PERFORMANCE OF METSULFURON METHYL 10% + CHLORIMURON ETHYL 2% ON WEED INHIBITION, GROWTH AND YIELD OF AROMATIC AMAN RICE VARIETIES

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*This is to certify that thesis entitled, "**PERFORMANCE OF METSULFURON METHYL 10 % + CHLORIMURON ETHYL 2 % ON WEED INHIBITION, GROWTH AND YIELD OF AROMATIC AMAN RICE VARIETIES**" submitted to the Faculty of Agriculture, Sher-e-BanglaAgricultural University, Dhaka, in partial fulfillment of the requirements for the degreeof **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **NASRIN SULTANA** Registration no. **13-05490** 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 of duringthe course of this investigation has duly been acknowledged.

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ABSTRACT

The field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University (SAU), during July to December 2018 with a view to find out the performance of modern aromatic rice as affected by the herbicidal weed control method. Weed control methods *viz.*: W_0 – No herbicide Used (Control), W_1 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1}, W_2 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and W_3 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1} and 30 days old seedlings of V_1 - BRRI dhan70, V_2 - BRRI dhan79 and V_3 - BRRI dhan80 were transplanted on the well-puddled experimental plots on 04 August 2018 by using two seedlings $hill^{-1}$. The experiment was laid out in a split plot design with three replications. The size of the individual plot was 4 m × 2.5 m and total numbers of plots were 36. There were 12 treatment combinations. Herbicidal weed control was placed along the main plot and variety in the sub plot. The results revealed that number of days to weed emergence and number of weeds in a plot were significantly influenced by the different weed control treatments. The minimum number of days to weed emergence and maximum weed species m^{-2} were observed from the plot where no herbicides were used.On the other hand, the maximum number of days to weed emergence and minimum weed species m^{-2} were observed from the plot where Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1}were used. Among the varieties The lowest number of weed species m^{-2} were observed from BRRI dhan79 plot. Different weed control treatments with varietal combination had significant effect on crop growth parameters and yield and yield-contributing characters of aromatic rice varieties. The tallest plant was observed from Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1} and BRRI dhan79 (123.10 cm). The highest effective tiller (18.87), longest panicle (35.81 cm), maximum total filled grain $panicle^{-1}$ (97.97), maximum number of filled grain $panicle^{-1}$ (86.46), highest weight of 1000-grain (29.24 g), highest grain yield (6.24 t ha^{-1}), highest harvest index (68.25 %) and maximum days to weed emergence (24.33 days) was obtained from the combination Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70. The combination of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and BRRI dhan70 showed better performance on growth and yield of rice under the present study.

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LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
Anon.	Anonymous
AIS	Agriculture Information Service
BARC	Bangladesh Agricultural Research Council
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BNNC	Bangladesh National Nutrition Council
BRRI	Bangladesh Rice Research Institute
CRRI	Central Rice Research Institute
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
DRR	Directorate of Rice Research
eds.	Editors
et al.	et alii (and others)
etc.	et cetera (and other similar things)
FAO	Food and Agriculturel Organization
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
IRRI	International Rice Research Institute
L.	Linnaeus
LSD	Least Significant Difference
i.e.	id est (that is)
MoP	Muriate of Potash
NPTs	New Plant Types

SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	Variety
viz.	Namely

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) belonging to the family *Poaceae* and subfamily *Oryzoideae* is the staple food for half of the world's population. With a compact genome, the cultivated rice species *Oryza sativa* represents model for other cereals as well as other monocot plants (Shimamoto and Kyozuka, 2002). Rice cultivation is favored by the hot, humid climate and the large number of deltas across Asia's vast tropical and sub-tropical areas.

Rice is one of the most important staple food crops, which supplies major source of calories for above 45% of the world population. Particularly to the people of Asian countries. Rice stands the second in the world after wheat in area and production. It occupies an area of 153.76 m. ha with an annual production of 598.85 mt. with a productivity of 4895 kg ha^{-1} in the world (FAO, 2017). Asia produces and consumes 90% of world's rice. Among the rice growing countries, India ranks the 1st in area following by China and Bangladesh. Rice is a major cereal crop of India occupied an area of 41.91 m. ha and production of 83.13 mt. with average productivity of 8.84 t ha^{-1} (FAO, 2018).

Rice is the most important cereal crop in Bangladesh and it is our staple food. Approximate 75% of the total cultivated land covering about 11.58 million ha produces approximate 30 million tons of rice annually (BBS 2018). The 2nd largest part of the total production of rice comes of Aman rice after Boro. Bangladesh earns about 31.6% of her Gross Domestic Product (GDP) from agriculture (BBS, 2017) in which rice is the main crop. Agriculture in Bangladesh is characterized by intensive crop production with rice based cropping system. Rice is also the principal commodity of trade in our internal agricultural business. The average yield of rice in our country is around 4.57 t ha^{-1} which is less than the world average (7.48 t ha^{-1}) and frustratingly below the highest yield recorded (9.65 t ha^{-1}) in Australia (FAO, 2019). On the other

hand, HYV (High Yielding Variety) is cultivated in 40, 67,000 ha land and total production of rice is 156, 32,000 m tons and the average rice production of hybrid varieties is 4.41 m tons and HYV varieties are 3.84 m ton in the year of 2013–2014 (BBS, 2019).

In Bangladesh three distinct classes of rice, based on the season of cultivation namely Aus, Aman and Boro are cultivated during the period April to July, August to December and January to May, respectively. Aus, amanand Boro rice were recently reported to account for 7%, 38%, and 55%, respectively, of the total rice production in Bangladesh. Among three growing seasons (Aus, Aman and Boro) Aman rice occupies the highest area coverage (34% of gross cropping area). There are 47 aman rice varieties cultivated in Bangladesh including aromatic, non-aromatic, hybrid and HYV rice (BRRI, 2018). Rice production needs to be increased by 50% or more above the current production level to meet the rising food demand (Sunyob *et al.*, 2015).

More than four thousand wild races of rice are adapted in our country. Some of these have some good qualities i.e. taste, aroma, fineness, and protein content (Kaul *et al.*, 1982). Aromatic rice is a special type of rice containing natural ingredient 2-acetyl-1-pyrroline, responsible for their fragrant taste and aroma (Hossain *et al.*, 2008; Gnanavel and Anbhazhagan, 2010) and had 15 times more 2-acetyl-1-pyrroline content than non-aromatic rice (0.14 and 0.009 ppm, respectively) (Singh *et al.,* 2000). In addition, 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). A number of fine rice namely, Chinigura, Badshabhog, Kalijira, Kataribhog, Dhadkhani, Sakkorkhora, Radhunipagal, Ukunmadhu, Tulshimala, Mohonbhog, Rajbhog, Modhumala etc. are grown by the farmers in Bangladesh in a limited area. Most of the aromatic rice varieties in Bangladesh are traditional photoperiod sensitive types and are grown during aman season. Demand for aromatic rice in recent years has increased largely for both internal consumption and export

(Singh *et al.*, 2000). Islam *et al.* (2010a) observed that the yield of aromatic rice was lower (1.5–2.0 tha^{-1}) but its higher price and low cost of cultivation generated higher profit margins compared to other varieties grown in the area. The aromatic rice is used in many ways by the people like polau, khir, firny, jarda etc. Fine rice has high market value, because of high price and taste of this rice. 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 for export show an increasing trend (Das and Baqui, 2000). Most of the aromatic rice varieties in Bangladesh are traditional photoperiod sensitive types and are grown during *aman* season (Baqui *et al.*, 1997). Now-a-days, food security especially attaining self-sufficiency in rice production is a burning issue in Bangladesh. In such condition, increasing rice production can play a vital role. The increased rice production has been possible largely through the adoption of modern scientific knowledge and technology.

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).

Weeds are commonly found in Bangladesh, about 350 species are recorded in Asian countries and these weeds cause roughly 33% of total crop loss in different crops. 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. Weed infestation and interference is a serious problem in rice fields that significantly decreases yield. Weeds that commonly found in Bangladesh are *Echinochloa colonum, Echinochloa cruss-galli, Digitaria setigera, Eleusine indica, Cyperus difformis, Cyperus rotundus, Monochoria vaginalisetc*. Weed infestation management plays an important role in crop production having a great influence on growth, yield and yield contributing characters of transplanted aman rice. Weed depends on availability of water supply, soil texture and structure, location of field, weather and climatic condition of the field, depth of plough pan and organic matter content of soil (Hossen *et al.*, 2015). Without weed control, yield losses have been estimated 16% to 48% in transplant aman rice (Alam *et al.*, 1996).

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 day's 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 (Phuhong *et al.*, 2005). In large-scale production, herbicide based weed management has become the smartest and most viable option as scarcity and high cost of labour (Anower *et al.*, 2012). Therefore, 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.

Based on the facts, the present study was undertaken with the following objectives:

1. To determine suitable dose of Metsulfuron methyl 10% + Chlorimuron ethyl 2% for controlling weed, and optimum growth and yield of transplanted Aman rice varieties.

2. To compare the yield performance and weed tolerance of three modern aman rice varieties

CHAPTER II

REVIEW OF LITERATURE

Weed control is one of the important factors for successful crop production. Weed control by herbicides is a common practice in many countries of the world as well as Bangladesh due to its competitive advantages over other methods. However, research work in the field of weed science especially with the efficacy of herbicides is scanty in Bangladesh. Although some sporadic research works have been done on herbicides but intensive research works have not been evaluated under different conditions in Bangladesh for controlling weeds in rice fields especially with aman rice. Research works at Bangladesh and abroad in controlling weeds in rice fields using different herbicides are reviewed below:

2.1 Effect of different herbicides

2.1.1 Weed population and weed control efficiency

Hassan and Upasani (2015) conducted an experiment to find out the effect of crop establishment and weed control method on weed dynamics, growth and productivity of rice under wet land situation. The treatment comprised of 4 methods of crop establishment: transplant, SRI, drum seeded and broadcast in main plot and 4 methods of weed control: pyrazosulfuron 0.02 kg ha^{-1} PE + mechanical weeding at 25 DAS or DAT, weeding by cono weeder at 25 DAS or DAT, hand weeding at 25 and 40 DAS or DAT and weedy check in sub-plot. The result revealed that among establishment and weed control methods, transplant and application of pyrazosulfuron 0.20 kg ha^{-1} + one mechanical weeding at 25 DAS or DAT was the most productive. Application of pyrazosulfuron 0.20 kg ha−1 + one mechanical weeding at 25 DAS or DAT in transplanted or broadcasted rice was the most effective in suppressing weed population and weed dry matter accumulation compared to other weed control methods.

Kumaran *et al.* (2015) evaluated the herbicide (Bispyribac sodium 10% SC) on weed control and its impact on nutrient uptake in direct seeded lowland rice. The results revealed that Early Post-Emergence (EPOE) application of Bispyribac sodium 10% SC @ 40 g ha^{-1} showed higher weed control efficiency and lesser weed density, nutrient uptake at reproductive stage of the crop in lowland rice field.

Moonmoon (2015) carried out a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50). This experiment consisted of nine treatments, *viz*., T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}], T_8: Two hand weeding at 20 DAT and 40 DAT. Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}] treatment had killed the highest number of weeds while its residual activity remained up to 45 days. Therefore, the highest weed control efficacy (98.74%) was recorded from Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}] treatment and it had checked seven weed species including the dominating weed Behua (*Cyperus difformis*) from rice field. On the other hand, the highest weed infestation was recorded in control treatment.

Ramesha *et al.* (2015) evaluated the phytotoxicity and bio-efficacy of pyrazosulfuron ethyl 10% WP (5, 10, 15 and 20 g ha^{-1} as spray) against the weeds in transplanted rice. Sprays of Saathi (Market Sample) @ 15 g ha^{-1}, Pretilachlor 50% EC @ 500 ml ha^{-1}, hand weeding at 15 and 40 days after planting (weed free check) and a weedy check (untreated check) were also evaluated. The dominant weeds were *Echinochloa colona, Panicum repens, Cynodon doctylon, Ludwigia parviflora, Leptochloa chinensis and Cyperus sp*. Application of pyrazosulfuron ethyl 10% WP at 20 g ha^{-1} was the most

effective in controlling the associated weeds without any phytotoxic effect in rice field.

Zahan *et al.* (2015) set up a research work to observe the performance of pre and post-emergence herbicides in rice (*Oryza sativa*) established by minimum tillage unpuddled transplanting. The results revealed that pyrazosulfuron-ethyl followed by orthosulfamuron and (butachlor + propanil) reduced weed biomass by 96–97% compared to non-treated weedy plots. On the other hand, pyrazosulfuron-ethyl with one post-emergence herbicide either (butachlor + propanil) or 2,4-D reduced weed by 91 to 92 %. Butachlor followed by orthosulfamuron followed by (butachlor + propanil) also reduce weed biomass by 91% compared to non-treated control. The results suggest that pyrazosulfuron-ethyl was the most effective pre-emergence herbicide in unpuddled transplanting system especially when applied with orthosulfamuron and / or (butachlor + propanil) or 2,4-D as a post-emergence herbicides.

Jacob *et al.* (2014) conducted an experiment on the impact of both pre-emergence and post-emergence herbicides in rice field. Among the pre-emergence herbicides, oxyfluorfen was sprayed at 3 days after sowing (DAS) and butachlor and pretilachlor were sprayed at 6 DAS. Pyrazosulfuron-ethyl, an early post-emergence herbicide, was sprayed at 8 DAS. The herbicides cyhalofop-butyl, fenoxaprop-p-ethyl, metamifop, penoxsulam, bispyribac sodium and azimsulfuron are post-emergence in action and were sprayed at 20 DAS. Hand weeded (hand weeding at 20 and 40 DAS) and unweeded controls were included for comparison with the herbicide treatments. The best herbicide for control of grass weeds was either fenoxaprop-p-ethyl @ 60 g ha^{-1} or cyhalofop-butyl @ 80 g ha^{-1}, both applied at 20 DAS. Broad spectrum weed control can be made possible by spraying herbicide combinations.

Mallikarjun *et al.* (2014) studied the effect of herbicides on weed control and yield of wet seeded rice which involves three pre-emergence herbicides *viz.*, butachlor, anilophos fb and oxyflurofen applied as alone and each of these followed by two post-emergent herbicides 2, 4- sodium salt, bispyribac sodium

and one hand weeding at 25 days. The results revealed that sequential application of butachlor and anilophos fb, bispyribac sodium, 2, 4-D sodium salt and one hand weeding at 25 days was recorded significantly lower weed population and dry weight of weeds *viz.*, monocots, dicots and sedges in equal manner which ultimately indicates that higher weed control efficiency over rest of the treatments except weed free check and hand weeding thrice.

Acharya and Bhattacharya (2013) investigated the efficacy of sulfonyl urea herbicide like pyrazosulfuron-ethyl, benzothiadiazinone like bentazon alone and its combination with MCPA, clefoxydim and quinclorac were studied in comparison to traditional acetamides like butachlor and pretilachlor under field condition in transplanted Boro rice. The dominating weed species in the experimental site were grasses like *Echinochloa crus-galli, Paspalum distichum,* sedges like C*yperus iria, Fimbristylis miliacea* and broad-leaved weeds like *Ammania baccifera* and *Ludwigia parviflora*. The herbicidal treatments were significantly superior to weedy check. The pyrazosulfuron ethyl @ 30 g ha^{-1} applied as pre-emergence, with a weed control efficiency of 71.78%, was recorded to be the most effective in controlling predominant weeds, in comparison to acetamide and benzothiadiazinone herbicides.

Faruq (2013) from his field research on the effect of herbicide (Prechlor 500 EC) on the growth and yield of transplant Aman rice found that application of Prechlor 500 EC @ 1.5 L ha^{-1} showed the best performance in reducing weed density, weed dry weight and in increasing weed control efficiency.

Madhukumar *et al.* (2013) evaluated the relative efficacy of different herbicides for weed control in aerobic rice cultivation system. Among different herbicidal treatments, pre-emergent application of bensulfuron methyl @ 60 g + pretilachlor @ 600 g ha^{-1} recorded significantly higher weed control efficacy (91.37%) and lower total weed density and dry weight (72 No. m^{-2} and 3.65 g 0.25 m^{-2}, respectively), followed by two hand weedings at 20 and 40 DAS and oxyfluorfen @ 90 g ha^{-1} as pre-emergent spray followed by 2, 4-DEE as post-emergent spray @ 500 g ha^{-1} at 25 DAS.

Chowdhury (2012) set up a field experiment in amanseason with a view to finding 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. The result showed that pre-emergence herbicide Sunrice 150WG controlled weeds very significantly. Application of Sunrice 150WG showed the highest weed control efficiency of 95.28% at 30 DAT and 78.95% at 60 DAT.

Pal *et al.* (2012) studied the efficacy of pyrazosulfuron-ethyl against weeds in transplanted rice. The major associated weeds were - *Echinochloa colona, Cyperus difformis, Ammania baccifera, Ludwigia octovalvis* and *Monochoria vaginalis*. Pyrazosulfuron-ethyl at 42.0 g ha^{-1} applied at 3 DAT was the most effective in managing associated weed species and returned with the lower weed index (10.80%).

Abdul *et al.* (2011) evaluated the efficacy of pre and post-emergence herbicides applied either alone or in a sequence for weed control in dry seeded fine rice cv. Super basmati. Three herbicides namely Stomp 455CS (pendimethalin) at 1650 g a.i. ha^{-1} as pre-emergence, Nominee 100SC (bis-pyribac sodium) and Ryzelan 240SC (penoxsulam) at 30 and 15 g a.i. ha^{-1} respectively, were used as early post-emergence (15 DAS). Pendimethalin was also followed by either of these herbicides. A weedy check and weed free treatments were maintained for comparison. Results indicated that pendimethalin followed by post

emergence application of bispyribac sodium and penoxsulam gave more than 80% reduction in weed density and weed dry weight over control. Moreover, sequential applications of herbicides were better than alone in dry seeded rice.

Al-Mamun *et al.* (2011) carried out an experiment to find out an effective and economic herbicide to control weeds in winter rice field. 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 indicated that these herbicides were not toxic to rice plants. Weed control efficiency (WCE) ranged 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 a) conducted field experiments during dry season (Boro) 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. The researchers 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, the lowest weed number and dry weight of weeds, which eventually resulted in lower weed index that were comparable to weed free conditions.

Mamun *et al*. (2011 a) evaluated the performance of Acetochlor 50% EC for weed suppression, finding out an appropriate dose of the herbicide and its impacts on transplanted rice. Acetochlor 50% EC @ 200, 250 and 300 ml ha^{-1} were applied. Pretilachlor 50% EC@ 1 L ha^{-1}, weed free and unweeded control were used for comparison. The most dominant weeds were *Cyperus diffornis, Monochoria vaginalis* and *Echinochloa crus-galli* in year 1 and *Cyperus diffformis* and *Echinochloa crus-galli* in year 2. *Cyperus diffformis* was at the higher rank of dominance in both years. Application of Acetochlor 50% EC @ 250 ml gave more than 80% weed control efficiency, lower number and dry weight of weeds that were comparable to the standard in both seasons.

Mamun *et al*. (2011 c) set up a field experiments to evaluate the performance of Bensulfuron-methyl + Pretilachlor 6.6% GR for weed suppression and its

impacts on transplanted rice. They 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 to evaluate the weed control efficiency of some pre-emergence herbicides in transplanted rice. 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) carried out an experiment on integrated weed management and spacing to evaluate degree of weed control and yield of transplanted amanrice (cv. BRRI dhan37). They observed that among the weed control treatments, Pretilachlor + one hand weeding at 40 DAT performed the best for controlling weeds at 30 DAT (79.53%) and moderate for controlling weeds at 60 DAT (75.65%).

Bari (2010) set up an experiment 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. He found that pre-emergence herbicides performed better regarding weed control efficiency. 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 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 it was applied as post-emergence.

Bhuiyan *et al.* (2010) conducted an experiment during boroseason for observing the control of mixed weed flora in transplanted rice (*Oryza sativa L.*). They 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 herbicides 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) carried out a field experiment 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 the highest weed control efficiency (90.12%).

