WEED CONTROL EFFICIENCY OF HERBICIDE MIXTURES IN TRANSPLANTED AMAN RICE VARIETIES

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*This is to certify that thesis entitled, "**WEED CONTROL EFFICIENCY OF HERBICIDE MIXTURES IN TRANSPLANTED AMAN RICE VARIETIES**" 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 bonafide research work carried out by **Zobayra Haque Jame,** Registration no.**14-05827** 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.

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MY

BELOVED PARENTS

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ABSTRACT

A field experiment was carried out at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh from July to December-2019, to investigate the efficacy of herbicide mixtures against weeds in transplanted *aman* rice varieties. The experiment consisted of two factors i.e., herbicide treatments 4 levels *viz*., *w*eedy check(H0), Bispyribac-sodium WP @ 150 g ha^{-1}(H1), Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}(H3) and Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}(H4) and T. *aman* rice varieties 4 levels *viz.,* Chinigura(V1), BR11(Mukta)(V2), BRRI dhan56(V3), and BRRI hybrid dhan6(V4). The experiment was laid out in a split-plot design placing herbicide mixtures in main plots and rice varieties in sub plots with three replications. Results indicated that thirteen weed species infested the experimental plots belonging to nine families where the most dominating were broadleaf and sedge weed species. *Monochoria vaginalis* was the most dominant weed with (36 and 18 m^{-2} having relative density (15.93 and 16.98 % respectively) in weedy check plot at 30 and 60 DAT, respectively. Application of different herbicides, rice varieties, and their combination significantly influenced weed control and crop performance. Applications of mixed herbicides gave superior rice yields over the single herbicide where Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} reduced weeds growth and biomass significantly. Among rice varieties, BR11(Mukta) rice variety produced the highest grain yield(4.71 t ha^{-1}) with better yield contributing parameters and grain yield. Application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} in BR11(Mukta) rice variety produced the highest grain yield (5.57 t ha^{-1}), straw yield (6.76 t ha^{-1}), biological yield (12.33 t ha^{1}), and harvest index (45.09%) which also recorded the highest gross return (1,46,010 Tk.), net return (88,699 Tk.) and benefit-cost ratio (2.55) comparable to other combinations. This indicated that herbicide mixture application in the best way of controlling complex weed flora and enhanced productivity and profitability in transplanted rice.

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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 Resource Development Institute
T	Ton
TSP	Triple Super Phosphate
Wt.	Weight

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop and a primary food source for more than one-third of the world's population (Sarkar *et al.,* 2017). Worldwide, rice provides 27% of dietary energy supply and 20% dietary protein (Kueneman, 2006). It constitutes 95% of the cereal consumed and supplies more than 80% of the calories and about 50% of the protein in the diet of the general people of Bangladesh (Yusuf, 1997). The world's rice demand is projected to increase by 25% from 2001 to 2025 to keep pace with population growth (Salam *et al.,* 2020), and therefore, meeting this ever-increasing rice demand in a sustainable way with shrinking natural resources is a great challenge. Rice has a tremendous influence on the agrarian economy of the country. The annual production of rice in Bangladesh is about 36.28 million tons from 11.52 million ha of land (BBS, 2018). According to the USDA report in 2021 rice production for the 2020-21 marketing year is expected to rise to 36.3 million tonnes in Bangladesh as further cultivation of hybrid and high yield variety plantings increases. The country is expected to import 200,000 tonnes of rice in the 2020-21 marketing year to ease food security tensions brought on by the COVID-19 pandemic (USDA, 2021).

There are three distinct growing seasons of rice in Bangladesh, according to changes in seasonal conditions such as *aus*, *aman* and *boro*. More than half of the total production (55.50 %) is obtained in *boro* season occurring in December–May, second largest production in *aman* season (37.90 %) occurring in July-November and little contribution from *aus* season (6.60 %) occurring in April-June (APCAS, 2016). Among three growing seasons, *aman* rice occupies the highest area coverage. The *aman* rice crop occupies 67 percent of the cropped area of 85.77 hectares. In 2020, the amount of land used for HYV varieties is 44.47 lakh (4.44 million) hectares, hybrid 2.40 lakh (0.24 million) hectares, local varieties 7.15 lakh (0.75 million) hectares and for broadcast *aman* 3.12 lakh (0.31 million) hectares of cultivable land. The total land under the *aman* crop was 57.14 lakh (5.71 million) hectares (Magzter, 2021). Recently, food security especially attaining self-sufficiency in rice production is a burning issue in Bangladesh. The average yield of rice is almost less than 50% of the world's average rice grain yield. The national mean yield (2.60 t ha^{-1}) of rice in

Bangladesh is lower than the potential national yield (5.40 t ha^{-1}) and world average yield (3.70 t ha^{-1}) (Pingali *et al.*, 1997). The lower yield of transplanted *aman* rice has been attributed to several reasons. In such conditions, increasing rice production can play a vital role. Therefore, attempts must be made to increase the yield per unit area by adopting modern rice varieties, applying improved technology and management practices (such as irrigation, spacing, weed, insect, etc).

Crop performance is closely related to weed growth. Weeds are the most important threat under upland or aerobic rice systems, resulting in yield losses between 30 and 98 percent (Ramana *et al.,* 2014). Among the harmful pest, weeds contribute maximum losses in crop production, which may potentially reduce crop production by 34%, followed by animal pests (18%) and pathogens by 16% (Abbas *et al.,* 2018). The high competitive ability of weeds exerts a serious negative effect on crop production. Globally, actual yield losses due to pests have been estimated at approximately 40%, of which weeds caused the highest loss (32%) (Rao *et al.,*2007). Weeds compete with rice plants severely for space, nutrients, air, water, and light and adversely affect the plant height, leaf architecture, tillering habit, and crop growth (Miah *et al.,* 1990*)*. In Bangladesh, weed infestation reduces the grain yield by 70-80% in *aus* rice (early summer), 30- 40% for transplanted *aman* rice (autumn), and 22-36% for modern *boro* rice cultivars (winter rice) (BRRI, 2008). Although hand weeding is the popular weed control method in Bangladesh, weed control is often imperfect or delayed due to the unavailability of labor during the peak period. Mechanical weeding and chemical weed control are the alternatives to hand weeding. In recent years, chemical weed control (*viz:* herbicide application) has increased in Bangladesh (Ahmed *et al*., 2014).

Now-a-days the use of herbicide is gaining popularity in rice culture due to their rapid effects and less cost involvement compared to traditional methods of weeding (Mian and Mamun, 1969). However, removal of weeds at their critical period by traditional means may not be possible at the peak period of labor demand. In such a situation herbicides are promising alternatives in controlling weed (Rao and Pilla, 1974; De Datta, 1980). Herbicides have become the major weed management tool for weed control in a crop field but continuous and indiscriminate use of herbicides may alter their degradation and pose persistence problems due to residual effects beyond harvest, threatening health and ecology. The use of herbicides of a different mode of action and chemistry is desirable to reduce the problem of residue buildup, a shift in weed flora (Rajkhowa *et al.,* 2006), and the development of herbicide resistance in weeds (Rao, 1999).

Herbicide mixture may be one of the options for management or delay of cross-resistance development against these herbicides (Dhawan *et al*., 2009). Different pre-mix and tank-mix combinations are being tried out to control mixed weeds (Yadav *et al*., 2008) which will not only reduce the total volume of herbicide but also ease and economize its application. Singh (2007) found that sole dependence on herbicides having a single mode of action is also not advisable as it has contributed to shifting towards difficulty to control weeds and the rapid evolution of multiple herbicide resistance, which is a threat to wheat production. Bharat and Kachroo (2007) reported that tank mix application of fenoxaprop + metribuzin (120 + 100 g ha^{-1}), sulfosulfuron + 2, 4-D (25 + 500 g ha^{-1}), clodinafop + metsulfuron methyl (60 + 2 g ha^{-1}), isoproturon + 2, 4-D (1000 + 500 g ha^{-1}) and metribuzin (175 or 200 g ha^{-1}) significantly reduced both grass and broadleaf weeds. Applying two or more herbicides simultaneously, either using prepackage mixtures or by mixing different herbicides products before the applications, is a very common approach in intensive agriculture. At present condition in Bangladesh, the use of mixed herbicides against weeds in transplanted *aman* rice has increased for its effectiveness day by day.

