INFLUENCE OF WEED CONTROL METHODS ON THE GROWTH AND YIELD OF AROMATIC *AMAN* RICE VARIETIES

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CERTIFICATE

This is to certify that the thesis entitled, **"INFLUENCE OF WEED CONTROL METHODS ON THE GROWTH AND YIELD OF AROMATIC *AMAN* RICE VARIETIES"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN AGRONOMY,** embodies the result of a piece of *bona fide* research work carried out by **IMTIAZ FARUK CHOWDHURY,** Registration No. **06-02019** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission.

Dated:

Place: Dhaka, Bangladesh

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DEDICATED TO

MY

BELOVED PARENTS

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INFLUENCE OF WEED CONTROL METHODS ON THE GROWTH AND YIELD OF AROMATIC *AMAN* RICE VARIETIES

ABSTRACT

A field experiment was conducted in medium fertile soil at Sher-e-Bangla Agricultural University (90º33´ E longitude and 23º77´ N latitude), Dhaka, Bangladesh during July to December, 2011 in *aman* season with a view to find out the performance of transplant aromatic rice varieties under different weed control methods. The experiment was carried out with four varieties *i.e*. BRRI dhan34, BRRI dhan37, BRRI dhan50 and Chinigura in the main plot and five weed management methods viz. control (no weeding), one hand weeding at 15 DAT, two hand weeding 15 DAT + 40 DAT, Topstar 400SC (Oxadiargyl 400 g L^{-1}) @ 100 g ha^{-1} as post-emergence and Sunrice 150WG (Ethoxysulfuron 150 g kg^{-1}) @ 185 ml ha^{-1} as pre-emergence herbicide in the sub plot in split plot design. Twenty three different weed species infested the field among which *Echinochloa crussgalli* (51.79%) at 15 DAT, *Cyperus michelianus* (56.14%) at 30 DAT, *Cyperus esculentus* (24.93%) and *Cyperus difformis* (24.54%) at 45 DAT, *Cyperus esculentus* (33.6%) at 60 DAT and *Ludwigia octovalvis* (21.88%) at 75 DAT were dominant. BRRI dhan34 gave highest (3.16 t ha^{-1}) and BRRI dhan50 produced lowest grain yield (1.88 t ha^{-1}). The result showed that pre-emergence herbicide Sunrice 150WG controlled weeds very significantly which showed highest growth and yield contributing characters of rice. Application of Sunrice 150WG showed highest weed control efficiency at 30 DAT 95.28% and 78.95% at 60 DAT. The grain yield produced by Sunrice 150WG was 50.73%, 32.07%, 11.95% and 5.25% higher than the yield obtained from control, one hand weeding, two hand weeding and Topstar 400SC treated plots, respectively. Considering weed control cost, Sunrice 150WG was found more economic for controlling weeds in transplant aromatic *aman* rice and benefit cost ratio was 2.26 whereas, 1.17, 1.30, 1.46 and 2.14 were found from control, one hand weeding at 15 DAT, two hand weeding at 15 DAT + 40 DAT and Topstar 400SC, respectively. The interaction showed that BRRI dhan34 in combination with Sunrice 150WG produced the highest grain yield (4.10 t ha^{-1}) while lowest grain yield (1.44 t ha^{-1}) was obtained from BRRI dhan50 in control treatment.

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LIST OF ACRONYMS

AEZ	=	Agro- Ecological Zone
AIS	=	Agriculture Information Service
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
B:C	=	Benefit Cost ratio
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centi-meter
cv.	=	Cultivar
DAT	=	Days after transplanting
^{0} 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
HYV	=	High yielding variety
hr	=	hour
IRRI	=	International Rice Research Institute
Kg	=	kilogram
LV	=	Local variety
LYV	=	Low yielding varieties
LSD	=	Least significant difference
m	=	Meter
m^2	=	meter squares
MV	=	Modern variety
mm	=	Millimeter
viz.	=	namely
ns	=	Non significant
%	=	Percent
CV %	=	Percentage of Coefficient of Variance
ppm	=	Parts per million
SAU	=	Sher-e- Bangla Agricultural University
t ha^{-1}	=	Tons per hectare

Chapter 1

INTRODUCTION

INTRODUCTION

Rice is the staple food for nearly half of the world's population. However, more than 90% of this rice is consumed in Asia, where it is a staple food for a majority of the population including 560 million hungry people (Mohanty, 2013). It is estimated that by the year 2025, the world's farmers should produce about 60% more rice than at present to meet the food demands of the expected world population at that time (Fageria, 2007). The people in Bangladesh depend on rice and have tremendous influence on agrarian economy of Bangladesh. The population of Bangladesh became almost double over last three decade from 72 million in 1972 to 140 million in 2005 with an average increase by over 2 million per year and to feed the increased population in 2020, about 32800 thousand metric tons of rice will be needed to produce in the country (MoA, 2007). In Bangladesh, rice is grown under three distinct seasons namely *aus*, *aman* and *boro* in irrigated, rainfed and deep water conditions. The area and the production of rice in our country in 2011-2012 are 11.53 million hectares and 33.91 million tons, respectively (AIS, 2013). The majority of rice area is covered by *aman* (autumn) rice is 5.58 million hectares with the total production of 12.80 million metric tons and the average yield is 2.29 metric tons per hectare (AIS, 2013).

In Bangladesh, more than four thousand landraces of rice are adopted in different parts of this country. Some of these are unique for quality traits including fineness, aroma, taste and protein contents (Kaul *et al.,* 1982). But most high quality cultivars are low yielding (Shakeel *et al*., 2005). Aromatic rices constitute a small but special group of rice which is considered best in quality. These rices have long been popular in the orient but now becoming more popular in Middle East, Europe and the United States (Singh *et al.,* 2000). This contains natural ingredient 2- acetyl-1-pyrroline which is responsible for their fragrant taste and aroma (Gnanavel *et al.*, 2010). Aromatic rice as reported by Singh *et al.* (2000), had 15 times more 2- acetyl -1- pyrroline content than non - aromatic rice (0.14 and 0.009 ppm, respectively). In addition to 2- acetyl -1- pyrroline, there are about 100 other volatile compounds, including 13 hydrocarbons, 14 acids, 13 alcohols, 16 aldehydes, 14 ketones, 8 esters, 5 phenols and some other compounds, which are associated with the aroma development in rice (Singh *et al.*, 2000). The demand for special purpose aromatic rice has dramatically increased over the past two decades in the world. Aromatic rice varieties are rated best in quality and fetch a much higher price than non-aromatic rice. The demands for aromatic rice both for internal consumption and also for export show an increasing trend (Das and Baqui, 2000). Most of the aromatic rice varieties in Bangladesh are traditional photo-period sensitive types and are grown during *aman* season (Baqui *et al.*, 1997). Cultivation of fine as well as aromatic rice has been gaining popularity in Bangladesh over the recent years, because of its huge demand both for internal consumption and export (Das and Baqui, 2000). Aromatic rice varieties have occupied about 12.5% of the total transplant *aman* rice cultivation (BBS, 2005).

Weeds grow in the crop fields throughout the world. It is often said, “Crop production is a fight against weeds” (Mukhopadhyay and Ghosh, 1981). The prevailing climatic and edaphic conditions are highly favorable for luxuriant growth of numerous species of weeds which offer a keen competition with rice crop. Since weeds and crops largely use the same resources for their growth, they will compete when these resources are limited (Zimdahl, 1980). Weeds in tropical zones cause yield loss on rice of about 35% (Oerke and Dehne, 2004). Most of the weeds derive their nourishment through rapid development and manifested by quick root and shoot development. Uncontrolled weeds cause grain yield reduction up to 76% under transplanted conditions in India (Singh *et al*., 2004). Weeds are the most competitors in their early growth stages than the later and hence the growth of crops slows down and grain yield decreases (Jacob and Syriac, 2005). Studying competition between weeds and crops can help many societies reach their goals of increased food production (Ehteshami and Esfehani, 2005).

In a rice field, variety of weeds grown are generally classified into three groups namely, grasses, sedges and broadleaf weeds according to their morphological character. In Bangladesh the traditional methods of weed control practices include preparatory land tillage, hand weeding by hoe and hand pulling. Usually two or three hand weeding are normally done for growing a rice crop depending upon the nature of weeds, their intensity of infestation and the crop grown. Hand weeding is highly labor-intensive (as much as 190 person days ha^{-1}) (Roder, 2001). Due to high wages as well as unavailability of labor during peak season, hand weeding is not an economically viable option for the farmers. Weed control in transplant *aman* rice by mechanical and cultural methods is expensive (Mitra *et al.*, 2005). In contrast, chemical weed control is easier and cheaper. On the other hand chemical methods lead to environmental pollution and negative impact on public health (Phuong *et al.*, 2005). However, herbicide selectivity and application dose may reduce the pollution in some extent. This issue needs to examine weed management practices that help keeping lower weed population and better control. So, the vegetation community consisting of rice crops and weeds should be seen and regarded as a competitive and cooperative system that has to be managed appropriately. Therefore, the study has been undertaken to fulfill the following objectives.

1. Find out the effect of variety on the growth and yield of aromatic rice,
2. Evaluate the different weed management methods in aromatic *aman* rice, and
3. Assessment of economic performances of different weed control methods.

Chapter 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Variety is an important factor as it influences the plant population per unit area, availability of sunlight, nutrient competition, photosynthesis, respiration etc. which ultimately influence the growth and development of the crops. In agronomic point of view weed management for modern rice cultivation has become an important issue. Considering the above points, available literature was reviewed under different rice variety and weed control of rice.

2.1 Effect of variety

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. Some available information and literature related to the effect of variety on the yield of aromatic & non-aromatic rice are discussed below.

2.1.1 Effect on growth characters

2.1.1.1 Plant height

Bisne *et al.* (2006) conducted an experiment with eight promising varieties using four CMS lines and showed that plant height differed significantly among the varieties and Pusa Basmati gave the highest plant height in each line.

Om *et al.* (1998) conducted an experiment with hybrid rice cultivars ORI 161 and PMS 2A x IR 31802 and found taller plants in ORI 161 than in PMS 2A x IR 31802.

BINA (1993) evaluated the performance of four rice varieties- IRATOM 24, BR14, BINA13 and BINA19. It was found that varieties differed significantly in respect of plant height.

BRRI (1991) conducted that plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in *boro* season.

Hosain and Alam (1991) found that the plant height in modern rice varieties in *boro* season BR3, BR11, BR14 and pajam were 90.4, 94.5, 81.3 and 100.7 cm respectively.

Miah *et al.* (1990) conducted an experiment where 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.

2.1.1.2 Tillering pattern

Bisne *et al.* (2006) conducted an experiment with eight promising varieties using four CMS lines and showed that tiller number hill^{-1} differed significantly among the varieties and Pusa Basmati gave the highest tiller number hill^{-1} in each line.

Jones *et al.* (1996) reported that two experiments were conducted in 1994 to identify weed competitive cultivars. The varieties CG14 and CG20 gave the maximum tillers under all levels of management.

2.1.1.3 Total dry matter production

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.

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.

2.1.2 Effect on yield contributing characters

2.1.2.1 Effective tillers hill^{-1}

Jones *et al.* (1996) conducted two experiments in 1994 to identify weed competitive cultivars. The varieties CG14 and CG20 gave the maximum tillers under all levels of management.

2.1.2.2 Panicle length, filled grains panicle $^{-1}$, unfilled grains panicle^{-1}, filled grain percentage, 1000-grain weight

Hossain *et al.* (2007) conducted a field experiment at the Hajee Mohammad Danesh Science and Technology University Farm, Dinajpur, Bangladesh during transplant *aman* (T. *aman)* season of 2004 and found that weight of 1000 grains was highest in BRRI dhan38.

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%.

Guilani *et al.* (2003) studied on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran, during 1997. 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.

2.1.3 Effect on grain yield and straw yield

Al-Mamun *et al.* (2011) carried out an experiment at the Agronomy Farm of Bangladesh Rice Research Institute, Gazipur, During December 2008 to June 2009 in winter season on Surjamoni and BRRI dhan29 and observed that the highest grain yield (6.96 t ha^{-1}) was obtained from Surjamoni when treated with Bouncer 10WP @ 150g ha^{-1}, which was 49% higher than control. BRRI dhan29 produced also the highest grain yield when treated with same treatment, which was 37% higher than control.

Bhuiyan *et al.* (2011) conducted a field experiment to evaluate the performance of different weed management options regarding effective weed control, yield and yield contributing characters of three popular BRRI *aman* varieties having different growth duration (BRRI dhan39, BRRI dhan49 and BR11) in 2008 and 2009 at Bangladesh Rice Research Institute, regional station, Rajshahi and found that among the varieties, BR11 produced significantly higher yield (5.02 t ha^{-1}) and lowest yield was recorded in BRRI dhan39 (3.58 t ha^{-1}).

Hassan *et al.* (2010) carried out a field experiment on transplant *aman* rice cv. BRRI dhan41 and found that highest straw yield was recorded from the treatment combination of three hand weeding regimes with two seedlings $hill^{-1}$ in most of the evaluated traits. The weakest treatment combination was the no weeding with five seedlings $hill^{-1}$.

Reza *et al*. (2010) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh, during the period from January to April 2008 and found that Pajam produced the higher grain yield (4.0 t ha^{-1}) than BRRI dhan28 (2.79 t ha^{-1}).

Bisne *et al.* (2006) conducted an experiment with eight promising varieties using four CMS lines and showed that grain yield differed significantly among the varieties and Pusa Basmati gave the highest grain yield in each line.

Franje *et al.* (1992) found that tall traditional cultivars to be more competitive than the relatively short stature BRRI advanced lines. However they concluded that yields of modern cultivars improved with increased weeding while yields of traditional cultivars did not.

2.1.4 Effect on weed population and weed control efficiency

Al-Mamun *et al.* (2011) carried out an experiment at the Agronomy Farm of Bangladesh Rice Research Institute, Gazipur, During December 2008 to June 2009 in winter season on Surjamoni and BRRI dhan29 and observed that *Paspalum distichum* was the dominating weed species in the experimental site.

Biswas *et al.* (2011) conducted a field experiment at Agronomy field of Sher-e-Bangla Agricultural University, Bangladesh during December 2010 to May 2011 including 16 popular inbred and hybrid rice varieties. They concluded that at 30 DAT, the significantly highest weed population of 119.00 and 117.00 m^{-2} was found in BRRI dhan29 and BRRI dhan45 respectively whereas BR3 and BRRI dhan50 resulted the lowest weed population of 31.00 and 38.00 m^{-2} respectively. Similar lowest weed population i.e. 35.33 and 36.00 m^{-2} was also found in BRRI dhan50 and BRRI hybrid dhan1 respectively at 60 DAT.

Bhuiyan *et al.* (2010) conducted an experiment during *boro* 2006 at Gazipur and Comilla location for the control of mixed weed flora in transplanted rice (*Oryza sativa L.*) and reported that *Cynodon dactylon*,*Scirpus maritimus*, *Monochoria vaginalis*,*Cyperus difformis*, *Fimbristylis miliacea, Cyperus iria, Marsilea quadrifolia* and *Alternanthera philoxeroides* were the major weeds in the experimental plots.

Reza *et al.* (2010) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh, during the period from January to April 2008 and found eight weed species to infest the crop were *Echinochloa crusgalli, Scirpus mucronatus, Cyperus difformis, Panicum repens, Digitaria ischaemum, Monochoria vaginalis, Leersia hexandra* and *Marsilia quadrifolia.* Among the weed species, *E. crusgalli* was the dominant one. They reported that the higher weed dry matter accumulation per unit area (7.98 g m^{-2}) was obtained from shorter variety, BRRI dhan28 and the lower weed dry weight (5.51 g m^{-2}) from the taller variety, Pajam.

Salam *et al.* (2010) carried out a field experiment at the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, to evaluate the effect of herbicide on growth and yield in *boro* rice (Binadhan-5).Ten weed species belonging to four families namely Angta, Chechra, Arail, Joina, Durba, Panee kachu, Sabuj nakphul, Shusni shak, Holud mutha and Khudeshama were found to grow in the experimental plots.

Hasanuzzaman *et al.* (2007) reported that 16 different weed species were observed in transplanted *aman* rice field where *Sagittaria guyanensis* and *Sphenoclea zeylanica* were the most dominant species.

Mian *et al.* (2007) observed eight weed species in transplanted *aman* rice field, namely *Paspalum scrobiculatum* L., *Echinochloa colonum* L., *Fimbristylis littralis* (L.) Vahl.*Cyperus iria* L., *Alisma plantago* L., *Jussieua decurrens* (Walt.) DC., *Polygonum orientale* L. and *Sphenocelea zeylanica* Gaertn. Among them, *Paspalum scrobiculatum* L. was the most dominating species in respect of summed dominance ratio (SDR of 41.71) and relative dry weight (RDW of 60.18%). All weed species except *A. plantago* and *J. decurrens* were found dominant in semi-dwarf modern cultivars (BR11 and BR22) than in traditional tall cultivars (Nizersail and Biroi).

Mitra *et al.* (2005) conducted an experiment and found *Fimbristylis miliacea, Scirpus murconatus* and *Monochoria vaginalis* as dominant weed species in transplanted *aman* rice field.

Houque *et al.* (2003) reported that BRRI dhan34 was the most competitive variety, which provided the least accumulation of weed dry matter per unit area. The ranking was BRRI dhan 34≈ Binashail >Nizershail >BRRI dhan 39 >BRRI dhan 33.

Chandra and Pandey (2001) stated that weed competition was severe in scented paddy culture, in view of its early slow growth rates.

Janiya *et al.* (1996) stated that cultivation of competitive cultivars is a way of reducing weed infestation in rice field. Cultivars that are able to suppress or tolerate pressure possess characters that confer competitive ability.

Bari *et al.* (1995) observed 53 weed species to grow in transplanted *aman* rice field. In respect of abundance value the three most important weeds were *Fimbristylis miliacea, Paspalum scrobiculatrm* and *Cyperus rotundus*.

Venkataraman and Goplan (1995) observed that the most important weed species in transplanted low land rice in Tamil Nadu, India, were *Echinochloa crus-galli, Cyperus difformis, Echinochloa Colonum, Cyperus iria, Fimbristylis miliacea, Scirpus spp, Eclipta alba, Ludwigia parviflora, Marsilea quadrifolia* and *Monochoria vaginaliz.*

Mamun *et al.* (1993) from the same location identified 60 weed species in T. *aman* rice of which *Fimbristylis miliacea, Lindernia antipoda* and *Eriocaulen cinereesm* were the most important weed species.

Garity *et al.* (1992) stated that growing competitive variety of rice could bring benefit equivalent to one to two hand weeding.

Biswas *et al.* (1992) reported that lower weed biomass was obtained from Hashikolmi, a traditional cultivar than modern varieties like BR20 and BR21, which they attributed due to Hashikolmi's better ability to intercept more sunlight in the canopy than that of modern varieties.

Moody (1992) suggested that if short stature, short duration and high yielding crops are to be cultivated efficiently, the associated weed would be controlled because these cultivars do not compete with weeds as well as do the tall and long duration rice crop.

2.2 Effect of weed control

Weed is one of the limiting factors for successful rice production. Among various cultural practices, weeding play a vital role in the production and yield of rice through controlling the weeds as well as make the environment favorable for rice production. To justify the present study attempts have been made to incorporate some of the important findings of different scientists and research workers in this country and elsewhere of the world.

2.2.1 Effect on growth characters

2.2.1.1 Plant height

Khan and Tarique (2011) carried out an experiment during June to December 2006 and observed that the longest plant was observed in completely weed free condition throughout the crop growth period. On the other hand, plant height appeared next to the highest was found in two hand weeding treatment. However, lowest value was observed in no weeding treatment.

Hassan *et al.* (2010) carried out a field experiment on transplant *aman* rice cv. BRRI dhan41 and observed that highest plant height was recorded from the treatment combination of three hand weeding regimes with two seedlings hill^{-1} in most of the evaluated traits. The weakest treatment combination was the no weeding with five seedlings hill^{-1}.

Hasanuzzaman *et al.* (2008) stated that Ronstar 25EC @ 1.25 L ha^{-1} + IR5878 50 WP @ 120 g ha^{-1} was most efficient that influenced plant height according to the effectiveness of the treatments.

Hasanuzzaman *et al.* (2007) conducted an experiment on transplanted (T) '*aman*' rice at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh during July-November, 2006 and stated that plant height was significantly affected by different weeding treatments.

2.2.1.2 Tillering pattern

Khan and Tarique (2011) carried out an experiment during June to December 2006 and observed that highest total tillers plant^{-1} was observed in completely weed free condition throughout the crop growth period. On the other hand, total tillers plant^{-1} that appeared next to the highest was found in two hand weeding treatment. However, shorter plant was found in no weeding treatment.

Hassan *et al.* (2010) carried out a field experiment on transplant *aman* rice cv. BRRI dhan41 and recorded data on total effective tillers hill^{-1}. Highest value was recorded from the treatment combination of three hand weeding regimes with two seedlings hill^{-1} in most of the evaluated traits. The weakest treatment combination was the no weeding with five seedlings hill^{-1}.

Ashraf *et al.* (2006) conducted an experiment in Lahore, Pakistan, during 2004 and 2005 in kharif seasons, for screening of herbicides for weed management in transplanted rice (cv. Basmati-2000). Hand weeding resulted in 20.8 compared to 16.6 for the control in case of total tillers plant^{-1}.

2.2.1.3 Total dry matter production

Bhuiyan *et al.* (2011) conducted a field experiment to evaluate the performance of different weed management options regarding effective weed control, yield and yield contributing characters of three popular BRRI *aman* varieties having different growth duration (BRRI dhan39, BRRI dhan49 and BR11) in 2008 and 2009 at Bangladesh Rice Research Institute, regional station, Rajshahi and found that total dry matter was significantly highest in plot of three hand weeding at 15, 30 & 45 DAT, 20.17 g m^{-2} and post-emergence herbicide + 1 hand weeding at 30 DAT, 22.2 g m^{-2}.

Reza *et al.* (2010) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh, during the period from January to April 2008 and found that *Echinochloa crusgalli* was the major weed having the highest absolute density (12.70 m^{-2}), relative density (36.95 m^{-2}), dry matter accumulation (1.85 g m^{-2}) and intensity of weed infestation (0.46).

BRRI (1998) reported that Cinosulfuron and Oxadiazon showed better performance than Butachlor in terms of biomass and plant population and also stated that two hand weeding gave the highest weeding cost of herbicide treatment.

2.2.1.4 Crop growth rate and relative growth rate

Salehian *et al.* (2012) conducted an experiment to determine the most important yield related traits and competition with weeds in rice cultivars by path analysis to study the relative characteristics with growth of weeds in four different rice cultivars and two treatments of competition. Results showed that between cultivars, mean crop growth rate of Fajr cultivar (CGR=7.39 g m^{-2} d^{-1}) in this experiment was more than Ghaem (CGR=7.39 g m^{-2} d^{-1}).

Ali *et al.* (2008) conducted an experiment on the effect of integrated weed management and spacing on the weed flora and on the growth of transplanted *aman* rice to evaluate the weeding treatments viz. no weeding, two hand weeding at 15 and 40 days after transplanting (DAT), one weeding with BRRI push weeder at 15 DAT + one hand weeding at 40 DAT, pre-emergence application of M.Chlor 5G (Butachlor) at 5 DAT + one hand weeding at 40 DAT, pre-emergence application of Oxastar 25 EC (Oxadiazon) at 5 DAT + one hand weeding at 40 DAT, pre- emergence application of Rifit 500EC (Pretilachlor) at 5 DAT + one hand weeding at 40 DAT and three plant spacing's viz. 20cm x 10cm, 25cm x 15cm and 30cm x 20cm. It was evident that among the weed control treatments, Pretilachlor + one hand weeding gave the highest crop growth rate (0.71 g $hill^{-1}day^{-1}$) at 45-60 DAT.

Remesan *et al.* (2007) conducted an experiment on Wet land paddy weeding- A comprehensive comparative study from south India to evaluate the weeding tools quantitatively & qualitatively in terms of weeding performance. They concluded that CGR & RGR showed less variation with treatments viz. hand weeding, Rotary weeding + one hand weeding, Cono weeding + one hand weeding, Rotary weeding alone, Cono weeding alone, even though those had higher values for hand weeding which were followed by Cono weeding + one hand weeding, Rotary weeding + one hand weeding, Cono weeding and Rotary weeding, respectively.

Irshad *et al.* (2002) carried out an experiment on growth analysis of transplanted fine rice under different competition durations with Barnyard grass to identify the effect of different competition periods of barnyard grass (0, 20, 40, 60 and throughout the growth period after transplanting) on the growth behavior of fine rice. They stated that CGR showed significant differences due to different durations of barnyard grass competition.

2.2.2 Effect on yield contributing characters

2.2.2.1 Effective tillers hill^{-1}

Hassan *et al.* (2010) carried out a field experiment on transplant *aman* rice cv. BRRI dhan41 and found that highest number of effective tillers hill^{-1} was recorded from the treatment combination of three hand weeding regimes with two seedlings hill^{-1} in most of the evaluated traits. The weakest treatment combination was the no weeding with five seedlings hill^{-1}.

Hasanuzzaman *et al.* (2008) stated that Ronstar 25EC @ 1.25 L ha^{-1} + IR5878 50 WP @ 120 g ha^{-1} was the most efficient for the number of effective tillers hill^{-1} according to the effectiveness of the treatments.

Raju *et al.* (2003) observed the effect of pre-emergence application of Pretilachlor plus Safener 0.3 kg ha^{-1}, Butachlor 1 kg ha^{-1} and post-emergence herbicide like Butanil 3.0 kg ha^{-1} on 4, 8 and 15 days after sowing. They found that Pretilachlor plus Safener 0.3 kg ha^{-1} gave the highest productive tillers m^{-2}.

Haque (1993) evaluated the efficiency of Oxadiazon in transplanted *aman* rice and observed that Oxadiazon 2.0 litre ha^{-1}gave maximum effective tillers $hill^{-1}$.

2.2.2.2 Panicle length, filled grains panicle $^{-1}$, unfilled grains $panicle^{-1}$, filled grain percentage, 1000-grain weight

Khan and Tarique (2011) observed that the effects of weeding regimes were significant in respect of yield and most of the characters. The longest panicle and heavier 1000 grain weight were observed in completely weed free condition throughout the crop growth period. On the other hand, values that appeared next to the highest were found in two hand weeding treatment. However, panicle length and heavier 1000 grain weight were lowest in no weeding treatment.

Hassan *et al.* (2010) recorded the highest value of 1000 grain weight from the treatment combination of three hand weeding regimes with two seedlings $hill^{-1}$ in most of the evaluated traits. The weakest treatment combination was the no weeding with five seedlings $hill^{-1}$.

Karim and Ferdous (2010) conducted an experiment at the net house of the Department of Agronomy, Bangladesh Agricultural University during the period from June to December 2008 to study the effects of plant density of grass weeds on plant characters and grain production of transplanted *aus* rice cv. BR26. They found that the number of filled grains $panicle^{-1}$ and 1000 grain weight were negatively related to weed density.

Nahar *et al.* (2010) carried out a field experiment to study the effect of spacing and weeding regime on the performance of transplant *aman* rice cv. BRRI dhan41 and observed that weeding regime had significant effect on all the parameters except 1000 grain weight.

Ashraf *et al.* (2006) conducted an experiment in Lahore, Pakistan, during 2004 and 2005 kharif seasons, for screening of herbicides for weed management in transplanted rice (cv. Basmati-2000) and observed that the highest number of grains panicle^{-1} (135.50) was obtained from hand weeding treatment.

2.2.3 Effect on grain yield and straw yield

Al-Mamun *et al.* (2011) carried out an experiment at the Agronomy Farm of Bangladesh Rice Research Institute, Gazipur, During December 2008 to June 2009 in winter season on Surjamoni and BRRI dhan29 and observed that the highest grain yield (6.96 t ha^{-1}) was obtained from Surjamoni when treated with Bouncer 10WP @ 150g ha^{-1}, which was 49% higher than control. BRRI dhan29 produced also the highest grain yield when treated with same treatment, which was 37% higher than control.

Bhuiyan *et al.* (2011) conducted a field experiment to evaluate the performance of different weed management options regarding effective weed control, yield and yield contributing characters of three popular BRRI *aman* varieties having different growth duration (BRRI dhan39, BRRI dhan49 and BR11) in 2008 and 2009 at Bangladesh Rice Research Institute, regional station, Rajshahi and found that, irrespective of weed management options, hand weeding and post-emergence herbicide with one supplement hand weeding produced significantly higher yield 4.89 and 4.80 t ha^{-1}, respectively while lowest yield was recorded in control (3.29 t ha^{-1}).

Bhuiyan *et al.* (2011) conducted field experiments at BRRI farm, Bhanga , Faridpur (AEZ 12-Lower Ganges River Floodplain) and at Burichang of Comilla district (AEZ 19-Old Meghna Estuarine Floodplain) during dry season (*Boro*) 2007 to assess the effectiveness of different pre-emergence herbicide for weed management in direct wet seeded rice and its impact on phytotoxic effect, plant growth and yield of rice and found that pre-emergence application of Sofit N 300EC @ 450 and 600 g a.i. ha^{-1} led to higher yield attributes and grain yield of rice that were comparable to weed free conditions at both agro-ecological zones of Bangladesh.

Khaliq *et al.* (2011) reported that manual weeding scored highest paddy yield of 4.17 t ha^{-1}. Bispyribac sodium with 3.51 t ha^{-1} paddy yield appeared superior to penoxsulam. Sorghum, sunflower and wheat residues resulted in statistically similar paddy yields of 2.85, 2.80 and 2.58 t ha^{-1}, respectively. Bispyribac sodium exhibited maximum marginal rate of return of 23.76%. Chemical control proved to be a viable strategy with higher economic returns.

Khan and Tarique (2011) carried out an experiment during June to December 2006 and stated that the highest grain yield and straw yield were observed in completely weed free condition throughout the crop growth period. On the other hand, values that appeared next to the highest were found in two hand weeding treatment and lowest in no weeding treatment.

Mamun *et al.* (2011) conducted field experiments at Bangladesh Rice Research Institute (BRRI), Gazipur during *boro*, 2009 and *aus*, 2010 to evaluate the performance of Bensulfuron methyl + Pretilachlor 6.6% GR for weed suppression and its impacts on transplanted rice and observed that application of Bensulfuron methyl + Pretilachlor 6.6% GR @ 652 g a.i. ha^{-1} resulted in higher yield attributes and grain yield of transplanted rice that were comparable to the standard in both seasons.

Shultana *et al.* (2011) conducted an experiment at Bangladesh Rice Research Institute, Gazipur, during winter season 2009 to evaluate the weed control efficiency of some pre-emergence herbicides in transplanted rice and found that among the evaluated herbicides, Rigid 50 EC (pretilachlor) @ 1L, Alert 18WP (bensulfuron + acetachlor) @ 400 g, Kildor 5G (butachlor) @ 25 kg, Bigboss 500EC (pretilachlor) @ 1L, Rifit 500EC (pretilachlor) @ 1L, Ravchlor 5G (butachlor) @ 25 kg, Succour 50EC (pretilachlor) @ 1L and Topstar 80WP (oxadiazon) @ 75 g ha^{-1} showed grain yields above 4.00 t ha^{-1} which were comparable to the standard check; however, weed free plots gave the highest grain yield as anticipated.

Ali *et al.* (2010) conducted an experiment at the Agronomy farm, Sher-e-Bangla Agricultural University, Dhaka during the period July-December, 2006 to evaluate weed control and yield of transplanted *aman* rice (cv. BRRI dhan37) as affected by integrated weed management and spacing and observed that among the weed control treatments Pretilachlor + one hand weeding at 40 DAT performed best for controlling weeds which ultimately contributed to the highest grain yield (3.60 t ha^{-1}).

Bari (2010) carried out an experiment at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh (BSMRAU) during 2007-08 using eight herbicides, i.e. Oxadiazone, Butachlor, Pretilachlor and Anilphos from pre-emergence, and MCPA, Ethoxysulfuran, Pyrazosulfuran Ethyl and Oxadiarzil from post-emergence category in transplanted wetland rice during *aman* (autumn), *aus* (summer) and *boro* (winter) growing seasons to study their effects on weed control and rice yield and found that the highest grain yield of 4.18 t ha^{-1} was contributed by weed free treatment, while the least (2.44 t ha^{-1}) was by weedy check. Among the herbicide treatments, the highest grain yield of 4.08 t ha^{-1} was obtained from Butachlor, while the lowest (2.83 t ha^{-1}) grain production was harvested in the plots receiving MCPA @ 125% of the recommended rate. Results further revealed a positive relationship between Butachlor rate and grain yield, although a declining trend was apparent at higher than the recommended rates, while a negative relationship was found in MCPA treatments.

Bhuiyan *et al.* (2010) conducted an experiment during *boro* 2006 at Gazipur and Comilla location for the control of mixed weed flora in transplanted rice (*Oryza sativa L.*) and stated that among different treatment, weed free plots produced highest grain yield followed by Oxadiargyl 400SC @ 75 g a.i. ha^{-1} which is comparable with other doses of Oxadiargyl 400SC in both locations.

Gnanavel and Anbhazhagan (2010) suggested that pre-emergence application of Oxyfluorfen 0.25 kg ha^{-1} followed by post-emergence application of bispyribac sodium 0.05 kg + metsulfuron methyl @ 0.01 kg ha^{-1} recorded higher grain yield of aromatic rice (5.32 t ha^{-1}).

Hassan *et al.* (2010) carried out a field experiment on transplant *aman* rice cv. BRRI dhan41 and found that highest straw yield was recorded from the treatment combination of three hand weeding regimes with two seedlings $hill^{-1}$ in most of the evaluated traits. The weakest treatment combination was the no weeding with five seedlings $hill^{-1}$.

Islam *et al.* (2010) revealed that pre-emergence herbicide Rifit 500 EC showed the best performance in achieving comparatively better grain yield. As a result net income was also increased. The highest grain yield (3.61 t ha^{-1}) was obtained from Rifit 500 EC. BRRI dhan41 gave the highest grain yield (4.43 t ha^{-1}) with Rifit 25 EC @ 1.0 L ha^{-1}.

Karim and Ferdous (2010) conducted an experiment at the net house of the Department of Agronomy, Bangladesh Agricultural University during the period from June to December 2008 and stated that the highest grain yield (15.09 g pot^{-1}) was found under weed free condition. Grain yield was reduced by 2.66%, 12.59%, 44.93% and 54.01% due to competition from 2, 4, 6 and 8 number of weeds of *E. indica*, whereas the yield was reduced by 57.19%, 58.98%, 82.31% and 79.26%, respectively due to competition from 2, 4, 6 and 8 number of weeds of *E. crusgalli*.

Nahar *et al.* (2010) carried out a field experiment to study the effect of spacing and weeding regime on the performance of transplant *aman* rice cv. BRRI dhan41 and reported that weed free condition produced the highest grain yield (4.35 t ha^{-1}) whereas no weeded condition produced the lowest grain yield (2.02 t ha^{-1}).

Salam *et al.* (2010) carried out a field experiment at the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, to evaluate the effect of herbicide on growth and yield in *boro* rice (Binadhan-5). The highest grain yield (7.15 t ha^{-1}) and straw yield (7.37 t ha^{-1}) were found due to application of Machete 5G @ 25 kg ha^{-1}.