Bakare *et al.* (2008) studied a formulated mixture of propanil + triclopyr which was evaluated at 2, 3 and 4 L ha^{-1} alongside with a check chemical (OrizoplusR made up of propanil + 2, 4-D Amine) and the results showed significant difference occurred in the level of weed control. Propanil + triclopyr though controlled weeds; the control level was significantly lower than the check OrizoplusR in each respective application rate. There was no phytotoxic effect of the herbicides on rice, indicating that the herbicides are not injurious to rice crop. As post-emergence herbicide in lowland rice, formulated mixture of propanil + triclopyr is recommended to be applied at 3–4 L ha^{-1}.

Kabir *et al.* (2008) conducted an experiment to assess weed dynamics and yield performance of transplanted aman rice field (cv. BRRI dhan39) with different weed control treatments. Weed density, weed biomass and weed control efficiency were significantly influenced by different weed control treatments under good water management practices. Other than weed free treatment, Butachlor 5 G @ 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 minimum weed density (16 g m^{-2}) as well as weed biomass (9.27 g m^{-2}) and

the highest weed control efficiency (82.57%). Butachlor application along with one manual weeding accompanied by proper water management might be the best option to combat weed problems in transplanted amanrice field.

Shamim *et al.* (2008) reported the methods of crop establishment, time of herbicide application and their interaction significantly influenced the number and dry weight of weeds and yield of Boro rice cv. BRRI dhan29. The highest number and dry weight of weed were recorded in control and the lowest in herbicide application after 3 days of seeding or transplanting. Weed control efficiency was higher in those receiving early application of herbicide. The highest weed control efficiency was in herbicide application at 3 days after seeding or transplanting. Phytotoxicity of herbicide increased with the earliness of herbicide application and highest phytotoxicity was observed in direct seeded thick row having herbicide application 3 days after sowing.

Mukherjee and Malty (2007) reported that Butachlor 1.0 kg ha^{-1} at 3 days after transplanting + almix 20 WP (Chlorimuron-7 ethyl + Metsulfuron-methyl) 4.0 g ha^{-1} at 20 days after transplanting showed higher weed control efficiency compared with season long weed control and weed-free condition on transplanted rice.

Dhiman (2006) evaluated the efficacy of various combination of 2,4-D axilofos and chlorinuron in controlling weed infestation in transplanted rice field. Application of 500 g 2,4-D ha^{-1} in combination with chlorinuron resulted in the highest control of grasses, sedges and broad leaved weeds in rice field.

Halder *et al.* (2005) studied the comparative efficacy of Pyrazosulfuron Ethyl (PSE) alone and its combination with Molinate against weed complex of Boro paddy. The predominant weed species were *Echinochloa crus-galli*, *Cyperus iria, Fimbristylis miliacea, Scripus maritimus, Monochoria vaginalis, Ludwigia parviflora* and *Ammania baccifera.* The result of the experiment revealed that among all the chemicals tried in this investigation, PSE 10% WP @ 16 g ha^{-1} was the best in reducing weed population and weed dry weight without showing any phytotoxic symptoms in rice.

Saha (2005) carried out an experiment to compare the efficacy of Butachlor (948 g ha^{-1}) Pretilachlor (500 or 750 g ha^{-1}), Pyrazosulfuron-ethyl (40 or 50 g ha^{-1}), Bensulfuron methyl (40 or 50 g ha^{-1}) + Butachlor (938 g ha^{-1}) and 2 times hand weeding (20 and 40 DAT) or 3 times hand weeding (20, 40 and 60 DAT) for controlling weed flora in transplanted rice under rainfed shallow lowland. Results indicated that all treatments significantly reduced weed dry matter and density.

Kalhirvelan and Vaiyapuri (2003) evaluated the effect of weed management practices on transplanted rice using Pretilachlor at 187, 250 and 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 treatment 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} resulted in the lowest weed density and weed dry weight.

Mahajan *et al.* (2003) reported that application of Pretilachlor alone or in combination with Safener and hand weeding resulted in the lowest weed density and weed dry matter in direct seeded puddled rice field.

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

Moorthy *et al.* (2002) investigated the efficacy of pre and post-emergence herbicides in controlling weeds in rain fed upland direct sown rice. The treatments were 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 compared with twice hand weeding on 20 and 40 DAT.

Rangaraju (2002) carried out an experiment to study the effects of herbicide application and application time on weed flora and weed dynamics in dry

seeded rainfed rice. He observed that application of either Butachlor or Thiobencarb at 1.50 kga.i. ha^{-1} effectively controlled the weeds.

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 the treatment effectively controlled weed density.

Rajkhowa *et al.* (2001) initiated a trial to find out the most effective weed control and nutrient management practices for rice. Results revealed that Butachlor @ 1.0 kg ha^{-1} or pretilachlor @ 0.75 kg ha^{-1} applied three days after transplanting significantly reduced weed infestation until 45 DAT over weedy check. Nutrient management practices showed no significant variation in weed density and dry matter accumulation.

Agazzani *et al.* (1999) conducted an experiment to determine 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 of weeds in wet seeded rice field and observed that Oxadiazon and Cinsolfuron controlled weeds in rice field effectively providing 91−92% and 90−92% weed control efficiency, respectively.

Balaswamy (1999) from his experiments on effect of urea and herbicides on weed composition and density in transplanted rice found that hand weeding twice at 20 and 40 days after transplanting resulted in low weed numbers, followed by herbicides.

Moorthy *et al.* (1999) evaluated the effects of the pre-emergence herbicides viz., Pretialchlor + 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 (0.40 kg and 0.60 kg ha^{-1}), Butachlor + Safener (1.5 kg ha^{-1}) and Anilofos + Ethoxysulfuron (0.375 + 0.04 kg ha^{-1}) controlled the most dominant weeds (*Cyperus difformis* and *Fimbristylis miliacea*) which are comparable to those with the hand weeded control.

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

Chandra *et al.* (1998) recorded 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 in direct seeded puddled rice field. Among the herbicides, Oxadiazon was the most effective herbicidal treatment.

Mumal *et al.* (1998) observed that the weed species *Cyperus sp., Eichhornia crassipes, Echinochloa crus-galli, Echinochloa colonum, Fimbristylis sp., Monochoria vaginalis, Eclipta alba, Paspalum sp., Panicum sp., Commelina sp.* and *Cyanotis* sp. were significantly reduced by the application of Butachlor (at 1 kg active ingredient ha^{-1}), with monocot weeds being controlled better. Maximum weed control was observed when Butachlor was applied 1, 3, 5 and 7 days after broadcasting sprouted seeds.

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

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

Mondal and Nandal (1995) observed the efficiency of Rilof H and Rifit as herbicide in comparison to hand weeding in BR11 variety of Amanrice. The major weed in the rice field were *Cyperus iria*, *Scirpus mucronatus*,

Monochoria hatate and *Eleusine indica*. The lower doses of Rilof H @ 1 L ha^{-1} and Rifit @ 1 L ha^{-1} failed to kill the weeds properly. Higher doses of both Rilof H @ 3 L ha^{-1} and Rifit @ 2 L ha^{-1} had phytotoxic effects on the rice plant.

Chon *et al.* (1994) reported that 3.60 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} at six days after transplantation was found to be the most effective for controlling weeds in transplanted rice.

Kurmi and Das (1993) conducted an experiment on clay loam soil to evaluate the effect of pretilachlor (0.75–1.25 kg ha^{-1}) applied at 3 DAT, Pyrazosulfuron-ethyl (0.005–0.01 kg ha^{-1}) at 3 and 7 DAT, anilofos (0.4–0.6 kg ha^{-1}) at 7 DAT, Oxidiazon (0.4 kg ha^{-1}) at 7 DAT, 2,4-D (0.8 kg ha^{-1}) at 7 DAT and hand weeding twice at 20 and 40 DAT for controlling weeds in rice cv. IET 6987. The most problematic weeds were found to be *Echinochloa crus-galli, Eleusine indica, Digitaria sanguinalis, Cyperus iria, Cyperus rotundus, Scirpus juncoides, Fimbristylis miliacea, Monochoria vaginalis* and *Sphenoclea zeylanica*. All weed control treatments reduced weed dry matter from unweeded control values of 164.2–249.3 g m^{-2} to 20.3–131.0 g m^{-2}. Pyrazosulfuron-ethyl at 0.01 kg ha^{-1} applied at 7 DAT resulted in the greatest weed control (74.4–77.5%).

Singh and Bhan (1992) observed 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.

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.

Mian and Mamun (1989) observed that the weed species *Cyperus spp., Eichhornia crassipes, Echinochloa crus-galli, Echinochloa colonum, Fimbristylis sp., Monochoria vaginalis, Eclipta alba, Paspalum sp., Panicum sp., Commelina sp.* and *Cyanotis sp.* were significantly reduced by the application of Butachlor (at 1 kg active ingredient ha^{-1}) in transplanted Aman rice field. Maximum weed control was observed when Butachlor was applied at 1, 3, 5 and 7 days after broadcasting the sprouted seeds.

Zafar (1989) conducted an experiment to compare the relative performance of Butachlor (Machete 60 EC at 1.2 kg ha^{-1}), Oxadiazon (Ronstar at 0.54 kg ha^{-1}), Thiobencarb (Stam F 10G at 1.43 kg ha^{-1}) and Endimethalin (Stam 33EC at 1.43 kg ha^{-1}) in irrigated transplanted rice field. All herbicides gave above 83% weed control.

2.1.2 Growth parameters

2.1.2.1 Plant height

Moonmoon (2015) conducted a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50). This experiment consisted of nine treatments, *viz*., T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran + Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}], T_8: Two hand weeding at 20 DAT and 40 DAT. At the later growth stage, the tallest plant was obtained from Propyrisulfuran + Propanil [380 ml ha^{-1} + 1500 g ha^{-1}] treatment compared to the control treatment.

Hossen (2014) carried out a field experiment to find out the effect of three sources of Nitrogen *viz*., control, Prilled urea (PU) and USG (Urea Super Granule) and three weed control treatment viz. control, two hand weeding and pre-emergence herbicide Rifit 20EC on growth, yield and yield components of Kalijira, BRRI dhan37 and BRRI dhan38 transplant aromatic T. aman rice. Pre-emergence herbicide Rifit 20EC was applied at 5 DAT. Rifit 20EC applied plot showed taller plants while no weeding had the lowest value for plant height.

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

Dhiman (2006) reported the efficacy of various combination of 2,4-D axilofos and chlorinuron in controlling weed infestation in transplanted rice field. Application of 500 g 2,4-D ha^{-1} in combination with chlorinuron produced to the tallest plants.

2.1.2.2 Total dry matter

Bhuiyan *et al.* (2011 a) 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). The researcher reported that total dry matter was significantly the highest in plots, which received three hand weeding at 15, 30 & 45 DAT (20.17 g m^{-2}) and post-emergence herbicide + 1 hand weeding at 30 DAT (22.20 g m^{-2}).

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

2.1.2.3 Crop growth Rate (CGR)

Hossen (2014) carried out a field experiment to find out the effect of three sources of Nitrogen *viz.* control, Prilled urea (PU) and USG (Urea Super Granule) and three weed control treatment *viz.* control, two hand weeding and pre-emergence herbicide Rifit 20EC on growth, yield and yield components of Kalijira, BRRI dhan37 and BRRI dhan38 transplant aromatic T. aman rice. Pre-emergence herbicide Rifit 20EC was applied at 5 DAT. Rifit 20EC applied plot gave higher CGR value while no weeding had the lowest CGR.

Ali *et al.* (2008) conducted an experiment to observe the effect of integrated weed management and spacing on the weed flora and on the growth of transplanted aman rice. The weeding treatments were - 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.* 20 cm × 10 cm, 25 cm × 15 cm and 30 cm × 20 cm. 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.

2.1.2.4 Total tillers $hill^{-1}$

Moonmoon (2015) conducted a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI dhan50). This experiment consisted of nine treatments, *viz*., T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}], T_8: Two hand weeding at 20 DAT and 40 DAT. At the later growth stage, the maximum

number of tillers hill^{-1} was obtained from Propyrisulfuran + Propanil [380 ml ha^{-1} + 1500 g ha^{-1}] treatment compared to the control treatment.

Hossen (2014) carried out a field experiment to find out the effect of three sources of Nitrogen *viz.,* control, Prilled urea (PU) and USG (Urea Super Granule) and three weed control treatment viz. control, two hand weeding and pre-emergence herbicide Rifit 20EC on growth, yield and yield components of Kalijira, BRRI dhan37 and BRRI dhan38 transplant aromatic T. aman rice. Pre-emergence herbicide Rifit 20EC was applied at 5 DAT. Rifit 20EC applied plot gave higher number of total tillers per hill while no weeding had the lowest numbers of total tiller hill^{-1}.

Ahmed *et al*. (1998) conducted an experiment to investigate the effects of weed control on rice yield and its components. Six treatments were included in the study: no weed control, continuous weeding, weed control via herbicidal application and weed removal at 30, 45 and 60 DAT. The highest number of tillers m^{-2} (331) was recorded under continuous weeding followed by weed control at 30 DAT and herbicide.

Fofana *et al.* (1995) reported that rice farmers in West Africa largely rely on hand weeding as the main weed control method. Due to the limited availability of labour, weeding of the crop is often delayed or inadequate and crop losses due to weeds are severe. Rice varieties, which are able to compete strongly with weeds, would make a significant contribution to productivity and yield stability on farmer's field. Research was conducted to identify rice varieties, which can compete with weeds, and to determine the characteristics of rice plant, which contribute to competitiveness with weeds. They observed that weed biomass at harvest was lower with those rice varieties developing a large number of tillers and good root growth.

Zafar (1989) conducted an experiment to compare the relative performance of Butachlor (Machete 60EC at 1.2 kg ha^{-1}), Oxadiazon (Ronstar at 0.54 kg ha^{-1}), Thiobencarb (Stam F 10G at 1.43 kg ha^{-1}) and Endimethalin (Stam 33EC at

1.43 kg ha^{-1}) in irrigated transplanted rice field. Tillering in rice plants was not significantly enhanced by Oxadiazon application.

2.1.3 Yield and yield attributes

2.1.3.1 Effective tiller $hill^{-1}$

Moonmoon (2015) conducted a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI dhan50). This experiment consisted of nine treatments, *viz*., T_0: (control), T_1: Acetochlor + Bensulfuron-methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}] and T_8: Two hand weeding at 20 DAT and 40 DAT. At the later growth stage, the maximum number of effective tillers $hill^{-1}$ was obtained from Propyrisulfuran + Propanil [380 ml ha^{-1} + 1500 g ha^{-1}] treatment compared to the control treatment.

Madhukumar *et al.* (2013) evaluated the relative efficacy of different herbicides for weed control in aerobic rice cultivation system. Among different herbicidal treatments, pre-emergent application of bensulfuron methyl @ 60 g + pretilachlor @ 600 g ha^{-1} showed significantly higher productive tillers per hill (21.32); followed by two hand weedings at 20 and 40 DAS and oxyfluorfen @ 90 g ha^{-1} as pre-emergent spray followed by 2, 4-DEE as post-emergent spray @ 500 g ha^{-1} at 25 DAS.

Parvez *et al*. (2013) carried out a field trial to evaluate the effect of cultivar and weeding regime on the performance of transplant aman rice. The experiment consisted of two factors namely factor A: cultivar :- BRRI dhan41 and Nizershail; and factor B: weeding regime :- no weeding, one hand weeding at 21 DAT, two hand weeding at 21 and 42 DAT, application of Pretilachlor herbicide, application of Pretilachlor herbicide + one hand weeding at 21 DAT and weed free. The highest number of effective tillers $hill^{-1}$ was observed in

weed free treatment followed by application of Pretilachlor herbicide + one hand weeding at 21 DAT treatment.

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.

Dhiman (2006) reported the efficacy of various combination of 2,4-D axilofos and chlorinuron in controlling weed infestation in transplanted rice field. Application of 500 g 2,4-D ha^{-1} in combination with chlorinuron produced the highest number of effective tillers $hill^{-1}$.

Kumar and Uthayakumar (2005) conducted a field experiment to study the effect of sequential application of pre and post-emergence herbicides and possibility of weed management with and without herbicides in wet seeded rice. They used one hand weeding at 25 DAT, Butachlor @ 1 kg ha^{-1} at 8 DAT, 2,4-D @ 0.5 kg ha^{-1} at 25 DAT, two hand weeding at 25 and 50 DAT and unweeded control. Among the treatments, butachlor had significant effect on increased number of productive tillers $hill^{-1}$ of rice. The other weed control practices produced similar effect except unweeded control.

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 $hill^{-1}$.

2.1.3.2 Non-effective tillers hill^{-1}

Moonmoon (2015) conducted a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50). This experiment consisted of nine treatments, *viz.*, T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}], T_8: Two hand weeding at 20 DAT and 40 DAT. At the later growth stage, the minimum number of non-effective tillers hill^{-1} was obtained from Propyrisulfuran + Propanil [380 ml ha^{-1} + 1500 g ha^{-1}] treatment compared to the control treatment.

2.1.3.3 Panicle length

Moonmoon (2015) carried out a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50). This experiment consisted of nine treatments, *viz.*, T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}], T_8: Two hand weeding at 20 DAT and 40 DAT. At the later growth stage, the highest panicle length was obtained from Propyrisulfuran + Propanil [380 ml ha^{-1} + 1500 g ha^{-1}] treatment compared to the control treatment.

2.1.3.4 Number of panicles

Mallikarjun *et al.* (2014) studied the effect of herbicides on weed control and yield of wet seeded rice which involves three pre-emergence herbicides viz., butachlor, anilophos fb and oxyflurofen applied as alone and each of these

followed by two post-emergent herbicides 2, 4- sodium salt, bispyribac sodium and one hand weeding at 25 days. The results revealed that sequential application of butachlor and anilophos fb, bispyribac sodium, 2, 4-D sodium salt and one hand weeding at 25 days showed significantly higher number of panicles m^{-2}.

Mahajan *et al.* (2003) observed that application of Pretilachlor alone or in combination with Safener and hand weeding resulted in the highest number of panicles.

Ganeshwor and Godadhar (2000) conducted a research work to evaluate the effectiveness of herbicides on controlling weeds and improving grain yield in transplanted rice. All herbicides were effective in controlling the weeds at 21 DAT. The most effective weed control was exhibited by 2,4-D amine @ 0.80 kg a.i. ha^{-1}. The 2,4-D amine gave the highest values for total number of panicles (19.30 m^{-2}).

BRRI (1991 b) observed that using of Ronstar @ 3.0 L ha^{-1} had significantly improved the number of panicles of rice compared to two hand weeding.

2.1.3.5 Primary branch per panicle

Moonmoon (2015) conducted a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50). This experiment consisted of nine treatments, *viz.*, T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}], T_8: Two hand weeding at 20 DAT and 40 DAT. At the later growth stage, the highest number of primary branch $panicle^{-1}$ was obtained from Propyrisulfuran + Propanil [380 ml ha^{-1} + 1500 g ha^{-1}] treatment compared to the control treatment.

2.1.3.6 Secondary branch per panicle

Moonmoon (2015) carried out a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50). This experiment consisted of nine treatments, *viz.*, T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}], T_8: Two hand weeding at 20 DAT and 40 DAT. At the later growth stage, the maximum secondary branch $panicle^{-1}$ was obtained from Propyrisulfuran + Propanil [380 ml ha^{-1} + 1500 g ha^{-1}] treatment compared to the control treatment.

2.1.3.7 Number of filled grains $panicle^{-1}$

Moonmoon (2015) conducted a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50). This experiment consisted of nine treatments, *viz.*, T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}] and T_8: Two hand weeding at 20 DAT and 40 DAT. At the later growth stage, the maximum number of filled grains $panicle^{-1}$ was obtained from Propyrisulfuran + Propanil [380 ml ha^{-1} + 1500 g ha^{-1}] treatment compared to the control treatment.

Mallikarjun *et al.* (2014) studied the effect of herbicides on weed control and yield of wet seeded rice which involves three pre-emergence herbicides viz., butachlor, anilophos fb and oxyflurofen applied as alone and each of these followed by two post-emergent herbicides 2, 4- sodium salt, bispyribac sodium and one hand weeding at 25 days. The results revealed that sequential

application of butachlor and anilophos fb, bispyribac sodium, 2, 4-D sodium salt and one hand weeding at 25 days showed significantly higher number of grains per panicle.