Rice varieties colossally affect the development and pervasion of weed in the field. Normally short-height varieties face more weed infestation than the taller ones (Sarker, 1979). Thus, to keep away from the weed rivalry and to get the greatest yield from rice, an appropriate variety ought to be chosen. In Bangladesh, BRRI, BINA, IRRI, and diverse research organizations have been presented high-yielding rice varieties and it acquires positive monumental in rice production for the particular three distinct growing seasons (Haque and Biswas, 2011). Improving and expanding the world's supply will likewise rely on the development and improvement of rice varieties with better yield potential, and to adopt different traditional and biotechnological approaches for the advancement of high yielding varieties that have resistance against various biotic and abiotic stresses (Khush, 2005). Nowadays different high-yielding rice varieties are available in Bangladesh which have more yield potential than different conventional varieties (Akbar, 2004). The growth process of rice plants under different agro-climatic conditions differs due to the specific rice variety (Alam *et al*., 2012). 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). These high-yielding and hybrid rice variety, however, needs further evaluation under the different adaptive condition to interact with different agro-climatic conditions.

Some herbicide mixtures have been launched in Bangladesh for wide spectrum weed control in transplanted rice. But the information on its efficacy against weeds in transplanted rice varieties is very meager in the literature. Considering the above facts the present study was undertaken with the following objectives:

i. Observe the weed control efficiency of mixed herbicides

ii. Know the performance of transplanted *aman* rice varieties

iii. Identify weed flora present in the transplanted *aman* rice field

iv. Find out the combined effect of mixed herbicides with *aman* rice varieties

v. Work out the economics of the treatments

CHAPTER II

REVIEW OF LITERATURE

Reduction in crop yields due to weeds result from their multiferous ways of interfering with crop growth and crop culture. Weeds compete with crops for one or more plant growth factors such as mineral nutrients, water, solar energy, space and they can also host pests and diseases that can spread to cultivated crops and hinder crop cultivation operations. From an agronomic point of view, weed management has become a vital issue for modern rice cultivation. Among all weed control methods, the application of herbicide is the most effective for controlling weed as well as increasing yield. Rice productivity and total rice production in Bangladesh still have scope to increase if the proper crop management systems are followed. As herbicide mixtures have been recently introduced in Bangladesh there is meager literature on it. Therefore, an effort has been made to review the available literature on efficacy of different mixed herbicides against weeds in transplanted rice varieties considering these points, the available literature is reviewed in this chapter under appropriate head.

2.1 Presence of weed species in the rice field

Bhuiyan and Mahbub (2020) experimented to know the performance of Bensulfuron Methyl 1.1% + Metsulfuron Methyl 0.2%+ Acetochlor 14% WP against a wide range of weed control in transplanted rice of Bangladesh. Field trials were conducted at Bangladesh Rice Research Institute (BRRI), Gazipur during Aman, 2016 and Boro, 2016-17 to evaluate the efficacy of Bensulfuron methyl 1.1% + Metsulfuron methyl 0.2%+ Acetochlor 14% WP on weed suppression and performance of transplanted rice. Bensulfuron methyl 1.1% + Metsulfuron methyl 0.2%+ Acetochlor 14% WP @ 75, 90 and 105 g ha^{-1} were applied along with Bensulfuran methyl 14%+ Acetochlor 14% WP @ 750 g ha^{-1}, weed-free and unweeded control was used for assessment. In this experiment, the rice field was infested with different types of weeds. Among the infesting different categories of weeds, two were grasses, two sedges, and four broadleaves. The weed species were belonging to the families of Poaceae, Cyperaceae, Pontederiaceae, Marsileaceae, Sphenocleaceae, and Asteraceae. The broad leaved were: *Monochoria vaginalis, Marsilea minuta, Sphenoclea zeylanica,* and *Eclipta alba*, grasses were: *Echinochloa crus-galli*, *Cynodon dactylon* and sedges were *Cyperus difformis* and *Scirpus maritimus.*

Mishra (2019) carried out a field study through front line demonstrations during the Kharif season of 2017 and 2018 in villages of Ganjam district i.e., Gudiapalli, Jharapadar, Putipadar in Odisha on farmer's field with the active participation of farmers to evaluate the effect of herbicide Bensulfuron methyl plus pretilachlor in weed management of transplanted Kharif rice. The results revealed that the predominant weed flora observed during the study was *Digitaria sanguinalis, C.dactylon, E. colona*among the grasses, *C. difformis, C. iria, C. rotundus* among the sedges, and *Ludwigia parviflora, Ageratum conyzoides, Cleome viscose, Ammania baccifera, E.alba*among the broadleaved weeds were present as major weeds throughout the cropping period.

Yadav *et al.* (2018) conducted a field experiment at CCS HAU, Regional Research Station, Karnal during Kharif 2010 to 2014 to evaluate the bio-efficacy of pretilachlor 6.0% + pyrazosulfuron-ethyl 0.15% GR (ready-mix) against complex weed flora in transplanted rice and also to study its residual effects. Results from onstation experiment (2010 and 2011) revealed that the weed flora of the experimental field consisted of *E. crus-galli* (grassy), *A. baccifera* (broad-leaf weed), and *C. difformis* and *Fimbristylis miliaceae* (sedges) during Kharif 2010. During Kharif 2011, the weed flora of the experimental field consisted of *E.crus-galli, Leptochloa chinensis, Eragrostis tenella* (grasses), *A.baccifera* (broad-leaf weed), and *C.rotundus, C. difformis* and *F.miliaceae* (sedges).

Yadav *et al.* (2009) carried out a study on the efficacy of bispyribac-sodium during Kharif 2006 and 2007 at CCS Haryana Agricultural University Regional Research Station. The treatments included bispyribac 15, 20, 25, 30, and 60 gha^{-1} each at 15 days after transplanting (DAT) and 25 DAT, pretilachlor 750, and 1000 gha^{-1} at 3 DAT and butachlor 1500 gha^{-1} at 3 DAT along with weedy and weed-free checks. The experiment was laid out in a randomized block design with three replications. The major associated weeds in rice fields were *E. glabrescens* and *E. colona* (L.) among grasses, *A.baccifera* L. and *Euphorbia* sp. among broad-leaved weeds, and *F. miliacea* L. Vahl, *C. iria* L.,*C. rotundus* L., and *C. difformis* L. among sedges.

Bari *et al*. (1995) in the experiment at Banngladesh Agricultural Universityreported that the three important weeds of transplanted *aman* rice fields were *F.miliacea*, *Paspalum scrobiculatum,* and *C. rotundus.*

Mamun *et al.* (1993) reported that *F.miliacea*, *Lindernia antipola,* and *Eriocaulen cenerseem* were important species of weeds in transplant *aman* rice fields.

2.2 Effect of herbicide

2.2.1 Weed density

Bhuiyan and Mahbub (2020) based on their experiment observed that yield and yield attributing parameters and weed dynamics were greatly influenced by different weed management practices. Bensulfuron methyl 1.1% + Metsulfuron methyl 0.2%+ Acetochlor 14% WP @ 105 g ha^{-1} showed a good weed control efficiency but slightly phytotoxicity found in this dose. They suggested that Bensulfuron methyl 1.1% + Metsulfuron methyl 0.2%+ Acetochlor 14% WP @ 90 g ha^{-1} applied at one to the two-leaf stage of weed effective for annual weed control option instead of hand weeding at the peak period of labor to increase yield in transplanted rice.

