1998) and Shaloie *et al*. (2014) from their earlier experiments.

Table 3. Tillers hill^{-1} and Leaf area index at different days after transplanting for different rice varieties in *Boro* season

Rice variety	Tillers hill^{-1} at				Leaf area index at			
	30 DAT	50 DAT	70 DAT	90 DAT	30 DAT	50 DAT	70 DAT	90 DAT
BRRI dhan28	4.07 d	7.27 d	11.07 c	14.41 b	0.213 cd	0.921 b	2.74 c	5.03 b
BRRI hybrid dhan3	5.57 b	8.23 c	11.32 c	14.39 b	0.235 c	0.957 b	3.32 b	5.32 b
Heera 4	6.83 a	10.52 a	17.31 a	19.27 a	0.279 a	1.164 a	3.48 a	5.97 a
Sonarbangla 3	5.36 b	9.17 b	14.72 b	17.72 a	0.217 cd	0.898 b	3.02 bc	5.36 b
Moyna	5.01 c	8.02 c	11.82 c	14.38 b	0.212 cd	0.963b	3.01 bc	5.11 b
Jagoron	6.03 a	10.12 a	16.69 a	17.46 a	0.257 b	1.147 a	3.48 a	5.68 a
BRRI dhan45	5.00 c	8.12 c	12.02 c	15.67 b	0.223 cd	0.892 b	2.98 bc	5.07 b
$LSD_{(0.05)}$	0.474	0.842	1.446	1.498	0.018	0.056	0.245	0.509
CV (%)	5.82	5.98	6.62	5.37	3.95	6.78	3.37	5.43

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

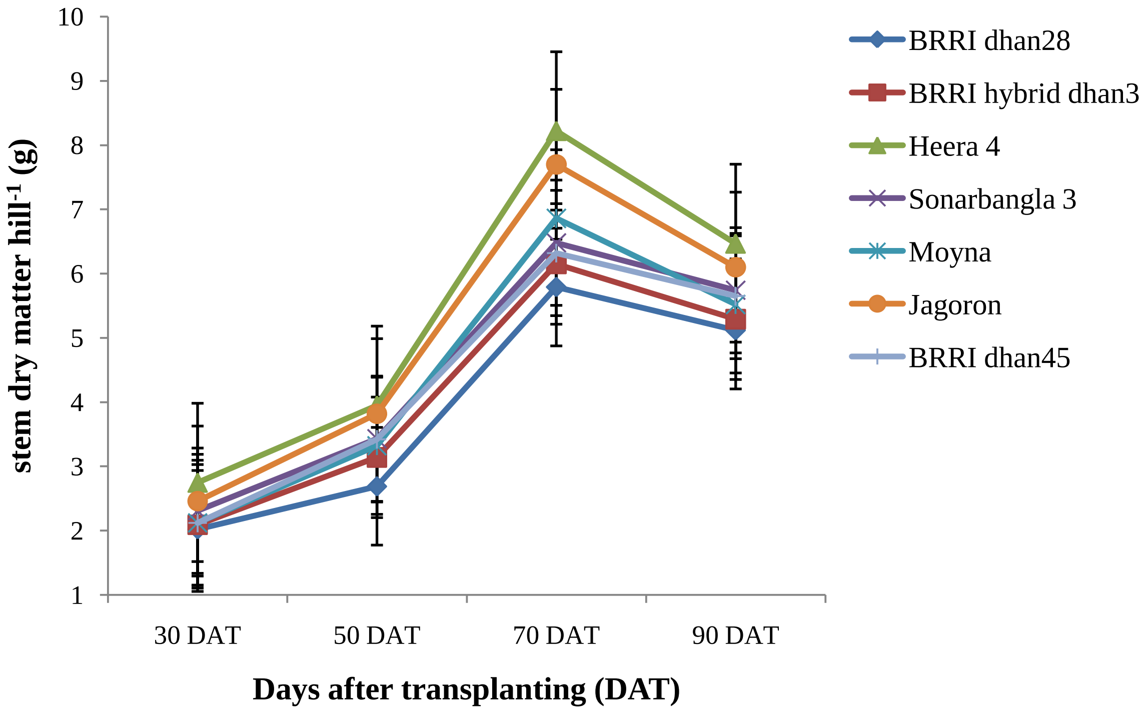

Figure 3. Stem dry matter hill^{-1} at different days after transplanting (DAT) in the test rice varieties. *Vertical bar represents LSD values*

4.5 Leaf dry matter hill^{-1}

Significant variation was observed in terms of leaf dry matter hill^{-1} for different varieties at 30, 50, 70 and 90 DAT (Appendix VII). At 30, 50, 70 and 90 DAT, the highest leaf dry matter hill^{-1} (1.74, 2.93, 6.52 and 5.98 g respectively) were recorded from Heera 4 which were statistically similar (1.68, 2.82, 6.34 and 5.12 g respectively) to Jagoron, whereas the lowest leaf dry matter hill^{-1} (1.37, 2.31, 5.25 and 4.35 g respectively) were recorded from BRRI dhan28 (Figure 4).

4.6 Total dry matter hill^{-1}

Statistically significant variation was recorded for total (stem and leaves) dry matter hill^{-1} for different varieties at 30, 50, 70 and 90 DAT (Appendix VIII). At 30, 50, 70 and 90 DAT, the highest total dry matter hill^{-1} (4.49, 6.88, 14.74 and 12.45 g respectively) were observed in Heera 4 which were statistically similar

(4.14, 6.64, 14.04 and 11.22 g respectively) to Jagoron, again the lowest values (3.39, 5.00, 11.04 and 9.47 g respectively) were found in BRRI dhan28 (Figure 5).