Madhukumar *et al.* (2013) evaluated the relative efficacy of different herbicides for weed control in aerobic rice cultivation system. Among different herbicidal treatments, pre-emergent application of bensulfuron methyl @ 60 g + pretilachlor @ 600 g ha^{-1} recorded significantly higher filled grains per panicle (88.23), followed by two hand weedings at 20 and 40 DAS and oxyfluorfen @ 90 g ha^{-1} as pre-emergent spray followed by 2, 4-DEE as post-emergent spray @ 500 g ha^{-1} at 25 DAS.

Parvez *et al*. (2013) evaluated the effect of cultivar and weeding regime on the performance of transplant aman rice. The experiment consisted of two factors namely factor A: cultivar :- BRRI dhan41 and Nizershail; and factor B: weeding regime :- no weeding, one hand weeding at 21 DAT, two hand weeding at 21 and 42 DAT, application of Pretilachlor herbicide, application of Pretilachlor herbicide + one hand weeding at 21 DAT and weed free. The highest number of filled grains $panicle^{-1}$ was observed in weed free treatment followed by application of Pretilachlor herbicide + one hand weeding at 21 DAT treatment.

Tamilselvan and Budhar (2001) conducted an experiment to see the effects of pre-emergence herbicides Butachlor @ 1.0 kg ha^{-1}, Butanil @ 1.0 kg ha^{-1}, Pretilachlor @ 0.4 kg ha^{-1}, Pretilachlor @ 0.4 kg ha^{-1}, Safener and Anilofos @ 0.3 kg ha^{-1} on rice cv. ADT 43. The herbicides were applied 8 days after sowing. The number of filled grain $panicles^{-1}$ was the highest with Anilofos @ 0.3 kg ha^{-1} (131.7) followed by Pretilochlor @ 0.40 kg ha^{-1} (126.3) and Butanil @ 1.0 kg ha^{-1} (122.1).

Ganeshwor and Godadhar (2000) set up a research work to evaluate the effectiveness of herbicides on controlling weeds and improving grain yield in transplanted rice. All herbicides were effective in controlling the weeds at 21 DAT. The most effective weed control was exhibited by 2,4-D amine @ 0.80

kg a.i. ha^{-1}. The 2,4-D amine gave the highest values for total number of grains $panicle^{-1}$ (18.65).

2.1.3.8 Number of unfilled grains $panicle^{-1}$

Moonmoon (2015) carried out a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50). This experiment consisted of nine treatments, *viz*., T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}] and T_8: Two hand weeding at 20 DAT and 40 DAT. At the later growth stage, the minimum number of unfilled grains $panicle^{-1}$ was obtained from Propyrisulfuran + Propanil [380 ml ha^{-1} + 1500 g ha^{-1}] treatment compared to the control treatment.

2.1.3.9 Weight of 1000-grains

Moonmoon (2015) conducted a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50). This experiment consisted of nine treatments, *viz*., T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}], T_8: Two hand weeding at 20 DAT and 40 DAT. At the later growth stage, the maximum weight of 1000-grains was obtained from Propyrisulfuran + Propanil [380 ml ha^{-1} + 1500 g ha^{-1}] treatment compared to the control treatment.

Madhukumar *et al.* (2013) carried out a research work to evaluate the relative efficacy of different herbicides for weed control in aerobic rice cultivation

system. Among different herbicidal treatments, pre-emergent application of bensulfuron methyl @ 60 g + pretilachlor @ 600 g ha^{-1} recorded significantly higher weight of 1000-grains (21.80 g) followed by two hand weedings at 20 and 40 DAS and oxyfluorfen @ 90 g ha^{-1} as pre-emergent spray followed by 2, 4-DEE as post-emergent spray @ 500 g ha^{-1} at 25 DAS.

Parvez *et al*. (2013) evaluated the effect of cultivar and weeding regime on the performance of transplant aman rice. The experiment consisted of two factors namely factor A: cultivar :- BRRI dhan41 and Nizershail; and factor B: weeding regime :- no weeding, one hand weeding at 21 DAT, two hand weeding at 21 and 42 DAT, application of Pretilachlor herbicide, application of Pretilachlor herbicide + one hand weeding at 21 DAT and weed free. The heaviest weight of 1000-grains was observed in weed free treatment followed by application of Pretilachlor herbicide + one hand weeding at 21 DAT treatment.

Ganeshwor and Godadhar (2000) conducted a research work to evaluate the effectiveness of herbicides on controlling weeds and improving grain yield in transplanted rice. All herbicides were effective in controlling the weeds at 21 DAT. The most effective weed control was exhibited by 2,4-D amine @ 0.80 kg a.i. ha^{-1}. The 2,4-D amine gave the highest values for weight of 1000-grains (24.69 g).

2.1.3.10 Grain yield

Hassan and Upasani (2015) carried out an experiment to find out the effect of crop establishment and weed control method on weed dynamics, growth and productivity of rice under wet land situation. The treatment comprised of 4 methods of crop establishment: transplant, SRI, drum seeded and broadcast in main plot and 4 methods of weed control: pyrazosulfuron 0.02 kg ha^{-1} PE + mechanical weeding at 25 DAS or DAT, weeding by cono weeder at 25 DAS or DAT, hand weeding at 25 and 40 DAS or DAT and weedy check in sub-plot. Application of pyrazosulfuron 0.20 kg ha^{-1} + one mechanical weeding at

25 DAS or DAT in transplanted or broadcasted rice was the most effective in producing higher rice grain yield compared to other weed control methods.

Moonmoon (2015) conducted a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50). This experiment consisted of nine treatments, *viz*., T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}] and T_8: Two hand weeding at 20 DAT and 40 DAT. The highest grain yield (6.35 t ha^{-1}) were obtained from Propyrisulfuran + Propanil [380 ml ha−1 + 1500 g ha−1]) treatment compared to the control treatment. The maximum yield loss (44.09%) was recorded in control treatment.

Ramesha *et al.* (2015) evaluated the phytotoxicity and bio-efficacy of pyrazosulfuron ethyl 10% WP (5, 10, 15 and 20 g ha^{-1} as spray) against the weeds in transplanted rice. Sprays of Saathi (Market Sample) @ 15g ha^{-1}, Pretilachlor 50% EC @ 500 ml ha^{-1}, hand weeding at 15 and 40 days after planting (weed free check) and a weedy check (untreated check) were also evaluated. Application of pyrazosulfuron ethyl 10% WP at 20 g ha^{-1} was the most effective in increasing the grain yield of rice without any phytotoxic effect.

Zahan *et al.* (2015) carried out a research work to observe the performance of pre and post-emergence herbicides in rice (*Oryza sativa*) established by minimum tillage unpuddled transplanting. Only pyrazosulfuron-ethyl followed by orthosulfamuron and (butachlor + propanil) achieved yields close to those of the weed-free treatments (5.42–6.04 t ha^{-1}). Among the herbicide treatments, sole application of butachlor produced low grain yield similar to the non-

treated crop (2.76–3.10 vs 3.13 t ha^{-1}) suggesting low activity of this herbicide on weed control in unpuddled soil.

Hashem (2014) conducted an experiment to observe the effects of crop density and reduced rates of Pretilachlor on weed control and grain yield in rice. He reported that at higher rice density, rice grain yield increased significantly from 1927 kg ha^{-1} to 3217 kg ha^{-1} as the rate of pretilachlor increased from 0 to 1.5 L ha^{-1}, but there was no further increase in yield above this rate. At medium and low densities, grain yield increased significantly as the rate of pretilachlor increased from 0 to 2 L ha^{-1}. In plots treated with recommended rate of pretilachlor (2 L ha^{-1}), there were no significant differences for grain yield among the crop densities, whereas; in untreated plots, the grain yield increased by 51% from low to high crop density. Planting rice at higher density can reduce herbicide rate by 25% without adverse effect on grain yield and can be an important component of integrated weed management strategy in lowland rice systems.

Hossen (2014) carried out a field experiment to find out the effect of three sources of Nitrogen *viz.* control, Prilled urea (PU) and USG (Urea Super Granule) and three weed control treatment *viz*. control, two hand weeding and pre-emergence herbicide Rifit 20EC on growth, yield and yield components of Kalijira, BRRI dhan37 and BRRI dhan38 transplant aromatic aman rice. Pre-emergence herbicide Rifit 20EC was applied at 5 DAT. Rifit 20EC applied plot gave the highest grain yield (3.23 t ha^{-1}). Interaction results among the factors showed that significantly higher grain yields were given by Rifit 20EC × BRRI dhan38 (3.71 t ha^{-1}) and interaction of USG × BRRI dhan38 × Rifit 20EC (4.28 t ha^{-1}).

Jacob *et al.* (2014) conducted an experiment on the impact of both pre-emergence and post-emergence herbicides in rice field. Among the pre-emergence herbicides, oxyfluorfen was sprayed at 3 days after sowing (DAS) and butachlor and pretilachlor were sprayed at 6 DAS. Pyrazosulfuron-ethyl, an

early post-emergence herbicide, was sprayed at 8 DAS. The herbicides cyhalofop-butyl, fenoxaprop-p-ethyl, metamifop, penoxsulam, bispyribac sodium and azimsulfuron are post-emergence in action and were sprayed at 20 DAS. Hand weeded (hand weeding at 20 and 40 DAS) and unweeded controls were included for comparison with the herbicide treatments. Broad spectrum weed control can be made possible by spraying herbicide combinations that could give higher yield.

Mallikarjun *et al.* (2014) studied the effect of herbicides on weed control and yield of wet seeded rice which involves three pre-emergence herbicides viz., butachlor, anilophos fb and oxyflurofen applied as alone and each of these followed by two post-emergent herbicides 2, 4- sodium salt, bispyribac sodium and one hand weeding at 25 days. Sequential application of butachlor and anilophos fb, 2, 4-D sodium salt and bispyribac sodium and one hand weeding at 25 DAS resulted in higher grain yield.

Singh *et al.* (2014) conducted an experiment to evaluate the performance of transplanted rice under pre-emergence herbicides and hand weeding techniques. The treatment consisted of seven weed management techniques *viz*., W_1 = Butachlor @ 1.5 kg a.i. ha^{-1}, W_2 = Butachlor @ 1.0 kg a.i. ha^{-1} + 2,4 D @ 1.0 kg a.i. ha^{-1}, W_3 = Bensulfuron methyl 0.6% + Pretilachlor 6% G @ 10.0 kg ha^{-1}, W_4 = Chlorimuron + Metsulfuron-methyl 20 WP @ 4 g a.i. ha^{-1}, W_5 = Pyrazosulfuron ethyl @ 30 g a.i. ha^{-1}, W_6 = Two hand weeding at 25 and 50 days after transplanting and W_7 = Weedy check (control). The highest grain yield (7.2 t ha^{-1}) was obtained from W_6 (two hand weedings) because of reduced dry weight of weeds and higher values of yield components. This was statistically at par with pre-emergence application of Pyrazosulfuronethyl (6.70 t ha^{-1}) and ready mix Chlorimuron + Metsulfuron methyl (6.20 t ha^{-1}).

Faruq (2013) from his field research on the effect of herbicide (Prechlor 500 EC) on the growth and yield of transplant Aman rice found that application of Prechlor 500 EC @ 1.50 L ha^{-1} reduced the grain yield.

Madhukumar *et al.* (2013) evaluated the relative efficacy of different herbicides for weed control in aerobic rice cultivation system. Among different herbicidal treatments, pre-emergent application of bensulfuron methyl @ 60 g + pretilachlor @ 600 g ha^{-1} recorded significantly higher grain yield (4100 kg ha^{-1}), followed by two hand weedings at 20 and 40 DAS and oxyfluorfen @ 90 g ha^{-1} as pre-emergent spray followed by 2, 4-DEE as post-emergent spray @ 500 g ha^{-1} at 25 DAS.

Parvez *et al*. (2013) set up a field experiment to study the effect of cultivar and weeding regime on the performance of transplant aman rice. The experiment consisted of two factors namely factor A: cultivar :- BRRI dhan41 and Nizershail; and factor B: weeding regime :- no weeding, one hand weeding at 21 DAT, two hand weeding at 21 and 42 DAT, application of Pretilachlor herbicide, application of Pretilachlor herbicide + one hand weeding at 21 DAT and weed free. BRRI dhan41 produced the higher grain yield than the cultivar Nizershail. The highest loss of grain yield was recorded in no weeding treatment and the lowest was recorded in weed free treatment followed by application of Pretilachlor herbicide + one hand weeding at 21 DAT in transplant aman rice (BRRI dhan41).

Abbassi *et al.*(2012) evaluated on general herbicides for rice (*Oryza sativa*) field in intermission flooded conditions and control of weeds including Barnyard grass (*Echinochloa crus-galli*), Sedges (*Juncus*) and Broadleaves. Treatments were: Butachlor 60% EC, Pertilachlor 50% EC, Oxadiargyl 30% EC, Pendimethalin 33% EC, Molinate 72% EC, Thiobencarb 50% EC, Clodinafop-propargyl 8% EC, Fenoxaprop 57% EW, 2,4-D 72% SL, Propanil 36% EC and Bentazone 48% SL at 4, 2, 3.4, 4, 6, 6, 0.6, 1, 2, 15 and 3 L ha^{-1}, respectively and Cinosulfuron 20% WG at 150 g ha^{-1}. The results indicated that “Pretilachlor + Pretilachlor” treatment showed the best performance based on EWRC standard evaluation and also had 3471 kg ha^{-1} grain yield which was the best output in comparison to other treatments. Also “Thiobencarb + mixed of Bentazone and Propanil”, “Oxadiargyl + mixed of Bentazone and Propanil”

and “Butachlor + mixed of Bentazone and Propanil” treatments with 3454, 3390 and 3349 kg ha^{-1} yield respectively had acceptable yield in comparison to three times of hand weeding check treatment with 3044 kg ha^{-1} yield.

Chowdhury (2012) set up a field experiment in aman season with a view to finding 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 at 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. BRRI dhan34 gave the highest (3.16 t ha^{-1}) and BRRI dhan50 produced the lowest grain yield (1.88 t ha^{-1}). The grain yield produced by application of 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. The interaction effect showed that BRRI dhan34 in combination with Sunrice 150WG produced the highest grain yield (4.10 t ha^{-1}) while the lowest grain yield (1.44 t ha^{-1}) was obtained from BRRI dhan50 in control treatment.

Pal *et al.* (2012) studied the efficacy of pyrazosulfuron-ethyl against weeds in transplanted rice. Pyrazosulfuron-ethyl at 42.0 g ha^{-1} applied at 3 DAT was the most effective in managing associated weed species and returned the maximum grain yield (3.30 t ha^{-1}) of rice.

Abdul *et al.* (2011) evaluated the efficacy of pre and post-emergence herbicides applied either alone or in a sequence for weed control in dry seeded fine rice cv. Super basmati. Three herbicides namely Stomp 455CS (pendimethalin) at 1650 g a.i. ha^{-1} as pre-emergence, Nominee 100SC (bis-pyribac sodium) and Ryzelan 240SC (penoxsulam) at 30 and 15 g a.i. ha^{-1} respectively, were used as early post-emergence (15 DAS). Pendimethalin was also followed by either

of these herbicides. A weedy check and weed free treatments were maintained for comparison. Maximum paddy yield (2.79 t ha^{-1}) was recorded where pendimethalin was followed by penoxsulam.

Al-Mamun *et al.* (2011) carried out an experiment 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 @ 150 g ha^{-1}, which was 49% higher than control. BRRI dhan29 showed the highest grain yield when treated with same treatment, which was 37% higher than control.

Bhuiyan *et al.* (2011 a) set up a field experiments during dry season (Boro) 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. They 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.

Bhuiyan *et al.* (2011 b) 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). They 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 the lowest yield was recorded in control (3.29 t ha^{-1}).

Khaliq *et al.* (2011) reported that manual weeding produced the highest paddy yield of 4.17 t ha^{-1} whereas, 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.

Shultana *et al.* (2011) conducted an experiment to evaluate the weed control efficiency of some pre-emergence herbicides in transplanted rice field. They found that 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 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.

Mamun *et al.* (2011 a) evaluated the performance of Acetochlor 50% EC for weed suppression to find out an appropriate dose of herbicide and its impacts on transplanted rice. Acetochlor 50% EC @ 200, 250 and 300 ml ha^{-1} were applied. Pretilachlor 50% EC@ 1 L ha^{-1}, weed free and unweeded control were used for comparison. Application of Acetochlor 50% EC @ 250 ml resulted in higher grain yield of transplanted rice that were comparable to the standard check in both seasons.

Mamun *et al.* (2011 b) conducted an experiment to find out an effective and economic herbicide to control weeds in winter rice. Becolor SG (Butachlor), Bouncer 10 WP (Pyrazosulfuron-ethyl) and Becofit 500 EC (Pretilachlor) were used to control 9 different weeds. The highest grain yield (6.96 t ha^{-1}) was obtained from Surjamoni when treated with Bouncer 10 WP @ 150 g ha^{-1}, which was 49% higher than control. BRRI dhan29 produced the highest grain yield (5.92 t ha^{-1}) when treated with same treatment which was 37% higher than control.

Mamun *et al.* (2011 c) carried out field experiments to evaluate the performance of Bensulfuron methyl + Pretilachlor 6.6% GR for weed suppression and its impacts on transplanted rice. They observed that application of Bensulfuron methyl + Pretilachlor 6.6% GR @ 652 g a.i. ha^{-1}

resulted in higher grain yield of transplanted rice that were comparable to the standard value.

Ali *et al.* (2010) set up an experiment on integrated weed management and spacing to evaluate the degree of weed control and yield of transplanted aman rice (cv. BRRI dhan37). The researchers observed that among different weed control treatments, Pretilachlor + one hand weeding at 40 DAT in combination performed the best for controlling weeds which ultimately contributed to the highest grain yield (3.60 t ha^{-1}).

Bari (2010) carried out an experiment 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. He observed 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 herbicidal 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 from 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 season for the control of mixed weed flora in transplanted rice (*Oryza sativa* L.) and stated that among different treatments, weed free plots produced the highest grain yield followed by Oxadiargyl 400SC @ 75 g a.i. ha^{-1} which was comparable with other doses of Oxadiargyl 400SC.

Gnanavel and Anbhazhagan (2010) carried out a field experiment 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} was associated with higher grain yield of aromatic rice (5.32 t ha^{-1}).

Islam *et al.* (2010 b) revealed that pre-emergence herbicide Rifit 500 EC showed the best performance in achieving comparatively better grain yield. 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}.

Salam *et al.* (2010) carried out a field experiment to evaluate the effect of herbicide on growth and yield in Boro rice (Binadhan-5). The highest grain yield (7.15 t ha^{-1}) was recorded from the application of Machete 5G @ 25 kg ha^{-1}.

Pacanoski and Glatkova (2009) conducted an experiment to study the use of herbicides for weed control in direct wet-seeded rice (*Oryza sativa* L.) in rice production regions in the Republic of Macedonia. Herbicidal treatments in Kocani and Probistip both localities significantly increased rice grain yield in comparison with untreated control.

Kabir *et al.* (2008) set up an experiment to assess weed dynamics and yield performance of transplanted aman rice (cv. BRRI dhan39) with different weed control treatments. 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. 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.

Mukherjee and Malty (2007) reported that Butachlor 1.0 kg ha^{-1} at 3 days after transplanting + almix 20 WP (Chlorimuron-7 ethyl + Metsulfuron-methyl) 4.0 g ha^{-1} at 20 days after transplanting showed higher grain yield compared with season long weed control and weed-free condition on transplanted rice.

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 increasing grain yield of rice than the weed-free treatment.

Dhiman (2006) carried out an experiment to determine the efficacy of various combination of 2,4-D axilofos and chlorinuron in controlling weed infestation in transplanted rice field. According to their report, application of 500 g 2,4-D ha^{-1} in combination with chlorinuron resulted in the maximum grain yield (5.83 t ha^{-1}).

Khan and Ashraf (2006) conducted an experiment to evaluate the effectiveness of herbicides on weed control and paddy yield in Boro rice. The treatment was Ronstar 25EC @ 2.0 L ha^{-1}. They found that use of Ronstar 25EC gave the maximum grain yield (5.65 t ha^{-1}).