Mishra (2019) reported that pre-emergence application of Bensulfuron methyl 60g ha^{-1} + Pretilachlor 600 gha^{-1} at 3 DAT recorded better weed control than hand weeding with weed density 14.2, 27.3, and 37.4 m^{-2} at 30, 60, and 90 DAT respectively. This was due to the application of 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. Weedy check recorded the maximum weed density 73.4, 104.2, and 128.6 m^{-2} at 30, 60, and 90 DAT respectively. Paulraj *et al.* (2019) carried out a field study during the Samba season of 2017 to evaluate the efficacy of pre and post-emergence herbicides in transplanted rice. The herbicides evaluated were Pretilachlor 6% + Pyrazosulfuron-ethyl 0.15% GR @ 10 kg ha^{-1} along with post emergence herbicides Fenoxaprop-p-ethyl 9.3% w/w @ 875 ml ha^{-1}, Bispyribac-sodium 10% SC @ 200 ml ha^{-1}. Results of the study revealed that among the treatments, application of (Pretilachlor + Pyrazosulfuron ethyl) + Bispyribac-sodium recorded the least weed count of 3.22 m^{-2}, 0.52 m-2, 2.59 m^{-2}, 1.54 m^{-2}, 0.52 m^{-2}, 0.54 m^{-2}, 1.26 m^{-2} of *E. colona*, *L.chinensis*, *C. rotundus*, *M. quardrifolia*, *S. zeylanica*, *E. alba* and *B. capensis*, respectively on 60 DAT. The treatment

(Pretilachlor + Pyrazosulfuron ethyl) + Fenoxaprop-p-ethyl was next in order and the treatment twice hand weeding on 20 and 40 DAT were at par. The highest weed count of 33.37 m^{-2}, 12.96 m^{-2}, 22.44 m^{-2}, 16.06 m^{-2}, 12.96 m^{-2}, 12.67 m^{-2}, 10.65 m^{-2} of *E. colona*, *L. chinensis*, *C. rotundus*, *M.quardrifolia*, *S. zeylanica*, *E. alba* and *B. capensis* on 60 DAT, respectively were recorded in unweeded control.

Mahbub and Bhuiyan, (2018) observed that the mixture of herbicides gave 80% control of annual and perennial weeds comparable to individual application of herbicides.

Yadav *et al.* (2009) reported that reduction density of grassy, as well as broad-leaved weeds and sedges, increased with a corresponding increase in the dose of bispyribac.

Rekha *et al.* (2003) reported that the weed density was the 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 weedy check.

Reddy *et al*. (2000) stated that weed control through herbicide effect on the germinating weed seeds over a prolonged duration and thereby exhausting weed seeds over a prolonged duration and thereby exhausting the weed seed reserves in the soil and thus reducing weed density in the crop field.

2.2.2 Weed dry weight

Mishra (2019) reported that the lowest weed dry weight was recorded with the application of Bensulfuron methyl 60gha^{-1} + Pretilachlor 600 gha^{-1} at 3 DAT with 8.13, 21.3, and 26.9 g m^{-2} at 30, 60, and 90 DAT, respectively might be due to effective control of weeds during early stages of crop growth by the herbicide. Untreated weedy check produced the maximum weed dry weight at all the crop growth stages (31.3 to 54.3g m^{-2}) because of higher weed intensity and its dominance in utilizing the sunlight, nutrients, moisture, *etc*. Suryakala *et al.* (2019) stated that all the weed control measures caused a significant reduction in the density of all the weeds over the weedy check. Weed dry matter was highly influenced by the differential application of herbicides, their combinations, and integration with manual weeding. Significantly lowest weed dry matter (26.82 kg ha^{-1}) was recorded in treatment *i.e.,* Pretilachlor + Pyrazosulfuron-ethyl + Bispyribac-sodium, followed by

Pretilachlor + Pyrazosulfuron-ethyl+ Fenoxaprop-p-ethyl (70.07 kg ha^{-1}), and the treatment twice hand weeding on 20 and 40 DAT (74.54 kg ha^{-1}) was at par. The highest weed dry matter production of 349.38 kg ha^{-1} on 60 DAT was recorded in unweeded control.

Das *et al.* (2017) reported that among the tested herbicides, bispyribac-sodium 10 WP at 30 g ha^{-1} applied at 25 days after transplanting (DAT) was most effective to check all types of weed population and their growth resulting in the lowest biomass of weeds due to its higher weed control efficiency.

Kumar *et al.* (2014) indicated that pre-emergence application of bensulfuron methyl + pretilachlor at 660 g a.i. ha^{-1} on 3 DAT and one hand weeding on 35 DAT recorded significantly higher grain and straw yield (6710 and 7717 kg ha^{-1}, respectively), lower weed population (31.33 no. m^{-2}), and their dry weight (37.80 kg ha^{-1}).

2.2.3 Weed control efficiency

Bhuiyan and Mahbub (2020) reported that the lower weed biomass as well as higher weed control efficiency in all the growing seasons exhibited by Bensulfuron methyl 1.1% + Metsulfuron methyl 0.2%+ Acetochlor 14% WP. Weed control efficiency improved with increases of herbicide dose irrespective of weed species.

Mishra (2019) reported that the weed control efficiency was higher with the application of Bensulfuron methyl 60g ha^{-1} + Pretilachlor 600 gha^{-1} at 3 DAT than hand weeding which varies from 74% at 30 DAT to 42.9% at 90 DAT. This might be due to the effect of weed during the initial stages of crop growth with herbicide application

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

Walker *et al.* (2002) reported that various herbicides give satisfactory weed control without reducing yield and increasing weed population pressure even if applied at lower rates. Weed control efficiency at a reduced dose of herbicide tends to be lower than recommended doses, although in many cases it may be 60–100% and acceptable commercially. Application of both pre and post-emergence herbicides at proper dose suppresses weed flora effectively, however, the use of a single herbicide rarely gives an effective weed control in rice.

2.2.4 Weed control index

Suryakala *et al.* (2019) conducted a study was during the Samba season of 2017 to evaluate the efficacy of pre and post-emergence herbicides in transplanted rice in the Cuddalore district. The new herbicides evaluated were Pretilachlor 6% + Pyrazosulfuron-ethyl 0.15% GR @ 10 kg ha^{-1} along with post emergence herbicides Fenoxaprop-p-ethyl 9.3% w/w @ 875 ml ha^{-1}, Bispyribac-sodium 10% SC @ 200 ml ha^{-1}. Results of the study revealed that the weed control index (WCI) ranged from 78.66-92.32% with various herbicide combinations. The highest WCE (92.32) was recorded in Pretilachlor + Pyrazosulfuron-ethyl + Bispyribac-sodium, while the lowest was recorded with twice hand weeding on 20 and 40 DAT (78.66).

Priya and Kubsad (2013) reported the higher weed control efficiency and the lower weed index in herbicide treatments compared to weedy check owing to lower weed dry weight, higher weed control efficiency, and lower weed index due to effective control of complex weed flora.

2.2.5 Plant height

Manisankar *et al.* (2019) revealed that application of glyphosate 2.5 kg ha^{-1} in rice as a pre-plant herbicide registered significantly higher growth parameters like plant height, tillers, and dry matter production and yield attributes and grain yield (4232 kg ha^{-1}) than control. Das *et al.* (2017) reported that the application of herbicides did not show any phytotoxic symptoms on rice plants.

Teja *et al.* (2017) conducted a field experiment during the wet season of 2012 and 2013 at farmer's field of village Binuria, Sriniketan, Birbhum, West Bengal, India with rice variety '*Swarna'* (MTU 7029) to study the effect of bensulfuron-methyl + pretilachlor and other herbicides on the growth of different weed species and productivity of transplanted rice. Twelve treatments in the experiment were assigned in a randomized block design with three replications. Results revealed that the plant height of rice varied significantly among the treatments. The highest plant height was recorded under the treatment with hand weeding at 20 and 40 DAT which was statistically at par with bensulfuron methyl 0.6%+ pretilachlor 6% at 60+600 g ha^{1} and all other doses of Bensulfuron methyl 0.6%+ Pretilachlor 6%, Azimsulfuron at 35 g ha^{-1} and Metsulfuron methyl + Chlorimuron-ethyl (Almix)+ Azimsulfuron at 4+35 g ha^{-1}at 45 DAT and the minimum in the control treatment (Weedy check).

