COMPETITIVE EFFECT OF FREE FLOATING PLANTS ON WEED CONTROL, GROWTH AND YIELD OF TRANSPLANTED AMAN RICE

MD. TANVIR WAHID

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

JUNE, 2021

COMPETITIVE EFFECT OF FREE FLOATING PLANTS ON WEED CONTROL, GROWTH AND YIELD OF TRANSPLANTED AMAN RICE

BY

MD. TANVIR WAHID

REGISTRATION NO: 14-05852

A Thesis

Submitted to the Faculty of Agriculture,

Sher-e-Bangla Agricultural University, Dhaka,

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE (M.S.)

IN

AGRONOMY

SEMESTER: JANUARY- JUNE, 2021

Approved by:

Dr. Sheikh Muhammad Masum	**Prof. Dr. Hazrat Ali**
Supervisor	**Co-Supervisor**

Prof. Dr. Tuhin Suvra Roy

Chairman

Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar

Dhaka-1207

CERTIFICATE

This is to certify that thesis entitled, "COMPETITIVE EFFECT OF FREE FLOATING PLANTS ON WEED CONTROL, GROWTH AND YIELD OF TRANSPLANTED AMAN RICE" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in AGRONOMY, embodies the result of a piece of bona-fide research work carried out by MD. TANVIR WAHID, Registration no. ***14-05852*** *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 during the course of this investigation has duly been acknowledged.

Date:

Place: Dhaka, Bangladesh

Dr. Sheikh Muhammad Masum

Department of Agronomy

Sher-e-Bangla Agricultural University,

Dhaka-1207

DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises to the Almighty Allah, the great, the gracious, merciful and supreme ruler of the universe who enables me to complete this present piece of work for the degree of Master of Science (M.S.) in the Department of Agronomy.

The author would like to express his deepest sense of gratitude, respect to his research supervisor, ***Dr. Sheikh Muhammad Masum****, Department of Agronomy, Sher- e-Bangla Agricultural University, for his kind and scholastic guidance, untiring effort, valuable suggestions, inspiration, extending generous help and encouragement during the research work and guidance in preparation of manuscript of the thesis.*

The author sincerely expresses his deepest respect and boundless gratitude to his co-supervisor ***Prof. Dr. Hazrat Ali,*** *Vice chancellor, First Capital University of Bangladesh, for his helpful suggestion and valuable advice during the preparation of this manuscript.*

It is highly appreciating words for ***Prof. Dr. Tuhin Suvra Roy*** *Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, for the facilities provided, in carrying out this work. The author also acknowledges with deep regards the help and cooperation received from his respected teachers and stuff of the Department of Agronomy, Sher-e-Bangla Agricultural University while carrying out this work.*

The author feels proud to express his sincere appreciation and gratitude to Ministry of Science and Technology, The People's Republic of Bangladesh for awarding him National Science and Technology (NST) fellowship.

At last but not the least, the author feels indebtedness to his beloved parents and brother whose sacrifice, inspiration, encouragement and continuous blessing paved the way to his higher education and reach at this stage. May Allah bless us.

The Author

COMPETITIVE EFFECT OF FREE FLOATING PLANTS ON WEED CONTROL, GROWTH AND YIELD OF TRANSPLANTED AMAN RICE VARIETIES

ABSTRACT

A study was conducted to find out the suppressing ability of floating weeds in T. *aman* rice (*Oryza sativa* L.) at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh from July 2019 to December 2019. The experiment consisted of two factors viz. rice varieties (3) i.e. Tulshimala, BR11(Mukta) and BRRI hybrid dhan6, and weed management (4) i.e. weedy check (control), Integrated Weed Management (one pre-emergence herbicide Pretilachlor 6% + pyrazosulfuron 0.15% and one hand weeding), spreading of Water Lettuce (*Pistia stratiotes*), Duckweed (*Lemna minor*) and Kariba weed (*Salvinia molesta*) in 0.5 m^2 area. The experiment was laid out in a split-plot design with three replications. The ranking of the relative rate of spreading (RRS) over the experiment *L. minor* > *S. molesta* > *P. stratiotes*. A total of 6 weed species representing 5 families were found from the transplanting to the later stage of rice growth where the occurrence of weed infestation related to rice variety and crop growth. BRRI hybrid dhan6 significantly suppressed weeds in related plots. Integrated weed management successfully control all weeds and gave the highest weed control efficiency and weed control index. Although weed biomass significantly reduced, the morphological and biomass characteristics of T. *aman* rice varieties got disadvantages when grown with *P. stratiotes* and *S. molesta*. Cultivation of BRRI hybrid dhan6 along with weed control through integrated weed management gave the highest grain yield (5.92 t ha^{-1}) and the highest economic return comparable to other treatment combinations. However, the spreading of *L. minor* facilitated optimal weed control and good yields were harvested without significant differences and as well as net return irrespective of varieties. Therefore, weed competitive variety should be considered along with the spreading of *L. minor* to reduce herbicide loads in the environment and to the evolution of cross-resistant weed populations.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF APPENDICES

LIST OF APPENDICES (Cont'd)

LIST OF PLATES

LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
CV%	Percentage of coefficient of variance
cv.	Cultivar
DAE	Department of Agricultural Extension
DAT	Days after transplanting
^{0}C	Degree Celsius
et al	And others
FAO	Food and Agriculture Organization
g	gram(s)
ha^{-1}	Per hectare
HI	Harvest Index
i.e.	That is
kg	Kilogram
Max	Maximum
mg	Milligram
Min	Minimum
MoP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Not significant
%	Percent
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
t	Ton
TSP	Triple Super Phosphate
Wt.	Weight

CHAPTER I

INTRODUCTION

Agrarian country Bangladesh is enriched with plenty of water as well as suitable climatic condition for rice production. The annual production of rice in Bangladesh is 35.30 million metric tons from 11.80 million acres of land (BBS, 2019). In Bangladesh, among three rice ecotypes namely *aus*, *aman*, and *boro aman* rice occupies the highest area coverage (Magzter, 2021). Total area coverage by *aman* rice of the financial year 2020-21 has been estimated at 5625907 hecters compared to 5559964 hecters of the financial year 2019-20 which is 0.87 % higher (BBS, 2022).

The growth process of rice plants under different agro-climatic conditions differs due to the specific rice variety (Alam *et al*., 2012). Variety itself is a genetic factor, which contributes a lot to produce the yield components and yield of a particular crop. Compared with conventional varieties, the high-yielding varieties have larger panicles resulting in an average increase of rice grain is 7.27% (Bhuiyan *et al*., 2014). BRRI (1991) reported that modern transplant *aman* rice varieties produced grain yield up to 6.5 t ha^{-1}. Therefore, varietal performance is an important factor for improving crop production.

Weeds are an integral part of agricultural systems which significantly reduce farmer’s profitability (Ahmed *et al*., 2014). Weeds compete with crop plants for light, nutrients, water, and space. In Bangladesh, the climate and edaphic conditions are highly favorable for weed growth (Ahmed *et al*., 2014). This can lead to significant yield losses without adequate weed management. In the absence of weed control, rice yield losses due to weeds ranged from 15% to 40% in transplanted rice, and 40% to 100% in direct-seeded rice (Rashid *et al*., 2012; Ahmed and Chauhan, 2014). However, the level of yield loss depends not only on the infestation, but also on the composition of weed flora. Farmers spend a lot of resources to reduce their impact, many a times quite unsuccessfully. Thus, the control of weeds in rice paddy fields is crucial for optimum production.

The types of weed management practices employed can directly influence the weed control cost and farm income. Herbicide-based weed control is consequently becoming more popular, as it can reduce overall costs by minimizing costly labor (Islam *et al.*

2017). In the last three decades, the use of herbicides in Bangladesh has increased 37-fold (BBS 2017). Yet although herbicides can effectively control rice weeds, sole dependence on chemical control measures poses both environmental and economic risks (Kumar *et al*., 2017). The former include the evolution of herbicide resistance in weeds and negative effects on non-target organisms, whereas the latter include additional costs involved in controlling new weed species that may result from shifts in weed flora with the use of chemical control methods (Hossain *et al*., 2020; Heap, 2021). As the herbicides are active substances, there are concerns about their effects on non-target organisms. Herbicide-resistant weeds and associated chemical pollution are serious environmental concerns. Prevention of the overuse of herbicides in rice paddy fields and the development of an alternative method without harming the agroecosystem are emerging issues. These factors permit integrated approaches to manage weeds while reducing the environmental hazards associated with herbicides, and high costs associated with manual weeding (Juraimi *et al*., 2013; Chauhan *et al*., 2015). Estimates indicate that farmers spend about US$100 to 300 ha^{-1}, which is about 10 % to 20 % of the total production cost for controlling weeds in rice fields (Islam *et a*l., 2017). Hence, integrated weed management (IWM) could be an effective strategy to reduce weed control costs, reduce the yield gap, and increase yield and profits from rice production.

Integrated weed management can be defined as the integration of more than one approach involving cultural, physical, biological, and chemical methods (Harker and Donovan, 2013). It consists of both chemical and nonchemical approaches and focuses on keeping weed populations below a certain threshold level by optimizing control measures strategically and holistically (Wilkerson *et al*., 2002).

Herbicides are used as a last resort in IWM, although where they are required, they should be used in an integrated management approach, such as integration of soil-active pre-emergence and post-emergence herbicides, rotation of herbicides with different modes of action (MOAs), or mixing of herbicides with different MOAs with best application practices (Harker *et al*., 2012; Harker and Donovan, 2013; Kumar *et al*., 2017). Different pre-mix and tank-mix combinations are being tried out to control mixed weeds in one go (Yadav *et al*., 2008) which will not only reduce the total volume of herbicide but also ease and economize its application. Some herbicides were reported to have not only controlled weeds but also increased the yield of the different rice varieties.

Small, floating, aquatic plants are often a conspicuous component of aquatic systems (Hillman, 1961). It can be either competitive with rice fields or suppressive of weeds without accumulation of nutrients from the field. The ability of *Azolla* to suppress other weeds has been mentioned in Philippino literature studies since 1927 (Moody and Janiya, 1992). Weed growth is suppressed when *Azolla* forms a thick, virtually light-proof mat. There are probably two mechanisms for this suppression, the most effective being the light-starvation of young weed seedlings by the blockage of sunlight (Lumpkin and Plucknett 1980). The other mechanism is the physical resistance to weed seedling emergence created by a heavy, interlocking *Azolla* mat, which does not affect the growth of rice (Pons, 1987). Bangun and Syam (1988) showed that an *Azolla* cover could significantly reduce weed infestation without harming the rice yield. Several studies have reported the suppressive effect of *Azolla* on rice weed species, such as *Utricularia flexuosa* Vanl, *Echinochloa crus- galli* (L.) Beauv., *Sagittaria* spp., *Cyperus difformis* L. and *Polygonum* sp. (Nguyen 1930; Ngo 1973; Talley *et al*..1977). *Pistia stratiotes* is a perennial aquatic macrophyte widely distributed throughout the world and is capable of removing several heavy metals from water, including Arsenic (Farnese *et al*., 2014). Aquatic floating plant-like duckweed (*Lemna* minor) is mainly used on phytoremediation and nutrient recovery from wastewater and for animal feedstock and the production of biofuels, due to its high growth rate, high biomass yield, excellent nutrient uptake ability, and tolerance to high nutrient levels (Cheng *et al*., 2002; Mohedano *et al.,* 2012). In transplanted rice, *S. molesta* was found to cause a 12.5% yield loss due to a reduction in panicle-bearing tillers (Azmi, 1988). Excessive growth of the free-floating plant causes a negative effect on the growth and development of the standing crop. Dense mats of the free-floating plant harm wetland rice ecosystems because they create anoxic conditions that strongly reduce plant diversity (Jansen *et al*., 1998). Invasions by introduced exotic species are partly responsible for the increase of floating plant dominance. However, eutrophication is likely to have boosted the spread of free-floating plants, too.

In Bangladesh, few studies have been conducted to find out the competitive effect of free-floating plants on weed control, growth, and yield of *aman* rice varieties. Research work on the combined effect of *T. aman* varieties and weed control (through herbicide and free-floating plants) is limited. Considering the above facts the present study was undertaken with the following objectives:

i. To identify weed flora to be present in transplanted *aman* rice under study.
ii. To evaluate the performance of transplanted *aman* rice varieties under the conditioned designed.
iii. To explore the spreading pattern of free-floating plants and its effect on agronomic features of rice varieties under study.
iv. To evaluate the competitive effects of free floating plants on weed control, growth and yield of rice varieties chosen for the study.
v. To find out the profitability of cropping the rice varieties through economic analysis with ongoing market prices of the products.

CHAPTER II

REVIEW OF LITERATURE

Weed infestation is a major constraint in rice cultivation and accounts for 45-51% yield losses in rice. Weed control through the sequential application of pre and post-emergence herbicides, especially with those of low-dose high-efficiency herbicides is highly recommended. But persistent herbicides can remain active in the environment for long periods, potentially causing soil and water contamination and adverse effects to non-target organisms. Application of biological control agents like aquatic macrophytes will positively or negatively impact weed and concerning weed dynamics in transplanted rice. In awareness of the above, an attempt was made in this section to collect and study relevant information available regarding the competitive effect of free-floating plants on weed control, growth, and yield of *aman* rice varieties in the country and abroad to gather knowledge helpful in conducting the present piece of work and subsequently writing up the result and discussion.

2.1 Weed flora of *aman* rice

Duary *et al*. (2015) noticed that when the water level was more than 2.5 cm, *Sphenoclea zeylanica, Monochoria vaginalis, Ammania baccifera* and *Hydrolea zeylanica* were the most predominant weeds.

In rainfed lowland rice, Malik *et al*. (2014) recorded *Echinochloa crus-galli* and *Paspalum scorbiculatum* among annual grasses, *Cyperus iria*, *C. difformis*, and *Fimbristylis miliacea* among sedges and *Sphenoclea zeylanica* and *Monochoria vaginalis* among broadleaf weeds as dominant weeds.

Acharya and Battacharya (2013) reported that under unweeded situations sedges constituted 38 percent of the weed population followed by broadleaf weeds (34 %) and grasses (28 %). Duary and Mukherjee (2013) reported that the Incidence of *Ludwigia parviflora* was observed with the highest frequency in lowland rice. The probable reason for its wide ecological amplitude might be the adaptation by special structures like pneumatophores. According to Sridevi *et al*. (2013), in shallow depths of water, the dominant grass species noted were *E. crus-galli* and *E. colona* and sedges were *C. iria*, *C. rotundus, and F. miliacea* and broad-leaved weed species were *Ammania baccifera, Marsilea quadrifolia*, and *Potamogeton distinctus*.

Monika *et al.* (2012) observed *E. crus-galli* as the dominant weed comprising 32.8 percent of the total weed population at the most critical period (25 DAT), while *M. vaginalis* was dominant at the harvest stage (18.8 %) in Kharif season.

Ravisankar *et al.* (2008) found that wet seeded rice grasses constituted 51.5 percent of the total weed population followed by sedges (30.9 %).

According to Mahajan *et al*. (2006), under a direct seeding system, the major weeds were *E. crus-galli* and *E. colona* among grasses, *C. difformis*, and C. *iria* among sedges, *Trianthema portulacastrum* and *Eclipta alba* among broadleaf weeds.

2.2 Weed competition in rice

Hassan and Upasani (2015) reported that weeds were the main problem of wetland rice as pre-germinated seeds and weed seeds in soil seed bank grew simultaneously thereby inviting competition for resources like moisture, nutrient, and light.

Mandal *et al*. (2013) found that every year weeds caused yield loss from 15 to 76 percent in rice crops among grasses, sedges, and broadleaf weeds, grasses are reported to be the heavy competitors to crop. Rao and Nag*aman*i (2013) reported that weeds were one among the most important biological constraint to increasing crop yield, acting at the same trophic level as the crop, weeds exploited a major share of the available resources for plant growth and thus hindered the attainment of maximum rice productivity.

According to Maity and Mukherjee (2008), uncontrolled weeds decreased rice yield by 96 percent in dry direct-seeded rice and 61 percent in wet direct-seeded rice systems.

2.3 Effect of competitive rice variety on weeds

Sohel *et al.* (2020) that the competitive ability of different rice varieties significantly reduces the weed population in the field which ultimately impacts the total dry matter accumulation by weed in m^{-2} area. Salam *et al.* (2020) observed that cultivars of rice influenced weed densities at different DATs.

Shawon *et al.* (2018) reported that the number of weeds was lower in the hybrid cultivated plots might be due to vigorous growth of the cultivar helped to reduce the weed population and hence lower in number.

Afrin *et al.* (2015) reported that the variety of rice significantly influenced the weed population, total weed dry weight, and weed control efficiency at various days after transplanting (DAT). The number of weeds or the weed population depends on the soil, environment, varieties, and other factors. As a result, variations in the weed population occurred.

Chauhan and Johnson (2011) reported that the high competitive cultivars would be rapid canopy closure so that shade under the canopy would suppress the growth of weeds resulting in a higher weed control index. Hybrids usually have better vigor than inbreeds; therefore, when possible, hybrids can also be used. They also reported that the weed control index could be attributed to less weed biomass observed due to their ability to suppress weeds.

2.4 Effect of weed management on rice growth characters

Salam *et al.* (2020) experimented to evaluate the effect of weed management practices on the performance of rice cultivars and reported that plant height was significantly influenced by cultivars.

Mahmud *et al.* (2017) experimented to investigate the response of some short-duration *aman* rice varieties to date of transplanting. The experimental result showed that plant height was significantly influenced by rice varieties and among them, BRRI dhan56 produced the tallest plant of 128.53 cm. BRRI dhan57 produced the shortest plant of 110.04 cm which is statistically similar to Binadhan-7 (110.51 cm).

Tyeb *et al.* (2013) reported that the variation in plant height is due to the effect of varietal differences. The variation of plant height is probably due to the genetic make-up of the cultivars.

Paul *et al.* (2019) undertook a study to detect short-statured rice plants with aromatic and long to medium slender grain where twelve advanced rice lines (derived from the local rice germplasm) with a local check Kataribhog were evaluated. Experiment rest showed that the highest total tiller numbers hill^{-1}at harvest was observed in the local aromatic rice genotype SAU ADL10 (18.75) whereas the minimum tiller numbers hill^{-1} (6.58) was obtained from SAU ADL12.

Nahida *et al.* (2013) reported that rice cultivars varied considerably in terms of crop growth characteristics as well as yield and yield contributing characters. Experimental results revealed that dry matter (DM) accumulation over time varied considerably due to variety. Among different Days After Transplanting (DAT), Kachra produced the highest dry matter (1420.7 g m^{-2}) and Kalijira produced the lowest dry matter (1105.7 g m^{-2}) at 92 DAT. They also reported that the difference in effective tillers $hill^{-1}$ is the genetic makeup of the variety, which is primarily influenced by heredity.

Mia and Shamsuddin (2011) conducted a field experiment to determine the physio morphological attributes concerning yield potential of modern and aromatic rice varieties and reported that the CGR is the product of LAI and NAR values, and higher CGR achieved in the modern varieties than the aromatic varieties may be due to the higher LAI.

Toshiyuki *et al.* (2006) reported that the genotypic difference in grain yield was most closely related to that in crop growth rate.

Hossain *et al.* (2005) found variation among the evaluated native aromatic rice cultivars in the case of fertile tillers $hill^{-1}$ which ranged from 8.6 to 11.4.

2.5 Effect of rice varieties on yield contributing characters

Akter *et al.* (2020) reported that the number of non-effective tiller hill-^{1} was significantly influenced due to different varieties. The maximum non effective tillers $hill^{-1}$(10.90) was observed in Chiniatap-2 which was statistically differed from all other varieties. The lowest non-effective tillers $hill^{-1}$ (2.33) was obtained from Badshabhog which was statistically similar with BRRI dhan38. Akondo *et al.* (2020) conducted a field experiment with six rice varieties to determine their growth and yield performance and found that all the growth and yield contributing attributes varied significantly among the six rice varieties. The results revealed that among the varieties Binadhan-16 had a significantly maximum number of filled spikelets/panicle (108.43) whereas a minimum number of filled spikelets/panicle (60.60) was observed in Binadhan-11 which was statistically identical to Binadhan-15 (63.87 cm). Variation in grain filling may have occurred due to genetic, environmental, or cultural management practices adopted. Khatun *et al.* (2020) reported that the maximum 1000-grain weight was observed in Binadhan-17 (27.25 g) that was statistically similar to Binadhan-11 (26.45

g) and Binadhan- 16 (26.88 g). The minimum 1000-grain weight observed in Binadhan-7 (21.94 g) was statistically different from other varieties. Latif *et al.* (2020) reported that 1000-grain weight was significantly different due to the varietal performance. The highest 1000-grain weight (26.33 g) was obtained in BR14 than BRRI dhan28 (22.60 g) and BRRI dhan29 (22.43 g).

Paul *et al.* (2019) observed the maximum panicle length (32.63 cm) was recorded in genotype SAU ADL10 genotype and the minimum panicle length of 26.33 cm was recorded in the SAU AD7 genotype.

Hossain *et al.* (2016) shown that different rice varieties and nutrient levels along with their interaction have a significant effect on the growth and yield of rice. It was observed that the panicle length of the crop was influenced by variety. Binadhan-10 produced a longer panicle (24.60 cm) compared to BRRI dhan28 (20.97 cm).

Chamely *et al.* (2015) reported that the longest panicle (23.19 cm) was found in the variety BRRI dhan29 and the smallest one was observed in BRRI dhan45. The variation as assessed might be due to genetic characters of the varieties primarily influenced by the heredity.

Jisan *et al.* (2014) carried out a study to examine the yield performance of some transplant *aman* rice varieties and showed that among different rice varieties BRRI dhan52 produced the highest number of total spikelets panicle^{1} (155.20) and the lowest number of total spikelets panicle^{-1} (118.80) was obtained from BRRI dhan57. Roy *et al.* (2014) reported that the number of spikelets per panicle in indigenous rice is generally lower compared to high-yielding varieties. They also found the difference in thousand grains weight due to morphological and varietal variation. Sarkar (2014) reported that the number of filled grains/panicles was influenced significantly due to variety.

Aminpanah *et al.* (2013) showed that there was a significant difference among rice varieties and lines under both weedy and weed-free conditions for 1000-grain weight. Under weed-free conditions, Nemat and Khazar had the highest and lowest (31.8 and 25.87 gram, respectively) of 1000-grain weight. But, under weedy conditions, Nemat with 30.7 gram and line 842 with 24.3 gram had the highest and lowest 1000-grain weight, respectively. Mahamud *et al.* (2013) reported that the variation in filled grains panicle^{-1} was recorded due to genotypic differences of varieties. Nahida *et al.* (2013)

reported that among the undesirable traits, the number of unfilled grains panicle^{-1} was an important one and played a vital role in yield reduction. The effect of variety on the number of unfilled grains panicle^{-1} was highly significant. Morichsail produced the lowest number of unfilled grains panicle^{-1} (11.17) which contributed the highest grain yield of that variety. This variation in the number of unfilled grains panicle^{-1} might be due to the genetic characteristics of the varieties.

Sohel *et al.* (2009) reported that differences in spikelets sterility varied significantly by variety and plant spacing.

Diaz *et al.* (2000) also reported that panicle length varied among varieties.

2.6 Effect on yield performance of rice varieties

Chowhan *et al.* (2019) found significant differences in harvest index among different rice varieties. From their experiment, they concluded that varieties Shakti-2 (V_4), Heera-1 (V_3), and BRRI dhan28 (V_1) had an identical harvest index of 50.9%, 48.5%, and 47.9 respectively. Only Bina dhan-14 (V_2) produced the harvest index (40.0%). It appears that hybrid rice maintained a higher harvest index.

Shawon *et al.* (2018) reported that among different rice varieties the highest grain yield (4.04 t ha^{-1}) was recorded in the hybrid variety Aloron. It might be the resultant effects of the highest tillers hill-^{1} and grains panicle^{-1} of those cultivars. Whereas the lowest grain yield (1.07 t ha^{-1}) was recorded in cultivar Doom which was at par with the variety BRRI dhan43 (1.32 t ha^{-1}).

Howlader *et al.* (2017) found that among the genotypes Moulata showed the highest biological yield (9.657 t ha^{-1}). Mahmud *et al.* (2017) experimented to investigate the response of some short duration *aman* rice varieties to date of transplanting and reported that among rice varieties the highest straw yield (5.67t ha^{-1}) is produced by BRRIdhan49 whereas the lowest (3.96 t ha^{-1}) straw yield was produced by BRRI dhan57. Rahman *et al.* (2017) reported that the highest harvest index was found in BRRI dhan59 (42.78%) and the lowest one was found in BRRI dhan28 (40.73%).

Ferdous *et al.* (2016) found that the highest grain yield was obtained from the interaction of BRRI dhan39 × weed-free condition which was statistically identical (5.50 t ha^{-1}) with the interaction of variety BR11 × two hand weedings at 15 and 35 DAT.

Hossain *et al.* (2014) found that the variation in biological yield was also found due to the variation in grain and straw yield.

Islam *et al.* (2013) reported that the varieties which produced a higher number of effective tillers $hill^{-1}$ and higher number of filled grains $panicle^{-1}$ also showed higher grain yield ha^{-1}.

Tyeb *et al.* (2013) reported that the variation in straw yield is due to the effect of varietal differences.

Uddin *et al.* (2011) reported that the harvest index differed significantly among the varieties due to its genetic variability.

Dutta (2002) reported that the genotypes, which produced a higher number of effective tillers per hill and a higher number of grains per panicle also showed higher grain yield in rice.

Shah *et al.* (1991) reported that variety had a great influence on the harvest index.

2.7 Impact of aquatic free-floating weeds on rice

Pulido (2016) reported that duckweeds may be viable sources of organic fertilizer, particularly supplying nitrogen (N) and phosphorus (P) to plants.

Wang *et al.* (2015) reported that in addition to enhancing rice production, duckweed may also suppress rice diseases, reduce the greenhouse gas footprint associated with rice cultivation and remediate heavy metal contaminants in paddy fields.

Hussner *et al*. (2014) reported that the dense mats of *Pistia stratiotes* block sunlight which limits the growth of submerged plant species and prevents wind-induced mixing of the water column causing reductions in dissolved oxygen.

Bilz *et al*. (2011) reported that *P. stratiotes* have the potential to impact native plant species due to their invasive smothering behavior. The invasion of alien invasive plants can increase competition for space with native aquatic plants and this will affect the most threatened aquatic plant species.

According to Li *et al.* (2009), the presence of duckweed in flooded rice fields is a common phenomenon and the inclusion of duckweed (*Lemna minor*) in rice paddy agroecosystems has been reported to reduce nitrogen loss from 20–54%.

Mbati and Neuenschwander (2005) reported that the impact of *Salvana molesta* can be devastating because weed mats block the use of waterways for transportation, cutting off access to important services and farms lands. It also provides habitats for vectors of human disease with socio-economic impacts.

Julien *et al*. (2002) reported that *S. molesta is* considered as a weed of paddy rice that reduces production by competing for water, nutrients, and space.

Labrada and Fornasari (2002) reported that water lettuce (*P. stratiotes)* is a major weed problem in the tropics, where its impact is similar to that of water hyacinth, both on the environment and the economy of the countries concerned. However, it was not a weed problem in Africa and Asia until recently and its weed status appears to be due to the pollution of water bodies and the presence of organic wastes and residues of fertilizers.

Storrs and Julien (1996) reported that *S. molesta* forms a single layer over water, but with continued growth, the mats become multi-layered and can reach up to 1 m in thickness. Thick mats support other colonizing plants, and the high biomass and stability of such mats make them difficult to dislodge and destroy. As with other aquatic weeds, mats of *S. molesta* impede access to and use of waterways for commercial and recreational purposes and degrade waterside aesthetics. The weed can clog water intakes and interfere with agricultural irrigation, water supply, and generation of electricity.

Sharma and Goel (1986) reported that through high growth rates and slow decomposition rates, *S. molesta* reduces the concentration of nutrients that would otherwise be available to primary producers and organisms that depend on them. Water under mats of *S. molesta* has a lower oxygen concentration (due to the reduced surface area of water available for oxygenation, inhibition of photosynthesis by submerged plants, and consumption of dissolved oxygen by decaying *S. molesta*), higher carbon dioxide and hydrogen sulphide concentrations, lower pH, and higher temperatures than in open water.

Ahmad et al. (1990) applied L. minor as a complementary source of N and recorded increased plant height, straw, and grain yields accompanied by an increase in N, P, and potassium (K) content of the rice plants.

2.8 Integrated weed management in rice

Das *et al.* (2017) reported that the effective control of weeds starting from the early crop growth stage might have resulted in better growth and yield of rice. The variation in grain yield under different treatments was the result of variation in weed density and weed biomass.

Lodhi (2016) reported that different weed control treatments caused remarkable variations in the number of tillers m^{-2} at different days after transplanting. Weedy check plots have the minimum number of tillers m^{-2}, which increased appreciably at all the growth intervals as the plots received weed control treatments. Application of Bensulfuron methyl + Pretilachlor (60+600) g ha^{-1} resulted in a markedly higher number of tillers m^{-2} over rest of the doses (48+480) and (72+720) g ha^{-1} and check herbicide Pendimethalin and Butachlor at all growth intervals.

Akbar *et al.* (2011) reported that hand weeding twice, pretilachlor @ 1 kg/ha, and butachlor @ 1.5 kg/ha recorded maximum plant height and tillers per unit area against the minimum in weedy check.

Sunil *et al.* (2010) reported that Bensulfuron methyl+ Pretilachlor (0.06+0.6 kg/ha) applied as pre-emergence recorded significantly higher plant height, leaf area, dry matter, and crop growth rate (CGR) as compared to the application of butachlor @ 1.5 kg/ha or two hand weeding

Olayinka and Etejere (2015) reported that all the weed control treatments had higher RGR as compared to the weedy check.

Hossain (2015) reported that the straw yield and harvest index of rice differ, due to application of different mix herbicide comparable to weedy check. Chowdhury (2012) founded the highest grain yield, straw yield, biological yield, harvest index from pre-emergence herbicide Sunrice 150WG treated plot.

2.9 Effect of weed control method on the economics of rice

Chakraborti *et al*. (2017) reported that pre-emergence application of pendimethalin at 1.0 kg ha^{-1} at 2 DAS *fb*. bispyribac-sodium at 25 g ha^{-1} at 20 DAS recorded the higher net returns (23,847 in 2014 and 26,010 in 2015) and return per rupee invested (2.02 and 2.11) in direct-seeded rice. Yogananda *et al*. (2017) reported that among the various treatments, the highest net returns (27,631ha^{-1}) and B: C (1.65) were recorded with the pre-emergence application of bensulfuron-methyl + pretilachlor 660 g ha^{-1} fb. post-emergence application of bispyribac- sodium @ 25 g ha^{-1} in DSR. Charan Teja *et al.* (2015) found that Pre-emergence application of bensulfuron methyl 0.6 % + pretilachlor 6 % at 60 + 600 g ha^{-1} at 3 DAS in wet season transplanted rice recorded significantly higher net returns (46,676 ha^{-1}) and B:C (1.82) as compared to unweeded check (20875 and 0.88, respectively).

Sukla *et al.* (2014) reported weed control in system of rice intensification method of rice cultivation with four times no-weeding showed significantly higher gross returns (90,152.92 and 97,745.91 ha^{-1}) over the rest of the weed management treatments including weedy check, but it was on par with combined application of pretilachlor as pre-emergent + bispyribac sodium as post emergent herbicide. Tamradhvaj Dadsena *et al.* (2014) reported that post-emergence application of fenoxaprop + chlorimuron + metsulfuron at 80 ml ha^{-1} at 25-30 DAS in DSR recorded more grain and straw yield (3.27 t ha^{-1} and 3.97 t ha^{-1}, respectively) and net returns of 16,120 ha^{-1} and it was at par with the application of cyhalofop butyl + chlorimuron + metsulfuron at 120 ml ha^{-1} at 25-30 DAS as postemergence application (3.23 t ha^{-1} 4.09 t ha^{-1} and 16080 ha^{-1}, respectively).

CHAPTER III

MATERIALS AND METHODS

This chapter presents a concise depiction of the experimental period, site description, climatic condition, crop or planting materials that were being used in the experiment, treatments, experimental design and layout, crop growing technique, fertilizers application, uprooting of seedlings, intercultural operations, data collection, and statistical analysis.

3.1 Location of the experimental site

3.1.1 Geographical location

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar Agargaon, Dhaka, 1207. The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meters above sea level.

3.1.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain. For better understanding of the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2 Experimental Duration

The experiment was conducted during July to December 2019 in transplanting *aman* season.

3.3 Soil Characteristics of the experimental field

The soil of the experimental site was silty clay loam in texture belonging to the Tejgaon series. The area represents the Agro-Ecological Zone of the Madhupur tract (AEZ No. 28) with pH 5.8–6.5, ECE-25–28 (Anon., 1988 b). Soil samples from 0- 15 cm depths were collected from the experimental field. The analytical data of the soil sample collected from the experimental area were analyzed in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka, and have been presented in Appendix II.

3.4 Climate condition of the experimental field

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity, and heavy precipitation with occasional gusty winds during the period from March to August, 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 Maximum and minimum temperature, relative humidity, and total rainfall were recorded by the meteorology center, Dhaka for the period of experimentation have been presented in Appendix III.

3.5 Planting material

Tulshimala, BR11(Mukta), and BRRI hybrid dhan6 were being used as test crops for this experiment.