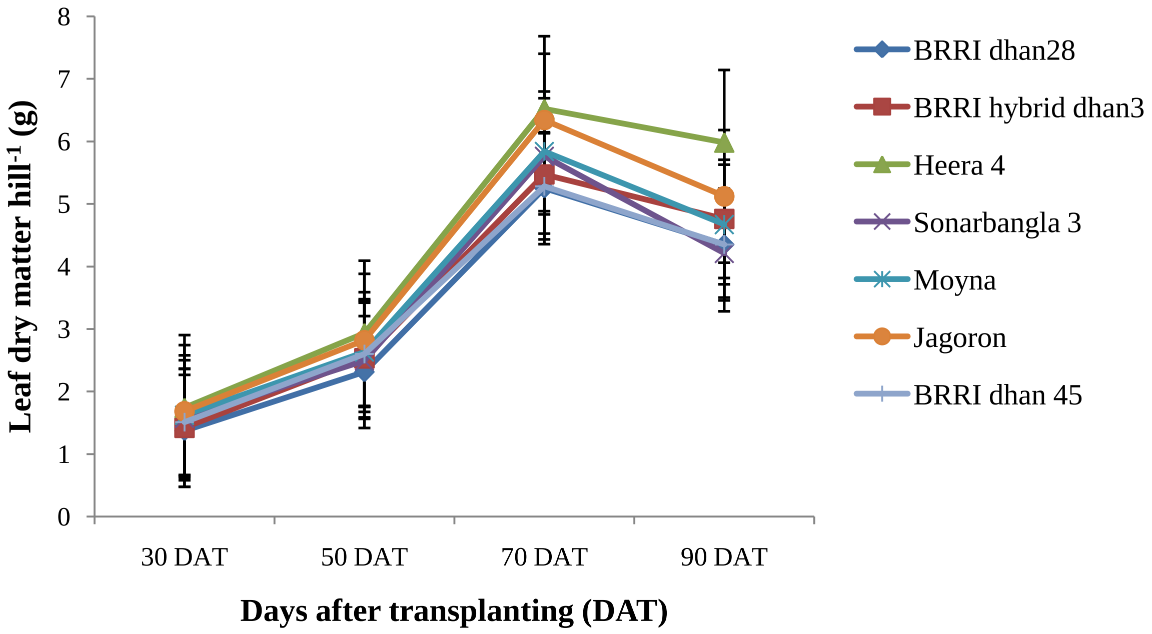

Figure 4. Leaf dry matter hill^{-1} at different days after transplanting (DAT) in the test rice varieties. *Vertical bar represents LSD values*

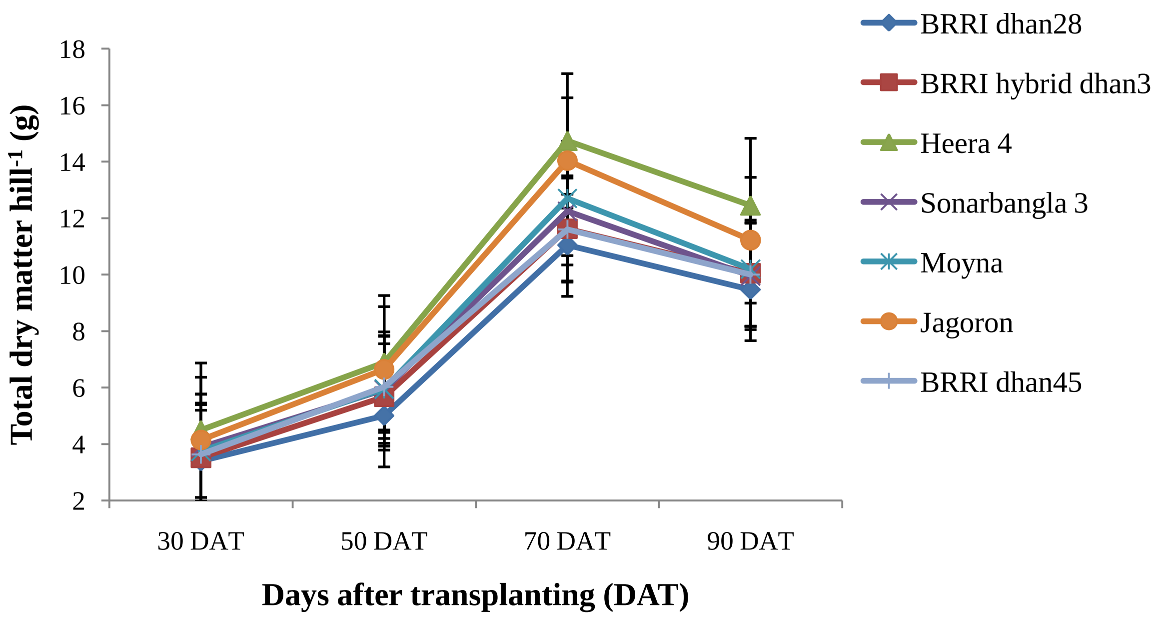

Figure 5. Total dry matter hill^{-1} at different days after transplanting (DAT) in the test rice varieties. *Vertical bar represents LSD values*

4.7 Shoot dry matter accumulation and its remobilization to grain

Statistically significant variation was recorded for shoot dry matter at pre-anthesis, shoot dry matter at maturity, change in shoot dry matter and shoot reserve translocation (Appendix IX).

4.7.1 Shoot dry matter at pre-anthesis period

For shoot dry matter at pre-anthesis period, the highest value (30.88 gm^{-2}) was recorded from Heera 4 which was statistically similar (29.97 and 29.90 gm^{-2} respectively) to Jagoron and Sonarbangla 3. Again the lowest value (24.93 gm^{-2}) was found in BRRI dhan28 (Table 4).

4.7.2 Shoot dry matter at maturity period

In consideration of shoot dry matter at maturity period the highest value (26.07 gm^{-2}) was recorded from Heera 4 which was statistically similar (25.52 and 25.51 gm^{-2} respectively) to Jagoron and Sonarbangla 3, again the lowest value (22.54 gm^{-2}) was found in BRRI dhan28 (Table 4).

4.7.3 Changes in shoot dry matter

For changes in shoot dry matter the highest value (4.81 gm^{-2}) was recorded from Heera 4 which was statistically similar (4.45, 4.39 and 4.30 gm^{-2} respectively) to Jagoron, Sonarbangla 3 and Moyna, again the lowest value (2.39 gm^{-2}) was found in BRRI dhan28 (Table 4).

4.7.4 Shoot reserve translocation

Consideration of shoot reserve translocation, the highest shoot reserve translocation (15.58%) was recorded from Heera 4 which was statistically similar (14.85%, 14.76% and 14.68% respectively) to Jagoron, Moyna and Sonarbangla 3, while the lowest (9.59%) was found in BRRI dhan28 which was followed (11.40%) by BRRI dhan45 (Table 4). This result revealed that the test hybrid variety had the advantage of shoot reserve translocation to the grains.

Table 4. Pre-anthesis dry matter accumulation in shoot and its translocation to the grain of different rice varieties in *Boro* season

Rice variety	Shoot dry matter at pre-anthesis (g m^{-2})	Shoot dry matter at maturity (g m^{-2})	Changes in shoot dry matter (g m^{-2})	Shoot reserve translocation (%)
BRRI dhan28	24.93 d	22.54 c	2.39 d	9.59 c
BRRI hybrid dhan3	28.04 b	24.32 b	3.72 b	13.27 b
Heera 4	30.88 a	26.07 a	4.81 a	15.58 a
Sonarbangla 3	29.90 a	25.51 a	4.39 a	14.68 a
Moyna	29.14 b	24.84 b	4.30 a	14.76 a
Jagoron	29.97 a	25.52 a	4.45 a	14.85 a
BRRI dhan45	27.37 c	24.25 b	3.12 c	11.40 bc
$LSD_{(0.05)}$	1.722	1.175	0.573	2.081
CV (%)	6.89	8.43	6.39	8.36

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

4.8 Days to maturity

Days to maturity of rice showed statistically significant variation due to different varieties (Appendix X). The maximum days to maturity (145.04 days) was observed in Sonarbangla 3 which was closely followed (140.19 days and 139.01 days respectively) by BRRI dhan45 and BRRI dhan28, while the minimum days to maturity (114.57) was found in Jagoron (Table 5).