Pacanoski and Glatkova (2009) conducted an experiment and observed that weed population in the trials was composed of 8 and 5 weed species in Kocani and Probistip locality, respectively. All applied herbicides showed high selectivity to rice, no visual injuries were determined at any rates in any year and locality. Herbicidal treatments in both localities significantly increased rice grain yield in comparison with untreated control.

Kabir *et al.* (2008) stated that the highest grain yield (5.22 t ha^{-1}) was obtained under good water management in weed free treatment followed by Butachlor 5G @ 2 kg ha^{-1} and one hand weeding (4.96 t ha^{-1}) under same water management. Results revealed that Butachlor application along with one manual weeding accompanied by proper water management might be the best option to combat weed problems as well as to obtain satisfactory grain yield in transplanted *aman* rice.

Baloch *et al.* (2006) made an experiment in NWFP, Pakistan to evaluate the effect of weed control practices on the productivity of transplanted rice. Among weed management tools, the maximum paddy yield was obtained in hand weeding, closely followed by Butachlor (Machete 60EC) during both cropping seasons.

BRRI (2006) stated that weed infestation and interference is a serious problem in rice fields that significantly decreases yield. In Bangladesh, weed infestation reduces rice grain yield by 70-80% in *aus* rice, 30-40% in transplanted *aman* rice and 22-36% for modern *boro* rice cultivars.

Manish *et al.* (2006) said that hand weeding at 15 and 30 DAT (days after transplanting) gave the highest grain yield, straw yield and harvest index.

Jacob and Syriac (2005) showed that adoption of 20 x 10 cm spacing and pre-emergence application of Anilofos+2, 4-D ethyl ester (0.40+0.53 kg a.i. ha^{-1}) at six days after transplanting supplemented with 2, 4-D Na salt (1.0 kg a.i. ha^{-1}) at 20 days after transplanting generally favored increased yield and net income.

Mitra *et al.* (2005) suggested two times weeding as the best practice to keep weed infestation at minimum level and to ensure higher yield in transplanted *aman* rice. Other than weed free condition, the highest grain yield (5.07 t ha^{-1}) was produced in two hand weeding and the lowest (2.46 t ha^{-1}) was in unweeded condition. One hand weeding at 25 DAT along with one mechanical weeding at around 40 DAT was also found to be effective next to two hand weeding in these regards. Pre-emergence herbicide Rifit 500 EC was not effective to keep weed infestation at minimum level and to ensure higher yield in transplanted *aman* rice.

Bijon (2004) observed that other than weed free condition, the highest grain yield (5.90 t ha^{-1}) was produced by BR11 under two hand weeding. It was further identified to reduce the weed seed bank status in rice soils and rice grains to the lowest extent in both farmer's field as well as experimental field.

Singh *et al*. (2004) reported that weed management is one of the major factors, which affect rice yield. Uncontrolled weeds cause grain yield reduction up to 76% under transplanted conditions.

Chandra and Solanki (2003) studied the effect of herbicides on the yield characteristics of direct sown flooded rice. The treatments were two hand weeding, Butachlor 2.0 kg $ha^{-1}$and Oxadiazon 0.8 kg ha^{-1}. They found that two hand weeding produced the highest grain yield (3.36 t ha^{-1}) and straw yield (6.53 t ha^{-1}).

Ferrero (2003) estimated that without weed control, at a yield level of 7.00 to 8.00 t ha^{-1}, yield loss can be as high as about 90%.

Moorthy *et al.* (2002) investigated the efficacy of pre and post-emergence herbicides in controlling weeds in rainfed upland direct sown rice. The application of Pretilachlor @ 625 g ha^{-1} and Butachlor 1600 @ g ha^{-1} on 2 days after sowing and the treatments gave effective weed control and produced highest grain yield compared with twice hand weeding on 20 and 40 DAT.

Selvam *et al.* (2001) observed the effect of time of sowing along with weed management practices in semidry rice. The treatments included sowing practices and herbicide, Pendimethalin 1.24 kg ha^{-1} at 8 days after rainfall, Pretilachlor 1.00 kg ha^{-1} at 4 DAS and 8 DAS, Pretilachlor + Safenerat 4 DAS and 8 DAS, hand weeding twice and unweeded control. All herbicides receiving plots were supplemented with one hand weeding at 25 DAS. Among the herbicides, Pendimethalin recorded the highest grain yield (3773 kg ha^{-1}) and was at par with Pretilachlor at 8 DAS.

Tamilselvan and Budhar (2001) studied the effects of pre-emergence herbicides Pretilachlor 0.4 kg a.i. ha^{-1}, Pretilachlor 0.4 kg a.i. ha^{-1} on rice cv. ADT 43. The herbicides were applied 8 days after sowing. The density and dry weight of weeds at 40 DAS were lower in herbicide treated plots than in unweeded and hand weeded plots. The weed control treatment had effect in increasing grain yield.

Gogoi *et al.* (2000) from Assam reported that different weed control practices significantly reduced the dry matter accumulation of weed and increased the rice yield over the unweeded control in transplanted rice. They also observed that combined weed control treatment like Oxadiazon 2.0 L ha^{-1} + 1 hand weeding increased grain yield (5.12 t ha^{-1}).

Hossain (2000) observed experiment oriented impact of different weeding approaches on rice like one hand weeding, two hand weeding, three hand weeding, Oxadiazon, Oxadiazon in combination with one hand weeding and observed that yield and yield contributing traits in rice production had upgraded by degrees with the higher frequency of hand weeding.

Moorthy *et al.* (1999) observed the performance of the pre-emergence herbicides Pretilachlor + safener, Butachlor + safener, Butachlor, Anilofos + Ethoxysulfuron, Thiobencarb and Anilofos for their efficiency to control weeds in direct sown rice under puddled soil condition. They observed that Pretilachlor + safener (0.4 kg ha^{-1} and 0.6 kg ha^{-1}, Butachlor + safener (1.5 kg ha^{-1}) and Anilofos + Ethoxysulfuron (0.37 + 0.04 kg ha^{-1}) produced yields comparable to those of the hand weeded control.

Sanjoy *et al.* (1999) observed that control of weeds played a key role in improving the yield of rice because of panicle m^{-2} increased 18% due to weed control over its lower level and significant yield increase was observed (43%) with weed control.

Singh and Kumar (1999) reported that maximum weed dry weight and the lowest grain yield were observed in the unweeded control in the scented rice variety Pusa Basmati-1.

Singh *et al.* (1999) studied the effect of various weed management practices on the weed growth and yield and nitrogen uptake in transplanted rice and weeds and reported that weed control until maturity removed significantly higher amount of nitrogen through weeds (12.97 kg ha^{-1}) and reduced the grain yield of rice by 49% compared to that of weed free crop up to 60 DAT.

Angiras and Rana (1998) observed that greatest yield was achieved form the Pretilachlor (0.8 kg ha^{-1}) + two hand weeding.

BRRI (1998) evaluated a new pre-emergence herbicide Golteer 5G (Butachlor) at Gazipur in transplanted *aus* rice and results indicated that hand weeding produced a slightly higher grain yield than Golteer application and weed biomass was lower in hand weeded plots followed by Golteer (Butachlor) treated plots.

Gogoi (1998) observed that Anilofos at 0.4 kg ha^{-1} gave significantly higher yield and the yield was not significantly different from the hand weeding at 20 days after transplanting.

Nandal *et al.* (1998) evaluated the performance of herbicide in direct seeded puddled rice during kharif season. They observed that the highest grain yield and gross margin was obtained from the Pretilachlor (1.0 kg ha^{-1}) + two hand weeding.

Thomas *et al.* (1997) reported that rice weed competition for moisture was maximum during initial stages and yield losses from uncontrolled weeds might be as high as 74%.

Bhattacharya *et al.* (1996) reported that although the hand weeding treatment gave the highest grain yield, the results indicated that this was laborious, time consuming and costly and hand weeding could be replaced by application of Butachlor at 1.00 kg a.i. ha^{-1}.

Madhu *et al.* (1996) at Bangalore, investigated the effectiveness of four herbicides, Pendimethylin, Anilofos, Butachlor and Oxyfluorfen at 2 application rates during dry and wet seasons in puddled seeded rice field and the results showed that grain and straw yields were higher in the plots treated with Butachlor @ 1.5 kg ha^{-1}.

Chowdhury *et al.* (1995) observed the effect of Oxadiazon in weed management and growth and yield of rice. Six different doses of Oxadiazon viz. 0, 1.5, 1.75, 2, 2.25 and 2.50 L ha^{-1} were used to control weeds in rice. They found that Oxadiazon significantly increased the yield of rice irrespective of the doses used. Out of these doses, 2.0 L ha^{-1} was found to be most effective with respect to grain yield and straw yield.

Mandal *et al.* (1995) reported the efficacy Pretilachlor as herbicide in comparison to hand weeding in BR11 variety. The lower doses of Pretilachlor at 1.00 L ha^{-1} failed to kill the weeds properly. The grain yield reduction due to weed infestation was 20.30%.

Kamalam and Bridgit (1993) reported that the average reduction in grain yield due to weed competition was 56 %.

BRRI (1990) stated that there was no significant difference in rice yield for using Oxadiazon as well as hand weeding. The highest grain yield was obtained from Oxadiazon @ 0.5 kg a.i. ha^{-1}.

Purushotham *et al.* (1990) observed that Oxadiazon (0.5 kg a.i. ha^{-1}) increased the grain and straw yields significantly than two manual weeding at 25 and 45 DAT.

Shivamdiah *et al.* (1987) investigated that Oxadiazon 0.75 kg ha^{-1} + one hand weeding gave significantly greater yields than herbicides alone. They also found that combination of herbicidal treatment and one hand weeding gave higher straw yield.

Navarez *et al.* (1982) showed in rainfed condition that the lack of weed control in tall rice cultivars resulted in the yield reduction by 41% but one hand weeding at 40 days after transplanting reduced the grain yield by 31%.

2.2.4 Cost benefit ratio

Hoque *et al.* (2012) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to study the economic performance of transplant *aman* rice under different methods of land preparation and weeding regime. The treatments included three methods of land preparation and weeding regime. In this experiment, net return and benefit -cost ratio were highest in crop raised in tractor prepared plots and weeds being controlled by Ronstar 25EC @ 2.0 L ha^{-1} + one hand weeding. One hand weeding recorded higher net return and benefit-cost ratio than two or three hand weeding. Between the single use of Ronstar 25EC @ 2.0 L ha^{-1} and 2, 4-D amine @ 1.84 L ha^{-1}, the former was more profitable than the later.

Al-Mamun *et al.* (2011) carried out an experiment at the Agronomy farm of Bangladesh Rice Research Institute, Gazipur, During December 2008 to June 2009 in winter season on Surjamoni and BRRI dhan29 and observed that the highest (2.77) benefit cost ratio (BCR) was obtained by Bouncer 10WP @ 150 g ha^{-1} and it suggests that it could be an alternative weed control option for profitable rice production.

Jacob and Syriac (2005) conducted a field experiment to study the effects of spacing and weed management practices on transplanted scented rice (Pusa Basmati 1) in the sandy clay loam soil of Vellayani during the winter season of 2001-02 showed that the benefit cost ratio for Anilofos + 2, 4-D ethyl ester was 2.07 as against 0.93 for unweeded check.

Toufiq (2003) reported that the benefit cost analysis showed a bit different trend than that of grain and straw yields where the maximum profit was noticed in Cinmethylin @ 0.75 t ha^{-1} + 1 weeding with Japanese rice weeder which was followed by Cinmetylin @ 0.75 t ha^{-1} + 1 hand weeding.

Razzaque *et al.* (1998) evaluated the efficiency of Oxadiazon as herbicide in transplanted *aman* rice. They observed that the application of Oxadiazon 2.0 L ha^{-1} achieved effective control of all the weed masses growing in the field and produced significantly higher grain yield. Also they observed that application of Oxadiazon 2.0 L ha^{-1} achieved the greatest profit.

Prasad and Rafey (1995) observed that application of Oxadiazon at pre-emergence and hoeing 30 days after sowing gave the maximum net return and showed a higher benefit cost ratio of 1.71.

2.2.5 Effect on weed population and weed control efficiency

Al-Mamun *et al.* (2011) carried out an experiment at the Agronomy farm of Bangladesh Rice Research Institute, Gazipur, during December 2008 to June 2009 in winter season to find out an effective and economic herbicide to control weeds. Surjamoni and BRRI dhan29 were used as rice cultivars. Weed control treatments were assigned using three rates of Becolor 5G (butachlor), Bouncer 10WP (pyrazosulfuron ethyl) and Becofit 500EC (Pretilachlor). Visual observation indicates that these herbicides were not toxic to rice plants. Weed control efficiency ranged (WCE) from 42 to 84%. Above 80% WCE was obtained by Becolor 5G @ 30 kg ha^{-1}, Bouncer 10WP @ 150 g ha^{-1} and Becofit 500EC @ 1.20 L ha^{-1}, respectively.

Bhuiyan *et al.* (2011) conducted Field Experiments at BRRI farm, Bhanga, Faridpur (AEZ 12-Lower Ganges River Floodplain) and at Burichang of Comilla district (AEZ 19-Old Meghna Estuarine Floodplain) during dry season (*Boro*) 2007 to assess the effectiveness of different pre-emergence herbicide for weed management in direct wet seeded rice and its impact on phytotoxic effect, plant growth and yield of rice and found that pre-emergence application of Sofit N 300EC @ 450 and 600 g a.i. ha^{-1} led to more than 80% weed control efficiency, lowest weed number and dry weight of weeds which eventually resulted in lower weed index, higher yield attributes and grain yield of rice that were comparable to weed free conditions at both agro-ecological zones of Bangladesh.

Mamun *et al.* (2011) conducted field experiments at Bangladesh Rice Research Institute (BRRI), Gazipur during *boro*, 2009 and *aus*, 2010 to evaluate the performance of Bensulfuron methyl + Pretilachlor 6.6% GR for weed suppression and its impacts on transplanted rice and found that application of Bensulfuron methyl + Pretilachlor 6.6% GR @ 652 g a.i. ha^{-1} gave more than 80% weed control efficiency.

Shultana *et al.* (2011) conducted an experiment at Bangladesh Rice Research Institute, Gazipur, during winter season 2009 to evaluate the weed control efficiency of some pre-emergence herbicides in transplanted rice and among the evaluated herbicides, Rigid 50 EC (pretilachlor) @ 1 L, Alert 18WP (bensulfuron + acetachlor) @ 400 g, Kildor 5G (butachlor) @ 25 kg, Bigboss 500EC (pretilachlor) @ 1 L, Rifit 500EC (pretilachlor) @ 1 L, Ravchlor 5G (butachlor) @ 25 kg, Succour 50EC (pretilachlor) @ 1 L and Topstar 80WP (oxadiazon) @ 75 g ha^{-1} showed above 80% weed control efficiency.

Ali *et al.* (2010) conducted an experiment at the Agronomy farm, Sher-e-Bangla Agricultural University, Dhaka during the period July-December, 2006 to evaluate weed control and yield of transplanted *aman* rice (cv. BRRI dhan37) as affected by integrated weed management and spacing and observed that among the weed control treatments Pretilachlor + one hand weeding at 40 DAT performed best for controlling weeds at 30 DAT (79.53%) and moderate for controlling weeds at 60 DAT (75.65%) which ultimately contributed to the highest grain yield (3.60 t ha^{-1}).

Bari (2010) carried out an experiment at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh (BSMRAU) during 2007-08 using eight herbicides, i.e. Oxadiazone, Butachlor, Pretilachlor and Anilphos from pre-emergence category, and MCPA, Ethoxysulfuran, Pyrazosulfuran Ethyl and Oxadiarzil from post-emergence category in transplanted wetland rice during *aman* (autumn), *aus* (summer) and *boro* (winter) growing seasons to study their effects on weed control and rice yield and found that pre-emergence herbicides performed better regarding weed control efficiency and rice yield. Based on the initial performance, butachlor and MCPA were further applied at concentrations ranging from 50% to 150% of the recommended rates in transplanted *aus* rice in 2009. Data indicated that butachlor provided better weed control efficiency and contributed to better crop growth and grain yield compared to MCPA irrespective of concentration. It might be due to that pre-emergence application of Butachlor provided effective early season weed control, which MCPA could not since apply as post-emergence.

Bhuiyan *et al.* (2010) conducted an experiment during *boro* 2006 at Gazipur and Comilla location for the control of mixed weed flora in transplanted rice (*Oryza sativa L.*) and reported that pre-emergence application of Oxadiargyl 400SC @ 75 g a.i. ha^{-1} had minimum population and dry weight of weeds which resulted satisfactory weed control efficiency than other herbicide and doses. They also reported that Oxadiargyl 400SC caused light phytotoxicity to rice plants when applied @ 100 g a.i. ha^{-1}.

Gnanavel and Anbhazhagan (2010) conducted a field experiment during 2008-09, to study the bio-efficacy of promising pre and post-emergence herbicides against weeds in transplanted aromatic basmati rice. They concluded that pre-emergence application of oxyfluorfen 0.25 kg ha^{-1} followed by post-emergence application of bispyribac sodium 0.05 kg + metsulfuron methyl @ 0.01 kg ha^{-1} recorded highest WCE (90.12%) favoring higher grain yield of aromatic rice (5.32 t ha^{-1}).

Kabir *et al.* (2008) stated that weed control efficiency were significantly influenced by different weed control treatments under water management practices. Other than weed free treatment, Butachlor 5G @ 2 kg ha^{-1} applied at 7 DAT along with one hand weeding at 40 DAT showed the best performance under good water management with the highest weed control efficiency (82.57%).

Samar *et al.* (2007) conducted an experiment to evaluate the effects of herbicides for managing weeds and optimizing the yield of wet seeded rice. It was concluded that application of Pendimethalin (1000 g a.i. ha^{-1}) or Pretilachlor with Safener (500 g a.i. ha^{-1}) as pre-emergence applications followed by one hand-weeding were effective in controlling weeds, increasing grain yield of rice, and resulting in higher net returns than the weed-free treatment.

Kalhirvelan and Vaiyapuri (2003) observed the effect of weed management practices on transplanted rice using Pretilachlor at 187, 250 or 375 g ha^{-1}, Pretilachlor and 2, 4 D at 180 + 180, 240+ 240 and 300+ 300 g ha^{-1} with twice hand weeding. They found that hand weeding recorded the lowest weed population (2.78 m^{-2}) and weed dry weight (155.70 kg ha^{-1}). Pretilachlor and 2, 4-D at 300 + 300 g ha^{-1} caused the lowest weed density and weed dry weight. Hand weeding recorded the highest grain and straw yields (5.81 and 7.26 t ha^{-1}, respectively) than Pretilachlor and 2, 4-D (5. 55 and 6.89 t ha^{-1}).

Mahajan *et al.* (2003) observed that application of Pretilachlor alone or in combination with Safener and hand weeding resulted in the lowest weed density and weed dry matter with highest grain yield and number of panicles.

Bhowmick (2002) said two hand weeding at 20 and 40 days after transplanting (DAT) in transplanted rice showed the highest control of weeds.

Bhowmick *et al.* (2002) revealed that *Echinochloa crus-galli, Cyperus iria, Cyperus rotundus* were the dominant weeds in transplanted rice. They observed that two hand weeding at 20 and 40 days after transplanting were able to control almost all categories of weeds.

Jena *et al.* (2002) observed that weed control treatments reduced weed density, dry matter and increased rice yield and Oxadiazon gave better weed control. They also found that application of Oxadiazon with hand weeding gave the highest weed control efficiency, grain and straw yield and harvest index.

Rangaraju (2002) in India determined the effect of herbicide application and application time on weed flora and weed dynamics of dry seeded rainfed rice and observed that application of Butachlor at 1.5 kg a.i. ha^{-1} effectively controlled the weeds.

Chandra and Pandey (2001) showed that hand weeding was the most effective in mitigating the weed dry matter accumulation and also reported that higher grain and straw yield were obtained with hand weeding.

Gnanasambandan and Murthy (2001) studied the efficiency of pre-emergence herbicide Butachlor @ 1250 g ha^{-1} which was applied at 4 days after transplanting and reported that treatments effectively controlled weed density and increased grain yield.

Islam *et al.* (2001) investigated the application of few doses of Pretilachlor (312.50-562.50 g a.i. ha^{-1}) and one hand weeding in transplanted rice. They found that Pretilachlor (312.50-562.50 a.i. ha^{-1}) and one hand weeding reduced weed population and dry matter weight.

Rajkhowa *et al.* (2001) reported that Butachlor 1.0 kg ha^{-1} applied three days after transplanting (DAT) significantly reduced weed infestation till 45 DAT and resulted in higher yield of rice over weedy check.

Agazzani *et al.* (1999) determined the best chemical control program against weeds in irrigated fields of dry sown rice. They found that effective weed control was obtained with pre-emergence applications of Pendimethalin alone or mixed with Thiobencarb and Oxadiazon followed by post-emergence treatments.

Ahmed *et al.* (1999) compared Oxadiazon and Cinosulfuron with hand weeding control and observed that Oxadiazon and Cinsolfuron controlled weeds in rice effectively providing 91-92% and 90-92% weed control efficiency, respectively.

Balaswamy (1999) found that hand weeding twice at 20 and 40 days after transplanting resulted in low weed numbers, followed by herbicides.

Sharma and Bhunia (1999) reported that Pendimethalin @ 1.5 kg ha^{-1} + one hand weeding resulted in highest weed control efficiency than any other treatments.

Chandra *et al.* (1998) observed that Oxadiazon 0.8 kg ha^{-1}, Butachlor 2.00 kg ha^{-1} and Thiobencarb 2.00 kg ha^{-1} provided 80.50, 78.30 and 35.10% weed control respectively. They found that Oxadiazon and Thiobencarb increased grain yield. Among the herbicides, Oxadiazon was the most effective herbicidal treatments.

Ahmed *et al.* (1997) reported that higher weed control efficiency (90.35%) was observed in herbicides with one hand weeding treatment than sole herbicides or conventional weed control methods.

Brar *et al.* (1997) assessed the efficacy of 0.5 kg Oxadiazon applied 5-15 days after transplanting compared to 0.3 kg Anilofos applied 3 days after transplanting (DAT) and hand weeding twice, for control of *Echinochloa crus-galli* in rice cv. PR-110 in sandy loam soil. Results indicated that best weed control and crop yield were achieved with Oxadiazon treatment applied < 10 DAT, these results were comparable to those achieved with Anilofos or hand weeding.

Alam *et al.* (1996) stated that weed control efficiency was higher in two hand weeding (90.67%) than dose of Oxadiazon and Cinosulfuron treatments.

Samanta *et al.* (1995) observed the effectiveness of weed control by manual weeding and with Oxadiazon in transplanted *aman* rice (BR11). Oxadiazon 2.0-4.0 L ha^{-1} and manual weeding twice were found effective in reducing the dry matter of total weeds significantly over the control, but none of the treatments except manual weeding twice controlled *Paspalum distichum* effectively.

Chon *et al.* (1994) reported that 3.6 kg ha^{-1} pre-emergence application of Butachlor inhibited shoot growth and development of *Echinochloa cruss-galli* and the rice plants showed a reduction and constriction of thickness of the leaf primordium while *Echinochloa cruss-galli* formed tubular like leaves and inhibited the elongation of the apical meristem.

Savithri *et al.* (1994) observed the efficiency of different pre-emergence herbicides in transplanted rice and they concluded that among the different herbicides, application of granular formulation of Butachlor @ 1.5 kg a.i. ha^{-1} six day after transplantation was found to be the most effective for controlling weeds in transplanted rice.

Singh and Singh (1994) observed that all weed control treatments decreased weed number and weed dry weight. The best weed control was given by Oxadiazon 0.4 kg a.i. ha^{-1} which gave the highest grain yield.

Janardhan *et al.* (1993) evaluated pre-emergence Pretilachlor 0.5-1.0 kg ha^{-1} on weed control in transplanted rice. They found that herbicidal treatment decrease weed dry weight and increased grain yield.

In another experiment Singh and Bhan (1992) found that two hand weeding resulted better weed control efficiency (72.3%) than Butachlor @ 1.5 kg ha^{-1} (54.4%) in transplanted rice under medium land condition.

Biswas *et al.* (1991) evaluated that Oxadiazon 1.0 and 0.5 kg a.i. ha^{-1} applied at 30 days after sowing with or without one supplemental hand weeding was compared with normal hand weeding and the results indicated that the use of Oxadiazon at 0.5 kg a.i. ha^{-1} was more economic than hand weeding for effective weed management.

Burhan *et al.* (1989) reported that Cinosulfuron @ 20 g ha^{-1} resulted in 85% control of *Monochoria vaginalis, Marsilea crenata, Cyperus spp Fimbristylis miliacea* and *Scirpus juncoides* but only 50-60% control of *Echinochloa crus-galli* in transplanted rice.

After studying the above information and literature related to the effect of variety and weed control methods, it can be concluded that variety and weed control methods have significant effect on the growth and yield of aromatic *aman* rice.

Chapter 3

MATERIALS AND METHODS

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

3.1 Location

The field experiment was conducted at the Agronomy field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from July to December, 2011. The location of the experimental site has been shown in Appendix I.

3.2 Soil

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium high land with non-calcarious dark grey soil. The pH value of the soil was 5.6. The physical and chemical properties of the experimental soil have been shown in Appendix II.

3.3 Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October to March. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology center, Dhaka for the period of experimentation have been presented in Appendix III.

3.4 Plant materials and features

Rice cv. BRRI dhan34, BRRI dhan37, BRRI dhan50 and Chinigura were used as plant materials for the present study. These varieties are recommended for aman season except BRRI dhan50. It is recommended for boro season. But since it has no photo sensitivity, it can be successfully cultivated in aman season. The features of these four varieties are presented below:

BRRI dhan34: BRRI dhan34 variety is grown in *aman* season. It is modern transplanted *aman* rice released by BRRI in 1997. The grain is short, thick and scented. The cultivar matures at 135 days of planting. It attains a plant height 117 cm. The cultivar gives an average yield of 3.50 t ha^{-1} (BRRI, 2011).

BRRI dhan37: It is modern transplanted *aman* rice developed from a cross of Basmati (D) and BR5 and released in 1998. The grains are of medium size and slender. The color, size and scent of BRRI dhan37 rice is about Katarivog. The end point of the rice grain is slightly bended and possesses a needle like small awn. The cultivar is photosensitive. It takes about 140 days to mature. The plant height of this cultivar is about 125cm. It has the average yield potential of about 3.50 t ha^{-1} (BRRI, 2000a).

BRRI dhan50: BRRI dhan50 is the only aromatic rice for boro season released by BRRI in 2008. Since it has no photosensitivity, it can be cultivated throughout the year. It is recommended for high land areas with good irrigation facilities and for *boro* season. The grain is long, slender, whitish and scented. It takes about 155 days to mature. The plant height of this cultivar is about 82cm. It has the average yield potential of about 6.0 t ha^{-1} (BRRI, 2011).

Chinigura: Chinigura is a local transplanted *aman* rice. It is highly photosensitive in nature and thus only adopted in transplanted *aman* season. This cultivar matures at 130-135 days of planting. It is well known for its characteristic aroma with short grain.

3.5 Treatments

The experiment consisted of two factors as mentioned below:

a) Factor A: Weed control

i) No weeding (Control) (W_0)
ii) One hand weeding at 15 DAT (W_1)
iii) Two hand weeding at 15 and 40 DAT (W_2)
iv) Topstar 400SC (Oxadiargyl) @ 100 g ha^{-1} (W_3)
v) Sunrice 150WG (Ethoxysulfuron) @ 185 ml ha^{-1} (W_4)

b) Factor B: Varieties

I. BRRI dhan34 (V_1)
II. BRRI dhan37 (V_2)
III. BRRI dhan50 (V_3)
IV. Chinigura (V_4)

The description of the weeding treatments is given below.

1) No weeding: Weeds were allowed to grow in the plots from transplanting to harvesting of the crop. No weeding was done.

2) One hand weeding: One hand weeding was done at 15 DAT.

3) Two hand weeding: Two hand weedings were done at 15 and 40 DAT, respectively.

4) Topstar 400SC (Oxadiargyl): Topstar 400SC was applied @ 100 g ha^{-1} at 5 DAT in 4-5 cm standing water for 3-5 days as pre-emergence herbicide.

5) Sunrice 150WG (Ethoxysulfuron): Sunrice 150WG was applied @ 185 ml ha^{-1} at 10 DAT when weeds were 2-3 leaf stage as post-emergence herbicide.

3.6 Description of herbicides

A short description of the herbicides used in the experiment is given in Table 1.

Table1. Short description of the herbicides used in the experiment

Trade name	Common name	Mode of action	Selectivity	Time of application
Topstar 400 SC	Oxadiargyl	Systemic	Transplanted rice, Sunflower and transplanted vegetables.	Pre-emergence
Sunrice 150 WG	Ethoxysulfuron	Systemic	Rice, cotton, sugar cane, turf and wheat.	Post-emergence

3.7 Design and layout

The experiment was laid out in a split plot design with three replications. The size of the individual plot was 5.0 m x 2.25 m and total numbers of plots were 60. There were 20 treatment combinations. Each block was divided into 20 unit plots. Variety was placed along the main plot and weeding treatments were placed in the sub plot. Lay out of the experiment was done on August 2, 2011 with interplot spacing of 0.50 m and inter block spacing of 0.75 m.

3.8 Seed collection, sprouting and sowing

Seeds of BRRI dhan34, BRRI dhan37 and BRRI dhan50 were collected from Bangladesh Rice Research Institute, Joydebpur, Gazipur. Seeds of Chinigura were collected from Kishoreganj district. Initially seed soaking was done in water for 24 hours and after wards they were kept tightly in jute sack for 2 days. When about 90% of the seeds were sprouted, they were sown uniformly in well prepared wet nursery bed on July 10, 2011. Seed bed size was 10 m long and 1.5 m wide.

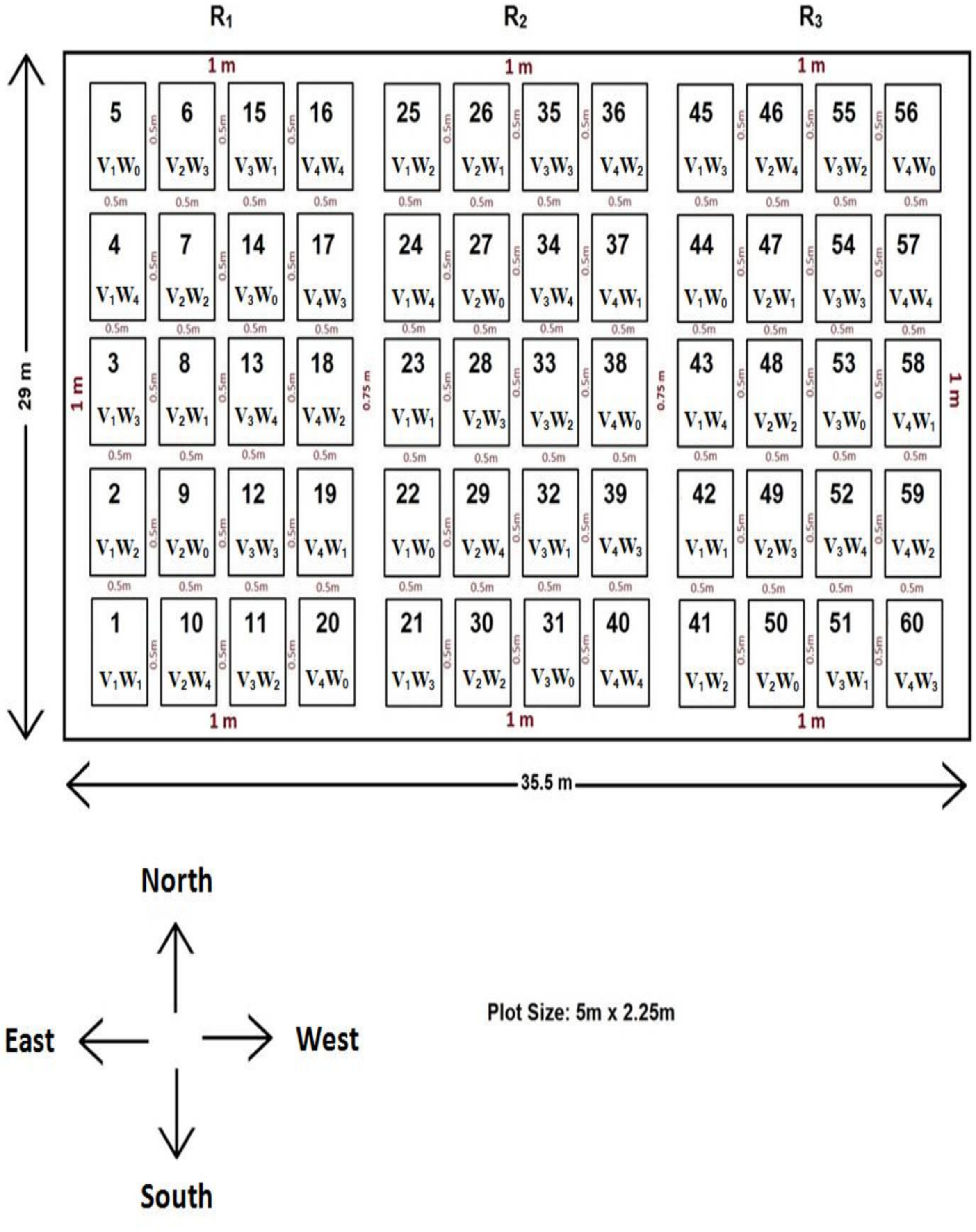

Plate 1: Layout of the experimental field

3.9 Land preparation

The experimental field was opened by a tractor driven rotavator 15 days before transplanting. It was then ploughed well to make the soil nearly ready for transplanting. Weeds and stubble were removed and the field was leveled by repeated laddering. The experimental field was then divided into unit plots and prepared before transplantation.

3.10 Fertilizer application

The field was fertilized with nitrogen, phosphate, potash, sulphur and zinc at the rate of 150, 100, 70, 60 and 10 kg ha^{-1} respectively in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate. The whole amount of all the fertilizers except urea were applied at the time of final land preparation and thoroughly incorporated with soil with the help of a spade. Urea was top dressed in three equal splits on 15, 30, and 45 DAT (BRRI, 2000b).

3.11 Uprooting and transplanting of seedling

The seedbeds were made wet by the application of water both in the morning and evening on the previous day before uprooting on August 8, 2011. The seedlings were then uprooted carefully to minimize mechanical injury to the roots and kept on soft mud in shade before they were transplanted. The twenty five days old seedlings were transplanted on the well puddled experimental plots on August 8, 2011 by using two seedlings $hill^{-1}$.

3.12 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.12.1 Gap filling

Seedlings in some hills were died off and those were replaced by healthy seedling within 10 days of transplantation.

3.12.2 Weeding

Weeding was done as per the experiment treatment.

3.12.3 Irrigation and drainage

The experimental plots required two irrigations during the crop growth season and sometimes drainages were done at the time of heavy rainfall.

3.12.4 Plant protection measures

There were negligible infestations of insect-pests during the crop growth period. Yet to keep the crop growth in normal, Basudin was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control stem borer and rice bug.