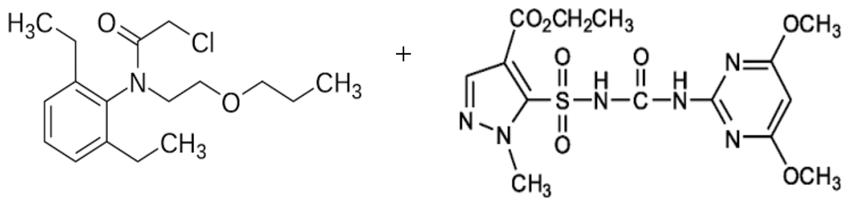
3.6 Description of the rice varieties

Name of variety	Developed by	Year of Release	Growing season	Average yield (t ha^{-1})
Tulshimala	Local variety	Local variety	*aman*	3 - 4
BR11(Mukta)	BRRI	1980	*aman*	6.5
BRRI hybrid dhan6	BRRI	2017	*aman*	6.0 - 6.5

Source: dhcrop.bsmrau.net

3.7 Description of the herbicides and free-floating aquatic plants used for weeds control in the experimental field

3.7.1. Pretilachlor 6% + pyrazosulfuron 0.15%

Trade name	UPL EROS
Name of registration holder	ACI Crop Care
IUPAC Name	2-chloro-N-(2,6-diethylphenyl)-N-(2-propox yethyl) acetamide +ethyl 5-1-methyl-1H-pyrazole-4-carboxylate
Structural formula	
Molecular weight	386.4
Formulation types	Wettable powder herbicide
Mode of actions	Selective pre-emergence herbicide. Inhibition of acetolactate synthase
Target Weeds	*Echinochloa crusgalli, E. colona, Eclipta alba, Cyperus iria, C. difformis, Fimbristylis miliacea*
Major crops	Transplanted Rice field
Application rate	9.88 kg ha^{-1}
Time of application	3 days after transplanting

3.7.2. *Pistia stratiotes*

Scientific name	*Pistia stratiotes*
	
Common Name	Water cabbage, water lettuce, Nile cabbage, or shellflower.
Family	*Araceae.*
Type	Noxious weed or invasive aquatic plant
Plant description	Pistia is a perennial monocotyledon with thick, soft leaves that form a rosette. It floats on the surface of the water, its roots hanging submersed beneath floating leaves. The leaves can be up to 14 cm long and have no stem. They are light green, with parallel veins, wavy margins, and are covered in short hairs which form basket-like structures which trap air bubbles, increasing the plant's buoyancy. The flowers are dioecious and are hidden in the middle of the plant amongst the leaves. Small green berries form after successful fertilization. The plant can also undergo asexual reproduction. Mother and daughter plants are connected by a short stolon, forming dense mats
Habitat	Wetland rice field, Irrigation channels, freshwater, pond, lakes, etc
Uses	Water lettuce is often used in tropical aquariums to provide cover for fry and small fish. It is also helpful as it outcompetes algae for nutrients in the water, thereby preventing massive algal blooms.

3.7.3. *Lemna minor*

Scientific name	*Lemna minor*
	
Common Name	Duckweed
Family	*Araceae*
Type	Aquatic weeds
Plant description	*Lemna minor* is a floating freshwater aquatic plant, with one, two, three, or four leaves each having a single root hanging in the water. As more leaves grow, the plants divide and become separate individuals. The root is 1–2 cm long. Leaves are oval, 1–8 mm long and 0.6–5 mm broad, light green, with three (rarely five) veins and small air spaces to assist flotation. It reproduces mainly vegetatively by division. Flowers are rarely produced and measure about 1 mm in diameter, with a cup-shaped membranous scale containing a single ovule and two stamens. The seed is 1 mm long, ribbed with 8-15 ribs. Birds are important in dispersing L. minor to new sites. The sticky root enables the plant to adhere to the plumage or feet of birds and can thereby colonize new ponds
Habitat	Wetland rice field, Irrigation channels, freshwater, pond, Lacks, etc
Uses	*L. minor* is used as animal fodder, bioremediation, for wastewater nutrient recovery, and other applications.

3.7.4. *Salvinia molesta*

Scientific name	*Salvinia molesta*
	
Common Name	Kariba weed
Family	*Salviniaceae*
Type	Noxious aquatic weeds
Plant description	Plants: perennial, heterosporous herbs, free-floating, with microspores and megaspores produced on the same plant, green, up to 30 cm long, 5 cm wide, mat-forming, mat to 2.5 cm thick (or much thicker, depending on local conditions such as water current, waves, etc.); roots absent; stems irregularly branched, pubescent.
Habitat	Wetland rice field, Irrigation channels, freshwater, pond, lakes, etc
Uses	Waterproof covering.

3.8 Seed collection and sprouting

BR11 (Mukta) and BRRI hybrid dhan6 were collected from BRRI (Bangladesh Rice Research Institute), Joydebpur, Gazipur, and Tulsimala were collected from Sherpur, Bangladesh. Healthy and disease-free seeds were selected following standard techniques. Seeds were immersed in water in a bucket for 24 hrs. These were then taken out of the water and kept in gunny bags. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hrs.

3.9 Raising of the *T. aman* seedlings

A typical system was followed in the raising of seedlings in the seedbed. The nursery bed was set up by puddling with continued ploughing followed by laddering. The sprouted seeds were planted as uniformly as possible. Irrigation was delicately given to the bed as and when required. No fertilizers were used in the nursery bed.

3.10 Preparation of experimental field

The experimental field was first opened on 3 August 2019 with the help of a power tiller, later the land was irrigated and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering, to have a good puddled field. Various kinds of weeds and developments of pest crops were disposed of from the field. After final land preparation, the field layout was made on 3 August 2019. Each plot were cleared in and finally leveled out with the help of a wooden board.

3.11 Fertilizer management

Plant nutrients (*viz*. nitrogen, phosphorus, potash, sulfur, zinc) for rice were given through urea, triple super phosphate, muriate of potash, gymsum, and zinc sulphate respectively.

The following doses of fertilizer were applied for the cultivation of *T. aman* rice

Fertilizers	Quantity (kg/ha)
Urea	150
TSP	100
MoP	70
Gypsum	60
Zinc sulphate	10

All of the fertilizers except urea were applied as basal dose at the time of final land preparation. Urea (150 kg ha^{-1}) was applied in equal three splits. The first dose of urea was applied at 21 days after transplanting (DAT). The second dose of urea was added as top dressing at 45 days (active vegetative stage) after transplanting and the third dose was applied at 60 days (panicle initiation stage) after transplanting recommended by BRRI.

3.12 Field operation

The different field operations performed during the present investigation are given below in chronological order in list form.

List of schedule of field operations done during experimentation.

Sl. No.	Field operations	Date
1	Preparation of nursery bed	6 July 2019
2	Sowing of seeds	10 July 2019
3	Land preparation for main field	3 August 2019
4	Puddling and leveling	3 August 2019
5	Fertilizer application except urea	3 August 2019
6	Layout of the experiment field	3 August 2019
7	Transplanting	4 August 2019
8	Spraying Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}	20 August 2019
9	Top dressing of urea given at early stage	24 August 2019
10	Top dressing of urea given at active vegetative stage	14 September 2019
11	Top dressing of urea given at panicle initiation stage	29 September 2019
12	Harvesting of crop	8-30 November 2019
13	Threshing and winnowing of produce	8-30 November 2019

3.13 Experimental treatments

The experiment consisted of two factors as mentioned below:

Factor A: T. *Aman* rice cultivars (3) *viz:*

V_1= Tulshimala
V_2 = BR11(Mukta)
V_3 = BRRI hybrid dhan6

Factor B: Weed Control (5) *viz:*

W_0= Weedy check (Control)
W_1= Integrated weed management (pre-emergence herbicide + one hand weeding)
W_2 = *Pistia stratiotes* (spreading 0.5 m^{-2})
W_3 = *Lemna minor* (spreading 0.5 m^{-2})
W_4 = *Salvinia molesta* (spreading 0.5 m^{-2})

3.14 Experimental design and layout

The experiment was laid out in a split-plot design having 3 replications. In the main plot, there was herbicide treatment and in the subplot, there was a variety of treatments. There were 15 treatment combinations and 45 unit plots. The unit plot size was 5.4 m^2 (2.7 m × 2 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively. the layout of the experimental field was shown in Appendix- IV.

3.15 Intercultural operations

3.15.1 Gap filling

Died off Seedlings in some hills, were replaced by the vigor and healthy seedling from the same source within 7 days of transplantation.

3.15.2 Application of irrigation water

Irrigation water was added to each plot according to the critical stage. Irrigation was done up to 5 cm.

3.15.3 Method of water application

The experimental plots were irrigated through irrigation channels. Centimeter marked sticks were installed in each plot which was used to measure the depth of irrigation water.

3.15.4 Herbicide application

Grain yield loss of rice can be mitigated if weeds, insect pests, and diseases are controlled at the right time. As a thumb role, if rice fields are kept weed-free for an initial one-third of the field duration (planting to maturity) of a rice variety, then crop loss could be avoided. Weeds are generally controlled mechanically (hand pulling, use of weeder, etc) and chemically. Weed control by herbicides is more profitable than hand weeding. Pre-emergence and post-emergence herbicides can be used for weed control. Herbicide was applied according to with par treatment requirement for each plot.

3.15.5 Plant protection measures

The crop was attacked by yellow rice stem borer (*Scirpopagain certulas*) at the panicle initiation stage which was successfully controlled with Sumithion @ 1.5 L ha^{-1}. Yet to keep the crop growth normal, Basudin was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control rice bug and leafhopper. The crop was protected from birds during the grain filling period by using the net and covering the experimental field.

3.15.6 General observations of the experimental field

Regular observations were made to see the growth and visual differences of the crops, due to the application of different treatments were applied in the experimental field. In general, the field looked nice with normal green plants. Incidence of stem borer, green leafhopper, leaf roller was observed during the tillering stage and there was also some rice bug were present in the experimental field. But any bacterial and fungal disease was not observed. The flowering was not uniform. Lodging occurred in local variety compared to hybrid variety due to rainfall.

3.15.7 Harvesting and post-harvest operation

The rice plant was harvested depending upon the maturity of grains and harvesting was done manually from each plot. The maturity of the crop was determined when 80–90% of the grains become golden yellow. Ten (10) pre-selected hills per plot from which different data were collected and 1.00 m^2 areas from the middle portion of each plot were separately harvested and bundled, properly tagged, and then brought to the threshing floor. Threshing was done by a pedal thresher. The grains were cleaned and sun-dried to the moisture content of 12%. Straw was also sun-dried properly. Finally grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.16 Data collection

The data were recorded on the following parameters

a) Observation on weeds

i. Relative rate of spread (RRS)
ii. Weed flora
iii. Weed population in weedy check plot (No.m^{-2})
iv. Relative weed density in weedy check plot (m^{-2})
v. Weed density (m^{-2})
vi. Weed dry weight (g m^{-2})
vii. Weed control efficiency (%)
viii. Weed control index (%)

b) Observation on crop

i). Crop growth characters

ix. Plant height (cm)
x. Number of tillers $hill^{-1}$
xi. Leaf area index (LAI)
xii. Dry matter accumulation (g $plant^{-1}$)
xiii. Crop growth rate (CGR) (mg cm^{-2} day^{-1})
xiv. Relative growth rate (mg g^{-1} day^{-1})
xv. Net assimilation rate (NAR) (mg cm^{-2} day^{-1})

ii) Yield contributing characters

xvi. Number of effective tillers $hill^{-1}$
xvii. Number of non-effective tillers $hill^{-1}$
xviii. Length of panicle (cm)
xix. Number of filled grains $panicle^{-1}$
xx. Number of unfilled grains $panicle^{-1}$
xxi. Total grains $panicle^{-1}$
xxii. Weight of 1000-grain (g)

3.17 Relations

i. Relationship of grain yield and leaf area index (LAI) and total dry matter production
ii. Correlation of grain yield with panicle m^{-2}, grains $panicle^{-1}$ and1000-grain weight

3.18 Procedure of recording data

i) Relative rate of spread (RRS)

RRS was calculated from percent cover in each floating weeds 45 days from the beginning of the experiment, according to the following formula of Dickinson and Miller (1998):

RRS = ((final cover - initial cover)/initial cover)/total # days

ii) Weeds flora

During experiments weeds found in the experiment, field was recorded and determine the weeds flora is present in T. *aman* rice

iii) Weed population in weedy check plot (No.m^{-2})

From the pre-demarcated area of 1 m^2 of weedy check plot, individual weed species name and their population were listed at 30 and 60 DAT for better understanding of the various weed interference of the experimented field.

iv) Relative weed density in weedy check plot

Relative weed density in the weedy check plot was estimated at 30 and 60 DAT. The relative weed density was worked out as per the formula given by Mishra (1968).

$$\text{Relative weed density (\%)} = \frac{\text{Number of individuals of same species}}{\text{Number of individuals of all species}} \times 100$$

v) Weed density (m^{-2})

From the pre-demarcated area of 1 m^2 of each plot, the total weeds were uprooted and were counted at 30 and 60 DAS in the experimental field of rice.

vi) Weed dry matter weight (m^{-2})

After counting the fresh weeds, weeds were then oven-dried at 80^{0}C until a constant weight was obtained. The sample was then transferred into desiccators and allowed to cool down to room temperature and then the final weight of the sample was taken at 30 and 60 DAS of rice respectively.

vii) Weed control efficiency (WCE)

Weed control efficiency was measured by using the following formula given by Mani *et al.*, (1973).

$$\text{WCE} = \frac{\text{Weed population in control} - \text{weed population in treated plot}}{\text{Weed population in control}} \times 100$$

viii) Weed control index (WCI)

Weed control efficiency was measured by using the following formula given by Mishra and Tosh, (1979).

$$\text{WCI} = \frac{\text{Weed dry weight in control} - \text{weed dry weight in treated plot}}{\text{Weed dry weight in control}} \times 100$$

ix) Plant height (cm)

The height of the randomly selected 10 plants was determined by measuring the distance from the soil surface to the tip of the leaf at 15 DAT intervals and harvest respectively. Mean plant height of rice plant were calculated and expressed in cm

x) Number of tillers hill^{-1}

The number of tillers hill^{-1} were counted at 15 days interval up to harvest from pre-selected hills and finally averaged as their number hill^{-1}. Only those tillers having three or more leaves were considered for counting.

xi) Leaf area index

Leaf area index was estimated manually by counting the total number of leaves per plant and measuring the length and average width of the leaf and multiplying by a factor of 0.75 (Kluen and Wolf, 1986). It was done at 30, 45, 60, and 90 DAT.

$$\text{Leaf area index} = \frac{\text{Surface area of leaf sample (cm}^2) \times \text{Correction factor}}{\text{Ground area from where the leaves were collected}}$$

xii) Dry matter accumulation plant^{-1}(g)

Dry matter accumulation plant^{-1} (g) was recorded at 30, 45, 60, and 90 DAT. The sample plants were oven-dried for 72 hours at 70°C and then data were recorded from plant samples plant^{-1} plot^{-1} selected at random from the outer rows of each plot leaving the borderline and expressed in gram.

xiii) Crop growth rate (CGR) (mg cm^{-2} day^{-1})

The average daily increment in plant stand is an important characteristic. The CGR is an increase in dry matter production per unit ground area per unit time. In the present investigation, the crop growth rate was worked out between 60 to 90 DAT with the help of the following formula given by Watson (1956).

Crop growth rate (CGR) = $\frac{W2-W1}{P(t2-t1)}$ mg cm^{-2} day^{-1}
Where,

P = ground area (cm^{-2})

W_1 = dry weight per unit area at t_1

W_2 = dry weight per unit area at t_2

t_1 = time of first sampling

t_2 = time of second sampling

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

The relative growth rate expresses the increase in dry weight at time intervals concerning initial weight. In practical situations, the mean relative growth rate was calculated from measurements on dry weight at the time intervals (Between 60 to 90 DAT) with the help of the following equation suggested by Beadle (1985).

Relative growth rate = $\frac{Ln(W2)-\mathrm{Ln}(W1)}{(t2-t1)}$

Where,

Ln = natural log values

W_1 = dry weight per unit area at t_1

W_2 = dry weight per unit area at t_2

t_1 = time of first sampling

t_2 = time of second sampling

xv) Net assimilation rate (NAR) (mg cm^{-2} day^{-1})

It is an increase in dry weight of plant per unit leaf area per unit time (Between 60 to 90 DAT). The net assimilation rate was calculated from the following equation given by Gregory (1926).

Net assimilation rate = $\frac{(W2-W1)(\mathrm{LnLA2}-\mathrm{LnLA1})}{(t2-t1)(\mathrm{LnLA2}-\mathrm{LnLA1})}$ mg cm^{-2} day^{-1}

Where,

LA_1 = leaf area of the first sampling

LA_2 = leaf area of the second sampling

W_1 = dry weight per unit area at t1

W_2 = dry weight per unit area at t2

t_1 = time of first sampling

t_2 = time of second sampling

Ln = natural log values

xvi) Panicle length (cm)

Measurement of panicle length was taken from the basal node of the rachis to the apex of each panicle. Panicle length was measured with a meter scale from 10 selected panicles and the average value was recorded.

xvii) 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 5 randomly selected hills at harvesting time and the average value was recorded.

xviii) 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 hill^{-1} were counted from 5 pre-selected (used in effective tiller count) hills at harvesting time and the average value was recorded.

xix) Number of filled grains panicle^{-1}

The total number of filled grains was collected randomly from selected 5 plants of a plot and then the average number of filled grains per panicle was recorded.

xx) Number of unfilled grains panicle^{-1}

The total number of unfilled grains was collected randomly from selected 5 plants of a plot based on, no or partially developed grain in panicle and then the average number of unfilled grains per panicle was recorded.

xxi) Number of total grains panicle^{-1}

The number of fertile grains panicle^{-1} alone with the number of sterile grains panicle^{-1} gave the total number of grains panicle^{-1}.

xxii) Weight of 1000-grain (g)

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight was expressed in gram.

xxiii) Grain yield (kg)

Grain yield was adjusted at 14% moisture. Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of the central 1m^2 area was measured and then record the final grain yield of each plot^{-1} and finally converted to t ha^{-1} in both locations. The grain yield t ha^{-1}was measured by the following formula:

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

xxiv) Straw yield (kg)

After separating the grains, the straw yield was determined from the central 1 m^2 area of each plot. After threshing, the sub-samples were sun-dried to a constant weight and finally converted to t/ha-^{1}. The straw yield t ha^{-1} was measured by the following formula:

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

xxv) Biological yield (t ha^{-1})

The summation of grain yield and above-ground straw yield was the biological yield. Biological yield =Grain yield + Stover yield.

xxvi) Harvest index (%)

The harvest index was calculated on a dry weight basis with the help of the following formula.

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

Here, Biological yield = Grain yield + straw yield

3.19 Economic analysis of rice cultivation

In this research from the beginning to end of the experiment, individuals cost data of all the heads of expenditure in each treatment were recorded carefully and classified according to Mian and Bhuiya (1977) as well as posted under different heads of cost of production.

i. Input cost

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

A. Non-material cost

Non-material cost is all the labors cost. Human labor was obtained from adult male laborers. In a day 8 hours working of labor was considered as a man's day. The mechanical labor came from the tractor. A period of eight working hours of a tractor was taken to be tractor day. Individual labor wages 400 taka day^{-1}.

B. Material cost

Its included seeds rate ha^{-1}, fertilizers, pesticide application, irrigation application cost

ii. Overhead cost

Overhead cost is the land cost. The value of the land varies from place to place. In this research, the value of land was taken Tk. 200000 per hectare. The interest on this cost was calculated for 6 months @ Tk. 12.5% per year based on the interest rate of the Bangladesh Krishi Bank.

iii. Miscellaneous cost (common cost)

It was 5% of the total input cost

iv. Gross Return from rice

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

v. Net return (NR)

Net return was calculated by using the following formula:

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

vi. Benefit-cost ratio of rice (BCR)

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

$$\mathrm{BCR} = \frac{\text{Grossreturn (Tk/ha)}}{\text{Cost of production (Tk/ha)}}$$

3.20 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program named Statistix 10 data analysis software and the mean differences were adjusted at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

Results obtained from the present study have been presented and discussed in this chapter to study the competitive effect of free-floating plants on weed control, growth, and yield of *aman* rice varieties. The data are given in different tables and figures. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Weed Parameters

4.1.1 Relative rate of spread (RRS)

From transplanting to 45 days, each species exhibited a different pattern of change in the mean cover through time (Fig. 1). The ranking of RRS over the experiment *Lemma minor* > *Salvinia molesta* > *Pistia stratiotes*. The mean cover of *Lemma minor* increased rapidly and had the highest cover throughout the experiment. This difference in outcome from the experiment can be attributed to *L. mino*r's and *S. molesta*'s increase in growth and *P. stratiotes*'s relatively slow growth with the co-growth of rice irrespective varieties. Dickinson and Miller (1998) observed that *S. minima*'s had relatively slow growth than *L.minor*.

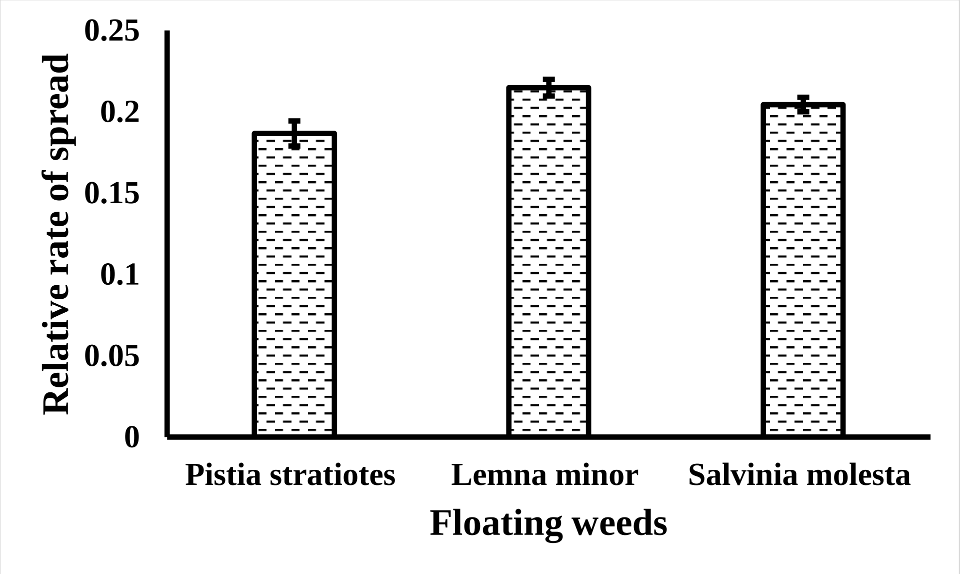


Figure 1. Relative rate of spread of floating weeds in T. *aman* rice varieties

4.1.2 Weed flora of T. *aman* rice

There are six weed species belonging to five families were found to infest the experimental rice field. These are given in Table 1. Among the infested weeds, *Echinochloa crus-galli* and *Leptochloa chinensis* were grasses from Poaceae family and *Fimbristylis miliacea* was sedge from Cyperacea family. Rest were broadleaf weeds i.e., *Enhydra fluctuans* from Asteraceae, *Sagittaria guayanensis* from *Alismataceae*, and *Ludwigia octovalvis* from Onagraceae family. However, all weeds were not found in the same variety of raised plots. Among the infested weeds, *L. chinensis* was not found in BRRI hybriddhan6 raised plots, *F. miliacea* was not found in Tulshimala and BRRI hybriddhan6 raised plots, and *L. octovalvis* was not found in BR11 and BRRI hybriddhan6 raised plots. *E. crus-galli*, *E. fluctuans*, and *S. guayanensis* were found throughout the experimental period whereas *L. chinensis*, *F. miliacea*, and *L. octovalvis* were found at the later stage of crop growth. Paiman *et al.* (2020) found that there are several types of weeds found in rice (i.e., grassy, sedges, and broad leaf), and the occurrence of weed infestation related to rice variety and crop growth.

Table 1. List of infesting weeds in the experimental field of T. *aman* rice at Sher-e-Bangla Agricultural University, Bangladesh

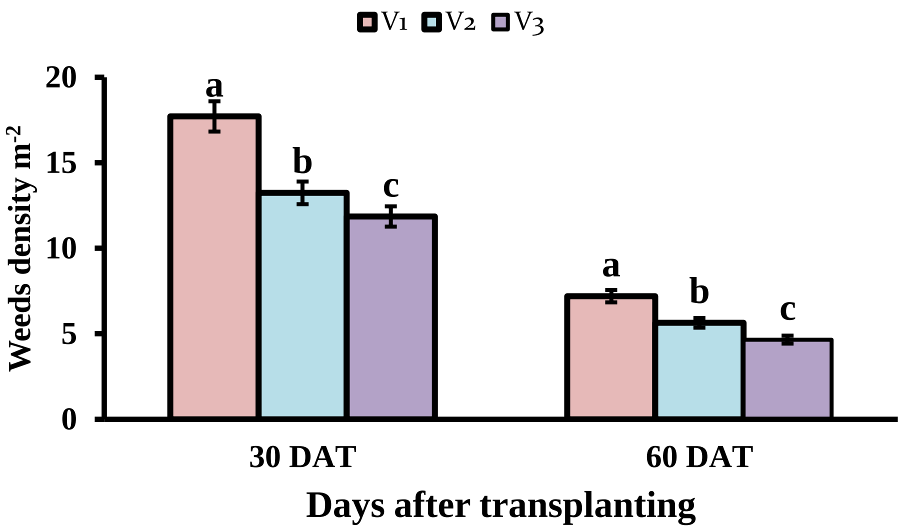
Sl. No.	Name	Type	Family	Infested variety	Occurrence
1.	*Echinochloa crus-galli*	Grass	Poaceace	V_1, V_2, and V_3	Throughout the season
2.	*Leptochloa chinensis*	Grass	Poaceace	V_1, V_2	At maximum vegetative stage
3	*Fimbristylis miliacea*	Sedge	Cyperaceae	V_2	At maximum vegetative stage
4	*Enhydra fluctuans*	Broadleaf	Asteraceae	V_1, V_2, and V_3	Throughout the season
5	*Sagittaria guayanensis*	Broadleaf	Alismataceae	V_1, V_2, and V_3	Throughout the season
6	*Ludwigia octovalvis*	Broadleaf	Onagraceae	V_1	At maximum vegetative stage

Here, V_1 = Tulshimala, V_2 = BR11 and V_3 = BRRI hybrid dhan6

4.1.3 Weed density m^{-2}

Effect of variety

The significant effect on weed density m^{-2} was found in different varieties at 30 DAT and 60 DAT (Fig. 2). Among the different rice varieties, the maximum weed density m-2 (17.71 and 7.20 at 30 and 60 DAT) was observed in the Tulshimala rice variety while the minimum weed density m-2 (11.86 and 4.66 at 30 and 60 DAT) was observed in BRRI hybrid dhan6 rice variety cultivation. The number of weeds was lower in the high-yielding rice variety might be due to vigorous growth of the variety helped to reduce the weed population and hence lower in number. Afrin *et al.* (2015) also found similar results which supported the present finding and reported that the number of weeds or the weed population, depends on the soil, environment, varieties, and other factors. As a result, variations in the weed population occurred. Gibson *et al.* (2001) reported that competitive rice cultivar viz., hybrids usually have better vigor than inbreeds and effectively suppress the infestation of weed populations or density.

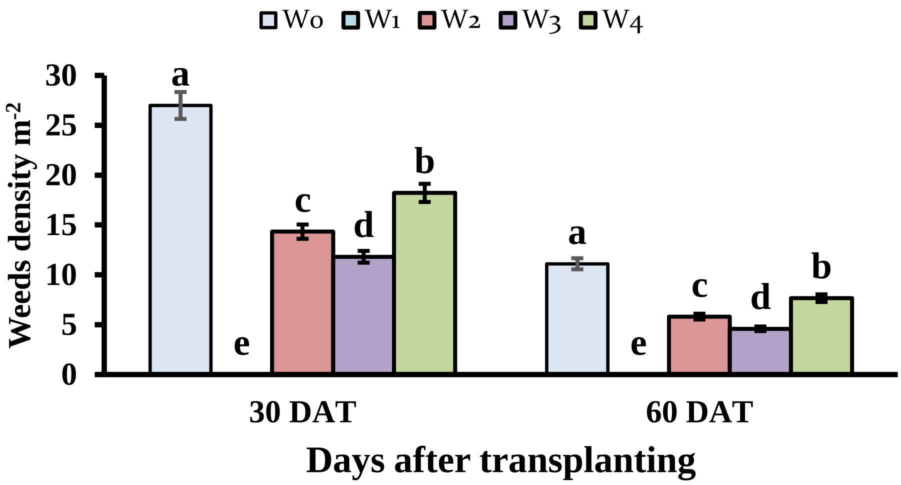


Here, V_1= Tulshimala, V_2 = BR 11, and V_3 = BRRI hybrid dhan6.

Figure 2. Effect of rice variety on weed density m^{-2} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

Application of different weed control treatments significantly affects weed density m^{-2} on T. *aman* rice (Fig. 3). Results revealed that maximum weed density m^{-2} (26.99 and 11.11 at 30 and 60 DAT, respectively) was recorded in weedy check plot while integrated weed management treated plot was recorded minimum weed density m^{-2} (0 and 0, respectively) at 30 and 60 DAT, respectively. This was due to the application of Pretilachlor 6% + pyrazosulfuron 0.15% WP 9.88 kg ha^{-1} mix herbicide which might have prevented the germination of susceptible weed species and also reduced the growth of germinated weeds by inhibiting the process of photosynthesis comparable to other weed control treatments. The result obtained from the present study was similar to the findings of Mahbub and Bhuiyan (2018) also reported that the mixture of herbicides gave 80% control of annual and perennial weeds comparable to individual application of herbicides. Rekha *et al.* (2003) and Reddy *et al.* (2000) also found similar results and reported that the weed density was highest in the weed check condition, and weed density was decreased under different weed management treatments, and among various treatments, all herbicidal treatments reduced weed density significantly compared with a weedy check due to reason that herbicide effect on the germinating weed seeds over a prolonged duration and thereby exhausting the weed seeds over a prolonged duration and thereby exhausting the weed seed reserves in the soil and thus reduced weed density in the crop field



W0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta*.

Figure 3.Effect of weed control treatments on weed density m^{-2} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

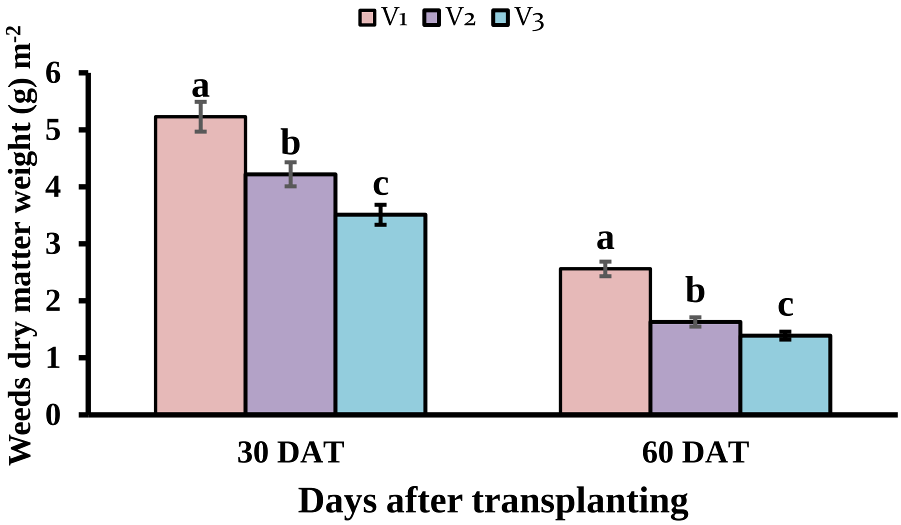
Combined effect of variety and weed control treatments on weeds density

The combined effect of variety and weed control treatments showed a significant effect on weeds density m^{-2} at 30 and 60 DAT (Table 2). Experiment results revealed that the weedy check plot along with Tulshimala rice cultivation recorded maximum weeds density m^{-2} (28.88 and 11.88) at 30 and 60 DAT. While application of mixed herbicide Pretilachlor 6% + pyrazosulfuron 0.15% WP 9.88 kg ha^{-1} mix herbicide and one hand weeding along with BRRI hybrid dhan6 rice cultivation gave minimum weeds density m^{-2} (0.0 and 0.0, respectively) at 30 and 60 DAT, respectively.

4.1.4 Weed dry weight m^{-2} (g)

Effect of variety

Rice varieties play an important role to control weeds to some extent levels which ultimately impacts dry weight accumulation by different weeds in the field. Rice variety showed significant variation in respect of weed dry weight m^{-2} at 30 and 60 DAT (Fig. 4). Results showed that among different rice varieties the maximum weed dry weight m^{-2} (5.23 and 2.56, respectively at 30 and 60 DAT, respectively) was observed in Tulshimala rice. While the minimum weed dry weight m^{-2} (3.51 and 1.49 g, respectively at 30 and 60 DAT, respectively) was observed in BRRI Hybrid dhan6 rice variety treatment. A similar result was also observed by Sohel *et al.* (2020) and reported that the competitive ability of different rice varieties significantly reduces the weed population in the field which ultimately impacts the total dry matter accumulation by weed in the m^{-2} area. The result found in this experiment is agreed with Chauhan and Johnson (2011) who reported that the high competitive varieties would be rapid canopy closure so that shade under the canopy would suppress the growth of weeds which ultimately reduce the dry matter accumulation by weeds.

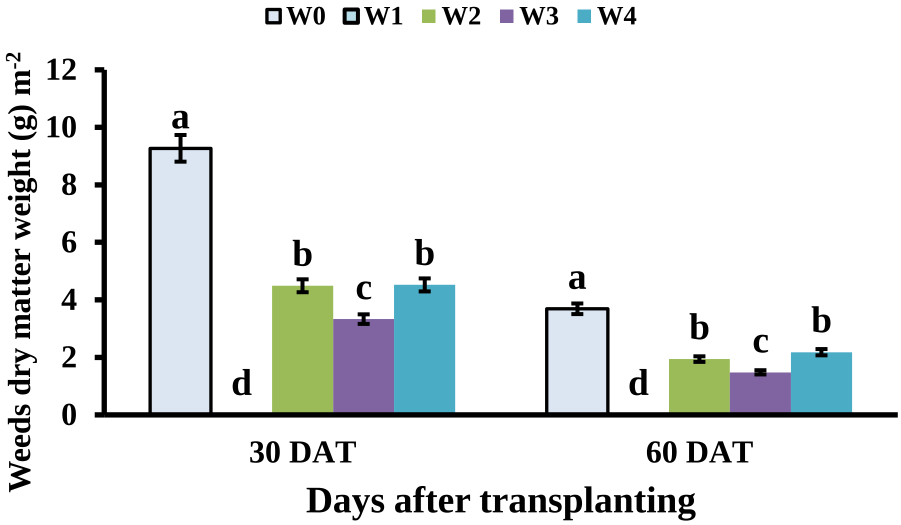


Here, V_1= Tulshimala, V_2 = BR11, and V_3 = BRRI hybrid dhan6.