Lodhi (2016) experimented to know the Efficacy of Bensulfuron methyl + Pretilachlor against weeds in transplanted rice at the Krishi Nagar Farm unit, Department of Agronomy, JNKVV, and Jabalpur during Kharifseason 2015. The experiment consisted of7 treatments *viz.* $T_{1=}$ Weedy check (Control), T_2= Bensulfuron methyl + Pretilachlor (48+480) g ha^{-1} application at 3 DAT, T_3 Bensulfuron methyl + Pretilachlor (60+600) g ha^{-1} application at 3 DAT, T_4 Bensulfuron methyl + Pretilachlor (72+720) g ha^{-1} application at 3 DAT, T_5 Pendimethalin 1300 g ha^{-1} application at 3 DAT, T_6 Butachlor 1500 g ha^{-1} application at 3 DAT, T_7 Hand Weeding at 20 and 40 DAT. The experiment was laid out with Randomized Block Design (RBD) and replicated 4 times. In general, the plant height was minimum under all the treatments during the early period of crop growth, which was increased with time and being the maximum at harvest. However, the rate of increase in plant height was higher between 30 and 60 DAT. At 30 DAT, the plant height was affected significantly under different treatments. Plant height was maximum (49.80 cm) under two hand weeding (20 and 40 DAT) followed by Bensulfuron methyl + Pretilachlor (60+600) g $ha-^{1}$ (48.23 cm) and (72+720) g ha^{-1}(47.85 cm) being at par amongst each other and significantly superior over remaining treatments. The lowest plant height (40.80 cm) was recorded in the weedy check.

2.2.6 Number of tillers

Paulraj *et al.* (2019) carried out a field study during the Samba season of 2017 to evaluate the efficacy of pre and post-emergence herbicides in transplanted rice. The herbicides evaluated were Pretilachlor 6% + Pyrazosulfuron-ethyl 0.15% GR @ 10 kg ha^{-1} along with post emergence herbicides Fenoxaprop-p-ethyl 9.3% w/w @ 875 ml ha^{-1}, Bispyribac-sodium 10% SC @ 200 ml ha^{-1}. Results of the study revealed that among the treatments, (Pretilachlor + Pyrazosulfuron ethyl) + Bispyribac-sodium recorded the highest number of tillers of 434 m^{-2}. The treatment (Pretilachlor + Pyrazosulfuron ethyl) + Fenoxaprop-p-ethyl was next in order and the treatment twice hand weeding on 20 and 40 DAT were on par. The least number of tillers of 323 m^{-2} were recorded in unweeded control.

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.

2.2.7 Dry matter accumulation

Lodhi (2016) reported that different weed control treatments caused remarkable variations in the quantity of dry matter accumulation at different days after transplanting and harvest respectively. Weedy check plots have the minimum quantity of dry matter production, 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 markedly higher dry matter accumulation (12.13, 49.85, and 99.25 g hill-^{1}) over the rest of the doses (48+480) and (72+720) g ha^{-1} and check herbicide Pendimethalin and Butachlor at all growth intervals.

2.2.8 Crop growth rate

Lodhi (2016) reported that weed control treatments have significant differences in crop growth rate (CGR). Hand weeding twice had the highest value of CGR (12.78 g m^{-2} day^{-1}) which was similar with Bensulfuron methyl + Pretilachlor @ (60+600) g a.i. ha^{-1} treated plot having GR (12.58 g m^{-2} day^{-1}) while the minimum in weedy check plot (8.96 g m^{-2} day^{-1}).

2.2.9 Relative growth rate

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

2.2.10 Net assimilation rate

Shultana *et al.* (2013) experimented at Bangladesh Rice Research Institute, Gazipur during the year 2012 to study the growth behavior of transplanted *aman* rice under different competition durations with *E. crus-galli*. Different durations of weed interference such as 20, 40, 60 days after transplanting, weeded and weed-free periods were. The results revealed the highest net assimilation rate(NAR) was found with no weed competition (3.50). On the other hand, the lowest net assimilation rate was observed in 60 days of weed competition (0.73) which is statistically similar throughout the growing period of rice weed competition (0.90). These results showed that an increase in competition period decreased the NAR probably due to less leaf area and shortage of other growth factors (nutrient, space, water, etc).

2.2.11 Number of effective tillers hill^{-1}

Yadav *et al.* (2018) observed that the number of effective tillers m^{-2} under pretilachlor + pyrazosulfuron-ethyl 615 gha^{-1} was at par with all other treatments except being superior to pyrazosulfuron-ethyl 15 g/ha and weedy check during both years.

Jabran *et al.* (2012) carried out a study with three herbicides (pendimethalin, penoxsulam, and bispyribac-sodium) and were evaluated for weed control in direct-planted rice on sandy loam soil. Weedy check and weed-free plots were established for comparison. Experiment results revealed that the herbicides' application effectively improved the yield and yield-related traits of DPR (Direct planted rice) over the control. The maximum amount of productive tillers (362.3) was recorded in the weed-free treatment, followed by the bispyribac-sodium (350.7) treatment, while the minimum number of productive tillers (244.3) was recorded in the weedy check.

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

Chowdhury (2012) noticed that weed controlled by Sunrise 150WG gave the highest effective tillers hill^{-1} while ineffective tillers hill^{-1} were found from no weeding treatment.

Raju *et al.* (2003) reported that the use of weedicide (Safener and Butachlor) gave the highest tiller hill^{-1} and the control plot produced maximum non effective tiller.

2.2.13 Panicle length

Jabran *et al.* (2012) carried out a study with three herbicides (pendimethalin, penoxsulam, and bispyribac-sodium) and were evaluated for weed control in direct-planted rice on sandy loam soil. Weedy check and weed-free plots were established for comparison. Experiment results revealed that the herbicides' application effectively improved the yield and yield-related traits of DPR (Direct planted rice) over the control. The maximum panicle length (23.5cm) was observed 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 gave the highest panicle length.

2.2.14 Filled grains

Paulraj *et al.* (2019) reported that pre-emergence herbicide application of Pretilachlor + Pyrazosulfuron-ethyl followed by post emergence herbicide application of Bispyribac-sodium produced more number of yield attributes and yield than unweeded control. The reason might be that the weed-free situation at the early stage favored the vigorous growth of seeding, without any crop weed competition and sustained nutrient availability leads to better uptake of NPK by the crop might have contributed to synchronous tillering and spikelet formation leading to a higher number of panicles m^{-2} and higher post-flowering photosynthesis and higher number of filled grains $panicle^{-1}$.

Teja *et al.* (2017) stated that effective and timely management of weeds through herbicides application 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.

2.2.15 Total grains $panicle^{-1}$

Hossain (2015) carried out a field experiment at the Agronomy research field of Sher-e-Bangla Agricultural University, Dhaka, from April to August 2014 to study the efficacy of herbicides to control weeds and the residual activity on the growth and yield of transplanted *aus* rice (Nerica). There were 13 treatments. Results revealed that significant variation was observed in the total number of grains $panicle^{-1}$ due to the effect of different herbicidal treatments. The highest number of grains $panicle^{-1}$ (69.00) was found from Propyrisulfuron @ 380 ml ha^{-1} + Propanil 60 WG @ 1500 g ha^{-1} treated plot while the lowest number of grains panicle^{-1} (54.67) was found from treatment weedy check or control treatment.

2.2.16 1000-grain weight

Daniel *et al.* (2012)reported that application of pendimethalin 0.75 kg/ha + HH at 40 days after sowing followed by anilophos 0.40 kg/ha + one hand hoeing at 20 and 40 DAS and butachlor 1.00 kg/ha + one hand hoeing, recorded higher rice yield component like productive tillers per hill (11.9), panicle weight (3.9g), number of grain /panicle (128.0) and test weight (25.5g).