3.13 Detecting the flowering stage (50%) and observation of heading

With experience, it was felt that identifying the flowering stage should need to follow regular field observations as flowering date (50%) were recorded after visual observations.

Variety	**Flowering date (50%)**
BRRI dhan34	23-10-2011 (76 DAT)
BRRI dhan37	26-10-2011 (79 DAT)
BRRI dhan50	03-10-2011 (56 DAT)
Chinigura	21-10-2011 (74 DAT)

3.14 General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants which were vigorous and luxuriant in the treatment plots than that of control plots.

3.15 Harvest and post-harvest operation

The maturity of crop was determined when 85% to 90% of the grains become golden yellow in color. From the centre of each plot 1 m^2 area was harvested to determine yield of individual treatment and converted into t ha^{-1}. The harvested crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in sun. Before harvesting, ten hills were selected randomly outside the sample area of each plot and cut at the ground level for collecting data on yield contributing characters.

Variety	**Harvesting date**
BRRI dhan34	05-12-2011 (120 DAT)
BRRI dhan37	06-12-2011 (120 DAT)
BRRI dhan50	31-10-2011 (84 DAT)
Chinigura	29-11-2011 (113 DAT)

3.16 Collection of data

3.16.1 Weed parameters

Weed density

The data on weed infestation as well as density were collected from each unit plot at 15 days interval up to 75 DAT. A plant quadrate of 1.0 m^2 was placed at three different spots of 11.25 m^2 of the plot. The middle quadrate was remained undisturbed for yield data. The infesting species of weeds within the first and third quadrate were identified and their number was counted species wise alternately at different dates.

Weed biomass

The weeds inside each quadrate for density count were uprooted, cleaned and separated species wise. The collected weeds were first dried in the sun and then kept in an electrical oven for 72 hours maintaining a constant temperature of 80^0C. After drying, weight of each species was taken and expressed to g m^{-2}.

Weed control efficiency

Weed control efficiency was calculated with the following formula developed by Sawant and Jadav (1985):

$$\text{Weed control efficiency (WCE)} = \frac{DWC - DWT}{DWC} \times 100$$

Where,

DWC = Dry weight of weeds in unweeded treatment

DWT = Dry weight of weeds in weed control treatment

Relative weed density (%)

Relative weed density was calculated by using the following formula:

$$\text{RWD} = \frac{\text{Density of individual weed species in the community}}{\text{Total density of all weed species in the community}} \times 100$$

3.16.2 Crop growth parameters

a. Plant height (cm) at 15 days interval up to harvest.
b. Tillers $hill^{-1}$ at 15 days interval up to harvest.
c. Dry matter weight of plant at 15 days interval including partitioning of different parts, CGR (Crop Growth Rate), RGR (Relative Growth Rate)
d. Days to flowering
e. Days to maturity

3.16.3 Yield Contributing Characters

a. Effective tillers $hill^{-1}$
b. Ineffective tillers $hill^{-1}$
c. Length of panicle (cm)

d. Fertile spikelets (filled grains) panicle^{-1}
e. Sterile spikelets (unfilled grains) panicle^{-1}
f. Filled grain percentage (%)
g. Weight of 1000 grains (g)

3.16.4 Yield and harvest index

a. Grain yield (t ha^{-1})
b. Straw yield (t ha^{-1})
c. Biological yield (t ha^{-1})
d. Harvest index (%)

3.17 Procedure of sampling for growth study during the crop growth period

Plant height (cm)

The height of the rice plants was recorded from 15 days after transplanting (DAT) at 15 days interval up to 75 DAT, beginning from the ground level up to tip of the flag leaf was counted as height of the plant. The average height of ten hills was considered as the height of the plant for each plot.

Tillers hill^{-1}

Total tiller number was taken from 15 DAT at 15 days interval up to 90 DAT. The average number of tillers of ten hills was considered as the total tiller no hill^{-1}.

Crop growth rate (g hill^{-1} day^{-1})

Crop growth rate was calculated by using the following standard formula (Radford, 1967 and Hunt, 1978) as shown below:

$$\text{CGR} = \frac{W_2 - W_1}{T_2 - T_1} \text{ g hill}^{-1} \text{ day}^{-1}$$

Where, W_1= Total plant dry matter at time T_1
W_2 = Total plant dry matter at time T_2

Relative growth rate (g hill^{-1} day^{-1})

Relative growth rate was calculated by using the following formula (Radford, 1967) as shown below:

$$RGR = \frac{LnW_2 - LnW_1}{T_2 - T_1} \text{ g hill}^{-1} \text{ day}^{-1}$$

Where, W_1 = Total plant dry matter at time T_1

W_2 = Total plant dry matter at time T_2

Ln = Natural logarithm

3.18 Procedure of data collection for yield and yield components

For assessing yield parameters except the grain and straw yields data were collected from 10 randomly selected hills from each of the plots. For yield measurement, an area of 1.0 m^2 from center of each plot was harvested.

Plant height

Plant height was measured from the soil level to the apex of the leaf or panicle in randomly 10 hills of each plot.

Effective tillers hill^{-1}

The total number of tillers hill^{-1} was counted from selected samples and were grouped in effective and non-effective tillers hill^{-1}.

Total grains panicle^{-1}

The number of filled grains panicle^{-1} plus the number of sterile grains panicle^{-1} gave the total number of grains panicle^{-1}.

Number of filled grains and sterile grains panicle^{-1}

Number of filled grains and sterile grains from randomly selected 10 hills were counted and average of which gave the number of filled grains and sterile grains panicle^{-1}. Presence of any food material in the grains was considered as filled grain and lacking of any food material in the grains was considered as sterile grains.

Weight of 1000 grains (g)

One thousand cleaned dried grains were randomly collected from the seed stock obtained from 10 hills of each plot and were sun dried properly at 14% moisture content and weight by using an electric balance.

Grain and straw yield (t ha^{-1})

An area of 1.0 m^2 harvested for yield measurement. The crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in sun.

Biological yield

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

Harvest index (%)

Harvest index is the relationship between grain yield and biological yield (Gardner *et al.,* 1985). It was calculated by using the following formula:

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

3.19 Economic analysis

From beginning to ending of the experiment, individual cost data on all the heads of expenditure in each treatment were recorded carefully and classified according to Mian and Bhuiya (1977) as well as posted under different heads of cost of production.

The rates of different items in transplanted *aman* rice were given in Appendix XII.

Input cost

Input costs were divided into two parts. These were as follows:

A. Non-material cost (labor)

The human labor was obtained from adult male laborers. Eight working hours of a laborer was considered as a man day. The mechanical labor came from the tractor. A period of eight working hours of a tractor was taken to be tractor day.

B. Material cost

The seed of test rice varieties (BRRI dhan34, BRRI dhan37 and BRRI dhan50) was purchased from BRRI Headquarter @ Tk.100 per kg. Seeds of Chinigura were collected from local market @ Tk.100 per kg. Chemical fertilizers eg. Urea, TSP, MP, Gypsum and Zinc sulphate were bought from the authorized dealer at Savar, Dhaka. Irrigation was done from the existing facilities of irrigation system of the Sher-e-Bangla Agricultural University field. Herbicides, fungicide and insecticide were bought from the respective dealers at local market.

Overhead cost

The interest on input cost was calculated for 6 months @ Tk. 12.5% per year based on the interest rate of the Bangladesh Krishi Bank. The value of land varies from place to place and also from year to year. In this study, the value of land was taken Tk. 200000 per hectare. The interest on the value of land was calculated @ 12.5% per year for 2 months for nursery and 4 months for main field.

Miscellaneous overhead cost (common cost)

It was arbitrarily taken to be 5% of the total running capital. Total cost of production has been given in Appendix XIII.

Gross return

Gross return from transplanted *aman* rice cultivation (Tk. ha^{-1}) = Value of grain (Tk ha^{-1}) + Value of straw (Tk ha^{-1}).

Net return

Net return was calculated by using the following formula:

Net return (Tk. ha^{-1}) = Gross return (Tk. ha^{-1}) – Total cost of production (Tk. ha^{-1})

Benefit cost ratio (BCR)

Benefit cost ratio indicated whether the cultivation is profitable or not which was calculated as follows:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return (Tk. per ha)}}{\text{Cost of production (Tk. per ha)}}$$

3.20 Statistical analysis

The recorded data were subjected to statistical analysis. Analysis of variance was done following two factor split plot design with the help of computer package MSTAT c. The mean differences among the treatments were adjusted by Duncan's Multiple Range Test (DMRT) at 5% level of significance.

Chapter 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from a study to investigate the influence of different methods of weed control on the growth, development and yield of transplanted aromatic *aman* rice varieties cv. BRRI dhan34, BRRI dhan37, BRRI dhan50 and Chinigura. The results of the weed parameters, crop characters and economic evaluation of the production of the crop as influenced by different weed control treatments have been presented and discussed in this chapter.

4.1 Infested weed species in the experimental field

It is a general observation that conditions favorable for growing aromatic *aman* rice are also favorable for exuberant growth of numerous kinds of weeds that compete with crop plants. This competition of weeds tends to increase when the weed density increases and interfere with the crop growth and development resulting poor yield. Twenty three weed species belonging to eleven families were found to infest the experimental crop. Local name, common name, scientific name, family and morphological type of the weed species have been presented in Table 2. The density and dry weight of weeds varied considerably in different weed control treatments.

The most important weeds of the experimental plot were *Cyperus michelianus, Echinochloa crussgalli, Cyperus esculentus, Sagittaria guyanensis, Alternanthera sessilis, Cyperus difformis, Cyperus esculentus* and *Ludwigia octovalvis* respectively. Among the twenty three species seven were aquatic, six were grasses, six were sedges, three were broad leaved and one was fern (Table 2). From a survey in BRRI farm, Bhanga, Faridpur and Burichang of Comilla district, Bangladesh, Bhuiyan *et al.* (2011) also reported that weed flora in the experimental plots observed in two agro-ecological zones comprised of grasses *Cynadon dactylon, Echinochloa crus-galli, Leptochloa chinensis,* the sedges*; Cyperus difformis, Scirpus juncoides, Fimbristylis* *miliaceae* and the broadleafs; *Monochoria vaginalis, Lindernia anagallis, Marsilea minuta andSphenoclea zeylanica.* Mamun *et al.* (2011) reported that *Echinochloa crus-galli, Scirpus maritimus, Monochoria vaginalis, Cyperus difformis, Cynodon dactylon, Marsilea minuta, Ludwigia octovalvis,Nymphaea nouchali* and *Desmodium trifolium* were important weed species of transplanted *aman* rice. The present result varied a little bit from those reports and this might be due to seasonal variation and location.

Table 2. Weed species found in the experimental plots in transplanted aromatic aman rice

SL No.	Local name	Common name	Scientific name	Family	Types
1	Durba	Bermuda grass	*Cynodon dactylon*	Gramineae	Grass
2	Chanci	Sessile joyweed	*Alternanthera sessilis*	Amaranthaceae	Aquatic
3	Malancha	Alligatorweed	*Alternanthera philoxeroides*	Amaranthaceae	Aquatic
4	Boro Shama	Barnyard Grass	*Echinochloa crussgalli*	Gramineae	Grass
5	Chandmala	Duck weed	*Sagittaria guyanensis*	Alismataceae	Aquatic
6	Sushni	European waterclover	*Marsilea quadrifolia*	Marsileaceae	Fern
7	Nakful	Nutsedge	*Cyperus michelianus*	Cyperaceae	Sedge
8	Joyna	Fringerush	*Fimbristylis miliaceae*	Cyperaceae	Sedge
9	Mutha	Nutgrass	*Cyperus rotundus*	Cyperaceae	Sedge
10	Jhilmorich	Gooseweed	*Sphenoclea zeylanica*	Sphenocleaceae	Broadleaf
11	Panilong	Willow primrose	*Ludwigia octovalvis*	Onagraceae	Broadleaf
12	Arail	Rice grass	*Leersia hexandra*	Gramineae	Grass
13	Behua	Small flower umbrella	*Cyperus difformis*	Cyperaceae	Sedge
14	Holdemutha	Yellow nutsedge	*Cyperus esculentus*	Cyperaceae	Sedge
15	Keshuti	Eclipta	*Eclipta alba*	Asteraceae	Broadleaf
16	Moyurleja	Red sprangletop	*Leptochloa panicea*	Gramineae	Grass
17	Chapra	Indian goosegrass	*Eleusine indica*	Gramineae	Grass
18	Chotoshama	Jungle rice	*Echinochloa colonum*	Gramineae	Grass
19	Ghagra	Cocklebur	*Xanthium indicum*	Compositae	Aquatic
20	Chech	Mud sedge	*Fimbristylis diphylla*	Cyperaceae	Sedge
21	Kanai bashi	Spider wort	*Commelina benghalensis*	Commelinaceae	Aquatic
22	Choto pani kochu	Monochoria	*Monochoria vaginalis*	Pontederiaceae	Aquatic
23	Keshordam	Creeping water primrose	*Jussicea repens*	Onagraceae	Aquatic

4.2 Weed importance according to date and variety

There are twenty three weed species belonging to eleven families were found to infest the experimental rice field. Weeds compete with crop plants for space, light, nutrients and water. When competition is severe, crop yield reduces drastically. There is another type of competition exists in the crop field except crop-weed competition i.e. weed-weed competition. In this experiment, several weed species were seen to be dominant at different dates and varieties i.e. weed dominance varied according to dates and variety (Table 3). In BRRI dhan34 (V_1) plots, sedge weeds were dominant (*Cyperus michelianus* and *Cyperus difformis having* 43.17% and 26.14%, respectively) at 30 DAT. On 60 DAT, sedge (*Cyperus esculentus* 22.76%), broadleaf (*Ludwigia octovalvis* and *Sphenoclea zeylanica* having 15.85% and 10.16%) and aquatic weeds (*Alternanthera sessilis* having 12.20%) showed dominance in BRRI dhan34 (V_1) plots. In case of BRRI dhan37 (V_2) plots, sedge weed (*Cyperus michelianus*) was more dominant than in BRRI dhan34 (V_1) plots having 66.09% at 30 DAT, although broadleaf weed (*Sphenoclea zeylanica*10.73%) were also present. At 60 DAT, sedge (*Cyperus esculentus* and *Cyperus difformis*), broadleaf (*Ludwigia octovalvis)*, aquatic (*Alternanthera sessilis*) and grass (*Leptochloa panicea*) weeds were severely infested the plots having 21.79%, 20.09%, 13.68%, 8.97% and 8.97% respectively. In BRRI dhan50 (V_3) plots, sedge weed (*Cyperus michelianus*) was more dominant than others having 62.55% at 30 DAT, although aquatic weed (*Alternanthera sessilis* 13.84%) were also present. On 60 DAT, sedge (*Cyperus esculentus* 23.10%), aquatic (*Alternanthera sessilis* 19.66%) and grass (*Echinochloa crussgalli* 10.34%) were the most dominant. In Chinigura (V_4) plots, sedge weeds (*Cyperus difformis*, *Cyperus michelianus* and *Cyperus rotundus*) were dominant alone having 34.67%, 33.15% and 10.36% respectively at 30 DAT. On 60 DAT, sedge (*Cyperus esculentus* 25.97%), aquatic (*Alternanthera sessilis* 21.32%) and grass (*Echinochloa crussgalli* 9.69%) were found dominant in Chinigura (V_4) plots.

Table 3.Weed importance according to date and variety in transplanted aromatic *aman* rice

Scientific name	Type	Weed Importance according to date and variety							
		BRRI dhan34 (V_1)		BRRI dhan37 (V_2)		BRRI dhan50(V_3)		Chinigura (V_4)	
		30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
Cynodon dactylon	Grass	0.44	0.00	0.37	0.00	0.74	3.79	1.80	0.00
Alternanthera sessilis	Aquatic	1.32	12.20	5.43	8.97	13.84	19.66	7.73	21.32
Alternanthera philoxeroides	Aquatic	0.00	0.00	0.00	0.00	0.62	0.69	2.07	0.00
Echinochloa crussgalli	Grass	0.00	0.81	0.00	4.27	0.49	10.34	0.28	9.69
Sagittaria guyanensis	Aquatic	2.50	3.03	3.08	0.00	2.22	2.07	3.04	0.00
Marsilea quadrifolia	Fern	5.87	4.88	0.99	2.56	3.46	0.69	0.00	1.16
Cyperus michelianus	Sedge	43.17	0.00	66.09	0.00	62.55	0.00	33.15	4.65
Fimbristylis miliaceae	Sedge	1.76	9.35	2.59	9.83	0.74	8.97	0.55	1.94
Cyperus rotundus	Sedge	9.99	2.25	7.40	4.27	5.44	0.00	10.36	0.00
Sphenoclea zeylanica	Broadleaf	3.67	10.16	10.73	1.71	1.48	5.52	3.18	6.20
Ludwigia octovalvis	Broadleaf	4.41	15.85	2.34	13.68	7.91	7.24	2.07	3.88
Leersia hexandra	Grass	0.44	3.25	0.12	1.71	0.49	0.69	0.00	1.94
Cyperus difformis	Sedge	26.14	7.72	0.12	20.09	0.00	2.76	34.67	10.85
Cyperus esculentus	Sedge	0.00	22.76	0.74	21.79	0.00	23.10	1.10	25.97
Eclipta alba	Broadleaf	0.00	0.00	0.00	0.85	0.00	4.83	0.00	0.39
Leptochloa panacea	Grass	0.00	2.44	0.00	8.97	0.00	3.10	0.00	3.88
Eleusine indica	Grass	0.00	0.00	0.00	1.28	0.00	4.14	0.00	1.16
Echinochloa colonum	Grass	0.29	3.66	0.00	0.00	0.00	2.41	0.00	6.98

4.3 Relative weed density (%)

Weed competes with another weed plants for their existence. In this experiment, several weed species were found to dominate the field at different dates (Table 4). This may be due to crop-weed competition, weed-weed competition or allelopathic effect (chemical secretion of one plant that inhibit the growth of others) of one plant to others. Although, occurrence of weed in the crop field mainly depends on various environmental factors (climate, rainfall etc.) and abiotic factors (soil types, topography of land etc.). At 15 DAT, grass and aquatic weeds dominated the field among them *Echinochloa crussgalli* (grass) scored highest (51.79% RWD) and *Sagittaria guyanensis* (aquatic) scored (29.16% RWD). Sedge weeds dominated the field at 30 DAT, 45 DAT & 60 DAT. At 30 DAT, *Cyperus michelianus* (56.14% RWD) *and Cyperus rotundus* (10.66% RWD) were the dominant weed species.

Table 4. Relative density (%) of different weed species infested the experimental area

SL No.	Common name	Types	Relative density (%)				
			15 DAT	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**
1	Bermuda grass	Grass	4.31	1.85	0.00	0.15	0.00
2	Sessile joyweed	Aquatic	6.39	8.89	6.83	28.33	0.25
3	Alligatorweed	Aquatic	1.37	0.50	0.10	0.15	0.00
4	Barnyard Grass	Grass	51.79	0.31	6.00	2.41	6.43
5	Duck weed	Aquatic	29.16	2.01	0.00	0.00	0.00
6	European waterclover	Fern	3.72	1.75	0.20	0.46	0.50
7	Nutsedge	Sedge	3.26	56.14	0.13	0.00	0.00
8	Fringerush	Sedge	0.00	1.20	7.31	11.67	10.50
9	Nutgrass	Sedge	0.00	10.66	0.00	0.00	0.00
10	Gooseweed	Broadleaf	0.00	3.81	0.16	0.18	3.49
11	Willow primrose	Broadleaf	0.00	5.17	5.87	6.05	21.88
12	Rice grass	Grass	0.00	0.39	4.47	0.73	2.45
13	Small flower umbrella	Sedge	0.00	7.17	24.54	2.47	0.00
14	Yellow nutsedge	Sedge	0.00	0.00	24.93	33.60	9.05
15	Eclipta	Broadleaf	0.00	0.00	9.78	0.48	1.58
16	Red sprangletop	Grass	0.00	0.00	7.32	5.81	9.01
17	Indian goosegrass	Grass	0.00	0.00	2.36	5.51	11.62
18	Jungle rice	Grass	0.00	0.14	0.00	1.99	3.45

At 45 DAT, Sedge weeds again dominated the field although another types being present. But *Cyperus esculentus* (24.93% RWD) and *Cyperus difformis* (24.54% RWD) scored the highest. At 60 DAT, some aquatic and grass weeds were prominent along with sedges. The dominant weeds were *Cyperus esculentus* (grass) and *Alternanthera sessilis* (aquatic) having 33.60% RWD and 28.33% RWD respectively. At 75 DAT, the scenario of competition was different. Several weed species were found dominating throughout the field belonging grass, sedge and broadleaf types. Although the competition was prominent among them, the RWD of population was *Ludwigia octovalvis (broadleaf), Eleusine indica* (grass) and *Fimbristylis miliaceae* (sedge) having 21.88%, 11.62% and 10.50%, respectively. Relative density of several weed species decreased at later stages (75 DAT) due to their completion of life cycle.

In this experiment, Sedge weeds dominated the crop field throughout the growing period. Grass weeds were prominent during the early and later period while broadleaf weeds were prominent during the later periods. This result is dissimilar with the findings of Hasanuzzaman *et al.* (2009) who observed that grasses and sedges were less dominating weed species. This might be due to seasonal and varietal variation.

4.4 Weed population

4.4.1 Effect of Variety

There was no significant variation observed on weed density at 15 DAT, 30 DAT, 45 DAT for varietal variation but significant variation observed at 60 DAT and 75 DAT (Figure 1 and Appendix IV). At 15 DAT, numerically highest weed population (34.60 m^{-2}) was recorded from BRRI dhan37 (V_2) and lowest weed population (22.67 m^{-2}) recorded from Chinigura (V_4). At 30 DAT, numerically highest weed population (107.6 m^{-2}) was observed from Chinigura (V_4) and lowest weed population (92.07 m^{-2}) was observed from BRRI dhan37 (V_2).

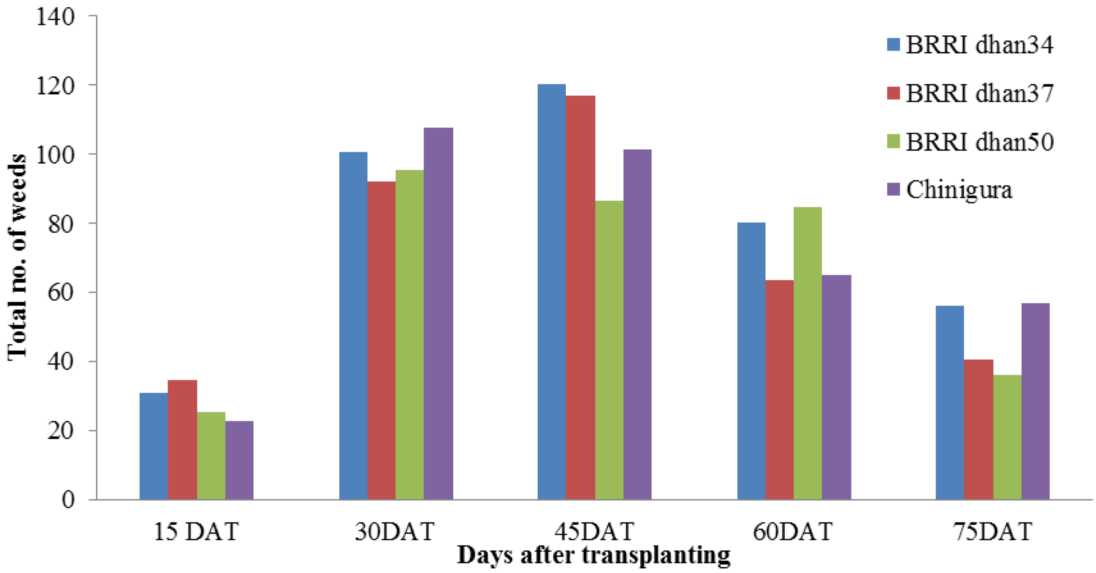

Figure 1. Effect of variety on weed population (m^{-2}) of T. *aman* rice at different days after transplanting (SE= 5.75, 13.90, 13.99, 6.63 and 5.57 for 15, 30, 45, 60 and 75 DAT)

Weed population (120.10 m^{-2}) was highest in BRRI dhan34 (V_1) and lowest (86.60 m^{-2}) was found in BRRI dhan50 (V_3) at 45 DAT. At 60 DAT, highest weed population (84.67 m^{-2}) was observed in BRRI dhan50 (V_3) which was statistically similar with V_1 and V_4. The lowest weed population (63.60 m^{-2}) was observed in case of BRRI dhan37 (V_2). At 75 DAT, highest weed population (56.73 m^{-2}) was observed in Chinigura (V_4) which was statistically similar to V_1 and V_2 and the lowest weed population (36.13 m^{-2}) was found in BRRI dhan50 (V_3). These results are in agreement with the findings of Chandra and Pandey (2001) who stated that weed competition was severe in scented paddy culture, in view of its early slow growth rates.

4.4.2 Effect of weed control treatments

Significant variation was observed on weed density throughout the growing period for different weed control treatments (Figure 2 and Appendix IV). The highest weed population was observed in control (W_0) throughout the growing period, which was statistically similar to one hand weeding (W_1) except 30 DAT. The lowest weed population was observed in case of Sunrice 150WG (W_4) which was statistically similar to Topstar 400SC (W_3) throughout the growing period. Herbicidal treatments drastically reduced weed population. This result was supported by Bhuiyan *et al.* (2010) who reported that pre emergence application of Oxadiargyl 400SC @ 75 g a.i. ha^{-1} had minimum population than any other herbicide and doses. Similar results were also stated by Bhuiyan *et al.* (2011), Kalhirvelan and Vaiyapuri (2003), Mahajan *et al.* (2003), Gnanasambandan and Murthy (2001), Islam *et al.* (2001), Samanta *et al.* (1995) and Singh and Singh (1994).

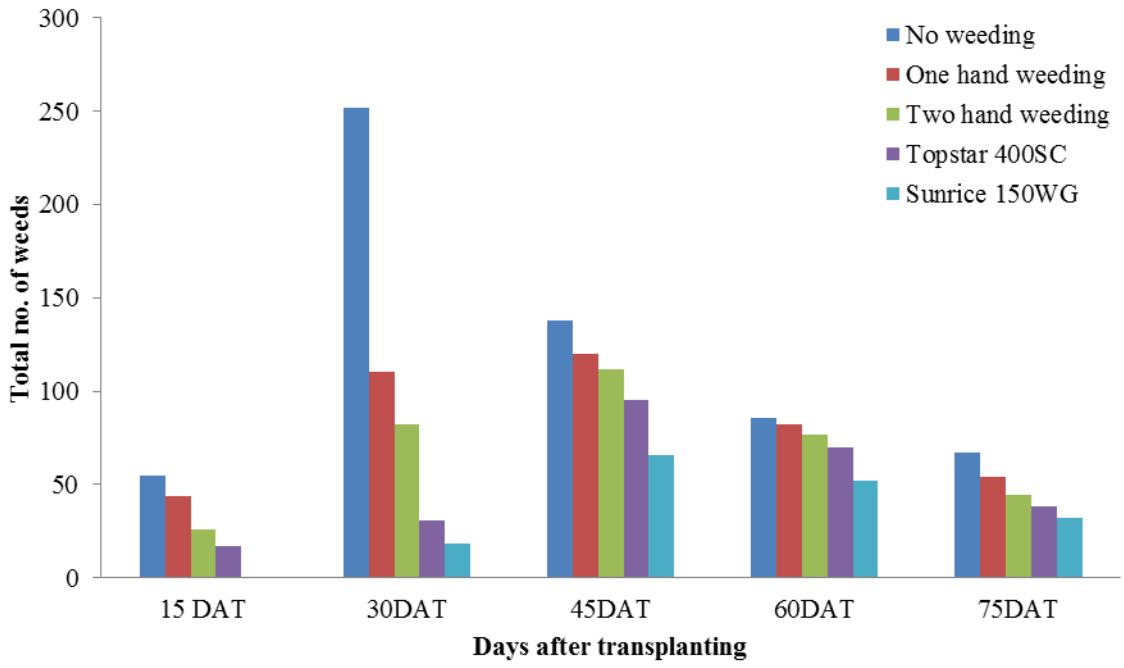

Figure 2. Effect of different weed control methods on weed population (m^2) of T. *aman* rice at different days after transplanting (SE= 6.43, 15.54, 15.64, 7.41 and 6.22 for 15, 30, 45, 60 and 75 DAT)

4.4.3 Interaction effect of variety and weed control treatments

For variety and weed management combination, significant variation was observed for weed density throughout the growing period shown in Table 5. At 15 DAT, the highest weed population (79.67 m^{-2}) was recorded from the combination of BRRI dhan37 and no weeding (V_2W_0) which was statistically similar with V_1W_0, V_1W_1, V_2W_2, V_3W_1, V_3W_2, and V_4W_1. The lowest weed population (0.00 m^{-2}) was recorded from combination of Chinigura and Sunrice 150WG (V_4W_4) which was statistically similar to V_1W_2, V_1W_3, V_1W_4, V_2W_2, V_2W_3, V_2W_4, V_3W_1, V_3W_2, V_3W_3, V_3W_4, V_4W_0, V_4W_1, V_4W_2 and V_4W_3. At 30 DAT, the highest weed population (270.30 m^{-2}) was observed from combination of BRRI dhan37 and no weeding (V_2W_0) which was statistically similar with V_1W_0, V_3W_0 and V_4W_0. The lowest weed population (12.00 m^{-2}) was recorded from the combination of Chinigura and Sunrice 150WG (V_4W_4) which was statistically similar with V_1W_2, V_1W_3, V_1W_4, V_2W_1, V_2W_2, V_2W_3, V_3W_1, V_3W_2, V_3W_3, V_3W_4, V_4W_2 and V_4W_3. Highest weed population (184.70

m^{-2}) was observed from the combinations of BRRI dhan37 and no weeding (V_2W_0) at 45 DAT which was statistically similar with V_1W_0, V1W_1, V_1W_2, V_1W_3, V_1W_4, V_2W_0, V_2W_1, V_2W_2, V_2W_3, V_3W_0, V_3W_1, V_3W_2, V_4W_0, V_4W_1 and V_4W_2. The lowest weed population (44.33 m^{-2}) was observed from the combinations of BRRI dhan50 and Sunrice 150WG (V_3W_4) which was statistically similar with V_1W_0, V_1W_1, V_1W_2, V_1W_3, V_1W_4, V_2W_1, V_2W_2, V_2W_3, V_2W_4, V_3W_0, V_2W_1, V_3W_2, V_3W_3, V_4W_0, V_4W_1, V_4W_2, V_4W_3 and V_4W_4. At 60 DAT, the highest weed population (96.67 m^{-2}) was observed under the combinations of BRRI dhan50 and no weeding (V_3W_0) which was statistically similar with V_1W_0, V_1W_1, V_1W_2, V_1W_3, V_1W_4, V_2W_0, V_2W_1, V_2W_2, V_2W_3, V_3W_1, V_3W_2, V_3W_3, V_3W_4, V_4W_0, V_4W_1, V_4W_2 and V_4W_3. Minimum weed population (30.00 m^{-2}) was observed from the combinations of Chinigura and Sunrice 150WG (V_4W_4) which was statistically similar with V_1W_3, V_1W_4, V_2W_0, V_2W_1, V_2W_2, V_2W_3, V_2W_4, V_3W_3, V_3W_4, V_4W_2 and V_4W_3. At 75 DAT, maximum weed population (79.33 m^{-2}) was recorded from the combinations of BRRI dhan34 and no weeding (V_1W_0) which was statistically similar with V_1W_1, V_1W_2, V_1W_3, V_1W_4, V_2W_0, V_2W_1, V_2W_2, V_3W_0, V_3W_1, V_4W_0, V_4W_1, V_4W_2, V_4W_3 and V_4W_4. Minimum weed density (21.67 m^{-2}) was observed from the combinations of BRRI dhan50 and Sunrice 150WG (V_3W_4) which was statistically similar with V_1W_2, V_1W_3, V_1W_4, V_2W_0, V_2W_1, V_2W_2, V_2W_3, V_2W_4, V_3W_0, V_3W_1, V_3W_2, V_3W_3, V_4W_2, V_4W_3 and V_4W_4. This result was similar with the findings of Gnanavel and Anbhazhagan (2010) who observed that Pre-emergence application of oxyfluorfen 0.25 kg ha^{-1} followed by post-emergence application of bispyribac sodium 0.05 kg + metsulfuron methyl @ 0.01 kg ha^{-1} recorded the least weed count (11.00 m^{-2}) in transplanted aromatic basmati rice.

Table 5. Interaction effect of variety and weed control methods on total number of weeds at 15, 30, 45, 60 and 75 DAT

Treatment combination	Total number of weeds at different days after transplanting (DAT)				
	15	30	45	60	75
V_1W_0	56.67 ab	227.00 ab	137.00 ab	82.00 ab	79.33 a
V_1W_1	50.33 ab	123.00 cd	133.00 ab	89.00 ab	67.33 a-c
V_1W_2	25.67 b-d	87.00 c-f	127.30 ab	84.33 ab	50.33 a-e
V_1W_3	22.33 b-d	37.67 d-f	116.30 ab	80.00 a-c	45.00 a-e
V_1W_4	0.00 d	28.00 d-f	86.67 ab	66.33 a-c	38.67 a-e
V_2W_0	79.67 a	270.30 a	184.70 a	78.00 a-c	57.00 a-e
V_2W_1	52.00 ab	92.00 c-f	124.30 ab	68.67 a-c	45.33 a-e
V_2W_2	23.67 b-d	52.67 c-f	118.00 ab	67.67 a-c	42.33 a-e
V_2W_3	17.67 b-d	27.33 d-f	81.33 ab	61.33 a-c	34.33 b-e
V_2W_4	0.00 d	18.00 d-f	76.00 b	42.33 bc	23.33 de
V_3W_0	44.33 a-c	269.70 a	115.00 ab	96.67 a	57.67 a-e
V_3W_1	40.33 a-d	76.67 c-f	107.70 ab	90.67 ab	39.00 a-e
V_3W_2	25.67 b-d	70.33 c-f	89.67 ab	87.33 ab	36.00 b-e
V_3W_3	13.67 b-d	44.67 d-f	76.33 b	78.33 a-c	26.33 c-e
V_3W_4	2.33 cd	16.67 ef	44.33 b	70.33 a-c	21.67 e
V_4W_0	38.67 a-d	241.30 ef	116.00 ab	86.00 ab	75.67 ab
V_4W_1	31.33 b-d	150.00 bc	115.70 ab	81.67 ab	65.67 a-d
V_4W_2	29.00 b-d	120.00 c-e	111.30 ab	68.33 a-c	49.33 a-e
V_4W_3	14.33 b-d	14.67 ef	106.00 ab	59.67 a-c	47.00 a-e
V_4W_4	0.00 d	12.00 f	57.33 b	30.00 c	46.00 a-e
SE	12.85	31.08	31.28	14.81	12.45
CV (%)	78.43	54.41	51.02	34.94	45.52

V_1= BRRI dhan34, V_2= BRRI dhan37, V_3= BRRI dhan50, V_4= Chinigura, W_0= No weeding, W_1= One hand weeding, W_2= Two hand weeding, W_3= Topstar 400SC, W_4= Sunrice 150WG

4.5 Weed biomass

4.5.1 Effect of Variety

No significant variation was observed on weed biomass for varietal variation throughout the growing season (Figure 3 and Appendix V). At 15 DAT, numerically highest weed biomass (1.19 g m^{-2}) was recorded from BRRI dhan37 (V_2) and lowest weed biomass (0.64 g m^{-2}) recorded from Chinigura (V_4). Numerically highest weed biomass (14.54 g m^{-2}) was recorded from BRRI dhan34 (V_1) and lowest weed biomass (10.46 g m^{-2}) recorded from BRRI dhan50 (V_4) at 30 DAT. On 45 DAT, 60 DAT and 75 DAT, Chinigura (V_4) was recorded the highest weed biomass 48.94, 22.50 and 19.47 g m^{-2}

respectively. BRRI dhan34 (V_1) was recorded the lowest weed biomass 36.00 and 17.21 g m^{-2} at 45 and 75 DAT respectively. At 60 DAT, BRRI dhan37 (V_2) attained the lowest weed biomass (17.83 g m^{-2}). This result was in agreement with Houque *et al.* (2003) who stated that BRRI dhan34 was the most competitive variety, which provided the least accumulation of weed dry matter per unit area.