Figure 4. Effect of variety on weed dry weight m^{-2} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

Weed dry weight m^{-2} was significantly influenced due to the application of different weed control treatments at 30 and 60 DAT (Fig. 5). Results showed that the maximum weed dry weight m-2 (9.27 and 3.69 g, respectively) at 30 and 60 DAT was recorded in the weedy check (W_0) plot. While application of integrated weed management recorded minimum weed dry weight m^{-2} (0.0 and 0.0 g, respectively) at 30 and 60 DAT, respectively. The differences of the dry matter accumulation by different weeds m^{-2} were due to the reason that the application of different weed control treatments alters the physiological and morphological activities of the weeds as a result dry matter accumulation by different weeds m^{-2} was reduced compared to non-treated one.



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta*.

Figure 5. Effect of weed control treatments on weed dry weight m^{-2} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Combined effect of variety and weed control treatments

The combined effect of variety and weed control showed a significant effect on weed's dry weight m-2 at 30 and 60 DAT (Table 5). Experiment results revealed that the weedy check plot along with Tulshimala rice cultivation (V_1W_0) recorded the maximum weeds dry weight m^{-2} (10.34 and 4.83 g, respectively) at 30 and 60 DAT, respectively. While application of integrated weed management along with BRRI hybrid dhan6 rice variety cultivation recorded the minimum weeds dry weight m^{-2} (0.00 and 0.00, respectively) at 30 and 60 DAT, respectively.

Table 2: Combined effect of variety and weed control treatments on weeds density and dry matter weight (g) m^{-2} of T. *aman* rice

Treatment Combinations	Weeds density m^{-2}		Weeds dry matter weight (g) m^{-2}	
	30 DAT	60 DAT	30 DAT	60 DAT
V_1W_0	28.88 a	11.88 a	10.34 a	4.83 a
V_1W_1	0.00 i	0.00 i	0.00 g	0.00 j
V_1W_2	19.22 d	7.33 d	5.56 c	2.67 d
V_1W_3	16.55 e	6.22 e	4.56 d	2.17 e
V_1W_4	23.88 c	10.55 c	5.67 c	3.13 bc
V_2W_0	26.55 b	11.22 b	8.74 b	3.32 b
V_2W_1	0.00 i	0.00 i	0.00 g	0.00 j
V_2W_2	13.22 f	5.55 f	4.67 d	1.67 fg
V_2W_3	10.22 g	4.22 g	3.23 e	1.26 hi
V_2W_4	16.22 e	7.22 d	4.46 d	1.89 f
V_3W_0	25.55 b	10.22 c	8.73 b	2.91 cd
V_3W_1	0.00 i	0.00 i	0.00 g	0.00 j
V_3W_2	10.55 g	4.55 g	3.23 e	1.48 gh
V_3W_3	8.67 h	3.33 h	2.19 f	1.02 i
V_3W_4	14.55 f	5.22 f	3.42 e	1.52 g
$LSD_{(0.05)}$	1.42	0.43	0.47	0.24
CV(%)	5.89	4.34	6.38	7.80

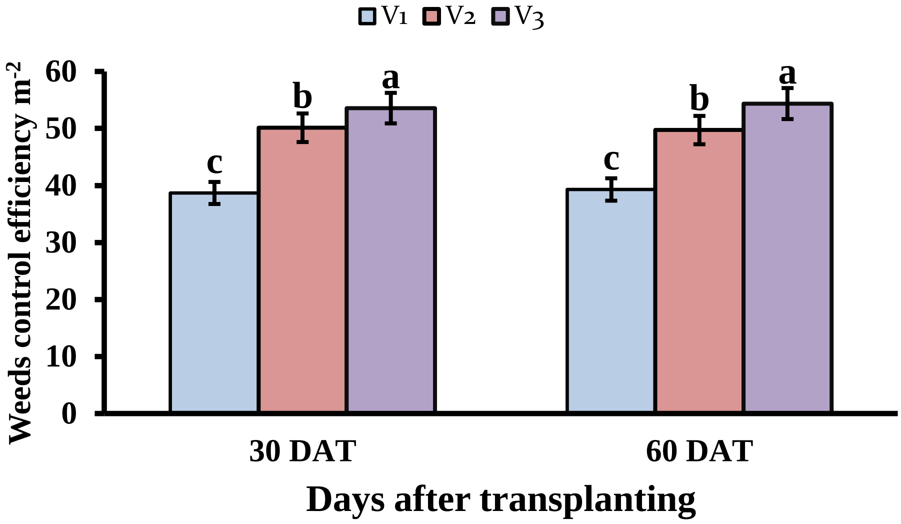
In a column means having a similar letter(s) are statistically similar and those having a dissimilar letter(s) differ significantly at a 0.05 level of probability.

V_1= Tulshimala, V_2 = BR11, V_3 = BRRI hybrid dhan6; W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor*, W_4 = *Salvinia molesta*

4.1.5 Weed control efficiency (%)

Effect of variety

Rice variety significantly effects on weed control efficiency of T. *aman* rice at 30 and 60 DAT (Fig. 6). Due to different rice varieties treatment, the weed control efficiency was ranged from 38.69 to 53.57% over the weedy check plot. Experiment results revealed that cultivation of BRRI Hybrid dhan6 rice variety recorded the maximum weed control efficiency (53.57 and 54.37%, respectively) at 30 and 60 DAT, respectively while the cultivation of Tulshimala rice variety recorded minimum weed control efficiency (38.69 and 53.57%, respectively) at 30 and 60 DAT, respectively. A similar result was also found by Afrin *et al.* (2015) who reported that weed control efficiency is significantly influenced by different rice varieties.

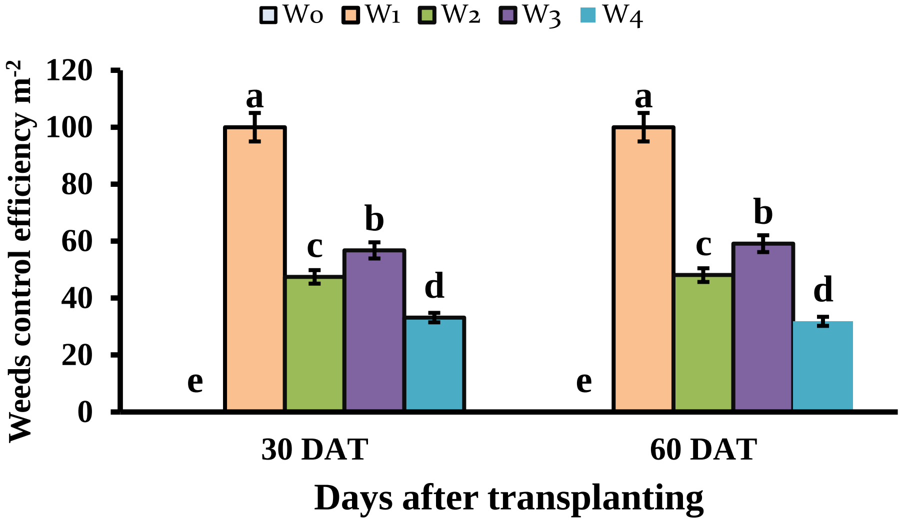


Here, V_1= Tulshimala, V_2 = BR 11, and V_3 = BRRI hybridd han6.

Figure 6. Effect of variety on weed control efficiency m^{-2} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

Application of different weed control treatments significantly affects weed control efficiency of T. *aman* rice at 30 and 60 DAT (Fig. 7). Due to weed control treatments application, weed control efficiency was ranged from 31.83 to 100% over the weedy check. Experiment results exposed that the highest weed control efficiency was observed IWM comparable to other treatments. However, all the weed control treatments suppressed weeds, but the magnitude of suppression was higher in IWM treated plots and it was (100 and 100 %, respectively) at 30 and 60 DAT, respectively. While the minimum weed control efficiency (0.0 and 0.0 %, respectively) at 30 and 60 DAT, respectively was observed in the weedy check. The differences in weed control efficiency were due to variation of weed density in the experimental plots which was attended through different weed control treatments. Different weed control treatments deteriorate the physiological and morphological features of weed and thus reduce weed density and increase weed control efficiency.



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta*.

Figure 7. Effect of weed control treatments on weed control efficiency m^{-2} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

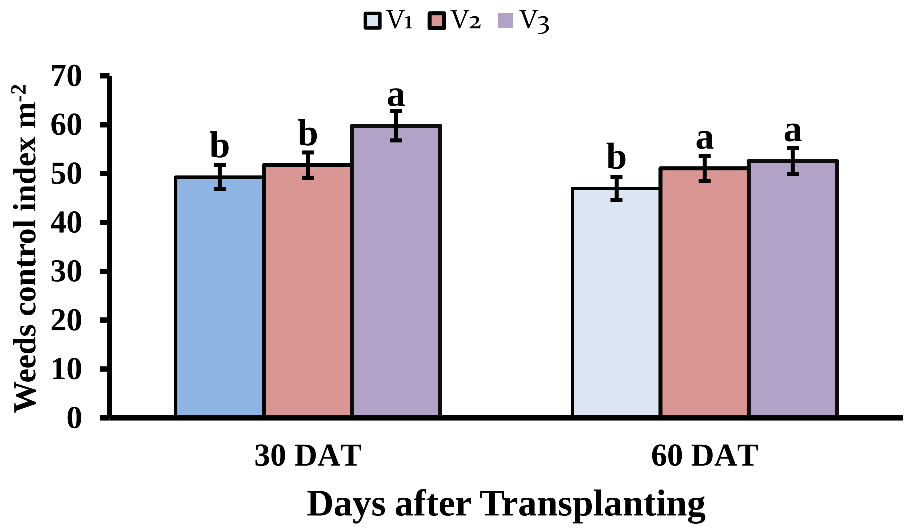
Combined effect of variety and weed control treatments

The combined effect of variety and weed control treatments showed a significant efficiency on weed control at 30 and 60 DAT (Table 3). Due to the combined effect of variety and weed control, the weed control efficiency was ranged from 17.42 to 100% over the weedy check plot. Experiment results revealed that the application of IWM along with Tulshimala rice variety recorded the maximum weed control efficiency (100 and 100%, respectively) at 30 and 60 DAT, respectively which was statistically similar with the application of IWM along with BR11 rice variety (100 and 100 %, respectively), application of IWM along with BRRI hybrid dhan6 rice variety (100 and 100 %, respectively). While the minimum weed control efficiency (0.0 and 0.0 %, respectively) at 30 and 60 DAT, respectively was recorded in weedy check along with Tulshimala rice variety which was statistically similar with the weedy check along with BR11 rice variety cultivation (0.0, and 0.0 %, respectively) and weedy check plot along with BRRI hybrid dhan6 rice variety (0.0 and 0.0 %, respectively) at 30 and 60 DAT, respectively.

4.1.6 Weed control index (%)

Effect of variety

Rice variety significantly effects on weed control index at 30 and 60 DAT (Fig. 8). Due to different rice varieties treatment, the weed control index was ranged from 49.27 to 59.77 % over the weedy check plot. Experiment results revealed that cultivation of BRRI Hybrid dhan6 rice variety cultivation recorded the maximum weed control index of 59.77 % at 30 DAT and 52.37 % at 60 DAT which was statistically similar with BR11 rice variety (51.04%) while the cultivation of Tulshimala rice variety cultivation recorded minimum weed control index 49.27% at 30 DAT which was statistically similar with BR11 rice variety and at 60 DAT 46.95 % weed control index was found in Tulshimala rice variety. Different rice varieties may have a higher competitive ability which helps to suppress the weeds population and reduce the resources utilization thus increasing weed control index by decreasing weeds biomass production. Similar results were also observed by Chauhan and Johnson (2011) who reported that weed control index could be attributed to less weed biomass due to high competitive variety's ability to suppress weeds.

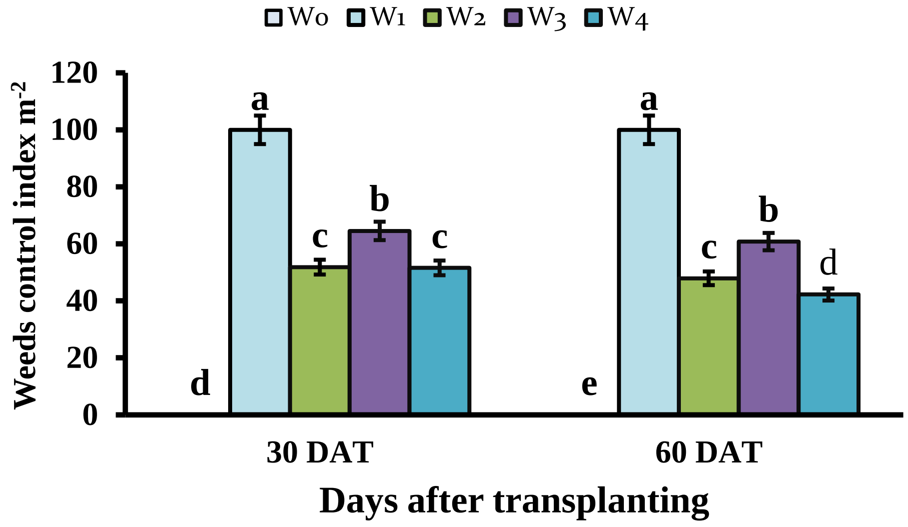


Here, V_1= Tulshimala, V_2 = BR 11, and V_3 = BRRI hybrid dhan6.

Figure 8. Effect of variety on weed control index m^{-2} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

Application of different weed control treatments significantly effects on weed control index of T. *aman* rice at 30 and 60 DAT (Fig. 9). Due to herbicide application, the weed control index was ranged from 33.14 to 100% over the weedy check plot. Experiment result revealed that the higher weed control index was noticed in plots receiving IWM comparable to others treated plots. However, all the weed control treatments suppressed weeds, but the magnitude of suppression was higher in IWM and it was 100 % both at 30 and 60 DAT while the minimum weed control index (0.0 and 0.0%, respectively) at 30 and 60 DAT, respectively was in recorded in weedy check. The differences in weed control index were due to different herbicidal effects on weeds which helps to alter the physiological and morphological features of the weeds and reduce solar energy absorption and thus reduction of dry matter accumulation and ultimately causing reduction of weed density in the crop field. The result obtained from the present study was similar to the findings of Suryakala *et al.* (2019) who reported that the weed control index (WCI) ranged from 78.66-92.32% with various herbicide combinations.



W0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta*.

Figure 9. Effect of weed control treatments on weed control index m^{-2} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Combined effect of variety and weed control treatments

The combined effect of variety and weed control showed a significant effect on weed control index at 30 and 60 DAT (Table 3). Due to the combined effect of variety and weed control, the weed control index was ranged from 17.42 to 100 % over the weedy check plot. Experiment results revealed that application of IWM along with Tulshimala rice variety cultivation recorded the maximum weed control efficiency (100 and 100 %) at 30 and 60 DAT which was statistically similar to the application of IWM along with BR-11 rice variety (100 and 100%, respectively), application of IWM along with BRRI hybrid dhan6 rice variety (100 and 100%, respectively) While the minimum weed control index (0.0 and 0.0 %) at 30 and 60 DAT was recorded in the weedy check plot along with Tulshimala rice cultivation which was statistically similar with weedy check plot along with BR 11 rice variety cultivation (0.0 and 0.0%, respectively), weedy check along with BRRI hybrid dhan6 rice variety cultivation (0.0 and 0.0%, respectively) cultivation at 30 and 60 DAT, respectively.

Table: 3 Combined effect of variety and weed control treatments on weeds control efficiency and index m^{-2} of T. *aman* rice

Treatment Combinations	Weeds control efficiency m^{-2}		Weeds control index m^{-2}	
	30 DAT	60 DAT	30 DAT	60 DAT
V_1W_0	0.00 h	0.00 h	0.00 g	0.00 g
V_1W_1	100.00 a	100.00 a	100.00 a	100.00 a
V_1W_2	33.40 f	38.14 f	45.90 ef	44.63 de
V_1W_3	42.65 e	47.46 e	55.63 d	55.01 c
V_1W_4	17.42 g	10.90 g	44.83 f	35.09 f
V_2W_0	0.00 h	0.00 h	0.00 g	0.00 g
V_2W_1	100.00 a	100.00 a	100.00 a	100.00 a
V_2W_2	50.21 d	50.55 e	46.58 ef	49.82 cd
V_2W_3	61.51 bc	62.40 c	63.07 c	62.20 b
V_2W_4	38.91 e	35.66 f	48.99 e	43.18 e
V_3W_0	0.00 h	0.00 h	0.00 g	0.00 g
V_3W_1	100.00 a	100.00 a	100.00 a	100.00 a
V_3W_2	58.71 c	55.49 d	63.02 c	49.30 c-e
V_3W_3	66.07 b	67.43 b	74.94 b	65.15 b
V_3W_4	43.08 e	48.94 e	60.89 c	48.39 de
$LSD_{(0.05)}$	4.69	3.31	3.40	6.24
CV(%)	5.87	4.10	3.76	7.38

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

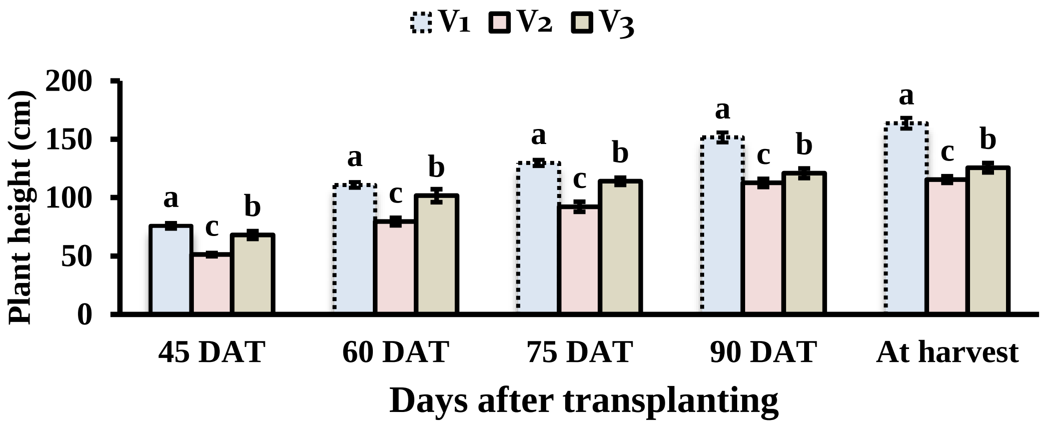
V_1= Tulshimala, V_2 = BR 11, V_3 = BRRI hybrid dhan 6; W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor*, W_4 = *Salvinia molesta*

4.2 Crop growth parameters

4.2.1 Plant height (cm)

Effect of variety

Cultivation of different rice varieties significantly influenced plant height at different days after transplanting (Fig.10). Experiment results showed that Tulshimala rice variety gave the highest plant height (75.83, 110.88, 129.71 151.55, and 163.68, respectively) at 45, 60, 75, 90 DAT, and at harvest, respectively, while BR11 rice variety gave the lowest plant height (51.20, 79.50, 92.19, 112.61, and 115.48 cm, respectively) at 45, 60, 75, 90 DAT, and at harvest, respectively. The variation in plant height is due to the effect of varietal differences. Mahmud *et al.* (2017) showed that plant height was significantly influenced by rice varieties. Tyeb *et al.* (2013) reported that the variation in plant height is due to the effect of varietal differences.

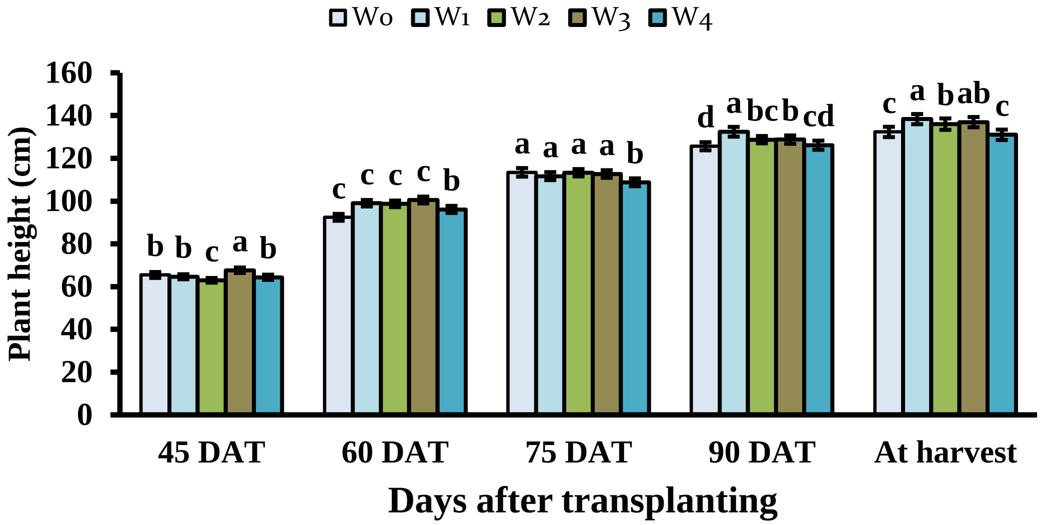


Here, V_1= Tulshimala, V_2 = BR 11, and V_3 = BRRI hybriddhan6.

Figure 10. Effect of variety on plant height of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

The plant height of T. *aman* rice was significantly varied due to the effect of different weed control treatments (Fig.11). The experimental result had shown that at 45 and 60 DAT the highest plant height (67.66 and 100.50 cm, respectively) was recorded in *L. minor* treatment which was statistically similar with IWM (98.99 cm) and *P. stratiotes* (98.72 cm). At 75 DAT the highest plant height (113.44 cm) was found from the weedy check whereas at 90 DAT and at harvest respectively the highest plant height (132.43 and 138.34 cm, respectively) was found from IWM treatment which was statistically similar with *L. minor* (136.93 cm) at harvest. A similar result was also observed by Lodhi (2016) who reported that different weed control treatments increased plant height comparable to the weedy check.



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta.*

Figure 11. Effect of weed control treatments on plant height of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtain three biological replications.

Combined effect of variety and weed control treatments

The combined effect of variety and weed control treatments was significantly influenced the plant height of T. *aman* rice (Table 4). The experimental result indicated that cultivation of Tulshimala variety with weed control through the spreading of *L. minor* in rice agroecosystems gave the highest plant height (77.87 and 113.54 cm, respectively) at 45 and 60 DAT, respectively which was statistically similar with the combination of Tulshimala and weedy check (77.61 cm), BR11 with IWM (75.87 cm), and Tulshimala with *S. molesta* (75.87 cm) at 45 DAT, and Tulshimala with IWM (113.54 cm) combinations at 60 DAT. At 75, 90 DAT, and at harvest, respectively the highest plant height (131.36, 159.19, and 166.00 cm, respectively) were found from the combination of Tulshimala and IWM which was statistically similar with Tulshimala and weedy check (131.30 cm), Tulshimala and *P. stratiotes* (130.61 cm), and Tulshimala and *S. molesta* (130.46 cm) at 75 DAT. Whereas at 45 and 60 DAT the lowest plant height (49.87 and 76.61 cm) was found from the combination of BR11 and weedy check, which was statistically similar with BR11 and IWM (50.24 cm), and with the BR11 and *S. molesta* (51.04 cm and 76.81 cm, respectively) at 45 DAT, and 60 DAT respectively. At 75, 90 DAT, and at harvest, respectively, the lowest plant height (87.59, 108.80, and 111.70 cm) was found from the combination of BR11 and *S.*

molesta which was statistically similar with, BR11 and weedy check (111.80 cm), and BR11 and *L. minor* (111.80 cm) at 90 DAT, and with BR11 and weedy check (113.34 cm) at harvest, respectively.

Table 4.Combined effect of variety and weed control treatments on plant height of *Aman* rice at different DAT

Treatment combinations	45 DAT	60 DAT	75 DAT	90 DAT	At harvest
V_1W_0	77.61±2.03 a	109.15±1.53bc	131.30±1.09a	147.83±2.42 b	160.60b±2.49
V_1W_1	75.87 ± 1.74a	111.86±1.44ab	131.36±1.01a	159.19±2.91 a	166.00a±2.48
V_1W_2	71.92 ± 1.62b	110.08 ±1.47 b	130.61±0.93a	148.52±2.18 b	167.53±2.76a
V_1W_3	77.87 ± 1.89a	113.54 ±1.54 a	130.46±0.97a	151.56±2.49 b	164.67 ±2.5 a
V_1W_4	75.87 ±2.39 a	109.78 ± 3.6 b	124.83±1.15b	150.67±2.63 b	159.60±2.18b
V_2W_0	49.87±1.11 g	76.61 ±2 h	91.96 ±1.76 e	111.80±1.96hi	113.34±1.52gh
V_2W_1	52.16±0.96ef	81.57 ±1.89 g	92.84 ±1.63 e	114.54±2.35fh	118.73 ±1.51 ef
V_2W_2	50.24±0.88fg	80.79 ±1.92 g	95.08 ±1.5 e	114.64±1.76fh	117.63 ±1.69 f
V_2W_3	52.72 ±1.03 e	81.76 ±2.01 g	93.50 ±1.56 e	113.30±2.01gi	116.00 ±1.53 fg
V_2W_4	51.04±0.98eg	76.81 ±2.08 h	87.59 ±1.62 f	108.80 ±2.21 i	111.70 ±1.54 h
V_3W_0	68.85 ±2.71 c	91.47 ±3.47 f	117.05±1.25c	117.34±2.33eg	123.10 ±2.15 d
V_3W_1	65.80 ±2.33d	103.56±3.28e	110.86±1.16d	123.56 ±2.8 c	130.31 ±2.14 c
V_3W_2	66.71±2.16cd	105.30 ±3.33 d	114.10±1.07cd	123.04 ±2.1 cd	122.86 ±2.39 d
V_3W_3	72.41 ±2.52b	106.22±3.47d	114.03±1.14cd	121.44± 2.4ce	130.14 ±2.16 c
V_3W_4	66.20 ±2.39d	101.74 ±3.6 e	113.98±1.15cd	118.99±2.63df	121.70 ±2.18 de
SE	2.26	3.44	4.14	4.52	3.81
CV(%)	2.06	2.10	2.20	2.09	1.67

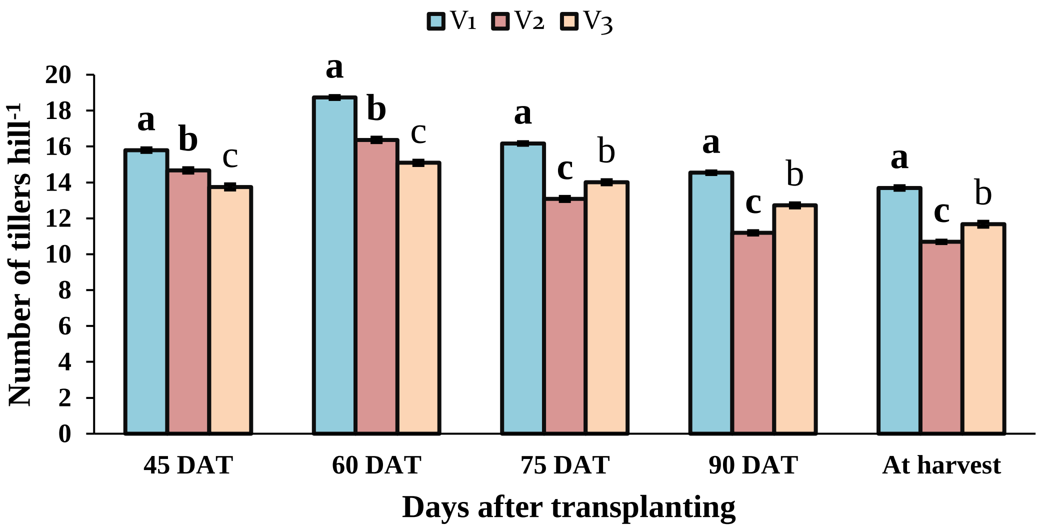
In a column means having a similar letter(s) are statistically similar and those having dissimilar letter(s) letter(s) differ significantly at a 0.05 level of probability.

V_1= Tulshimala, V_2 = BR 11, V_3 = BRRI hybriddhan 6; W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor*, W_4 = *Salvinia molesta*

4.2.2 Number of tillers hill^{-1}

Effect of variety

Cultivation of different rice varieties significantly influenced the number of tillers hill^{-1} at different days after transplanting (Fig.12). Experiment results revealed that Tulshimala (V_1) rice variety recorded the highest number of tillers hill^{-1} (15.80, 18.73, 16.17, 14.54, 13.69) at 45, 60, 75, 90 DAT and at harvest, respectively, while BRRI hybriddhan6 rice (V_3) recorded the lowest plant height (13.75 and 15.09) at 45 and 60 DAT. At 75, 90 DAT, and at harvest, respectively the lowest number of tillers hill^{-1} (13.08, 11.19, and 10.69 respectively) in BR11 (V_1) variety. The variation in the number of tillers hill^{-1} due to the effect of varietal differences. Paul *et al.* (2019) showed that the highest total tiller numbers hill^{-1} at harvest were observed in the local aromatic rice genotype SAU ADL10 (18.75) whereas the minimum tiller numbers hill^{-1} (6.58) was obtained from SAU ADL12.

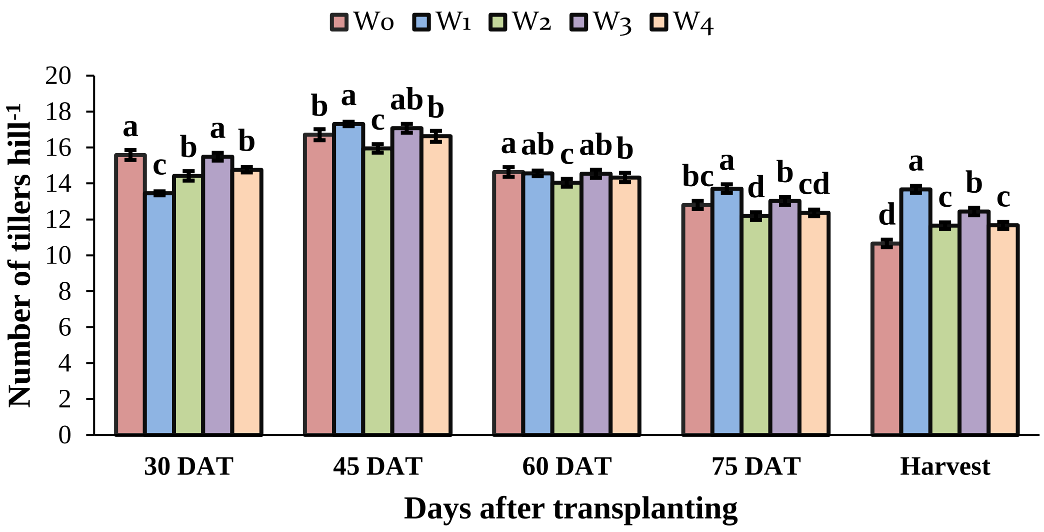


Here, V_1= Tulshimala, V_2 = BR 11, and V_3 = BRRI hybriddhan6.

Figure 12. Effect of variety on number of tillers hill^{-1} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

The number of tillers hill^{-1} of T. *aman* rice was significantly varied due to the effect of different weed control treatments (Fig. 13). The experimental result had shown that, at 45 DAT, the highest number of tillers hill^{-1} (15.58) was recorded in W_0 (Weedy check) treatment which was statistically similar with W_3 (15.49) treatment. At 60 DAT the highest number of tillers hill^{-1} W_1 (17.31) treatment was statistically similar with W_3 (17.07) treatment. At 75 DAT the highest number of tillers hill^{-1} (14.64) was recorded in W_0 (Weedy check) treatment which was statistically similar with W_1 (14.56) and W_3 (14.54) treatment. At 90 DAT and at harvest respectively highest number of tillers hill^{-1} (13.71 and 13.67) was recorded in W_1 treatment. Whereas the lowest number of tillers hill^{-1} (13.45) was recorded in W_1 treatment. At 60, 75, and 90 DAT the lowest number of tillers hill^{-1} (15.95, 14.04, and 12.18 respectively). At harvest respectively the lowest number of tillers hill^{-1} (10.66) was recorded in W_0 treatment (Weedy check) treatment.



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W3 = *Lemna minor* and W_4 = *Salvinia molesta.*

Figure 13. Effect of weed control treatments on number of tillers hill^{-1} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Combined effect of variety and weed control treatments

The combined effect of variety and weed control treatments was significantly influenced the number of tillers hill^{-1} of T. *aman* rice (Table 5). The experimental result revealed that cultivation of BRRI hybrid dhan6 variety along with weed control through the spreading of *L. minor* in rice agroecosystems (V_3W_3) recorded the highest number of tillers hill^{-1} (17.47) at 45 DAT which was statistically similar with V_2W_0 (17.40), V_1W_2 (17.07) and V_1W_0 (16.67). At 60 and 75 DAT, the highest number of tillers hill^{-1} (20.07 and 17.20) was observed in the V_1W_4 treatment combination which was statistically similar to the V_1W_3 (19.27) treatment combination at 60 DAT. At 90 DAT and at harvest respectively the highest number of tillers hill^{-1} (15.07 and 14.67) was observed in the V_1W_1 treatment combination which was statistically similar with V_3W_1 (15.00) at 90 DAT and with V_3W_1 (14.67) and V_1W_3 (14.53) treatment combination at harvest. Whereas the lowest number of tillers hill^{-1} (12.07) V_3W_2 treatment combination at 45 DAT, which was statistically similar with V_3W_0 (12.60). At 60 and 75 DAT, the lowest number of tillers hill^{-1} (13.27 and 11.73) V_3W_0 treatment combination which was statistically similar with V_3W_2 (14.00) at 60 DAT and with V_2W_3 (12.07) and V_2W_2 (12.13) at 75 DAT. At 90 DAT the lowest number of tillers hill^{-1} (10.13) V_2W_2 treatment combination which was statistically similar with V_3W_0 (10.60), V_2W_4 (10.67), and V_2W_3 (10.87) treatment combination. At harvest respectively, the lowest number of tillers hill^{-1} (9.13) V_3W_0 treatment combination which was statistically similar with the V_2W_4 (10.13) treatment combination.