Jabran *et al.* (2012) reported that the highest 1000 grains weight (22.5 g) of rice was observed in weed-free condition and the lowest 1000 grains weight(17.4 g) was observed in weedy check.

2.2.17 Grain yield

Suryakala *et al.* (2019) conducted a study was during the Samba season of 2017 to evaluate the efficacy of pre and post-emergence herbicides in transplanted rice in the Cuddalore district. The new herbicides evaluated were Pretilachlor 6% + Pyrazosulfuron-ethyl 0.15% GR @ 10 kg ha^{-1} along with post emergence herbicides Fenoxaprop-p-ethyl 9.3% w/w @ 875 ml ha^{-1}, Bispyribac-sodium 10% SC @ 200 ml ha^{-1}. Results of the study revealed that significantly higher grain yield and straw yield were recorded with Pretilachlor + Pyrazosulfuron-ethyl + Bispyribac-sodium (5163 and 7654 kg ha^{-1}) followed by Pretilachlor + Pyrazosulfuron-ethyl + Fenoxaprop-p-ethyl(4965 and7366 kg ha^{-1}) and was at par with twice hand weeding on 20 and 40 DAT (4787 and 7150 kg ha^{-1}), respectively. The lowest grain and straw yield (3046 and 4600 kg ha^{-1}) were recorded with unweeded control, respectively indicating the importance of weed management in the critical growth period of rice by herbicide application.

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.

Hossain and Mondal (2014) observed that tank-mix application of Bispyribac + Ethoxysulfuron, Pretilachlor, Metsulfuron-methyl + chlorimuron-ethyl and Pretilachlor + Bensulfuron resulted in more rice grain yield than their sole application.

Bari (2010) reported that herbicide treatments contributed to higher yield performance compared to control in all the growing seasons. Mastana *et al.* (2012) reported better performance of Bensulfuron methyl plus pretilachlor combination in controlling weeds and increasing yield in transplanted rice.

2.2.18 Straw yield

Hossain (2015) reported that the straw yield of rice differs, due to the application of different mix herbicides comparable to the weedy check. The highest straw yield (4.25 t ha^{-1}) was recorded from Propyrisulfuron @ 380 ml ha^{-1} + Propanil 60 WG @ 1500 g ha^{-1} herbicide treated plot while the lowest straw yield (1.42 t ha^{-1}) was found from weedy check

Chowdhury (2012) carried out an experiment at Sher-e- Bangla Agricultural University Agronomy field and scored the highest straw yield from the pre-emergence herbicide Sunrice 150WG treated plot.

2.2.19 Biological yield

Hasanuzzaman *et al.* (2008) observed that the biological yield was influenced by the effectiveness of the herbicidal treatments, where Ronstar® 25EC @ 1.25 L ha^{-1} + IR5878® 50 WP @ 120 g ha^{-1}), showed as the highest biological yield.

Harvest index

Hossain (2015) reported that the harvest index is significantly influenced due to different herbicide applications. Maximum harvest index (48.0 %) when rice was treated with Propyrisulfuron @ 130 ml ha^{-1}+Propanil 60 WG @ 2000 g ha^{-1} herbicide and the lowest harvest index (37.53 %) in weedy check which was due to the reason that the effective weed control in these combinations increased the 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 the weedy check.

2.3 Effect of rice varieties

2.3.1Weed density

Sohel *et al.* (2020) experimented at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to evaluate the effect of variety and weeding regime on the yield of transplant *aman* rice. The experiment consisted of three varietiesBRRI dhan49, BRRI dhan51, and BRRI dhan52, and six different weeding regimes such as no weeding, one hand weeding at 30 DAT, two hand weedings at 30 DAT and 45 DAT, three hand weedings at 30 DAT, 45 DAT and 60 DAT, application of Rifit 500 EC at 7 DAT and application of Rifit 500 EC at 7 DAT + One hand weeding at 30 DAT. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The experiment result showed that the weed population at 30, 45, and 60 days after transplanting (DAT) was significantly affected by variety. The highest weed population (5.33m^{-2}) at 30 DAT, (9.39 m^{-2}) at 45 DAT, and (14.44m^{-2}) at 60 DAT were found in BRRI dhan51 and the lowest weed population was obtained in BRRI dhan52 (3.33 m^{-2}) at 30 DAT (4.44m^{-2}) at 45 DAT and (11.22m^{-2}) at 60 DAT.

Salam *et al.* (2020) experimented at Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from December 2017 through May 2018 to evaluate the effect of weed management practices on the performance of boro rice cultivars and observed that cultivars did not exert any significant effect on weed density at 20 and 40 days after transplanting (DAT) but showed a significant effect on weed density at 60 DAT. At 60 DAT, the highest weed density (15.17 m^{-2}) was found in BRRI dhan74 and the lowest one (12.44 m^{-2}) was obtained in BRRI dhan28.

Shawon *et al.* (2018) conducted experiments on *aus* rice at the Agronomy Research Field of Sylhet Agricultural University, Sylhet, and in the farmer’s field of Jaintapur and Gowainghat Upazila, Sylhet to find out the competitiveness of *aus* rice varieties against weed infestation. The experiments were carried out from April to August 2014. Five commercial rice varieties *viz.* BR3, BRRI dhan48, hybrid variety Aloron, BRRI dhan43, Iratom-24 along with three (3) local varietiesAina Miah, Doom, and Kanihati were included in the research field trial. On the other hand, the survey of thirty farmer’s fields along with the researcher’s managed trial was conducted to know the weed situation. In farmer's field, 5 (five) varieties namely BR3, hybrid variety Aloron, BRRI dhan55, BRRI dhan48, and varietyAina Miah were included. Here each variety was considered as treatment. Significant variation was observed in different kinds of weeds among different varieties. The highest number of grasses ($35m^{-2}$) were recorded in BR3, on the other hand, the lowest number of grasses ($24m^{-2}$) was found from BRRI dhan43. The highest weed density was recorded in the rice variety BR3 plots and the lowest was in hybrid rice variety Aloron among all the tested varieties. 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) experimented to investigate the combined effect of herbicides on the weed management of rice at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh between December 2013 to May 2014. The experiment consisted of two varieties, BR14 (Gazi) and BRRI dhan28 along with nine different weed management treatments. Results revealed that the variety of rice significantly influenced the weed population, total weed dry weight, and weed control efficiency at 20, 40, and 60 days after transplanting (DAT). At all the sampling dates, a higher number of weeds was found in BRRI dhan28, showing the highest values of 63.81, 83.93, and $167.30m^{-2}$ at 20, 40, and 60 DAT, respectively, and a lower number of weeds m^{-2} was obtained in BR14, which exhibited the highest values of 49.33, 70.63 and $134.90m^{-2}$ at 20, 40 and 60 DAT, respectively. 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.

Kruepl *et al.* (2006) reported that height can compensate for an erectophile leaf habit, but a relatively short (and late-season) planophile habit can give the same shading rate and weed suppression of shorter weeds. Tall varieties may have an advantage over some very tall grasses and scrambling weeds but are not effective to grass or small weeds. On the other hand, tall varieties may cause problems, such as lodging, especially in winter-sown crops at lower and medium latitudes, and cause yield reduction.

Gibson and Fischer (2004) reported that rice cultivar (s) with strong weed competitiveness is deemed to be a low-cost safe tool for weed management. In general, varieties with high tillering ability, high early growth rate, high leaf area index and specific leaf area, long leaves, and droopy plant type are more weed suppressive.

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. Singlachar *et al.* (1978) reported that dwarf plants with their erect leaf habit promoted more weed growth and caused more loss than the tall variety.

2.3.2 Weed dry matter weight

Sohel *et al.* (2020) 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.

Afrin *et al.* (2015) reported that at the sampling dates, higher weed dry weight (gm^{-2}) was found in BRRI dhan28, the highest dry weight values were 2.93, 8.59, and 47.72 gm^{-2} at 20, 40, and 60 DAT, respectively and the lowest dry weight values were(gm^{-2}) found in BR14 where the values were 2.26, 7.12, and 37.26 gm^{-2} at 20, 40, and 60 DAT, respectively. The dry weight of weeds depended on the weed density, size, weight, and type.