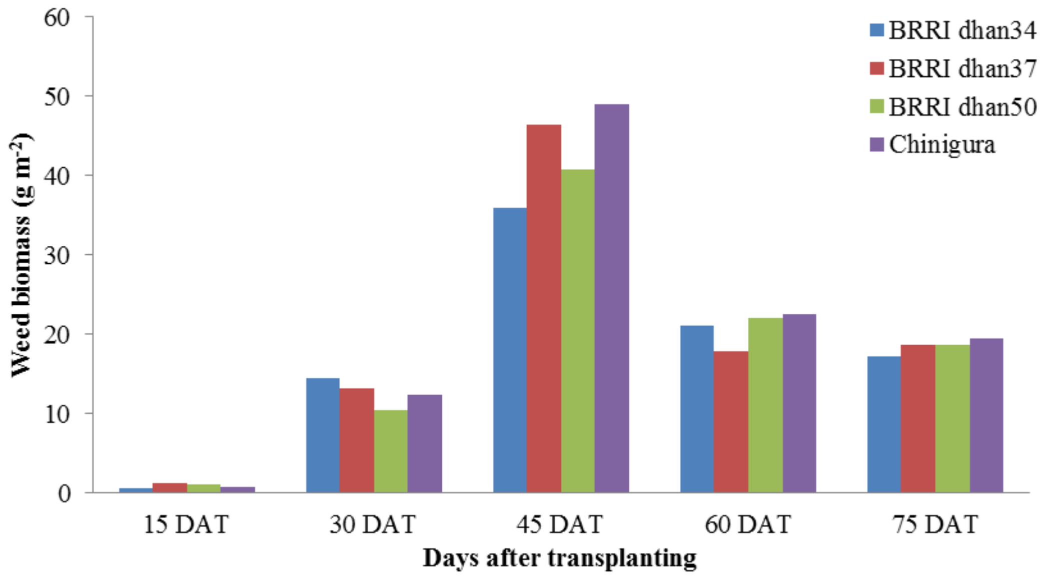

Figure 3. Effect of variety on weed biomass (g m^{-2}) of T. *aman* rice at different days after transplanting (SE= 0.18, 1.97, 8.19, 2.09 and 3.28 for 15, 30, 45, 60 and 75 DAT)

4.5.2 Effect of weed control treatments

Significant variation was observed on weed biomass for different weed control treatments shown in Figure 4 and Appendix V. The highest weed biomass was recorded from no weeding treatment (W_0) and hence the lowest weed biomass was recorded from Sunrice 150WG (W_4) over time. At 15 DAT, the highest weed dry matter (1.63 g m^{-2}) was observed from no weeding treatment (W_0) which was statistically similar with one hand weeding (W_1) and two hand weeding treatments (W_2). On the other hand the lowest weed biomass (0.12 g m^{-2}) was recorded from Sunrice 150WG (W_4), which was statistically similar with Topstar 400SC (W_3). Highest weed dry matter (37.02 g m^{-2}) was recorded from no weeding treatment (W_0) at 30 DAT whether the lowest dry matter (1.37 g m^{-2}) was recorded from Sunrice 150WG (W_4) which was statistically similar with Topstar 400SC (W_3). At 45 DAT, highest weed dry matter (65.73 g m^{-2}) was recorded from no weeding treatment (W_0) which was statistically similar with one hand weeding (W_1) and two hand weeding treatments (W_2). On the other hand, the lowest weed dry matter (25.35 g m^{-2}) was recorded from Sunrice 150WG (W_4) which was statistically similar with Topstar 400SC (W_3), two hand weeding (W_2) and one hand weeding treatments (W_1). On 60 DAT, no weeding treatment (W_0) was recorded the highest weed biomass (38.22 g m^{-2}) and Sunrice 150WG (W_4) recorded the lowest (7.19 g m^{-2}). At 75 DAT, the highest weed dry matter (28.05 g m^{-2}) was observed from no weeding treatment (W_0) which was statistically similar to one hand weeding (W_1) and two hand weeding treatments (W_2). On the other hand, the lowest weed dry matter (10.30 g m^{-2}) was recorded from Sunrice 150WG (W_4) which was statistically similar with Topstar 400SC (W_3), two hand weeding (W_2) and one hand weeding treatments (W_1). It reveals that pre and post emergence herbicides effectively reduced weed biomass. Similar findings were reported by Bhuiyan *et al.* (2010) who reported that pre emergence application of Oxadiargyl 400SC @ 75 g a.i. ha^{-1} had minimum dry weight of weeds which resulted satisfactory weed control than other herbicide and doses. This result is also similar with the findings of Bhuiyan *et al.* (2011), Bhuiyan *et al.* (2011), Gnanavel and Anbhazhagan (2010), Kalhirvelan and Vaiyapuri (2003), Mahajan *et al.* (2003), Islam *et al.* (2001) and Samanta *et al.* (1995).

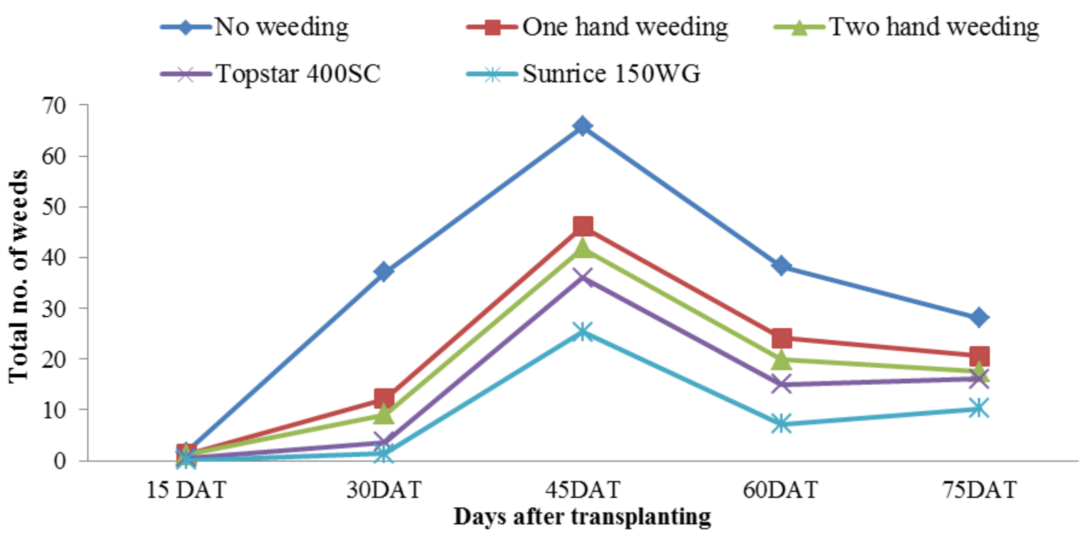

Figure 4. Effect of different weed control methods on weed biomass (g m^{-2}) of T. *aman* rice at different days after transplanting (SE=0.20, 2.20, 9.16, 2.34 and 3.67 for 15, 30, 45, 60 and 75 DAT)

4.5.3 Interaction effect of variety and weed control treatments

Significant variation was observed for weed biomass under different variety and weed management combinations throughout the growing period except 75 DAT (Table 6). At 15 DAT, the highest weed biomass (2.28 g m^{-2}) was observed from BRRI dhan37 and no weeding combination (V_2W_0), which was statistically similar with V_1W_0, V_2W_1, V_2W_2, V_3W_0, V_3W_1, V_3W_2, V_4W_0 and V_4W_1 and the lowest weed biomass (0.00 g m^{-2}) was recorded from BRRI dhan34 and Sunrice 150WG (V_1W_4), BRRI dhan37 and Sunrice 150WG (V_2W_4) and Chinigura and Sunrice 150WG (V_4W_4), which was statistically similar with V_1W_0, V_1W_1, V_1W_2, V_1W_3, V_2W_3, V_3W_1, V_3W_2, V_3W_3, V_3W_4, V_4W_1, V_4W_2 and V_4W_3. On 30 DAT, the highest weed biomass (45.33 g m^{-2}) was observed from BRRI dhan34 and no weeding combination (V_1W_0), which was statistically similar with V_2W_0 and V_4W_0 and the lowest weed biomass (0.62 g m^{-2}) was recorded from BRRI dhan37 and Sunrice 150WG (V_2W_4), which was statistically similar with V_1W_1, V_1W_2, V_1W_3, V_1W_4, V_2W_1, V_2W_2, V_2W_3, V_3W_1, V_3W_2, V_3W_3, V_3W_4, V_4W_1, V_4W_2, V_4W_3 and V_4W_4. The highest weed biomass (94.76 g m^{-2}) was observed from BRRI dhan37 and no weeding combination (V_2W_0) at 45 DAT, which was statistically similar with V_1W_0, V_1W_1, V_1W_2, V_1W_3, V_2W_1, V_2W_2, V_2W_3, V_3W_0, V_3W_1, V_3W_2, V_4W_0, V_4W_1, V_4W_2 and V_4W_3 and the lowest weed biomass (20.92 g m^{-2}) was recorded from BRRI dhan50 and Sunrice 150WG (V_3W_4), which was statistically similar with V_1W_0, V_1W_1, V_1W_2, V_1W_3, V_1W_4, V_2W_1, V_2W_2, V_2W_3, V_2W_4, V_3W_0, V_3W_1, V_3W_2, V_3W_3, V_4W_0, V_4W_1, V_4W_2, V_4W_3 and V_4W_4. At 60 DAT, the highest weed biomass (42.38 g m^{-2}) was observed from BRRI dhan50 and no weeding combination (V_3W_0), which was statistically similar with V_1W_0, V_1W_1, V_2W_0 and V_4W_0 and the lowest weed biomass (5.61 g m^{-2}) was recorded from BRRI dhan37 and Sunrice 150WG (V_2W_4), which was statistically similar with V_1W_3, V_1W_4, V_2W_1, V_2W_2, V_2W_3, V_3W_2, V_3W_3, V_3W_4, V_4W_2, V_4W_3 and V_4W_4. At 75 DAT, no significant variation was observed for weed biomass under different variety and weed management combinations. Numerically highest weed biomass (32.77 g m^{-2}) was recorded from BRRI dhan34 and no weeding treatment combination (V_1W_0) whereas the lowest weed biomass (8.37 g m^{-2}) was recorded from BRRI dhan50 and Sunrice 150WG (V_3W_4). This result was in agreement with the findings of Bhuiyan *et al.* (2011) who stated that weed dry matter was significantly highest in control plot (78.67 g m^{-2}) followed by (BRRI weeder, 45.03 g m^{-2}) and lowest in (three hand weeding at 15, 30 & 45 DAT, 20.17 g m^{-2}) and (post-emergence herbicide + 1 hand weeding at 30 DAT, 22.2 g m^{-2}) in three popular BRRI *aman* varieties having different growth duration (BRRI dhan39, BRRI dhan49 and BR 11) in 2008 and 2009. Also, Gnanavel and Anbhazhagan (2010) and Singh and Kumar (1999) reported that maximum weed dry weight and the lowest grain yield were observed in the unweeded control in the scented rice variety Pusa Basmati-1.

Table 6. Interaction effect of variety and weed control methods on weed biomass (g m^{-2}) at different days after transplanting

Treatment combination	Days after transplanting				
	15	30	45	60	75
V_1W_0	0.99 a-c	45.33 a	40.40 ab	32.95 a-c	32.77 a
V_1W_1	0.85 bc	11.12 c	39.68 ab	28.03 a-d	18.88 a
V_1W_2	0.72 bc	9.86 c	35.50 ab	24.18 b-f	13.02 a
V_1W_3	0.63 bc	4.79 c	35.22 ab	15.05 d-g	12.93 a
V_1W_4	0.00 c	1.62 c	29.22 b	5.64 g	8.43 a
V_2W_0	2.28 a	41.91 ab	94.76 a	36.30 ab	22.54 a
V_2W_1	1.66 ab	10.33 c	37.23 ab	18.87 c-g	20.86 a
V_2W_2	1.54 ab	9.36 c	36.74 ab	16.55 d-g	19.10 a
V_2W_3	0.49 bc	4.04 c	32.95 ab	11.84 e-g	18.97 a
V_2W_4	0.00 c	0.62 c	30.03 b	5.610 g	11.60 a
V_3W_0	1.67 ab	28.71 b	56.02 ab	42.38 a	29.78 a
V_3W_1	1.33 a-c	11.57 c	54.34 ab	24.33 b-f	21.14 a
V_3W_2	1.26 a-c	7.22 c	43.86 ab	18.74 c-g	19.60 a
V_3W_3	0.54 bc	3.58 c	28.34 b	16.10 d-g	14.50 a
V_3W_4	0.47 bc	1.24 c	20.92 b	8.78 fg	8.37 a
V_4W_0	1.57 ab	32.14 ab	71.73 ab	41.25 a	27.10 a
V_4W_1	0.98 a-c	15.51 c	52.94 ab	25.19 b-f	21.43 a
V_4W_2	0.85 bc	10.01 c	51.03 ab	20.24 c-g	18.24 a
V_4W_3	0.76 bc	2.03 c	47.75 ab	17.10 d-g	17.77 a
V_4W_4	0.00 c	2.01 c	21.24 b	8.74 fg	12.81 a
SE	0.41	4.39	18.32	4.67	7.34
CV(%)	75.73%	60.17%	73.80%	38.75%	68.75%

V_1= BRRI dhan34, V_2= BRRI dhan37, V_3= BRRI dhan50, V_4= Chinigura, W_0= No weeding, W_1= One hand weeding, W_2= Two hand weeding, W_3= Topstar 400SC, W_4= Sunrice 150WG

4.6 Weed control efficiency

4.6.1 Effect of Variety

Significant variation was observed for weed control efficiency due to varietal variation shown in Figure 5 and Appendix VI. At 30 DAT, BRRI dhan37 (V_2) recorded the highest weed control efficiency (68.75%) which was statistically similar with BRRI dhan34 (V_1) (65.03%) and Chinigura (V_4) (61.64%). The lowest weed control efficiency (57.83%) was recorded from BRRI dhan50 (V_3) which was statistically similar with BRRI dhan34 (V_1) and Chinigura (V_4). On 60 DAT, the highest weed control efficiency (50.05%) was observed for BRRI dhan37 (V_2) which was statistically similar with BRRI dhan50 (V_3) and

Chinigura (V_4). The lowest weed control efficiency (34.04%) was observed for BRRI dhan34 (V_1) which was statistically similar with Chinigura (V_4). This result was in agreement with Houque *et al.* (2003) who stated that BRRI dhan34 was the most competitive variety. This result was also supported with Franje *et al.* (1992) who found that tall traditional cultivars to be more competitive than the relatively short stature BRRI advanced lines.

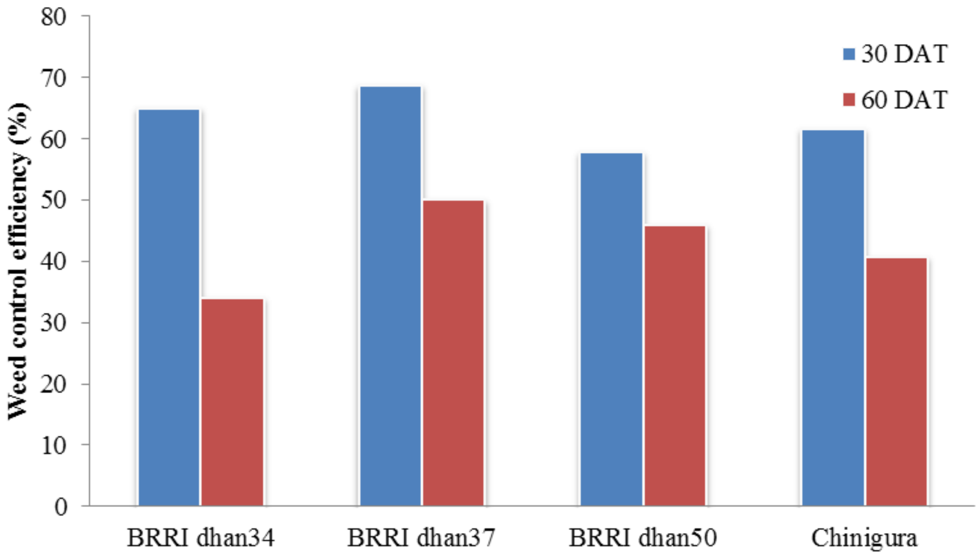

Figure 5. Effect of variety on weed control efficiency (%) of T. *aman* rice at different days after transplanting (SE=2.84 and 3.39 for 30 and 60 DAT)

4.6.2 Effect of weed control treatments

For different weed management treatments, significant variation was observed for weed control efficiency (Figure 6 and Appendix VI). At 30 DAT, Sunrice 150WG (W_4) scored the highest weed control efficiency (95.28%) which was statistically similar (88.96%) with Topstar 400SC (W_3) where it reduced to 78.95% at 60 DAT. The lowest weed control efficiency (0.00%) was observed under no weeding treatment (W_0) at 30 and 60 DAT. At later stage, the treatments showed lower efficiency which might be due to emergence of some new weed species at later stages. This result was dissimilar with Shultana *et al.*

(2011) and Bhuiyan *et al.* (2010) who found that Topstar 80WP (oxadiazon) @ 75 g ha^{-1} showed above 80% weed control efficiency. On the other hand, this result was in agreement with the findings of Al-Mamun *et al.* (2011), Bhuiyan *et al.* (2011), Mamun *et al.* (2011), Ali *et al.* (2010), Gnanavel and Anbhazhagan (2010) and Kabir *et al.* (2008).

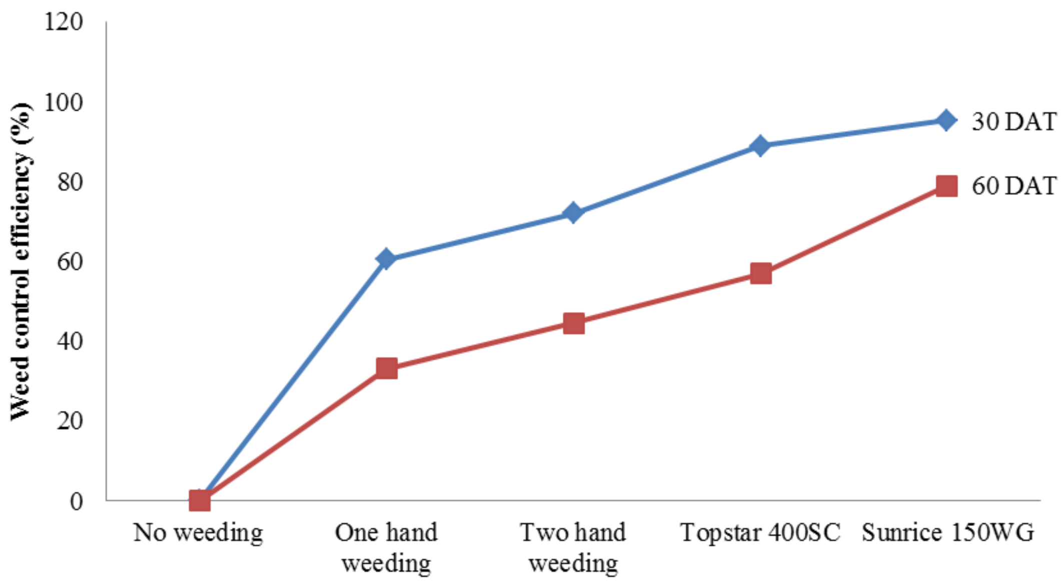

Figure 6. Effect of different weed control methods on weed control efficiency (%) of T. *aman* rice at different days after transplanting (SE=3.17 and 3.79 for 30 and 60 DAT)

4.6.3 Interaction effect of variety and weed control treatments

Significant variation was observed for weed control efficiency under different variety and weed control treatment combinations (Table 7). At 30 DAT, the highest weed control efficiency (98.95%) was recorded form combinations of BRRI dhan37 and Sunrice 150WG (V_2W_4), which was statistically similar with V_1W_3, V_1W_4, V_2W_2, V_2W_3, V_3W_3, V_3W_4, V_4W_3 and V_4W_4. The lowest weed control efficiency (0.00%) was observed under all the varieties (BRRI dhan34, BRRI dhan37, BRRI dhan50 and Chinigura) and no weeding treatment combinations (V_1W_0, V_2W_0, V_3W_0 and V_4W_0). At 60 DAT, the highest weed control efficiency (83.83%) was observed under combinations of BRRI dhan37 and Sunrice 150WG (V_2W_4) which was statistically similar with V_1W_4, V_2W_3,

V_3W_3, V_3W_4 and V_4W_4. The lowest weed control efficiency (0.00%) was recorded from all the varieties (BRRI dhan34, BRRI dhan37, BRRI dhan50 and Chinigura) and no weeding treatment combinations (V_1W_0, V_2W_0, V_3W_0 and V_4W_0). This result supported with the findings of Al-Mamun *et al.* (2011) who stated that above 80% WCE was obtained by Becolor 5G @ 30 kg ha^{-1}, Bouncer 10WP @ 150 g ha^{-1} and Becofit 500EC @ 1.20 L ha^{-1}, respectively in Surjamoni and BRRI dhan29. Similar results were reported by Ali *et al.* (2010) who observed that among the weed control treatments Pretilachlor + one hand weeding at 40 DAT performed best for controlling weeds at 30 DAT (79.53%) and moderate for controlling weeds at 60 DAT (75.65%) in transplanted *aman* rice (cv. BRRI dhan37).

Table 7. Interaction effect of variety and weed control methods on weed control efficiency (%) at 30 and 60 DAT

Treatment interaction	Days after transplanting	
	30	60
V_1W_0	0.00 h	0.00 i
V_1W_1	68.15 d-f	17.67 hi
V_1W_2	73.23 c-e	25.30 gh
V_1W_3	87.77 a-d	48.39 d-g
V_1W_4	96.00 ab	78.82 ab
V_2W_0	0.00 h	0.00 i
V_2W_1	74.90 b-e	46.15 d-g
V_2W_2	79.84 a-e	53.12 c-f
V_2W_3	90.03 a-c	67.14 a-d
V_2W_4	98.95 a	83.83 a
V_3W_0	0.00 h	0.00 i
V_3W_1	46.65 g	37.17 e-h
V_3W_2	65.86 ef	54.30 b-f
V_3W_3	84.29 a-e	59.76 a-e
V_3W_4	92.34 a-c	78.73 ab
V_4W_0	0.00 h	0.00 i
V_4W_1	51.74 fg	31.45 f-h
V_4W_2	68.85 d-f	45.53 d-g
V_4W_3	93.77 a-c	52.45 c-f
V_4W_4	93.82 a-c	74.42 a-c
SE	6.34	7.56
CV(%)	17.35	30.76

V_1= BRRI dhan34, V_2= BRRI dhan37, V_3= BRRI dhan50, V_4= Chinigura, W_0= No weeding, W_1= One hand weeding, W_2= Two hand weeding, W_3= Topstar 400SC, W_4= Sunrice 150WG

4.7 Crop growth parameters

4.7.1 Plant height

4.7.1.1 Effect of Variety

Plant height varied significantly for varietal variation throughout the going period (Figure 7 and Appendix VII). At 15 DAT, BRRI dhan37 (V_2) scored the highest plant height (32.94 cm) which was statistically similar (32.90 cm) with Chinigura (V_4). The lowest plant height (28.70 cm) was observed for BRRI dhan50 (V_3). On 30 DAT, Chinigura (V_4) was recorded the highest plant height (49.82 cm) which was statistically similar (48.70 cm) with BRRI dhan34 (V_1) and BRRI dhan50 (V_3) was recorded the lowest plant height (41.14 cm). In case of 45 DAT, the highest plant height (67.50 cm) was recorded BRRI dhan34 (V_1) whether the lowest plant height (57.18 cm) was recorded from BRRI dhan50 (V_3). BRRI dhan34 (V_1) was recorded the highest plant height (85.92 cm) at 60 DAT and the lowest plant height (71.34 cm) was observed from BRRI dhan50 (V_3). At 75 DAT and at harvest, the highest plant height (97.86 & 142.10 cm) was recorded from Chinigura (V_4) and the lowest plant height (71.22 & 70.69 cm) was recorded from BRRI dhan50 (V_3). This result was in agreement with Bisne *et al.* (2006) who described that plant height varies significantly among varieties.

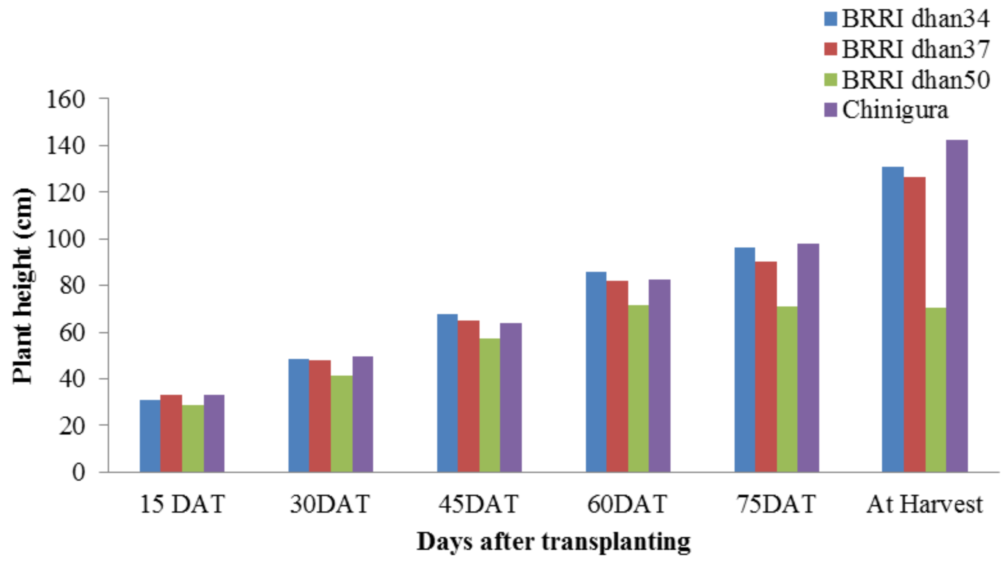

Figure 7. Effect of variety on plant height (cm) of T. *aman* rice at different days after transplanting (SE= 0.42, 0.47, 0.74, 0.67, 0.80 and 0.73 for 15, 30, 45, 60, 75 DAT and at harvest)

4.7.1.2 Effect of weed control treatments

There was significant variation observed for plant height due to different weed control treatments (Figure 8 and Appendix VII). Throughout the growing period, Sunrice 150WG (W_4) scored the highest plant height (34.91, 53.09, 69.24, 87.03, 95.12 and 123.10 cm at 15, 30, 45, 60, 75 DAT and at harvest, respectively) and no weeding treatment (W_0) attained the lowest (27.56, 41.30, 55.73, 72.59, 79.89 and 111.80 cm at 15, 30, 45, 60, 75 and at harvest, respectively) plant height. The results were in agreement with the findings of Khan and Tarique (2011) who found that the highest plant height was observed in completely weed free condition throughout the crop growth period with chemical weed control method and next in two hand weeding treatment whereas lowest value was observed in no weeding treatment. The results were in consistence with the findings of Hasanuzzaman *et al.* (2008), Hasanuzzaman *et al.* (2007) and Haque (1993).

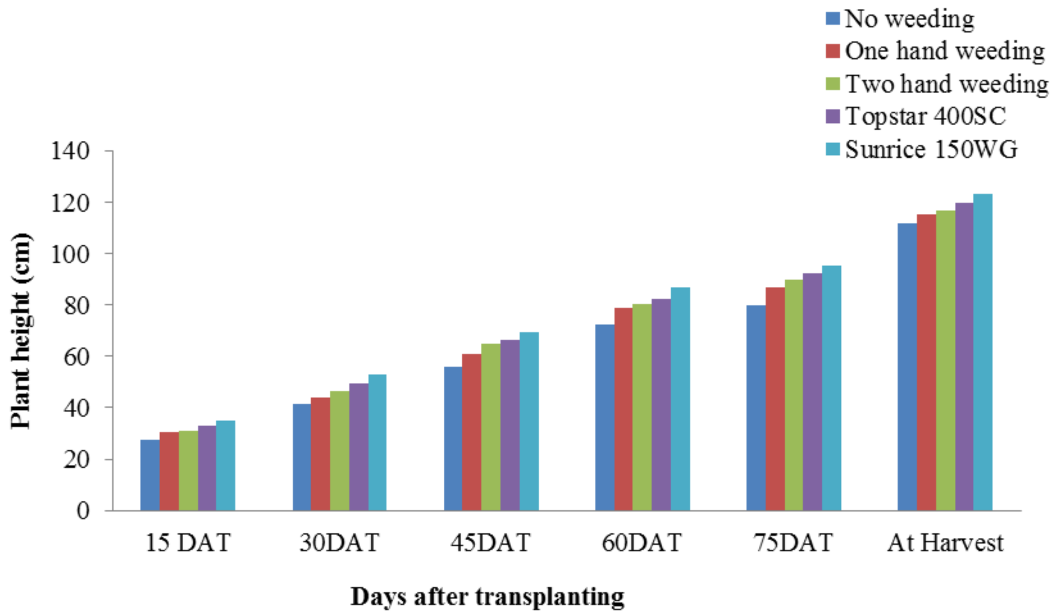

Figure 8. Effect of weed control methods on plant height (cm) of T. *aman* rice at different days after transplanting (SE= 0.47, 0.52, 0.83, 0.74, 0.89 and 0.82 for 15, 30, 45, 60, 75 DAT and at harvest)

4.7.1.3 Interaction effect of variety and weed control treatments

Plant height was significantly affected by the interaction of variety and weed control shown in Table 8. At 15 DAT, highest plant height (37.41 cm) was recorded from the combination of BRRI dhan37 and Sunrice 150WG (V_2W_4) which was statistically similar with V_1W_4 and the lowest (25.80 cm) was obtained from BRRI dhan50 and no weeding combination (V_3W_0) which was statistically similar with V_2W_0, V_3W_1, V_3W_2, V_3W_3 and V_4W_0. Combination of BRRI dhan34 and Sunrice 150WG (V_2W_4) scored the highest plant height (58.88 cm) at 30 DAT which was statistically similar with V_4W_4. On the other hand, the lowest plant height (37.33 cm) was recorded from the combination of BRRI dhan50 and no weeding (V_3W_0) which was statistically similar with V_3W_1. At 45 DAT and 60 DAT, highest plant height (72.37 cm and 93.82 cm) were recorded from the combinations of BRRI dhan34 and Sunrice 150WG (V_1W_4). The lowest plant height were recorded from the combinations of Chinigura with no weeding (V_4W_0) and BRRI dhan50 and no weeding combinations (V_3W_0) (53.02 and 67.79 cm), respectively. Chinigura and Sunrice 150WG (V_4W_4) achieved the highest plant height (105.50 cm) at 75 DAT which was statistically similar with V_1W_1, V_1W_2, V_1W_3, V_1W_4, V_2W_3, V_2W_4, V_4W_1, V_4W_2 and V_4W_3, while the lowest one (67.16 cm) was recorded from BRRI dhan50 and no weeding (V_3W_0) which was statistically similar with V_3W_1, V_3W_2, V_3W_3 and V_3W_4. At harvest, Chinigura and Sunrice 150WG (V_4W_4) treatment combination achieved the highest plant height (150.20 cm) which was statistically similar with V_4W_2 and V_4W_3. The lowest plant height (67.52 cm) was recorded from the combinations of BRRI dhan50 and no weeding (V_3W_0) which was statistically similar with V_3W_1, V_3W_2, V_3W_3 and V_3W_4.

Table 8. Interaction effect of variety and weed control methods on plant height (cm) at different dates after transplanting

Treatment combination	Plant height (cm)					
	Days after transplanting					
	15	30	45	60	75	At harvest
V_1W_0	29.89 f-h	40.63 hi	58.54 gh	78.75 fg	85.88 fg	126.70 fg
V_1W_1	29.97 e-h	44.17 g	66.09 c-e	84.82 c-e	94.73 c-e	129.40 ef
V_1W_2	30.03 e-h	45.58 fg	69.84 a-d	86.26 b-d	96.42 cd	130.30 ef
V_1W_3	31.99 d-g	54.22 bc	70.66 a-c	85.94 cd	99.58 bc	132.00 ef
V_1W_4	32.58 d-g	58.88 a	72.37 a	93.82 a	103.40 ab	134.10 de
V_2W_0	26.92 hi	42.28 gh	56.86 g-i	72.78 hi	81.76 g	118.40 h
V_2W_1	32.93 c-f	45.50 fg	61.43 e-g	80.39 ef	89.47 ef	122.70 gh
V_2W_2	32.42 d-g	47.94 ef	66.82 b-d	82.09 d-f	91.69 de	126.80 fg
V_2W_3	35.04 a-d	49.00 de	68.64 a-d	84.83 c-e	93.43 de	130.10 ef
V_2W_4	37.41 a	53.66 bc	72.19 ab	88.42 bc	95.86 cd	132.80 e
V_3W_0	25.80 i	37.33 j	54.48 hi	67.79 j	67.16 i	67.52 j
V_3W_1	26.93 hi	38.94 ij	56.02 g-i	69.77 ij	67.34 i	69.38 j
V_3W_2	27.80 hi	42.22 gh	57.23 g-i	71.24 h-j	72.19 hi	69.69 j
V_3W_3	29.50 gh	43.16 gh	57.80 g-i	72.81 hi	73.70 h	71.71 ij
V_3W_4	33.49 b-d	44.05 g	60.39 fg	75.11 gh	75.70 h	75.17 i
V_4W_0	27.65 hi	44.94 fg	53.02 i	71.06 h-j	84.78 fg	134.40 de
V_4W_1	31.95 d-g	47.66 ef	59.70 gh	80.82 ef	96.37 cd	139.00 cd
V_4W_2	33.09 c-e	49.39 de	65.04 d-f	82.66 d-f	99.33 bc	141.30 bc
V_4W_3	35.65 a-c	51.33 cd	68.38 a-d	86.51 b-d	103.30 ab	145.40 b
V_4W_4	36.17 ab	55.77 b	72.01 ab	90.78 ab	105.50 a	150.20 a
SE	0.95	1.04	1.65	1.49	1.79	1.64
CV(%)	5.23	3.85	4.51	3.21	3.48	2.42

V_1= BRRI dhan34, V_2= BRRI dhan37, V_3= BRRI dhan50, V_4= Chinigura, W_0= No weeding, W_1= One hand weeding, W_2= Two hand weeding, W_3= Topstar 400SC, W_4= Sunrice 150WG

4.7.2 Tillers hill^{-1}

4.7.2.1 Effect of Variety

Varietal variation had significant effect on tillers hill^{-1} over time except at 75 DAT (Figure 9 and Appendix VIII). Total tillers hill^{-1} increased up to 60 DAT and then decreased up to harvest among all the varieties. BRRI dhan50 (V_3) showed the highest number of tillers hill^{-1} (2.77, 7.79 and 14.04 at 15, 30 and 45 DAT respectively) throughout the growing period except at 60 DAT and at harvest. BRRI dhan34 (V_1) was recorded the highest tillers hill^{-1} (18.55) at 60 DAT and at harvest the highest tillers hill^{-1} (14.93) was observed from BRRI dhan37 (V_2) which was statistically similar (14.31) with BRRI dhan34 (V_1). The lowest tillers hill^{-1} at harvest (14.05) was recorded from Chinigura (V_4) which was statistically similar with BRRI dhan50 (V_3) and BRRI dhan34 (V_1). These results were in agreement with Bisne *et al.* (2006) and Jones *et al.* (1996).