Table 5. Combined effect of variety and weed control treatments on number of tillers hill^{-1} of *aman* rice at different days after transplanting

Treatment combinations	45 DAT	60 DAT	75 DAT	90 DAT	Harvest
V_1W_0	16.67 ±1.69 a	18.00 ±1.52 c-e	16.40 ±1.17 b	14.60±1.05ab	12.26 ±1.3 c
V_1W_1	14.07 ±0.67 c	18.00 ±0.62 c-e	15.28 ±0.7 e	15.07 ±1.09 a	14.67 ±1.17 a
V_1W_2	17.07 ±1.6 a	18.33 ±1.15 b-d	16.13 ±0.96 bc	14.07±0.97bc	13.47 ±1.11 b
V_1W_3	15.67 ±1.32 b	19.27 ±1.2 ab	15.870 ±1.01 cd	14.87±0.98ab	14.53 ±1.29 ab
V_1W_4	15.53 ±1.28 b	20.07 ±2.25 a	17.20 ±1.8 a	14.07±1.31bc	13.53 ±1.67 b
V_2W_0	17.40 ±2.08 a	18.87 ±2.34 bc	15.80 ±1.8 cd	13.20 d±1.33	10.60 ±0.89 e-g
V_2W_1	13.20 ±0.83 cd	17.53 ±0.96 de	13.07 ±1.1 g	11.07 ±1.38 f	11.67 ±0.81 c-e
V_2W_2	14.13 ±1.97 c	15.53 ±1.78 gh	12.13 ±1.51 hi	10.13 ±1.23g	10.40 ±0.77 fg
V_2W_3	13.33 ±1.63 cd	14.67 ±1.86 h-j	12.07 ±1.6 hi	10.87±1.25fg	10.67 ±0.88 efg
V_2W_4	15.27 ±1.09 b	15.27 ±2.34 hi	12.33 ±1.84 h	10.67±1.07fg	10.13 ±0.82 gh
V_3W_0	12.6 ±2.44 de	13.27 ±2.26 k	11.73 ±1.84 i	10.60±1.63fg	9.13 ±1.83 h
V_3W_1	13.07 ±0.97 d	16.40 ±0.92 fg	15.33 ±1.1 e	15.00 ±1.7 a	14.67 ±1.65 a
V_3W_2	12.07 ±2.31 e	14.00 ±1.72 jk	13.87 ±1.51 f	12.33 ±1.5 e	11.07 ±1.57 d-g
V_3W_3	17.47 ±1.9 a	17.27 ±1.79 ef	15.67 ±1.59 de	13.33±1.53cd	12.13 ±1.81 cd
V_3W_4	13.47 ±1.28 cd	14.53 ±2.26 ij	13.47 ±1.83 fg	12.33 ±1.31 e	11.34 ±1.67 c-f
SE	**0.97**	**0.97**	**0.44**	**0.86**	**1.12**
CV(%)	**3.92**	**3.45**	**1.83**	**3.96**	**5.55**

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

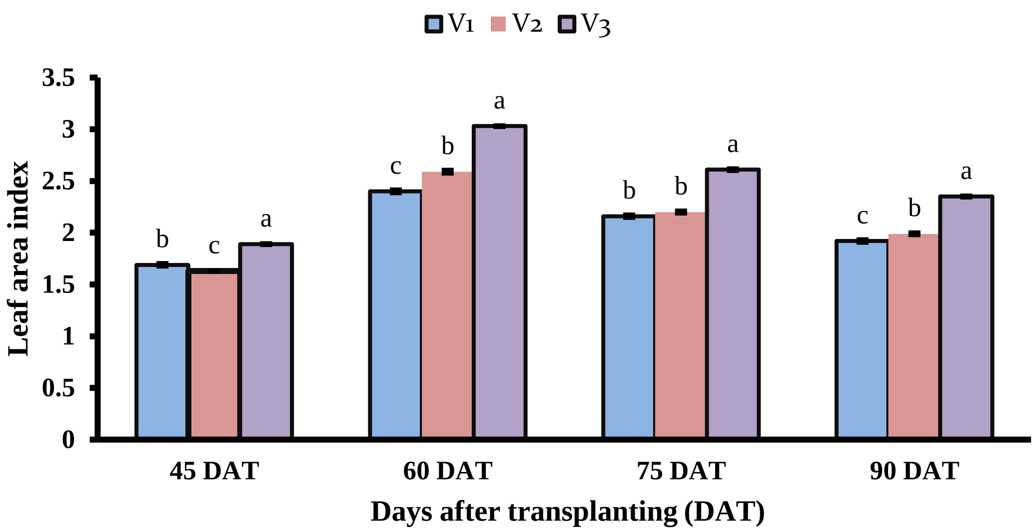
V_1= Tulshimala, V_2 = BR 11, V_3 = BRRI hybriddhan 6; W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes,* W_3 = *Lemna minor,* W_4 = *Salvinia molesta*

4.2.3 Leaf area index

Effect of variety

Leaf area index is significantly affected by different rice varieties at different DAT (Figure 14). Experiment results had shown that the BRRI hybrid dhan6 (V_3) rice variety recorded the highest leaf area index (1.89, 3.03, 2.61, and 2.35) at 45, 60, 75 DAT, and 90 DAT. While the BR11 (V_2) rice variety recorded the lowest leaf area index (1.63) at 45 DAT. At 60, 75 DAT, and at 90 DAT the lowest leaf area index (2.40, 2.16, and 1.92, respectively) was obtained from Tulshimala (V_1) rice variety. Hossain *et al.*

(2016) revealed that different rice varieties and nutrient levels along with their interaction have a significant effect on the growth and yield of rice. It was observed that the leaf area index of the crop was influenced by variety.

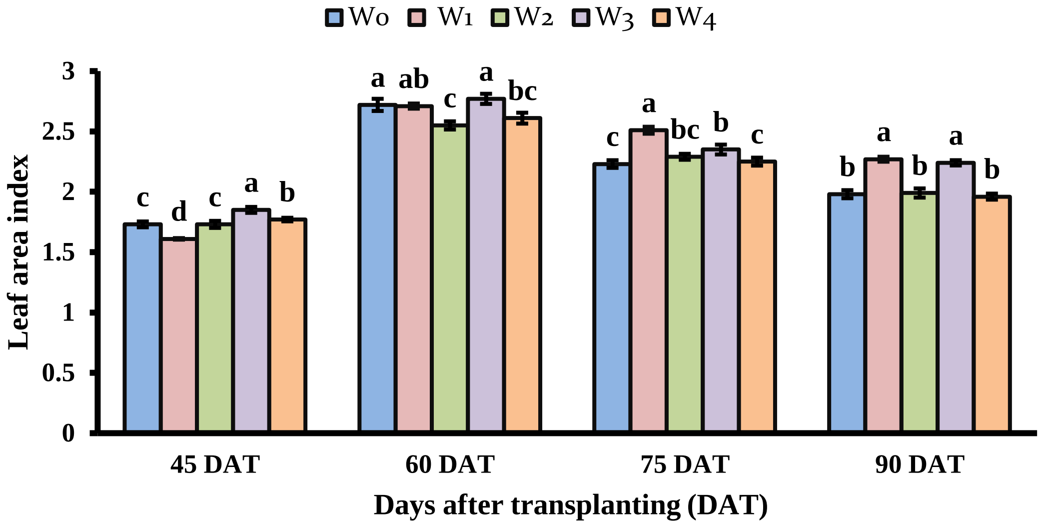


Here, V_1= Tulshimala, V_2 = BR11, and V_3 = BRRI hybrid dhan6.

Figure 14. Effect of variety on leaf area index of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

Different weed control treatments had a significant effect on the leaf area index of T. *aman* rice at different DAT (Fig. 15). Experimental results had shown that the highest leaf area index (1.85 and 2.77) was recorded in W_3 (*L. minor*) treatment at 45 and 60 DAT, which was statistically similar with W_0 (2.72) and W_1 (2.71) treatment at 60 DAT. At 75 and 90 DAT, the highest leaf area index (2.51 and 2.27) was recorded in the W_1 treatment, which was statistically similar to the W_3 (2.24) treatment at 90 DAT. Whereas At 45 DAT, the lowest leaf area index (1.61) was recorded in W_1 (IWM) treatment. At 60 DAT, the lowest leaf area index (2.55) was recorded in W_2 (*P. stratiotes*) treatment, At 75 DAT, the lowest leaf area index (2.23) was recorded in W_0 (Weedy check) treatment, which was statistically similar with W_4 (2.25) and W_2 (2.29) treatment. At 90 DAT, the lowest leaf area index (1.96) was recorded in W_4 (*S. molesta)* treatment, which was statistically similar with W_0 (1.98) and W_2 (1.99) treatment



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W3 = *Lemna minor* and W_4 = *Salvinia molesta*.

Figure 15. Effect of weed control treatments on leaf area index of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Combined effect of variety and weed control treatments

The combined effect of variety and weed control treatments was significantly influenced the leaf area index of T. *aman* rice at different days after transplanting (Table 6). Experimental results revealed that cultivation of Tulshimala variety along with weed control through the spreading of duckweed (*L. minor*) in rice agroecosystems (V_1W_3) recorded the highest leaf area index (2.10) at 45 DAT, which was statistically similar with V_3W_2 (2.04). At 60 DAT the highest leaf area index (3.21) was recorded in the V_3W_3 treatment combination, which was statistically similar with V_3W_4 (3.08) and V_3W_0 (3.04) treatment combination. At 75 and 90 DAT, the highest leaf area index (2.79 and 2.50) was recorded in the V_3W_1 treatment combination which was statistically similar to the V_3W_3 treatment combination recorded leaf area index (2.77 and 2.49) at 75 and 90 DAT. Whereas the lowest leaf area index (1.44) was recorded in the V_1W_2 treatment combination at 45 DAT. At 60, 75, and 90 DAT the lowest leaf area index (2.12, 1.87, and 1.59, respectively) was recorded in the V_1W_0 treatment combination which was statistically similar with V_1W_2 (2.24) treatment combination at 60 DAT; with V_2W_3 (1.93) and V_1W_4 (1.97) at 75 DAT, and with V_2W_2 (1.62) and V_1W_4 (1.70) treatment combination at 90 DAT.

Table 6. Combined effect of variety and weed control treatments on leaf area index of T. *aman* rice at different days after transplanting

Treatment combinations	45 DAT	60 DAT	75 DAT	90 DAT
V_1W_0	1.51 ± 0.05 f	2.12 ± 0.12 g	1.87 ± 0.07 i	1.59 ± 0.07 g
V_1W_1	1.56 ± 0.01 ef	2.46 ± 0.05 e	2.39 ± 0.06 cd	2.12 ± 0.05 c-e
V_1W_2	1.44 ± 0.07 g	2.24 ±0.08 fg	2.21 ± 0.05 e-g	1.97 ± 0.09 f
V_1W_3	2.10 ± 0.05 a	2.76 ± 0.1 d	2.34 ± 0.09 de	2.18 ± 0.04 bc
V_1W_4	1.83 ± 0.02 c	2.44 ±0.05 e	1.97 ± 0.06 hi	1.70 ± 0.03 g
V_2W_0	1.68 ± 0.01 d	3.01 ± 0.13 bc	2.52 ± 0.06 bc	2.11 ± 0.06 c-e
V_2W_1	1.58 ± 0.003 e	2.80 ± 0.05 d	2.34 ± 0.06 de	2.17 ± 0.04 b-d
V_2W_2	1.69 ± 0.02 d	2.48 ± 0.08 e	2.09 ± 0.07 gh	1.62 ± 0.07 g
V_2W_3	1.59 ± 0.01 e	2.34 ± 0.11 ef	1.93 ± 0.08 i	2.05 ± 0.04 d-f
V_2W_4	1.61 ± 0.008 e	2.32 ± 0.11 ef	2.15 ± 0.06 fg	2.02 ± 0.05 ef
V_3W_0	1.99 ± 0.03 b	3.04 ± 0.05 a-c	2.28 ± 0.05 d-f	2.25 ± 0.04 b
V_3W_1	1.68 ± 0.008 d	2.88 ± 0.02 cd	2.79 ± 0.05 a	2.50 ± 0.03 a
V_3W_2	2.04 ± 0.04 ab	2.93 ± 0.04 b-d	2.58 ± 0.04 b	2.41 ± 0.05 a
V_3W_3	1.86 ± 0.03 c	3.21 ± 0.05 a	2.77 ± 0.07 a	2.49 ± 0.03 a
V_3W_4	1.88 ± 0.02 c	3.08 ± 0.05 ab	2.62 ± 0.06 b	2.15 ± 0.03 b-d
SE	0.03	0.08	0.06	0.05
CV(%)	2.10	3.98	3.51	3.27

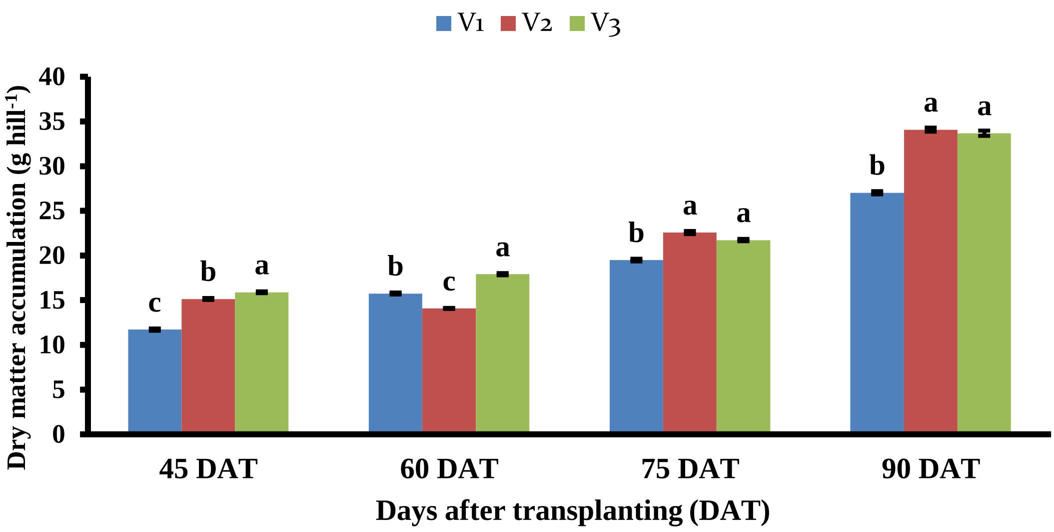
In a column means having a similar letter(s) are statistically similar and those having a dissimilar letter(s) differ significantly at a 0.05 level of probability.

V_1= Tulshimala, V_2 = BR 11, V_3 = BRRI hybrid dhan6; W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes,* W_3 = *Lemna minor,* W_4 = *Salvinia molesta*

4.2.4 Dry matter accumulation

Effect of variety

Different rice varieties significantly affect dry matter accumulation (g hill^{-1}) of T. *aman* rice at different DAT (Figure 16). Among different rice varieties, the BRRI hybrid dhan6 (V_3) rice variety recorded the highest dry matter accumulation (15.89 and 17.91 g hill^{-1}, respectively) at 45 and 60 DAT. At 75 and 90 DAT highest dry matter accumulation (21.73 and 33.68 g hill^{-1}, respectively) was recorded in BR11 (V_2) rice variety which was statistically similar with V_3 (22.57 and 34.08 g hill^{-1}, respectively) at 75 and 90 DAT. Whereas the lowest dry matter accumulation (11.71, 14.08,19.49, and 27.02 g hill^{-1}, respectively) at 45, 60, 75, and 90 DAT was recorded in Tulshimala (V_1) treatment. The dry matter accumulation (g hill^{-1}) differs among different varieties due to the reason that the individual variety has individual leaf area, growth stage, and resources utilization its surrounded which influences the dry matter accumulation (g hill^{-1}). Nahida *et al.* (2013) reported that dry matter (DM) accumulation over time varied considerably due to variety and it is more in high yielding variety comparable to the local one.

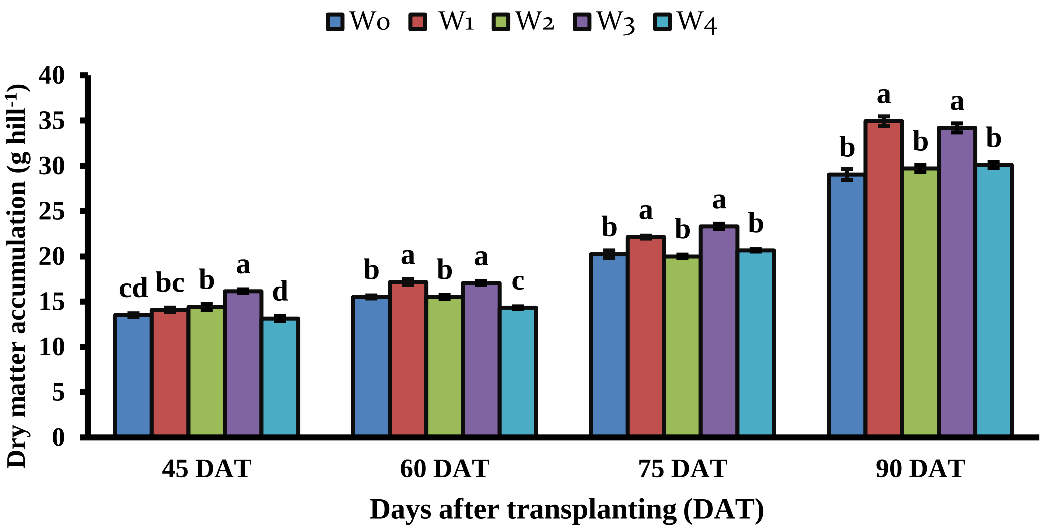


Here, V_1= Tulshimala, V_2 = BR11, and V_3 = BRRI hybrid dhan6.

Figure 16. Effect of variety on dry matter accumulation hill^{-1} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

Different weed control treatments significantly affect dry matter accumulation (g hill^{-1}) of T. *aman* rice at different days after transplanting (Figure 17). Among different weed control treatments, the highest dry matter accumulation (16.14, 17.04, 23.31 g hill^{-1}) was recorded in W_3 (*L. minor*) treatment which was statistically similar with W_1 (17.17 and 22.13 g hill^{-1}, respectively) at 60 and 75 DAT. At 90 DAT, the highest dry matter accumulation (34.94 g hill^{-1}) was recorded in W_1 (IWM) treatment which was statistically similar with W_3 (34.19 g hill^{-1}). Whereas at 45 and 60 DAT the lowest dry matter accumulation (13.12 and 14.33 g hill^{-1}, respectively) was recorded in W_3 (*S. molesta*) treatment which was statistically similar with W_0 (13.50 g hill^{-1}) at 45 DAT. At 75 and 90 DAT, the lowest dry matter accumulation (20.24 and 29.04 g hill^{-1}) was recorded in W_0 (Weedy check) treatment, which was statistically similar with W_2 (20.00 and 29.70 g hill^{-1}, respectively) and W_4 (20.66 and 30.09 g hill^{-1}, respectively) at 75 and 90 DAT. A similar result was also observed by Lodhi (2016) who reported that different weed control treatments caused remarkable variations in the quantity of dry matter accumulation at different days after transplanting.



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W3 = *Lemna minor* and W_4 = *Salvinia molesta.*

Figure 17. Effect of weed control treatments on dry matter accumulation hill^{-1} of T. *aman* rice at different days after transplanting. Bars represent ±SD values obtained from three biological replications.

Combined effect of variety and weed control treatments

The combined effect of variety and weed control was significantly influenced dry matter accumulation (g hill^{-1}) (Table 7) of T. *aman* rice at different days after transplanting. Experimental results revealed that cultivation of BRRI hybriddhan6 variety along with weed control through the spreading of duckweed (*L. minor*) in rice agroecosystems (V_2W_3) recorded the highest dry matter accumulation (16.99 g hill^{-1}) 45 DAT which was statistically similar with V_3W_3 (16.71 g hill^{-1}), V_3W_1 (16.70 g hill-

^{1}), V_2W_2 (16.61 g hill^{-1}) and V_3W_2 (15.98). At 60 DAT the highest dry matter accumulation (20.02 g hill^{-1}) was observed in the V_3W_1 treatment combination which was statistically similar to the V_3W_1 (19.14 g hill^{-1}) treatment combination. At 75 DAT the highest dry matter accumulation (26.84 g hill^{-1}) was observed in the V_2W_3 treatment combination. At 90 DAT the highest dry matter accumulation (40.78 g hill^{-1}) was observed in the V_3W_1 treatment combination which was statistically similar to the V_2W_3 (39.15 g hill^{-1}) treatment combination. Whereas the dry matter accumulation (9.84 g hill^{-1}) was recorded in the V_1W_4 treatment combination at 45 DAT, which was statistically similar with V_1W_2 (10.59 g hill^{-1}). At 60 the lowest dry matter accumulation (13.30 g hill^{-1}) was recorded in the V_2W_4 treatment combination which was statistically similar to V_2W_2 (13.43 g hill^{-1}) treatment combination. At 75 and 90 DAT, the lowest dry matter accumulation (16.85 and 22.92 g hill^{-1}) was recorded in the V_1W_0 treatment combination which was statistically similar with V_3W_2 (18.74 g hill^{-1}) and V_1W_2 (18.92 g hill^{-1}) at 75 DAT.

Table 7. Combined effect of variety and weed control treatments on dry matter weight hill-1 of T. *aman* rice at different days after transplanting

Treatment combinations	45 DAT	60 DAT	75 DAT	90 DAT
V_1W_0	11.51 ±1.14 fg	14.53 ±0.82 cd	16.85 ±2.78 g	22.92 ±2.86 e
V_1W_1	11.90 ±1.36 f	17.30 ±1.56 d	21.31 ±1.06 c-e	30.09 ±2.19 c
V_1W_2	10.59 ±1.87 gh	15.47 ±1.06 c	18.92 ±1.31 fg	26.59 ±0.99 d
V_1W_3	14.70 ±1.11 cd	17.19 ±1.1 b	20.98 ±2.01 c-f	28.90 ±2.01 c
V_1W_4	9.84 ±1.26 h	14.25 ±0.75 de	19.39 ±0.71 ef	26.63 ±2.19 d
V_2W_0	13.69 ±0.97 de	14.69 ±0.42 cd	20.70 ±3.1 c-f	30.02 ±4.14 c
V_2W_1	13.65 ±1.15 e	14.19 ±0.81 de	21.05 ±1.21 c-f	33.96 ±3.3 b
V_2W_2	16.61 ±1.58 a	13.43 ±0.55 e	22.34 ±1.49 b-d	34.03 ±1.79 b
V_2W_3	16.99 ±0.94 a	14.78 ±0.57 cd	26.84 ±2.29 a	39.15 ±3.07 a
V_2W_4	14.76 ±1.33 c	13.30 ±0.36 e	21.94 ±0.94 b-d	33.26 ±1.25 b
V_3W_0	15.30 ±0.91 bc	17.31 ±0.88 b	23.16 ±2.4 bc	34.21 ±3.91 b
V_3W_1	16.70 ±1.08 a	20.02 ±1.69 a	24.02 ±0.92 b	40.78 ±4.83 a
V_3W_2	15.98 ±1.49 ab	17.64 ±1.15 b	18.74 ±1.13 fg	28.48 ±2.88 cd
V_3W_3	16.71 ±0.88 a	19.14 ±1.19 a	22.11 ±1.74 b-d	34.52 ±4.53 b
V_3W_4	14.76 ±1.25 c	15.42 ±0.75 c	20.64 ±0.71 d-f	30.40 ±2.19 c
SE	1.02	0.95	2.17	1.97
CV(%)	4.25	3.53	6.07	3.71

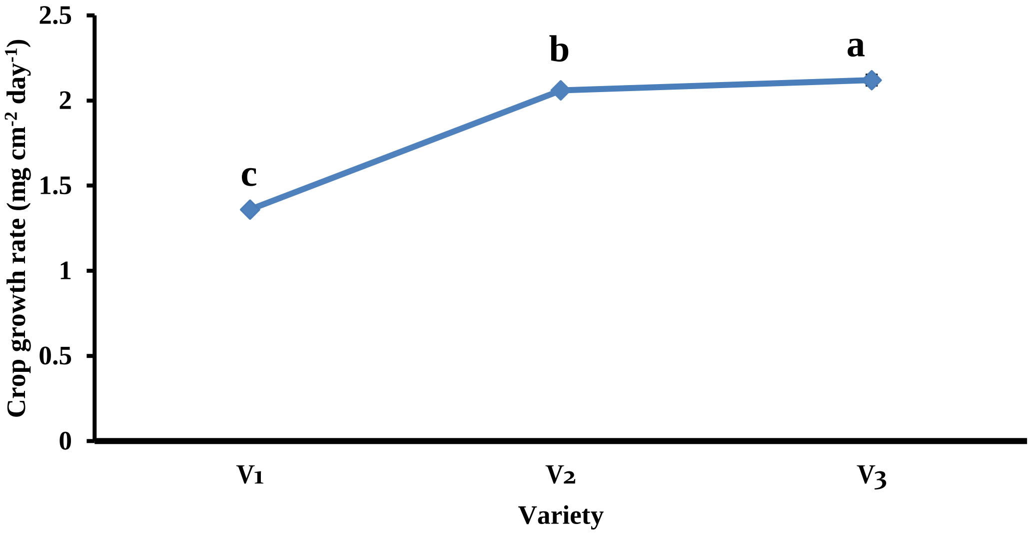
In a column means having a similar letter(s) are statistically similar and those having a dissimilar letter(s) differ significantly at a 0.05 level of probability.

V_1= Tulshimala, V_2 = BR 11, V_3 = BRRI hybrid dhan 6; W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor*, W_4 = *Salvinia molesta*

4.2.5 Crop growth rate

Effect of variety

Different rice varieties significantly affect the crop growth rate of T. *aman* rice (Figure 18). Experimental results had shown that the highest crop growth rate (2.12 mg cm^{-2} day^{-1}) was recorded in the BRRI hybrid dhan6 (V_3) rice variety while the lowest crop growth rate (1.36 mg cm^{-2} day^{-1}) was recorded in Tulshimala (V_1) rice variety. The crop growth rate is the product of leaf area index and net assimilation rate values, and a higher crop growth rate achieved in the modern varieties than the aromatic varieties may be due to the higher leaf area index. Toshiyuki *et al.* (2006) reported that the genotypic difference in grain yield was most closely related to that in crop growth rate.



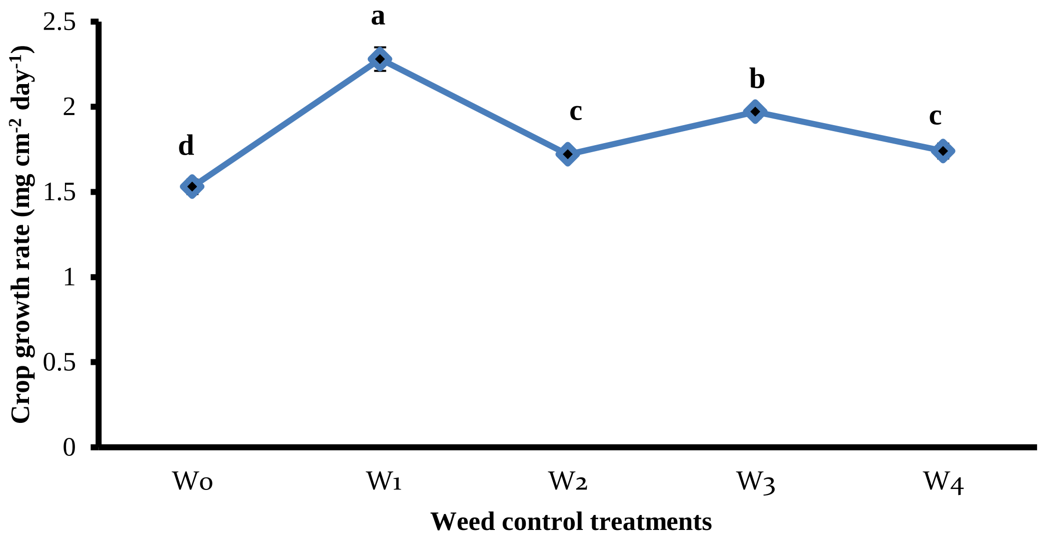
Here, V_1= Tulshimala, V_2 = BR11, and V_3 = BRRI hybrid dhan6.

Figure 18. Effect of variety on the crop growth rate of T. *aman* rice.

Effect of weed control treatments

The crop growth rate of T. *aman* rice was significantly varied due to the effect of different weed control treatments (Fig. 19). Experimental results had shown that weed control through integrated weed management (W_1) recorded the highest crop growth rate (2.28 mg cm^{-2} day^{-1}) whereas the lowest crop growth rate (1.53 mg cm^{-2} day^{-1}) was recorded in the weedy check plot (W_0). A similar result was also observed by Lodhi

(2016) who reported that different weed control treatments increased crop growth rate comparable to the weedy check.



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta.*

Figure 19. Effect of weed control treatments on the crop growth rate of T. *aman* rice.

Combined effect of variety and weed control treatments

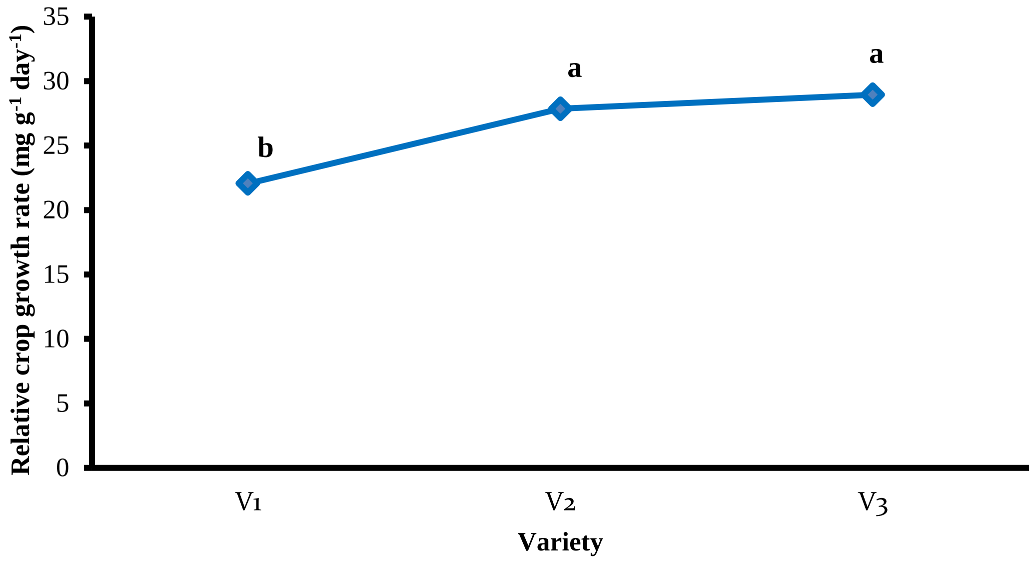
Combined effect of variety and weed control was significantly influenced the crop growth rate of T. *aman* rice (Table 8). Experimental results revealed that cultivation of BRRI hybriddhan6 variety along with weed control through integrated weed management (V_3W_1) recorded the highest crop growth rate (2.98 mg cm^{-2} day^{-1}). Whereas cultivation of Tulshimala variety along with weed check plot (V_1W_0) recorded the lowest crop growth rate (1.08 mg cm^{-2} day^{-1}).

4.2.6 Relative crop growth rate

Effect of variety

Cultivation of different rice varieties significantly affects the relative crop growth rate of T. *aman* rice (Fig. 20). The experimental result had shown that the highest relative crop growth rate (28.94 mg g^{-1} day^{-1}) was recorded in the BRRI hybrid dhan6 (V_3) rice variety which was statistically similar with BR11 (V_2) rice variety recorded relative crop growth rate (27.85 mg g^{-1} day^{-1}). While the lowest relative crop growth rate (22.05

mg g^{-1} day^{-1}) was recorded in Tulshimala (V_1) rice variety. Amin *et al.* (2002) reported that relative crop growth rate differs among different rice varieties.

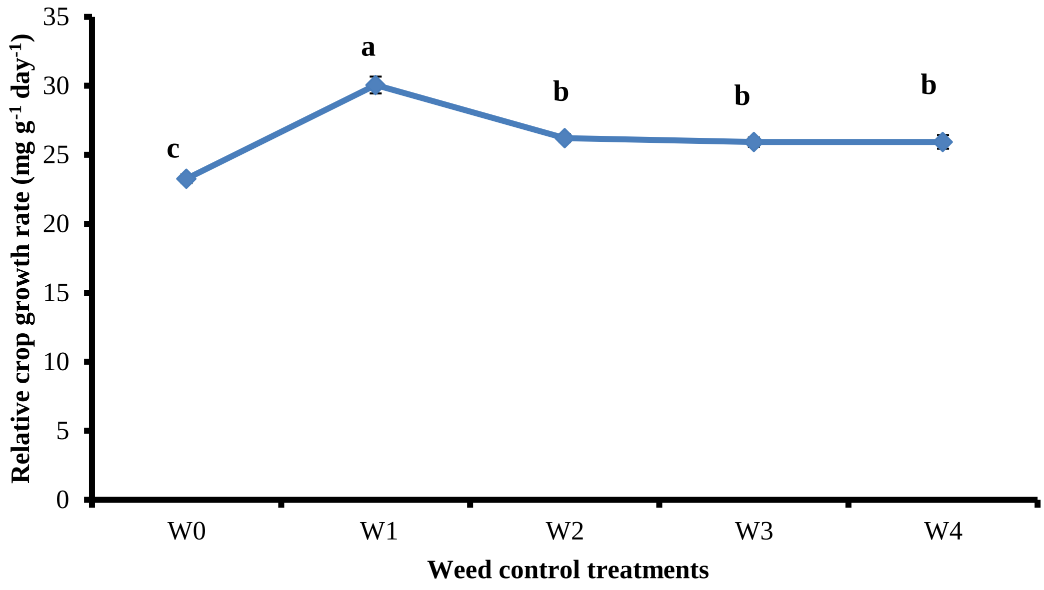


Here, V_1= Tulshimala, V_2 = BR11, and V_3 = BRRI hybrid dhan6.