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

2.3.3 Weed control efficiency

Afrin *et al.* (2015) reported that the higher weed control efficiency (%) at the sampling dates of 20 and 60 days after transplanting (DAT) was found in BR14 of 65.52 and 66.98%, respectively, and lower weed control efficiency of 56.59 and 64.13% was obtained in BRRI dhan28 at 20 and 60 DAT, respectively. However, the highest weed control efficiency of 61.32% was found in BRRI dhan28 at 40 DAT and a lower weed population was found in BR14 (60.35%) at 40 DAT.

2.3.4 Weed control index

Chauhan and Johnson (2011) reported that the weed control index could be attributed to less weed biomass due to the high competitive variety's ability to suppress weeds.

2.3.5 Crop growth parameters

2.3.5.1 Plant height

Salam *et al.* (2020) experimented at Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from December 2017 through May 2018 to evaluate the effect of weed management practices on the performance of *boro* rice varieties and reported that plant height was significantly influenced by varieties. The tallest plant (91.34 cm) was recorded from BRRI dhan28 and the shortest one (84.66 cm) was BRRI dhan74 which was statistically similar to BRRI dhan29.

Mahmud *et al.* (2017) experimented at Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during June to December 2013 to investigate the response of some short duration *aman* rice varieties to date of transplanting. The experiment consisted of three transplanting dates *viz.* 26 July, 5 August, and 15 August and seven short duration T. *aman* rice varieties *viz.* BRRI dhan33, BRRI dhan39, BRRI dhan49, BRRI dhan56, BRRI dhan57, BRRI hybrid dhan4 and Binadhan-7. The result showed that 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 Bina dhan-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 varieties.

2.3.5.2 Number of leaves

Akter *et al.* (2020) experimented to observe the growth and yield of traditional aromatic rice cultivars in the *boro* season and reported that the number of non-effective tiller hill^{-1} was significantly influenced due to different varieties. Results revealed that he leaves hill^{-1}of aromatic rice varieties were significantly influenced by varieties at harvest. The highest leaves hill^{-1} (65.00) were recorded from Chinigura which was statistically similar with Madhumala and Chiniatap-1 whereas; the lowest leaves hill^{-1} (38.33) were recorded from Kataribhog-2 which was statistically similar with Kataribhog-1, Kataribhog-2, BRRI dhan38, BRRI dhan38, and Chiniatap-2.

Luh and Stefanou (1991) reported that the variation of the number of leaves hill^{-1} might be due to the cause of genotypic characters of varieties and proper nutrient availability.

2.3.5.3 Number of tillers

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) followed by SAU ADL5 (15.58). The total tiller numbers hill^{-1} of SAU ADL1, SAU ADL3, SAU ADL4, SAU ADL6, SAU ADL8, SAU ADL11, and Kataribhog were statistically similar with SAU ADL5. The minimum tiller number hill^{-1} (6.58) was obtained from SAU ADL12.

2.3.5.4 Dry matter accumulation

Nahida *et al.* (2013) experimented to evaluate the performance of local aromatic rice cultivars viz. Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog. The rice cultivars varied considerably in terms of crop growth characteristics as well as yield and yield contributing characters. 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.

Amin *et al.* (2006) conducted and a field analysed data of a field experiment to discover the impact of variable dosages of N compost on development, tillering, and yield of three conventional rice varieties (viz. Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (*viz*. KK-4) and observed that traditional rice varieties accumulated a higher amount of dry matter than the modern rice variety.

2.3.5.5 Crop growth rate

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.

2.3.5.6 Relative growth rate

Amin *et al.* (2002) carried out a study to observe the varietal differences of rice growth to low nitrogen supply and reported that the RGRs of local varieties were generally higher than those of improved varieties.

2.3.5.7 Net assimilation rate

Lu *et al.* (2000) observed that a decrease in the rate of photosynthesis in leaves causes a parallel decrease in NAR and eventually low grain yield.

2.3.5.8 Number of effective tillers hill^{-1}

Nahida *et al.* (2013) experimented to evaluate the performance of local aromatic rice varieties *viz.* Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog. The rice varieties varied considerably in terms of crop growth characteristics as well as yield and yield contributing characters. Results revealed the highest number of effective tillers hill^{-1} (13.0) was produced by Kalijira and the lowest number of effective tillers hill-^{1} (7.13) was observed in Morichasail. The reason for the difference in effective tillers hill^{-1} is the genetic makeup of the variety, which is primarily influenced by heredity.

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.

2.3.5.9 Number of noneffective tillers hill^{-1}

Akter *et al.* (2020) experimented to observe the growth and yield of traditional aromatic rice cultivars in the *boro* season and reported that the number of non-effective tiller hill^{-1} was significantly influenced due to different varieties. Results revealed that the maximum noneffective tillers hill^{-1}(10.90) was observed in Chiniatap-2 which was statistically differed from all other varieties. The lowest noneffective tillers hill^{-1} (2.33) was obtained from Badshabhog which was statistically similar to BRRIdhan38.

2.3.5.10 Panicle length

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 maximum panicle length (32.63 cm) was recorded in genotype SAU ADL10 followed by SAU ADL9 (30.75 cm) which was statistically similar to SAU ADL3 (30.67), SAU AD6 (29.62). A minimum panicle length of 26.33 cm was recorded in SAU AD7 which was statistically similar to SAU AD1, SAU AD2, SAU AD4, SAU AD11, and Kataribhog.

Hossain *et al.* (2016) carried outa field experiment with *boro* rice (cv. Binadhan-10 and BRRIdhan28) at Kaligonj, Satkhira to evaluate the performance of two rice varieties under different nutrient management practices in saline soil. The rice varieties, such as BRRI dhan28 and Binadhan 10 were tested under 3 levels of nutrients (T_1= recommended dose of N, P, K, S, Zn, T_2 = T_1 + additional Gypsum @ 125 Kg ha^{-1} and T_3 = T_1 + additional Gypsum @ 190 Kg ha^{-1}) and the treatments were assigned in a split-plot arrangement with 3 replications. The study 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 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. Diaz *et al.* (2000) also reported that panicle length varied among varieties.

2.3.5.11 Filled grains panicle^{-1}

Akondo *et al.* (2020) conducted a field experiment with six rice varieties to determine their growth and yield performance. 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^{-1} (108.43) which was statistically similar to Binadhan-17 (100.10 cm). Binadhan-20 (85.90) and Binadhan-7 (80.40) gave statistically similar results. The minimum number of filled spikelets panicle^{-1} (60.60) was observed in Binadhan-11 which was statistically similar to Binadhan-15 (63.87 cm). Variation in grain filling may have occurred due to genetic, environmental, or cultural management practices adopted.

Sarkar (2014) reported that the number of filled grains panicle^{-1} influenced significantly due to variety. Mahamud *et al.* (2013) reported that the variation in filled grains panicle$^{–1}$ was recorded due to genotypic differences of varieties.

2.3.5.12 Unfilled grains panicle^{-1}

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.

2.3.5.13 Total grains panicle^{-1}

Jisan *et al.* (2014) carried out a study to examine the yield performance of some transplant *aman* rice varieties as influenced by different levels of nitrogen from June to November 2013 at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. Results 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 panicle^{-1} in indigenous rice is generally lower compared to high-yielding varieties.

2.3.5.14 1000-grain weight

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).

Khatun *et al.* (2020) conducted a field experiment with six rice varieties to determine their growth and yield performance. All the growth and yield contributing attributes varied significantly among the six rice varieties. The results revealed that maximum 1000-grain weight was observed in BINAdhan-17 (27.25 g) which was statistically similar to Binadhan-11 (26.45 g) and BINAdhan- 16 (26.88 g) and minimum 1000-grain weight observed in BINAdhan-7 (21.94 g). Roy *et al.* (2014) studied 12 rice varieties and found the difference in thousand grains weight due to morphological and varietal variation.