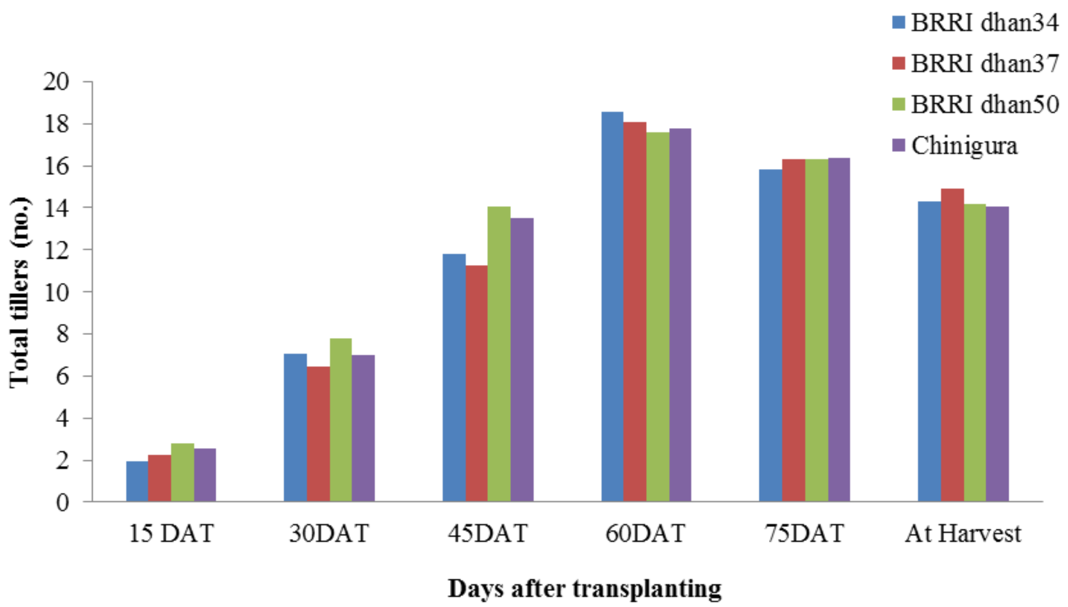

Figure 9. Effect of variety on tillers hill^{-1} (no.) of T. *aman* rice at different days after transplanting (SE= 0.06, 0.08, 0.16, 0.18, 0.18 and 0.22 for 15, 30, 45, 60, 75 DAT and at harvest)

4.7.2.2 Effect of weed control treatments

Different weed control treatments affected tiller production significantly throughout the growing period. Tillers hill^{-1} increased gradually up to 60 DAT and then decreased in all the weed control treatments due to mortality of ineffective tillers at later stages (Figure 10 and Appendix VIII). In case of unweeded treatment (W_0) tillers hill^{-1} decreased dramatically after 60 DAT, it might be due to high crop weed competition for light and nutrients. All weed control treatments contributed to significantly higher number of tillers hill^{-1} than unweeded and that trend continued throughout the growing period. At 60 DAT the highest number of tiller hill^{-1} (20.75) was found in W_4 (Sunrice 150WG) treatment and the second highest number of tiller hill^{-1} (19.42) was found in W_3 (Topstar 400SC) treatment which was significantly higher than W_0 (unweeded) treatment (14.86). Similar findings were reported by Khan and Tarique (2011) who observed that highest number of tillers plant^{-1} was observed in completely weed free condition throughout the crop growth period.

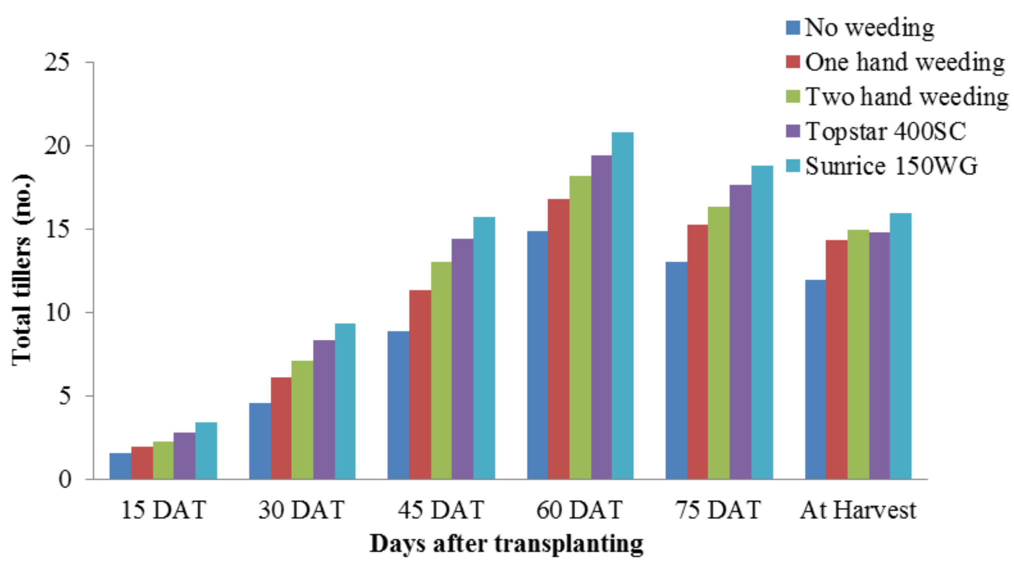

Figure 10. Effect of weed control methods on tillers hill^{-1} (no.) of T. *aman* rice at different days after transplanting (SE= 0.06, 0.09, 0.17, 0.20, 0.20 and 0.25 for 15, 30, 45, 60, 75 DAT and at harvest)

4.7.2.3 Interaction effect of variety and weed control treatments

The interaction effect of different weed control treatments and variety significantly influenced the number of tillers hill^{-1} at different DAT (Table 9). Treatment combinations of BRRI dhan50 and Sunrice 150WG (V_3W_4) was recorded the highest number of tillers hill^{-1} (3.83, 10.57 and 17.60) at 15, 30 and at 45 DAT respectively. At 60 DAT, highest number of tillers hill^{-1} (21.20) was recorded from the combinations of BRRI dhan34 and Sunrice 150WG (V_1W_4) and combinations of Chinigura and Sunrice 150WG (V_4W_4) scored highest (19.07) at 75 DAT. The lowest number of tillers hill^{-1} was recorded from the treatment combinations associated with no weeding (W_0) throughout the growing period.

Table 9. Interaction effect of variety and weed control methods on tillers hill^{-1} at different dates after transplanting

Treatment combination	Tillers hill^{-1}					
	Days after transplanting					
	15	30	45	60	75	At harvest
V_1W_0	1.37 m	4.00 m	9.10 hi	15.07 g	12.63 g	11.40 f
V_1W_1	1.43 lm	5.77 k	11.03 g	17.23 ef	15.00 ef	12.97 d-f
V_1W_2	1.67 k-m	7.37 fg	11.87 fg	19.17 bc	15.97 de	15.03 bc
V_1W_3	2.43 gh	8.50 cd	12.90 ef	20.07 ab	16.97 cd	15.23 a-c
V_1W_4	2.93 c-e	9.70 b	14.27 b-d	21.20 a	18.47 ab	16.90 a
V_2W_0	1.40 m	4.63 l	8.13 i	14.57 g	12.47 g	11.83 f
V_2W_1	1.80 j-l	6.10 jk	9.87 h	16.93 ef	15.53 de	15.07 bc
V_2W_2	2.00 i-k	6.40 ij	11.93 fg	18.57 cd	17.03 b-d	15.73 a-c
V_2W_3	2.63 e-g	7.17 gh	12.13 fg	19.43 bc	17.67 a-c	15.47 a-c
V_2W_4	3.30 bc	8.07 de	14.17 cd	20.83 a	18.80 a	16.53 ab
V_3W_0	1.97 i-k	4.63 l	8.57 i	14.90 g	13.30 g	12.67 ef
V_3W_1	2.17 h-j	6.27 i-k	12.07 fg	16.33 f	14.93 ef	14.63 cd
V_3W_2	2.63 e-g	7.70 e-g	14.80 bc	17.40 ef	16.63 cd	14.53 cd
V_3W_3	3.23 b-d	9.80 b	17.17 a	19.17 bc	18.03 a-c	13.97 c-e
V_3W_4	3.83 a	10.57 a	17.60 a	20.77 a	18.77 a	15.10 bc
V_4W_0	1.53 lm	5.00 l	9.67 h	14.90 g	13.73 fg	11.73 f
V_4W_1	2.27 g-i	6.20 jk	12.33 f	16.57 ef	15.60 de	14.60 cd
V_4W_2	2.53 f-h	6.80 hi	13.50 de	17.63 de	15.73 de	14.30 c-e
V_4W_3	2.87 d-f	7.90 ef	15.27 b	19.03 bc	17.77 a-c	14.57 cd
V_4W_4	3.43 b	8.97 c	16.83 a	20.20 ab	19.07 a	15.07 bc
SE	0.13	0.19	0.35	0.38	0.46	0.54
CV(%)	9.10	4.58	4.78	3.63	4.92	6.51

V_1= BRRI dhan34, V_2= BRRI dhan37, V_3= BRRI dhan50, V_4= Chinigura, W_0= No weeding, W_1= One hand weeding, W_2= Two hand weeding, W_3= Topstar 400SC, W_4= Sunrice 150WG

4.7.3 Total dry matter production

4.7.3.1 Effect of Variety

Dry matter is the material which was dried to a constant weight. Total dry matter (TDM) production indicates the production potential of a crop. A high TDM production is the first perquisite for high yield. TDM of roots, leaves, leaf sheath + stem and or panicles of all varieties were measured at 15, 30, 45, 60 and at 75 DAT. It was evident from Figure 10 that irrespective of treatments TDM of all the varieties significantly varied at all sampling dates. Figure 11 shows that BRRI dhan34 (V_1) achieved the highest dry matter throughout the growing period (1.86, 13.96, 26.00, 57.54 and 88.02 g hill^{-1} at 15, 30, 45, 60 and at 75 DAT respectively). Lower amount of dry matter production was observed in BRRI dhan50 (V_3) throughout the growing period except at 45 DAT. This may be due to the highest number of tiller mortality. Dissimilar results were reported by Amin *et al.* (2006) who stated that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

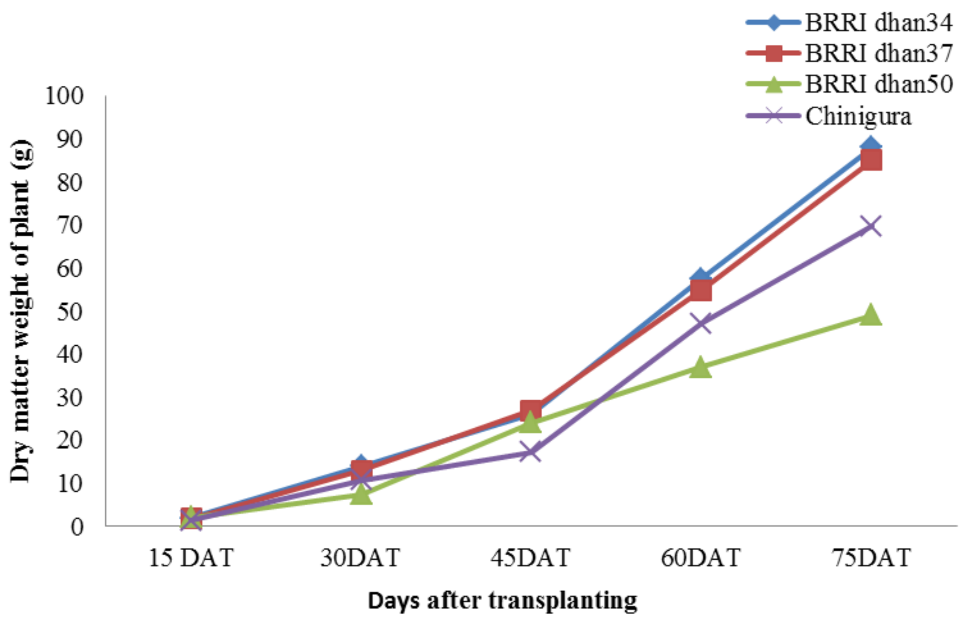

Figure 11. Effect of variety on total dry matter production of T. *aman* rice at different days after transplanting (SE= 0.14, 0.40, 0.46, 1.20 and 2.00 for 15, 30, 45, 60 and 75 DAT)

4.7.3.2 Effect of weed control treatments

Total dry matter (TDM) increased exponentially with time. TDM was significantly affected by different weed control treatments (Figure 12 and Appendix IX). From the early stages distinct differences were visible among the weed control treatments in TDM production. The lowest TDM throughout the growing period was observed in unweeded treatment (W_0). All of the weed control treatments gave statistically similar results from 15 to 75 DAT. Among all the weed control treatments, Sunrice 150WG (W_4) achieved the highest TDM throughout the growing period. Similar results were observed by Bhuiyan *et al.* (2011).

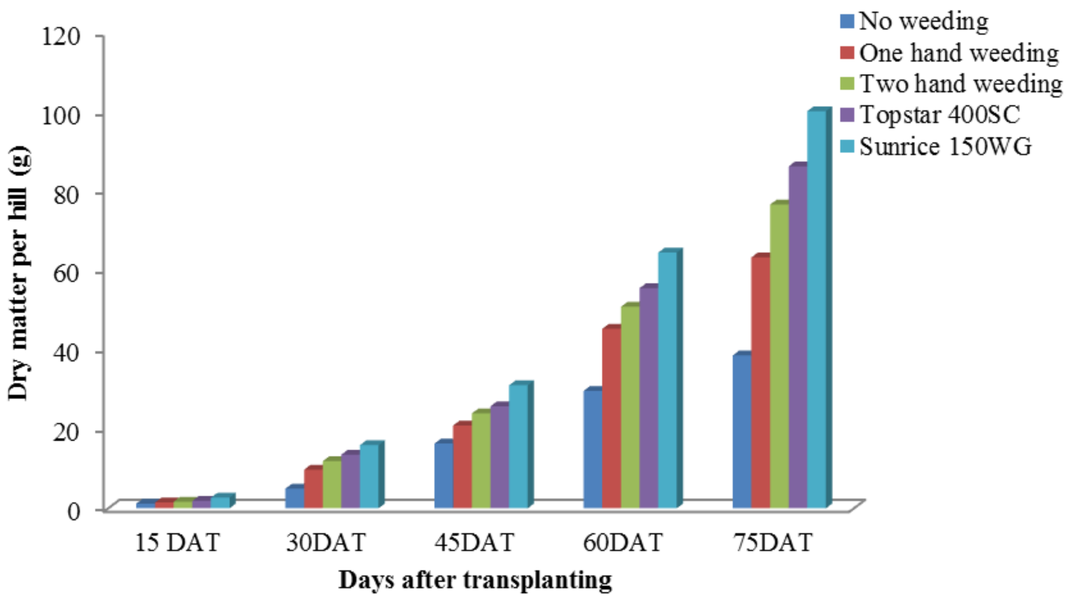

Figure 12. Effect of weed control methods on total dry matter production of T. *aman* rice at different days after transplanting (SE= 0.16, 0.45, 0.52, 1.34 and 2.23 for 15, 30, 45, 60 and 75 DAT)

4.7.3.3 Interaction effect of variety and weed control treatments

The interaction of weed control treatments and variety had significant effect on TDM production throughout the growing period (Table 10). All the weed control treatments gave higher TDM over time and gave lower TDM at no weeding. The treatment combination of BRRI dhan34 and Sunrice 150WG (V_1W_4) produced the highest TDM over time except at 15 DAT & 45 DAT (22.66, 84.45 and 136.70 g hill^{-1} respectively). It might be due to the luxuriant growth of weeds up to 15 DAT in the treatment plot that were controlled by Sunrice 150WG.

Table 10. Interaction effect of variety and weed control methods on total dry matter weight hill^{-1} at different dates after transplanting

Treatment combination	Dry matter weight of plant hill^{-1} (g) Days after transplanting				
	15	30	45	60	75
V_1W_0	1.33 cd	6.27 i-k	17.13 ij	34.80 ij	42.88 j-l
V_1W_1	1.77 b-d	10.73 ef	24.06 e-g	48.08 f-h	68.55 f-i
V_1W_2	1.89 b-d	13.03 de	28.00 cd	54.09 ef	80.95 ef
V_1W_3	2.17 bc	17.13 bc	28.05 cd	66.27 bc	111.00 bc
V_1W_4	2.23 bc	22.66 a	32.77 b	84.45 a	136.70 a
V_2W_0	1.22 cd	4.09 jk	16.14 ij	28.83 jk	38.35 kl
V_2W_1	1.65 b-d	10.94 ef	24.18 e-g	49.19 f-h	72.27 e-h
V_2W_2	1.66 b-d	15.17 cd	26.83 de	59.66 c-e	97.72 cd
V_2W_3	1.85 b-d	15.92 bc	29.59 cd	63.24 cd	100.90 c
V_2W_4	2.66 b	18.21 b	37.58 a	73.57 b	116.20 b
V_3W_0	1.22 cd	3.69 k	19.03 hi	25.93 k	32.30 l
V_3W_1	1.50 cd	6.70 h-j	20.91 gh	35.68 ij	47.53 jk
V_3W_2	1.64 b-d	7.54 g-i	23.52 fg	36.58 ij	48.04 jk
V_3W_3	1.80 b-d	9.29 f-h	26.70 d-f	42.18 hi	55.94 ij
V_3W_4	3.92 a	9.71 fg	30.62 bc	44.70 gh	61.76 hi
V_4W_0	1.00 d	5.88 i-k	13.01 k	28.98 jk	40.75 kl
V_4W_1	1.00 d	10.62 ef	14.45 jk	48.22 f-h	64.90 g-i
V_4W_2	1.48 cd	11.80 ef	17.36 ij	53.02 e-g	79.77 ef
V_4W_3	1.60 b-d	11.83 ef	18.63 hi	50.47 f-h	77.31 e-g
V_4W_4	1.97 b-d	13.15 de	23.13 g	55.31 d-f	86.07 de
SE	0.32	0.90	1.03	2.67	4.47
CV(%)	30.80	13.82	7.57	9.42	10.60

V_1= BRRI dhan34, V_2= BRRI dhan37, V_3= BRRI dhan50, V_4= Chinigura, W_0= No weeding, W_1= One hand weeding, W_2= Two hand weeding, W_3= Topstar 400SC, W_4= Sunrice 150WG

4.7.4 Crop growth rate (CGR)

4.7.5.1 Effect of Variety

Crop growth rate is a measure of the increase in size, mass or number of crops over a period of time. The increase can be plotted as a logarithmic or exponential curve in many cases. It varied significantly due to variety shown in

Figure 13 and Appendix X. At 15-30 DAT, BRRI dhan34 (V_1) scored the highest CGR (0.81 g hill^{-1} day^{-1}) which was statistically similar (0.74 g hill^{-1} day^{-1}) with BRRI dhan37 (V_2). The lowest CGR (0.36 g hill^{-1} day^{-1}) was observed from BRRI dhan50 (V_3). On 30-45 DAT, BRRI dhan50 (V_3) was recorded the highest CGR (1.12 g hill^{-1} day^{-1}) and Chinigura (V_4) was recorded the lowest CGR (0.44 g hill^{-1} day^{-1}). In case of 45-60 DAT, the highest CGR (2.10 g hill^{-1} day^{-1}) was recorded by BRRI dhan34 (V_1) which was statistically similar (1.99 and 1.87 g hill^{-1} day^{-1}) with Chinigura (V_4) and BRRI dhan37 (V_2) respectively. Whether the lowest CGR (0.86 g hill^{-1} day^{-1}) was recorded from BRRI dhan50 (V3). BRRI dhan34 (V_1) was recorded the highest CGR (2.03 g hill^{-1} day^{-1}) at 60-75 DAT which was statistically similar (2.01 and 1.50 g hill^{-1} day^{-1}) with BRRI dhan37 (V_2) and Chinigura (V_4) respectively. The lowest CGR (0.81g hill^{-1} day^{-1}) was observed from BRRI dhan50 (V_3).

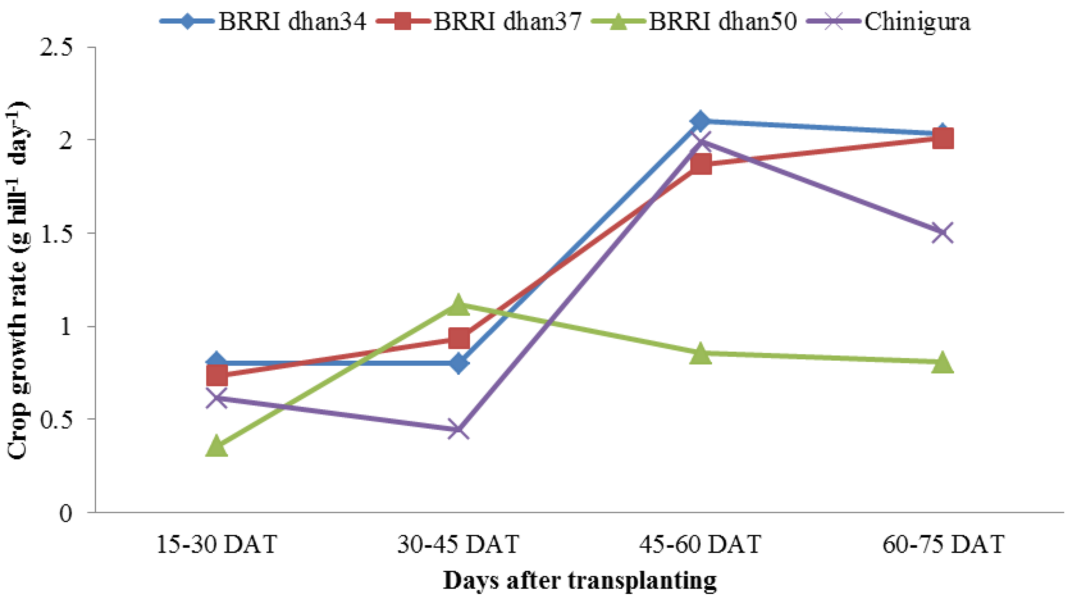

Figure 13. Effect of variety on crop growth rate (g hill^{-1} day^{-1}) of T. *aman* rice at different days after transplanting (SE= 0.03, 0.04, 0.08 and 0.18 for 15-30, 30-45, 45-60 and 60-75 DAT)

4.7.5.2 Effect of weed control treatments

The growth rate of rice crop was significantly influenced by different weed control treatments over time except at 60-75 DAT (Figure 14 and Appendix X). Unweeded treatment (W_0) showed the lowest CGR throughout the growing period. It revealed that severe weed infestation might hamper the growth and development of rice plants drastically (Figure 14). At 15-30 DAT, the treatment W_4 (Sunrice 150WG) gave the highest CGR (0.88 g hill^{-1} day^{-1}). At 30-45 DAT, treatment W_4 gave the highest CGR (1.01 g hill^{-1}day^{-1}) and the other treatments remained statistically similar with no weeding (W_0). At 45-60 DAT, treatment Sunrice 150WG (W_4) gave the highest CGR (2.23 g hill^{-1} day^{-1}) which was statistically similar to Topstar 400SC (W_3) treatment (0.74 g hill^{-1} day^{-1}). At 60-75 DAT, the highest CGR (2.38 g hill^{-1} day^{-1}) was recorded from Sunrice 150WG (W_4) which was statistically similar with Topstar 400SC (W_3) treatment (2.05 g hill^{-1} day^{-1}). From the results, it was seen that the higher CGR was obtained from 45-60 DAT and then it declined. It might be due to the late season weed infestation which put adverse impact on CGR.

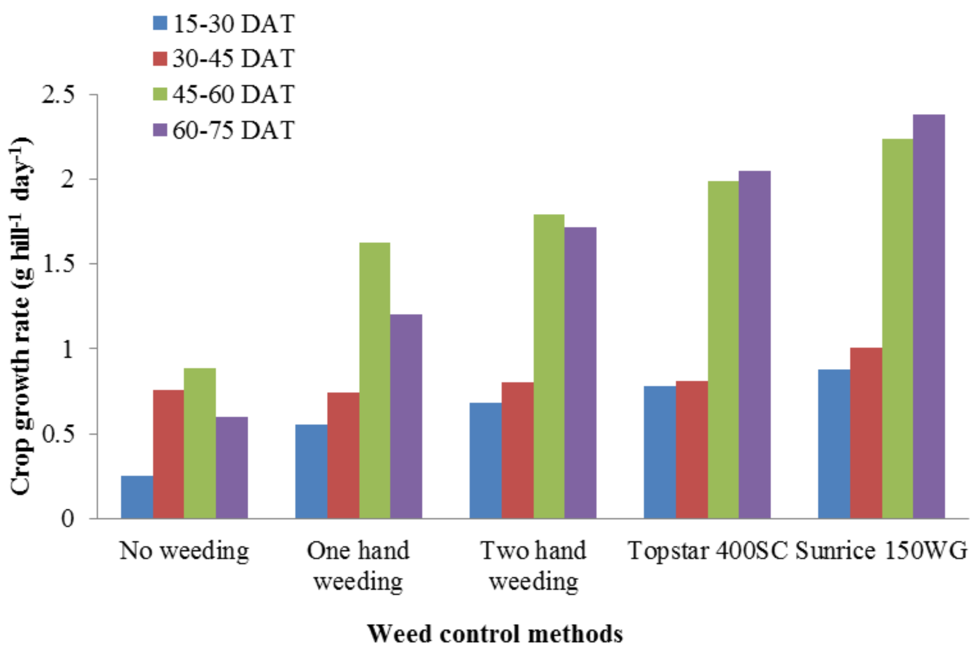

Figure 14. Effect of weed control methods on crop growth rate (g hill^{-1} day^{1}) of T. *aman* rice at different days after transplanting (SE= 0.03, 0.04, 0.09 and 0.20 for 15-30, 30-45, 45-60 and 60-75 DAT)

4.7.5.3 Interaction effect of variety and weed control treatments

The interaction of weed control treatments and variety significantly influenced the CGR throughout the growing period (Table 11). In most of the treatment combinations, CGR increased gradually up to 45-60 DAT and then declined. At the beginning of the crop growth (15-30 DAT), V_1W_4 showed the highest CGR (1.36 g hill^{-1} day^{-1}). At 30-45 DAT, V_3W_4 showed the highest CGR (1.39 g hill^{-1} day^{-1}). At 45-60 DAT and 60-75 DAT, V_1W_4 gave the highest CGR (3.44 and 3.48 g hill^{-1} day^{-1}) among all the treatment combinations. It implied that several weed control treatments effectively controlled the weeds.

Table 11. Interaction effect of variety and weed control methods on crop growth rate (g hill^{-1} day^{-1}) at different days after transplanting

Treatment combination	Crop growth rate (CGR)			
	Days after transplanting			
	15-30	30-45	45-60	60-75
V_1W_0	0.33 f-h	0.73 e-g	1.18 e-g	0.54 fg
V_1W_1	0.60 de	0.89 c-f	1.60 d-f	1.36 d-g
V_1W_2	0.74 cd	1.00 c-e	1.74 c-e	1.79 b-f
V_1W_3	1.00 b	0.73 e-g	2.55 b	2.98 ab
V_1W_4	1.36 a	0.67 fg	3.45 a	3.48 a
V_2W_0	0.19 gh	0.81 d-f	0.85 gh	0.64 fg
V_2W_1	0.62 de	0.88 c-f	1.67 c-e	1.54 c-g
V_2W_2	0.90 bc	0.78 d-f	2.19 b-d	2.54 a-d
V_2W_3	0.94 bc	0.91 c-f	2.24 bc	2.51 a-d
V_2W_4	1.03 b	1.29 ab	2.40 b	2.84 a-c
V_3W_0	0.16 h	1.02 b-e	0.46 h	0.42 g
V_3W_1	0.35 f-h	0.95 c-f	0.98 gh	0.79 e-g
V_3W_2	0.39 fg	1.07 b-d	0.87 gh	0.76 e-g
V_3W_3	0.50 ef	1.16 a-c	1.03 f-h	0.92 e-g
V_3W_4	0.38 fg	1.39 a	0.94 gh	1.14 e-g
V_4W_0	0.32 f-h	0.48 gh	1.06 fg	0.78 e-g
V_4W_1	0.64 de	0.25 h	2.25 bc	1.11 e-g
V_4W_2	0.69 de	0.37 h	2.38 b	1.78 b-f
V_4W_3	0.68 de	0.45 gh	2.12 b-d	1.79 b-f
V_4W_4	0.75 cd	0.67 fg	2.15 b-d	2.05 b-e
SE	0.066	0.089	0.18	0.39
CV(%)	18.41	18.65	18.61	42.95

V_1= BRRI dhan34, V_2= BRRI dhan37, V_3= BRRI dhan50, V_4= Chinigura, W_0= No weeding, W_1= One hand weeding, W_2= Two hand weeding, W_3= Topstar 400SC, W_4= Sunrice 150WG

4.7.6 Relative growth rate (RGR)

4.7.6.1 Effect of Variety

Relative growth rate is the increase of materials per unit of plant materials per unit of time. RGR of rice plant varied significantly due to variety shown in Figure 15. At 15-30 DAT, BRRI dhan34 (V_1) scored the highest RGR (0.07 g hill^{-1} day^{-1}). The lowest RGR (0.05 g hill^{-1} day^{-1}) was observed for BRRI dhan50 (V_3). On 30-45 DAT, BRRI dhan50 (V_3) was recorded the highest RGR (0.08 g hill^{-1} day^{-1}) and Chinigura (V_4) was recorded the lowest RGR (0.05 g hill^{-1} day^{-1}). In case of 45-60 DAT, the highest RGR (0.10 g hill^{-1} day^{-1}) was recorded from BRRI dhan34 (V_1) whether the lowest RGR (0.07 g hill^{-1} day^{-1}) was recorded from BRRI dhan50 (V_3). BRRI dhan37 (V_2) was recorded the highest RGR (0.09 g hill^{-1} day^{-1}) at 60-75 DAT and the lowest RGR (0.06 g hill^{-1} day^{-1}) was observed from BRRI dhan50 (V_3).

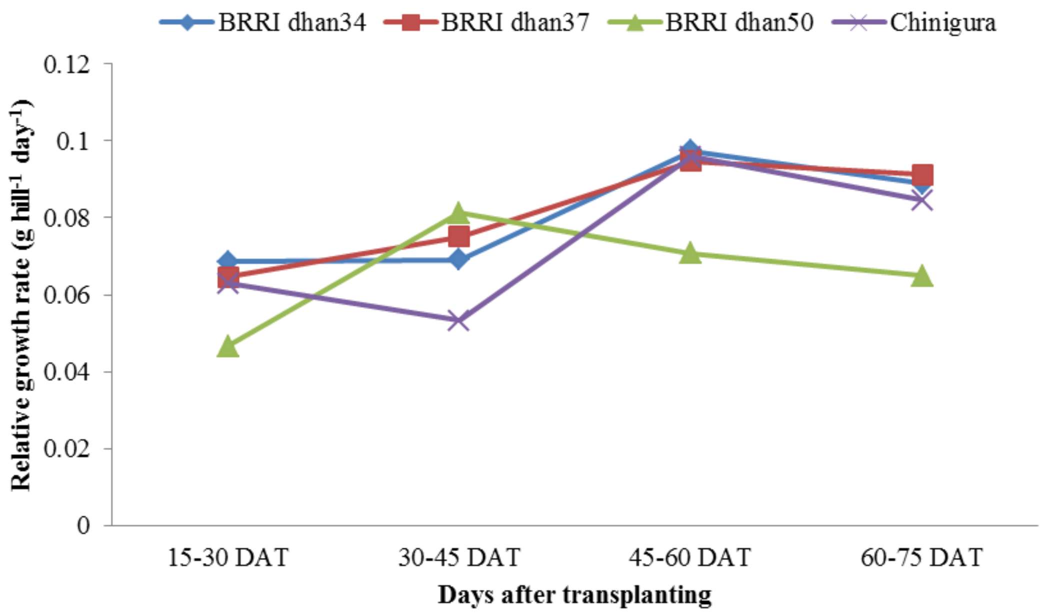

Figure 15. Effect of variety on relative growth rate (g hill^{-1} day^{-1}) of T. *aman* rice at different days after transplanting (SE= 0.00026 for 15-30, 30-45, 45-60 and 60-75 DAT)

4.7.6.2 Effect of weed control treatments

Relative growth rate was significantly affected by different weed control treatments over time. Treatment W_4 (Sunrice 150WG) gave the highest RGR (0.07, 0.07, 0.10 and 0.10 g hill^{-1} day^{-1} at 15-30 DAT, 30-45 DAT, 45-60 DAT and 60-75 DAT respectively) throughout the growing period. While, W_0 treatment (no weeding) gave lowest RGR over time except at 30-45 DAT where W_1 treatment attained the lowest (Figure 16). After 45-60 DAT, the RGR value attained by the weed control treatments showed a declining pattern except in W_4. It revealed that weeds affected RGR of transplanted *aman* rice in the later stages of the crop. A similar finding was also reported by Ahmed *et al.* (1997).