Figure 20. Effect of variety on the relative crop growth rate of T. *aman* rice.

Effect of weed control treatments

The relative crop growth rate of T. *aman* rice was significantly varied due to the effect of different weed control treatments. Experimental results had shown that weed control through integrated weed management (W_1) recorded the highest relative crop growth rate (30.06 mg g^{-1} day^{-1}) whereas the lowest crop growth rate (23.27 mg g^{-1} day^{-1}) was recorded in the weedy check plot (W_0). Olayinka and Etejere (2015) reported that all the weed control treatments had higher RGR as compared to the weedy check.



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta.*

Figure 21. Effect of weed control treatments on the relative crop growth rate of T. *aman* rice.

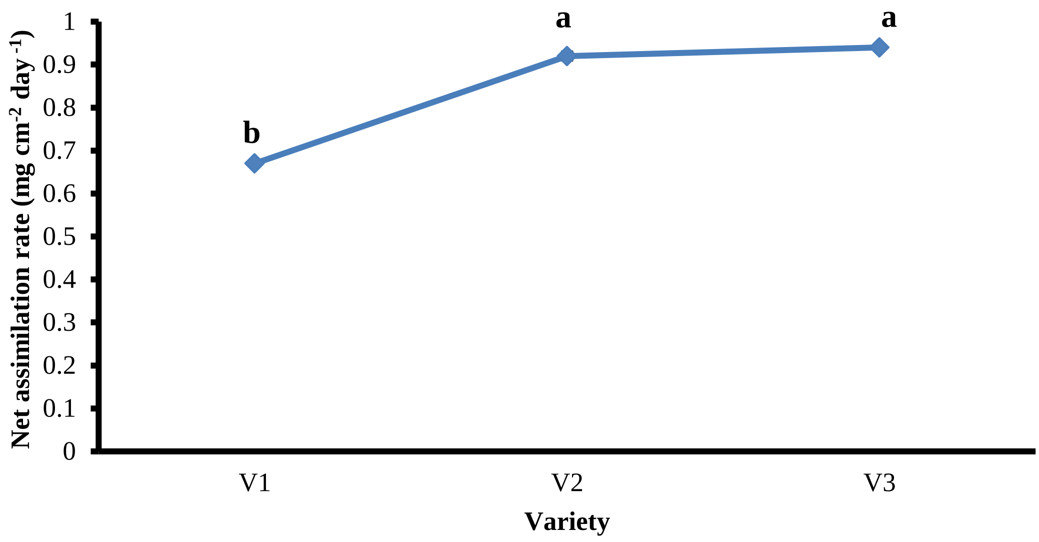
Combined effect of variety and weed control treatments

The combined effect of variety and weed control was significantly influenced relative to the crop growth rate of T. *aman* rice (Table 8). The experimental result revealed that cultivation of BRRI hybriddhan6 variety along with weed control through integrated weed management (V_3W_1) recorded the highest relative crop growth rate (35.29 mg g^{-1} day^{-1}). Whereas cultivation of Tulshimala variety along with weed check plot (V_1W_0) recorded the lowest relative crop growth rate (20.51 mg g^{-1} day^{-1}) which was statistically similar with V_1W_4 (21.15 mg g^{-1} day^{-1}) treatment combination.

4.2.7 Net assimilation rate

Effect of variety

Net assimilation rate is an important factor as it relates to crop growth and development. The experimental result had shown that the highest net assimilation rate (0.94 mg cm^{-2} day^{-1}) was recorded in the BRRI hybrid dhan6 (V_3) rice variety which was statistically similar with BR11 (V_2) rice variety recorded net assimilation rate (0.92 mg cm^{-2} day^{-1}). While the lowest net assimilation rate (0.67 mg cm^{-2} day^{-1}) was recorded in Tulshimala (V_1) rice variety. Different rice varieties significantly influenced the net assimilation rate due to the reason that individual varieties had individual leaf area, growth rate, resources utilization ability, and genetic make-up.

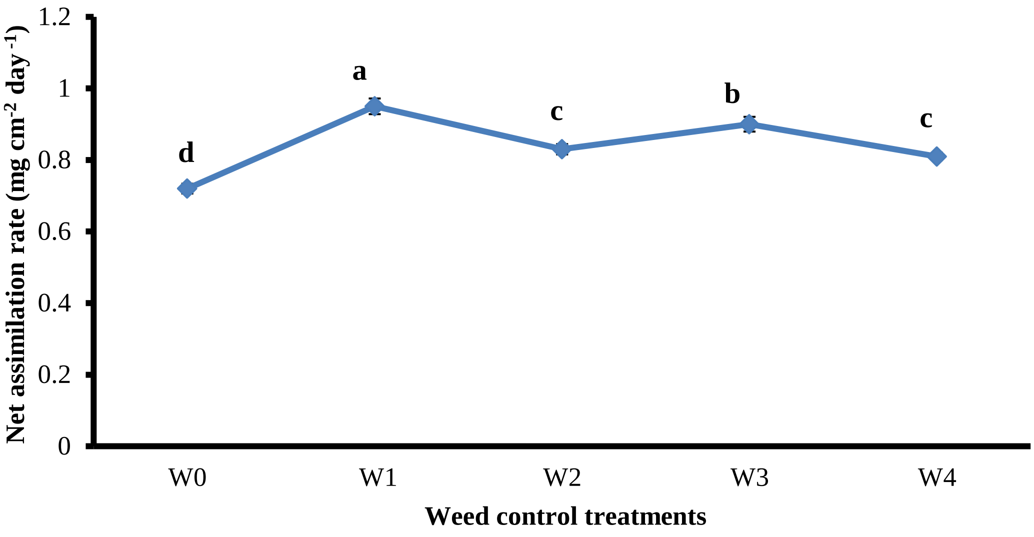


Here, V_1= Tulshimala, V_2 = BR11, and V_3 = BRRI hybrid dhan6.

Figure 22. Effect of variety on net assimilation rate of T. *aman* rice.

Effect of weed control treatments

The net assimilation rate of T. *aman* rice was significantly varied due to the effect of different weed control treatments. The experimental result had shown that weed control through integrated weed management (W_1) recorded the highest net assimilation rate (0.95 mg cm^{-2} day^{-1}) whereas the lowest net assimilation rate (0.72 mg cm^{-2} day^{-1}) was recorded in weedy check plot (W_0). Shultana *et al.* (2013) revealed that the highest net assimilation rate (NAR) was found with no weed competition, on the other hand, the lowest net assimilation rate was observed in the control treatment.



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta*.

Figure 23. Effect of weed control treatments on net assimilation rate of T. *aman* rice.

Combined effect of variety and weed control treatments

The combined effect of variety and weed control treatments was significantly influenced the net assimilation rate of T. *aman* rice (Table 8). The experimental results revealed that cultivation of BRRI dhan6 variety along with weed control through integrated weed management (V_3W_1) recorded the highest net assimilation rate (1.13 mg cm^{-2} day^{-1}) which was statistically similar with V_3W_1 (1.10 mg cm^{-2} day^{-1}).Whereas cultivation of Tulshimala variety along with weed check plot (V_1W_0) recorded the lowest net assimilation rate (0.62 mg cm^{-2} day^{-1}) which was statistically similar with V_1W_2 (0.66 mg cm^{-2} day^{-1}), V_2W_0 (0.67 mg cm^{-2} day^{-1}) and V_1W_3 (0.68 mg cm^{-2} day^{-1}) treatment combination.

Table 8: Combined effect of variety and weed control treatments on the crop growth rate, relative crop growth rate, and net assimilation rate of T. *aman* rice

Treatment Combinations	Crop growth rate	Relative crop growth rate	Net assimilation rate
V_1W_0	1.08 ± 0.07 i	20.51 ± 0.19 h	0.62 ± 0.003 g
V_1W_1	1.56 ± 0.12 g	23.00 ± 0.38 f	0.69 ± 0.005 f
V_1W_2	1.36 ± 0.06 h	22.69 ± 0.18 fg	0.66 ± 0.003 fg
V_1W_3	1.53 ± 0.06 g	22.88 ± 0.21 fg	0.68 ± 0.005 fg
V_1W_4	1.29 ± 0.2 h	21.15 ± 1.12 gh	0.70 ± 0.01 f
V_2W_0	1.54 ± 0.1 g	23.28 ± 0.66 f	0.67 ± 0.02 fg
V_2W_1	2.29 ± 0.17 b	31.89 ± 1.3 b	1.02 ± 0.03 b
V_2W_2	2.08 ± 0.08 d	28.09 ± 0.62 d	0.93 ± 0.02 cd
V_2W_3	2.19 ± 0.09 c	25.17 ± 0.71 e	1.10 ± 0.03 a
V_2W_4	2.19 ± 0.11 bc	30.85 ± 1 bc	0.86 ± 0.01 e
V_3W_0	1.96 ± 0.18 e	26.01 ± 0.7 e	0.87 ± 0.013 de
V_3W_1	2.98 ± 0.29 a	35.29 ± 1.38 a	1.13 ± 0.02 a
V_3W_2	1.73 ± 0.15 f	27.90 ± 0.67 d	0.89 ± 0.01 c-e
V_3W_3	2.21 ± 0.16 bc	29.70 ± 0.75 cd	0.94 ± 0.02 c
V_3W_4	1.73 ± 0.19 f	25.82 ± 1.12 e	0.84 ± 0.01 e
SE	0.05	0.89	0.02
CV(%)	3.42	4.17	4.35

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

V_1= Tulshimala, V_2 = BR 11, V_3 = BRRI hybrid dhan 6; W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes,* W_3 = *Lemna minor*, W_4 = *Salvinia molesta*

4.3 Yield contributing characters

4.3.1 Number of effective tillers hill^{-1}

Effect of variety

Rice varieties significantly affect number of effective tillers hill^{-1} of *aman* rice (Table 9). The highest number of effective tillers hill^{-1} (11.40) was recorded in BRRI hybrid dhan6 (V_3) variety which was statistically similar to Tulshimala (V_1) variety and recorded number of effective tillers hill^{-1} (11.07). While the lowest number of effective tillers hill^{-1} (9.96) was under BR 11 (V_2) variety. The variation of effective tillers hill^{-1} is probably due to the genetic make-up of the variety. The result obtained from the present study was similar to the findings of Nahida *et al.* (2013) who reported that the reason for the difference in effective tillers hill^{-1} is the genetic makeup of the variety, which is primarily influenced by heredity.

Effect of weed control treatments

Number of effective tillers hill^{-1} of *aman* rice was significantly varied due to the effect of the different weed control treatments (Table 9). The experimental result had shown that weed control through integrated weed management (W_1) recorded the highest number of effective tillers hill^{-1} (12.74), whereas the lowest number of effective tillers hill^{-1} (8.93) was recorded in the weedy check plot (W_0). The weeds in the weedy plot grew unchecked and availed growth factors profusely that created ecological stress utilizing the available nutrient and moisture and thus reduced the number of tillers. Increased number of tillers in case of cultural and chemical weed control treatments might be attributed to the creation of weed-free environment for crop plants which rendered them to grow without stress and properly utilized all the growth factors resulting in better tillering. Rammana *et al.* (2007) observed that the maximum number of total and effective tillers was recorded in weed-free plots. Chowdhury (2012) noticed that weed controlled by Sunrise 150WG gave the highest effective tillers hill^{-1} while non effective tillers hill^{-1} were found from no weeding treatment.

Combined effect of variety and weed control treatments

The combined effect of variety and weed control treatments was significantly influenced number of effective tillers hill^{-1} (Table10). Experimental results revealed that cultivation of BRRI hybrid dhan6 variety along with weed control through integrated weed management (V_3W_1) recorded the highest number of effective tillers hill^{-1} (14.47). Whereas cultivation of Tulshimala variety along with weed check plot (V_1W_0) recorded the lowest number of effective tillers hill^{-1} (8.59) which was statistically similar with V_3W_0 (8.80), V_2W_4 (9.33), V_2W_0 (9.40), and V_2W_2 (9.60) treatment combination.

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

Effect of variety

Different rice varieties significantly affect the number of non-effective tillers hill^{-1}of *aman* rice (Table 9). Experimental results had shown that the highest number of non-effective tillers hill^{-1} (2.63) was recorded in Tulshimala (V_1) variety. While the lowest number of non-effective tillers hill^{-1} (9.96) was from BRRI hybrid dhan6 (V_3) variety.

Effect of weed control treatments

Number of non-effective tillers hill^{-1} of *aman* rice was significantly varied due to the effect of the different weed control treatments (Table 9). Experimental results had shown that the weedy check (W_0) recorded the highest number of non-effective tillers hill^{-1} (1.73), whereas the lowest number of non-effective tillers hill^{-1} (0.93) was recorded in weed control through integrated weed management (W_1).

Combined effect of variety and weed control treatments

The combined effect of variety and weed control was significantly influenced the number of non-effective tillers hill^{-1} (Table 10). Experimental results revealed that cultivation of Tulshimala variety along with weedy check plot (V_1W_0) recorded the highest number of non-effective tillers hill^{-1} (3.67). Whereas cultivation of BRRI hybrid dhan6variety along with weed control through integrated weed management (V_3W_1) recorded the lowest number of non-effective tillers hill^{-1} (0.20) which was statistically similar with V_3W_3(0.24), V_3W_4 (0.28) andV_2W_2(0.29) treatment combination.

4.3.3 Length of panicle (cm)

Effect of variety

Cultivation of different rice varieties significantly influenced the panicle length of *aman* rice (Table 9). Experimental results revealed that cultivation of BRRI hybrid dhan6 rice variety (V_3) recorded the highest panicle length (29.20 cm) while the BR 11 (V_2) rice variety recorded the lowest panicle length (24.06 cm) which was statistically similar to the cultivation Tulshimala (V_1) rice variety (24.14 cm). Different rice varieties have different panicle lengths due to the genetic makeup of the variety, and higher panicle length is obtained from high yielding varieties comparable to low yielding rice varieties. Hossain *et al.* (2016), Chamely *et al.* (2015) and Diaz *et al.* (2000) found similar results which supported the present study and reported that panicle length varied among varieties.

Effect of weed control treatments

Panicle length of *aman* rice was significantly varied due to the effect of the different weed control treatments (Table 9). The experimental result had shown that weed control through integrated weed management (W_1) recorded the highest panicle length (26.20) which was statistically similar with W_2 (25.87 cm) and W_3 (26.19 cm) treatment. Whereas the lowest panicle length (25.36 cm) was recorded in the weedy check (W_0) which was statistically similar with W_2 (25.37 cm) treatment. Weed control treatment had a positive effect on the length of the panicle and recorded a significantly higher value than the weedy check. The higher values in weed-free conditions might be due to the better photosynthetic efficiency of crop plants under unshared favorable micro-ecological conditions. These values significantly decreased to the minimum in weedy check because the weeds exploited the favorable environment for their growth and compete severely with the crop plants thus restricting the supply of nutrients to the reproductive cell by utilizing most of the nutrients for themselves. Jabran *et al.* (2012) observed the maximum panicle length (23.5cm) in the bispyribac-sodium treatments and the minimum panicle length (16.4cm) in the weedy check. Mahajan *et al.* (2003) stated that application of Pretilachlor alone or in combination with Safener and hand weeding resulted in the highest panicle length.

Combined effect of variety and weed control treatments

The combined effect of variety and weed control was significantly influenced panicle length of *aman* rice (Table 10). Experimental results revealed that cultivation of BRRI hybrid dhan6 variety along with weed control through integrated weed management (V_3W_1) recorded the highest panicle length (29.96 cm) which was statistically similar with V_3W_3 (29.26 cm) treatment combination whereas cultivation of BR11 variety along with weedy check plot (V_2W_0) recorded lowest panicle length (23.06 cm) which was statistically similar with V_1W_4 (23.22 cm) treatment combination.

4.3.4 Number of filled grains panicle^{-1}

Effect of variety

Rice varieties significantly influenced number of filled grains panicle^{-1} of *aman* rice (Table 9).Experimental results had shown that among different rice varieties cultivation of Tulshimala (V_1) rice variety recorded the highest number of filled grains panicle^{-1} (123.13) which was statistically similar to BRRI hybrid dhan6(V_3) rice variety recorded number of filled grains panicle^{-1} (121.12). While cultivation of BR11 (V_2) variety recorded the lowest number of filled grains panicle^{-1} (101.26). The result obtained from the present study was similar to the findings of Akondo *et al.* (2020) who reported that variation in grain filling may have occurred due to genetic, environmental, or cultural management practices adopted. Sarkar (2014) and Mahamud *et al.* (2013) also concluded from their study that the variation in filled grains panicle$^{–1}$ was recorded due to genotypic differences of varieties.

Effect of weed control treatments

Different weed control treatments significantly influenced the number of filled grains panicle^{-1} of *aman* (Table 9). Experiment results had shown that weed control through integrated weed management (W_1) recorded the highest number of filled grains panicle^{-1} (130.24) while weedy check plot (W_0) recorded the lowest number of filled grains panicle^{-1} (95.73). The weeds in the weedy plot grew unchecked and availed growth factors profusely that created ecological stress utilizing the available nutrient and moisture and thus reduced the number of filled grains panicle^{-1}. Teja *et al.* (2017) reported that effective and timely management of weeds facilitated the crop plants to have sufficient space, light, nutrients, and moisture, and thus the yield components like the number of filled grains per panicle increased.

Combined effect of variety and weed control treatments

Combined effect of variety and weed control was significantly influenced the number of filled grains panicle^{-1} of *aman* rice (Table 10). Experimental results revealed that cultivation of Tulshimala variety along with weed control through integrated weed management (V_1W_1) recorded the highest number of filled grains panicle^{-1}(139.24 cm) which was statistically similar with V_3W_1 (138.43) treatment combination. Whereas cultivation of BR11 variety along with the weedy check (V_2W_0) recorded the lowest number of filled grains panicle^{-1} (79.29).

4.3.5 Number of unfilled grains panicle^{-1}

Effect of variety

Cultivation of different rice varieties significantly influenced number of unfilled grains panicle^{-1} of *aman* rice ((Table 9). Experimental results had shown that among different rice varieties cultivation of BR11 (V_2) rice variety recorded the highest number of unfilled grains panicle^{-1} (30.96) whereas cultivation of Tulshimala (V_1) variety recorded the lowest number of filled grains panicle^{-1} (22.71).

Effect of weed control treatments

Different weed control treatments significantly influenced number of unfilled grains panicle^{-1} of *aman* rice (Table 9). Experiment results had shown that the weedy check plot (W_0) recorded the highest number of filled grains panicle^{-1} (30.55). Whereas weed control through integrated weed management (W_1) recorded the lowest number of unfilled grains panicle^{-1} (22.95).

Combined effect of variety and weed control treatments

Cultivation of different rice varieties along with weed control had a significant effect on the number of unfilled grains panicle^{-1} of *aman* rice (Table 10). Experimental results revealed that cultivation of BR 11 variety along with weedy check plot (V_2W_0) recorded the highest number of unfilled grains panicle^{-1}(32.95) which was statistically similar with V_2W_4 (32.84), V_2W_3 (32.74), and V_3W_4 (31.57) treatment combination. Whereas cultivation of Tulshimala variety along with integrated weed management (V_1W_1) recorded lowest number of unfilled grains panicle^{-1}(17.89) which was statistically similar with V_1W_3 (20.19) treatment combination.

4.3.6 Number of total grains panicle^{-1}

Effect of variety

Rice varieties significantly influenced number of total grains panicle^{-1} of *aman* rice ((Table 9). Experimental results had shown that among different rice varieties, cultivation of Tulshimala (V_1) rice variety recorded the highest number of filled grains panicle^{-1} (145.83) which was statistically similar to BRRI hybrid dhan6(V_3) rice variety recorded number of total grains panicle^{-1} (148.99). While cultivation of BR 11 (V_2) variety recorded the lowest number of total grains panicle^{-1} (132.21). Jisan *et al.* (2014) reported that variation in total grains panicle$^{–1}$ was recorded due to genotypic differences of varieties.

Effect of weed control treatments

Different weed control treatments significantly influenced number of total grains panicle^{-1} of *aman* rice (Table 9). Experiment results had shown that weed control through integrated weed management (W_1) recorded the highest number of total grains panicle^{-1} (153.19) which was statistically similar to W_3 (*L. minor*) treatment and recorded total grains panicle^{-1} (151.52). While weedy check plot (W_0) recorded the lowest number of total grains panicle^{-1} (126.28). Different weed control treatments increasing total grains panicle^{-1} over weedy check plot.

Combined effect of variety and weed control treatments

The combined effect of variety and weed control was significantly influenced number of total grains panicle^{-1} of *aman* rice (Table 10). Experimental results revealed that cultivation of BRRI hybrid dhan6 variety along with weed control through integrated weed management (V_3W_1) recorded the highest number of filled grains panicle^{-1}(162.72) which was statistically similar with V_3W_3 (160.07) and V_1W_1 (157.13) treatment combination. Whereas cultivation of BR11 variety along with weedy check plot (V_2W_0) recorded the lowest number of total grains panicle^{-1}(112.24).

4.3.7 1000-grain weight (g)

Effect of variety

Cultivation of different rice varieties significantly affects 1000-grain weight of *aman* rice (Table 9).Experimental results revealed that the highest 1000-grain weight (25.56 g) was recorded in BRRI hybrid dhan6 (V_3) variety cultivation. While the lowest 1000 grains weight (11.93 g) was recorded in Tulshimala (V_1) rice variety cultivation. The differences of the 1000 grains weight among different rice varieties may be attributed to the varietal performance and genetic makeup of the varieties. Khatun *et al.* (2020) also found similar results which supported the present study and reported that different rice varieties showed different 1000-grain weight which is due to morphological and varietal variation.

Effect of weed control treatments

Different weed control treatment significantly affects 1000 grains weight of *aman* rice (Table 9). Experimental results had shown that weed control through integrated weed management (W_1) recorded the highest 1000-grain weight (21.50 g). While weedy check plot (W_0) recorded the lowest 1000-grain weight (19.36 g). Different weed control-treated plot increasing total grains panicle^{-1} over weedy check plot. The reduction in 1000 grains weight in the weedy check was possibly due to severe weed infestation in the crop field. The weeds grow freely and attain vigour, enabling them to compete with the crop plants for nutrients, moisture, and sunlight throughout the growing season and thus suppress the crop growth which hampers the fullest yield potential. Jabran *et al.* (2012) reported that the highest 1000-grain weight (22.5 g) of rice was observed in weed-free condition and the lowest 1000-grain weight (17.4 g) was observed in weedy check.

Combined effect of variety and weed control treatments

The combined effect of variety and weed control was the effect on 1000 grains weight of *aman* rice (Table 10). Experimental results revealed that cultivation of BRRI hybrid dhan6 variety along with weed control through integrated weed management (V_3W_1) recorded the highest 1000-grain weight (25.83) which was statistically similar with V_3W_3 (25.83), V_3W_2 (25.58), and V_3W_4 (25.48) treatment combination. Whereas cultivation of Tulshimala variety along with weedy check plot (V_1W_0) recorded lowest 1000-grain weight (11.00) which was statistically similar with V_1W_2 (11.33) treatment combination.

Table 9. Effect of individual treatment on the yield contributing characters of *aman* rice

Variety	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Total grains panicle^{-1} (no.)	1000-grain Weight (g)
V_1	11.07 ± 2 a	2.63 ± 0.64 a	24.14 ± 0.71 b	123.13 ± 15.52 a	22.71 ± 4.27 c	145.83 ± 11.78 a	11.93 ± 1.38 c
V_2	9.96 ± 1.36 b	0.73 ± 0.43 b	24.06 ± 0.78 b	101.26 ± 11.95 b	30.96 ± 3.04 a	132.21 ± 10.63 b	23.47 ± 1.58 b
V_3	11.40 ± 2.16 a	0.27 ± 0.24 c	29.20 ± 0.8 a	121.12 ± 13.67 a	27.86 ± 3.21 b	148.99 ± 12.18 a	25.56 ± 1.04 a
SE	0.29	0.03	0.17	1.48	0.64	1.74	0.09
CV(%)	7.37	8.45	1.86	3.53	6.47	3.36	1.27
Weed Control	**Effective tillers hill^{-1} (no.)**	**Non-effective tillers hill^{-1} (no.)**	**Panicle length (cm)**	**Filled grains panicle^{-1} (no.)**	**Unfilled grains panicle^{-1} (no.)**	**Total grains panicle^{-1} (no.)**	**1000-grains Weight (g)**
W_0	8.93 ± 1.64 d	1.73 ± 1.53 a	25.36 ± 2.72 b	95.73 ± 12.86 e	30.55 ± 2.46 a	126.28 ± 10.98 d	19.36 ± 6.5 d
W_1	12.74 ± 1.81 a	0.93 ± 0.94 e	26.20 ± 2.86 a	130.24 ± 13.13 a	22.95 ± 4.2 d	153.19 ± 10.75 a	21.50 ± 5.94 a
W_2	10.55 ± 1.36 c	1.10 ± 0.9 c	25.87 ± 2.43 a	117.66 ± 10.55 c	26.14 ± 3.04 c	143.80 ± 7.6 b	19.97 ± 6.63 c
W_3	11.43 ± 1.43 b	1.01 ± 1.07 d	26.19 ± 2.34 a	124.32 ± 15.05 b	27.20 ± 6.04 c	151.52 ± 11.69 a	20.94 ± b 6.77
W_4	10.39 ± 1.37 c	1.27 ± 1.17 b	25.37 ± 2.79 b	107.89 ± 5.39 d	29.03 ± 4.87 b	136.91 ± 3.86 c	19.83 ± 6.37 c
SE	0.31	0.02	0.20	1.42	0.65	1.77	0.17
CV(%)	6.17	4.75	1.67	2.63	5.08	2.64	1.80

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, V_1= Tulshimala, V_2 = BR 11, V_3 = BRRI hybrid dhan6, W_0= Weedy check (Control), W_1= Integrated weed management W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta*.

Table 10. Combined effect of variety and weed control treatments on yield contributing characters of *aman* rice

Treatments	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Total grains panicle^{-1} (no.)	1000-grain Weight (g)
V_1W_0	8.59 ±1.64g	3.67 ±1.64a	24.24 ±1.93c	99.99 ±3.33g	29.94 ±1.3bc	129.93 ±4.64g	11.00 ±1.12h
V_1W_1	12.54 ±1.81b	2.13 ±1.81 d	24.19 ±2.03c	139.24 ±3.39a	17.89 ±2.24g	157.13 ±5.64a-c	13.67 ±1.03e
V_1W_2	11.27 ±1.36c-e	2.20 ±1.36d	24.37 ±1.72c	128.43 ±2.73 c	22.84 ±1.62 f	151.27 ±4.35cd	11.33 ±1.1gh
V_1W_3	12.13 ±1.43bc	2.40 ±1.43 c	24.67 ±1.67c	135.81 ± 3.89ab	20.19 ±3.23g	156.00 ±7.12bc	12.00 ±1.17f
V_1W_4	10.80 ±1.48de	2.73 ±1.48b	23.22 ±2.23d	112.17 ±1.22e	22.67 ±1.96f	134.84 ±3.18fg	11.67 ±0.83fg
V_2W_0	9.40 ±1.12fg	1.20 ±1.12e	23.06 ±2.12d	79.29 ±2.56h	32.95 ±0.94a	112.24 ±3.5h	22.00 ±1.28d
V_2W_1	11.20 ±1.24c-e	0.47 ±1.24g	24.45 ±2.23c	113.07 ±2.61e	26.67 ±1.6 de	139.74 ±4.22ef	25.00 ±1.17b
V_2W_2	9.60 ±0.93fg	0.80 ±0.93 f	24.18 ±1.89c	104.59 ±2.1fg	29.57 ±1.16bc	134.16 ±3.26fg	23.00 ±1.31c
V_2W_3	10.27 ±0.98ef	0.40 ±0.98gh	24.64 ±1.82 c	105.77 ±2.9 f	32.74 ±2.29a	138.51 ±5.29 f	25.00 ±1.34b
V_2W_4	9.33 ±0.93fg	0.80 ±0.93f	23.97 ±2.17c	103.59 ±1.07fg	32.84 ±1.86a	136.43 ±2.92 f	22.33 ±1.26d
V_3W_0	8.80 ±1.78g	0.33 ±1.78hi	28.78 ±2.17b	107.91 ±2.93ef	28.77 ±0.99cd	136.68 ±3.92 f	25.07 ±0.85b
V_3W_1	14.47 ±2 a	0.20 ±2 j	29.96 ±2.28a	138.43 ±2.99a	24.29 ±1.69f	162.72 ±4.68a	25.83 ±0.77 a
V_3W_2	10.78 ±1.47 de	0.29 ±1.47ij	29.06 ±1.95b	119.98 ±2.4d	26.01 ±1.22e	145.99 ±3.63de	25.58 ±0.86ab
V_3W_3	11.89 ±1.55b-d	0.24 ±1.55ij	29.26 ±1.8ab	131.39 ±3.43bc	28.68 ±2.42cd	160.07 ±5.85ab	25.83 ±0.88a
V_3W_4	11.05 ±1.48c-e	0.28 ±1.48ij	28.91 ±2.23b	107.91 ±1.23f	31.57 ±1.96ab	139.48 ±3.18 f	25.48 ±0.83ab
SE	1.12	0.10	0.72	5.09	2.33	6.33	0.62
CV(%)	6.17	4.75	1.67	2.63	5.08	2.64	1.80

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

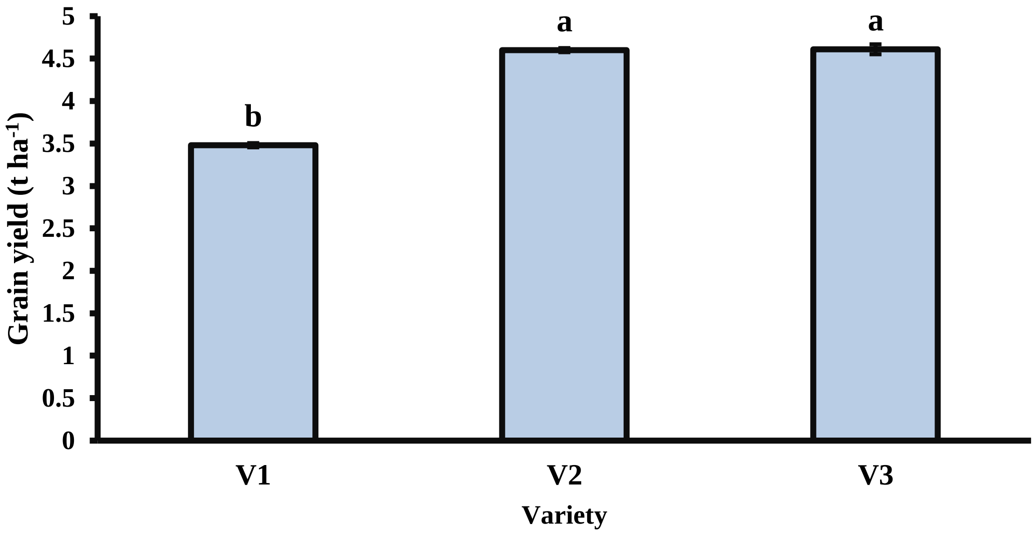
Here, V_1= Tulshimala, V_2 = BR 11, V_3 = BRRI hybrid dhan6, W_0= Weedy check (Control), W_1= Integrated weed management W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta*.

4.4 Yield characters

4.4.1 Grain yield (t ha^{-1})

Effect of variety

Rice varieties significantly influenced the grain yield of T. *aman* rice (Figure 24). Experiment results had shown that among different rice varieties, cultivation of BRRI hybrid dhan6 (V_3) rice variety recorded the highest grain yield (4.61 t ha^{-1}) which was statistically similar with (4.60 t ha^{-1}) BR 11 rice (V_2) variety. While cultivation of Tulshimala rice variety (V_1) recorded the lowest grain yield (3.48 t ha^{-1}) compared to others varieties of cultivation. The differences in grain yield among different rice varieties were due to the differences in genetic makeup which influences filled grains per panicle along with 1000-seed weight collectively contributed to yield difference among varieties. The result obtained from the present study was similar to the findings of Islam *et al.* (2013) who reported that the varieties which produced the highest number of effective tillers $hill^{-1}$ and higher number of filled grains $panicle^{-1}$ also showed higher grain yield ha^{-1}. Dutta (2002) also reported that the genotypes, which produced the highest number of effective tillers $hill^{-1}$ and higher number of grains $panicle^{-1}$ also showed higher grain yield in rice.

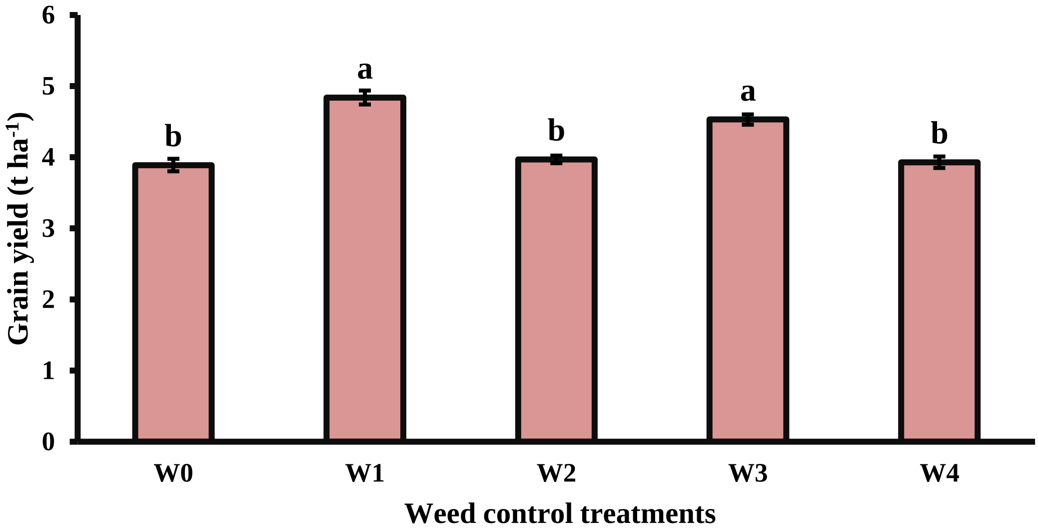


Here, V_1= Tulshimala, V_2 = BR11, and V_3 = BRRI hybrid dhan6.