4.9 Panicles hill^{-1}

Statistically significant variation was recorded for number panicles hill^{-1} of different varieties (Appendix X). The maximum number of panicles hill^{-1} (14.82) was recorded from Heera 4 which was closely followed (13.57) by Jagoron. On the other hand, the minimum number (10.29) was recorded from BRRI dhan45 which was statistically similar (10.45, 10.53 and 10.62) to BRRI dhan28, BRRI hybrid dhan3 and Moyna (Table 5). Shaloie *et al*. (2014) reported that panicle length was longest in hybrid Hb_2 than Hb_1.

4.10 Effective tillers hill^{-1}

Different varieties of rice varied significantly in terms of number of effective tillers hill^{-1} (Appendix X). The maximum number of effective tillers hill^{-1} (14.83) was found in Heera 4 which was statistically similar (13.64) to Jagoron, while the minimum number (10.43) was observed in BRRI dhan45 (Table 5).

4.11 Ineffective tillers hill^{-1}

Different varieties of rice varied significantly in terms of number of ineffective tillers hill^{-1} (Appendix X). The minimum number of ineffective tillers hill^{-1} (1.93) was found in Heera 4 which was statistically similar (2.03) to Jagoron, while the maximum number (3.29) was observed in Moyna which was followed (2.86 and 2.55 respectively) by Sonarbangla 3 and BRRI hybrid dhan3 (Table 5).

4.12 Total tillers hill^{-1}

Significant variation was found for number of total tillers hill^{-1} of different varieties (Appendix X). The maximum number of total tillers hill^{-1} (16.73) was recorded from Heera 4 which was closely followed (15.67) by Jagoron. On the other hand, the minimum number of total tillers hill^{-1} (12.73) was recorded from BRRI dhan45 which was statistically similar (12.87 and 13.27) to BRRI dhan28 and BRRI hybrid dhan3 (Figure 6).

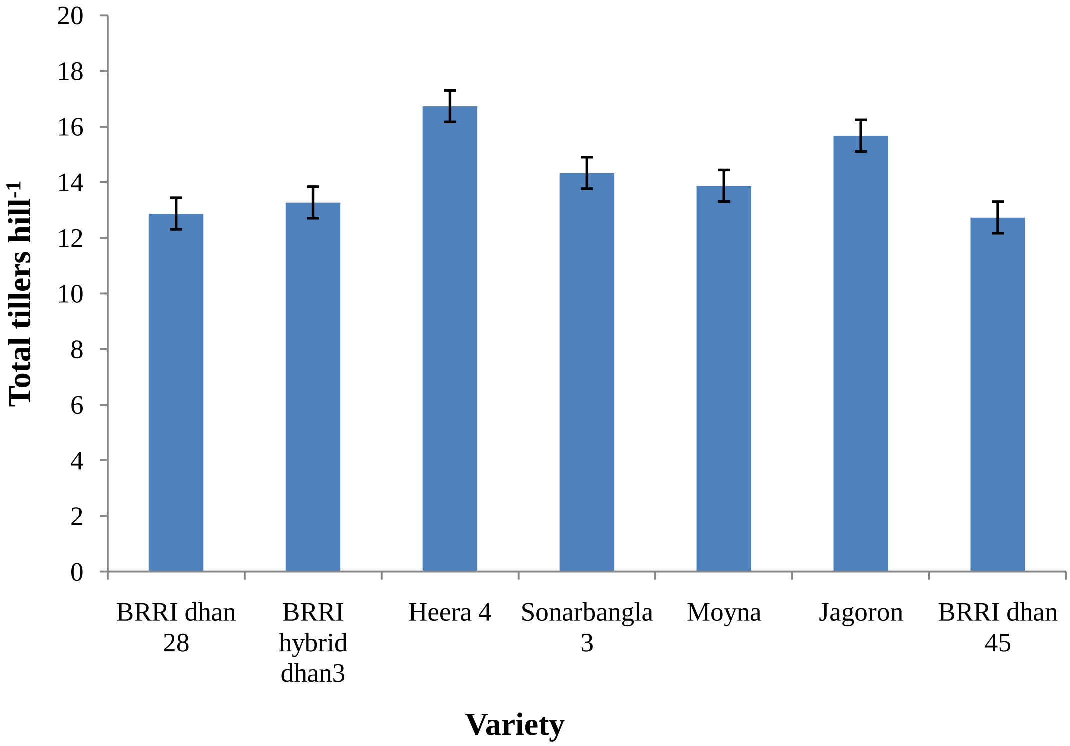

Figure 6. Total tillers hill^{-1} in the test rice varieties during *Boro* season. *Vertical bar represents LSD values*

4.13 Panicle length

Panicle length varied significantly for different varieties of rice (Appendix X). The longest panicle (23.63 cm) was found in Jagoron which was statistically similar (23.51 cm and 23.23 cm) to Heera 4 and Sonarbangla 3 respectively, while the shortest panicle length (18.77 cm) was attained from BRRI dhan28 which was statistically similar (18.79 cm) to BRRI dhan45 (Table 5). Devaraju *et al.* (1998)

in a study with hybrid rice cultivar KRH2 and 1R20 as a check variety and reported that the increased grain yield of KRH2 was mainly attributed to the tallest panicle length. Idris and Matin (1990) conducted an experiment with six varieties and observed that panicle length differed among varieties and it was greater in IR 20 than in indigenous and high yielding varieties.

4.14 Filled grains panicle^{-1}

Statistically significant variation was observed for number of filled grains panicle^{-1} of different variety (Appendix X). The maximum number of spikelets grains per panicle (88.60) were recorded from Heera 4 which was statistically similar (87.87, 83.40 and 82.80) with Jagoron, Sonarbangla 3 and Moyna, again the minimum number of filled spikelets panicle^{-1} (70.27) was recorded from BRRI dhan28 which was statistically similar (74.80 and 75.53) to BRRI dhan45 and BRRI hybrid dhan3 (Table 5). Murthy *et al.* (2004) recorded different number of filled spikelets for different varieties.

4.15 Unfilled grains panicle^{-1}

Number of unfilled grains panicle^{-1} showed significant variation due to different varieties (Appendix X). The minimum number of unfilled grains panicle^{-1} (6.61) was recorded from Heera 4 which was statistically similar (7.02 and 7.32) to Jagoron and Sonarbangla 3, while the maximum number (9.62) was recorded from Moyna which was statistically similar (9.42, 9.12 and 8.82) to BRRI dhan28, BRRI dhan45 and BRRI hybrid dhan3 respectively (Table 5). BINA (1993) conducted an experiment with four varieties/advanced lines and reported significant variation in unfilled grains panicle^{-1}.