Aminpanah *et al.* (2013) conducted a field experiment to compare the competitive ability of rice cultivars and lines against barnyardgrass at Rice Research Station in Tonekabon, Iran. Results 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 the lowest (31.8 and 25.87 gram, respectively) 1000-grain weight. Under weedy conditions, Nemat with 30.7 gram and line 842 with 24.3 gram had the highest and lowest 1000-grain weight, respectively.

2.3.5.15 Grain yield

Khatun *et al.* (2020) conducted a field experiment with six rice varieties to determine their growth and yield performance and observed that among different rice varieties Maximum grain yield was observed in Binadhan-17 (6.13 t ha^{-1}) that was significantly different from other varieties. Minimum grain yield observed in BRRI dhan39 (4.49 t ha^{-1}) was statistically similar to BRRI dhan33 (4.57 t ha^{-1}) and Binadhan- 7 (4.86 t ha^{-1}). Maximum absolute growth rate, total dry matter. Filled spikelet panicle^{-1} and also maximum 1000-seed weight collectively contributed to the higher grain yield in BINAdhan-17 compare to other varieties.

Shawon *et al.* (2018) carried out an experiment on *aus* rice at the Agronomy Research Field of Sylhet Agricultural University, Sylhet, and in the farmer's field of Jaintapur and Gowainghat Upazila, Sylhet to find out the competitiveness of *aus* rice varieties against weed infestation and reported that among different rice varieties the highest grain yield (4.04 t ha^{-1}) was recorded in the hybrid variety Aloron which was statistically similar with the variety BRRI dhan48 (3.19 t ha^{-1})and Iratom-24 (3.06 t ha^{-1}) which was presented in. It might be the resultant effects of the highest tillers hill-^{1} and grains $panicle^{-1}$ of those varieties. 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}).

Ferdous *et al.* (2016) carried out a field experiment to study the effect of weed management practices on the performance of transplanted *aman* rice varieties. The experimental treatments comprised three varieties viz. BR11, BRRI dhan39 and Binadhan7 and seven weeding treatments viz., weedy check, hand weeding at 15 and 35 DATs, application of early post-emergence herbicide Manage (Pyrazosulfuron ethyl), application of pre-emergence herbicide Rifit (Pretilachlor), Manage + one hand weeding at 35 DAT, application of Rifit + one hand weeding at 35 DAT and weed-free. The experiment was laid out in a randomized complete block design with three replications. The results revealed that The highest grain yield was obtained from the interaction of BRRI dhan39 × weed-free condition which was statistically similar(5.50 t ha-1) with the interaction of variety BR11 × two hand weedings at 15 and 35 DAT. Therefore it may be concluded that BR11 rice could be cultivated using two hand weedings at 15 and 35 DAT for obtaining a higher 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}.

Dutta (2002) reported that the genotypes, which produced a higher number of effective tillers $hill^{-1}$ and a higher number of grains $panicle^{-1}$ also showed a higher grain yield in rice.

2.3.5.16 Straw yield

Mahmud *et al.* (2017) experimented at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from June to December 2013 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 which statistically similar to Binadhan-7. The lowest (3.96 t ha^{-1}) straw yield was produced by BRRI dhan57.

Tyeb *et al.* (2013) reported that the variation in straw yield is due to the effect of varietal differences. Among different varietal performances, the highest straw yield was produced in BRRI dhan46 (6.43 t ha^{-1}) which was similar to BRRI dhan52 (6.29 t ha^{-1}) and BRRI dhan51 (6.24 t ha^{-1}). The lowest one was obtained from BRRI dhan41 (4.22 t ha^{-1}).

2.3.5.17 Biological yield

Howlader *et al.* (2017) conducted an experiment at the Research Field Laboratory of the Department of Agricultural Botany, Patuakhali Science and Technology University (PSTU), Patuakhali during the period from July to December 2013 to evaluate among the local T *aman* rice genotypes for obtaining the most productive genotype regarding the growth and yield performance under southern region and found that among the genotypes Moulata showed the highest biological yield (9.657 t ha^{-1}). However, Lalmota (7.75 t ha^{-1}) showed a statistically close biological yield to Lalchicon (7.537 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.

2.3.5.18 Harvest index

Chowhan *et al.* (2019) found significant differences in harvest index among different rice varieties. From their experiment, they observed that Varieties Shakti-2, Heera-1, and BRRI dhan28 had a similar harvest index of 50.9%, 48.5%, and 47.9, respectively. OnlyBinadhan14 produced the harvest index (40.0%). It appears that hybrid rice maintained a higher harvest index.

Rahman *et al.* (2017) conducted a study to observe the competitiveness of winter rice varieties against weed under dry direct-seeded conditions during the dry season (February to June) 2016 at the Agronomy Field Laboratory and Weed Management

Laboratory, Bangladesh Agricultural University, Mymensingh. Fourteen rice varieties namely, BRRI dhan28, BRRI dhan29, BRRI dhan47, BRRI dhan50, BRRI dhan55, BRRI dhan58, BRRI dhan59, BRRI dhan67, Binadhan-5, Binadhan-6, Binadhan-8, Binadhan-10, BRRI hybrid dhan3, and Agrodhan-14 were grown under weedy and weed-free conditions. Results revealed that variety had a significant effect on the harvest index. However, the harvest index ranged from 40.73 to 42.78%. The highest harvest index was found in BRRI dhan59 (42.78%) and the lowest one was found in BRRI dhan28 (40.73%).

Uddin *et al.* (2011) reported that the harvest index differed significantly among the varieties due to its genetic variability. Shah *et al.* (1991) reported that variety had a great influence on the harvest index.

2.4 Economic viability

Salam *et al.* (2020) experimented at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from December 2017 through May 2018 to evaluate the effect of weed management practices on the performance of boro rice varieties and reported that from the economic analysis of the study the highest BCR was obtained from BRRI dhan29 with the application of pre-emergence herbicide followed by one hand weeding at 40 DAT which was close to BRRI dhan29 with the application of early post-emergence herbicide, BRRI dhan74 with the application of pre-emergence herbicide Superhit and BRRI dhan74 with the application of early post-emergence herbicide. The lowest BCR was obtained from BRRI dhan28 with no weeding (control) treatment

Mishra (2019) reported that the pre-emergence application of Bensulfuron methyl 60g/ha + Pretilachlor 600 g/ha at 3 DAT recorded the higher gross return of Rs.72320.8 ha^{-1} with a net return of Rs. 30688.2 ha^{-1} over farmer's practice were in one hand weeding at 40 DAT observed the gross return of Rs 64944 ha^{-1} with a net return of Rs 19631.8qha^{-1}. Higher B: C ratio(1.74) was found in improved technology due to higher net return as compared to farmer's practice (1.43). The weedy check showed the lowest net return this was due to higher yield with the use of herbicide in the early growth stage.

Suryakala *et al.* (2019) reported that application of (Pretilachlor + Pyrazosulfuron ethyl) + Bispyribac-sodium registered the higher net income of Rs.52170 ha^{-1} and return rupee^{-1} invested of Rs. 2.52. It was followed by (Pretilachlor + Pyrazosulfuron ethyl) + Fenoxaprop-p-ethyl. The lowest net income of Rs. 21171 ha^{-1} and return rupee^{-1} invested of Rs. 1.71 was recorded in unweeded control.

Barla and Upasani (2018) experimented to know the effect of upland rice varieties on the relative composition of weeds in Jharkhandduring the wet cropping season of 2011 and 2012 at Zonal Research Station, East Singhbhum under upland ecology to assess and identify crop parameters responsible for competitiveness of rice varieties. Total thirteen upland varieties including ten improved and three traditional varieties were tested under weedy and weed-free conditions. Results revealed that among varieties Vandana produced significantly higher grain yield (3.0tha^{-1}) over other varieties consequently recorded higher net return and B: C ratio similar to variety Anjali.