Figure 24. Effect of variety on grain yield of T. *aman* rice. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

Different weed control treatments significantly influenced the grain yield of T. aman rice. (Figure 25). Experimental results had shown that weed control through integrated weed management (W_1) recorded the highest grain yield (4.84 t ha^{-1}), which was statistically similar with W_3 (*Lemna minor*) treatment and recorded grain yield (4.84 t ha^{-1}). Whereas the lowest grain yield (3.89 t ha^{1}) was recorded in the weedy check (W_0). The crop that received weed-free treatment recorded the highest values of growth and yield attributes resulting in higher grain yield. Integrated weed management through application of Pretilachlor 6% + pyrazosulfuron 0.15% reduced the population of weed and dry weight of weed caused significantly restricted growth of weed and lesser competition for light, moisture, and space by weeds as compared to rest of the weed control treatments. On the other hand, the inclusion of duckweed (*L. minor*) in rice agro ecosystems has been reduced nitrogen loss and increased the availability of nutrients to the crop which influences the grain yield of rice.



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W3 = *Lemna minor* and W_4 = *Salvinia molesta.*

Figure 25. Effect of weeds control treatments on grain yield of aman rice. Bars represent ±SD values obtained from three biological replications.

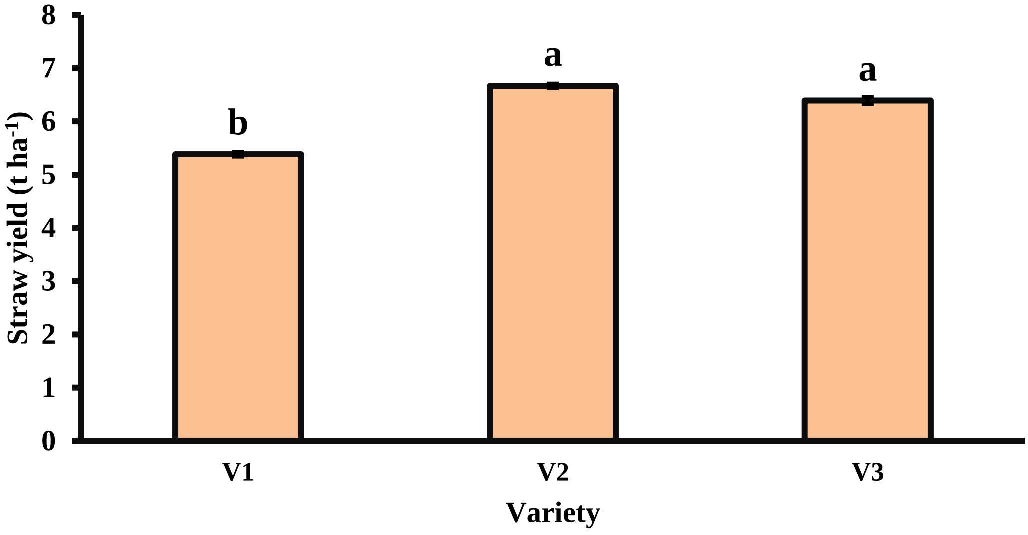
Combined effect of variety and weed control treatments

Grain yield was significantly influenced due to the combined effect of variety and weed control on T. *aman* rice. (Table 12). It was cleared from the experimental data that, cultivation of BRRI dhan6 along with weed control through integrated weed management (V_3W_1) recorded the highest grain yield (5.92 t ha^{-1}) comparable to other treatment combinations. Whereas the lowest grain yield (2.91 t ha^{-1}) was recorded in the cultivation of Tulshimala along with weedy check plot (V_1W_0 treatment combination), which was statistically similar with V_1W_4 (3.35 t ha^{-1}) and V_1W_2 (3.35 t ha^{-1}) treatment combination.

4.4.2 Straw yield (t ha^{-1})

Effect of variety

Different rice varieties caused significant variation in respect of straw yield of T. *aman* rice (Figure 26). Among different rice varieties, cultivation of BR 11 (V_2) rice variety recorded the highest straw yield (6.67 t ha^{-1}) which was statistically similar with (6.39 t ha^{-1}) BRRI dhan6 rice (V_3) variety. While cultivation of the Tulshimala rice variety (V_1) recorded the lowest straw yield (5.38 t ha^{-1}) compared to others varieties cultivation. Mahmud *et al.* (2017) and Tyeb *et al.* (2013) also found similar results and they reported that the variation in straw yield was due to the effect of varietal differences.

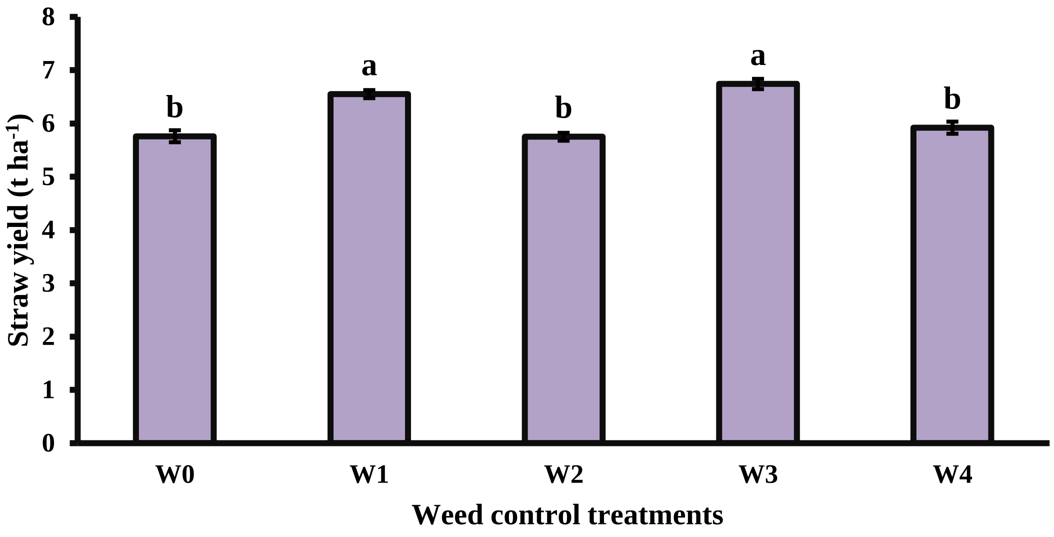


Here, V_1= Tulshimala, V_2 = BR11, and V_3 = BRRI hybrid dhan6.

Figure 26. Effect of variety on straw yield of T. *aman* rice. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

Different weed control treatments significantly influenced the straw yield of T. *aman* rice. (Figure 27). Experimental results had shown that weed control through the inclusion of duckweed (*L. minor*) in rice agroecosystems (W_3) recorded the highest straw yield (6.74 t ha^{-1}), which was statistically similar with W_1 (Integrated weed management) treatment and recorded straw yield (6.55 t ha^{-1}). Whereas the lowest straw yield (5.75 t ha^{1}) was recorded in the weedy check (W_0) which was statistically similar with (5.76 t ha^{1}) W_2 and (5.92 t ha^{1}) W_4 treatment. Yao *et al.* (2017) reported that urea combined with the duckweed *Spirodela polyrhiza* increased rice yields by 9–10%, indicating that duckweed can serve as a green fertilizer to increase straw yield while simultaneously reducing nitrogen loss in rice production. Hossain (2015) also found similar results which supported the present finding and reported that the straw yield of rice differs, due to the application of different mix herbicides comparable to the weedy check.



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W3 = *Lemna minor* and W_4 = *Salvinia molesta.*

Figure 27. Effect of weeds control treatments on straw yield of T. *aman* rice. Bars represent ±SD values obtained from three biological replications.

Combined effect of variety and weed control treatments

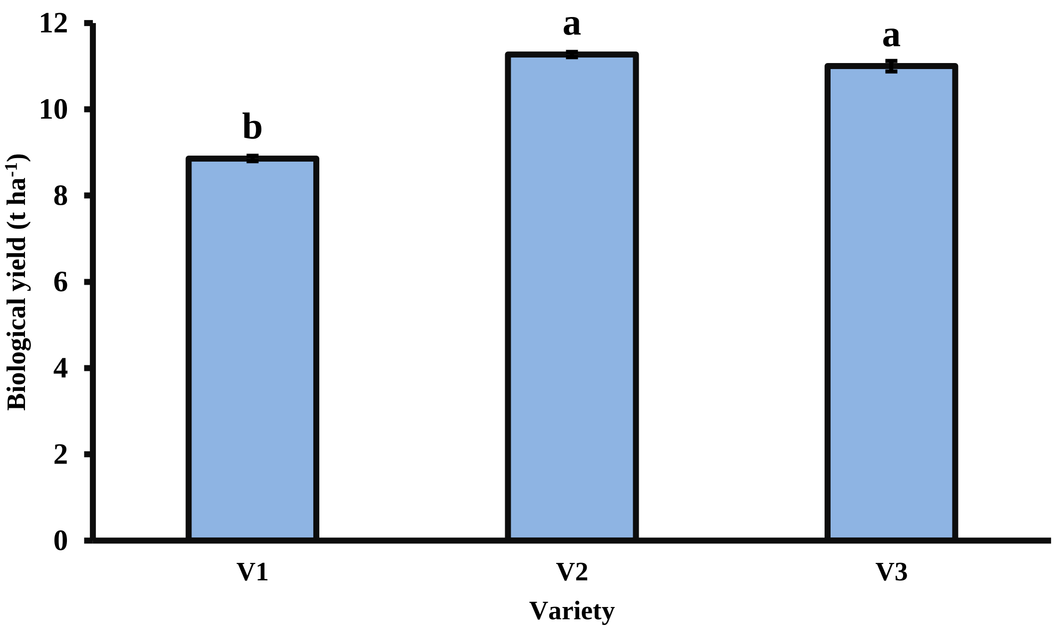
The straw yield was significantly influenced due to the combined effect of variety and weed control treatments on T. *aman* rice. (Table 12). Experimental data revealed that cultivation of BR 11 along with inclusion of duckweed (*L. minor*) in rice agroecosystems (V_2W_3) recorded the highest straw yield (7.68 t ha^{-1}) which was statistically similar with the V_3W_1 (7.27 t ha^{-1}) treatment combination. Whereas the lowest straw yield (5.75 t ha^{-1}) was recorded in the cultivation of Tulshimala along with weedy check plot (V_1W_0 treatment combination), which was statistically similar with V_1W_2 (5.19 t ha^{-1}), V_1W_4 (5.34 t ha^{-1}), and V_3W_2 (5.45 t ha^{-1}) treatment combination.

4.4.3 Biological yield (t ha^{-1})

Effect of variety

Different rice variety caused significantly variation in respect of biological yield of aman rice (Fig. 28). Among different rice varieties, cultivation of BR 11 (V_2) rice variety recorded the highest biological yield (11.27 t ha^{-1}) which was statistically similar with (11.00 t ha^{-1}) BRRI hybrid dhan6 rice (V_3) variety. While cultivation of

Tulshimala rice variety (V_1) recorded the lowest straw yield (8.86 t ha^{-1}) compared to others varieties cultivation. The differences of straw yield may be attributed to the genetic makeup and variation of the different rice varieties. Howlader *et al.* (2017) found that among the genotypes Moulata showed the highest biological yield (9.657 t ha^{-1}). Hossain *et al.* (2014) found that, the variation in biological yield was also found due to the variation in grain and straw yield.

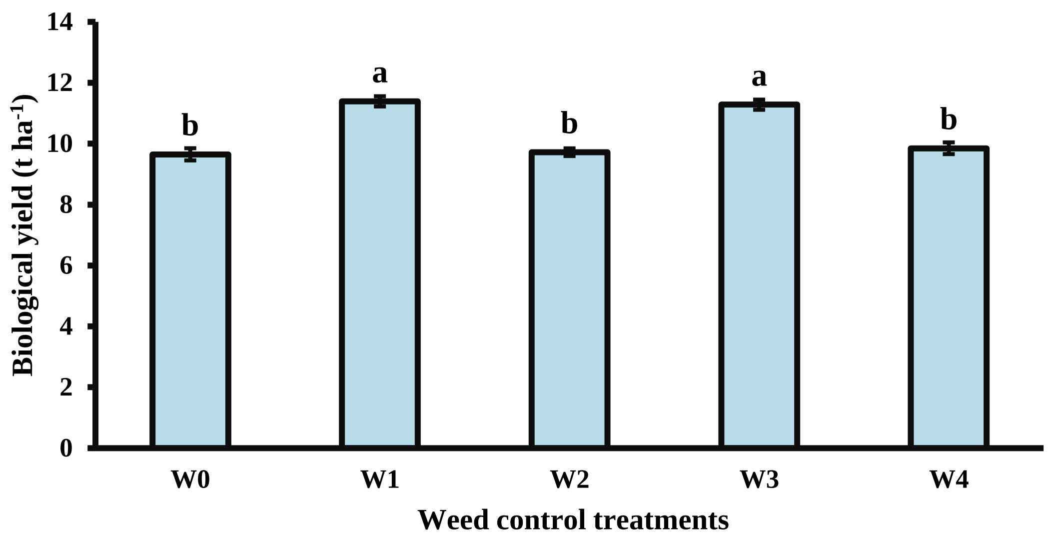


Here, V_1= Tulshimala, V_2 = BR 11 and V_3 = BRRI hybrid dhan6.

Figure 28. Effect of variety on biological yield of T. *aman* rice. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

Different weed control treatment significantly influenced biological yield of T. *aman* rice. (Fig. 29). Experimental results had shown that, weed control through integrated weed management (W_1) recorded the highest biological yield (11.39 t ha^{-1}), which was statistically similar with W_3 (*L. minor*) treatment and recorded biological yield (11.28 t ha^{-1}). Whereas the lowest biological yield (9.65 t ha^{1}) was recorded in weedy check plot (W_0) which was statistically similar with W_2 (9.72 t ha^{1}) and W_4 (9.85 t ha^{1}) treatment.



W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W3 = *Lemna minor* and W_4 = *Salvinia molesta.*

Figure 29. Effect of weeds control treatments on biological yield of aman rice Bars represent ±SD values obtain three biological replications.

Combined effect of variety and weed control treatments

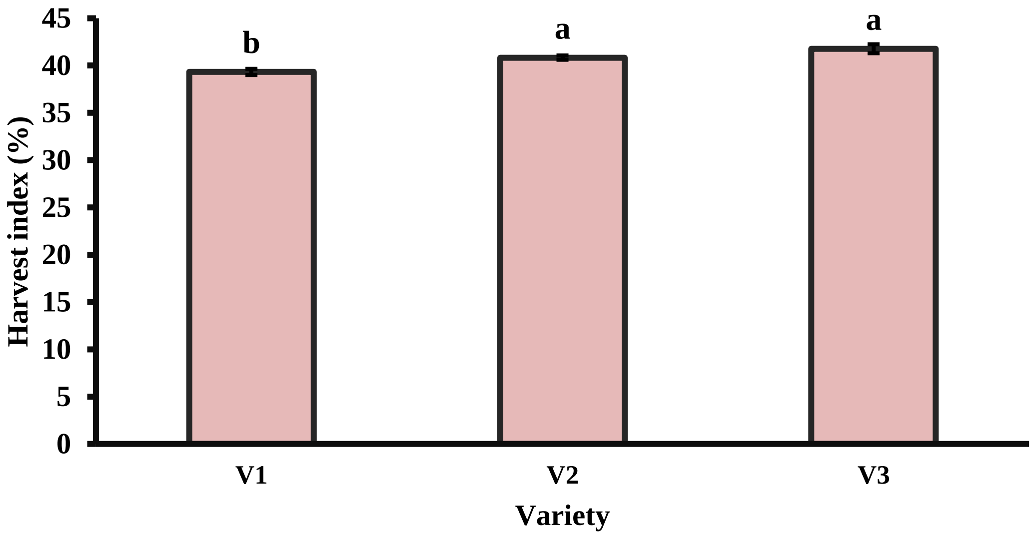
Biological yield significantly influenced due to the combined effect of variety and weed control on T. *aman* rice. (Table 12). Experimental data showed that, cultivation of BRRI dhan6 along with weed control through integrated weed management (V_3W_1) recorded the highest biological yield (13.19 t ha^{-1}) which was statistically similar with V_2W_3 (12.87 t ha^{-1}) treatment combination. Whereas the lowest biological yield (7.46 t ha^{-1}) was recorded in cultivation of Tulshimala along with weedy check plot (V_1W_0 treatment combination), which was statistically similar with V_1W_2 (8.68 t ha^{-1}) and V_1W_4 (8.69 t ha^{-1}) treatment combination.

4.4.4 Harvest index (%)

Effect of variety

Rice varieties significantly influenced harvest index of T. *aman* rice. (Fig. 30). Experiment results had shown that among different rice varieties, cultivation of BRRI hybrid dhan6 (V_3) rice variety recorded the highest harvest index (41.78 %) which was statistically similar with (40.84 %) BR 11 rice (V_2) variety. While cultivation of

Tulshimala rice variety (V_1) recorded the lowest harvest index (39.33 %) compared to others varieties cultivation. Harvest index differed significantly among the varieties due to its genetic variability. Chowhan *et al.* (2019) found significant differences of harvest index among different rice varieties. From their experiment, they concluded that Varieties Shakti-2 (V_4), Heera-1 (V_3) and BRRI dhan28 (V_1) had an identical harvest index of 50.9%, 48.5% and 47.9 respectively. Only BINAdhan-14 (V_2) produced the harvest index (40.0%). It appears that hybrid rice maintained higher harvest index. Rahman *et al.* (2017) reported that the highest harvest index was found in BRRI dhan59 (42.78%) and the lowest one was found in BRRI dhan28 (40.73%).

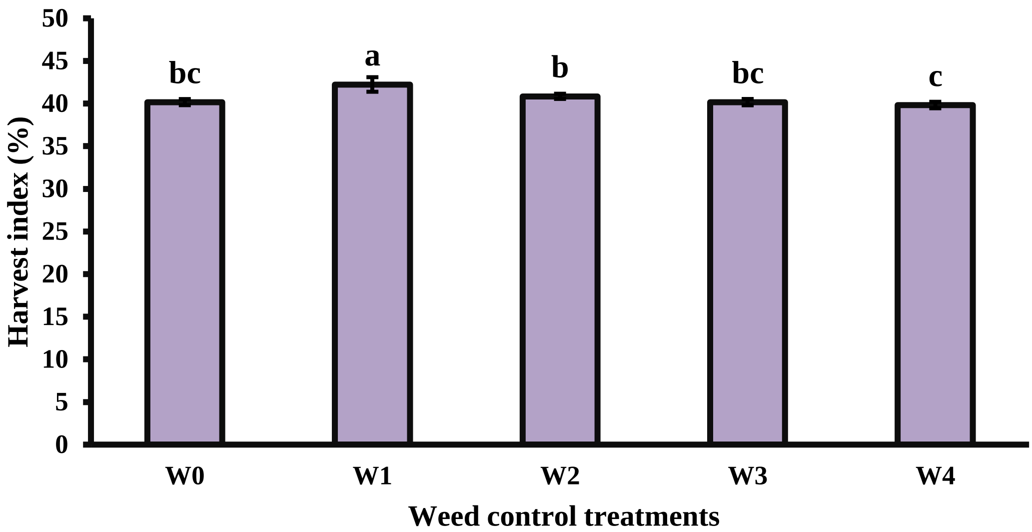


Here, V_1= Tulshimala, V_2 = BR 11 and V_3 = BRRI hybrid dhan6.

Figure 30. Effect of variety on harvest index of T. *aman* rice. Bars represent ±SD values obtained from three biological replications.

Effect of weed control treatments

Different weed control treatment significantly influenced harvest index of T. *aman* rice. (Figure 31). Experimental results had shown that, weed control through integrated weed management (W_1) recorded the highest harvest index (42.24 %). Whereas the lowest harvest index (39.83) was recorded in *S. molesta* treated plot (W_4) which was statistically similar with W_0 (40.17 %) and W_3 (40.17) treatment. The variation of harvest index which was due to reason that the effective weed control through herbicide based integrated weed management, increased number of productive tillers, crop dry matter, and the plants produced longer panicles which ultimately improve grain yield buy reducing the crop weed competition as compared to various weeds inoculation plot. Chowdhury (2012) founded the highest grain yield, straw yield, biological yield, harvest index from pre-emergence herbicide Sunrice 150WG treated plot.



W_0= Weedy check (Control), W_1=Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta.*

Figure 31. Effect of weeds control treatments on harvest index of T. *aman* rice. Bars represent ±SD values obtained from three biological replications.

Combined effect of variety and weed control treatments

Cultivation of different rice varieties along with weed control significantly influenced harvest index of T. *aman* rice. (Table 12). Experimental data showed that, cultivation of BRRI dhan6 along with weed control through integrated weed management (V_3W_1) recorded the highest harvest index (44.94 %). Whereas the lowest harvest index (38.56 %) was recorded in cultivation of Tulshimala along with *S. molesta* treated plot (V_1W_4 treatment combination), which was statistically similar with V_1W_3 (39.04 %), V_1W_0 (39.08 %) and V_1W_1 (39.76 %) treatment combination.

Table 11. Combined effect of variety and weed control treatments on grain, straw, biological yield (t ha^{-1}) and harvest index (%) of T. *aman* rice

Treatment Combinations	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1W_0	2.91 ± 0.29 i	4.55 ± 0.62 e	7.46 ± 1.02 e	39.08 ± 1.32 ef
V_1W_1	3.91 ± 0.33 e-h	5.94 ± 0.42 cd	9.85 ± 0.75 b-d	39.76 ± 3.15 d-f
V_1W_2	3.49 ± 0.17 g-i	5.19 ± 0.41 de	8.68 ± 0.38 de	40.20 c-e ±1.12
V_1W_3	3.76 ± 0.24 f-h	5.88 ± 0.53 cd	9.64 ± 0.73 cd	39.04 ± 1.36 ef
V_1W_4	3.35 ± 0.64 hi	5.34 ± 1.02 de	8.69 ± 0.45 de	38.56 ± 2.032 f
V_2W_0	4.18 ± 0.29 c-f	6.09 ± 0.59 cd	10.27 ± 0.97 bc	40.72 ± 0.92 bd
V_2W_1	4.68 ± 0.32 bc	6.46 ± 0.4 bc	11.14 ± 0.7 b	42.03 ± 2.19 b
V_2W_2	4.56 ± 0.18 cd	6.60 ± 0.38 bc	11.16 ± 0.35 b	40.86 ± 0.78 bd
V_2W_3	5.19 ± 0.24 b	7.68 ± 0.5 a	12.87 ± 0.69 a	40.34 ± 0.94 ce
V_2W_4	4.39 ± 0.26 c-e	6.51 ± 0.59 bc	10.90 ± 0.91 bc	40.28 ± 0.97 ce
V_3W_0	4.57 ± 0.7 cd	6.65 ± 1.01 bc	11.22 ± 0.61 b	40.71 ± 1.91 bd
V_3W_1	5.92 ± 0.78 a	7.27 ± 0.68 ab	13.19 ± 1.09 a	44.94 ± 2.56 a
V_3W_2	3.86 ±0.43 e-h	5.45 ± 0.67 de	9.31 ±0.38 d	41.48 ± 1.62 bc
V_3W_3	4.65 ± 0.57 bc	6.67 ± 0.87 bc	11.32 ± 1.06 b	41.12 ± 1.96 bd
V_3W_4	4.04 ± 0.64 d-g	5.91 ± 1.02 cd	9.95 ± 0.49 b-d	40.67 ± 2.03 bd
SE	0.58	0.92	1.47	1.53
CV(%)	8.06	8.88	8.38	2.23

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

V_1= Tulshimala, V_2 = BR 11, V_3 = BRRI hybrid dhan 6; W_0= Weedy check (Control), W_1=Integrated weed management, W_2 = *Pistia stratiotes,* W_3 = *Lemna minor*, W_4 = *Salvinia molesta*

4.5 Relationship of grain yield and leaf area index (LAI) and total dry matter production

A positive linear relationship was observed between grain yield, leaf area index and total dry matter production of T. *aman* rice. From the Figure 32 and 33 it is observed that, the regression equation y = 8.457x + 13.93 and y =1.479x + 1.140 gave a good fit to the data, and the co-efficient of determination, R^2 = 0.250 and 0.307 (figure 34) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a strongly positive relationship between grain yield and leaf area index, and leaf area index and total dry matter production of aman rice. In the present experiment the yield and yield contributing character were significantly varied due to rice variety and different weed control treatments. Among different treatment combinations the highest leaf area index (2.50) at 90 DAT was recorded in BRRI hybrid dhan6 along with integrated weed management (V_3W_1). Due to leaf area increased grain yield (5.92 t ha^{-1}) and total dry matter accumulation (40.78 g $hill^{-1}$ at 90 DAT) increased 30.7 % and 25 %.

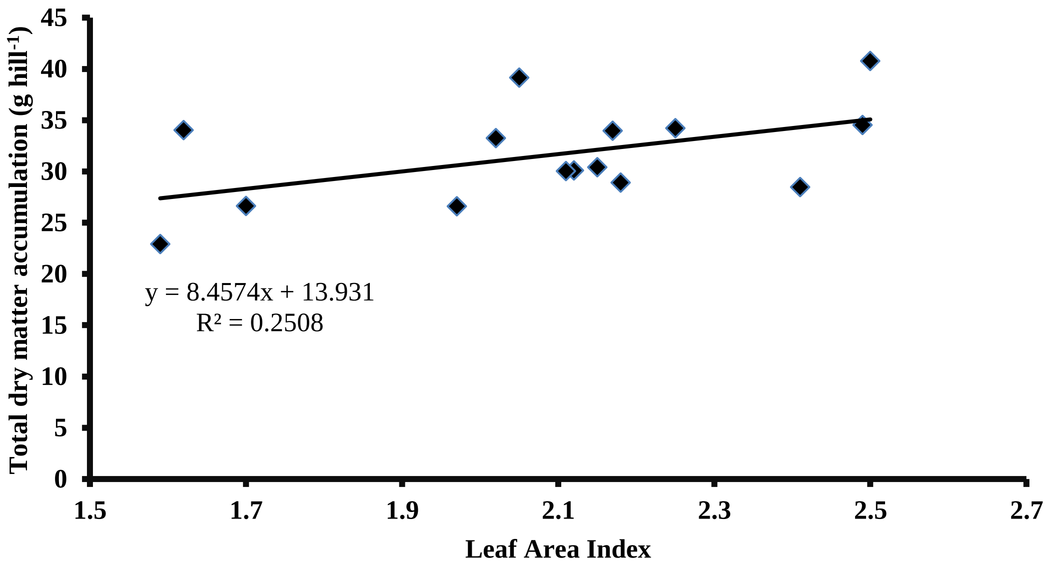


Figure 32. Relationship between leaf area index (LAI) and total dry matter production of T. *aman* rice.

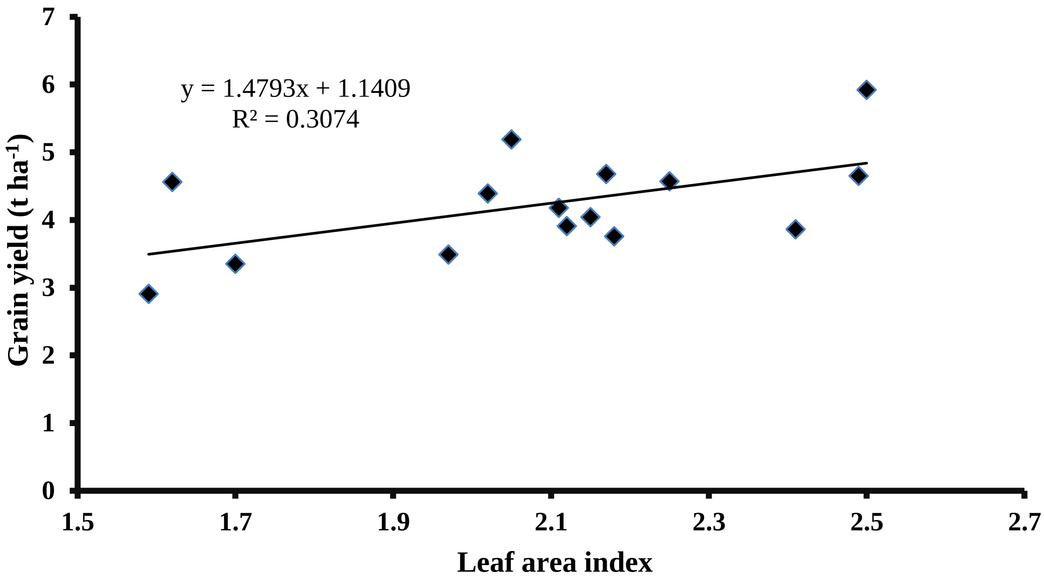


Figure 33. Relationship between leaf area index (LAI) and grain yield of T. *aman* rice.

4.6 Correlation of grain yield with panicle length, grains panicle^{-1} and 1000-grain weight

From the Figure 34 it is found that grain yield was positively correlated with panicle length (R^2=0.191) grains panicle^{-1} (R^2=0.337), and 1000-grain weight (R^2=0.583). From the correlation study (Figs. 35, 36), it appears that grain yield increase with increasing panicle length, grains panicle^{-1} and 1000-grain weight. And in this experiment highest grain yield (5.92 t ha^{-1}) recorded in BRRI dhan6 along with integrated weed management (V_3W_1).

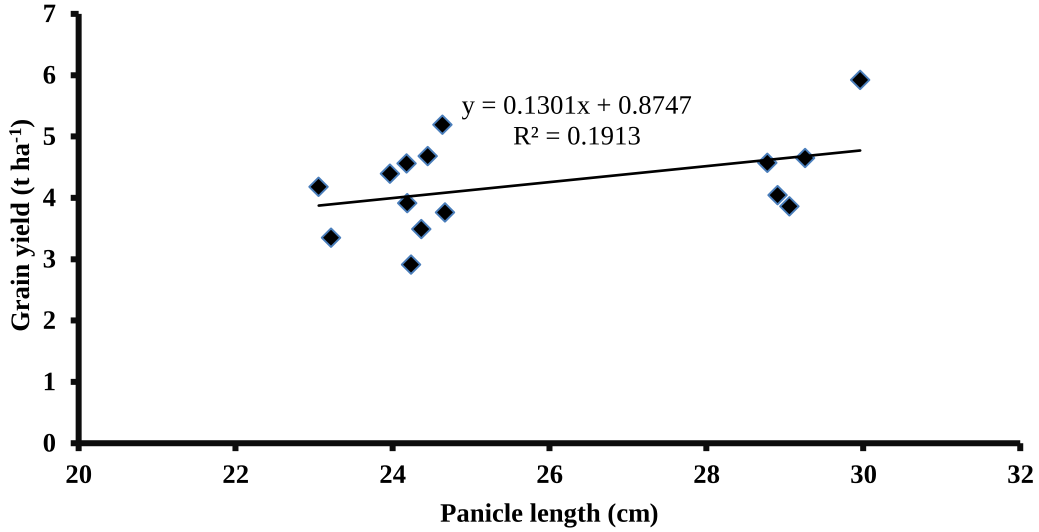


Figure 34. Relationship between panicle length and grain yield of T. *aman* rice.

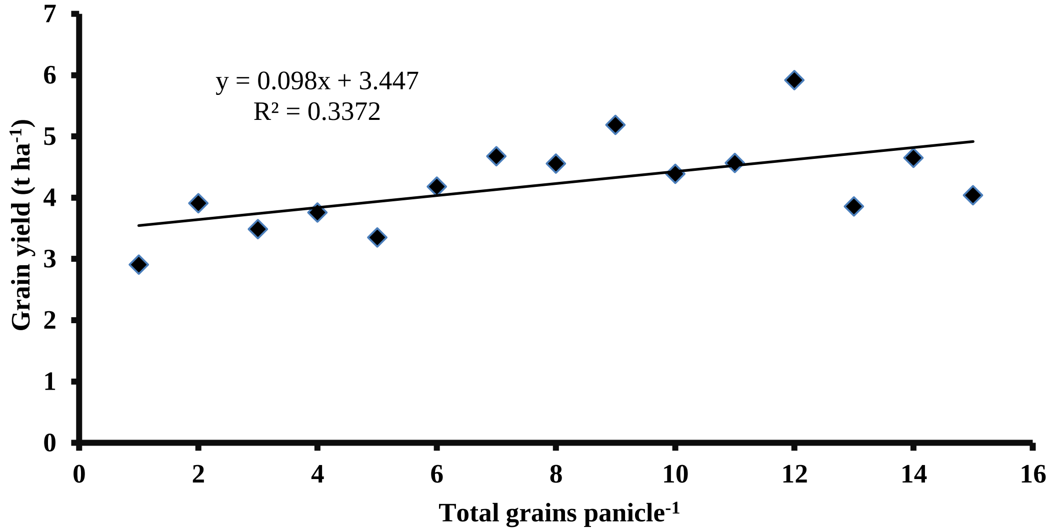


Figure 35. Relationship between total grains panicle^{-1} and grain yield of T. *aman* rice.