4.16 Total spikelets panicle^{-1}

Statistically significant variation was recorded for total spikelets panicle^{-1} for different varieties (Appendix X). The maximum number of total spikelets panicle^{-1} (95.30) was recorded from Heera 4 which was statistically similar (95.00, 92.53 and 90.83) to Jagoron, Moyna and Sonarbangla 3. On the other hand the minimum number of total spikelets panicle^{-1} (79.80) was observed in BRRI dhan28 (Figure 7). Xu *et al.* (1998) and Wang (2001) observed that the restorer lines showed more spikelets than maintainer lines.

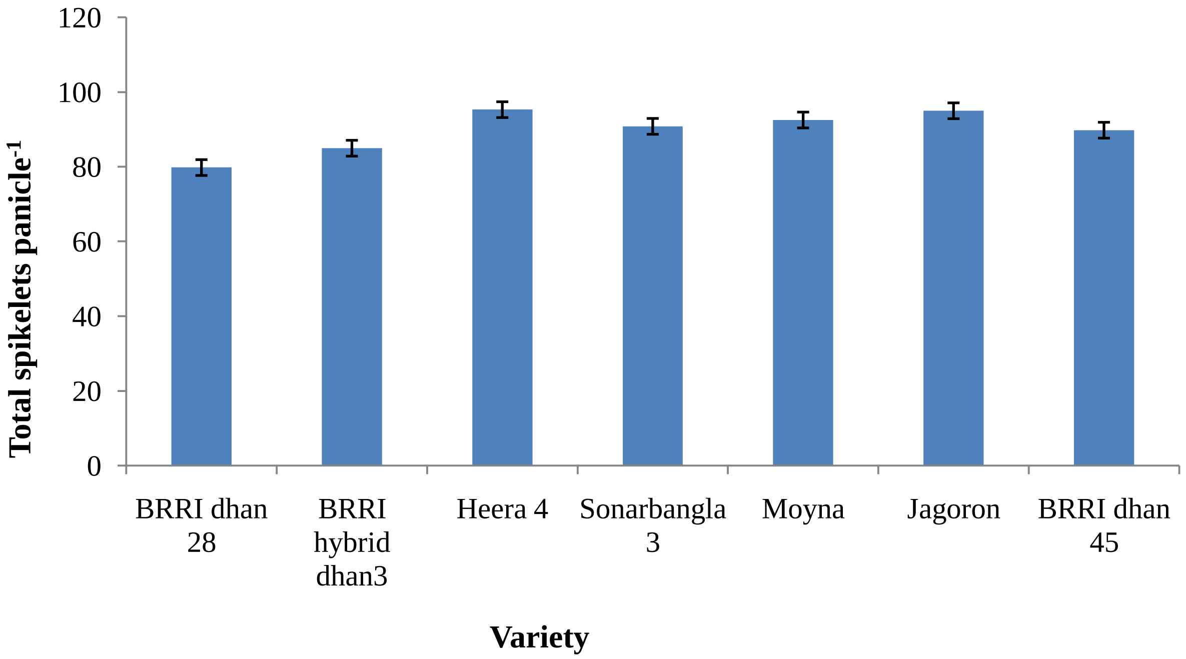

Figure 7. Total spikelets panicle^{-1} in the test rice varieties during *Boro* season.
Vertical bar represents LSD values

4.17 Spikelets fertility

Statistically significant variation was recorded for spikelets fertility for different varieties (Appendix X). The highest spikelets fertility (92.97%) were recorded from Heera 4 which was statistically similar (92.49% and 91.82%) to Jagoron and Sonarbangla 3, while the lowest spikelets fertility (88.06%) was observed in BRRI dhan28 (Figure 8).

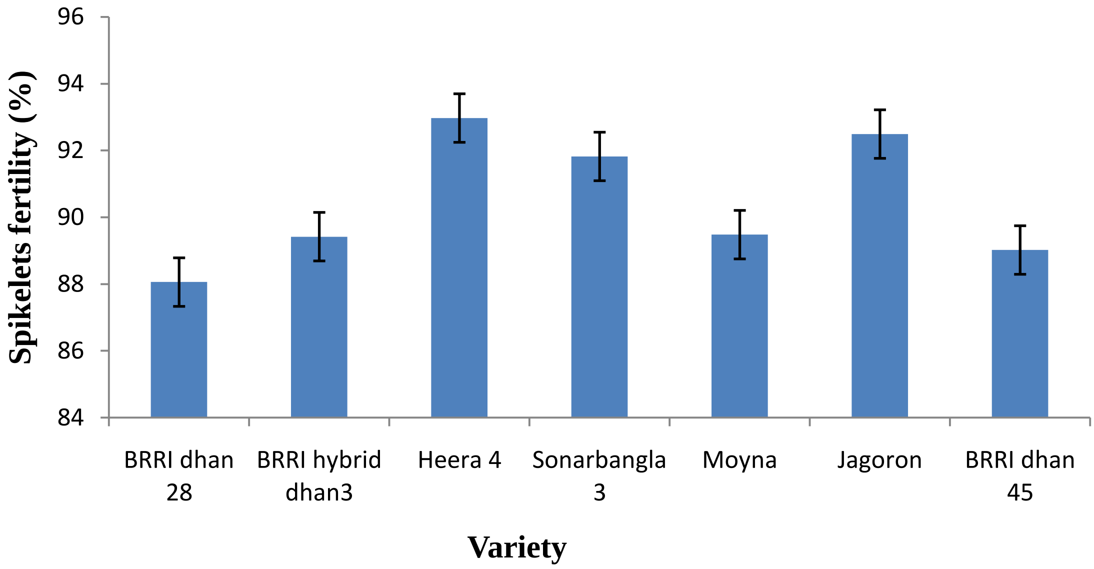

Figure 8. Spikelets fertility (%) in the test rice varieties during *Boro* season.

Vertical bar represents LSD values

4.18 1000 grains weight

Weight of 1000 grains showed significant variation due to different varieties (Appendix X). The highest weight of 1000 grains (23.26 g) was found in Heera 4 which was statistically similar (23.11 g) to Jagoron, while the lowest weight of 1000 grains (19.69 g) was recorded from BRRI dhan28 which was statistically similar (20.14 g, 20.40 g and 20.53 g respectively) to Moyna, BRRI dhan45 and BRRI hybrid dhan3 (Table 5). Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers and observed that IR36 gave the highest 1000-grain weight (21.07g).