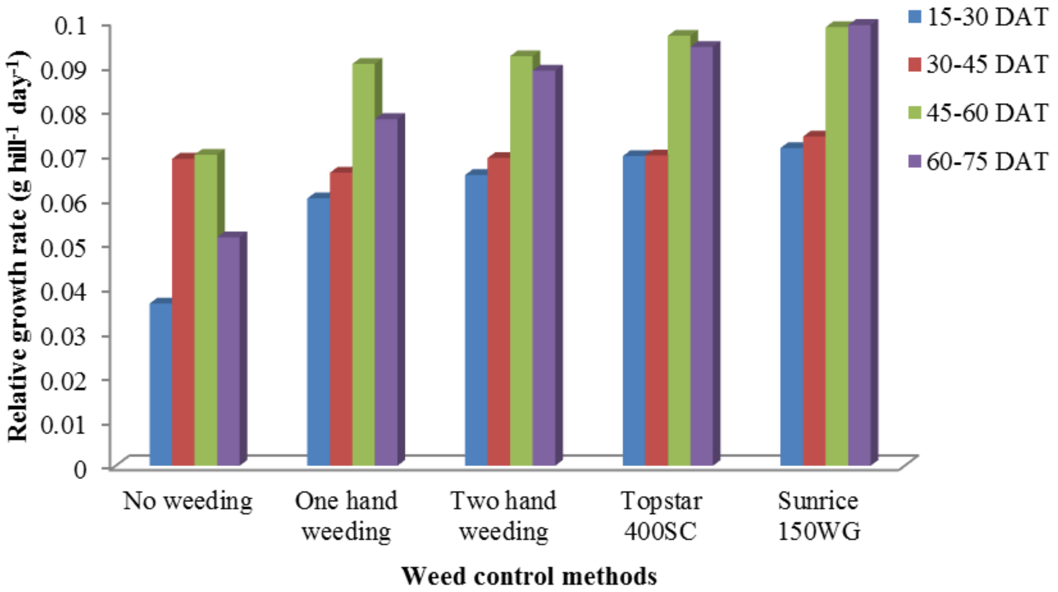

Figure 16. Effect of weed control methods on relative growth rate (g hill^{-1} day^{-1}) of T. *aman* rice at different days after transplanting (SE= 0.00029 for 15-30, 30-45, 45-60 and 60-75 DAT)

4.7.6.3 Interaction effect of variety and weed control treatments

The interaction between the weed control treatments and variety significantly influenced RGR in all dates of observations shown in Table 12. During 15-30

DAT, highest RGR (0.087 g $hill^{-1}day^{-1}$) was found by the treatment V_1W_4. During 30-45 DAT, highest RGR (0.087 g $hill^{-1}day^{-1}$) was found by the treatment V_3W_4. During 45-60 and 60-75 DAT, highest RGR (0.114 and 0.113 g $hill^{-1}$ day^{-1}) was observed in the treatment V_1W_4. The initial high rate of RGR during the period of 15-30 DAT and 45-60 DAT was observed from the results (Table 12). This might be due to the rapid tiller emergence of the crop during this period. A growing organ is consumer of photosynthate and RGR is balanced between sources and sink (Khan *et al.* 1981).

Table 12. Interaction effect of variety and weed control methods on relative growth rate (g $hill^{-1}$ day^{-1}) at different days after transplanting

Treatment combination	Relative growth rate (RGR)			
	Days after transplanting			
	15-30	30-45	45-60	60-75
V_1W_0	0.046 j	0.069 i	0.081 i	0.047 n
V_1W_1	0.063 g	0.073 g	0.092 h	0.082 g
V_1W_2	0.069 d	0.078 ef	0.094 g	0.094 e
V_1W_3	0.078 b	0.067 j	0.106 b	0.110 b
V_1W_4	0.087 a	0.058 k	0.114 a	0.113 a
V_2W_0	0.029 k	0.072 h	0.073 kl	0.052 m
V_2W_1	0.065 fg	0.074 g	0.093 gh	0.086 f
V_2W_2	0.075 c	0.070 i	0.101 ef	0.106 c
V_2W_3	0.076 c	0.074 g	0.102 de	0.105 c
V_2W_4	0.079 b	0.085 b	0.104 c	0.109 b
V_3W_0	0.026 l	0.079 de	0.053 n	0.047 n
V_3W_1	0.047 j	0.077 f	0.075 jk	0.066 k
V_3W_2	0.051 i	0.080 d	0.070 m	0.065 k
V_3W_3	0.058 h	0.083 c	0.079 i	0.070 j
V_3W_4	0.051 i	0.087 a	0.076 j	0.077 i
V_4W_0	0.046 j	0.057 k	0.073 l	0.060 l
V_4W_1	0.065 ef	0.039 n	0.102 de	0.079 h
V_4W_2	0.067 e	0.049 m	0.103 cd	0.093 e
V_4W_3	0.067 e	0.055 l	0.100 f	0.092 e
V_4W_4	0.070 d	0.066 j	0.100 f	0.098 d
SE	0.0006	0.0006	0.0006	0.0006
CV(%)	8.97	11.42	10.55	21.59

V_1= BRRI dhan34, V_2= BRRI dhan37, V_3= BRRI dhan50, V_4= Chinigura, W_0= No weeding, W_1= One hand weeding, W_2= Two hand weeding, W_3= Topstar 400SC, W_4= Sunrice 150WG

4.8 Yield contributing characters

4.8.1 Panicle length

4.8.1.1 Effect of Variety

The panicle length varied significantly due to variety shown in Figure 17. It was observed that BRRI dhan37 (V_2) produced significantly longer (26.52 cm) panicle which was statistically similar with BRRI dhan34 (V_1). The second highest panicle length (24.93 cm) was measured from Chinigura (V_4) and the shortest panicle length (19.97 cm) was measured from BRRI dhan50 (V_3). This confirms the report of Ahmed *et al.* (1997) and Idris and Matin (1990) who showed that panicle length was differed due to variety.

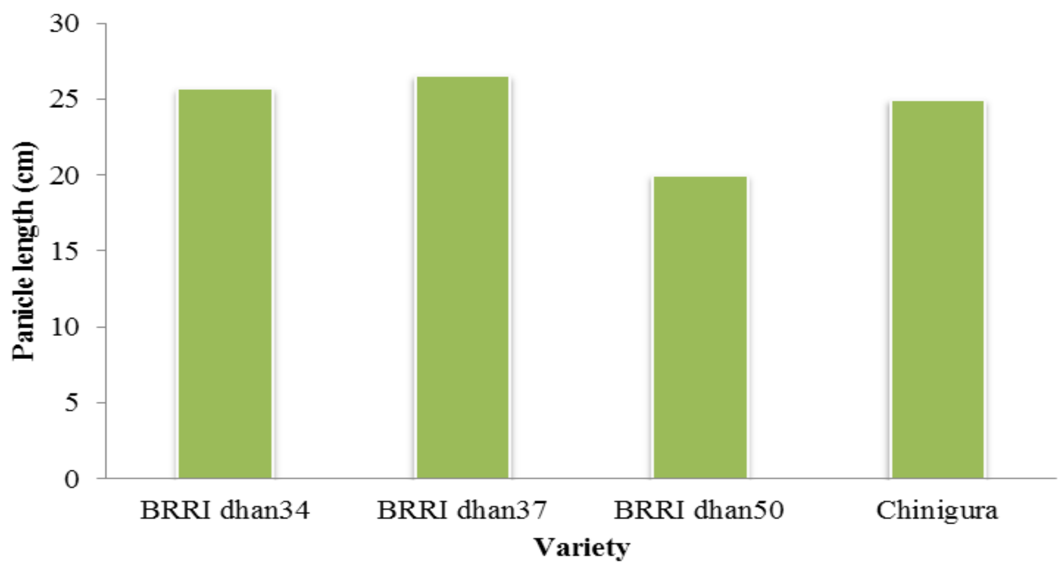

Figure 17. Effect of variety on panicle length (cm) of T. *aman* rice (SE= 0.39)

4.8.1.2 Effect of weed control treatments

The panicle length varied significantly due to weed control treatments shown in Figure 18. It was observed that the longest panicle (25.62 cm) was observed from the treatment W_4 (Sunrice 150WG). The shortest (23.51 cm) panicle length was observed from control treatment (W_0) which was statistically similar with W_1, W_2 and W_3 (Figure 6). This confirms the report of Khan and

Tarique (2011) and Hasanuzzaman *et al.* (2008) who observed that panicle length was differed due to different weed control treatments.

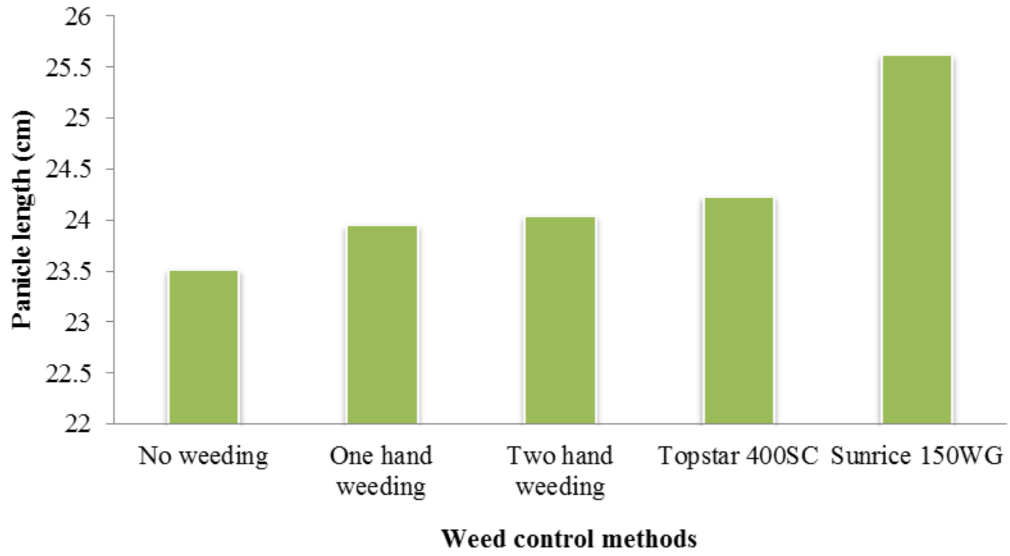

Figure 18. Effect of weed control methods on panicle length (cm) of T. *aman* rice (SE= 0.43)

4.8.1.3 Interaction effect of variety and weed control treatments

Panicle length was significantly affected by the interaction of variety and weed control (Table 13). Longest (29.91 cm) panicle was observed from the combination BRRI dhan37 with Sunrice 150WG (V_2W_4). Second highest panicle length (25.80 cm) was obtained from the combination of BRRI dhan37 with Topstar 400SC (V_2W_3) which was statistically similar with V_1W_0, V_1W_1, V_1W_2, V_1W_3, V_1W_4, V_2W_0, V_2W_1, V_2W_2, V_2W_3, V_4W_1, V_4W_2, V_4W_3, V_4W_4 and shorter (18.97 cm) was found from the combination BRRI dhan50 with no weeding (V_3W_0) which was at par with V_3W_1, V_3W_2, V_3W_3 and V_3W_4.

4.8.2 Effective tillers hill^{-1}

4.8.2.1 Effect of Variety

The effective tiller varied significantly due to variety shown in Figure 19. It was observed that BRRI dhan37 (V_2) produced significantly the highest effective tiller (11.01). The second highest effective tiller (10.21) was measured from BRRI dhan34 (V_1) and the lowest effective tiller (8.69) was obtained from BRRI dhan50 (V_3). Similar results were observed by Jones *et al.* (1996).

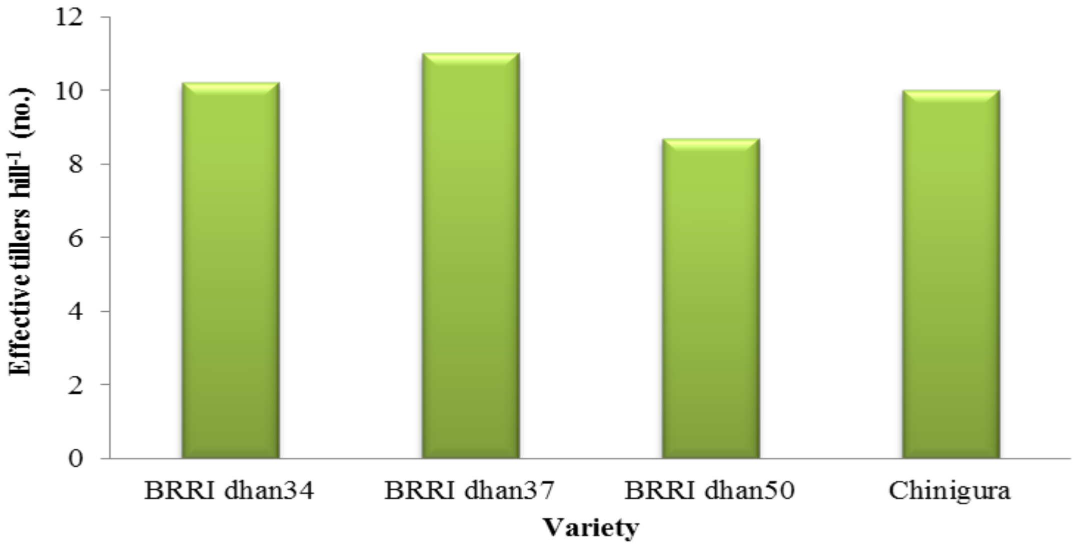

Figure 19. Effect of variety on effective tillers hill^{-1} (no.) of T. *aman* rice (SE= 0.12)

4.8.2.2 Effect of weed control treatments

Weed control by Sunrise (W_4) gave the highest effective tiller (12.36) (Figure 20). The second highest effective tiller (11.06) was obtained from the effect of Topstar (W_3). No weeding (W_0) in the field gave the lowest effective tiller (6.56). These results were in similar to the findings of Hasanuzzaman *et al.* (2008) and Raju *et al.* (2003) who stated that use of weedicide (Ronstar 25 EC, Safener and Butachlor) gave the highest effective tiller.

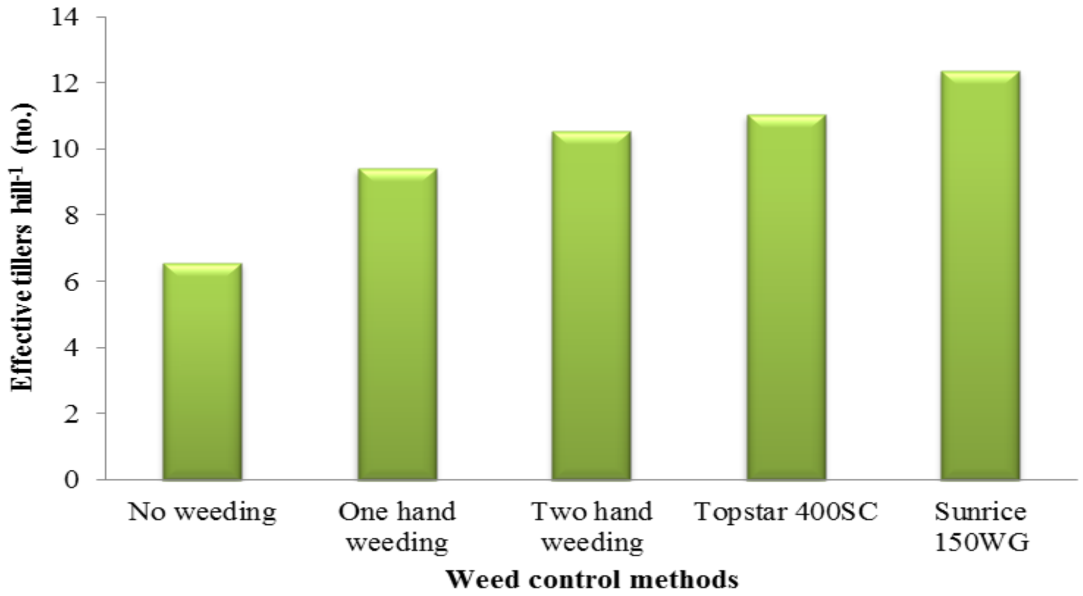

Figure 20. Effect of weed control methods on effective tillers hill^{-1} (no.) of T. *aman* rice (SE=0.13)

4.8.2.3 Interaction effect of variety and weed control treatments

Effective tiller was significantly affected by the interaction of variety and weed control (Table 13). The highest effective tiller (13.37) was obtained from the combination BRRI dhan34 with Sunrice (V_1W_4) which was at par with V_2W_4. Second highest effective tiller (12.20) was obtained from the combination of V_2W_3 which was statistically similar with V_1W_3, V_2W_2 and V_4W_4. The lowest (6.60) was found from the combination BRRI dhan34 with no weeding (V_1W_0) was at par with V_2W_0, V_3W_0 and V_4W_0. Similar findings were reported by Khan and Tarique (2011), Hassan *et al.* (2010) and Ashraf *et al.* (2006) who stated that effective tillers hill^{-1} varied due to various varieties and weed control treatments.

4.8.3 Non-effective tillers hill^{-1}

4.8.3.1 Effect of Variety

The non-effective tiller varied significantly due to variety shown in Figure 21. It was observed that BRRI dhan50 (V_3) produced the highest non-effective tiller (5.49). The lowest non-effective tiller (3.92) was measured from BRRI dhan37 (V_2) which was statistically similar with BRRI dhan34 (V_1) and Chinigura (V_4).

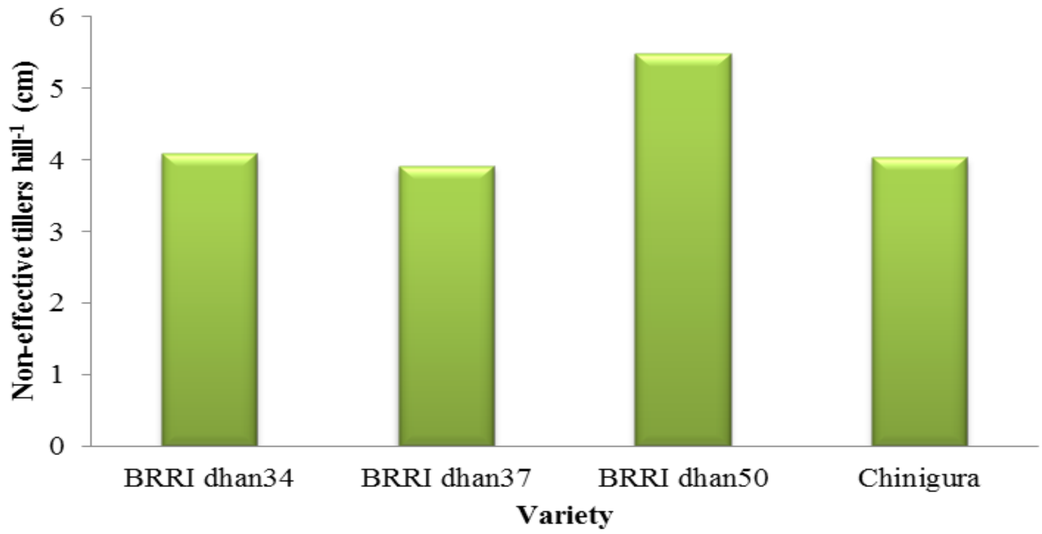

Figure 21. Effect of variety on non-effective tillers hill^{-1} (no.) of T. *aman* rice (SE= 0.21)

4.8.3.2 Effect of weed control treatments

Weeding had significant effect on non-effective tiller (Figure 22). No weeding treatment (W_0) gave the highest non-effective tiller (5.35) which was statistically similar with one hand weeding treatment (W_1). The lowest non-effective tiller (3.54) was measured from Sunrise (W_4) which was statistically similar with treatment comprising Topstar (W_3). Similar findings were reported by Khan and Tarique (2011).

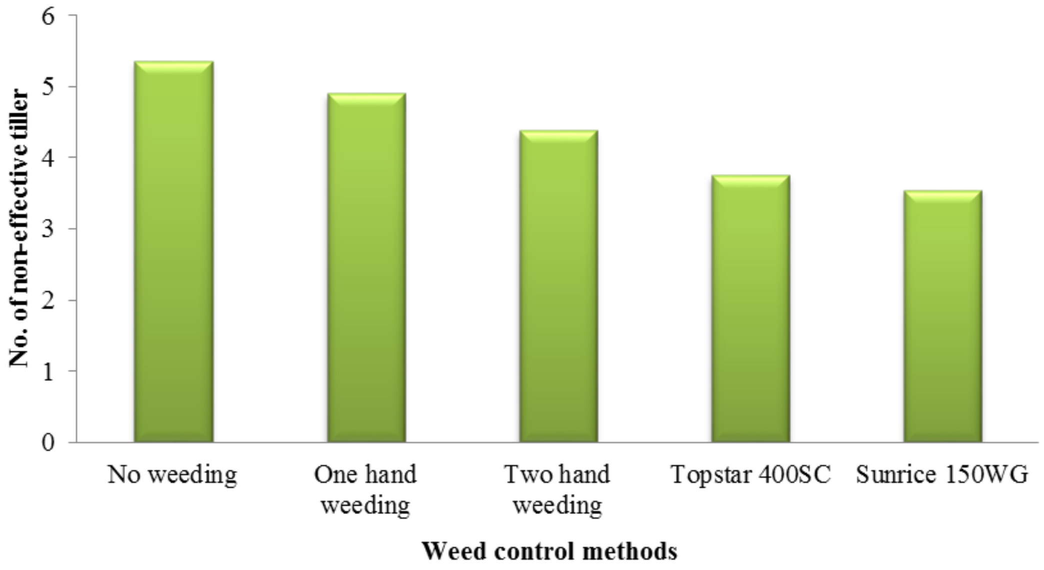

Figure 22. Effect of weed control methods on non-effective tillers hill^{-1} (no.) of T. *aman* rice (SE= 0.24)

4.8.3.3 Interaction effect of variety and weed control treatments

Non-effective tiller was significantly affected by the interaction of variety and weed control (Table 13). The highest non-effective tiller (6.57) was obtained from the combination BRRI dhan50 with no weeding (V_3W_0) which was at par with V_3W_1. Second highest non effective tiller (5.73) was obtained from the combination of V_3W_3. The lowest (3.10) was found from the combination Chinigura with Sunrise 150WG (V_4W_5) which was at par with V_1W_2, V_1W_3, V_1W_4, V_1W_5, V_2W_2, V_2W_3, V_2W_4, V_2W_5, V_3W_4, V_3W_5, V_4W_2, V_4W_3 and V_4W_4.

4.8.4 Filled grains panicle^{-1}

4.8.4.1 Effect of Variety

Significant variation was observed in filled grain due to the effect of variety shown in Figure 23. The highest filled grain (141.10) was found in Chinigura (V_4). The second highest filled grain (119.50) was obtained from BRRI dhan34 (V_1). The lowest filled grain (78.19) was gained from BRRI dhan50 (V_3). Chinigura produced 80% more filled grain than BRRI dhan50. These results were in agreement with Ahmed *et al.* (1997) who reported that percent filled grain was the highest in Nizersail (a local variety) followed by BR25 and the lowest in BR11 and BR23.

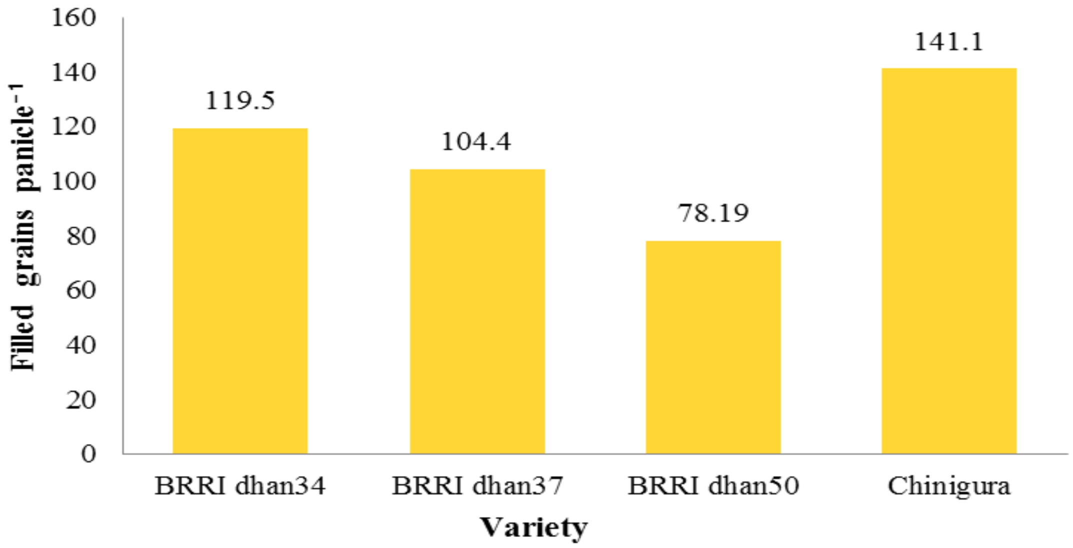

Figure 23. Effect of variety on filled grain panicle^{-1} (no.) of T. *aman* rice (SE= 4.08)

4.8.4.2 Effect of weed control treatments

Significant variation was found in filled grain due to the effect of weed control (Figure 24). The highest filled grain (120.50) was obtained from the effect of Sunrice 150WG (W_4) which was statistically identical with the effect of one hand weeding (W_1), two hand weeding (W_2) and Topstar 400 WG (W_3). The lowest filled grain (105.10) was obtained from no weeding treated plot (W_0). Sunrice 150WG (W_4) gave 14% more filled grain than no weeding (W_0). This result supports the findings of Hasanuzzaman *et al.* (2008) and Salam *et al.* (2010) who showed that application of herbicide contributed mainly increasing the number of grain panicle^{-1}. But dissimilar findings were stated by Karim and Ferdous (2010) who revealed that the number of filled grains panicle^{-1} was negatively related to weed density.

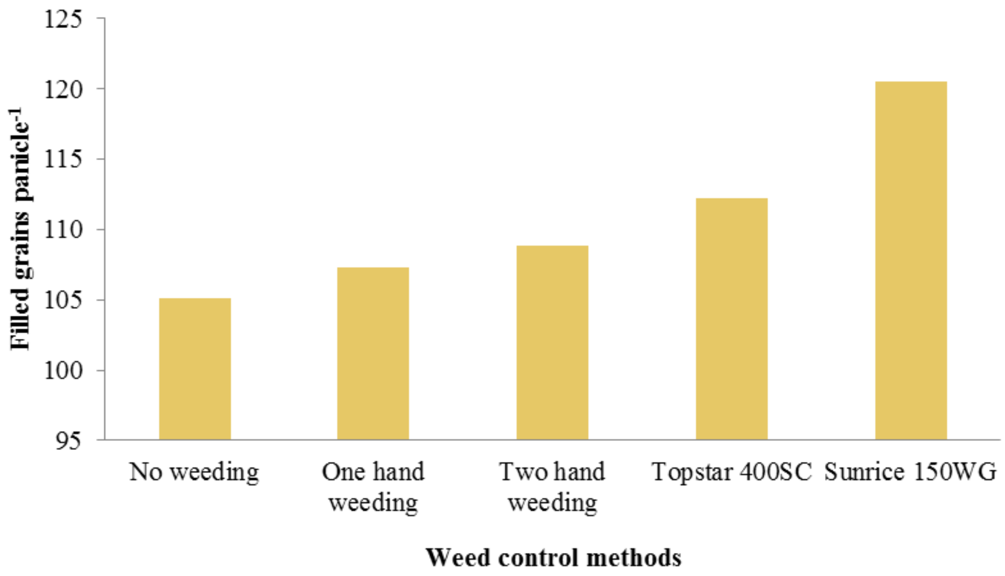

Figure 24. Effect of weed control methods on filled grain panicle^{-1} (no.) of T. *aman* rice (SE= 4.56)

4.8.4.3 Interaction effect of variety and weed control treatments

Significant variation was obtained in filled grain due to the interaction effect of variety and weed control (Table 13). The highest filled grain (149.70) was obtained from the interaction effect of Chinigura with Sunrice 150WG (V_4W_4) which was statistically at par with V_4W_3, V_4W_2, V_4W_1, V_4W_0, V_1W_4, V_1W_3 and V_2W_4. The lowest filled grain (76.73) was found from the interaction effect of BRRI dhan50 with no weeding (V_3W_0) which was statistically similar with V_3W_1, V_3W_2, V_3W_3, V_3W_4, V_2W_0, V_2W_1, V_2W_2 and V_2W_3. These results were in agreement with the findings of Salam *et al.* (2010) who showed that the increased yield in *boro* rice (Binadhan-5) is due to the application of herbicide contributed mainly from increasing the number of panicles hill^{-1} and number of grain panicle^{-1}. Similar results were also shown by Ashraf *et al.* (2006) who stated that in transplanted rice (cv. Basmati-2000) the highest number of grains per panicle was 135.50 during the second year in the case of hand weeding. But dissimilar results were observed by Karim and Ferdous (2010) who stated that the number of filled grains panicle^{-1} was negatively related to weed density in transplanted *aus* rice cv. BR26.

4.8.5 Unfilled grains panicle^{-1}

4.8.5.1 Effect of Variety

Significant variation was obtained in unfilled grain due to the effect of variety (Figure 25). BRRI dhan50 (V_3) produced highest unfilled grain (33.02). The second highest unfilled grain (25.17) was obtained from BRRI dhan37 (V_2) and lowest unfilled grain (15.93) from Chinigura (V_4). BRRI dhan50 produced 51.76% highest unfilled grain than Chinigura. Similar findings were reported by Ahmed *et al.* (1997).

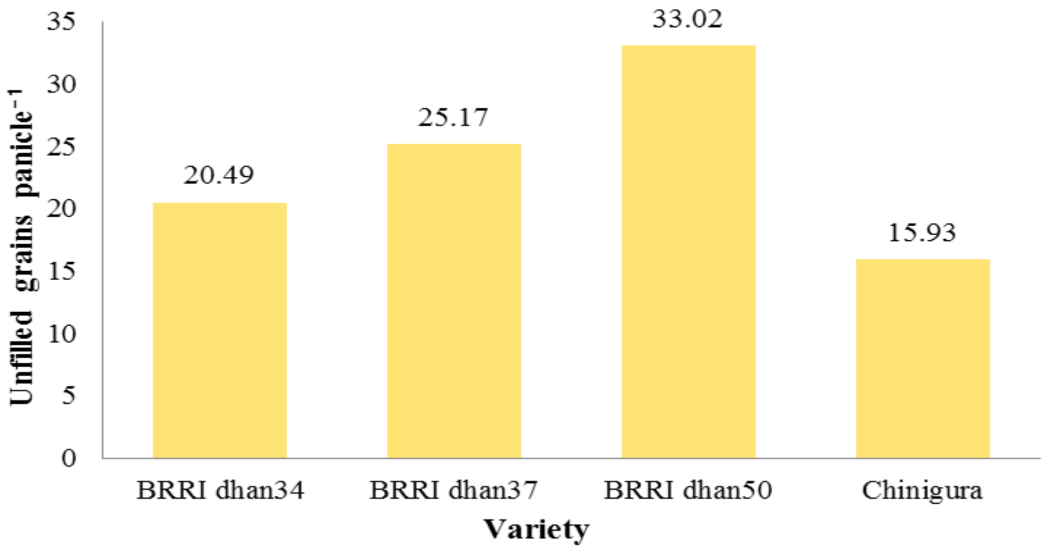

Figure 25. Effect of variety on unfilled grain panicle^{-1} (no.) of T. *aman* rice (SE= 1.31)

4.8.5.2 Effect of weed control treatments

Effect of weeding showed significant variation in unfilled grain (Figure 26). No weeding (W_0) gave highest unfilled grain (27.04) which was statistically identical with one (W_1) and two hand weeding (W_2). The lowest unfilled grain (20.78) was obtained from Sunrice 150WG (W_4) which was statistically at par with Topstar 400SC (W_3). No hand weeding (W_0) produced 23.15% higher unfilled grain than Sunrice 150WG (W_4).

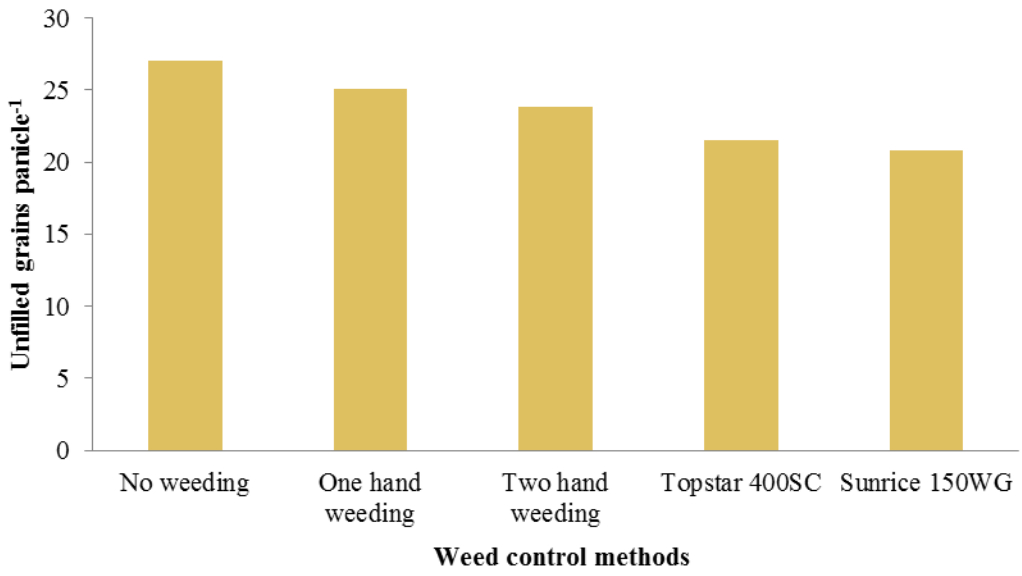

Figure 26. Effect of weed control methods on unfilled grain panicle^{-1} (no.) of T. *aman* rice (SE= 1.47)

4.8.5.3 Interaction effect of variety and weed control treatments

Significant variation was obtained in unfilled grain due to the interaction effect of variety and weed control method shown in Table 13. Interaction effect of BRRI dhan50 with one hand weeding (V_3W_0) gave highest unfilled grain (35.50) which was statistically similar with V_3W_1, V_3W_2, V_3W_3, V_3W_4, V_1W_0, V_2W_0, V_2W_0 and V_2W_2. The lowest unfilled grain (14.57) was found from the interaction effect of Chinigura with Sunrice 150WG (V_4W_4).

4.8.6 Filled grain percentage (%)

4.8.6.1 Effect of Variety

Varietal effect on filled grain percentage was found significant in this experiment (Figure 27). The highest (89.79%) filled grain was obtained from Chinigura (V_4) and the second highest (85.42%) filled grain was obtained in BRRI dhan34 (V_1). The lowest (70.37%) filled grain was obtained in BRRI dhan50 (V_3). This finding supports the observations of Guilani *et al.* (2003) who stated that filled grain percentage varied among different varieties. Similar findings were observed by Ahmed *et al.* (1997) who reported that Nizersail produced highest filled grain percentage among the variety studied.