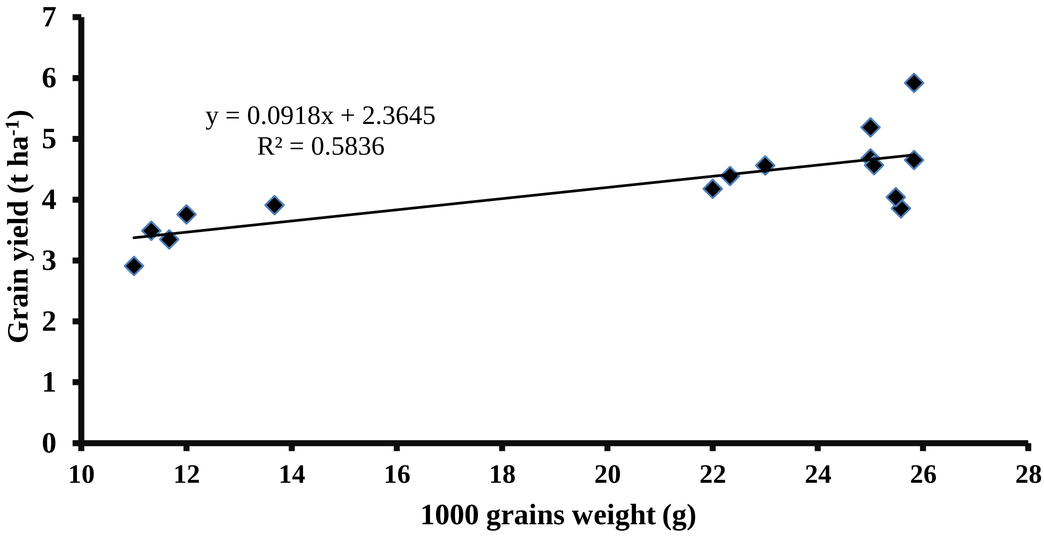


Figure 36. Relationship between 1000-grain weight and grain yield of T. *aman* rice

4.7 Economic viability of different treatments combination

The economic performance of different treatments combination were determined on per hectare area basis, which includes total cost of production, gross returns, net returns and benefit cost ratio (profit over per taka investment) under treatments imposed (Table 12).

4.7.1 Total cost of production

Cost of production varied due to different weed control treatments and rice variety cultivation. The cost of production was varied mainly for the herbicide based integrated weed management system. In case of weedy check, there was no involvement of cost for weed control. In this experiment highest total cost of production was occurred in integrated weed management system along different rice variety cultivation and lowest in weed check and others weed control treatment along with different rice variety cultivation.

4.7.2 Gross return (Tk.)

Gross return was influenced by different rice variety cultivation along with weed control treatments. The highest gross return (155270 taka) was recorded in BRRI hybrid dhan6 variety cultivation along with integrated weed management. While the lowest

(77300 Tk) was obtained from Tulshimala rice variety cultivation along with weedy check plot.

4.7.3 Net return (Tk.)

Net return was varied by different rice variety cultivation along with weed control treatments. The highest net return (155270 Tk.) was recorded in BRRI hybrid dhan6 variety cultivation along with integrated weed management while the lowest (77300 Tk.) war obtained in Tulshimala rice variety cultivation along with weedy check plot.

4.7.4 Benefit cost ratio (BCR)

Benefit cost ratio varied in different rice variety cultivation along with weed control treatments (Table 12). The highest benefit cost ratio (2.60) was recorded in BRRI hybrid dhan6 variety cultivation along with integrated weed management because this treatment reduced weed density (0.11) and weed biomass (0.33) per meter square result in less weed crop competition that ultimately influenced grain yield (5.92 t ha^{-1}) and biological yield (13.19 t ha^{-1}). While the lowest benefit cost ratio (1.38) was obtained in Tulshimala rice variety cultivation along with weedy check plot. Chakraborti *et al*. (2017) reported that pre emergence application of pendimethalin at 1.0 kg ha^{-1} at 2 DAS *fb* bispyribac-sodium at 25 g ha^{-1} at 20 DAS recorded the higher net returns (23,847 in 2014 and 26,010 in 2015) and return per rupee invested (2.02 and 2.11) in direct seeded rice. Yogananda *et al*. (2017) reported that among the various treatments, highest net returns (27,631h a^{-1}) and B: C (1.65) was recorded with pre-emergence application of bensulfuron-methyl + pretilachlor 660 g ha^{-1} fb. post-emergence application of bispyribac- sodium @ 25 g ha^{-1} in DSR.

Table 12. Cost of production, return and Benefit cost ratio (BCR) of transplanted T. *aman* rice varieties under different weed control treatments

Treatment combinations	Gross retrun (Tk.)	Total cost of production	Net return	BCR
V_1W_0	77300	55865	77300	1.38
V_1W_1	103690	59607	103690	1.74
V_1W_2	92440	55865	92440	1.65
V_1W_3	99880	55865	99880	1.79
V_1W_4	89090	55865	89090	1.59
V_2W_0	110590	55865	110590	1.98
V_2W_1	123460	59607	123460	2.07
V_2W_2	120600	55865	120600	2.16
V_2W_3	137430	55865	137430	2.46
V_2W_4	116260	55865	116260	2.08
V_3W_0	120900	55865	120900	2.16
V_3W_1	155270	59607	155270	2.60
V_3W_2	101950	55865	101950	1.82
V_3W_3	122920	55865	122920	2.20
V_3W_4	106910	55865	106910	1.91

Here, V_1= Tulshimala, V_2 = BR 11, V_3 = BRRI hybrid dhan6, W_0= Weedy check (Control), W_1= Integrated weed management W_2 = *Pistia stratiotes*, W_3 = Lemna minor and W_4 = *Salvinia molesta*.

CHAPTER V

SUMMARY AND CONCLUSION

The present piece of work was carried out at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh from July to December-2019, to investigate the competitive effect of free-floating plants on weed control, growth, and yield of T. *aman* rice varieties. The experiment consisted of two factors *viz*. Factor A: T. *aman* rice varieties i.e. V_1 = Tulshimala, V_2 = BR11 (Mukta) and V_3 = BRRI hybrid dhan6, and Factor B: Weed control treatments i.e. W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes*, W_3 = *Lemna minor* and W_4 = *Salvinia molesta*.

The total numbers of unit plots were 45. The size of the unit plot was 5.4 m^2 (2.7 m × 2 m). The experiment was laid out in a split-plot design having three replications. In the main plot, there were varieties and in the subplot, was Weed control treatments. There were 15 treatment combinations and 45 unit plots. The unit plot size was 5.4 m^2 (2.7 m × 2 m). Twenty five days old seedlings of Tulshimala, BR11, and BRRI hybrid dhan6 rice varieties were transplanted on the well puddled experimental plots on August 3, 2019, by using two seedlings $hill^{-1}$. Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} selective pre-emergence mixed herbicide was applied at 3 DAT in 4-5 cm standing water for 3-5 days. Free-floating plants (*P. stratiotes*, *L. minor*, and *S. molesta*) were introduced to the research plot at 3 DAT in a 0.5m^{-2} area of the plot.

The data on weed parameters were collected at 30 DAT and 60 DAT. Weed parameters such as total weed population in weedy check plot (no. m^{-2}); weed density (no. m^{-2}); weed biomass (g m^{-2}); weed control efficiency (%) and weed control index were observed at different intervals. The data on growth characters *viz*. plant height, total tillers $hill^{-1}$; leaf area index; total dry matter accumulation $plant^{-1}$; crop growth rate; relative growth rate, and net assimilation rate were recorded at different intervals. At harvest yield and yield contributing characters like effective tillers $hill^{-1}$, non-effective tillers $hill^{-1}$, total grains $panicle^{-1}$, filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, total grains $panicle^{-1}$, 1000-grain weight, grain yield, straw yield, biological yield, and harvest index were recorded. Relationship between grains yield, leaf area index total dry matter production, and correlation of grains yield with panicle length, grains per panicle, and 1000-grain also estimated. To determine the economic viability of different weed control treatments to control weeds on T. *aman* rice, the total cost of production, gross return, and net return was calculated to determine the benefit-cost ratio.

There are six weed species belonging to five families were found to infest the experimental rice field. Among the infested weeds, *Echinochloa crus-galli* and *Leptochloa chinensis* were grasses from Poaceae family and *Fimbristylis miliacea* was sedge from Cyperacea family. Rest were broadleaf weeds i.e., *Enhydra fluctuans* from Asteraceae, *Sagittaria guayanensis* from *Alismataceae,* and *Ludwigia octovalvis* from Onagraceae family. However, all weeds were not found in the same variety of raised plots. Among the infested weeds, *L. chinensis* was not found in BRRI hybriddhan6 raised plots, *F. miliacea* was not found in Tulshimala and BRRI hybrid dhan6 raised plots, and *L. octovalvis* was not found in BR11 and BRRI hybrid dhan6 raised plots. *E. crus-galli*, *E. fluctuans,* and *S. guayanensis* were found throughout the experimental period whereas *L. chinensis*, *F. miliacea*, and *L. octovalvis* were found at the later stage of crop growth.

Different weed control treatments significantly affect weeds and influence crop growth, yield, and yield contributing characters. Among different weed control treatments, IWM treated plot was recorded the minimum weed density m^{-2} (0.00 and 0.00, respectively), weed dry weight m^{-2} (0.00 and 0.00 g, respectively), the maximum weed control efficiency (100 and 100 %, respectively), and weed control index (100 and 100 %) at 30 and 60 DAT, respectively. At 45 and 60 DAT, the highest plant height (67.66 and 100.50 cm, respectively) was recorded in *L. minor* treatment which was statistically similar with IWM (98.99 cm) and *P. stratiotes* (98.72 cm). At 75 DAT the highest plant height (113.44 cm) was found from the weedy check whereas at 90 DAT and at harvest respectively the highest plant height (132.43 and 138.34 cm, respectively) was found from IWM treatment which was statistically similar with *L. minor* (136.93 cm) at harvest. The highest leaf area index (1.85 and 2.77, respectively) was recorded in W_3 (*L. minor*) treatment at 45 and 60 DAT, respectively, which was statistically similar with W_0 (2.72) and W_1 (2.71) treatment at 60 DAT. At 75 and 90 DAT, the highest leaf area index (2.51 and 2.27) was recorded in the W_1 treatment, which was statistically similar to the W_3 (2.24) treatment at 90 DAT. Among different weed control treatments, the highest dry matter accumulation (16.14, 17.04, 23.31 g hill^{-1}, respectively) was recorded in W_3 (*L. minor*) treatment which was statistically similar with W_1 (17.17 and 22.13 g hill^{-1}, respectively) at 60 and 75 DAT, respectively. At 90 DAT, the highest dry matter accumulation (34.94 g hill^{-1}) was recorded in W_1 (IWM) treatment which was statistically similar with W_3 (34.19 g hill^{-1}). Weed control through integrated weed management (W_1) recorded the highest crop growth rate (2.28 mg cm^{-2} day^{-1}) and the highest net assimilation rate (0.95 mg cm^{-2} day^{-1}).

Different weed control treatments significantly affect yield contributing characters *viz.* number of effective tillers hill$^{-1,}$ number of filled grains panicle^{-1}, number of filled grains panicle^{-1}, and 1000 grains weight. Weed control through integrated weed management (W_1) recorded the highest number of effective tillers hill^{-1} (12.74), weed control through integrated weed management (W_1) recorded the highest panicle length (26.20) which was statistically similar with W_2 (25.87 cm) and W_3 (26.19 cm) treatment. Weed control through integrated weed management (W_1) recorded the highest number of filled grains panicle^{-1} (130.24), weed control through integrated weed management (W_1) recorded the highest number of total grains panicle^{-1} (153.19) which was statistically similar with W_3 (*L. minor*) treatment and recorded total grains panicle^{-1} (151.52). Integrated weed management (W_1) recorded the highest 1000-grain weight (21.50 g).

Yield characters *viz.* Grain, straw, biological yields, and harvest index were significantly higher under all the weed control treatments over weedy check plots. Weed control through integrated weed management (W_1) recorded the highest grain yield (4.84 t ha^{-1}), which was statistically similar with W_3 (*Lemna minor*) treatment and recorded grain yield (4.84 t ha^{-1}). Weed control through the spreading of duckweed (*L. minor*) in rice agroecosystems (W_3) recorded the highest straw yield (6.74 t ha^{-1}), which was statistically similar with W_1 (Integrated weed management) treatment and recorded straw yield (6.55 t ha^{-1}). Weed control through integrated weed management (W_1) recorded the highest biological yield (11.39 t ha^{-1}), which was statistically similar with W_3 (*L. minor*) treatment and recorded biological yield (11.28 t ha^{-1}). Weed control through integrated weed management (W_1) recorded the highest harvest index (42.24 %).

Rice varieties significantly affect weeds and influence crop growth, yield, and yield contributing characters. Among different rice varieties, cultivation of BRRI hybrid dhan6 rice variety was recorded the minimum weed density m^{-2} (11.86 and 4.66), weed dry weight m^{-2} (3.51 and 1.49 g g), the maximum weed control efficiency (53.57 and 54.37%), and weed control index (59.77 and 52.37 %) at 30 and 60 DAT. Growth characters of rice *viz.* plant height, number of tillers $hill^{-1}$ were higher in Tulshimala rice variety comparable to others rice varieties cultivation. LAI, dry matter accumulation $plant^{-1}$, CGR (2.12 mg cm^{-2} day^{-1}), net assimilation rate (0.94 mg cm^{-2} day^{-1}) were highest in BRRI hybrid han6 which was statistically similar with BR11 rice variety (0.92 mg cm^{-2} day^{-1}).

Yield contributing characters *viz.* the maximum effective tillers $hill^{-1}$ (11.40) was recorded under BRRI hybriddhan6 rice variety cultivation which was statistically similar with Tulshimala rice variety (11.07), maximum panicle length (29.20 cm), and maximum filled grains $panicle^{-1}$ (121.12) was recorded under BRRI hybrid dhan6 rice variety cultivation. Total grains $panicle^{-1}$ (148.99) was recorded under BRRI hybriddhan6 rice variety cultivation which was statistically similar with Tulshimala rice variety (145.83) and 1000 grains weight (25.56) were significantly higher under BRRI hybriddhan6 rice variety cultivation, while noneffective tiller $hill^{-1}$ (0.27) was minimum in BRRI hybriddhan6 cultivation and unfiled grains panicle $^{-1}$ (22.71) was markedly less under Tulshimala rice variety cultivation.

Yield characters *viz.* Grain, straw, biological yields, and harvest index were significantly different among rice varieties. Cultivation of BRRI hybrid dhan6 rice variety recorded the highest grain yield (4.61 t ha^{-1}) which was statistically similar with (4.60 t ha^{-1}) BR11 rice variety cultivation. Among different rice varieties, cultivation of BR 11 rice variety recorded the highest straw yield (6.67 t ha^{-1}) which was statistically similar with (6.39 t ha^{-1}) BRRI hybrid dhan6 rice variety straw yield. Among different rice varieties, cultivation of BR11 rice variety recorded the highest biological yield (11.27 t ha^{-1}) which was statistically similar with (11.00 t ha^{-1}) BRRI hybrid dhan6 rice variety. Cultivation of BRRI hybrid dhan6 rice variety recorded the highest harvest index (41.78 %) which was statistically similar with (40.84 %) BR11 rice variety.

Different rice varieties along with weed control treatment significantly affect weeds and influence crop growth, yield, and yield contributing characters. Among different treatment combination integrated weed management along with BRRI hybrid dhan6 rice variety cultivation recorded the minimum weeds dry weight m^{-2} (0.00 and 0.00, respectively), minimum weeds dry weight m^{-2} (0.00 and 0.00), the maximum weed control efficiency (100 and 100%, respectively) and weed control index (100 and 100 %, respectively) at 30 and 60 DAT, respectively. Growth characters of rice *viz.* plant height and number of tillers $hill^{-1}$ were recorded higher under BRRI hybrid dhan6 variety along with weed control through the spreading of *L. minor* in rice agroecosystems. Cultivation of Tulshimala variety along with weed control through the spreading of duckweed (*L. minor*) in rice agroecosystems recorded the highest leaf area index (2.10) at 45 DAT, which was statistically similar with the cultivation of BRRI hybrid dhan6 with weed control through IWM in rice agroecosystems (2.04). At 60 DAT the highest leaf area index (3.21) was recorded in the V_3W_3 treatment combination, which was statistically similar with V_3W_4 (3.08) and V_3W_0 (3.04) treatment combination. At 75 and 90 DAT, the highest leaf area index (2.79 and 2.50) was recorded in the V_3W_1 treatment combination which was statistically similar to the V_3W_3 treatment combination recorded leaf area index (2.77 and 2.49) at 75 and 90 DAT. cultivation of BRRI hybrid dhan6 variety along with weed control through the spreading of duckweed (*L. minor*) in rice agroecosystems (V_2W_3) recorded the highest dry matter accumulation (16.99 g $hill^{-1}$) 45 DAT which was statistically similar with V_3W_3 (16.71 g $hill^{-1}$), V_3W_1 (16.70 g $hill^{-1}$), V_2W_2 (16.61 g $hill^{-1}$) and V_3W_2 (15.98). At 60 DAT the highest dry matter accumulation (20.02 g $hill^{-1}$) was observed in the V_3W_1 treatment combination which was statistically similar to the V_3W_1 (19.14 g $hill^{-1}$) treatment combination. At 75 DAT the highest dry matter accumulation (26.84 g $hill^{-1}$) was observed in the V_2W_3 treatment combination. At 90 DAT the highest dry matter accumulation (40.78 g $hill^{-1}$) was observed in the V_3W_1 treatment combination which was statistically similar to the V_2W_3 (39.15 g $hill^{-1}$) treatment combination. Whereas the dry matter accumulation (9.84 g $hill^{-1}$) was recorded in the V_1W_4 treatment combination at 45 DAT, which was statistically similar to V_1W_2 (10.59 g $hill^{-1}$

Yield contributing parameters *viz.* effective tillers $hill^{-1}$, panicle length, filled grains $panicle^{-1}$ and total grains $panicle^{-1}$ were significantly different among treatment combinations. Cultivation of BRRI hybrid dhan6 variety along with weed control through integrated weed management (V_3W_1) recorded the highest number of effective tillers $hill^{-1}$ (14.47). Cultivation of BRRI hybrid dhan6 rice variety (V_3) recorded the highest panicle length (29.20 cm). Among different rice varieties cultivation of Tulshimala (V_1) rice variety recorded the highest number of filled grains panicle^{-1} (123.13) which was statistically similar with BRRI hybrid dhan6(V_3) rice variety recorded number of filled grains panicle^{-1} (121.12). Among different rice varieties, cultivation of Tulshimala (V_1) rice variety recorded the highest number of filled grains panicle^{-1} (145.83) which was statistically similar with BRRI hybrid dhan6(V_3) rice variety recorded number of total grains panicle^{-1} (148.99).

Yield characters *viz.* grain yield, straw yield, biological yield, and harvest index were significantly different among treatment combinations. Cultivation of BRRI hybrid dhan6 along with weed control through integrated weed management (V_3W_1) recorded the highest grain yield (5.92 t ha^{-1}) comparable to other treatment combinations. Cultivation of BR11 along spreading of duckweed (*L. minor*) in rice agroecosystems (V_2W_3) recorded the highest straw yield (7.68 t ha^{-1}) which was statistically similar with V_3W_1 (7.27 t ha^{-1}) treatment combination, cultivation of BRRI hybrid dhan6 along with weed control through integrated weed management (V_3W_1) recorded the highest biological yield (13.19 t ha^{-1}) which was statistically similar with V_2W_3 (12.87 t ha^{-1}) treatment combination. Cultivation of BRRI dhan6 along with weed control through integrated weed management (V_3W_1) recorded the highest harvest index (44.94 %).

A positive linear relationship was observed between grain yield, leaf area index, and total dry matter production of T. *aman* rice which was influenced by different weed control treatments along with rice varieties cultivation for weed control. Due to leaf area increased grain yield and total dry matter production increased 30.7 % and 25 %.

Grain yield was also positively correlated with yield contributing characters and it appears that grain yield increase with increasing panicle length, grains panicle^{-1}, and 1000 grains weight. It was observed from the experiment results that among different treatment combinations BRRI hybrid dhan6 variety cultivation along with integrated weed management was the most economically viable treatment and recorded the highest gross return (155270 Tk.), net return (155270 Tk), and benefit-cost ratio (2.60) comparable to others treatments combination.

Based on the above results of the present experiment it was found that:

1. The mean cover of *L. minor* increased rapidly and had the highest cover throughout the experiment followed by *S. molesta* and *P. stratiotes*.
2. Different types of weeds found in rice (i.e., grassy, sedges, and broadleaf), and the occurrence of weed infestation related to rice variety and crop growth.
3. BRRI hybrid dhan6 rice variety significantly suppressed weed density. Integrated weed management successfully control all weeds and gave the highest weed control efficiency and weed control index. Therefore, cultivation of BRRI hybrid dhan6 along with weed control through integrated weed management gave the highest grain yield (5.92 t ha^{-1}) and the highest economic return comparable to other treatment combinations.
4. However, the spreading of *L. minor* also increases grain yield and as well as net return irrespective of varieties.
5. The experimental results also suggest that morphological and biomass characteristics of T. *aman* rice varieties get disadvantages when grown with *P. stratiotes* and *S. molesta*.

However, to reach a specific conclusion and recommendation, more research works should be done especially the phytoremediation by *P. stratiotes and S. molesta* over different Agro Ecological Zones (AEZ) of Bangladesh.

REFERENCES

Acharya, S.S. and Bhattacharya, S. P. (2013). Comparative efficacy of pyrazosulfuron ethyl and bentazon with acetamides for weed control in transplanted boro rice (*Oryza sativa L*.) in the lower gangetic plain zone of west bengal, India. *Intl. J. Boi. Stress Manag.* **4**(4): 506-509.

Afrin, N., Bhuiya, S., Uddin, R., Bir, S. and Park, K. (2015). Combined effect of herbicides on the weed management of rice. *Res. Crops.* **16**(3): 416.

Ahmad, Z., Hossain, N.S., Hussain, S.G. (1990). Effect of duckweed (*Lemna minor*) as complement to fertilizer nitrogen on the growth and yield of rice. *Intl. J. Trop. Agric*. **8**: 72–79.

Ahmed, S., Salim, M. and Chauhan, B.S. (2014). Effect of weed management and seed rate on crop growth under direct dry seeded rice systems in Bangladesh. *PLOS ONE*. **9**(7): e101919.

Akbar, N. and Ali, E. (2011). Weed management improves yield and quality of direct seeded rice. *Australian J. Crop Sci.* **5**(6): 688-694.

Akondo, M., Hossain, M., Akter, S. and Islam, M. (2020). Growth and yield performance of BINA released six promising *aman* rice varieties of Bangladesh. *Asian Pl. Res. J*. **6**(3): 18-25.

Akter, A., Bonni, F.A., Haq. M.E., Shithi, N., Sultana, N., Runia, M.J., Shiddika, A. and Nahar, M.B. (2020). Growth and yield of traditional aromatic rice cultivars in boro season. *Asian J. Res. Bot.* **3**(3): 18-27.

Alam, M.S., Biswas, B.K., Gaffer, M.A. and Hossain, M.K. (2012). Efficiency of weeding at different stages of seedling emergence in direct-seeded aus rice. *Bangladesh J. Sci. Ind. Res*. **30**(4): 155-167.

Amin, M.R., Hamid, A., Choudhury, R.U., Raquibullah, S.M. and Asaduzzaman, M. (2006). Nitrogen fertilizer effect on tillering, dry matter production and yield of traditional varieties of rice. *Intl. J. Sustain. Crop Prod*. **1**(1):17-20.

Aminpanah, H., Sorooshzadeh, A., Zand, E. and A. Moumeni. (2013). Competitiveness of rice (*Oryza sativa* L.) cultivars against barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv.) in lowland rice fields. *Thai J. Agric. Sci*. **46**(4): 209-217.

Azmi, M. (1988). Weed competition in rice production. Proceedings of the National Seminar and Workshop on Rice Field Weed Management, (NSWRFWM'88), Penang, Malaysia, pp: 5-5.

Bari, M.N. 2010. Effects of hetrbicides on weed suppression and rice yield in transplanted wetland rice. *Pakistan J. Weed Sci. Res*. **16(**4): 349-361.

Bangun P. and Syam M. 1988. Weed management in rice crops. PADI 2, 579–599.

BBS. (2018). Year book of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics. Statistical Division, Ministry of Planning. Government of the People's Republic of Bangladesh, Dhaka 37.

Beadle, C.L. (1985). Plant growth analysis. The techniques in bioproductivity analysis and photosynthesis (ed.) by coombs JC, Hall DP, Long SP and Scrulo CO, J.M.O. Pergamon press. pp. 20-25.

Bhuiyan, M.K.A., Mridha, A.J., Ahmed, G.J.U., Begum, J.A. and Sultana, R. (2014). Performance of chemical weed control in direct wet seeded rice culture under two agro ecological conditions of Bangladesh. *Bangladesh J. Weed Sci.* **1**(1): 1-7.

Bilz, M., Kell, S.P., Maxted, N. and Lansdown, R.V. (2011) European red list of vascular plants. Publications Office of the European Union, Luxembourg. pp. 1-10.

Bangladesh Rice Research Institute, (2008). Annual Report for (2007). Bangladesh Rice Research Institute, Joydevpur, Bangladesh. pp. 28-35.

Chakraborti, M., Duary, B. and Datta, M. (2017). Effect of weed management practices on nutrient uptake by direct seeded upland rice under tripura condition. *Intl. J. Cur. Microb. App. Sci.* **6**(12): 66-72.

Chamely, S.G., Islam, N., Hoshain, S. Rabbani, M.G., Kader, M.A. and Salam, M.A. (2015). Effect of variety and nitrogen rate on the yield performance of boro rice. *Prog. Agric.* **26**(1): 6-14.

Charan Teja, K., Duary, B., Mukesh, K. and Bhowmick, M.K. (2015). Effect of bensulfuron-methyl + pretilachlor and other herbicides on mixed weed flora of wet season transplanted rice. *Intl. J. Agric. Environ. Biotechnol*. **8**(2): 323-329.

Chauhan, B. S. and Johnson, D. E. (2011). Row spacing and weed control timing affect yield of aerobic rice. *Fuel and Ener. Abst*. **121**(2): 226-231.

Chauhan, B. S. and Operia, (2011). Effect of tillage systems and herbicides on weed emergence, weed growth and grain yield in dry-seeded rice. *Field Crops Res.* **137**: 56-69.

Cheng, J., Bergman, B.A., Classen, J. J., Stomp, A. M. and Howard, J.W. (2002). Nutrient recovery from swine lagoon water by *Spirodela punctata*. Bioresour. *Technol.* **81**: 81–85.

Chowdhury, I.F. (2012). Influence of weed control methods on the growth and yield of aromatic *aman* rice varieties. M.S. Thesis, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Daniel, P.S., Poonguzhalan, R., Mohan, R. and Suburayalu, E. (2012). Weed management for enhanced production of aerobic rice. *Indian J. Weed Sci.* **44**(4): pp. 270-273.

Das, T., Banerjee, M., Malik, G.C. and Mandal, B. (2017). Efficacy of herbicides against weeds in transplanted wet reason rice (*Oryza Sativa* L.). *IOSR. J. Agric. Vet. Sci.* **10**(5): 1-3.

Diaz, S.H., Castro, R. and Morejon, R. (2000). Morpho-agronomic characterization of varieties of rice. Instituto Nacional de ciencias Agricolas, Gaveta Postall, San Jose, de las, Lajsa, La Habna. **21**(3): 81-86.

Dickinson, M.B. and. Miller, T.E. (1998). Competition among small, free-floating, aquatic plants. *Am. Midl. Nat.* **140**:55-67.

Duary, B. and Mukherjee, A. (2013). Distribution pattern of predominant weeds in wet season and their management in West Bengal, India. In: *Proceedings of the 24th Asian-Pacific Weed Science Society Conference*, 22-25 October, 2013, Bandung, Indonesia, pp. 191-199.

Duary, B., Mishra, M.M., Dash, R. and Teja, K.C. (2015). Weed management in lowland rice. *Indian J. Weed Sci.* **47**(3): 224-232.

Dutta, R.K., Baset-Mia, M.A. and Khanam, S. (2002). Plant architecture and growth characteristics of fine grain and aromatic rices and their relation with grain yield. *Intl. Rice Comm. Newslett.* **51**:51-56.

Edris, K.M., Islam, A.M.T., Chowdhury, M.S. and Haque, A.K.M.M. (1979). Detailed soil survey of Bangladesh, Dept. Soil Survey, BAU and Govt. Peoples Republic of Bangladesh. p. 118.

Farnese, F.S., de Oliveira, J.A., Gusman, G.S., Leão, G.A., Ribeiro, C. and Siman, L.I. (2013). Plant responses to arsenic: the role of nitric oxide. *Water Air Soil Poll.* **224**: 1660.

Ferdous, J., Islam, N., Salam, M.A. and. Hossain, M.S. (2016). Effect of weed management practices on the performance of transplanted aman rice varieties. *J. Bangladesh Agril. Univ.* **14**(1): 17–22.

Gregory, F.G. (1926). The effect of climatic conditions on the growth of barley. *Ann. Bot.* **40**: 1-26.

Harker, K.N. and O'Donovan, J.T. (2013) Recent weed control, weed management, and integrated weed management. *Weed Technol.* **27**:1–11.

Harker, K.N., O'Donovan, J.T., Blackshaw, R.E., Beckie, H.J., Smith, M.C. and Maxwell, B.D. (2012). *Our view. Weed Sci*. **60**: 143–144.

Hasanuzzaman, M., Ali, M.H., Alam, M.M., Akther, M. and Alam, K.F. (2008). Evaluation of preemergence herbicide and hand weeding on the weed control efficiency and performance of transplanted aus rice. *Am-Euras. J. Agron.* **2**(3): 138-143.

Hassan, D. and Upasani, R. R. (2015). Effect of crop establishment and weed control methods on productivity of rice (*Oryza sativa* L.). *J. Crop Weed*. **11**: 228-230.

Heap, I. (2021). International herbicide-resistant weed database. http://www.weedscience. org.com.

Hillman, W.S. (1961). The Lemnaceae, or duckweeds: a review of the descriptive and experimental literature. *Botanical Rev*. **27**: 221–287.

Hossain, A. and Mondal, D.C. (2014). Weed management by herbicide combinations in transplanted rice. *Indian J. Weed Sci.* **46**(3): 220–23.

Hossain, A. and Mondal, D.C. (2014). Weed management by herbicide combinations in transplanted rice. *Indian J. Weed Sci.* **46**(3): 220–23.

Hossain, K., Gathala, M.K., Timsina, J., Johnson, D. and Krupnik, T.J. (2020). Multi-year weed community dynamics and rice yields as influenced by tillage, crop establishment, and weed control: implications for rice-maize rotations in the eastern Gangetic plains. *Crop Prot.* **138**: 105334.

Hossain, M.E., Haque, A.N.A., Haque, M.E. and Lee, H. (2016). Performance and productivity of boro rice varieties cultivated in saline area of Satkhira. *J. Biosci. Agric. Res.* **8**(2): 726-733.

Hossain, M.H. (2015). Efficacy and residual activity of herbicide on growth and yield of transplanted aus rice. M.S. Thesis, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

Hossain, M.F., M.S.U. Bhuiya and Ahaed, M. (2005). Morphological and agronomic attributes of some local and modern aromatic rice varieties of Bangladesh. *Asian J. Pl. Sci*. **4**: 664 666.

Howlader, M.H.K., Rasel, M., Ahmed, M.S., Hasan, M.M. and Banu, L.A. (2017). Growth and yield performance of local transplant *aman* genotypes in southern region of Bangladesh. *Prog. Agric.* **28**(2): 109-113.

Hussner, A. (2014a). Long-term macrophyte mapping documents a continuously shift from native to non-native aquatic plant dominance in the thermally abnormal river efrat (North Rhine-Westphalia, Germany). *Limnologica.* **48**: 39-45.

Islam, A.K.M.M., Popy, F.S., Hasan, A.K. and Anwar, M.P. (2017). Efficacy and economics of herbicidal weed management in monsoon rice of Bangladesh. *J. Sci. Agric.* **1**: 275–293.

Islam, N., Kabir, M.Y., Adhikary, S.K. and Jahan, M.S. (2013). Yield performance of six local aromatic rice cultivars. *J. Agric. Vet. Sci.* **6**(3): 58–62.

Jabran, K., Ehsanullah, Hussain, M., Farooq, M., Babar, M., Doğan, M. and Lee, D. (2012). Application of bispyribac-sodium provides effective weed control in direct-planted rice on a sandy loam soil. *Weed Bio. Manag.* **12**(3): 136-145.

Jisan, M. T., Paul, S. K. and Salim, M. (2014). Yield performance of some transplant *aman* rice varieties as influenced by different levels of nitrogen. *J. Bangladesh Agril. Univ.* **12**(2): 321–324.

Jisan, M. T., Paul, S. K. and M. Salim. (2014). Yield performance of some transplant *aman* rice varieties as influenced by different levels of nitrogen. *J. Bangladesh Agril. Univ.* **12**(2): 321–324.

Johnston, K., Jackie, B., Karen, G., Moira, O. and Alison, M. (1998). Valuing temporary and chronic health states associated with breast screening. *Soc. Sci. Medicine.* **47**: 213–222.

Julien, M. H., Center, T. D. and Tipping, P. W. (2002). Floating fern (*Salvinia*), pp.17-32 in: Biological Control of Invasive Plants in the Eastern United States. United States Department of Agriculture, Forest Service. Forest Health Technology Enterprise Team-Morgantown, West Virginia. Van Driesche, R., Blossey, B., Hoddle, M., Lyon, S., and Reardon, R., 2002. Publication FHTET -2002-04. pp 413.

Keulen, A. O. and Wolf, K. D. F. (1986). Production potential and nitrogen-use efficiency of sweetcorn (*Zea mays*) as influenced by different planting densities and nitrogen levels. *Indian J. Agril. Sci.***79**: 351–355.

Khaliq, A., Matloob, A., Ahmad, N., Rasul, F. and Awan, I. U. (2012). Post emergence chemical weed control in direct seeded fine rice. *J. Anim. Pl. Sci.* **22**(4): 1101-1106.

Khatun, S., Mondal, M., Khalil, M., Roknuzzaman, M. and Mollah, M. (2020). Growth and yield performance of six aman rice varieties of Bangladesh. *Asian Res. J. Agric*. **12**(2): 1-7.

Kiran, Y.D., Subramanyam, D. and Sumathi, V. (2010). Growth and yield of rice as influenced by sequential application of herbicides. *Indian J. weed sci*. **42**(3&4): 226 228.

Kumar, R.S., Durairaj, S.N., Daisy, M. and Archana. H.A. 2014. Studies on weed management practices in transplanted rice. *Trend. Bio.* **7**(23): 3882-3885.