Table 5. Yield contributing characters of different rice varieties in *Boro* season

Rice variety	Days to maturity	Panicles $hill^{-1}$ (No.)	Effective tillers $hill^{-1}$ (No.)	Ineffective tillers $hill^{-1}$ (No.)	Panicle length (cm)	Filled grains $panicle^{-1}$ (No.)	Unfilled grains $panicle^{-1}$ (No.)	Weight of 1000-grains (g)
BRRI dhan28	139.01 ab	10.45 d	10.48d	2.39 bc	18.77 c	70.27e	9.42 a	19.69 c
BRRI hybrid dhan3	129.33 c	10.53 d	10.72d	2.55 b	20.65 b	75.53d	8.82 a	20.53 bc
Heera 4	137.00 b	14.82 a	14.83a	1.93 c	23.51 a	88.6a	6.61 b	23.26 a
Sonarbangla 3	145.04 a	12.07 c	11.64c	2.86 b	23.23 a	83.4b	7.32 b	21.61ab
Moyna	138.12 b	10.62 d	10.66d	3.29 a	19.72 b	82.8b	9.62 a	20.14 bc
Jagoron	114.57 d	13.57 b	13.64b	2.03 c	23.63 a	87.87a	7.02 b	23.11 a
BRRI dhan45	140.19 ab	10.29 d	10.43d	2.30 bc	18.79 c	74.80d	9.12 a	20.40 bc
$LSD_{(0.05)}$	7.236	0.765	0.264	0.775	2.249	5.48	0.961	1.094
CV (%)	5.63	4.76	8.89	16.76	6.57	5.35	7.55	8.83

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

4.19 Grain yield

Significant variation was recorded for grain yield of rice due to different varieties (Appendix XI). The highest grain yield (7.80 t ha^{-1}) was observed in Heera 4 which was statistically similar (7.08 t ha^{-1}) to Jagoron and closely followed (6.35 t ha^{-1} and 6.18 t ha^{-1}) by Sonarbangla 3 and Moyna. On the other hand, the lowest grain yield (4.23 t ha^{-1}) was recorded from BRRI dhan28 (Figure 9). Swain *et al*. (2006) reported that the control cultivar IR64, with high translocation efficiency and 1000-grain weight and lowest spikelet sterility recorded a grain yield of 5.6 t ha^{-1} that was statistically similar to the hybrid line PA6201. Xie *et al.* (2007) reported different yield for different variety.

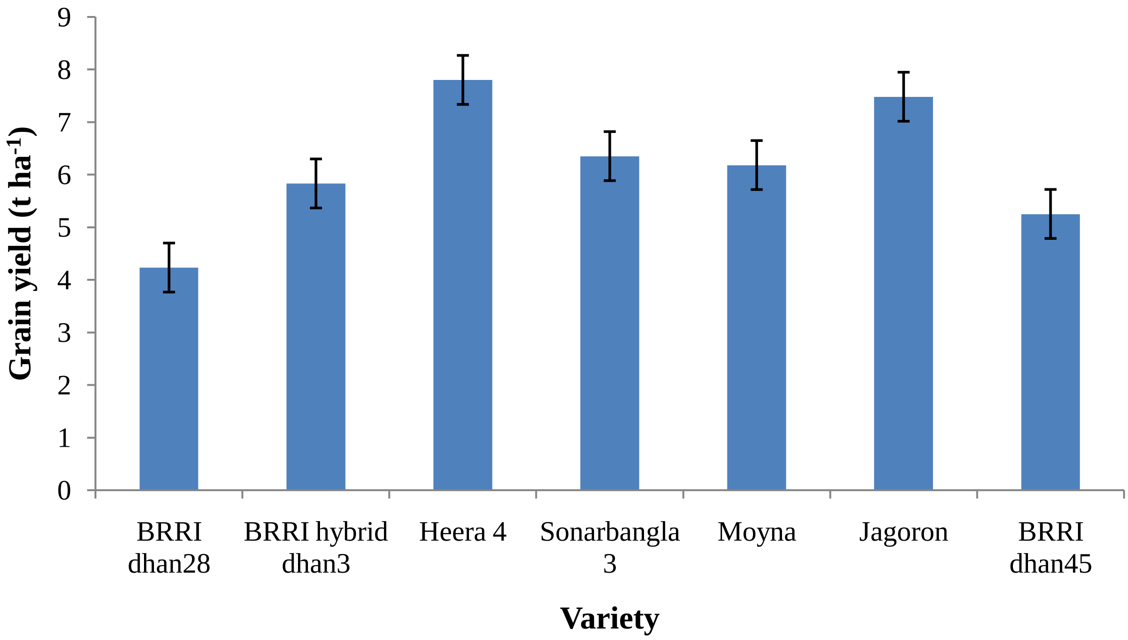

Figure 9. Grain yield in the test rice varieties during *Boro* season. *Vertical bar represents LSD values*

4.20 Straw yield

Straw yield of rice showed statistically significant variation for different varieties of rice (Appendix XI). The highest straw yield (9.39 t ha^{-1}) was found in Jagoron which was statistically similar (9.21 t ha^{-1} and 8.86 t ha^{-1} respectively) to Heera 4 and Sonarbangla 3, while the lowest straw yield (6.24 t ha^{-1}) was attained from BRRI dhan28 which was closely followed (6.46 t ha^{-1}) by BRRI dhan45 (Figure 10).