Dhiman and Singh (2005) set up an experiment to evaluate the effects of low doses of herbicides on weeds, nutrient uptake and yield of transplanted rice. The treatments were 2,4-D @ 500 g ha^{-1}, anilofos @ 400 g ha^{-1}, hand weeding at 20, 40 and 60 days after transplanting and weedy control. 2,4-D and hand weeding significantly influenced nutrient uptake by the crop and gave the highest grain yields. The lowest uptake was recorded in weedy control. 2,4-D registered 88% and 83% higher grain yield in the year of 2001 and 2002, respectively, compared with the weedy control.

Jacob and Syriac (2005) showed that adoption of 20 cm × 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 favoured increased yield.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

amanrice. Other than weed free condition, the highest grain yield (5.07 t ha^{-1}) was recorded from 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 500EC was not effective to keep weed infestation at minimum level and to ensure higher yield in transplanted amanrice.

Saha (2005) carried out an experiment to compare the efficacy of Butachlor (948 g ha^{-1}) Pretilachlor (500 or 750 g ha^{-1}), Pyrazosulfuron-ethyl (40 or 50 g ha^{-1}), Bensulfuron methyl (40 or 50 g ha^{-1}) + Butachlor (938 g ha^{-1}) and 2 hand weeding (20 and 40 DAT) or 3 hand weeding (20, 40 and 60 DAT) times for controlling weed flora in transplanted rice under rainfed shallow lowland. The highest grain yield of 5.75 t ha^{-1} was obtained from Pyrazosulfuron-ethyl applied at 40 or 50 g ha^{-1}.

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}).

Kalhirvelan and Vaiyapuri (2003) conducted an experiment to study the effect of weed management practices on transplanted rice using Pretilachlor at 187, 250 and 375 g ha^{-1}, Pretilachlor and 2, 4-D at 180 + 180, 240 + 240 and 300 + 300 g ha^{-1} with twice hand weeding. Hand weeding recorded the highest grain yield (5.81 t ha^{-1}) than Pretilachlor and 2, 4-D (5.55 t ha^{-1}).

Mahajan *et al.* (2003) observed that application of Pretilachlor alone or in combination with Safener and hand weeding resulted in the highest grain yield of direct seeded puddled rice.

Saini (2003) carried out a field investigation to evaluate the efficacy of Pyrazosulfuron-ethyl, in transplanted rice (cv. RP-2421). Pyrazosulfuron-ethyl

at 20 g ha^{-1} applied as spray was as effective as its higher rate (25 g ha^{-1}) applied as spray and broadcast after sand mix and enhanced the grain yield of rice.

Jena *et al.* (2002) observed that weed control treatments increased rice yield and application of Oxadiazon with hand weeding gave the highest grain yield of direct seeded rainfed lowland rice.

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

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 the treatment increased grain yield.

Rajkhowa *et al.* (2001) initiated a trial to find out the most effective weed control and nutrient management practices for rice. Results revealed that Butachlor @ 1.0 kg ha^{-1} or pretilachlor @ 0.75 kg ha^{-1} applied three days after transplanting resulted in higher yield of rice over weedy check.

Selvam *et al.* (2001) conducted an experiment on the effect of time of seed sowing along with weed management practices in some dry rice. The treatments included sowing practices and herbicide, Pendimethalin 1.24 litre ha^{-1} at 8 days after rainfall (DAR), Pretilachlor 1.0 litre ha^{-1} at 4 DAR and 8 DAR, Pretilachlor + Safener at 4 DAR and 8 DAR, hand weeding twice and unweeded control. All herbicides receiving plots were supplemented with one hand weeding at 25 DAR. Among the herbicides, Pendimethalin recorded the highest grain yield (3773 kg ha^{-1}) and was at par with Pretilachlor at 8 DAR.

Tamilselvan and Budhar (2001) set up an experiment to see the effects of pre-emergence herbicides Butachlor @ 1.0 kg ha^{-1}, Butanil @ 1.0 kg ha^{-1},

Pretilachlor @ 0.4 kg ha^{-1}, Pretilachlor @ 0.4 kg ha^{-1}, Safener and Anilofos @ 0.3 kg ha^{-1} on rice cv. ADT 43. The herbicides were applied 8 days after sowing. The weed control treatments were equally effective in increasing grain yield.

Gogoi *et al.* (2000) 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} + one hand weeding increased grain yield (5.12 t ha^{-1}).

Ganeshwor and Godadhar (2000) conducted a research work to evaluate the effectiveness of herbicides on controlling weeds and improving grain yield in transplanted rice. All herbicides were effective in controlling the weeds at 21 DAT. The most effective weed control was exhibited by 2,4-D amine @ 0.80 kg a.i. ha^{-1}. All herbicides gave higher rice grain yields compared with the weedy control. The 2,4-D amine gave the highest values for grain yield (3.89 t ha^{-1}) and percentage of seed setting (96.60%).

Hossain (2000) studied the effects of different weed control treatments in direct seeded Aus rice where one hand weeding, two hand weeding, three hand weeding, Ronstar and Ronstar + hand weeding were used as treatments. He observed that yield and yield contributing characters increased with the increase in frequency of hand weeding.

Moorthy *et al.* (1999) evaluated the effects of the pre-emergence herbicides Pretialchlor + 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 (0.40 kg and 0.60 kg ha^{-1}), Butachlor + Safener (1.5 kg ha^{-1}) and Anilofos + Ethoxysulfuron (0.375 + 0.04 kg ha^{-1}) produced yields comparable to those with the hand weeded control.

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

Ahmed *et al*. (1998) conducted an experiment to investigate the effects of weed control on rice yield and its components. Six treatments were included in the study: no weed control, continuous weeding, weed control via herbicidal application and weed removal at 30, 45 and 60 DAT. The highest grain yield (5.14 t ha^{-1}) was recorded in continuous weeding, followed by weed control at 30 DAT and herbicide.

Angiras and Rana (1998) observed that the maximum yield was achieved from the Pretilachlor (0.8 kg ha^{-1}) + two hand weeding in direct seeded puddled sprouted rice field.

BRRI (1998) evaluated a new pre-emergence herbicide Golteer 5G (Butachlor) in transplanted ausrice. Results indicated that hand weeding treated plots produced a slightly higher grain yield than Golteer (Butachlor) treated plots.

Chandra *et al.* (1998) from their experiments on determining efficiency of herbicides in direct seeded puddled rice recorded that Oxadiazon and Thiobencarb increased grain yield of rice.

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 was obtained from the Pretilachlor (1.0 kg ha^{-1}) + two hand weeding treatment.

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 the best crop

yield was achieved with Oxadiazon treatment applied at less than 10 DAT; these results were comparable to those achieved with Anilofos or hand weeding.

BRRI (1996) observed that Ronstar @ 12 L (3.0 L ha^{-1} and 2.0 L ha^{-1}) treated plots had significantly higher grain yield of rice compared to two hand weedings. It also indicated that 2.0 L Ronstar ha^{-1} gave significantly higher grain yield than 3.0 L Ronstar ha^{-1}.

Bhattacharya *et al.* (1996) carried out an experiment for determining the efficiency of some new generation herbicides in controlling weed of transplanted Boropaddy. They reported that although the hand weeding treatment resulted in 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) set up a field experiment to evaluate the effectiveness of four herbicides, Pendimethylin, Anilofos, Butachlor / Safener and Oxyfluorfen at 2 application rates during dry and wet seasons in puddled seeded rice field. The results showed that grain yield was higher in the plots treated with Butachlor / Safener @ 1.50 kg ha^{-1}.

Chowdhury *et al.* (1995) conducted an experiment to study 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 the most effective with respect to grain yield.

Mondal and Nandal (1995) assessed the efficiency of Rilof H and Rifit as herbicide in comparison to hand weeding in BR11 variety of Amanrice. The major weed in the rice field were *Cyperus iria*, *Scirpus mucronatus*, *Monochoria hatate* and *Eleusine indica*. Plots treated with Rilof H @ 3 L ha^{-1}

produced the highest grain yield (6.0 t ha^{-1}) which was identical with the treatments of hand weeding at 21, 38 and 55 DAT and Rifit @ 2 L ha^{-1}. The grain yield reduced 20.30% due to weed infestation.

Singh and Singh (1994) from their experiment on herbicidal control of weed in transplanted rice in rainfed low land condition recorded that the best method for weed control was recorded from Oxadiazon 0.4 kg a.i. ha^{-1}, which gave the highest grain yield of rice.

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 increased grain yield of transplanted rice.

Kurmi and Das (1993) conducted an experiment on clay loam soil to evaluate the effect of pretilachlor (0.75–1.25 kg ha^{-1}) applied at 3 DAT, Pyrazosulfuron-ethyl (0.005–0.01 kg ha^{-1}) at 3 and 7 DAT, anilofos (0.4–0.6 kg ha^{-1}) at 7 DAT, Oxidiazon (0.4 kg ha^{-1}) at 7 DAT, 2,4-D (0.8 kg ha^{-1}) at 7 DAT and hand weeding twice at 20 and 40 DAT for controlling weeds in rice cv. IET 6987. All weed control treatments increased rice grain yields from 2016–2768 kg ha^{-1} to 4321–4757 kg ha^{-1}.

BRRI (1991 b) observed that using of Ronstar @ 3.0 L ha^{-1} had significantly improved grain yield of rice compared to two hand-weeding. It also indicated that 2.0 L Ronstar 25 EC ha^{-1} gave slightly higher grain yield than 3.0 L Ronstar 25 EC ha^{-1}.

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) reported that Oxadiazon (0.5 kg a.i. ha^{-1}) increased the grain yield significantly than two manual weeding at 25 and 45 DAT.

Mian and mamun (1989) from their experiment on chemical control of weeds in transplant aman rice observed that yield of rice was influenced by the time of application of Butachlor (at 1 kg active ingredient ha^{-1}) herbicide in transplanted Aman rice field.

Zafar (1989) conducted an experiment to compare the relative performance of Butachlor (Machete 60 EC at 1.2 kg ha^{-1}), Oxadiazon (Ronstar at 0.54 kg ha^{-1}), Thiobencarb (Stam F 10 G at 1.43 kg ha^{-1}) and Endimethalin (Stam 33 EC at 1.43 kg ha^{-1}) in irrigated transplanted rice field. Oxadiazon application significantly increased rice yield.

Shivamdiah *et al.* (1987) investigated that application of Oxadiazon 0.75 kg ha^{-1} + one hand weeding in combination gave significantly higher grain yield than use of herbicide alone.

2.1.3.11 Straw yield

Moonmoon (2015) conducted a field experiment to find out the herbicidal efficacy and residual activity on transplanted aromatic Boro rice (cv. BRRI Dhan50). This experiment consisted of nine treatments, *viz*., T_0: (control), T_1: Acetochlor + Bensulfuron- methyl (changer) [750 g ha^{-1}], T_2: Pyrazosulfuron-ethyl (super powder) 150 g ha^{-1}. T_3: Bispyribac sodium (extra power) 150 g ha^{-1}, T_4: Pretilachlor (superhit) 1 L ha^{-1}. T_5: Pretilachlor + Triasulfuron (Rifit + logran) 1 L ha^{-1} + 10 g ha^{-1}, T_6: Propyrisulfuran+ Propanil [500 ml ha^{-1} +1000 g ha^{-1}], T_7: Propyrisulfuran + Propanil [380 ml ha^{-1} +1500 g ha^{-1}] and T_8: Two hand weeding at 20 DAT and 40 DAT. The highest straw yield (7.11 t ha^{-1}) was obtained from Propyrisulfuran + Propanil [380 ml ha^{-1} + 1500 g ha^{-1}] treatment compared to the control treatment.

Madhukumar *et al.* (2013) set up an experiment to study the relative efficacy of different herbicides for weed control in aerobic rice cultivation system. Among different herbicidal treatments, pre-emergent application of bensulfuron methyl @ 60 g + pretilachlor @ 600 g ha^{-1} recorded significantly higher straw yield (4961 kg ha^{-1}); followed by two hand weedings at 20 and 40 DAS and

oxyfluorfen @ 90 g ha^{-1} as pre-emergent spray followed by 2, 4-DEE as post-emergent spray @ 500 g ha^{-1} at 25 DAS.

Parvez *et al*. (2013) evaluated the effect of cultivar and weeding regime on the performance of transplant aman rice. The experiment consisted of two factors namely factor A: cultivar :- BRRI dhan41 and Nizershail; and factor B: weeding regime :- no weeding, one hand weeding at 21 DAT, two hand weeding at 21 and 42 DAT, application of Pretilachlor herbicide, application of Pretilachlor herbicide + one hand weeding at 21 DAT and weed free. BRRI dhan41 produced the higher straw yield than the cultivar Nizershail.

Salam *et al.* (2010) carried out a field experiment to evaluate the effect of herbicide on growth and yield in Boro rice (Binadhan-5). The highest straw yield (7.37 t ha^{-1}) was recorded from the application of Machete 5G @ 25 kg ha^{-1}.

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 straw yield (6.53 t ha^{-1}).

Kalhirvelan and Vaiyapuri (2003) observed the effect of weed management practices on transplanted rice using Pretilachlor at 187, 250 and 375 g ha^{-1}, Pretilachlor and 2, 4-D at 180 + 180, 240 + 240 and 300 + 300 g ha^{-1} with twice hand weeding. Hand weeding recorded the highest straw yield (7.26 t ha^{-1}) than Pretilachlor and 2, 4-D (6.89 t ha^{-1}).

Jena *et al.* (2002) recorded that application of Oxadiazon with hand weeding gave the highest straw yield.

Madhu *et al.* (1996) set up a field experiment to evaluate the effectiveness of four herbicides, Pendimethylin, Anilofos, Butachlor / Safener and Oxyfluorfen at 2 application rates during dry and wet seasons in puddled seeded rice field.

The results showed that straw yields were higher in the plots treated with Butachlor / Safener @ 1.50 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 the most effective with respect to straw yield.

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

2.1.3.12 Harvest index

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

2.2 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.

2.2.1 Effect on weed population and weed control efficiency

Al-Mamun *et al.* (2011) carried out an experiment 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 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. Similarly, the 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) set up an experiment during *Boro* season 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 and to study the effect of nitrogen doses on the weed infestation and yield of *Boro* rice 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) conducted a field experiment 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.), *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 (Nizershail 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.

Hoque *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 dhan34≈ Binashail >Nizershail >BRRI dhan39 >BRRI dhan33.

Shivamdiah *et al.* (1987) investigated that combination of Oxadiazon 0.75 kg ha^{-1} + one hand weeding gave significantly higher straw yield than herbicide alone.

Bari *et al.* (1995) recorded 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*.

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.

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 need to be controlled

effectively because these cultivars do not compete with weeds as well as do the tall and long duration rice crop.

2.2.2 Growth parameters

2.2.2.1 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) carried out an experiment with hybrid rice cultivars ORI 161 and PMS 2A × IR 31802 and found taller plants in ORI 161 than in PMS 2A × IR 31802.

BRRI (2000) evaluated that performance of four varieties *viz.* Basmati 406(4508), Kataribhog and BRRI dhan34 during aman season and reported that plant height differed significantly among the varieties. Result revealed that the tallest plant (126 cm) was recorded from Basmati 406 and the shorter one (115 cm) was observed from kataribhog.

Alam *et al.* (1996) conducted an experiment to evaluate the performance of different rice varieties. Among those varieties, Kalizira produced the tallest plant, which was followed by pajam. However, among the others, BR9 produced the highest plant height followed by BR7 and these were statistically identical with pajam.

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 a) concluded that plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in *Boro* season.

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

2.2.2.2 Total dry matter

Amin *et al.* (2006) carried out 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 and Bansful Chikon) which was compared with that of a modern variety (*viz.* KK-4). They reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

2.2.2.3 Total tillers hill^{-1}

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) set up two experiments in 1994 to identify weed competitive cultivars. They reported that the varieties CG14 and CG20 gave the maximum tillers under all levels of management.

2.2.3 Yield and yield attributes

2.2.3.1 Number of filled grains panicle^{-1}

Ahmed *et al.* (1997 b) carried out 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, Nizershail. 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 Nizershail followed by BR25 and the lowest in BR11 and BR23.

2.2.3.2 Weight of 1000-grains

Hossain *et al.* (2007) conducted a field experiment on chemical and physical properties of aromatic rice varieties as influenced by transplanting date in transplant *aman* season and found that weight of 1000-grains was the highest in BRRI dhan38.

Guilani *et al.* (2003) carried out experiment to study on crop yield and yield components of rice cultivars (Anboori, Champa and LD183). 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.

BRRI (2000) evaluated the performance of three advanced lines BR438-2B-2-2-2-4, BR4384-2B-2-2-6 and BR4284-2B-2-2-HR3 along with two standard checks and seven local checks in 11 locations. Kataribhog and Khaskani were used as standard check and Chinking, Basmati, Kalijira, Philippine Katari, Chinigura, Chiniatop and Bashful as local checks. In Sonagazi and Bogra sadar, the yield performances of advanced lines were excellent with more than 4.0 t ha^{-1}. About 30% higher yield was obtained from the advanced lines over the checks.

2.2.3.3 Grain yield

Al-Mamun *et al.* (2011) carried out an experiment 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 a) 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). They 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}).

Reza *et al*. (2010) carried out an experiment to study the effect of nitrogen doses on the weed infestation and yield of *Boro* rice 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.

2.2.3.4 Straw yield

Hassan *et al.* (2010) carried out a field experiment on transplant *aman* rice cv. BRRI dhan41 and found that the 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 $hill^{-1}$.

CHAPTER III

MATERIALS AND METHODS

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

3.1 Location of the experimental field

The field experiment was conducted at the research field of Sher-e- Bangla Agricultural University Farm, Dhaka during the period from June to November, 2018. The location of the experimental site has been shown in Appendix I.

3.2 Soil of the experimental field

Soil of the experimental site was silty clay loam in texture belonging to Tejgaon series (Anon., 1988). The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8–6.5, ECE-25–28 (FAO-UNDP, 1988). The analytical data of the soil sample collected from the experimental area were determined in the Soil Testing Laboratory of Soil Resources Development Institute (SRDI), Khamarbari, Dhaka and have been presented in Appendix II.

3.3 Climate of the experimental area

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds but scanty rainfall associated with moderately low temperature prevailed during the period from March to August (Idris *et al*., 1979). The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology centre, Dhaka for the period of experimentation have been presented in Appendix III.

3.4 Plant materials and features

Rice cv. BRRI dhan70, BRRI dhan79 and BRRI dhan80 were used as plant materials for the present study. These varieties are recommended for aman season. The features of these three varieties are presented below:

BRRI dhan70: BRRI dhan70 variety is grown in *aman* season. It is a modern transplanted *aman* rice released by Bangladesh Rice Research Institute (BRRI) in 2014. It is semi-photosensitive and semi-lodging tolerant. Its grain is very long slender and scented (BRRI, 2015).

Height	:	125 cm
Maturity	:	130 days
Number of grains panicle^{-1}	:	170–200
1000 grain weight	:	20.00 g
Amylose	:	21.70 %
Yield	:	4.80 t ha^{-1}

BRRI dhan79: BRRI dhan79 variety is grown in *aman* season. It is modern transplanted *aman* rice released by BRRI in 2017. The grain is short, thick. It is semi-photosensitive and semi-lodging tolerant. BRRI dhan79 was water logging tolerant variety. (BRRI, 2018).

Height	:	112 cm
Maturity	:	135 days
Number of grains panicle^{-1}	:	170–200
1000 grain weight	:	22.60 g
Amylose	:	25.20 %
Yield	:	5.50 t ha^{-1}

BRRI dhan80: BRRI dhan80 variety is grown in*aman* season. It is modern transplanted *aman* rice released by BRRI in 2017. The grain is short, thick and scented. It is semi-photosensitive and semi-lodging tolerant. (BRRI, 2018).