Kumar, V., Opena, J., Valencia, K., Thi, H.L., Son, N.H., Donayre, D.K., Janiya, J., Johnson, D. E. (2017). Rice weed management in Southeast Asia. Pages 282–307 in Rao AN and Matsumoto H eds. Weed management in rice in the asian-pacific region. Asian-Pacific Weed Science Society (APWSS); The Weed Science Society of Japan, Japan and Indian Society of Weed Science, India.

Labrada, R. and Fornasari, L. (2002). Management of problematic aquatic weeds in Africa. FAO efforts and achievements during the period 1991-2001. Food and Agriculture Organization of the United Nations, Rome, p.28.

Lumpkin T.A. and Plucknett D.L. 1980. Azolla: botany, physiology and use as a green manure. Econ. Bot. 34, 111–153.

Latif, A., Islam, M.S., Hasan, A.K., Salam, M.A., Rahman, A. and Zaman, F. (2020). Effect of source of irrigation water on yield performance of Boro rice. *Arc. Agric. Environ. Sci.* **5**(3): 254-260.

Li, H., Liang, X. Q., Lian, Y. F., Xu, L. and Chen, Y. X. (2009). Reduction of ammonia volatilization from urea by a floating duckweed in flooded rice fields. *Soil Sci. Soc. Am. J.* **73**: 1890.

Lodhi, R. (2016). Efficacy of bensulfuron methyl + pretilachlor against weeds in transplanted rice. M. S. Thesis, Department of Agronomy,Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur.

Lu, J., Ookawa, T. and Hirasawa T. (2000). The effects of irrigation regimes on the water use, dry matter production and physiological responses of paddy rice. *Pl. and Soil.* **223**: 209–218.

Madukumar, V. (2011). Evaluation of pre and post emergent herbicides in aerobic rice. M. Sc. (Agri.) Thesis. Univ. Agric. Sci. Bengaluru.

Magzter. (2021). Business Standard Newspaper. September 16, 2020. pp. 1-2. https://www. magzter.com/IN/Business-Standard-Private Ltd/BusinessStandard /Newspaper/519197.

Mahajan, G., Sardana, V., Brar, A.S. and Gill, M.S. (2006). Effect of seed rates, irrigation intervals and weed pressure on productivity of direct seeded rice. *Indian J. Agric. Sci.* **76**: 156-759.

Mahamud, J.A., Haque, M.M. and Hasanuzzaman, M. (2013). Growth, dry matter production and yield performance of transplanted a*man* rice varieties influenced by seedling densities per hill. *Intl. J. Sust. Agric.* **5**(1): 16–24.

Mahmud, S., Hassan, M.M., Rahman, M.M. and Jannat, M. (2017). Response of short duration *aman* rice varieties to date of transplanting. *J. Bangladesh Agril. Univ.* **15**(1): 1–6.

Maity, S. K. and Mukherjee, P.K. (2008). Integrated weed management in dry direct seeded rice. *Indian J. Agron.* **53**: 116-120.

Malik, R. K., Kumar, V., Yadav, A. and Mc Donald, A. (2014). Conservation agriculture and weed management in south Asia: perspective and development. *Indian J. Weed Sci.* **46**(1): 31-35.

Mamun, M.A.A., Shultana, R., Rana and M.M., Mridha, A.J. (2013). Economic threshold density of multi species weed for direct seeded rice. *Asian J. Agric. Rural Develop*. **8**: 523-531.

Mandal, M.K., Duary, B. and De, G.C. (2013). Effect of crop establishment and weed management practices on weed growth and productivity of Basmati rice. *Indian J. Weed Sci.* 45(3): 166–170.

Mani V.S., Malla, M.L., Gautam, K.C. and Bhagwandas, (1973). Weed killing chemicals in potato cultivation. *Indian Fmg.* **23**(8): 17-18.

Maqsood, M. (1998). Growth and yield of rice and wheat as influenced by different planting methods and nitrogen levels in rice-wheat cropping system. Ph. D Thesis. Department of Agronomy. University of Agriculture, Faisalabad.

Mazid, M.A., Jabbar, M.A., Riches, C.R., Robinson, E.J.Z., Mortimer, M. and Wade, L.J. (2001). Weed management implications of introducing dryseeding of rice in the barind tract of Bangladesh. Pages 211-216 in Proceedings of the Brighton Crop Protection Conference, November 13–15, 2001. Brighton, UK: British Crop Protection Council.

Mbati, G. and Neuenschwander, P. (2005). Biological control of three floating water seeds, *Eichhornia crassipes*, *Pistia stratiotes*, and *Salvinia molesta* in the Republic of Congo. *Bio. Control.* **50**: 635-645.

Mia, M. A. B. and Shamsuddin, Z. H. (2011). Physio-morphological appraisal of aromatic fine rice (*Oryza sativa* L.) in relation to yield potential. *Intl. J. Bot.* **7**: 223-229.

Mishra, A. and Tosh, G. C. (1979). Chemical weed control studies on dwarf wheat. *J. Res. Quat.* **10**: 1-6.

Mishra, A. and Tosh, G. C. (1979). Chemical weed control studies on dwarf wheat. *J. Res. Quat.* **10**: 1-6.

Mitra, B.K., Karim, A.J.M.S., Haque, M.M., Ahmed, G.J.U. and Bari, M.N. (2005). Effect of weed management practices on transplanted *aman* rice. *J. Agron.* **4**: 238-241.

Monika, S., Upadhyay V. B. and Singh, P. (2012). Weed dynamics and production efficiency of rice-based cropping system. *Indian J. Weed Sci.* **44**(1): 21–25.

Moody K. and Janiya J.D. 1992. The role of Azolla in weed control in rice. Philipp. J. Weed Sci. 19, 79–102.

Nagesh, C.R. (2016). Efficacy of pre and post emergent herbicides in direct seeded rice under cauvery command area of Karnataka. M.Sc (Agri.) *Thesis*, Univ. Agric. Sci. Bengaluru, Karnataka.

Nahida, I., Kabir, M.Y., Adhikary, S.K. and Jahan, M.S. (2013). Yield performance of six local aromatic rice cultivars. *IOSR. J. Agric. Veterin. Sci*. **6**(3): 58-62.

Nguyen C.T. 1930. L'Azolle cultivee comme engrais vert. Bull. Econ. Indochine 33, 335–350.

Oerke, E.C. (2006). Crop losses to pests. *The J. Agric. Sci*. **144**: 31-43.

Olayinka, B. and Etejere, E. (2015). Growth analysis and yield of two varieties of groundnut (*Arachis hypogaea* L.) as influenced by different weed control methods. *Indian J. Pl. Physiol.***20**(2): 130-136.

Paul, S., Biswas, P.K., Islam, M.S., Siddique, S.S., Shirazy, B.J. and Kobir, M.S. (2019). Screening of advanced aromatic rice lines using morphological and physico-chemical characteristics. *Bangladesh J. Agron.* **22**(2): 91-102.

Paiman, Ismail, S.N.F. and Abdullah, A.S. (2020). Recent developments of weed management in rice fields. *Rev. Agr. Sci.* **8**: 343–353.

Paulraj, S, Murugan, G., Stalin, P., Saravanaperumal, M. and Suseendran, K. (2019). Effect of pre and post emergence herbicides on weed flora and yield of transplanted rice. *Pl. Arc.* **19**(2): 3093-3096.

Pons T.L. 1987. Growth rates and competitiveness to rice of some annual weed species. In: Studies on Weeds and Rice Competition (ed. by Sorianegara I.). Biotrop, Bogor, Indonesia, 13–21.

Pulido, C. F. (2016). Duckweed as a sustainable soil amendment to support crop growth, enhance soil quality, and reduce agricultural runoff. Dissertation, The Pennsylvania State University.

Rahman, A., Islam, A., Arefin, M., Rahman, M. and Anwar, M. (2017). Competitiveness of winter rice varieties against weed under dry direct seeded conditions. *Agric. Sci.* **8**(12): 1415-1438.

Raju, A., Pandian, B.J., Thukkaiyannan, P. and Thavaprakash, N. (2003). Effect of weed management practices on the yield attributes and yield of wet seeded rice. *Acta. Agron*. *Hungarica*. **51**(4):461-464.

Rammana, A.V., Reddy, D.S. and Ramakumar, K. (2014). Influence of sowing time and nitrogen levels on growth, yield and N uptake of rainfed upland rice varieties. The Andhra. Agric. J. **54**(3&4): 114–120.

Rao, A.N. and Nagamani, A. (2013). Eco-efficient weed management approaches for rice in tropical Asia. In: *Proceedings 4th Tropical Weed Science Conference,* 23-25 January, 2013, Chiang Mai, Thailand. pp. 78-87.

Rashid, M.H., Alam, M.M., Rao, A.N. and Ladha, J.K. (2012). Comparative efficacy of pretilachlor and hand weeding in managing weeds and improving the productivity and net income of wet-seeded rice in Bangladesh. *Field Crops Res*. **128**: 17–26.

Ravisankar, N., Chandrsekaran, B., Raja, R., Din, M., and Chaudhuri, S.G. (2008). Influence of integrated weed management practices on productivity and profitability of wet seeded rice (*Oryza sativa*). *Indian J. Agron*. **53**(1): 57-61.

Roy, S.K., Ali, M.Y., Jahan, M.S., Saha, U.K., Ahmad, H.M.S., Hassan, M.M. and Alam, M.M. (2014). Evaluation of growth and yield attributing characteristics of indigenous boro rice varieties. *Life Sci. J*. **11**: 122-126.

Salam, M.A., Sarker, S. and Sultana, A. (2020). Effect of weed management on the growth and yield performances of boro rice cultivars. *J. Agric. Food and Environ.* **1**(4): 19- 26.

Sarkar, S. C. (2014). Performance of five selected hybrid rice varieties in aman season. M. S. Thesis, Dept of Agricultural Botany, Shere- Bangla Agril, University. Dhaka, Bangladesh.

Shah, M. H., Khusu, M.K., Khande, B.A. and Bali, A.S. (1991). Effect of spacing and seedlings per hill on transplanted rice under late sown. *Indian J. Agron.* **36**(2): 274-275.

Sharma, K.P. and Goel, P.K. (1986). Studies on decomposition of two species of *Salvinia*. *Hydrobiologia.* **131**: 57-61.

Shawon, S.D., Islam, M.N., Biswas, M. and Sarker, S. (2018). Competitiveness of aus rice varieties against weed infestation. *J. Sylhet Agril. Univ.* **5**(1): 7-14.

Shultana, R., Mamun, M.A.A. and Mridha, A. (2013). Impacts of different competition duration of *Echinochloa crus-galli* on transplanted aman rice. *American Open J. Agric. Res*. **1**(5): 14 - 23.

Sohel, M.A.T., Siddique, M.A.B., Asaduzzaman, M., Alam, M.N. and Karim, M.M. (2009). Varietal performance of transplant aman rice under differnt hill densities. *Bangladesh J. Agril. Res*. **34**(1):33-39.

Sohel, M.S.H., Haque, M.A., Mondol, M.M.A., Rana, M.M., Hasan, A.K. and Hossain, M. D. (2020). Influence of variety and weeding regime on the yield of transplant aman rice. *Intl. J. Biosci.* **16**(4): 390-403.

Sridevi, V., Jeyaraman, S., Chinnusamy, C. and Chellamuthu, V. (2013). Weed management in lowland rice (*Oryza sativa* L.) ecosystem a review. *Intl.J. Agric. Sci. Res.* **3**(3**)**: 13-22.

Storrs, M.J. and Julien, M.H. (1996). *Salvinia.* A Handbook for the Integrated Control of *Salvinia molesta* in Kakadu National Park. Northern Landscapes Occasional Papers N°1. Australian Nature Conservation Agency. Darwin, Australia.

Sukla, V.N., Srivastava, V.K., Smita Singh, A. and Kumar, V. (2014). Growth, yield and economics potential of rice as influenced by different age of seedling, cultivar and weed management under system of rice intensification. *Indian J. Agric. Sci*. **84**(5): 628-636.

Sunil, C.M., Shekara, B.G., Anilkumar, S.N., Kalyanamurthy, K.N. and Vijay Mahanthesh, (2011). Economics and uptake of nutrient by crops and weeds as influenced by weed control practices in aerobic rice. *Adv. Res. J. Crop Improv.* **1**(2): 183-186.

Sunil, C.M., Shekara, B.G., Kalyanamurthy, K.N. and Shankaralingappa, B.C. (2010). Growth and yield of aerobic rice as influenced by integrated weed management practices. *Indian J. Weed Sci.* **42**(4): 180-183.

Suryakala, P., Murugan, G., Saravanaperumal, M., Suseendran, K and Stalin, P. (2019). Effect of weed management practices with new generation herbicides in transplanted rice. *J. Pharma. Phytochemi:*.**8**(3): 3913-3915.

Tamradhvaj, D., Arunbabu, T. and Manmohan, M. (2014). Effect of weed management practices on weed parameters, yield and nutrient uptake of direct seeded upland rice. *Ann Pl. Soil Res.* **16**(4): 294-299.

Teja, K.C., Duary, B., Kumar, M. and Bhowmick, M.K. (2017). Effect of bensulfuron methyl+pretilachlor and other herbicides on mixed weed flora of wet season transplanted rice. *Intl. J. Agric. Environ. Biotech.* **8**(2): 323-329.

Toshiyuki, T., Shoji, M., Takahiro, N., Akihiro, O. and Tatsuhiko, S., Takeshi, H. (2006). Rice yield potential is closely related to crop growth rate during late reproductive period. *Field Crops Res.* **96**(2-3): 328-335.

Tyeb, A., Paul, S.K. and Samad, M.A. (2013). Performance of variety and spacing on the yield and yield contributing characters of transplanted aman rice. *J. Agro. Environ*. **7**(1): 57-60.

Uddin, M.J., Ahmed, S., Harun–or–Rashid, M., Hasan, M.A. and Asaduzzaman, M. (2011). Effect of spacing on the yield and yield attributes of transplanted aman rice cultivars in medium lowland ecosystem of Bangladesh. *J. Agric. Res.* **49**(4): 465–476.

Wang, C., Li, S., Lai, D.Y.F., Wang, W. and Ma, Y. (2015) The effect of floating vegetation on CH4 and N2O emissions from subtropical paddy fields in China. *Paddy Water Environ.* **13**: 425-431.

Watson, D.J. (1956). The dependence of net assimilation rate on leaf area index. *Ann. Bot. N. S*. **18**: 29-31.

Yadav D.B., Singh, S. and Yadav, A. (2008). Evaluation of azimsulfuron and metsulfuron-methyl alone and in combination for weed control in transplanted rice. *Indian J. Weed Sci.* **40(**1&2**)**: 16-20.

Yadav, D.B., Yadav, A. and Poonia, S.S. (2009). Evaluation of bispyribac-sodium for weed control in rice. *Indian J. Weed Sci*. **41**(1&2): 23-27.

Yadav, D.B., Yadav, A., Punia, S.S., Singh, N. and Duhan, A. (2018). Pretilachlor + pyrazosulfuron-ethyl (ready-mix) against complex weed flora in transplanted rice and its residual effects. *Indian J. Weed Sci*. **50**(3): 257-261.

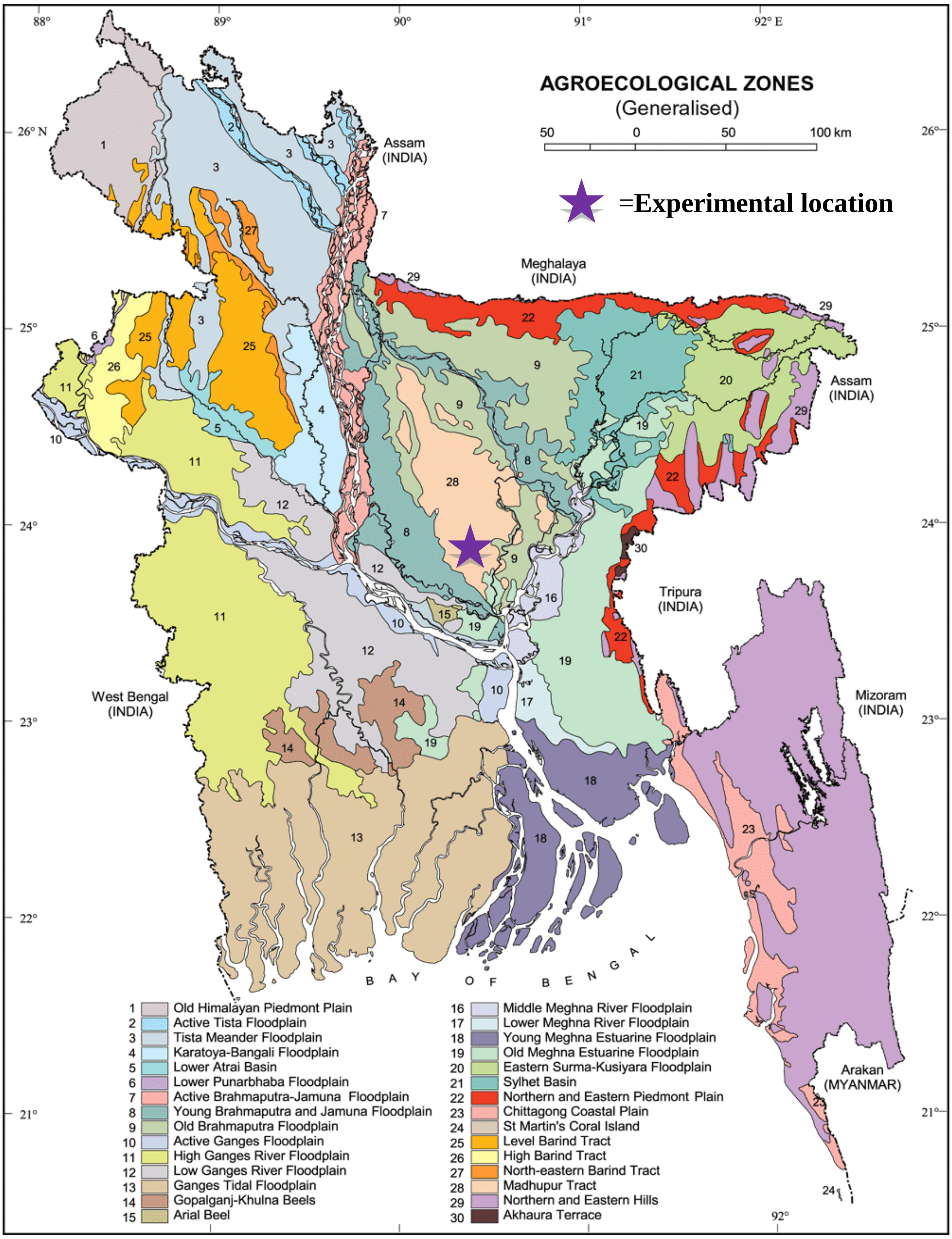
Yang, H., Yu, D., Zhou, J., Zhai, S., Bian, X. and Weih, M. (2018). Rice-duck co-culture for reducing negative impacts of biogas slurry application in rice production systems. *J Environ. Manag.* **213**: 142-150.

Yao, Y., Zhang, M., Tian, Y., Zhao, M., Zhang, B., Zhao, M., Zeng, K. and Yin, B. (2017). Duckweed (*Spirodela polyrhiza*) as green manure for increasing yield and reducing nitrogen loss in rice production. *Field Crop Res*. **214**: 273–282.

Yogananda, S. B., Thimmegowda, P. and Shruthi, G. K. (2017). Weed management effect on growth and yield of wet direct-seeded rice in Cauvery command area of Karnataka. *Indian J. Weed Sci*. **49**(3): 219-222.

APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

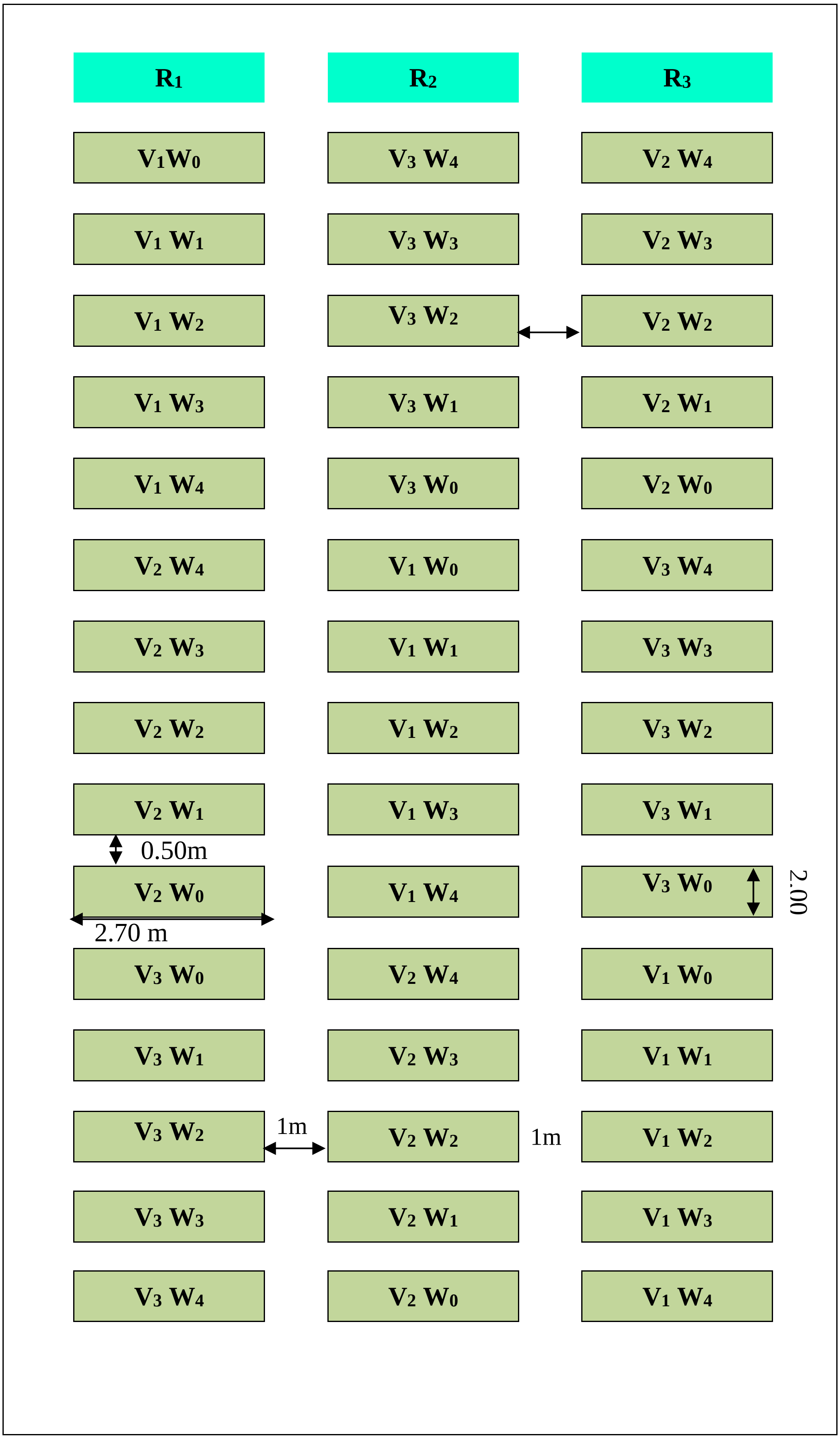
Physical characteristics	
Constituents	**Percent**
Sand	26 %
Silt	45 %
Clay	29 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10

Appendix III. Monthly meteorological information during the period from July 2019 to December, 2019

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	July	32.6	26.8	81	114
	August	32.6	26.5	80	106
	September	32.4	25.7	80	86
	October	31.2	23.9	76	52
	November	29.6	19.8	53	00
	December	28.8	19.1	47	00

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Layout of the experimental field



LEGEND

Rice varieties (3) viz;

V_1= Tulshimala,
V_2 = BR 11,
V_3 = BRRI hybrid dhan6

Weed control treatment (5) viz

W_0= Weedy check (Control),
W_1= Integrated weed management
W_2 = *Pistia stratiotes*,
W_3 = *Lemna minor* and
W_4 = *Salvinia molesta.*

Appendix V. Analysis of variance of the data of weed density (m^{-2}) and weed dry weight ($g\ m^{-2}$) at 30 and 60 DAT

Mean square of					
Source		Weed density (m^{-2}) at		Weed dry weight ($g\ m^{-2}$) at	
	Df	30 DAT	60 DAT	30 DAT	60 DAT
Replication (A)	2	1.953	0.175	0.3496	0.4380
Varity (V)	2	139.922**	24.456**	11.1035**	5.7637**
Error	4	0.989	0.101	0.0772	0.0150
Weed control (W)	4	871.065**	150.145**	99.4907**	15.8557**
V×W	8	13.645**	2.977**	0.9144**	0.4418**
Error	24	0.707	0.064	0.0760	0.0210

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of weed control efficiency (%) and weed control index (%) at 30 and 60 DAT

Mean square of					
Source		Weed control efficiency (%) at		Weed control index (%) at	
	Df	30 DAT	60 DAT	30 DAT	60 DAT
Replication (A)	2	14.0	19.5	39.6	121.2
Varity (V)	2	909.7**	893.5**	452.3**	126.8**
Error	4	3.2	12.2	13.5	14.1
Weed control (W)	4	11934.6**	12132.9**	11594.1**	11657.4**
V×W	8	154.8**	197.0**	80.6**	28.5**
Error	24	7.7	3.8	4.1	13.7

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of plant height of T. *aman* rice at different DAT

Mean square of plant height at						
Source	Df	45 DAT	60 DAT	75 DAT	90 DAT	At harvest
Replication (A)	2	16.96	3.43	42.33	26.83	5.22
Varity (V)	2	2373.63**	3900.08**	5324.67**	6313.99**	9686.28**
Error	4	2.67	2.60	3.33	6.89	9.60
Weed control (W)	4	27.07**	91.13**	32.50**	65.34**	87.70**
V×W	8	8.40**	22.32**	14.25*	17.54*	13.68*
Error	24	1.80	4.17	6.04	7.19	5.10

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of number of tillers hill^{-1} of T. *aman* rice at different DAT

Mean square of number of tillers hill^{-1} at						
Source	Df	45 DAT	60 DAT	75 DAT	90 DAT	At harvest
Replication (A)	2	11.4667	10.4667	13.6827	12.7127	13.2667
Varity (V)	2	15.8506**	51.1440**	37.8295**	42.1378**	35.1034**
Error	4	0.2667	0.2667	0.0627	0.3427	0.5333
Weed control (W)	4	6.8431**	2.4003**	0.5229**	3.3034**	11.2595**
V×W	8	10.0340**	8.9236**	7.9467**	4.6315**	2.3488**
Error	24	0.3333	0.3333	0.0693	0.2577	0.4444

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data of leaf area index of T. *aman* rice at different DAT

Mean square of leaf area index at					
Source	Df	45 DAT	60 DAT	75 DAT	90 DAT
Replication (A)	2	0.00200	0.01400	0.00467	0.00200
Varity (V)	2	0.27712**	1.52895**	0.91495**	0.84241**
Error	4	0.00100	0.01000	0.00767	0.00100
Weed control (W)	4	0.07035**	0.07293**	0.11401**	0.20499**
V×W	8	0.11005**	0.21759**	0.16535**	0.10376**
Error	24	0.00133	0.01133	0.00667	0.00467

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix X. Analysis of variance of the data of dry matter accumulation plant^{-1} of T. *aman* rice at different DAT

Mean square of dry matter accumulation plant^{-1} at					
Source	Df	45 DAT	60 DAT	75 DAT	90 DAT
Replication (A)	2	8.8035	6.1212	0.0667	3.267
Varity (V)	2	55.2486**	43.1785**	38.1305*	235.503**
Error	4	0.3820	0.6667	2.4667	0.933
Weed control (W)	4	12.8066**	18.1366**	17.8926**	68.107**
V×W	8	2.1451**	3.6294**	11.6369**	26.778**
Error	24	0.3153	0.8667	1.6667	1.378

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix XI. Analysis of variance of the data of crop growth rate, relative crop growth rate and net assimilation rate of T. *aman* rice

Mean square of				
Source	Df	Crop growth rate	Relative crop growth rate	Net assimilation rate
Replication (A)	2	0.00467	0.600	0.00200
Varity (V)	2	2.65950**	206.001**	0.33151**
Error	4	0.00367	1.500	0.00100
Weed control (W)	4	0.74622**	53.142**	0.07082**
V×W	8	0.22076**	18.019**	0.02622**
Error	24	0.00400	1.200	0.00133

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix XII. Analysis of variance of the data of Effective tillers hill^{-1}, non-effective tillers hill^{-1} and Panicle length of T. *aman* rice.

Mean square of				
Source	Df	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Panicle length
Replication (A)	2	24.0349	1.6149	4.274
Varity (V)	2	8.5117**	23.3830**	129.835**
Error	4	0.6338	0.0104	0.231
Weed control (W)	4	17.7072**	0.9132**	1.567**
V×W	8	2.0034**	0.2922**	0.550*
Error	24	0.4447	0.0033	0.185

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix XIII. Analysis of variance of the data of filled, unfilled, total grains panicle^{-1} and 1000 grains weight of T. *aman* rice

Mean square of					
Source	Df	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	Total grains panicle^{-1}	1000 grains Weight
Replication (A)	2	74.80	19.289	18.14	17.267
Varity (V)	2	2191.73**	260.494**	1191.74**	807.442**
Error	4	16.49	3.089	22.82	0.067
Weed control (W)	4	1683.62**	75.987**	1106.18**	6.918**
V×W	8	102.64**	16.126**	89.39**	1.446**
Error	24	9.16	1.906	14.13	0.133

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix XIV. Analysis of variance of the data of on grain, straw, biological yield and harvest index of T. *aman* rice

Mean square of					
Source	Df	Grain yield	Straw yield	Biological yield	Harvest index
Replication (A)	2	0.28578	1.04435	2.4019	1.2545
Varity (V)	2	6.27602**	6.88560**	26.0125**	22.9472**
Error	4	0.00868	0.13130	0.1922	1.0287
Weed control (W)	4	1.66099**	1.97793**	6.9351**	8.3190**
V×W	8	0.59027**	0.79186**	2.6167**	2.0451**
Error	24	0.11641	0.29768	0.7554	0.8223
Total	44				

**: Significant at 0.01 level of probability
*: Significant at 0.05 level of probability

Appendix XV. Wages and price of different items used in the experiment

Input cost= Non material cost + Material cost

A. Non material cost

Items	No. of labor required	Amount taka
Seed bed preparation	8	3200
Planting of transplanting rice plant	20	8000
Tractor operation	1	400
Harvesting & others works	20	8000
	Grand total= 19600	

(Individual labor wages 400 taka day^{-1}).

B. Material cost

Sl. No.	Quantity (kg/ha)/times	Items Cost (Tk)	Cost (Tk/ha)
Seed rate ha^{-1}	30	25	750
Fertilizers			
Urea	150	16	2400
TSP	100	22	2200
MP	70	15	1050
Gypsum	60	8	480
Zinc sulphate	10	250	2500
Irrigation	2 times	2000	4000
Tractor	1	3000	3000
Pesticide	2	1500	3000
(Excluding herbicide application)			Grand total= 19380

Overhead cost

Land value ha^{-1} was 200000 taka. Land cost at 12.5 % interest for 6 month was 12500 taka.

Miscellaneous cost (common cost)

It was 5% of total input cost

Weed control cost

Items	Items Cost (Amount/Taka)	Quantity/ha	Cost (Tk/ha)	Application cost (Tk) (Equipments and others)	Total cost (Taka)
W_0	0	0	0	0	0
W_1	1kg/300 taka	9.88 kg/ha	2964	400	3364
W_2	0	0	0	0	0
W_3	0	0	0	0	0
W_4	0	0	0	0	0

Note *viz. Here,* W_0= Weedy check (Control), W_1= Integrated weed management, W_2 = *Pistia stratiotes* W_3 = Lemna minor, W_4 = *Salvinia molesta*

Appendix XVI. Total cost of production of T. *aman* rice varieties cultivations

Total cost of production

Non-material cost (i)	Material cost (Excluding herbicide) (ii. a)	Weed control cost (ii. b)	Total input cost (A = i+ ii)	Interest on input cost @ 12.5% for 6 month (B)	Miscellaneous cost is 5% of total input cost (C)	Overhead cost (D)	Total cost of production (A+B+C+D)
19600	19380	0	38980	2436	1949	12500	55865
19600	19380	3364	42344	2646	2117	12500	59607
19600	19380	0	38980	2436	1949	12500	55865
19600	19380	0	38980	2436	1949	12500	55865
19600	19380	0	38980	2436	1949	12500	55865

Appendix XVII. Gross return from T. *aman* rice cultivation

Gross return from rice cultivation

Rice value (With husk) = 1 kg 25 taka so 1 ton = 25000 taka

Straw value= 1 kg 1 taka so 1 ton = 1000 taka

Treatment	Grain yield (t/ha)	Value	Straw yield (t/ha)	Value	Gross retrun (Tk)
V_1W_0	2.91	72750	4.55	4550	77300
V_1W_1	3.91	97750	5.94	5940	103690
V_1W_2	3.49	87250	5.19	5190	92440
V_1W_3	3.76	94000	5.88	5880	99880
V_1W_4	3.35	83750	5.34	5340	89090
V_2W_0	4.18	104500	6.09	6090	110590
V_2W_1	4.68	117000	6.46	6460	123460
V_2W_2	4.56	114000	6.6	6600	120600
V_2W_3	5.19	129750	7.68	7680	137430
V_2W_4	4.39	109750	6.51	6510	116260
V_3W_0	4.57	114250	6.65	6650	120900
V_3W_1	5.92	148000	7.27	7270	155270
V_3W_2	3.86	96500	5.45	5450	101950
V_3W_3	4.65	116250	6.67	6670	122920
V_3W_4	4.04	101000	5.91	5910	106910

PLATE

Plate 1. Transplanting *aman* rice to research field

Plate 2. Spreading of *Salvinia molesta* in research plot

Plate 3. Spreading of *Pistia stratiotes* in research plot

Plate 4: Spreading of *Lemna minor* in research plot

Plate 5: Infestation of weed in research plot under control treatment