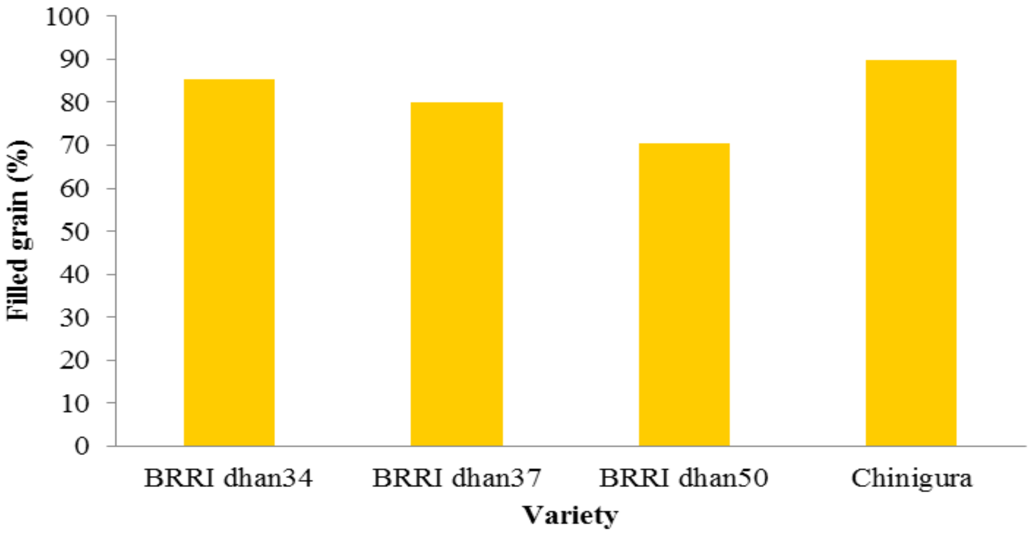

Figure 27. Effect of variety on filled grain percentage (%) of T. *aman* rice (SE= 1.04)

4.8.6.2 Effect of weed control treatments

Significant variation was observed on filled grain percentage due to different weed control treatments (Table 28). All the weed control treatments performed better than the unweeded treatment (W_0). Among the weed control treatments, the highest filled grain percentage (84.40%) was recorded from Sunrice 150WG (W_4) which was statistically similar with Topstar 400SC (W_3) and two hand weeding treatments (W_2). The lowest filled grain percentage (78.76%) was recorded from no weeding (W_0) treatment.

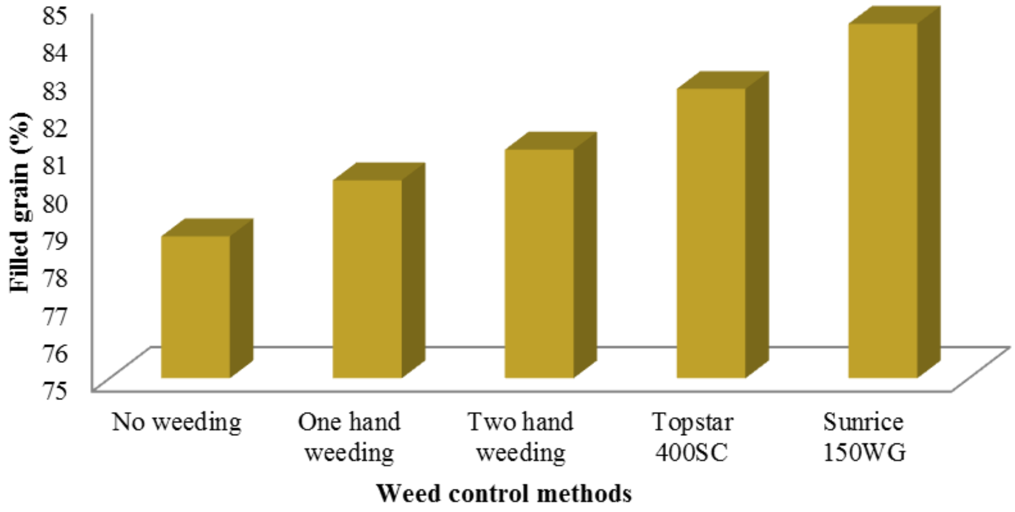

Figure 28. Effect of weed control methods on filled grain percentage (%) of T. *aman* rice (SE= 1.17)

4.8.6.3 Interaction effect of variety and weed control treatments

Interaction of variety and weed control treatments was affected significantly in terms of filled grain (Table 13). The highest (91.13%) filled grain percentage was obtained from the interaction effect of Chinigura and Sunrice 150WG (V_4W_4) which was statistically similar with V_1W_1, V_1W_2, V_1W_3, V_1W_4, V_2W_4, V_4W_0, V_4W_1, V_4W_2 and V_4W_3. The lowest (68.38%) was obtained from the interaction effect of BRRI dhan50 and no weeding combination (V_3W_0) which was statistically similar with V_3W_1, V_3W_2, V_3W_3, V_3W_4 and V_2W_0.

4.8.7 1000 grain weight

4.8.7.1 Effect of Variety

Weight of 1000 grains showed significant variation among the different varieties. BRRI dhan50 produced highest 1000 grain weight (17.33 g). The second highest 1000 grain weight (14.80 g) was found in BRRI dhan37 (Figure 29). The lowest 1000 grain weight (10.59 g) was obtained from BRRI dhan34. Similar findings were reported by Hossain *et al.* (2007).

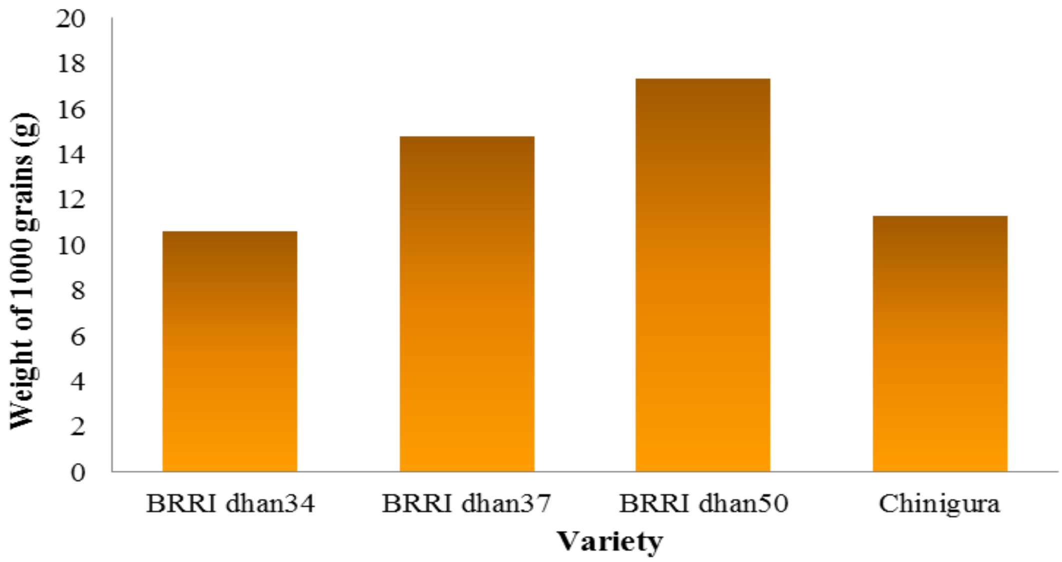

Figure 29. Effect of variety on filled 1000 grain weight (g) of T. *aman* rice (SE= 0.17)

4.8.7.2 Effect of weed control treatments

Effect of weeding showed significant variation in 1000 grain weight. Sunrice 150WG (W_4) gave the highest 1000 grain weight (14.04 g) which was statistically similar with Topstar 400SC (W_3) and two hand weeding (W_2) (Figure 30). The lowest 1000 grain weight (13.00 g) was found from no weeding (W_0). This finding was in agreement with Khan and Tarique (2011), Hassan *et al.* (2010) and Raju *et al.* (2003) who showed that weeding regime had significant effect on 1000 grain weight. But this result was dissimilar with the findings of Nahar *et al.* (2010) and Karim and Ferdous (2010) who observed that 1000 grain weight was negatively related to weed density.

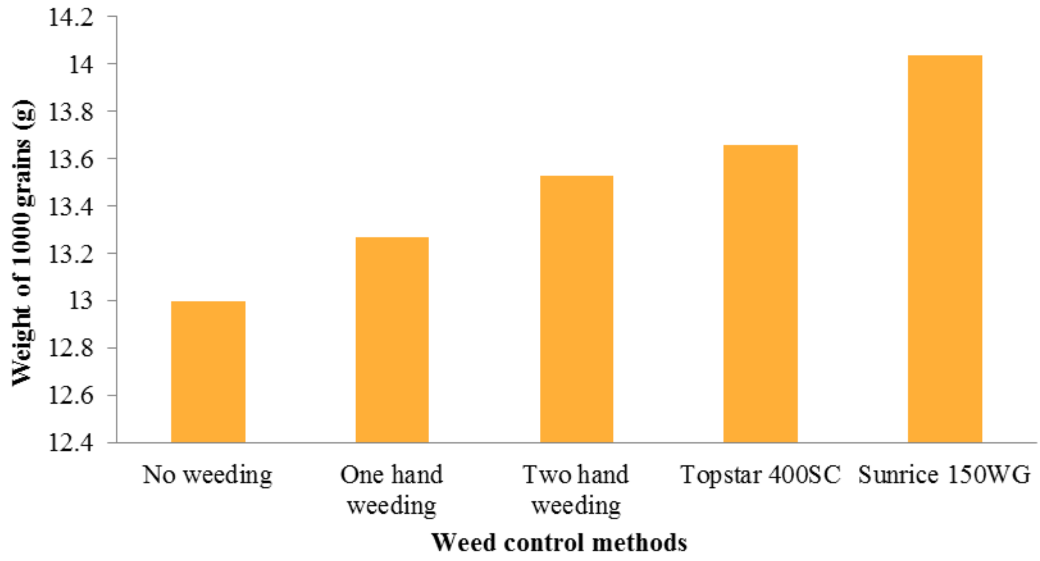

Figure 30. Effect of weed control methods on 1000 grain weight (g) of T. *aman* rice (SE= 0.19)

4.8.7.3 Interaction effect of variety and weed control treatments

Interaction effect of variety and weeding showed significant variation in 1000 grain weight shown in Table 13. The highest grain weight (17.82 g) was found from the interaction effect of BRRI dhan50 and Sunrice 150WG (V_3W_4) which was statistically similar with V_3W_3, V_3W_2, V_3W_1 and V_3W_0. The second highest grain weight (15.32 g) was obtained from the interaction effect of BRRI dhan37 with Sunrice 150WG (V_2W_4) which was statistically at par with V_2W_3, V_2W_2 and V_2W_1. The lowest grain weight (10.25 g) was found with the interaction effect of BRRI dhan34 with no weeding (V_1W_0) which was statistically similar with V_IW_1, V_IW_2, V_IW_3, V_IW_4, V_4W_0, V_4W_1, V_4W_2 and V_4W_3. This result supports the findings of Hassan *et al.* (2010) who reported that weight of 1000 grains varied significantly due to various weed control treatments in transplant *aman* rice cv. BRRI dhan41. But this result was not in agreement with Nahar *et al.* (2010) who found that weeding regime had significant effect on all the parameters except 1000 grain weight in transplant *aman* rice cv. BRRI dhan41.

Table 13. Interaction effect of variety and weed control methods on yield contributing characters of aromatic T. *aman* rice

Treatment Interactions	Yield contributing characters						
	Panicle length (cm)	Effective tillers hill^{-1} (no.)	Non effective tillers hill^{-1} (no.)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Filled grain (%)	1000-grain weight (g)
V_1W_0	25.21 b	6.60 h	4.80 b-d	114.00 c-e	26.27 a-f	82.14 c-f	10.25 e
V_1W_1	25.62 b	8.57 g	4.40 b-e	116.40 b-e	21.10 b-g	84.39 a-e	10.35 e
V_1W_2	25.64 b	11.40 b-d	3.83 c-e	116.60 b-e	18.73 d-g	86.06 a-d	10.52 e
V_1W_3	25.81 b	11.20 cd	3.83 c-e	121.80 a-e	18.50 d-g	86.51 a-c	10.69 de
V_1W_4	26.00 b	13.37 a	3.60 c-e	128.70 a-d	17.83 e-g	87.99 a-c	11.16 de
V_2W_0	25.59 b	6.767 h	5.07 bc	95.00 ef	29.37 a-c	75.78 f-h	13.95 c
V_2W_1	25.60 b	10.90 de	4.17 b-e	99.03 d-f	28.00 a-d	78.26 e-g	14.53 bc
V_2W_2	25.70 b	11.80 bc	3.93 c-e	103.00 d-f	27.37 a-e	78.57 d-g	15.08 bc
V_2W_3	25.80 b	12.20 b	3.26 de	103.40 d-f	20.87 b-g	82.59 b-f	15.12 bc
V_2W_4	29.91 a	13.30 a	3.17 de	121.40 a-e	20.27 c-g	85.50 a-e	15.32 b
V_3W_0	18.97 c	6.10 h	6.57 a	76.73 f	35.50 a	68.38 h	16.80 a
V_3W_1	19.95 c	8.07 g	6.57 a	76.87 f	34.13 a	69.49 h	17.13 a
V_3W_2	20.09 c	8.80 g	5.73 ab	77.57 f	33.60 a	69.74 h	17.33 a
V_3W_3	20.19 c	10.80 de	4.30 b-e	77.63 f	31.40 a	71.27 gh	17.55 a
V_3W_4	20.64 c	9.67 f	4.30 b-e	82.13 f	30.47 ab	72.97 gh	17.82 a
V_4W_0	24.25 c	6.77 h	4.97 bc	134.80 a-c	17.03 fg	88.75 a-c	11.00 de
V_4W_1	24.62 b	10.13 ef	4.47 b-e	136.80 a-c	17.03 fg	88.87 a-c	11.08 de
V_4W_2	24.75 b	10.27 ef	4.03 c-e	138.10 a-c	15.53 g	89.87 a-c	11.20 de
V_4W_3	25.10 b	10.97 ef	3.60 c-e	145.90 ab	15.50 g	90.32 ab	11.27 de
V_4W_4	25.93 b	11.97 bc	3.10 e	149.70 a	14.57 g	91.13 a	11.87 d
SE	0.87	0.26	0.48	9.12	2.94	2.33	0.39
CV(%)	6.20	4.54	18.85	14.27	21.52	4.96	4.95

V_1= BRRI dhan34, V_2= BRRI dhan37, V_3= BRRI dhan50, V_4= Chinigura, W_0= No weeding, W_1= One hand weeding, W_2= Two hand weeding, W_3= Topstar 400SC, W_4= Sunrice 150WG

4.9 Yield

4.9.1 Grain yield

4.9.1.1 Effect of Variety

Grain yield varied significantly for different varieties shown in Figure 31 and Appendix XI. The highest grain yield (3.16 t ha^{-1}) was recorded by BRRI dhan34 (V_1) which was statistically similar with BRRI dhan37 (V_2) producing 3.15 t ha^{-1}. The second highest grain yield (2.77 t ha^{-1}) was recorded from Chinigura (V_4). The lowest grain yield (1.88 t ha^{-1}) was recorded from BRRI dhan50 (V_3). This result was similar with Franje *et al.* (1992) who found that yields of modern cultivars improved with increased weeding while yields of traditional cultivars did not. Dissimilar results were found by Reza *et al.* (2010) who stated that Pajam (a local variety) produced the higher grain yield (4.0 t ha^{-1}) than BRRI dhan28 (2.79 t ha^{-1}).

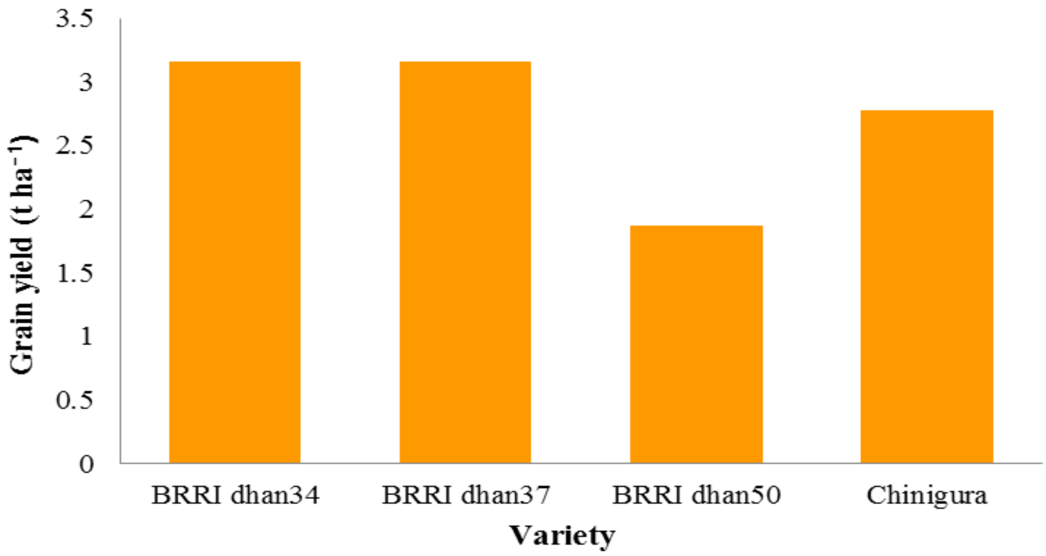

Figure 31. Effect of variety on grain yield (t ha^{-1}) of T. *aman* rice (SE= 0.02)

4.9.1.2 Effect of weed control treatments

Significant variation was observed for grain yield due to different weed control treatments (Figure 32 and Appendix XI). The highest yield (3.43 t ha^{-1}) was recorded from Sunrice 150WG (W_4) and the lowest yield (1.69 t ha^{-1}) was obtained from no weeding treatment (W_0). Similar findings were reported by Al-Mamun *et al.* (2011), Bhuiyan *et al.* (2011), Bhuiyan *et al.* (2011), Khan and Tarique (2011), Mamun *et al.* (2011), Shultana *et al.*(2011), Ali *et al.* (2010), Bhuiyan *et al.* (2010), Gnanavel and Anbhazhagan (2010), Islam *et al.* (2010), Nahar *et al.* (2010), Salam *et al.* (2010) and Pacanoski and Glatkova (2009) who observed that application of chemical herbicides significantly increases grain yield of rice.

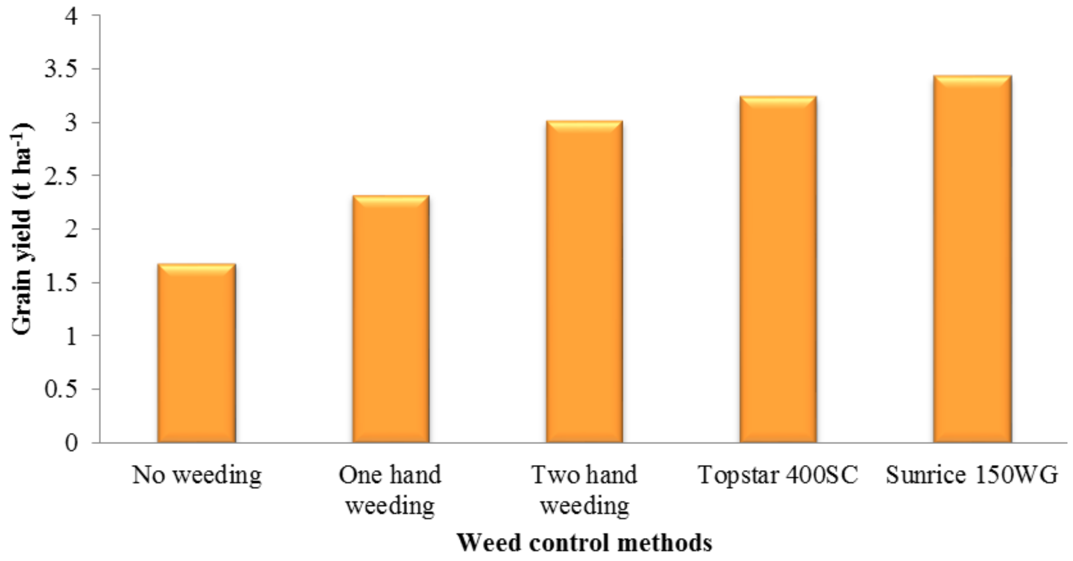

Figure 32. Effect of weed control methods on grain yield (t ha^{-1}) of T. *aman* rice (SE= 0.03)

4.9.1.3 Interaction effect of variety and weed control treatments

The grain yield varied significantly due to different varietal and weed control treatment combinations (Table 14). The highest grain yield (4.10 t ha^{-1}) was recorded from BRRI dhan34 and Sunrice 150WG combination (V_1W_4) which was statistically similar with BRRI dhan34 and Topstar 400SC (V_1W_3), BRRI dhan37 and Sunrice 150WG (V_2W_4). The lowest grain yield (1.44 t ha^{-1}) was recorded from BRRI dhan50 and no weeding treatment combination (V_3W_0). This result is in agreement with Al-Mamun *et al.* (2011) who reported that the highest grain yield (6.96 t ha^{-1}) was obtained from Surjamoni when treated with Bouncer 10WP @ 150 g ha^{-1}, which was 49% higher than control. BRRI dhan29 also produced the highest grain yield when treated with same treatment, which was 37% higher than control. Ali *et al.* (2010) found that among the weed control treatments Pretilachlor + one hand weeding at 40 DAT performed best for contribution to the highest grain yield (3.60 t ha^{-1}). Singh and Kumar (1999) reported that the lowest grain yield was observed in the unweeded control in the scented rice variety Pusa Basmati-1. Similar results were also reported by Islam *et al.* (2010), Nahar *et al.* (2010), Salam *et al.* (2010), Gnanavel and Anbhazhagan (2010) and Bijon (2004).

4.9.2 Straw yield

4.9.2.1 Effect of Variety

There was significant variation observed for straw yield due to varietal variation (Figure 33 and Appendix XI). BRRI dhan34 (V_1) recorded the highest straw yield (5.97 t ha^{-1}) and the second highest straw yield (5.31 t ha^{-1}) was obtained from BRRI dhan37 (V_2). BRRI dhan50 (V_3) recorded the lowest (4.30 t ha^{-1}) straw yield. Similar findings were also reported by Hassan *et al.* (2010).

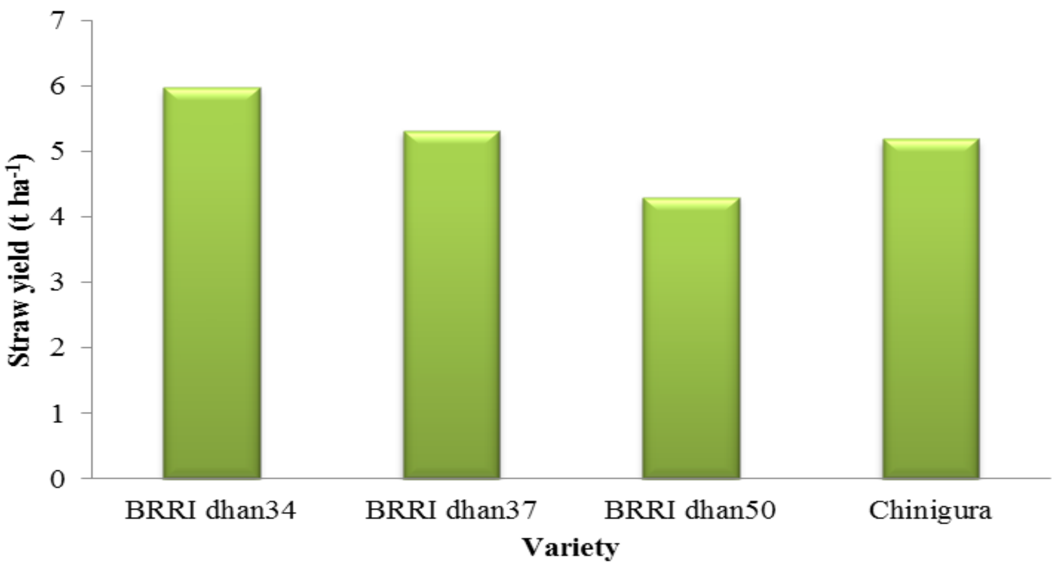

Figure 33. Effect of variety on straw yield (t ha^{-1}) of T. *aman* rice (SE= 0.06)

4.9.2.2 Effect of weed control treatments

Significant variation was also observed due to different weed control treatments (Figure 34). Highest straw yield (5.97 t ha^{-1}) was recorded from Sunrice 150WG (W_4) and the lowest (3.95 t ha^{-1}) was recorded from no weeding (W_0) treatment. This result was in agreement with the findings of Khan and Tarique (2011), Salam *et al.* (2010), Manish *et al.* (2006) and

Chandra and Solanki (2003) who revealed that weeding had significant variation on straw yield of rice.

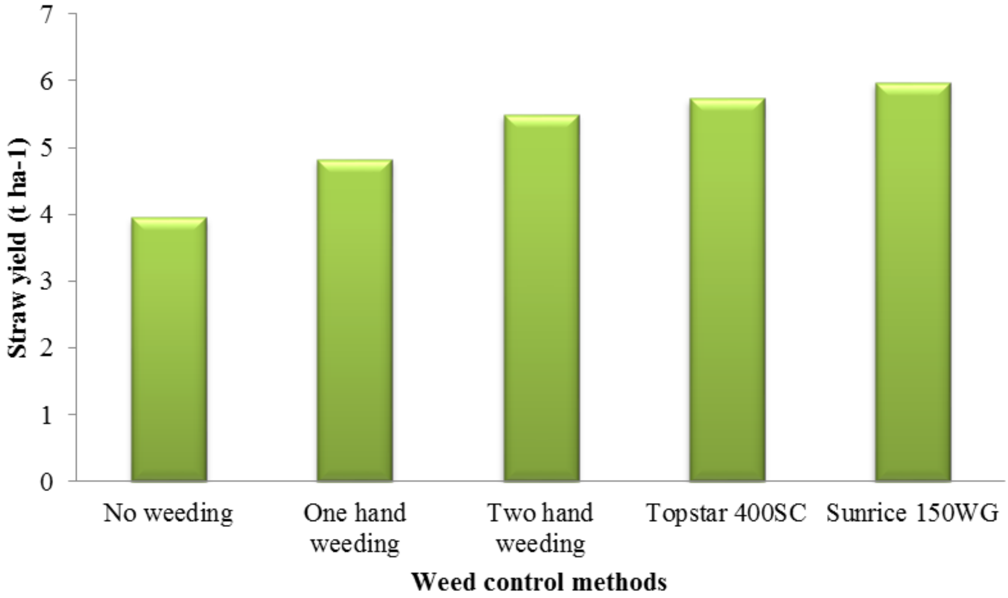

Figure 34. Effect of weed control methods on straw yield (t ha^{-1}) of T. *aman* rice (SE= 0.07)

4.9.2.3 Interaction effect of variety and weed control treatments

The straw yield varied significantly due to different varietal and weed control treatment combinations (Table 14). The highest straw yield (6.85 t ha^{-1}) was obtained from the combination BRRI dhan34 with Sunrice 150WG (V_1W_4) which was at par with V_1W_3 (6.67 t ha^{-1}). The lowest (3.27 t ha^{-1}) was found from the combination BRRI dhan50 with no weeding (V_3W_0). This result was similar to the findings of Salam *et al.* (2010) who stated that the highest straw yield (7.37 t ha^{-1}) were found due to application of Machete 5G @ 25 kg ha^{-1} in *boro* rice (BINA dhan5). Similar results were also observed by Hassan *et al.* (2010).

4.9.3 Biological yield

4.9.3.1 Effect of Variety

The biological yield varied significantly due to variety shown in Figure 35 and Appendix XI. It was observed that BRRI dhan34 (V_1) produced significantly highest biological yield (9.13 t ha^{-1}). The second highest biological yield (8.47 t ha^{-1}) was measured from BRRI dhan37 (V_2) and the lowest biological yield (6.17 t ha^{-1}) was recorded from BRRI dhan50 (V_3).

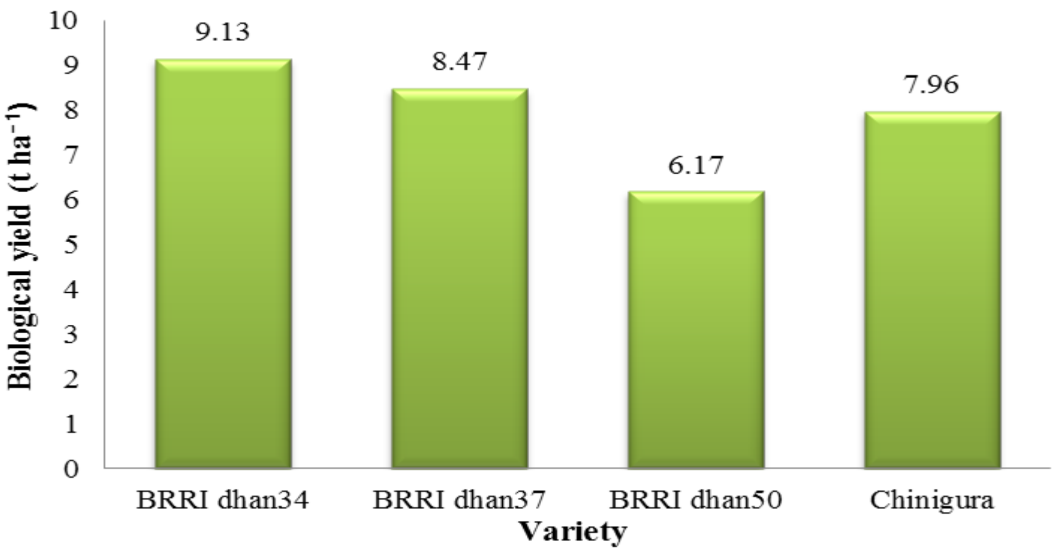

Figure 35. Effect of variety on biological yield (t ha^{-1}) of T. *aman* rice (SE= 0.07)

4.9.3.2 Effect of weed control treatments

The biological yield varied significantly due to different weed control treatments shown in Figure 36 and Appendix XI. Weeds controlled by Sunrice 150WG (W_4) gave the highest biological yield (9.40 t ha^{-1}). The second highest biological yield (8.98 t ha^{-1}) was obtained from the effect of Topstar 400SC (W_3). No weeding (W_0) treatment gave the lowest biological yield (5.64 t ha^{-1}).

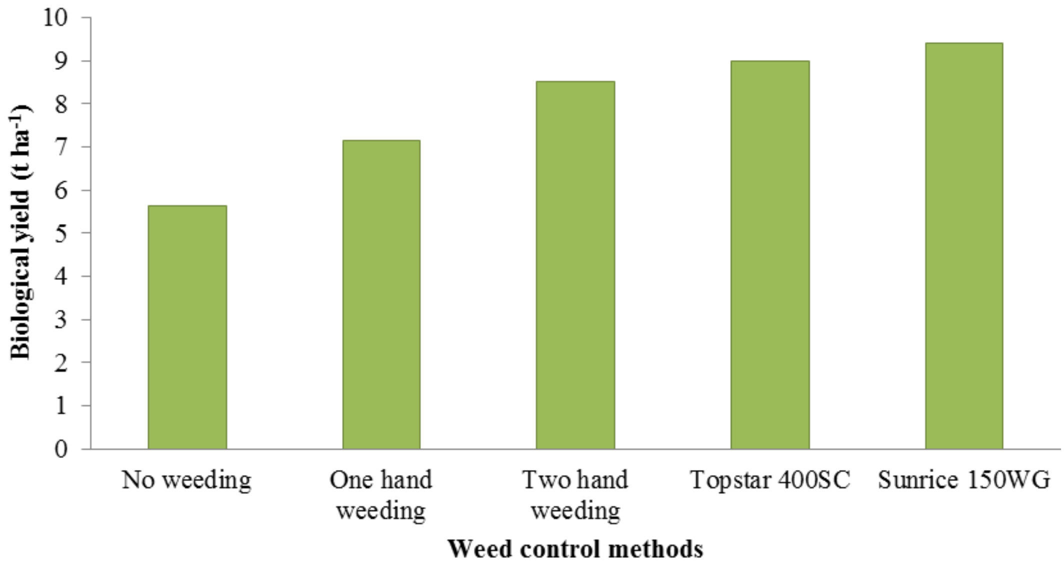

Figure 36. Effect of weed control methods on biological yield (t ha^{-1}) of T. *aman* rice (SE= 0.08)

4.9.3.3 Interaction effect of variety and weed control treatments

Biological yield was significantly affected by the interaction of variety and weed control (Table 14). The highest biological yield (10.95 t ha^{-1}) was obtained from the combination BRRI dhan34 with Sunrice 150WG (V_1W_4) which was at par with V_1W_3. The lowest biological yield (4.71 t ha^{-1}) was found from the combination BRRI dhan50 with no weeding (V_3W_0). This result was similar to the findings of Salam *et al.* (2010) who stated that the highest grain yield (7.15 t ha^{-1}) and straw yield (7.37 t ha^{-1}) were found due to application of Machete 5G @ 25 kg ha^{-1}.

4.9.4 Harvest index

4.9.4.1 Effect of Variety

Variety showed significant variation in harvest index (Figure 37 and Appendix XI). BRRI dhan37 (V_2) showed the highest harvest index (36.65%) whereas lowest harvest index (30.37%) in BRRI dhan50 (V_3).

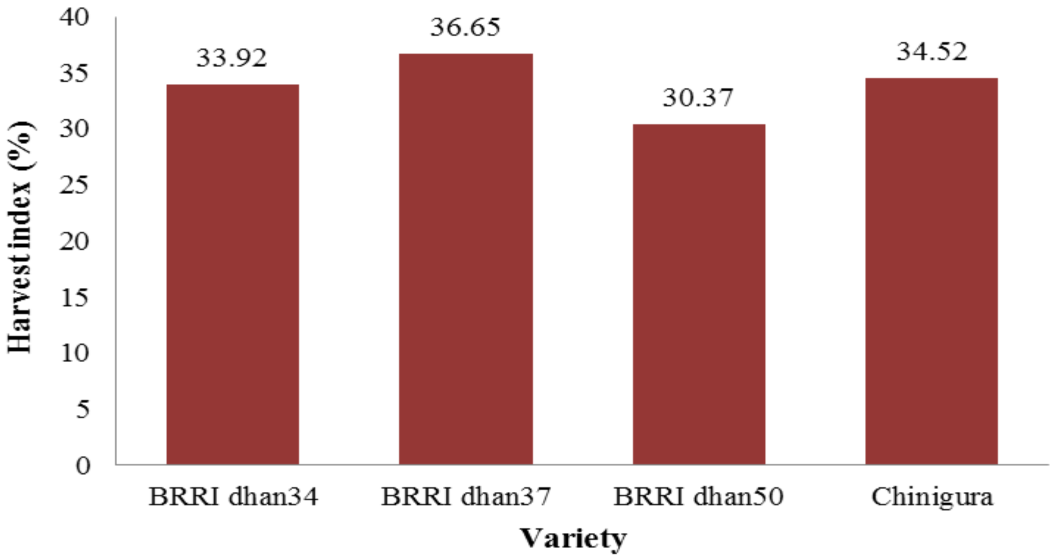

Figure 37. Effect of variety on harvest index (%) of T. *aman* rice (SE= 0.28)

4.9.4.2 Effect of weed control treatments

Significant variation was observed in harvest index due to the effect of weeding (Figure 38 and Appendix XI). The highest harvest index (36.07%) was found due to the effect of Sunrice 150WG (W_4) which was statistically similar with Topstar 400SC (W_3) and two hand weeding treatment (W_2) (35.66 and 35.16%, respectively). No weeding (W_0) gave the lowest harvest index (30.03%). Similar findings were observed by Manish *et al.* (2006) who stated that weeding had significant variation on harvest index.