Height	:	120 cm
Maturity	:	130–135 days
Number of grains panicle^{-1}	:	200–220
1000 grain weight	:	26.20 g
Amylose	:	23.60 %
Yield	:	5.50–6.00 t ha^{-1}

3.5 Description of the herbicides in tabular form

A short description of the herbicides used in the experiment is given in the table below:

Trade Name	Common Name	Mode of Action	Selectivity	Time of Application
Cimarron	Metsulfuron methyl	Systemic	For rice	Pre-emergence
DuPont	Chlorimuron ethyl	Systemic	For soybeans	Pre-emergence

3.6 Experimental treatments

The experiment consisted of two factors as mentioned below:

Factor A: Herbicide

W_0: No herbicide used (Control),
W_1 : Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1},
W_2 : Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1}
W_3 : Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1}.

Factor B: Variety

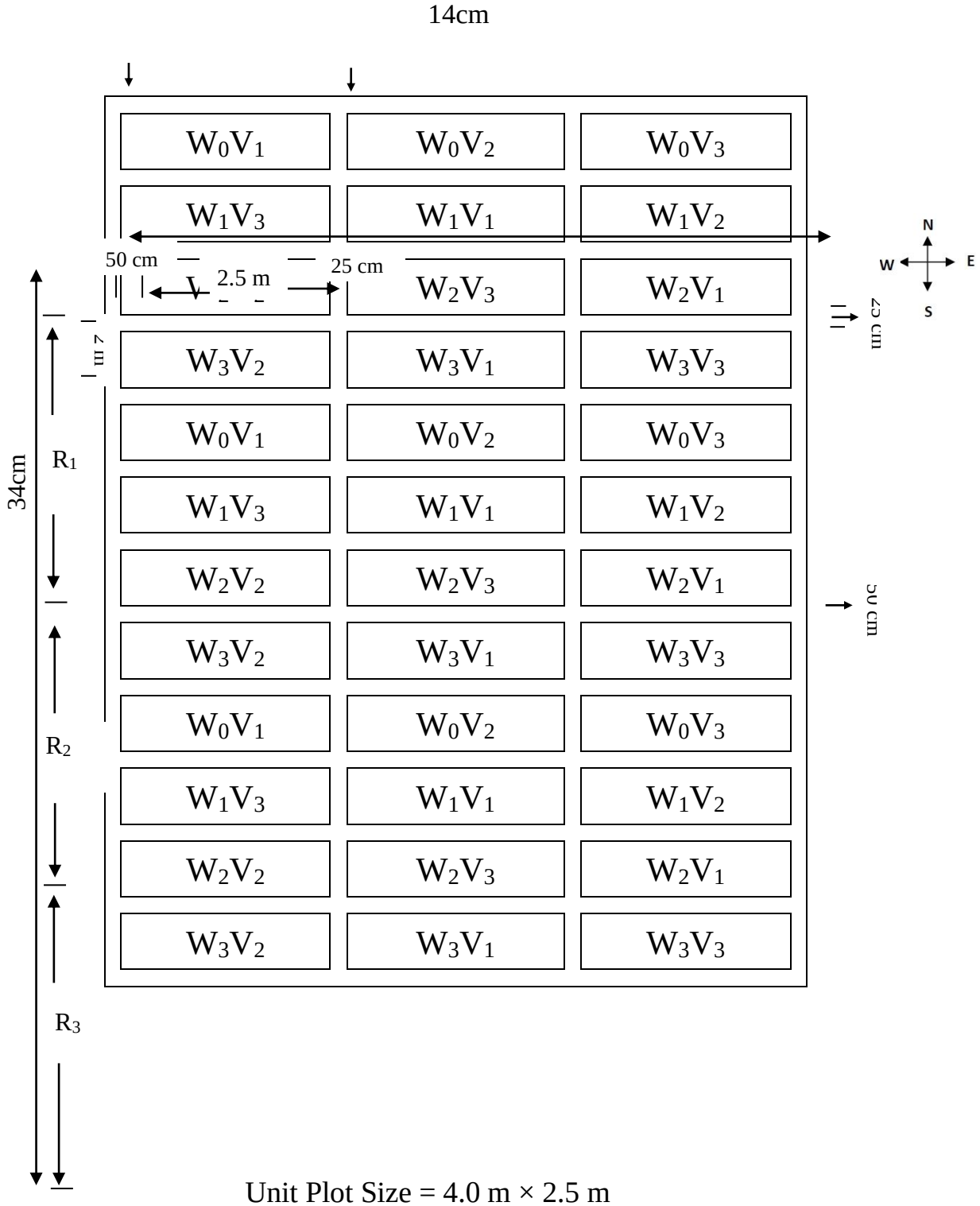
V_1 : BRRI dhan70,
V_2 : BRRI dhan79
V_3 : BRRI dhan80.

3.6.1 Treatment combinations

Based on the above-mentioned two treatment factors, the experiment was consisted of 12 treatment combinations as W_0V_1, W_0V_2, W_0V_3, W_1V_1, W_1V_2, W_1V_3, W_2V_1, W_2V_2, W_2V_3, W_3V_1, W_3V_2, and W_3V_3.

3.6.2 Experimental design and layout

The experiment was laid out in a split plot design with three replications. The size of the individual plot was 4.0 m × 2.5 m and total numbers of plots were 36. There were 12 treatment combinations. Each block was divided into 3 unit plots. Herbicidal weed control treatment was placed along the main plot and variety in the sub-plot. Layout of the experiment was done on 10 July 2018 with inter-plot spacing of 0.25 m and inter-block spacing of 0.50 m (Figure 1).



Unit Plot Size = 4.0 m × 2.5 m

Plot Spacing = 0.25 m

Between replication = 0.50 m

Figure 1:Field layout of the experiment in Split plot design.

3.7 Cultivation procedure

3.7.1 Growing of Crop

a) Plant materials collection

Healthy and vigorous seeds of aman rice cv. BRRI dhan70, BRRI dhan79 and BRRI dhan80 were collected from Bangladesh Rice Research Institute, Joydebpur, Gazipur.

b) Seed sprouting

Healthy seeds were selected by specific gravity method. Seeds were then immersed in water in bucket for 24 hours. Then seeds were taken out of water and kept thickly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

c) Seed bed preparation and raising of seedlings

A piece of high land was selected in the research filed of Sher-e-Bangla Agricultural University Farm, Dhaka for raising seedlings. The land was puddled well with country plough followed by levelling with a ladder. The sprouted seeds were sown in the seedbed on 30 June, 2018. Proper care was taken to raise the healthy seedlings in the nursery bed. Weeds were removed and irrigation was given in the nursery bed as and when necessary.

d) Final land preparation

The land was first opened with a tractor drawn disc plough on 15 July 2018. The land was then puddled thoroughly by repeated ploughing and cross ploughing with a country plough and subsequently levelled by laddering. The field layout was made on 23 July, 2018 according to experimental specification immediately after final land preparation. Weeds and stubbles were cleaned off from individual plots and finally plots were levelled properly by wooden plank so that no water pocket could remain in the field.

e) Fertilizer application

The land was fertilized with urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate at 250, 120, 120, 100 and 10 kg ha^{-1}, respectively (BRRI, 2016), which supplied 115 kg N, 55.20 kg P_2O_5, 72 kg K_2O, 18.50 kg S and 2.30 kg Zn per hectare. The whole amount of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at the time of final land preparation. Urea was applied in three equal split at 15, 30 and 45 days after transplanting (DAT).

f) Uprooting of seedlings

The seedbed was made wet by application of water in the morning and evening on the previous day before uprooting. The seedlings were uprooted without causing any mechanical injury to the roots and were kept in the soft mud in shade. The age of seedling on the day of uprooting was 28 days.

g) Transplanting

28 days old seedlings were transplanted on 27 July, 2018 in 36 experimental plots which were puddled further with spade on the day of transplanting. Transplanting was done by using two seedlings $hill^{-1}$ with 25 cm × 15 cm spacing between the rows and hills, respectively.

3.7.2 Intercultural operation

a) Gap filling

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

b)Weed control

Weeds were controlled by applying herbicides as per experimental specification. In case of 'no herbicide used' treatment-plots, no herbicides were applied.

c) Irrigation and drainage

Flood irrigation was given to maintain a level of standing water up to 2–4 cm till maximum tillering stage and after that, a water level of 7–10 cm was maintained up to grain filling stage and then drained out after milk stage to enhance maturity.

d) Herbicide application

Herbicides was applied with urea fertilizer 15 days after transplanting.

e) Plant protection measures

The crop was attacked by yellow rice stem borer (*Scirpophaga incertulus*) at the panicle initiation stage which was successfully controlled applying Sumithion @ 1.5 L ha^{-1}. Yet to keep the crop growth in normal, Basudin was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml $ha^{-1}$was applied to control rice bug.

f) 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 dhan70	02-10-2018 (68 DAT)
BRRI dhan79	11-10-2018 (77 DAT)
BRRI dhan80	04-10-2018 (70 DAT)

g) 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.

3.8 Harvesting, threshing and cleaning

The rice plant was harvested depending upon the maturity of grains and harvesting was done manually from each plot. Maturity of crop was determined when 80–90%of the grains become golden yellow in colour. Ten (10) pre-selected hills per plot from which different data were collected and 3.00 m^2areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to thethreshing floor. Proper care was taken for harvesting, threshing and cleaning of rice seed.

Variety	Harvesting Data
BRRI dhan70	06-11-2018 (130 DAT)
BRRI dhan79	11-11-2018 (135 DAT)
BRRI dhan80	09-11-2018 (133 DAT)

Fresh weight of grain and straw were recorded plot wise. Finally the weight was adjusted to a moisture content of 14 %. The straw was sun dried and the yields of grain and straw $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.9 Recording of plant data

The data on different growth parameters were recorded at 20, 45 and 70 days after transplanting (DAT) and at harvest, whereas those on yield parameters were taken at harvest from pre-demarcated area.

3.9.1 Crop growth parameters

a) Plant height
b) Dry weight hill^{-1}
c) Number of effective tillers hill^{-1}
d) Number of non-effective tillers hill^{-1}

3.9.2 Yield contributing parameters

a) Panicle length
b) Number of total grains panicle^{-1}
c) Number of filled grains panicle^{-1}
d) Number of unfilled grains panicle^{-1}
e) Weight of 1000-grain

3.9.3 Yield parameters

a) Grain yield
b) Straw yield
c) Biological yield
d) Harvest index

3.9.4 Weed parameters

a) Days to weed emergence
b) Number of weed species

3.10 Procedure of recording data

3.10.1 Plant height

The height of the rice plants was recorded from 20 days after transplanting (DAT) at 25 days interval up to 70 DAT and at harvesting stage. Using the method described by Gomez (1972) was the height of plant for all the entries on 10 randomly selected plants from the middle rows. The height was measured from the base of the plant to the tip of the longest leaf or tip of the longest ear head, whichever was longer and the average was recorded in centimetres.

3.10.2 Dry weight hill^{-1}

Dry weight hill^{-1} was recorded from 20 days after transplanting (DAT) at 25 days interval up to 70 DAT and at harvesting stage by drying plant sample. Data were recorded as the average of ten (10)-sample hill plot^{-1} selected at random from the outer rows of each plot leaving the borderline and expressed in gram.

3.10.3 Number of effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tillers per hill. Data on effective tiller per hill were recorded from 10 randomly selected hill at harvesting time and average value was recorded.

3.10.4 Number of non-effective tillers hill^{-1}

The total number of non-effective tillers hill^{-1} was counted as the tillers, which have no panicle on the head. Data on non-effective tiller per hill were counted from 10 pre-selected (used in effective tiller count) hill at harvesting time and average value was recorded.

3.10.5 Panicle length

Panicle length was measured with a meter scale from 10 selected panicles and average value was recorded and expressed in centimeters.

3.10.6 Number of total grains panicle^{-1}

Number of total grains panicle^{-1} was calculated by summation of filled and unfilled grains panicle^{-1}.

3.10.7 Number of filled grains panicle^{-1}

The total number of filled grains was collected randomly from selected 10 plants of a plot and then average number of filled grains per panicle was recorded.

3.10.8 Number of unfilled grains penicle^{-1}

The total number of unfilled grains was collected randomly from selected 10 plants of a plot on the basis of not grain in spikelet and then average number of unfilled grains per panicle was recorded.

3.10.9 Weight of 1000-grain

One thousand clean and dried seeds were randomly taken from the four sample hills of each plot and the weight was taken in an electrical balance and expressed in gram.

3.10.10 Grain yield

Final grain yield was adjusted at 14% moisture and expressed in ton per hectare. The grain yield t ha^{-1}was measured by the following formula:

$$\text{Grain yield (t ha}^{-1}) = \frac{\text{Grain yield per unit plot (kg)} \times 10000}{\text{Area of unit plot in square meter} \times 1000}$$

3.10.11 Straw yield

The straw yield t ha^{-1} was measured by the following formula:

$$\text{Straw yield (t ha}^{-1}) = \frac{\text{Straw yield per unit plot (kg)} \times 10000}{\text{Area of unit plot in square meter} \times 1000}$$

3.10.12 Biological yield

Grain yield together with straw yield was regarded as biological yield and calculated with the following formula:

$$\text{Biological yield (t ha}^{-1}) = \text{Grain yield (t ha}^{-1}) + \text{Straw yield (t ha}^{-1})$$

3.10.13 Harvest index (%)

Harvest index denotes the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Economic Yield (Grain weight)}}{\text{Biological Yield (Total weight)}} \times 100$$

3.10.14Days to weed emergence

After transplanting of rice seedling keenly observed the emergence twice in a day (morning and afternoon) until 30 days after transplanting (DAT).

3.10.15Number of weed species

Data on weed population were collected from each plot at harvesting time of the rice plants. Weeds grown in the quadrate (1 m × 1 m) were identified and the quadrate was placed randomly at three places in each plot as following by Cruz *et al.* (1986) method. The weeds within the quadrate were counted species-wise and converted to number m^{-2} by the average number of two samples. The species were identified with the help of 'Bangladesher Agacha Parichiti' (Karim and Kabir, 1995) and Major Weeds of the Philippines (Moody *et al*., 1984). Observations on weed density were recorded using quadrate method as described by Pound and Clements (1998). Frequency of different weeds was determined and density of each species was calculated according to Odum (1971).

$$\text{Weed species (Number } m^{-2}) = \frac{\text{Total number of weeds}}{\text{Total surveyed unit area}}$$

3.11 Statistical Analysis

The recorded data were compiled and subjected to statistical analysis. Analysis of variance following a split plot design was done with the help of MSTAT C (Russell, 1986) and Microsoft office Excel 2013 package program. The mean differences among the weed control treatments were adjudged by Duncan's New Multiple Range Test (Gomez and Gomez, 1984). The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from thestudy to investigate the influence of different methods of weed control on the growth, development and yield of transplanted aromatic rice varieties. The results of the crop characters and weed parameters of the production of the crop as influenced by different weed control treatments have been presented and discussed in this chapter. Data on different crop characters have been presented in Figure 2–5 and Table 1–6. The analyses of variance (ANOVA) on different parameters were presented in Appendices IV to VI.

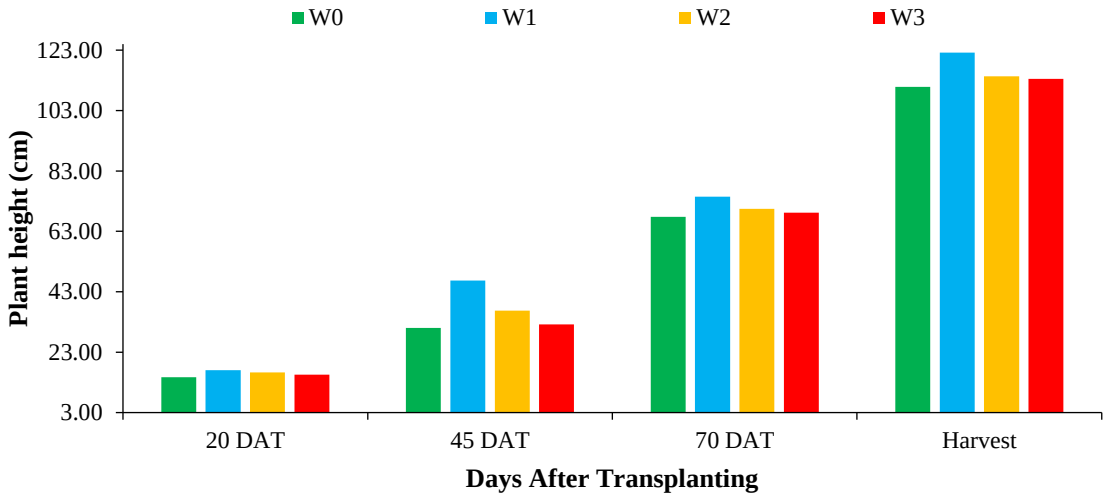
4.1. Crop growth parameters

4.1.1. Plant height

Effect of herbicide

The plant height varied significantly due to the application of different doses of herbicides in the rice field (Figure 2 and Appendix IV). Throughout the growing period, Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1} (W_1) scored the tallest plant (17.07, 46.71, 74.48 and 122.17 cm at 20, 45, 70 DAT and at harvest, respectively) and no weeding treatment (W_0) attained the shortest (14.70, 31.05, 67.78 and 110.80 cm at 20, 45, 70 and at harvest, respectively) plant. Attalla and Kholosy (2002) reported that herbicide application significantly enhanced plant height of rice. Weeding reduced crop-weed competition thus enhanced plant height significantly. Similar results were observed by Zannat (2014) and Islam (2014). 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).



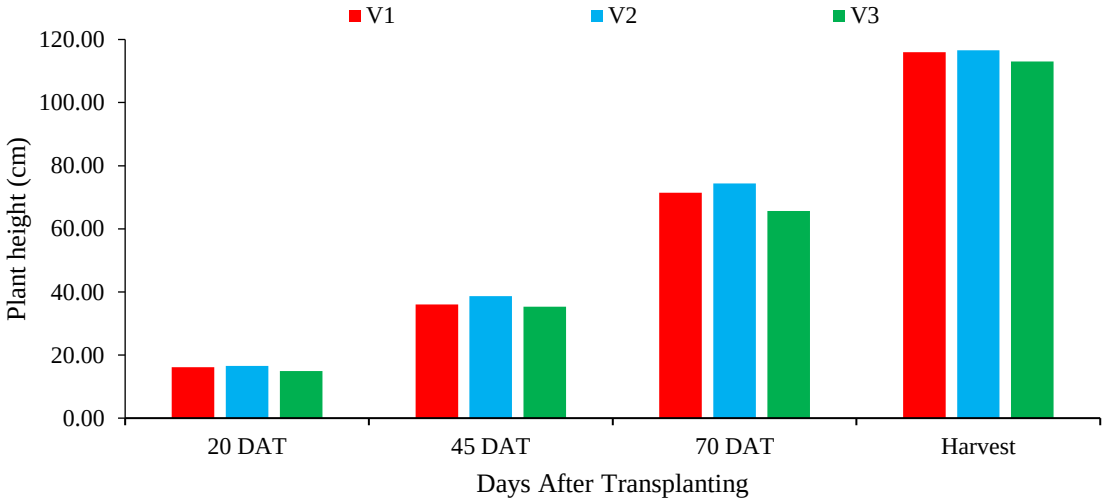
W_0 – No herbicide Used (Control), W_1 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1}, W_2 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and W_3 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1}.

Figure 2. Effect of herbicide on plant height of transplant aman rice at different days after transplanting (DAT) and at harvest (LSD $_{(0.05)}$value = 1.17, 1.82, 1.24 and 1.85 at 20 DAT, 45 DAT, 70 DAT and harvest, respectively).

Effect of variety

Plant height varied significantly for varietal variation throughout the going period (Figure 3 and Appendix IV). BRRI dhan79 showed the highest and BRRI dhan80 showed the lowest plant height at all the growth stages studied.At 20 DAT, BRRI dhan79 (V_2) scored the tallest plant (16.58 cm) which was statistically similar (16.16 cm) with BRRI dhan70 (V_1) whereas, the shortest plant (14.97 cm) was observed for BRRI dhan80 (V_3). On 45 and 70 DAT, BRRI dhan79 (V_2) showed the highest plant height (38.62 and 74.36 cm at 45 and 70 DAT, respectively) and BRRI dhan80 (V_3) showed the lowest plant height (35.36 and 65.61 cm at 45 and 70 DAT, respectively). At harvest, the tallest plant (116.63 cm) was recorded from BRRI dhan79 (V_1) which was statistically similar (115.98 cm) with BRRI dhan70 (V_1) whereas, the lowest

plant height (113.03 cm) was recorded from BRRI dhan80 (V_3). Probably the genetic makeup of varieties was responsible for the variation in plant height. Attalla and Kholosy (2002) reported that herbicide application significantly enhanced plant height of rice. Weeding reduced crop-weed competition thus enhanced plant height significantly. This result was in agreement with Bisne *et al.* (2006) who reported that plant height varies significantly among varieties. Similar results were observed by Zannat (2014) and Islam (2014).