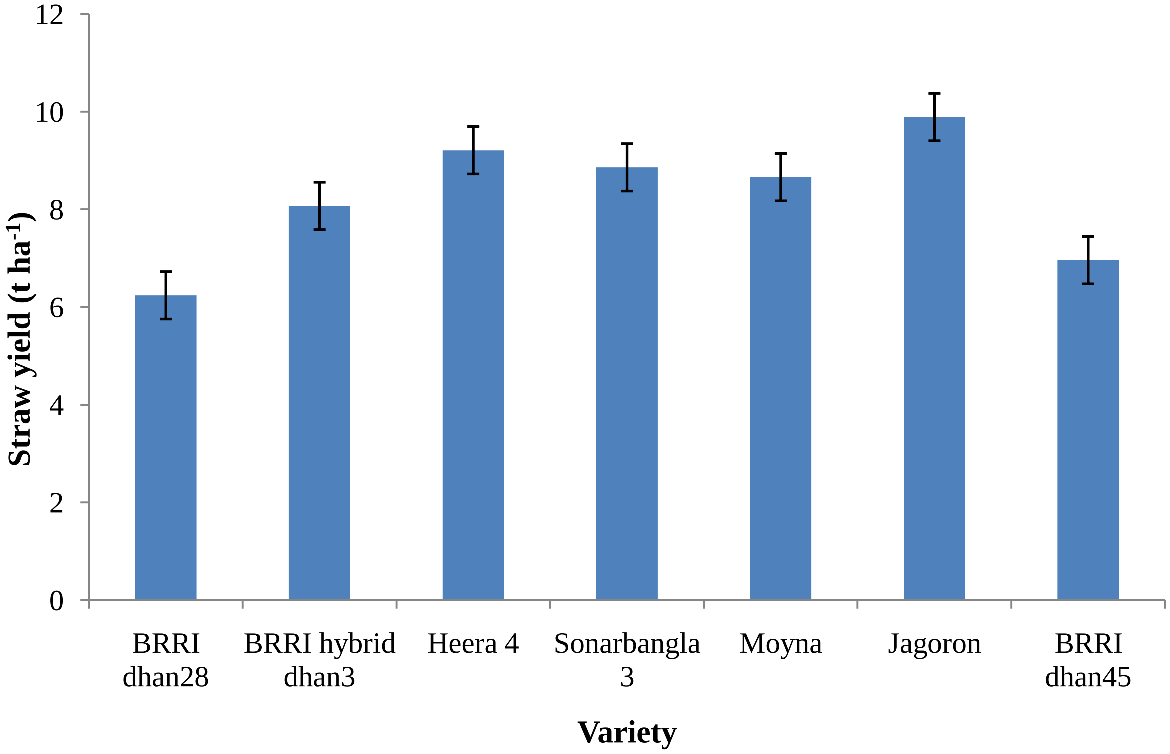

Figure 10. **Straw yield in the test rice varieties during *Boro* season.** *Vertical bar represents LSD values*

4.21 Biological yield

Statistically significant variation was recorded for biological yield of rice due to different varieties (Appendix XI). The highest biological yield (17.01 t ha^{-1}) was observed in Heera 4 which was statistically similar (16.47 t ha^{-1}) to Jagoron and closely followed (15.21 t ha^{-1} and 14.84 t ha^{-1}) by Sonarbangla 3 and Moyna, whereas the lowest biological yield (10.47 t ha^{-1}) was found in BRRI dhan28 which was statistically similar (11.01 t ha^{-1}) to BRRI dhan45 (Figure 11).

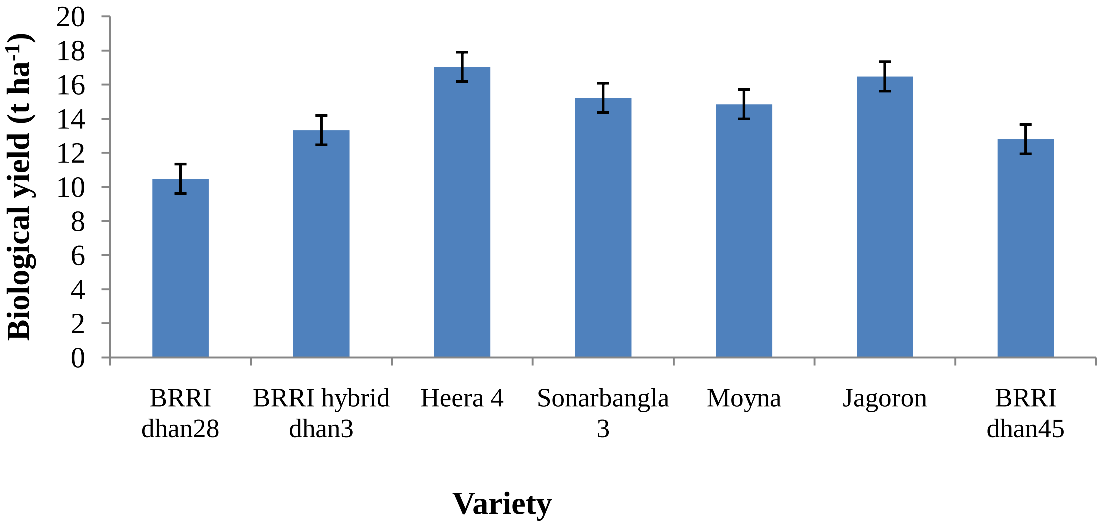

Figure 11. Biological yield in the test rice varieties during *Boro* season. *Vertical bar represents LSD values*

4.22 Harvest index

Harvest index of rice varied significantly due to different varieties (Appendix XI). The highest harvest index (45.86%) was found in Heera 4 which was followed (42.99%, 41.75% and 41.64% respectively) by Jagoron, Sonarbangla 3 and Moyna. Again the lowest harvest index (40.40%) was recorded from BRRI dhan28 (Figure 12).

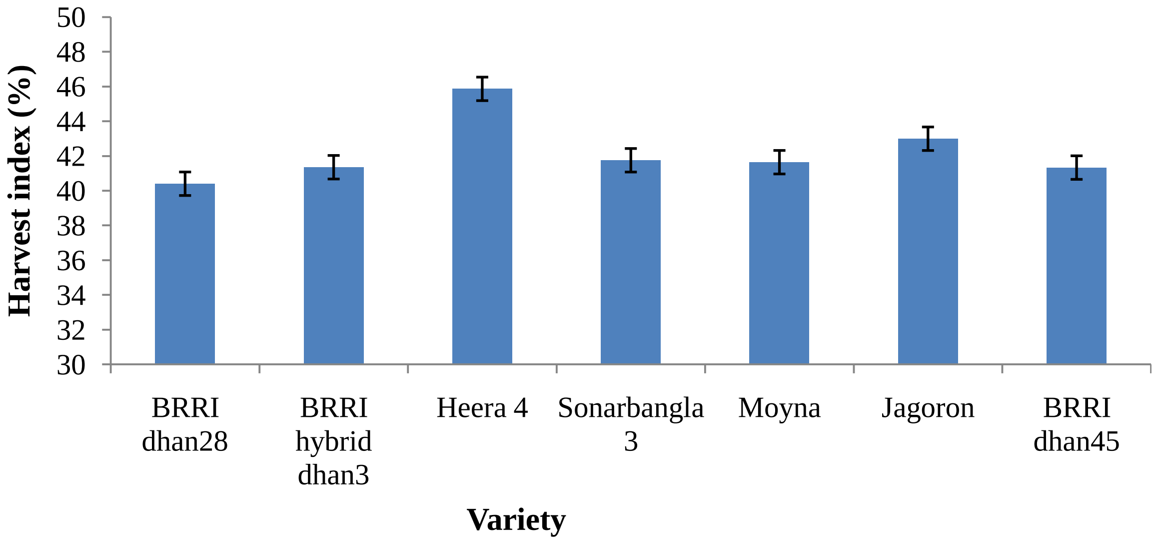

Figure 12. **Harvest index in the test rice varieties during *Boro* season.** *Vertical bar represents LSD values*

4.23 Source-sink relationship

Ratio of spikelets number to leaf area (at heading), yield sink to leaf area (at heading) and grain dry matter accumulated from current photosynthetic assimilation to leaf area (heading to maturity) reflected source-sink relation (Table 6). Heera 4 (0.31 no. cm^{-2}), Jagoron (0.30 no. cm^{-2}) and Sonarbangla 3 (0.27 no. cm^{-2}) varieties maintained considerable higher ratio of spikelets number to leaf area (at heading) compared to inbred BRRI dhan28 (0.22 no. cm^{-2}) in *Boro* season. In addition, the highest ratio of yield sink to Leaf Area (At heading) was recorded from Heera 4 (14.09 mg cm^{-2}) which was followed (13.88, 13.39, 13.02 mg cm^{-2} respectively) by Jagoron, Sonarbangla 3 and Moyna, while the lowest value was recorded from BRRI dhan28 (11.09 mg cm^{-2}). This result indicated that the test hybrid varieties had higher source use efficiency from panicle initiation (PI) stage to heading stage. This efficiency ultimately helped to produce the larger sink in the test hybrid varieties.