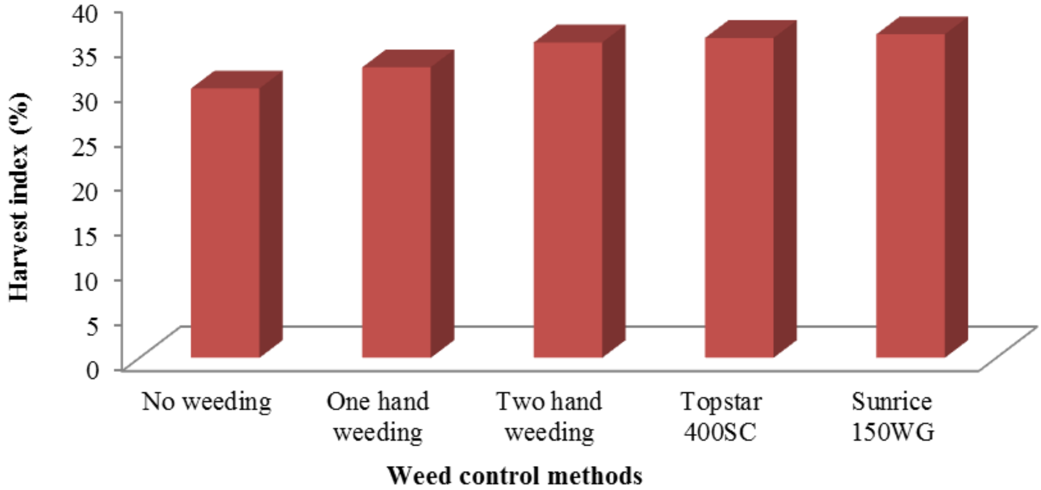

Figure 38. Effect of weed control methods on harvest index (%) of T. *aman* rice (SE= 0.31)

4.9.4.3 Interaction effect of variety and weed control treatments

Interaction effect of variety and weeding showed significant variation in harvest index (Table 14). The highest harvest index (40.08%) was observed from the interaction effect of BRRI dhan37 with Topstar 400SC (V_2W_3) which was at par with V_2W_4. The lowest harvest index (27.45%) was obtained from the interaction of BRRI dhan34 with two hand weeding (V_1W_0).

Table 14. Interaction effect of variety and weed control methods on yield and harvest index of aromatic T. *aman* rice

Treatment Interactions	Yield and harvest index			
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1W_0	1.74 h	4.60 ef	6.34 i	27.45 i
V_1W_1	2.53 e	5.47 d	8.00 f	31.67 fg
V_1W_2	3.45 c	6.27 b	9.72 c	35.61 cd
V_1W_3	3.98 ab	6.67 a	10.65 ab	37.41 bc
V_1W_4	4.10 a	6.85 a	10.95 a	37.44 bc
V_2W_0	1.80 h	4.03 gh	5.84 j	30.91 gh
V_2W_1	2.57 e	4.77 ef	7.33 gh	35.03 de
V_2W_2	3.52 c	5.70 d	9.22 d	38.16 b
V_2W_3	3.90 b	5.83 cd	9.73 c	40.08 a
V_2W_4	4.00 ab	6.23 bc	10.23 b	39.09 ab
V_3W_0	1.44 i	3.27 i	4.71 k	30.65 gh
V_3W_1	1.73 h	4.12 gh	5.85 j	29.56 h
V_3W_2	1.97 g	4.40 fg	6.37 i	30.91 gh
V_3W_3	2.07 fg	4.78 ef	6.85 h	30.16 gh
V_3W_4	2.17 f	4.92 e	7.08 gh	30.59 gh
V_4W_0	1.77 h	3.92 h	5.69 j	31.13 gh
V_4W_1	2.47 e	4.93 e	7.40 g	33.35 ef
V_4W_2	3.13 d	5.58 d	8.72 e	35.95 cd
V_4W_3	3.03 d	5.63 d	8.67 e	35.00 de
V_4W_4	3.47 c	5.87 b-d	9.33 cd	37.14 bc
SE	0.05	0.14	0.16	0.63
CV(%)	3.22	4.54	3.57	3.20

V_1= BRRI dhan34, V_2= BRRI dhan37, V_3= BRRI dhan50, V_4= Chinigura, W_0= No weeding, W_1= One hand weeding, W_2= Two hand weeding, W_3= Topstar 400SC, W_4= Sunrice 150WG

4.10 Economic performance of different weed control treatments

The cost of production and return of unit plot of aromatic *aman* rice varieties (cv. BRRI dhan34, BRRI dhan37, BRRI dhan50 and Chinigura) converted into hectare and discussed below.

Economic performance of aromatic *aman* rice varieties (cv. BRRI dhan34, BRRI dhan37, BRRI dhan50 and Chinigura) was varied for different weed control treatments in the present experiment. The cost of production was varied mainly for the weeding cost. The weeding cost was varied mainly for laborers and material required under different weed control treatments.

In case of no weeding, there was no involvement of cost for weed control. In the treatment one hand weeding (W_1), 40 laborers were required for weeding ha^{-1}. In the treatment W_2 (two hand weeding), 70 laborers were required for weeding ha^{-1}. In case of herbicidal treatments, Topstar 400SC (W_3) and Sunrice 150WG (W_4) only one laborer was used for herbicide spraying. The weeding cost was Tk. 1260.00 and 1220.00 for the treatment of Topstar 400SC (W_3) and Sunrice 150WG (W_4).

Including weeding cost, the highest cost of production was (Tk. 53413.00 ha^{-1}) for the treatment W_2 (two hand weeding) and the lowest cost of production was (Tk. 38013.00) for the treatment no weeding (W_0) (Table 15). The second highest cost of production was (Tk. 46813.00) for the treatment one hand weeding (W_1).

4.10.1 Gross return

Gross return was influenced by different weed control treatments (Table 15). The highest gross return (Tk. 88757.23 ha^{-1}) was obtained from the treatment Sunrice 150WG (W_4) and the lowest gross return (Tk. 44661.81 ha^{-1}) was obtained from no weeding treatment (W_0). The second highest gross return (Tk. 84009.54 ha^{-1}) was obtained from Topstar 400SC (W_3).

Table 15. Cost of production, return and Benefit cost ratio (BCR) of aromatic rice under different treatments

Treatments	Cost of production (Tk./ha)			Gross return Tk. ha^{-1}			Net income	BCR
	Fixed cost of production	Weeding cost	Total cost	From grain	From straw	Total		
W_1	38013	0	38013	40707.81	3954	44661.81	6648.81	1.17
W_2	38013	8800	46813	56069.70	4821	60890.70	14077.70	1.30
W_3	38013	15400	53413	72757.97	5488	78245.97	24832.97	1.46
W_4	38013	1260	39273	78280.54	5729	84009.54	44736.54	2.14
W_5	38013	1220	39233	82790.23	5967	88757.23	49524.23	2.26

W_0= No weeding, W_1= One hand weeding, W_2= Two hand weeding, W_3= Topstar 400SC, W_4= Sunrice 150WG

4.10.2 Net return

Net return varied in different weed control treatments (Table 15). The highest net return (Tk. 49524.23 ha^{-1}) was obtained from the treatment Sunrice 150WG (W_4). The second highest net return (Tk. 44736.54 ha^{-1}) was obtained from the treatment Topstar 400SC (W_3). Lowest net return (Tk. 6648.81 ha^{-1}) was achieved from the unweeded treatment (W_0).

4.10.3 Benefit Cost ratio

Benefit cost ratio varied in different weed control treatments (Figure 39). It was evident that the herbicidal plots gave the higher BCR than the other treatments. Among all the treatments, Sunrice 150WG (W_4) gave the highest BCR (2.26). The second highest BCR (2.14) was given by the treatment Topstar 400SC (W_3). The unweeded treatment (W_0) showed the lowest BCR (1.17). This might be because of less production due to higher weeds competition. Two hand weeding treatment (W_2) also performed well with BCR (1.46) but labor involvement was a crucial issue. It can be concluded from economic point of view that, herbicide might serve as most beneficial means of weed control. This result supports the findings of Al-Mamun *et al.* (2011) who concluded that the highest (2.77) benefit cost ratio (BCR) was obtained by Bouncer 10WP @ 150 g ha^{-1} and it suggests that it could be an alternative weed control option for profitable rice production for Surjamoni and BRRI dhan29. Similar results were also reported by Jacob and Syriac (2005) who stated that the benefit cost ratio for anilofos + 2, 4-D ethyl ester was (2.07) as against (0.93) for unweeded check on transplanted scented rice (Pusa Basmati 1).

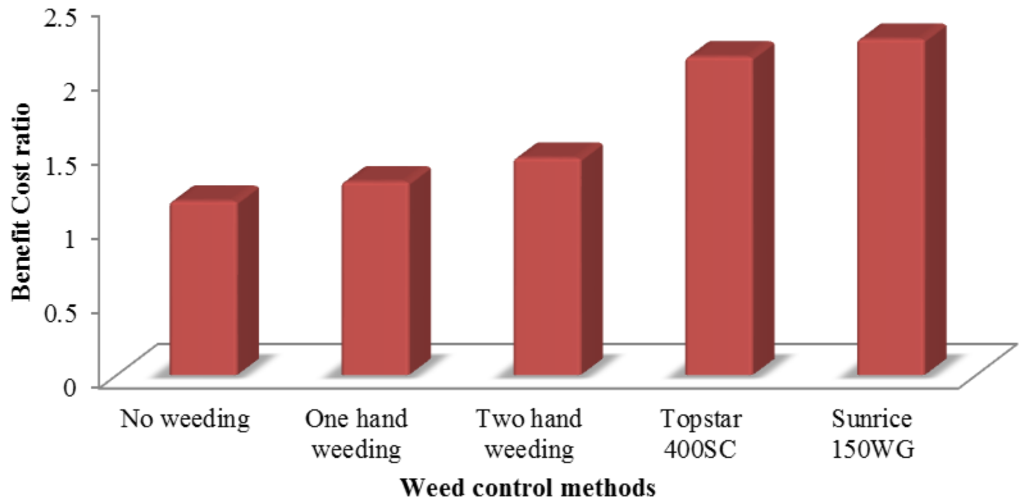

Figure 39. Effect of weed control methods on benefit cost ratio (%) of T. *aman* rice

Chapter 5

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The present piece of work was done at the Agronomy field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from July to December, 2011 to find out the influence of different weed control methods on the growth and yield of aromatic *aman* rice varieties cv. BRRI dhan34, BRRI dhan37, BRRI dhan50 and Chinigura.

The experiment was laid out in a split plot design with three replications. The size of the individual plot was 5.0 m x 2.25 m and total numbers of plots were 60. There were 20 treatment combinations. Variety was placed along the main plot and weed control methods were placed along the sub plot. The weeding treatments were no weeding (W_0), one hand weeding at 15 DAT (W_1), two hand weedings at 15 DAT and 40 DAT (W_2), Top star 400SC (Oxadiargyl) @ 100 g ha^{-1} (W_3) and Sunrice 150WG (Ethoxysulfuron) @ 185 ml ha^{-1} (W_4). Top star 400SC, a pre-emergence herbicide was applied at 5 DAT in 4-5 cm standing water for 3-5 days. Sunrice 150WG, a post-emergence herbicide was applied at 10 DAT when weeds were 2-3 leaf stage. Twenty five days old seedlings of BRRI dhan34, BRRI dhan37, BRRI dhan50 and Chinigura were transplanted on the well puddled experimental plots on August 8, 2011 by using two seedlings $hill^{-1}$.

The data on weed parameters were collected from 15 DAT to 75 DAT. Weed parameters such as total weed population (no. m^{-2}); relative weed density (RWD %), weed biomass (g m^{-2}) and weed control efficiency (%) were examined. The data on growth parameters viz. plant height, total tillers $hill^{-1}$; total dry matter $hill^{-1}$, crop growth rate and relative growth rate were recorded during the period from 15 to 75 DAT. At harvest, characters like plant height, total tillers $hill^{-1}$, effective tillers $hill^{-1}$, non-effective tillers $hill^{-1}$, total grains $panicle^{-1}$, filled grains $panicle^{-1}$, sterile grains $panile^{-1}$, filled grain percentage (%), 1000 grain weight, grain yield, straw yield, biological yield and harvest index were recorded. To determine the economic feasibility of different weed control methods on aromatic *aman* rice, total cost of production, gross return and net return were calculated to determine the benefit cost ratio.

Twenty three weed species infested the experimental plots belonging to eleven families. The most important weeds of the experimental plots were *Cyperus michelianus, Echinochloa crussgalli, Cyperus esculentus, Sagittaria guyanensis, Alternanthera sessilis, Cyperus difformis, Cyperus esculentus* and *Ludwigia octovalvis* respectively. Weed density, relative weed density, weed biomass and weed control efficiency were significantly influenced by the weed control treatments. The highest weed density and weed biomass were observed in the no weeding treatment throughout the growing period. The lowest weed density and weed biomass were found in the Sunrice 150WG treatment was at par with Topstar 400SC. At 30 DAT & 60 DAT, weed control efficiency (95.28% & 78.95%, respectively) was highest by Sunrice 150WG treatment. In this experiment, Sedge weeds dominated the crop field throughout the growing period with the highest relative weed density (*Cyperus michelianus* 56.14% at 30 DAT, *Cyperus esculentus* 24.93% and 33.60% at 45 and 60 DAT, respectively). Grass weeds were prominent during the early (*Echinochloa crussgalli* 51.79% at 15 DAT) and later period (*Eleusine indica* 11.62% at 75 DAT) while broadleaf weeds were prominent during the later periods (*Ludwigia octovalvis* 21.88% at 75 DAT).

Different weed control treatments had significant effect on crop growth parameters viz. tillers hill^{-1}, plant height, plant dry weight, crop growth rate (CGR) and relative growth rate (RGR) at different DAT. The highest plant height was observed in BRRI dhan34 with Sunrice 150WG (V_1W_4) 58.88, 72.37 and 93.82 cm at 30, 45 and 60 DAT respectively. The highest tillers hill^{-1} was observed in BRRI dhan50 with Sunrice 150WG (V_3W_4) 10.57, 17.60 and 20.77 at 30, 45 and 60 DAT respectively. Plant dry weight hill^{-1} was highest in BRRI dhan34 with Sunrice 150WG (V_1W_4) 22.66 and 84.45 g hill^{-1} at 30 and 60 DAT respectively. Crop growth rate (CGR) and relative growth rate (RGR) was highest in BRRI dhan34 with Sunrice 150WG (V_1W_4).

Weed control treatments had significant effect on the yield and yield contributing characters viz. effective tillers hill^{-1}, grain yield, straw yield and biological yield was highest in BRRI dhan34 with Sunrice 150WG (V_1W_4) treatment and harvest index was highest in BRRI dhan37 with Topstar 400SC (V_2W_3) treatment. The lowest non-effective tiller and highest filled grain percentage (%) was found in Chinigura with Sunrice 150WG (V_4W_4) treatment. 1000 grain weight was found highest in BRRI dhan50 with Sunrice 150WG (V_3W_4) treatment.

From the economic point of view, it was observed that the benefit cost ratio was the highest (2.26) from Sunrice 150WG (W_4) treatment which was followed by Topstar 400SC (W_3), Two hand weeding (W_2), one hand weeding (W_1) and no weeding (W_0) (2.14, 1.46, 1.30 and 1.17, respectively).

Based on the results of the present experiment, the following conclusion can be drawn:

1. Sedge weeds dominated the crop field throughout the growing period with the highest relative weed density in the study area.
2. Weed control method played a vital role for the growth and yield of aromatic T. *aman* rice.
3. BRRI dhan34 produced highest grain yield (3.16 t ha^{-1}), straw yield (5.97 t ha^{-1}) and biological yield (9.13 t ha^{-1}) due to highest dry matter production throughout the growing season and comparatively higher weed control efficiency.
4. Among the weed control methods, Sunrice 150WG was found the best for controlling weeds at 30 DAT (95.28%) and moderate for controlling weeds at 60 DAT (78.95%).
5. BRRI dhan34 with Sunrice 150WG gave the highest grain yield (4.10 t ha^{-1}), straw yield (6.85 t ha^{-1}) and biological yield (10.95 t ha^{-1}) due to highest dry matter production throughout the growing period.
6. Among all the weed control methods, Sunrice 150WG obtained the highest benefit cost ratio (2.26).

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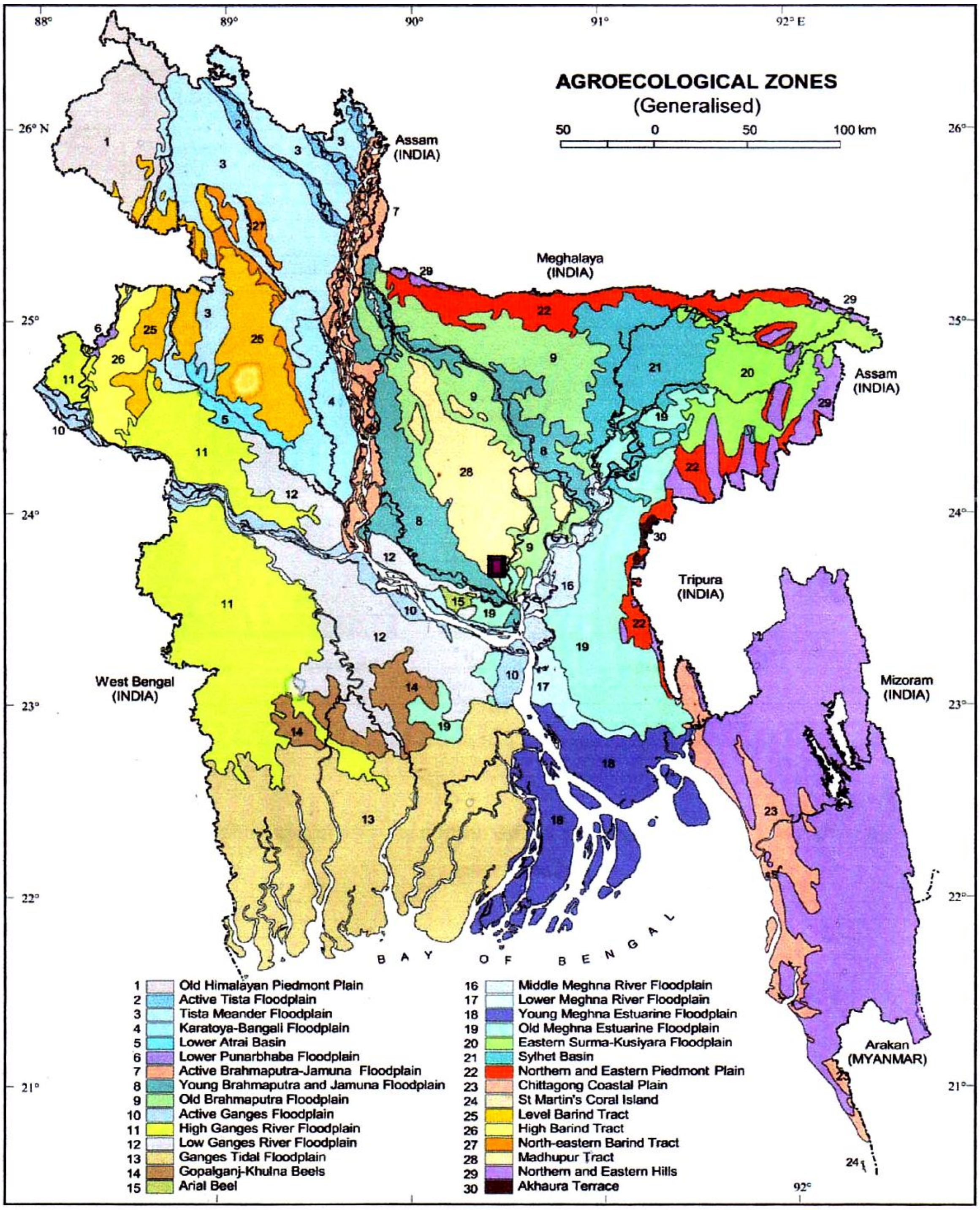
APPENDICES

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II: Physical and chemical properties of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Characteristics	*Value*
Partical size analysis	
% 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: SRDI (Soil Resources Development Institute), Farmgate, Dhaka

Appendix III: Weather data, 2011, Dhaka

Month	Average RH (%)	Average Temperature (ºC)		Total Rainfall (mm)	Average Sunshine hours
		Min.	Max.		
June	83	26.5	34.2	619	4.8
July	81	25.2	31.8	761	4.3
August	80	26.7	33.5	514	4.7
September	79	24.4	31	183	3.6
October	78	22.8	31.3	341	4.9
November	73	18.9	28.6	107	5.8
December	69	16.6	23.2	0	5.6

Source: Bangladesh Meterological Department (Climatic Division), Agargaon, Dhaka-1207

Appendix IV. Means square values for weed density m^{-2} of T. *aman* rice at different days after transplanting

Sources of variation	DF	Means square values at different days after transplanting				
		15	30	45	60	75
Replication	2	1002.87	3729.95	43260.35	106.87	1419.32
Variety (V)	3	439.44^{ns}	198.64^{ns}	3572.80^{ns}	2028.68*	1691.93*
Error (a)	6	532.96	1249.59	3190.68	4241.53	1412.52
Weed control (W)	4	4809.53*	98930.56*	4379.57*	1579.23*	1283.44*
VxW	12	456.81*	3412.49*	2253.36*	778.32*	381.75*
Error (b)	32	495.52	5636.12	2935.37	1203.20	464.86
CV (%)		78.43%	76.68%	51.02%	45.57%	45.52%

*Significant at 5% level

ns- Non significant

Appendix V. Means square values for weed biomass m^{-2} of T. *aman* rice at different days after transplanting

Sources of variation	DF	Means square values at different days after transplanting				
		15	30	45	60	75
Replication	2	3.24	85.00	1342.91	576.77	490.01
Variety (V)	3	0.90^{ns}	44.12^{ns}	503.43^{ns}	67.10^{ns}	13.30^{ns}
Error (a)	6	0.29	53.60	715.74	137.73	346.66
Weed control (W)	4	4.07*	2447.14*	2660.37*	1601.03*	509.25*
VxW	12	0.24*	41.96*	445.16*	22.87*	28.42^{ns}
Error (b)	32	0.50	57.92	1006.87	65.55	161.66
CV (%)		75.73%	60.17%	73.80%	38.75%	68.75%

*Significant at 5% level

ns- Non significant

Appendix VI. Means square values for weed control efficiency (%) of T. *aman* rice at different days after transplanting

Sources of variation	DF	Means square values at different days after transplanting	
		30	60
Replication	2	999.97	464.07
Variety (V)	3	326.74*	718.15*
Error (a)	6	381.67	813.93
Weed control (W)	4	17314.73*	10306.13*
VxW	12	97.65*	124.82*
Error (b)	32	120.66	172.58
CV (%)		17.35%	30.76%

*Significant at 5% level

ns- Non significant

Appendix VII. Means square values for Plant height (cm) of T. *aman* rice at different days after transplanting

Sources of variation	DF	Means square values at different days after transplanting					
		15	30	45	60	75	At harvest
Replication	2	8.74	24.63	19.41	2.76	1034.81	36.83
Variety (V)	3	60.88*	227.54*	293.73*	590.11*	2229.22*	15194.77*
Error (a)	6	12.12	28.22	27.67	90.55	245.86	128.28
Weed control (W)	4	92.92*	253.56*	330.93*	334.68*	412.74*	226.24*
VxW	12	6.60*	15.60*	17.35*	13.79*	15.16*	10.71*
Error (b)	32	2.69	3.25	8.18	6.64	9.56	8.08
CV (%)		5.23%	3.85%	4.51%	3.21%	3.48%	2.42%

*Significant at 5% level

ns- Non significant

Appendix VIII. Means square values for tillers hill^{-1} of T. *aman* rice at different days after transplanting

Sources of variation	DF	Means square values at different days after transplanting					
		15	30	45	60	75	At harvest
Replication	2	0.99	2.88	0.27	0.75	1.01	6.37
Variety (V)	3	1.83*	4.44*	26.62*	2.56*	1.07^{ns}	2.25*
Error (a)	6	0.08	0.68	0.83	0.23	0.65	1.36
Weed control (W)	4	6.19*	41.83*	85.68*	63.06*	58.60*	26.63*
VxW	12	0.06*	1.09*	2.37*	0.31*	0.55*	1.63*
Error (b)	32	0.05	0.11	0.37	0.43	0.64	0.88
CV (%)		9.10%	4.58%	4.78%	3.63%	4.92%	6.51%

*Significant at 5% level

ns- Non significant

Appendix IX. Means square values for total dry matter production (g hill^{-1}) of T. *aman* rice at different days after transplanting

Sources of variation	DF	Means square values at different days after transplanting				
		15	30	45	60	75
Replication	2	1.17	58.33	11.33	10.16	623.71
Variety (V)	3	0.99*	126.13*	281.07*	1272.26*	4763.81*
Error (a)	6	0.32	5.03	7.95	12.37	50.08
Weed control (W)	4	3.91*	207.73*	360.15*	2025.80*	6623.78*
VxW	12	0.46*	14.68*	12.16*	131.23*	510.17*
Error (b)	32	0.30	2.40	3.19	21.46	59.87
CV (%)		30.80%	13.82%	7.57%	9.42%	10.60%

*Significant at 5% level

ns- Non significant

Appendix X. Means square values for crop growth rate (g $hill^{-1}$ day^{-1}) of T. *aman* rice at different days after transplanting

Sources of variation	DF	Means square values at different days after transplanting			
		15-30	30-45	45-60	60-75
Replication	2	0.21	0.36	0.19	2.44
Variety (V)	3	0.58*	1.21*	4.93*	4.98*
Error (a)	6	0.03	0.10	0.12	0.35
Weed control (W)	4	0.71*	0.13*	3.13*	5.96ns
VxW	12	0.08*	0.07*	0.51*	0.63*
Error (b)	32	0.01	0.02	0.10	0.47
CV (%)		18.41%	18.65%	18.61%	42.95%

*Significant at 5% level

ns- Non significant

Appendix XI. Means square values for grain yield, straw yield, biological yield and harvest index of T. *aman* rice at different days after transplanting

Sources of variation	DF	Means square values			
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.01	0.16	0.07	7.92
Variety (V)	3	7.33*	5.31*	20.81*	114.87*
Error (a)	6	0.01	0.05	0.07	1.67
Weed control (W)	4	2.00*	9.26*	36.08*	247.02*
VxW	12	0.15*	0.17*	0.86*	14.78*
Error (b)	32	0.01	0.05	0.07	1.35
CV (%)		3.48%	4.06%	3.41%	3.58%

*Significant at 5% level

ns- Non significant

Appendix XII. Operation wise break up of labour required per hectare of transplanted aromatic *aman* rice

Sl No.	Item of work	Tractor driven	Rate (Tk.)		Labor (No.)	Rate (Tk.)		Total (Tk)
			Per Tractor day	Total (Tk.)		Per labor	Total (Tk.)	
01	Seed soaking and Treatment				1	220	220	220
02	Ploughing, laddering and seed bed preparation				4	220	880	880
03	Carrying manure,fertilizer and spreading				2	220	440	440
04	Sowing seeds and other operations				2	220	440	440
05	Uprooting of seedling				2	220	440	440
06	Preparation of main field by ploughing and laddering	2	220	440	15	220	3300	3740
07	Trimming, spading of corners and removing stubbles				2	220	440	440
08	Transplanting in the main field				15	220	3300	3300
09	Gap filling				2	220	440	440
10	Irrigation (2 times)				2	220	440	440
11	Fertilizer top dressing and applying pesticide				3	220	660	660
12	Harvesting, binding and carrying etc.				6	220	1320	1320
13	Threshing and winnowing				4	220	880	880
14	Drying and heaping				4	220	880	880
15	Storing				4	220	880	880
						Grand total=		15400

Appendix XIII. Cost of production per hectare of transplanted aman rice excluding weeding cost

A. Material cost:

Sl No.	Items	Quantity	Rate	Cost (Tk.)
01	Cost of seed	20 kg/ha	100 Tk/kg	2000
02	Cost of manures and fertilizers			
	a) Cowdung	5 ton/ha	250 Tk/ton	1250
	b) Urea	150 kg	7 Tk/kg	1050
	c) TSP	100 kg	13 Tk/kg	1300
	d) MOP	70 kg	10 Tk/kg	700
	e) Gypsum	60 kg	5 Tk/kg	300
	f) Zinc Sulphate	10 kg	40 Tk/kg	400
03	Cost of irrigation water (2 times)			1500
04	Cost of pesticide			1000
			Grand total=	9500

Total input cost (Running capital) = (15400 +9500) Tk. = 24900 Tk.

B. Overhead cost:

Sl No.	Items	Cost (Tk.)
01	Tax of land for 6 month	125
02	Interest of running capital @7% for 6 month	1743
03	Interest on fixed capital taking the value of land as Tk. 1 Lakh for 6 months or Leasing value of 1 ha for 6 month	10000
04	Miscellaneous (approximately 5% of the running capital)	1245
	Total=	13113

Total cost of production (excluding weeding cost) = Running capital + Overhead cost = (24900 + 13113) Tk = 38013 Tk

Appendix XIV. Weeding cost of different weed control treatments for one hectare of land of transplanted aromatic *aman* rice

Treatments	No. of labor	Labor cost	Herbicide cost	Total Weeding cost
W_0	0	0	-	0
W_1	40	8800	-	8800
W_2	70	15400	-	15400
W_3	1	220	1040	1260
W_4	1	220	1000	1220

Appendix XV. Economic performance of different weed control treatments

Incase of all weeding method, same cost was 38013 Tk.

1 Mon= 37.32 Kg.

1 mon grain = 900 Tk.   i.e., 1 ton grain price = 900/37.32x1000= 24115.76 Tk.

1 ton straw= 1000 Tk.

W_0= No weeding	
Input	Output
Labor Cost = 0 Total cost = 38013 Tk.	Grain yield = 1.688 t ha^{-1} = 1.688x24116= 40707.81 Tk. Straw yield = 3.954 t ha^{-1} = 3.954x1000= 3954 Tk. Total Income: 44661.81 Tk.
BCR: 1.17 Tk. return per Tk. invested	
W_1= One hand weeding	
Input	Output
Labor Cost = 220x40 =8800 Tk. Total Cost = 38013+8800 Tk. =46813 Tk.	Grain yield = 2.325 t ha^{-1} = 2.325x24116= 56069.70 Tk. Straw yield = 4.821 t ha^{-1} = 4.821x1000= 4821 Tk. Total Income: 60890.70 Tk.
BCR: 1.30 Tk. return per Tk. invested	
W_2= Two hand weeding	

Input	Output
Labor Cost = 220 x70 =15400 Tk. Total Cost = 38013+15400 Tk. =53413 Tk.	Grain yield = 3.017 t ha^{-1} = 3.017x24116= 72757.97 Tk. Straw yield = 5.488 t ha^{-1} = 5.488x1000= 5488 Tk. Total Income: 78245.97 Tk.
BCR: 1.46 Tk. return per Tk. invested	
W_3= Topstar 400SC	
Input	Output
Labor Cost= 220 x1=220 Tk. Herbicide cost=1040 Tk. Total Cost = 38013+220+1040 Tk. =39273 Tk.	Grain yield = 3.246 t ha^{-1} = 3.246x24116= 78280.54 Tk. Straw yield = 5.729 t ha^{-1} = 5.729x1000= 5729 Tk. Total Income: 84009.54 Tk.
BCR: 2.14 Tk. return per Tk. invested	
W_4= Sunrice 150WG	
Input	Output
Labor Cost= 220 x1=220 Tk. Herbicide cost= 1000 Tk. Total Cost = 38013+220+1000 Tk. =39233 Tk.	Grain yield = 3.433 t ha^{-1} = 3.433x24116= 82790.23 Tk. Straw yield = 5.967 t ha^{-1} = 5.967x1000= 5967 Tk. Total Income: 88757.23 Tk.
BCR: 2.26 Tk. return per Tk. invested	

LIST OF PLATES

Plate 2: Field view of unweeded plot (W_0)

Plate 3: Field view of one hand weeding at 15 DAT treatments (W_1) plot

Plate 4: Field view of two hand weeding at 15 & 40 DAT treatments (W_2) plot

Plate 5: Field view of Topstar 400SC (W_3) treated plot

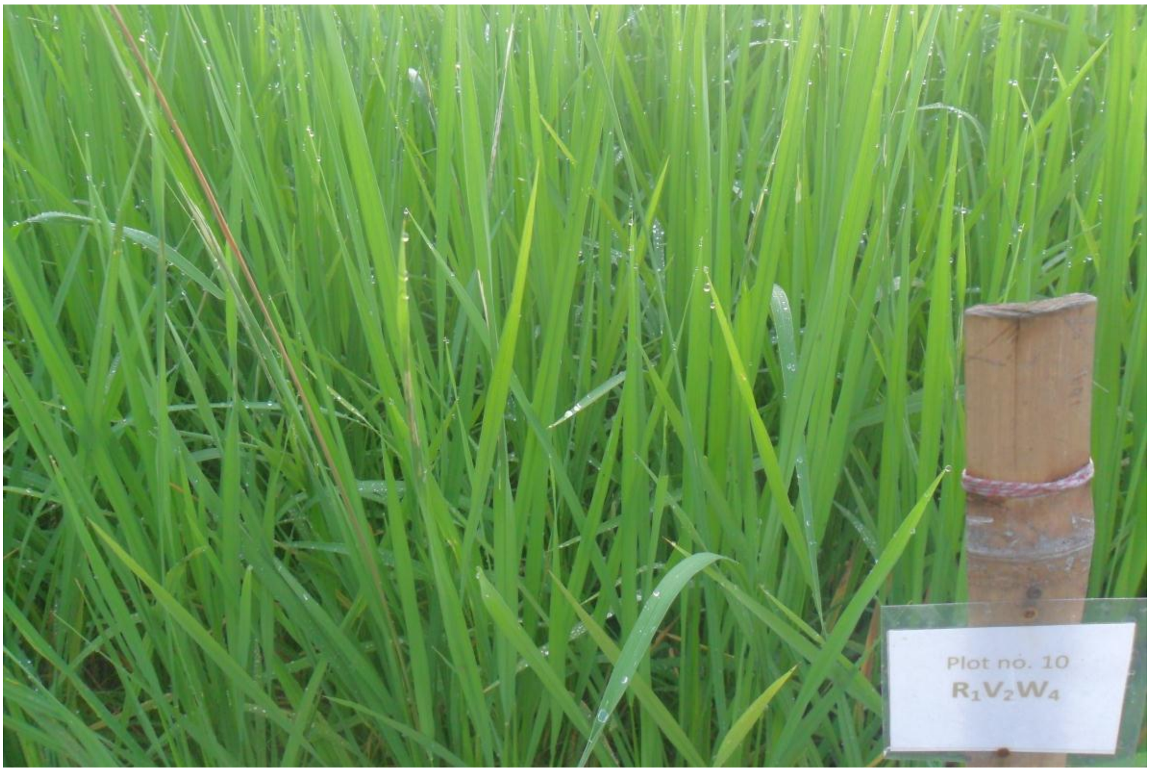


Plate 6: Field view of Sunrice 150WG (W_4) treated plot