V_1 – BRRI dhan70, V_2 – BRRI dhan79 and V_3 – BRRI dhan80

Figure 3. Effect of variety on plant height of transplant aman rice at different days after transplanting (DAT) and at harvest ($LSD_{(0.05)}$ value = 0.69, 1.72, 0.50 and 1.54 at 20 DAT, 45 DAT, 70 DAT and harvest, respectively).

Interaction effect

Plant height was significantly affected by the interaction of herbicide and variety shown in Table 1 and Appendix IV. At 20 DAT, the tallest plant (20.67 cm) was recorded from the combination of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1} and BRRI dhan79 (W_1V_2) whereas, the shortest (14.00 cm) was obtained from no weeding and BRRI dhan80 combination (W_0V_3) which was statistically identical with W_0V_2 (14.33 cm) and statistically similar with W_3V_3 (14.44 cm). Combination of Metsulfuron

methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1} and BRRI dhan79 (W_1V_2) scored the highest plant height (51.56 cm) at 45 DAT. On the other hand, the lowest plant height (29.44 cm) was recorded from the combination of no weeding and BRRI dhan80 combination (W_0V_3) which was statistically similar with W_3V_1 (30.89 cm). At 70 DAT, the highest

Table 1. Interaction effect of herbicide and variety on plant height of transplant aman rice at different days after transplanting (DAT) and at harvest.

Treatment combination	Plant height (cm)			
	20 DAT	45 DAT	70 DAT	Harvest
W_0V_1	15.78 c-e	32.00 gh	72.00 e	114.40 b-d
W_0V_2	14.33 g	31.71 gh	70.11 f	112.90 de
W_0V_3	14.00 g	29.44 i	61.22 j	105.10 f
W_1V_1	15.22 ef	46.00 b	70.22 f	121.40 a
W_1V_2	20.67 a	51.56 a	86.22 a	123.10 a
W_1V_3	15.33 de	42.56 c	67.00 g	122.00 a
W_2V_1	17.44 b	35.11 ef	62.33 i	114.80 bc
W_2V_2	15.44 c-e	39.22 d	76.00 c	114.60 b-d
W_2V_3	16.11 cd	35.89 e	72.89 d	113.60 cd
W_3V_1	16.18 c	30.89 hi	81.00 b	113.30 cd
W_3V_2	15.89 c-e	32.00 gh	65.11 h	115.90 b
W_3V_3	14.44 fg	33.56 fg	61.33 j	111.40 e
LSD(0.05)	**0.81**	**1.99**	**0.57**	**1.77**
CV (%)	**7.93**	**8.14**	**5.47**	**5.89**

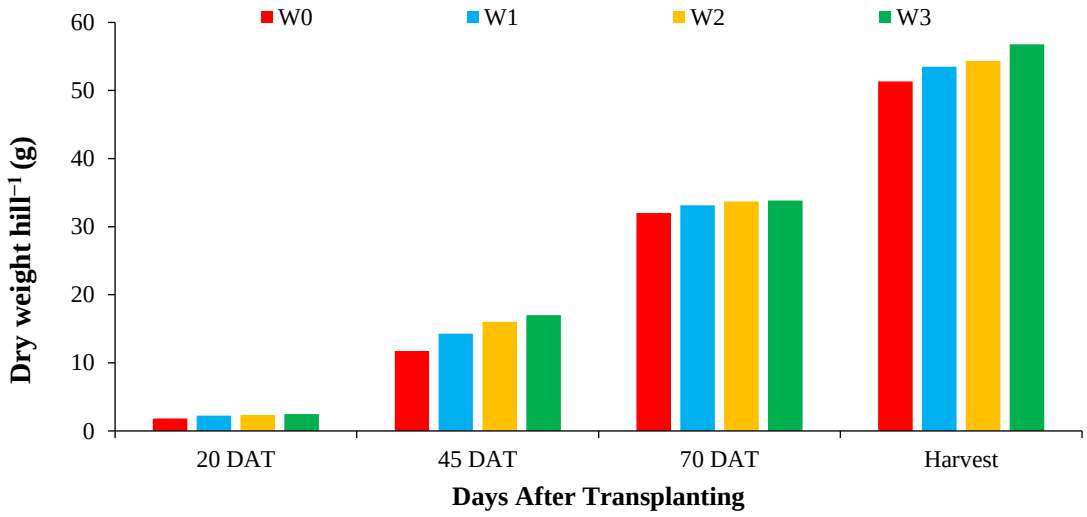
In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probabilityW_0 – No herbicide Used (Control), W_1 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1}, W_2 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and W_3 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1}.V_1 – BRRI dhan70, V_2 – BRRI dhan79 and V_3 – BRRI dhan80.

plant height (86.22 cm) were recorded from the combinations of Metsulfuronmethyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1} and BRRI dhan79 (W_1V_2). Whereas, the lowest plant height were recorded from the combinations of no weeding and BRRI dhan80 combination (W_0V_3) (61.22 cm) which was statistically identical with W_3V_3 (61.33 cm). Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1} and BRRI dhan79 (W_1V_2) achieved the tallest plant (123.10 cm) at harvest which was statistically identical with W_1V_3 (122.00 cm) and W_1V_1 (121.40 cm), while the lowest one (105.10 cm) was recorded from no weeding and BRRI dhan80 (W_0V_3).

4.1.2. Dry weight $hill^{-1}$

Effect of herbicide

Dry weight $hill^{-1}$ increased exponentially with time. Dry weight $hill^{-1}$ was significantly affected by different weed control treatments (Figure 4 and Appendix IV). From the early stages, distinct differences were visible among the weed control treatments in dry weight $hill^{-1}$ production. Among all the weed control treatments, Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1} (W_3) achieved the highest dry weight $hill^{-1}$ (2.46, 17.00, 33.82 and 56.80 g at 20, 45, 70 DAT and at harvest, respectively) throughout the growing period which was statistically identical with W_2 (2.32 g), W_1 (2.25 g) at 20 DAT and W_2 (33.70 g) at 70 DAT. On the other hand, the lowest dry weight $hill^{-1}$ (1.81, 11.75, 32.01 and 51.31 g at 20, 45, 70 DAT and at harvest, respectively) throughout the growing period was observed in no weeding treatment (W_0). Similar results were observed by Bhuiyan *et al.* (2011a).

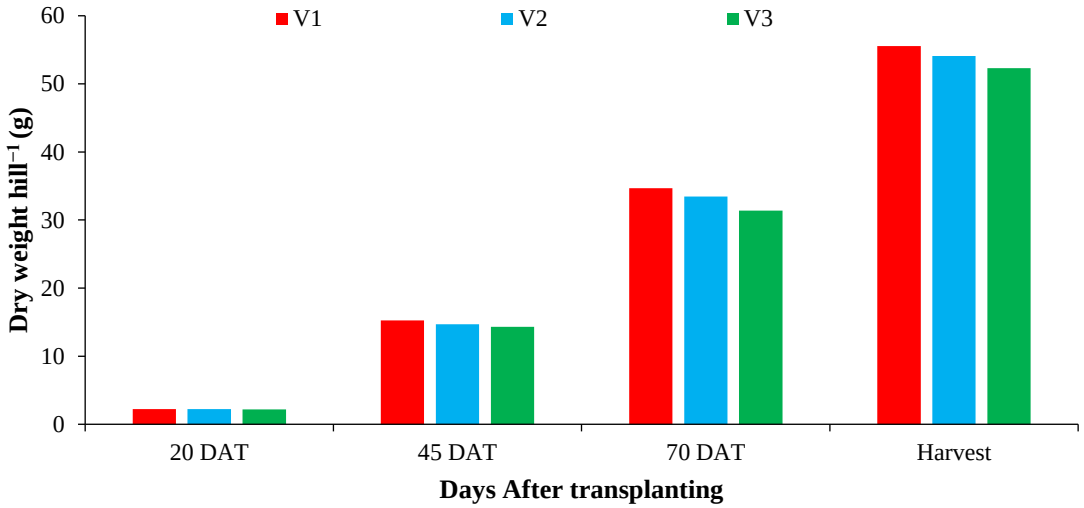


W_0 – No herbicide Used (Control), W_1 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1}, W_2 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and W_3 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1}.

Figure 4. Effect of herbicide on dry weight hill^{-1} of transplant aman rice at different days after transplanting (DAT) and at harvest ($LSD_{(0.05)}$value = 0.24, 0.63, 0.14 and 0.48 at 20 DAT, 45 DAT, 70 DAT and harvest, respectively).

Effect of variety

Dry weight hill^{-1} is the material, which was dried to a constant weight. Total dry weight hill^{-1} production indicates the production potential of a crop. A high dry weight hill^{-1} production is the first perquisite for high yield. Total dry weight hill^{-1} of roots, leaves, leaf sheath + stem and/or panicles of all varieties were measured at 20, 45, 70 DAT and at harvest. It was evident from Figure 4 and Appendix IV that irrespective of treatments dry weight hill^{-1} of all the varieties significantly varied at all sampling dates. Figure 5 shows that BRRI dhan70 (V_1) achieved the highest dry weight throughout the growingperiod (2.23, 15.24, 34.65 and 55.55 g hill^{-1} at 20, 45, 70 DAT and at harvest, respectively) which was statistically identical with BRRI dhan79 (33.47 g hill^{-1}) at 70 DAT.



V_1 – BRRI dhan70, V_2 – BRRI dhan79 and V_3 – BRRI dhan80.

Figure 5. Effect of variety on dry weight hill^{-1} of transplant aman rice at different days after transplanting (DAT) and at harvest ($LSD_{(0.05)}$ value = NS, 0.47, 1.37 and 0.22 at 20 DAT, 45 DAT, 70 DAT and harvest, respectively).

On the other hand, the lower amount of dry weight production was observed in BRRI dhan80 (V_3) throughout the growing period (2.19, 14.33, 31.39 and 52.29 g hill^{-1} at 20, 45, 70 DAT and at harvest, respectively). This may be due to the highest number of tiller mortality.

Interaction effect

The interaction of weed control treatments and variety had significant effect on dry weight hill^{-1} production throughout the growing period (Table 2 and Appendix IV). All the weed control treatments gave higher dry weight over time and gave lower dry weight at no weeding. The treatment combination of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1} with BRRI dhan70 (W_3V_1) produced the highest dry weight over time (2.80, 18.86, 38.29 and 69.84 g hill^{-1} at 20, 45, 70 DAT and at harvest, respectively). On the other hand, the treatment combination of no weeding with BRRI dhan80 (W_0V_3) produced the lowest dry weight over time (1.69, 11.26, 29.61 and 44.96 g hill^{-1} at 20, 45, 70 DAT and at harvest, respectively) which was statistically identical

with W_0V_2 (1.80 g hill^{-1}) at 20 DAT and similar with W_0V_2 (29.80 g hill^{-1}) and W_0V_2 (29.99 g hill^{-1}) at 70 DAT.

Table 2. Interaction effect of herbicide and variety on dry weight hill^{-1} of transplant aman rice at different days after transplanting (DAT) and at harvest.

Treatment combination	Dry weight hill^{-1} (g)			
	20 DAT	45 DAT	70 DAT	Harvest
W_0V_1	1.94 f	18.86 a	29.99 fg	46.84 i
W_0V_2	1.80 g	12.70 f	29.80 fg	45.70 j
W_0V_3	1.69 g	11.26 g	29.61 g	44.96 k
W_1V_1	2.09 cd	8.65 h	34.97 cd	51.59 f
W_1V_2	2.59 bc	12.86 f	36.44 bc	62.00 b
W_1V_3	2.68 b	13.75 e	34.29 d	60.73 c
W_2V_1	2.54 c	14.65 d	37.58 ab	57.17 d
W_2V_2	2.04 ef	16.24 c	32.03 e	60.87 c
W_2V_3	2.17 d	17.10 b	31.85 e	47.50 h
W_3V_1	2.80 a	18.86 a	38.29 a	69.84 a
W_3V_2	2.18 d	16.98 b	31.34 ef	47.86 g
W_3V_3	1.97 f	15.15 d	31.85 e	52.69 e
$LSD_{(0.05)}$	**0.11**	**0.55**	**1.58**	**0.25**
CV (%)	**9.75**	**9.13**	**9.57**	**7.27**

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

W_0 – No herbicide Used (Control), W_1 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1}, W_2 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and W_3 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1}.

V_1 – BRRI dhan70, V_2 – BRRI dhan79 and V_3 – BRRI dhan80.

4.1.3 Number of effective tillers hill^{-1}

Effect of herbicide

The number of effective tillers hill^{-1} was significantly influenced by different herbicide treatment (Table 3 and Appendix V). Weed control by Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} (W_2) gave the maximum effective tiller (15.59). On the other hand, no weed control (W_0) treatment in the field gave the minimum effective tiller (8.56). These results were dissimilar 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.

Effect of variety

Productive tillers unit area^{-1} determined the final yield of rice. This is why it is said that the higher the effective tillers, the higher the yield. It was evident from (Table 3 and Appendix V) that variety had significant effect on numbers of effective tiller hill^{-1}. BRRI dhan70 (V_1) produced higher number (13.65) and BRRI dhan79 (V_2) produced lower number (9.86) of productive tiller. Similar results were observed by Jones *et al.* (1996). The same result was reported by Peng *et al.* (1996). He found a negative correlation between maximum tiller number and percentage of productive tillers. On the other hand, the dissimilar result was reported by Hossen (2014). Found that BRRI dhan70 produced maximum effective tillers hill^{-1}.

Interaction effect

Effective tiller hill^{-1} was significantly affected by the interaction of herbicide and variety (Table 3 and Appendix V). The highest effective tiller (18.87) was obtained from the combination Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70 (W_2V_1). On the other hand, the lowest number of effective tillers (6.75) was found from the combination ofno herbicide with BRRI dhan79 (W_0V_2). The 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.

4.1.4 Number of non-effective tillers hill^{-1}

Effect of herbicide

The number of non-effective tillers hill^{-1} varied significantly due to the application of different herbicides (Table 3 and Appendix V). The maximum number of non-effective tillers hill^{-1} (12.63) was obtained from W_0 (no weeding) treatment. The minimum number of non-effective tillers hill^{-1} (6.65) was obtained from W_2 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1}) treatment. Different weed management treatment kept the land weed free and soil was aerated which facilitated the crop for absorption of greater amount plant nutrient, moisture and greater reception of solar radiation for growth, which resulted in lower number of non-effective tillers hill^{-1}. Similar findings were reported by Khan and Tarique (2011).

Effect of variety

It was found that variety had significant effect on numbers of non-effective tiller hill^{-1}(Table 3 and Appendix V). BRRI Dhan79 (V_2) produced maximum (11.33) number of non-effective tiller whereas; BRRI Dhan70 (V_1) produced minimum number (8.57) of non-productive tiller.

Interaction effect

Non-effective tiller hill^{-1} was significantly influenced by the interaction of herbicide with variety (Table 3 and Appendix V). The maximum non-effective tillers (16.73) was obtained from the combination of no herbicide with BRRI dhan79 (W_0V_2) whereas, the lowest (4.90) was found from the combinationof Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70 (W_2V_1).

4.2 Yield and other crop character

4.2.1 Panicle length

Effect of herbicide

The panicle length varied significantly due to weed control treatments shown in Table 3 and Appendix V. It was observed that the longest panicle (31.73 cm) was observed from the treatment W_2 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1}) whereas, the shortest (26.85 cm) panicle length was observed from no herbicide used treatment (W_0). 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.

Effect of variety

The panicle length varied significantly due to variety shown in Table 3 and Appendix V. It was observed that BRRI dhan70 (V_1) produced significantly longer (33.34 cm) panicle. The second longer panicle length (30.36 cm) was measured from BRRI dhan80 (V_3) and the shortest panicle length (24.67 cm) was measured from BRRI dhan79 (V_2). This confirms the report of Idris and Matin (1990) and Ahmed *et al.* (1997)who showed that panicle length was differed due to variety.

Interaction effect of herbicidal weed control and variety

Panicle length was significantly affected by the interaction of herbicide and variety (Table 3 and Appendix V). The longest (35.81 cm) panicle was observed from the combination Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70 (W_2V_1). Second highest panicle length (33.66 cm) was obtained from the combination of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1} with BRRI dhan70 (W_1V_1) and the

shorter(20.53 cm) was found from the combination no weed control and BRRI dhan79 (W_0V_2).

4.2.2 Number of total grains panicle^{-1}

Effect of herbicide

Number of total grains panicle^{-1} varied significantly due to the application of different herbicides in aromatic rice field (Table 3 and Appendix V). The maximum number of total grains panicle^{-1} (92.37) was recorded from W_2 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1}) treatment. On the other hand, the minimum number (78.93) of total grains panicle^{-1} was obtained from W_0 (no weed control) treatment. Geethu *et al.* (2014) reported that plants were affected by weed competition resulting reduce the total number of grains panicle^{-1}. Singh *et al*. (1999) also reported that weeding increase the number of grains panicle^{-1}.

Effect of variety

Number of total grains panicle^{-1} varied significantly due to the varieties in aromatic rice field (Table 3 and Appendix V). The maximum number of total grains panicle^{-1} (93.38) was recorded from V_1 (BRRI dhan70) treatment. On the other hand, the minimum number (80.26) of total grains panicle^{-1}was obtained from V_2 (BRRI dhan79) treatment.

Interaction effect

Significant variation was obtained in the number of total filled grain panicle^{-1} due to the interaction effect of herbicide and variety shown in Table 3 and Appendix V. Interaction effect of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70 (W_2V_1) gave maximum total filled grain panicle^{-1} (97.97). On the other hand, the minimum total filled grain

panicle^{-1} (73.57) was found from the interaction effect of no herbicide used with BRRI dhan79 (W_0V_2).

Table 3. Effect of herbicide, variety and their interaction on effective tillers hill^{-1}, non-effective tillers hill^{-1}, panicle length and total grains panicle^{-1} of transplant aman rice

Treatment	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Total grains panicle^{-1} (no.)
Herbicide				
W_0	8.56 d	12.63 a	26.85 c	78.93 d
W_1	11.60 b	9.61 c	29.67 b	83.97 c
W_2	15.59 a	6.65 d	31.73 a	92.37 a
W_3	11.30 c	10.70 b	29.57 b	88.92 b
$LSD_{(0.05)}$	**0.30**	**0.42**	**0.74**	**0.97**
CV (%)	**24.61**	**25.25**	**6.80**	**6.82**
Variety				
V_1	13.65 a	8.57 c	33.34 a	93.38 a
V_2	9.86 c	11.33 a	24.67 c	80.26 c
V_3	11.77 b	9.79 b	30.36 b	84.51 b
$LSD_{(0.05)}$	**0.32**	**0.31**	**0.25**	**0.50**
CV (%)	**18.11**	**13.98**	**14.95**	**7.78**
Interaction				
W_0V_1	9.92 g	9.17 g	30.66 e	86.67 f
W_0V_2	6.75 i	16.73 a	20.53 j	73.57 j
W_0V_3	9.01 h	12.00 c	29.36 g	76.56 i
W_1V_1	12.57 d	11.51 d	33.66 b	94.20 b
W_1V_2	10.17 g	10.26 f	25.20 i	76.84 i
W_1V_3	12.05 e	7.06 j	30.14 f	80.87 h
W_2V_1	18.87 a	4.90 k	35.81 a	97.97 a
W_2V_2	12.55 d	7.44 i	27.69 h	87.47 e
W_2V_3	15.34 b	7.60 i	31.70 d	91.67 c
W_3V_1	13.24 c	8.70 h	33.24 c	94.67 b
W_3V_2	9.98 g	10.90 e	25.24 i	83.17 g
W_3V_3	10.67 f	12.50 b	30.24 f	88.93 d
$LSD_{(0.05)}$	**0.37**	**0.36**	**0.28**	**0.57**
CV (%)	**26.87**	**31.35**	**14.43**	**9.22**

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

W_0 – No herbicide Used (Control), W_1 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1}, W_2 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and W_3 – Metsulfuromethyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1}.V_1 – BRRI dhan70, V_2 – BRRI dhan79 and V_3 – BRRI dhan80.