Tabulated data of *Boro* season showed that ratio of grain dry matter accumulated from current photosynthetic assimilation to leaf area (heading to maturity) was significantly higher in Heera 4 (11.01 mg cm^{-2}) than all studied varieties. These results suggested that Heera 4 had the genotypic superiority over the test varieties in respect of post heading photosynthetic assimilation per unit leaf area (higher source use efficiency). Higher yield sink per unit leaf area in all the studied hybrids indicated that the shoot reserve remobilization played substantial role in its higher yield over inbred varieties.

4.23.1 Grain dry matter from current photosynthate (GDMCPn)

Percentage of grain dry matter accumulated from current photosynthate (GDMCPn%) varied significantly among the studied hybrid and inbred varieties (Table 6). Grain dry matter accumulated from current photosynthate ranged from 75.79% to 83.19% in *Boro* season respectively among the varieties. Heera 4 (83.19%) accumulated significantly higher percentage of dry matter from current photosynthate in grain compared to all the studied varieties in *Boro* season. This value was closely followed (82.99%, 80.95%, 79.93% and 78.66% respectively) by Jagoron, Sonarbangla 3, BRRI hybrid dhan3 and Moyna, while the lowest value(75.79%) was recorded from BRRI dhan45.

Table 6. Source-sink relation of the hybrid and inbred rice varieties in *Boro* season

Rice variety	Ratio of spikelets no. to LA (at heading) No.cm^{-2}	Ratio of yield sink to LA (at heading) mg. cm^{-2}	Ratio of GDMCPn to average LA (heading to maturity) mg. cm^{-2}	GDMCPn (%)
BRRI dhan28	0.22d	11.09c	8.80bc	75.95c
BRRI hybrid dhan3	0.23cd	12.98bc	10.04b	79.93bc
Heera 4	0.31a	14.05a	11.01a	83.19a
Sonarbangla 3	0.27b	13.39b	10.14ab	80.95b
Moyna	0.26b	13.02b	9.62b	78.66b
Jagoron	0.30a	13.88ab	10.79a	82.99a
BRRI dhan45	0.24c	11.37c	8.68c	75.79c
$LSD_{(0.05)}$	0.152	1.352	0.734	3.217
CV (%)	5.67	7.75	4.54	8.94

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
DM= dry matter, LA =leaf area, GDMCPn= Grain dry matter from current photosynthate.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from November 2013 to March 2014, to study the source-sink relationship and yield performance of hybrid rice varieties in *Boro* season. BRRI dhan28, BRRI hybrid dhan3, Heera 4, Sonarbangla 3, Moyna, Jagoron and BRRI dhan45 were used as test crop. The experiment was laid out in Randomized Complete Block Design with three replications.

At 30, 50, 70 and 90 DAT, the tallest plant heights (37.29, 56.49, 79.23 and 98.83 cm respectively) were recorded from Jagoron , whereas the shortest heights (29.28, 47.68, 71.12 and 87.30 cm respectively) were recorded from BRRI dhan28 . The maximum number of tillers hill^{-1} (6.83, 10.52, 17.31 and 19.27 respectively) were found in Heera 4, while the minimum number (4.07, 7.27, 11.07 and 14.41 respectively) were observed in BRRI dhan28. The highest LAI (0.279, 1.164, 3.48 and 5.97 respectively) was observed in Heera 4 and the lowest LAI (0.213, 0.921, 2.74 and 5.03 respectively) was found in BRRI dhan28 . The highest stem dry matter hill^{-1} (2.75, 3.95, 8.22 and 6.47 g respectively) were found in Heera 4, while the lowest values (2.02, 2.69, 5.79 and 5.12 g respectively) were attained from BRRI dhan28. The highest leaf dry matter hill^{-1} (1.74, 2.93, 6.52 and 5.98 g respectively) were recorded from Heera 4, whereas the lowest values (1.37, 2.31, 5.25 and 4.35 g respectively) were recorded from BRRI dhan28. The highest total dry matter hill^{-1} (4.49, 6.88, 14.74 and 12.45 g respectively) were observed in Heera 4, again the lowest values (3.39, 5.00, 11.04 and 9.47 g respectively) were found in BRRI dhan28. The highest values for shoot dry matter at pre-anthesis (30.88 gm^{-2}) and at maturity (26.07 gm^{-2}) were recorded from Heera 4, while the lowest values (24.93 and 22.54 gm^{-2} respectively) were attained from BRRI dhan28. For changes in shoot dry matter the highest value (4.81 gm^{-2}) was recorded from Heera 4 and the lowest value (2.39 gm^{-2}) was found in BRRI dhan28 . The highest shoot reserve translocation (15.58%) was recorded from

Heera 4, while the lowest (9.59%) was found in BRRI dhan28. The maximum days to maturity (145.04 days) was observed in Sonarbangla 3, while the minimum days to maturity (114.57) was found in Jagoron. The maximum number of effective tillers hill^{-1} (14.83) was found in Heera 4, while the minimum number (10.43) was observed in BRRI dhan45. The longest panicle length (23.63 cm) was found in Jagoron while the shortest panicle length (18.77 cm) was attained from BRRI dhan28. The maximum number of total spikelets panicle^{-1} (95.30) was recorded from Heera 4 and the minimum number (79.80) was observed in BRRI dhan28. The highest spikelets fertility (92.97%) was recorded from Heera 4, while the lowest value (88.06%) was observed in BRRI dhan28. The highest weight of 1000 grains (23.26 g) was found in Heera 4, while the lowest weight (19.69 g) was recorded from BRRI dhan28. The highest grain yield (7.80 t ha^{-1}) was observed in Heera 4 and, the lowest value (4.23 t ha^{-1}) was recorded from BRRI dhan28. The highest straw yield (9.39 t ha^{-1}) was found in Jagoron, while the lowest value (6.24 t ha^{-1}) was attained from BRRI dhan28. The highest biological yield (17.01 t ha^{-1}) was observed in Heera 4 whereas the lowest biological yield (10.47 t ha^{-1}) was found in BRRI dhan28. The highest HI (45.86%) was found in Heera 4, again the lowest HI (40.40%) was recorded from BRRI dhan28. In addition, Heera 4 maintained highest ratio of spikelets number to LA (0.31 no. cm^{-2}) (at heading), while the lowest value (0.22 no. cm^{-2}) was observed in BRRI dhan28. The highest ratio of yield sink to LA (At heading) was recorded from Heera 4 (14.09 mg cm^{-2}), while the lowest value (11.09 mg cm^{-2}) was recorded from BRRI dhan28. Heera 4 (83.19%) accumulated significantly higher percentage of dry matter from current photosynthate in grain, while the lowest value (75.79%) was recorded from BRRI dhan45. These results suggested that Heera 4 had the genotypic superiority over the tested varieties in respect of post heading photosynthetic assimilation per unit leaf area (higher source use efficiency).