4.2.3 Number of filled grains panicle^{-1}

Effect of herbicide

Significant variation was found in filled grains panicle^{-1} due to the application of different herbicides in the aromatic rice field (Table 4 and Appendix V). The maximum number of filled grain panicle^{-1} (77.67) was recorded from W_2 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1}) treatment whereas, the minimum number of filled grain panicle^{-1} (51.08) was obtained from W_0 (no weed control) treatment. Weeding reduce crop-weed competition and provides scope to the plants for efficient utilization of solar radiation and nutrients. This might be responsible to higher number of grains panicle^{-1}. Similar results were reported by Islam (2014) and Zannat (2014). On other hand, the highest number of grains was produced in the weed free condition in rice field (Khan, 2013; Sanjoy *et al*., 1999 and Chowdhury *et al.*,1995). This result was not supported 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}. However, similar findings were stated by Karim and Ferdous (2010) who revealed that the number of filled grains panicle^{-1} was negatively related to weed density.

Effect of variety

Significant variation was found in filled grains panicle^{-1} due to the varieties in the aromatic rice field (Table 4 and Appendix V). The maximum number of filled grain panicle^{-1} (75.78) was recorded from V_1 (BRRI dhan70) treatment and the minimum number of filled grain panicle^{-1} (55.96) was obtained from V_2 (BRRI dhan79) treatment. These results were in agreement with Ahmed *et al.* (1997a) who reported that percent filled grain was the highest in Nizersail (a local variety) followed by BR25 and the lowest in BR11 and BR23.

Interaction effect

Significant variation was found in filled grains panicle^{-1} due to the application of different herbicides with varieties in the aromatic rice field (Table 4 and Appendix V). The maximum number of filled grain panicle^{-1} (86.46) was recorded from the interaction effect of W_2V_1 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70) treatment and the second maximum was found (79.49) W_3V_1 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1} with BRRI dhan70) treatment. On the other hand, the minimum number of filled grain panicle^{-1} (41.89) was obtained from W_0V_2 (no weed control with BRRI dhan79) treatment. 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.

4.2.4 Number of unfilled grains panicle^{-1}

Effect of herbicide

Unfilled grains panicle^{-1} varied significantly due to the application of different herbicides (Table 4 and Appendix V). The height number of unfilled grains panicle^{-1} (27.85) was recorded from W_0 (no weed control) treatment. The lowest number of unfilled grain panicle^{-1} (14.70) was obtained from W_2 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1}) treatment. Rafiquddualla (1999) observed that maximum non-effective tillers hill^{-1} and sterile grains were found from the no weeding regimes.

Effect of variety

Significant variation was obtained in unfilled grain due to the effect of variety (Table 4 and Appendix V). BRRI dhan79 (V_2) produced highest unfilled grain (24.30). The second highest unfilled grain (21.21) was obtained from BRRI dhan80 (V_3) and the lowest unfilled grain (17.60) from BRRI dhan70 (V_1). BRRI dhan79 produced 33.76 % highest unfilled grain than BRRI dhan70. Similar findings were reported by Ahmed *et al.* (1997a).

Interaction effect

Significant variation was obtained in unfilled grain due to the interaction effect of weed control method and variety shown in Table 4 and Appendix V. Interaction effect of no weed control with BRRI dhan79 (W_0V_2) gave highest unfilled grain (31.68) whereas, the lowest unfilled grain (11.51) was found from the interaction effect of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70 (W_2V_1).

4.2.5 Weight of 1000-grains

Effect of herbicide

Herbicidal weed control showed significant variation in weight of 1000-grain (Table 4 and Appendix V). Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} (W_2) gave the highest weight of 1000-grain (27.52 g). On the other hand, the lowest weight of 1000-grain (20.33 g) was found from no weed control (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. However, this result was dissimilar with the findings of Nahar *et al.* (2010) and Karim and Ferdous (2010) who observed that weight of 1000-grainwas negatively related to weed density.

Effect of variety

Weight of 1000 grains showed significant variation among the different varieties (Appendix V). BRRI dhan70 (V_1) produced highest weight of 1000-grain (26.24 g) and the second highest weight of 1000-grain (23.88 g) was found in BRRI dhan80 (V_3) (Table 4). The lowest weight of 1000-grain(21.59 g) was obtained from BRRI dhan79 (V_2). Similar findings were reported by Hossain *et al.* (2007).

Interaction effect

Interaction effect of herbicidal weed control and variety showed significant variation in weight of 1000-grainshown in (Table 4 and Appendix V). The highest weight of 1000-grain (29.24 g) was found from the interaction effect of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70 (W_2V_1). The second highest weight of 1000-grain (28.29 g) was obtained from the interaction effect of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1} with BRRI dhan70 (W_3V_1) which was statistically identical with W_2V_3 (27.83 g). The lowest weight of 1000-grain (18.34 g) was found with the interaction effect of no weed control with BRRI dhan79 (W_0V_2). 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. However, this result was not in agreement with Nahar *et al.* (2010) who found that weeding regime had significant effect on all the parameters except weight of 1000-grainin transplant *aman* rice cv. BRRI dhan41.

Table 4. Effect of herbicide, variety and their interaction on filled grains panicle^{-1}, unfilled grains panicle^{-1} and weight of 1000-grainof transplant aman rice.

Treatments	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	weight of 1000-grain(g)
Herbicide			
W_0	51.08 d	27.85 a	20.33 d
W_1	61.23 c	22.74 b	23.39 c
W_2	77.67 a	14.70 d	27.52 a
W_3	70.06 b	18.86 c	24.37 b
$LSD_{(0.05)}$	**2.49**	**1.62**	**0.40**
CV (%)	**11.30**	**12.97**	**0.94**
Variety			
V_1	75.78 a	17.60 c	26.24 a
V_2	55.96 c	24.30 a	21.59 c
V_3	63.29 b	21.21 b	23.88 b
$LSD_{(0.05)}$	**1.76**	**1.29**	**0.50**
CV (%)	**10.50**	**15.17**	**2.57**
Interaction			
W_0V_1	62.32 e	24.35 cd	21.61 e
W_0V_2	41.89 i	31.68 a	18.34 g
W_0V_3	49.03 h	27.53 b	21.05 ef
W_1V_1	74.85 c	19.35 f	25.83 c
W_1V_2	51.23 g	25.61 c	20.98 f
W_1V_3	57.62 f	23.25 de	23.36 d
W_2V_1	86.46 a	11.51 i	29.24 a
W_2V_2	69.87 d	17.60 g	25.49 c
W_2V_3	76.69 c	14.98 h	27.83 b
W_3V_1	79.49 b	15.20 h	28.29 b
W_3V_2	60.85 e	22.29 e	21.54 ef
W_3V_3	69.83 d	19.10 f	23.29 d
$LSD_{(0.05)}$	**2.03**	**1.41**	**0.58**
CV (%)	**14.44**	**18.05**	**4.13**

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probabilityW_0 – No herbicide Used (Control), W_1 – Metsulfuronmethyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1}, W_2 – Metsulfuron methyl 10% Chlorimuron ethyl 2% @ 20 g ha^{-1} and W_3 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1}.

V_1 – BRRI dhan70, V_2 – BRRI dhan79 and V_3 – BRRI dhan80.

4.3 Yield parameters

4.3.1 Grain yield

Effect of herbicide

Rice grain yield (t ha^{-1}) varied significantly due to the application different herbicides in the aromatic rice field (Table 5 and Appendix VI). The highest grain yield (5.66 t ha^{-1}) was recorded from W_2 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1}) treatment. On the other hand, the lowest grain yield (4.29 t ha^{-1}) was obtained from W_0 (no weed control) treatment. These might be due to the fact that the weeding kept the rice field less infested and soil was well aerated which facilitated the crop for absorption of greater amount of plant nutrients, moisture and greater reception of solar radiation for better growth. Chowdhury *et al.* (1995) reported that the highest grain yield was produced from weed free plot because of less competition with weeds. The similar results also reported by several authors (Singh *et al.*, 2014; Acharya and Bhattacharya, 2013; Halder *et al.*, 2005; Saha, 2005 and Tamilselvan and Budhar, 2001). The dissimilar findings were reported by Al-Mamun *et al.* (2011), Bhuiyan *et al.* (2011a), Bhuiyan *et al.* (2011b), Khan and Tarique (2011), Mamun *et al.* (2011c), Shultana *et al.*(2011), Ali *et al.* (2010), Bhuiyan *et al.* (2010), Gnanavel and Anbhazhagan (2010), Islam *et al.* (2010b), 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.

Effect of variety

Rice grain yield (t ha^{-1}) varied significantly for different varieties shown in Table 5 and Appendix VI. The highest grain yield (5.48 t ha^{-1}) was recorded by BRRI dhan70 (V_1). The second highest grain yield (4.94 t ha^{-1}) was recorded from BRRI dhan80 (V_3). On the other hand, the lowest grain yield (4.44 t ha^{-1})

was recorded from BRRI dhan79 (V_2). This result was similar with Chowdhury (2012) and Franje *et al.* (1992) who found that yields of modern cultivars

Table 5: Effect of herbicide, variety and their interaction on grain yield, straw yield and biological yield of transplant aman rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Herbicide			
W_0	4.29 c	5.71 a	10.00
W_1	4.93 b	5.01 b	9.94
W_2	5.66 a	4.15 c	9.81
W_3	4.94 b	4.88 b	9.82
LSD $_{(0.05)}$	**0.46**	**0.36**	**NS**
CV (%)	**11.30**	**12.94**	**0.94**
Variety			
V_1	5.48 a	4.12 c	9.60 b
V_2	4.44 c	5.59 a	10.03 a
V_3	4.94 b	5.11 b	10.05 a
LSD$_{(0.05)}$	**10.50**	**15.17**	**2.57**
CV (%)			
Interaction			
W_0V_1	4.38 fg	5.15 cd	9.53 def
W_0V_2	4.11 g	6.48 a	10.59 a
W_0V_3	4.37 fg	5.51 b	9.88 cd
W_1V_1	5.52 c	4.19 f	9.37 ef
W_1V_2	4.49 ef	5.55 b	10.04 bc
W_1V_3	4.79 de	5.30 bc	10.09 bc
W_2V_1	6.24 a	2.93 g	9.17 f
W_2V_2	4.84 d	4.97 d	9.81 cde
W_2V_3	5.89 b	4.54 e	10.43 ab
W_3V_1	5.78 bc	4.20 f	9.98 cd
W_3V_2	4.32 fg	5.35 bc	9.67 cde
W_3V_3	4.72 de	5.10 cd	9.82 cde
LSD$_{(0.05)}$	**0.33**	**0.28**	**0.45**
CV (%)	**14.44**	**18.05**	**4.13**

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

W_0 – No herbicide Used (Control), W_1 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1}, W_2 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and W_3 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1}.

V_1 – BRRI dhan70, V_2 – BRRI dhan79 and V_3 – BRRI dhan80.

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}).

Interaction effect

Rice grain yield (t ha^{-1}) varied significantly due to different weed control treatment and varietal combinations (Table 5 and Appendix VI). The highest grain yield (6.24 t ha^{-1}) was recorded from Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and BRRI dhan70 combination (W_2V_1) treatment whereas, the lowest grain yield (4.11 t ha^{-1}) was recorded from no weed control and BRRI dhan 79 combination (W_0V_2) treatment which was the statistically similar with W_3V_2 (4.32 t ha^{-1}), W_0V_3 (4.37 t ha^{-1}) and W_0V_1 (4.38 t ha^{-1}). 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.* (2010a), Nahar *et al.* (2010), Salam *et al.* (2010), Gnanavel and Anbhazhagan (2010) and Bijon (2004).

4.3.2 Straw yield

Effect of herbicide

Rice straw yield (t ha^{-1}) varied significantly due to the application of different herbicides in the aromatic rice field (Table 5 and Appendix VI). The maximum

straw yield (5.71 t ha^{-1}) was recorded from W_0 (no weed control) treatment and the second maximum (5.01 t ha^{-1}) was recorded from W_1 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1}) which was statistically similar to and W_3 (4.88 t ha^{-1}) treatment whereas, the minimum straw yield (4.15 t ha^{-1}) was obtained from W_2 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1}) treatment. Rafiquddaulla (1999) observed that the weed dry weight was significantly affected by the weeding regimes. The maximum straw yield was obtained from weed free condition which was similar to three hand weeding at 20, 40 and 60 DAT. 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.

Effect of variety

There observed significant variation for straw yield (t ha^{-1}) due to varietal variation (Table 5 and Appendix VI). BRRI dhan79 (V_2) recorded the maximum straw yield (5.59 t ha^{-1}) and BRRI dhan70 (V_1) recorded the minimum straw yield (4.12 t ha^{-1}). Similar findings were also reported by Hassan *et al.* (2010).

Interaction effect

The straw yield (t ha^{-1}) varied significantly due to different weed control and varietal treatment combinations (Table 5 and Appendix VI). The maximum straw yield (6.48 t ha^{-1}) was obtained from the combination no weed control with BRRI dhan79 (W_0V_2). On the other hand, the minimum (2.93 t ha^{-1}) was found from the combination Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70 (W_2V_1). 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).

4.3.3 Biological yield

Effect of herbicide

The biological yield (t ha^{-1}) varied non-significantly due to different weed control treatments shown in Table 5 and Appendix VI. Table 5 showed that no weed control (W_0) gave the numerically highest biological yield (10.00 t ha^{-1}) and weeds controlled by Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} (W_2) treatment gave the numerically lowest biological yield (9.81 t ha^{-1}). Similar results were also observed by Hossen(2014). Variations inbiological yield among the treatment were dependent upon the severity of weed infestation thus affected grain yield and straw yield. Ahmed *et al.* (1998) reported that grain and straw yield both (biological yield) decreased with increasing weed population and weed competition duration that also partially supported the present experimental result.

Effect of variety

The biological yield (t ha^{-1}) varied significantly due to variety shown in Table 5 and Appendix VI. It was observed that BRRI dhan80 (V_3) produced significantly highest biological yield (10.05 t ha^{-1}) which was statistically similar with BRRI dhan79 (10.03 t ha^{-1}) and the lowest biological yield (9.60 t ha^{-1}) was recorded from BRRI dhan70 (V_1). Similar results were also observed by Hossen(2014) and Chowdhury (2012).

Interaction effect

Biological yield (t ha^{-1}) was significantly affected by the interaction of different weed control and varietal treatment combinations in aromatic rice field (Table 5 and Appendix VI). The highest biological yield (10.59 t ha^{-1}) was obtained from the combination noi weed control with BRRI dhan70 (W_0V_2) which was statistically similar with W_2V_3 (10.43 t ha^{-1}), W_1V_3 (10.09 t ha^{-1}) and W_1V_2 (10.04 t ha^{-1}). On the other hand, the lowest biological yield (9.17 t ha^{-1}) was found from the combination Metsulfuron methyl 10% +

Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70 (W_2V_1) which was statistically similar with W_1V_1 (9.37 t ha^{-1}) and W_0V_1 (9.53 t ha^{-1}). 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}.

4.3.4 Harvest index

Effect of herbicide

Harvest index (%) of rice varied significantly due to the application of different herbicides in the aromatic rice field (Table 6 and Appendix VI). The harvest harvest index (58.02 %) was recorded from W_2 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1}) treatment. On the other hand, the lowest harvest index (43.01 %) was obtained from W_0 (no weed control) treatment. These findings are further supported with the work of Al-Mamun *et al.* (2011) and Bhuiyan *et al.* (2011b), who obtained better yields in rice with herbicide use. Similar findings were observed by Manish *et al.* (2006) who stated that weeding had significant variation on harvest index.

Effect of variety

Variety showed significant variation in harvest index (Table 6 and Appendix VI). BRRI dhan70 (V_1) showed the highest harvest index (57.76 %) whereas, the lowest harvest index (44.38 %) in BRRI dhan79 (V_2). Similar results were also observed by Hossen(2014) and Chowdhury (2012).

Interaction effect

Interaction effect of weeding and variety showed significant variation in harvest index (Table 6 and Appendix VI). The highest harvest index (68.25%) was observed from the interaction effect of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70 (W_2V_1). On the other

hand, the lowest harvest index (38.84 %) was obtained from the interaction of no weed control with BRRI dhan79 (W_0V_2).

Table 6. Effect of herbicide, variety and their interaction on harvest index, days to weed emergence and number of weed species m^{-2} in transplant aman rice

Treatment	Harvest index (%)	Days to weed emergence	Weed species m^{-2} (no.)
Herbicide			
W_0	43.01 c	11.11 d	17.71 a
W_1	50.34 b	16.11 c	12.72 b
W_2	58.02 a	22.78 a	5.51 d
W_3	50.23 b	18.56 b	9.19 c
$LSD_{(0.05)}$	**3.98**	**1.97**	**0.86**
CV (%)	**8.14**	**8.01**	**6.42**
Variety	**12.16**	**28.43**	**46.08**
V_1	57.76 a	17.42	10.96 b
V_2	44.38 c	16.92	10.14 c
V_3	49.07 b	17.08	12.75 a
$LSD_{(0.05)}$	**2.37**	**NS**	**6.42**
CV (%)	**13.47**	**1.49**	
Interaction			**11.83**
W_0V_1	45.97 de	10.00 f	16.75 c
W_0V_2	38.84 f	12.00 e	17.52 b
W_0V_3	44.23 e	11.33 ef	18.86 a
W_1V_1	58.86 b	16.33 d	12.10 e
W_1V_2	44.65 e	15.33 d	11.56 e
W_1V_3	47.50 cd	16.67 d	14.51 d
W_2V_1	68.25 a	24.33 a	5.25 h
W_2V_2	49.34 c	22.00 b	3.52 i
W_2V_3	56.47 b	22.00 b	7.75 g
W_3V_1	57.95 b	19.00 c	9.72 f
W_3V_2	44.68 e	18.33 c	7.97 g
W_3V_3	48.07 cd	18.33 c	9.87 f
$LSD_{(0.05)}$	**2.74**	**1.49**	**0.67**
CV (%)	**16.45**	**26.13**	**43.25**

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

W_0 – No herbicide Used (Control), W_1 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1}, W_2 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and W_3 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1}.

V_1 – BRRI dhan70, V_2 – BRRI dhan79 and V_3 – BRRI dhan80.

4.4 Weed parameters

4.4.1 Days to weed emergence

Effect of herbicide

Days to weed emergence varied significantly due to weed control treatments shown in Table 6 and Appendix VI. It was observed that the maximum weed emergence (22.78 days) was observed from the treatment W_2 (Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1}) whereas, the minimum weed emergence (11.11 days) was observed from no herbicide used treatment (W_0).

Effect of variety

Days to weed emergence varied non-significantly due to deferent varieties shown in Table 6 and Appendix VI. It was observed that the numerically maximum weed emergence (17.42 days) was observed from the treatment V_1 (BRRI dhan70) whereas, the minimum weed emergence (16.92 days) was observed from BRRI dhan79 treatment (V_2).

Interaction effect

Interaction effect of weeding and variety showed significant variation in weed emergence (Table 6 and Appendix VI). The maximum weed emergence (24.33 days) was observed from the interaction effect of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70 (W_2V_1). On the other hand, the minimum weed emergence (10.00 days) was obtained from the interaction of no weed control with BRRI dhan70 (W_0V_1) which was statistically similar with W_0V_3 (11.33 days) and W_0V_2 (12.00 days).

4.4.2 Number of weed species m^{-2}

a) Effect of herbicide

Significant variation was observed on weed density throughout the growing period for different weed control treatments (Table 6 and Appendix VI). The highest weed population (17.71 no. m^{-2}) was observed in control (W_0) treatment throughout the harvesting time whereas, the lowest weed population (5.51 no. m^{-2}) was observed in case of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} (W_2). Herbicidal treatments drastically reduced weed population. This result was supported by Bhuiyan *et al.* (2010) who reported that pre emergence application of Metsulfuron methyl @ 75 g ha^{-1} had minimum population than any other herbicide and doses. Similar results were also stated by Bhuiyan *et al.* (2011a), 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). Rafiqudduallа (1999) observed that no weeding regimes produced the highest weed density. Madhukumar *et al*. (2013) reported that unweeded field produces significantly higher total weed density (253.00 no. m^{-2}).

b) Effect of variety

There was significant variation observed on weed density at harvesting time for varietal variation (Table 6 and Appendix VI). At harvesting time, the highest weed population (12.75 no. m^{-2}) was observed in BRRI dhan80 (V_3) whereas, the lowest weed population (10.14 no. m^{-2}) was observed in case of BRRI dhan79 (V_2). 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.

c)Interaction effect

For herbicidal weed control and varietal combination, significant variation was observed for weed density throughout the growing period shown in Table 6 and Appendix VI. The maximum no. of weed population (18.86 m^{-2}) was recorded from the combinations of no weeding and BRRI dhan80 (W_0V_3) which was second maximum population (17.52 no. m^{-2}) was recorded from W_0V_2. On the other hand, the minimum no. of weed density (3.52 m^{-2}) was observed from the combinations of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and BRRI dhan79 (W_2V_2). This result was similar with the findings of Gnanavel and Anbhazhagan (2010) who observed that Pre-emergence application of Metsulfuron methyl 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.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University (SAU), during July to December 2018 with view to finding out the performance of modern aromaticrice as affected by the herbicidal weed control method. The experiment was laid out in a split plot design with three replications. The size of the individual plot was 4 m × 2.5 m and total numbers of plots were 36. There were 12 treatment combinations. Herbicidal weed control was placed along the main plot and Variety in the sub plot.Weed control methods *viz.*: W_0 – No herbicide Used (Control), W_1 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1}, W_2 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and W_3 – Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1}. 30 days old seedlings of V_1 - BRRI dhan70, V_2 - BRRI dhan79 and V_3 - BRRI dhan80 were transplanted on the well-puddled experimental plots on 04 August 2018 by using two seedlings $hill^{-1}$.

Data were collected on the following parameters - plant height (cm), dry weight $hill^{-1}$ (g), number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, panicle length (cm), 1000-seed weight (g), number of filled grains $panicle^{-1}$, number of unfilled grains $panicle^{-1}$, total number of grains $panicle^{-1}$, grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}), harvest index (%), weed species (no. m^{-2}) and days to weed emergence. The collected data were analysed by computer package program MSTAT-C software. The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability.

Effect of herbicidal weed control showed significant variation on plant height, dry weight $hill^{-1}$, number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, panicle length, 1000-seeds weight, number of filled grains $panicle^{-1}$, number of unfilled grains $panicle^{-1}$, total number of grains $panicle^{-1}$,

grain yield, straw yield, harvest index, weed species and days to weed emergence for harvesting stages of aromatic rice except biological yield. Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1} (W_1) scored the longest plant (122.17 cm) and no weeding treatment (W_0) attained the shortest plant (110.80 cm). Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1} (W_3) achieved the highest dry weight $hill^{-1}$ (56.80 g) and the lowest dry weight $hill^{-1}$ (51.31 g) was observed in no weeding treatment (W_0). Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} (W_2) gave the maximum effective tiller (15.59), maximum number of total grains $panicle^{-1}$ (92.37), longest panicle (31.73 cm), maximum number of filled grain $panicle^{-1}$ (77.67), highest weight of 1000-grain (27.52 g), highest grain yield (5.66 t ha^{-1}), highest wighest harvest index (58.02 %) and maximum weed emergence (22.78 days). On the other hand, no weed control (W_0) treatment in the field gave the minimum effective tiller (8.56), shortest panicle length (26.85 cm), minimum number of total grains $panicle^{-1}$ (78.93), minimum number of filled grain $panicle^{-1}$ (51.08), lowest weight of 1000-grain (20.33 g), lowest grain yield (4.29 t ha^{-1}), lowest harvest index (43.01 %), minimum weed emergence (11.11 days) and lowest weed population (5.51 no. m^{-2}). No weed control (W_0) treatment gave themaximum number of non-effective tillers $hill^{-1}$ (12.63), heighest number of unfilled grains $panicle^{-1}$ (27.85),maximum straw yield (5.71 t ha^{-1}),highest biological yield (10.00 t ha^{-1}) andhighest weed population (17.71 no. m^{-2}). On the other hand, Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} (W_2) treatment gave the minimum number of non-effective tillers $hill^{-1}$ (6.65), lowest number of unfilled grain $panicle^{-1}$ (14.70), minimum straw yield (4.15 t ha^{-1}) and lowest biological yield (9.81 t ha^{-1}).

Effect of deferent varieties showed significant variation on plant height, dry weight $hill^{-1}$, number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, panicle length, 1000-seeds weight, number of filled grains $panicle^{-1}$, number of unfilled grains $panicle^{-1}$, total number of grains $panicle^{-1}$, grain yield, straw yield, harvest index, weed species and days to weed emergence for

harvesting stages of aromaticrice. BRRI dhan79 (V_1) was recorded the tallest plant (116.63 cm), maximum number of non-effective tiller (11.33) whereas, the lowest plant height (113.03 cm), minimum number of non-productive tiller (8.57) was recorded from BRRI dhan80 (V_3). BRRI dhan70 (V_1) achieved the highest dry weight (55.55 g hill^{-1}), higher number of productive tiller (13.65), longer panicle (33.34 cm), maximum number of total grains panicle^{-1} (93.38), maximum number of filled grain panicle^{-1} (75.78), highest weight of 1000-grain (26.24 g), highest grain yield (5.48 t ha^{-1}), highest harvest index (57.76 %) and maximum weed emergence (17.42 days). On the other hand, BRRI dhan79 (V_2) was observed the lowest dry weight (52.29 g hill^{-1}), lower number of productive tiller (9.86), shortest panicle length (24.67 cm), minimum number (80.26) of total grains panicle^{-1}, minimum number of filled grain panicle^{-1} (55.96), lowest weight of 1000-grain (21.59 g), lowest grain yield (4.44 t ha^{-1}), lowest harvest index (44.38 %) and minimum weed emergence (16.92 days).

Interaction effect of weeding and variety showed significant variation in plant height, dry weight hill^{-1}, number of effective tillers hill^{-1}, number of non-effective tillers hill^{-1}, panicle length, 1000-seeds weight, number of filled grains panicle^{-1}, number of unfilled grains panicle^{-1}, total number of grains panicle^{-1}, grain yield, straw yield, harvest index, weed species and days to weed emergence for harvesting stages of aromatic rice. Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 15 g ha^{-1} and BRRI dhan79 (W_1V_2) achieved the tallest plant (123.10 cm), while the lowest (105.10 cm) was recorded from no weeding and BRRI dhan80 (W_0V_3). The treatment combination of Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 25 g ha^{-1} with BRRI dhan70 (W_3V_1) produced the highest dry weight (69.84 g hill^{-1}) whereas, the treatment combination of no weeding with BRRI dhan80 (W_0V_3) produced the lowest dry weight (44.96 g hill^{-1}).The highest effective tiller (18.87), longest panicle (35.81 cm), maximum total filled grain panicle^{-1} (97.97), maximum number of filled grain panicle^{-1} (86.46), highest weight of 1000-grain (29.24 g), highest grain yield (6.24 t ha^{-1}), highest harvest index (68.25 %) and

maximum weed emergence (24.33 days)was obtained from the combination Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} with BRRI dhan70 (W_2V_1). On the other hand, the lowest number of effective tiller (6.75), shorter panicle (20.53 cm), minimum total filled grain $panicle^{-1}$ (73.57), minimum number of filled grain $panicle^{-1}$ (41.89), lowest weight of 1000-grain(18.34 g), lowest grain yield (4.11 t ha^{-1}), lowest harvest index (38.84 %) and minimum weed emergence (10.00 days)was found from the combination no weed control with BRRI dhan79 (W_0V_2). The results obtained from all other treatments showed intermediate results compared to the highest and the lowest value of all growth and yield parameters.

Conclusion

1. It may be concluded from the results that different weed control treatment and varieties is very much promising for higher aromatic rice yield.

2. The Metsulfuron methyl 10% + Chlorimuron ethyl 2% @ 20 g ha^{-1} and BRRI dhan70showed better performance on growth and yield under the present study.

Recommendations

The present experiment was conducted only one season even in a single location. Therefore, it is difficult to recommend this finding without further study. By considering the results of the present experiment, further studies in the following areas are suggested below:

1. Studies of similar nature could be carried out in different Agro Ecological Zones (AEZ) in different seasons of Bangladesh for the evaluation of zonal adaptability.

2. In this study, minimum ten different herbicide and all aromatic rice varieties was used to get accurate result.

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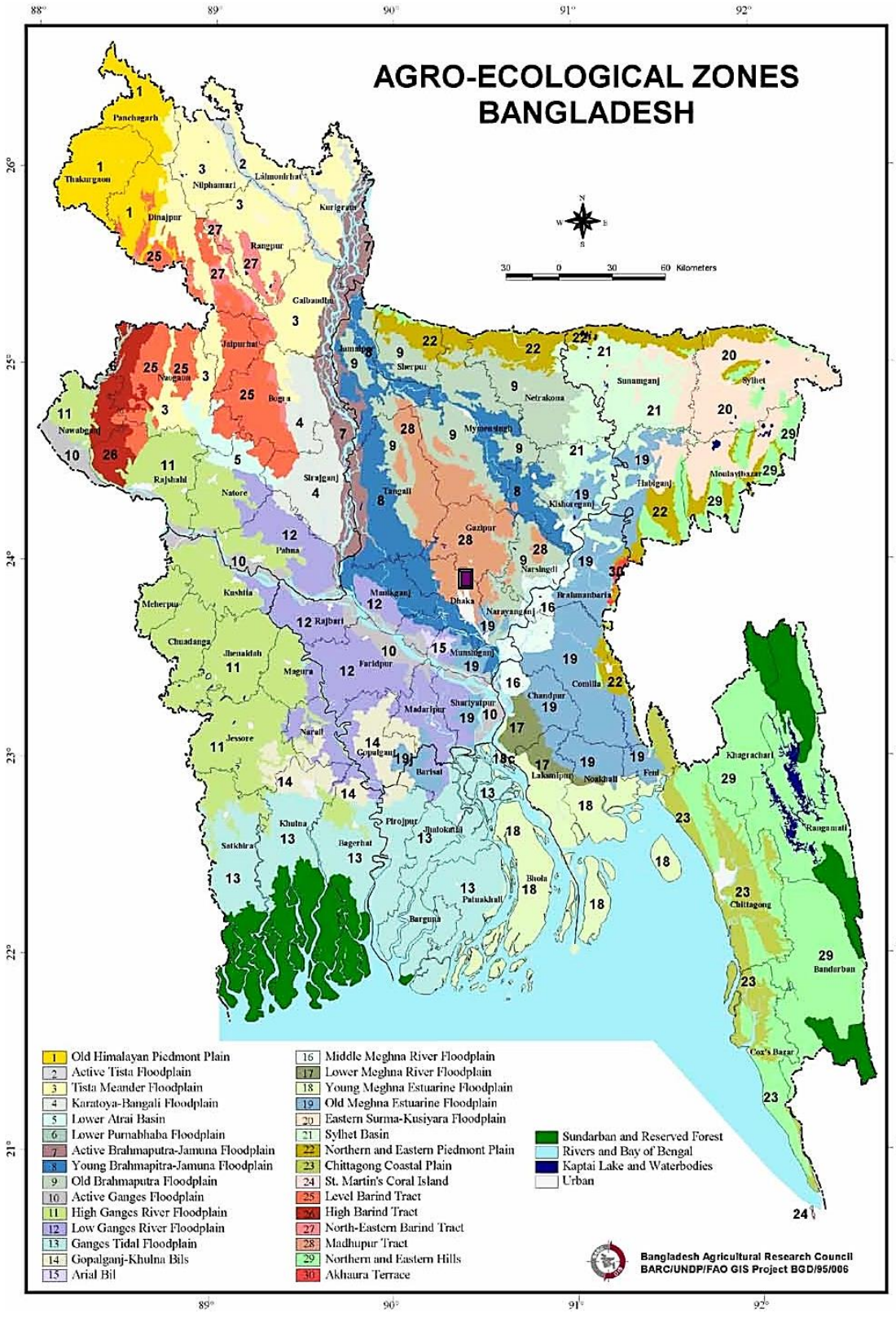
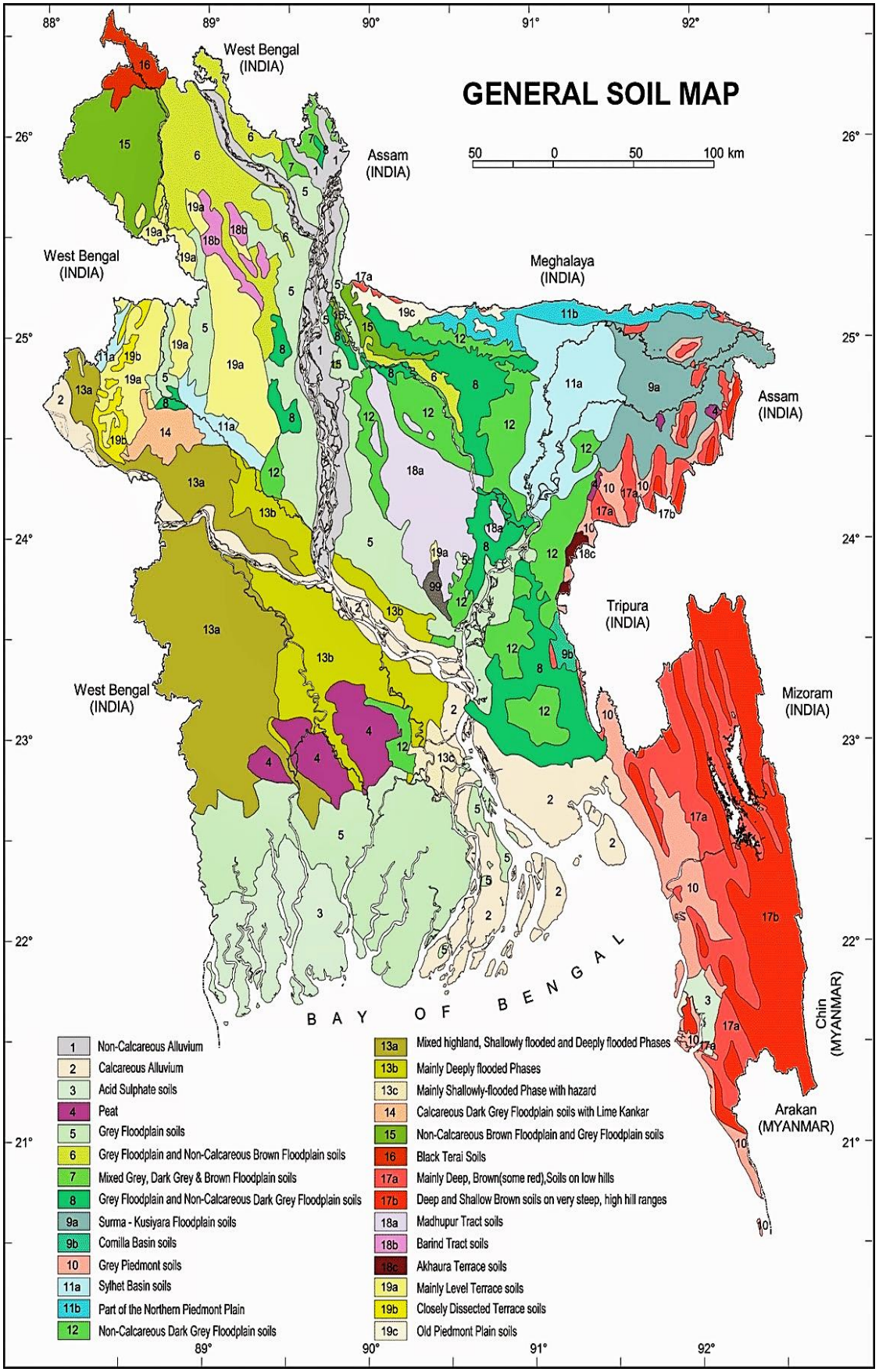
APPENDICES

Appendix I(A): Map showing the experimental sites under study



■The experimental site under study

Appendix I (B): Map showing the general soil sites under study



Appendix II: Characteristics of Agronomy Farm soil is analysed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Potato-Aus rice-Aman rice

B. Physical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30

C. Chemical properties of the initial soil

Characteristics	Value
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix III: Monthly average temperature, relative humidity and total rainfall of theexperimental site during the period from June 2018 to November 2018

Year	Month	Temperature			Relative Humidity (%)	Total Rainfall (mm)	Sunshine (Hour)
		Max (°C)	Min (°C)	Mean (°C)			
2018	June	34	28	30	73	88.6	300
	July	33	27	30	76	46.53	268
	August	34	27	30	76	66.92	302
	September	34	27	30	71	64.14	292.5
	October	33	26	30	59	33	238
	November	33	25	29	51	12.3	210.5

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka.

Appendix IV: Mean sum- square values for plant height and dry weight hill^{-1} of transplant aman rice at different days after transplanting (DAT) and at harvest as influenced by herbicide, variety and their interaction

Source of variation	df	Plant height				Dry matter hill^{-1}			
		20 DAT	45 DAT	70 DAT	Harvest	20 DAT	45 DAT	70 DAT	Harvest
Replication	2	76.159	131.351	300.077	153.855	0.135	4.142	29.249	55.621
Herbicide (A)	3	5.883*	6.669*	37.077*	133.105*	0.698**	47.443*	6.141*	46.363*
Error	6	0.343	2.658	0.387	0.861	0.014	0.098	1.520	0.057
Variety (B)	2	6.639*	35.816*	211.461*	154.849*	0.004^{NS}	2.554**	32.815*	32.030*
AB	6	11.987*	242.954*	247.951*	20.526*	0.369**	27.826*	37.520*	319.550*
Error	16	0.217	1.321	0.110	1.049	0.004	0.099	0.832	0.021

* Significant at 5% level of probability

** Significant at 1% level of probability

Appendix V: Mean sum- square values for effective tillers hill^{-1}, non- effective tillers hill^{-1}, panicle length, total grains panicle^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1} and weight of 1000-grainof transplant aman rice as influenced by herbicide, variety and their interaction

Source of variation	**df**	**Effective tiller hill^{-1}**	**Non-effective tiller hill^{-1}**	**Panicle length**	**Total grains panicle^{-1}**	**Filled grains panicle^{-1}**	**Unfilled grains panicle^{-1}**	**1000-grains weight**
Replication	2	0.347	0.417	2.475	110.961	7.270	1.729	1.143
Herbicide (A)	3	75.374*	56.318*	36.140*	309.563*	1182.445*	282.755*	78.980*
Error	6	0.022	0.044	0.137	0.234	1.554	0.660	0.040
Variety (B)	2	43.112*	22.998*	233.285*	537.254*	1204.981*	134.716*	64.988*
AB	6	2.891**	18.126*	3.508**	11.555*	11.509*	0.562**	3.129**
Error	16	0.045	0.044	0.026	0.110	1.378	0.666	0.112

* Significant at 5% level of probability

** Significant at 1% level of probability

Appendix VI: Mean sum- square values for grain yield, straw yield, biological yield, harvest index of transplant aman rice and days to weed emergence and number of weeds m^{-2} as influenced by herbicide, variety and their interaction

Source of variation	**df**	**Grain yield**	**Straw yield**	**Biological yield**	**Harvest Index**	**Days to weed emergence**	**Number of weeds m^{-2}**
Replication	2	0.235	0.270	0.745	0.795	3.528	0.359
Herbicide (A)	3	2.814**	3.713**	0.075^{NS}	337.980*	213.583*	243.524*
Error	6	0.052	0.032	0.048	3.975	0.972	0.185
Variety (B)	2	3.236**	6.770*	1.121**	553.281*	0.778^{NS}	21.315*
AB	6	0.322**	0.269**	0.502**	24.727*	3.222**	2.141**
Error	16	0.036	0.026	0.067	2.498	0.736	0.149

* Significant at 5% level of probability

** Significant at 1% level of probability