From the findings, it is observed that all the studied hybrids showed better performance in case of tillering, leaf area development pattern, source use efficiency and yield performance compared to inbred varieties. Among all test rice varieties Heera 4 hybrid rice was the best among the test varieties in consideration of source-sink relationship and yield performance. Jagoron was statistically similar to Heera 4 in terms of maximum attributes.

Considering the situation of the present experiment, the followings can be recommended-

1. Heera 4 and Jagoron may be chosen to cultivate in *Boro* season for higher grain yield.

2. Such experiment is needed to conduct in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performance.

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APPENDICES

Appendix I. Characteristics of the soil of experimental field

A. Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Expeimental Field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November, 2013 to March 2014

Month (2013)	Air temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
November	30.4	15.6	79	0
December	29.0	13.0	72	1
January	28.1	11.1	55	1
February	33.9	12.2	67	45
March	34.6	16.5	65	88

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix III. Analysis of variance of the data on plant height of rice as influenced by different variety

Source of variation	Degrees of freedom	Mean square Plant height (cm) at				
		30 DAT	50 DAT	70 DAT	90 DAT	Harvest
Replication	2	0.185	1.966	0.905	11.916	17.869
Treatment (Variety)	6	23.515**	38.941**	33.387**	57.704**	39.997**
Error	12	8.185	9.463	9.911	11.830	12.868

**: Significant at 0.05 level of significance.

Appendix IV. Analysis of variance of the data on tillers hill^{-1} of rice as influenced by different variety

Source of variation	Degrees of freedom	Mean square Tillers hill^{-1} at			
		30 DAT	50 DAT	70 DAT	90 DAT
Replication	2	0.091	0.002	0.236	0.640
Treatment (Variety)	6	2.034**	3.999**	19.138**	11.529**
Error	12	0.474	0.842	1.446	1.498

**: Significant at 0.05 level of significance.

Appendix V. Analysis of variance of the data on leaf area index of rice as influenced by different variety

Source of variation	Degrees of freedom	Mean square			
		Leaf area index at			
		30 DAT	50 DAT	70 DAT	90 DAT
Replication	2	0.000	0.000	0.059	0.039
Treatment (Variety)	6	0.002**	0.040**	0.325**	0.471**
Error	12	0.018	0.056	0.245	0.509

**: Significant at 0.05 level of significance;

Appendix VI. Analysis of variance of the data on stem dry matter plant^{-1} of rice as influenced by different variety

Source of variation	Degrees of freedom	Mean square				
		Stem dry matter hill^{-1} (g) at				
		30 DAT	50 DAT	70 DAT	90 DAT	Harvest
Replication	2	0.030	0.016	0.011	0.186	0.193
Treatment (Variety)	6	0.224**	0.327**	0.569**	0.642**	2.408**
Error	12	0.301	0.142	0.543	0.470	0.692

**: Significant at 0.05 level of significance

Appendix VII. Analysis of variance of the data on leaf dry matter plant^{-1} of rice as influenced by different variety

Source of variation	Degrees of freedom	Mean square				
		Leaf dry matter hill^{-1} (g) at				
		30 DAT	50 DAT	70 DAT	90 DAT	Harvest
Replication	2	0.002	0.004	0.002	0.195	0.076
Treatment (Variety)	6	0.050**	0.130**	0.228**	1.228**	0.679**
Error	12	0.071	0.121	0.201	0.902	0.211

**: Significant at 0.05 level of significance

Appendix VIII. Analysis of variance of the data on total dry matter plant^{-1} of rice as influenced by different variety

Source of variation	Degrees of freedom	Mean square				
		Total dry matter hill^{-1} (g) at				
		30 DAT	50 DAT	70 DAT	90 DAT	Harvest
Replication	2	0.045	0.031	0.012	0.512	0.087
Treatment (Variety)	6	0.422**	0.842**	1.490**	3.288**	5.518**
Error	12	0.355	0.242	0.801	1.502	1.560

**: Significant at 0.05 level of significance

Appendix IX. Analysis of variance of the data on pre-anthesis dry matter accumulation in shoot and its translocation to the grain of rice as influenced by different variety

Source of variation	Degrees of freedom	Mean square			
		Shoot dry matter at pre-anthesis (g m^{-2})	Shoot dry matter at maturity (g m^{-2})	Changes in shoot dry matter (g m^{-2})	Shoot reserve translocation (%)
Replication	2	4.873	5.092	0.132	1.234
Treatment (Variety)	6	52.671**	88.965**	8.095**	62.456**
Error	12	1.722	1.175	0.573	2.081

**: Significant at 0.05 level of significance;

Appendix X. Analysis of variance of the data on yield contributing characters of rice as influenced by different variety

Source of variation	Degrees of freedom	Mean square				
		Days from sowing to harvest	Panicles $hill^{-1}$ (No.)	Effective tillers $hill^{-1}$ (No.)	Ineffective tillers $hill^{-1}$ (No.)	Length of panicle (cm)
Replication	2	27.931	0.074	0.328	0.436	0.159
Treatment (Variety)	6	260.109**	9.353**	0.676**	6.749**	10.831**
Error	12	7.236	0.765	0.264	0.775	2.249

**: Significant at 0.05 level of significance

Appendix X. Cont'd

Source of variation	Degrees of freedom	Mean square				
		Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Total grains panicle^{-1} (No.)	Spikelets fertility (%)	Weight of 1000-grains (g)
Replication	2	9.745	0.366	13.585	3.562	0.068
Treatment (Variety)	6	147.724**	4.734**	110.621**	123.78**	3.992**
Error	12	5.481	0.961	17.031	1.980	1.094

**: Significant at 0.05 level of significance;

Appendix XI. Analysis of variance of the data on yield contributing characters and yield of rice as influenced by different variety

Source of variation	Degrees of freedom	**Mean square**			
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index (%)
Replication	2	1.328	0.357	2.490	8.525
Treatment (Variety)	6	10.629**	3.844**	26.631**	26.595**
Error	12	0.720	0.541	0.620	2.724

**: Significant at 0.05 level of significance