Sunil *et al.* (2010) reported that pre-emergence application of bensulfuron methyl + pretilachlor (6.6 GR) @ 0.06 + 0.6 kg ha^{-1} + one inter cultivation at 40 DAS recorded significantly higher grain and straw yields (4425 and 5020 kg ha^{-1}), lower weed population, and dry weight (17 and 2.32 g m^{-2}). This treatment also resulted in higher net returns and a B: C ratio.

Based on the above research, it is revealed that herbicide mixtures selection on rice variety plays a significant role in successful rice production. Therefore present research was conducted to evaluated the effective and economical weed control in *aman* rice of Bangladesh.

CHAPTER III

MATERIALS AND METHODS

The present investigation is entitled“Weed Control efficiency of Herbicide Mixtures in Transplanted Aman Rice Varieties ”. The material used and methodology adopted during the investigation are presented in this chapter under the appropriate heads.

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 sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain. A 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 the period from July to December 2019 in the 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. Soil samples from 0-15 cm depths were collected from the experimental field. 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 (Edris *et al*., 1979). The detailed meteorological data in respect of Maximum and minimum temperature, relative humidity, and total rainfall were recorded by the meteorology centre, Dhaka for the period of experimentation have been presented in Appendix III.

3.5 Crop/planting materials

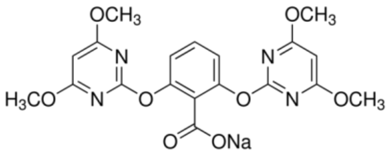
Chinigura, BR11, BRRI dhan56, and BRRI Hybrid dhan6 were being used as test crops for this experiment.

Table 1. Agronomic characteristics of rice varieties

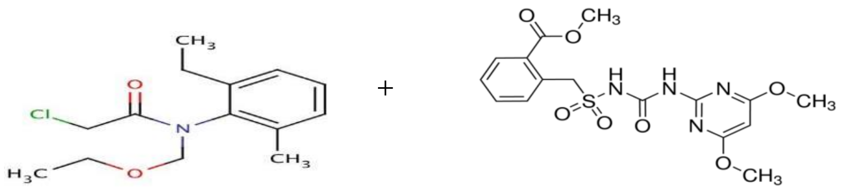
Name of variety	Developed by	Year of Release	Growing season	Thousand seed weight (g)	Average yield (t ha^{-1})
Chinigura	Local variety	Local variety	*Aman*	12-14 g	2.5-3
BR11(Mukta)	BRRI	1980	*Aman*	27 g	6.5
BRRI dhan56	BRRI	2011	*Aman*	23 g	5.0
BRRI hybrid dhan6	BRRI	2017	*Aman*	25 g	6.5

3.6 Description of the herbicides, used for weed controlling in the experimental field

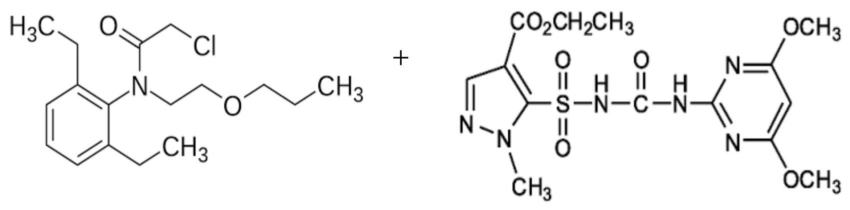
3.6.1 Bispyribac sodium

Trade name	Xtrapower 20WP
Name of registration holder	ACI Crop Care
IUPAC Name	sodium 2,6-bis(4,6-dimethoxypyrimidin-2-yloxy) benzoate
Structural formula	
Molecular weight	452.3
Formulation types	Wettable powder herbicide
Mode of actions	A post-emergence herbicide for the control of grasses, sedges, and broad-leaved weeds in paddy rice and other crops/situations. It is a selective, systemic post-emergent herbicide. After application, it gets absorbed by foliage and roots. Inhibits plant amino acid synthesis - Acetohydroxyacid synthase (AHAS).
Target Weeds	Alligatorweed, duckweed, mosquito fern, water fern, water hyacinth, water pennywort, parrot feather; annual bluegrass; creeping bentgrass
Major crops	Aquatic situations such as transplanted rice (Paddy), drainage ditches, lakes, marshes; Golf courses, turfgrass & sod farms
Application rate	150 g ha^{-1}
Time of application	20 days after transplanting

3.6.2 Acitachlor 14% + Bensulfuron methyl 4%

Trade name	Ayna plus-18WP
Name of registration holder	Jass Agro Limited
IUPAC Name	2-chloro-N-ethoxymethyl-6-ethylacet-o-toluidide
Structural formula	
Molecular weight	269.77
Formulation types	Wettable powder herbicide
Mode of actions	It is a systemic compound with foliar and soil activity, and it works rapidly after it is taken up by the plant. Its mode of action is by inhibiting cell division in the shoots and roots of the plant, and it is biologically active at low use rates
Target Weeds	Grasses and *Echinochloa* spp., sedges and broadleaf weeds,
Major crops	Transplanted rice (paddy) field
Application rate	750 g ha^{-1}
Time of application	12 days after transplanting

3.6.3 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 Seed collection and sprouting

Chinigura, BR11(Mukta), BRRI dhan56, and BRRI Hybrid dhan6 were collected from BRRI (Bangladesh Rice Research Institute), Joydebpur, Gazipur. 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.

3.8 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.

3.9 Preparation of experimental field

The experimental field was first opened on 30 July 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 2 August 2019. Each plot was cleared in and finally leveled out with the help of a wooden board.

3.10 Field operation

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

Table 2. List of schedule of field operations done during experimentation

Sl. No.	Field operations	Date
1	Preparation of nursery bed	5 July 2019
2	Sowing of seeds	8 July 2019
3	Final land preparation for main field	2 August 2019
4	Puddling and leveling	2 August 2019
5	Fertilizer application except urea	2 August 2019
6	Layout of the experiment field	2 August 2019
7	Transplanting	3 August 2019
8	Spraying Bispyribac sodium WP @ 150 g ha^{-1}	23 August 2019
9	Spraying Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}	15 August 2019
10	Spraying Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}	6 August 2019
11	Top dressing of urea given at early stage	24 August 2019
12	Top dressing of urea given at active vegetative stage	13 September 2019
13	Top dressing of urea given at panicle initiation stage	28 September 2019
14	Harvesting of crop	8-30 November 2019
15	Threshing and winnowing of produce	8-30 November 2019

3.11 Fertilizer management

Plant nutrients *viz*. N, P, K, S, and Zn for rice were given through urea (150 kg ha^{-1}), triple superphosphate (100 kg ha^{-1}), muriate of potash (70 kg ha^{-1}), gypsum (60 kg ha^{-1}), and zinc sulphate (10kg ha^{-1}), respectively. Based on the soil test the following doses of fertilizers were applied according to the recommendation by BRRI for the cultivation of T. *aman* rice. 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 Experimental treatments

The experiment consisted of two factors as mentioned below:

Factor A: Herbicide treatment (4) *viz:*

H_0= Weedy check

H_1= Bispyribac sodium WP @ 150 g ha^{-1}

H_2= Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}

H_3= Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}

Factor B: T. *aman* rice varieties (4) *viz:*

V_1= Chinigura

V_2 = BR11(Mukta)

V_3 = BRRI dhan56

V_4 = BRRI hybrid dhan6

3.13 Experimental design and layout

The experiment was laid out in a split-plot design having three replications. In the main plot, there was herbicide treatment and in the subplot, rice varieties. There were 16 treatment combinations and 48 unit plots. The unit plot size was 5.04 m^2 (2.8 m × 1.8 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.

3.14 Intercultural operations

3.14.1 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.

3.14.2 Application of irrigation water

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

3.14.3 Method of irrigation

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.

3.14.4 Herbicide application

Herbicide was taken into a knapsack sprayer and mixed with water then applied of respective plot. For herbicide application, only 1 labor was required and maintaining 4-5 cm water level at 65-70 days after transplanting.

3.14.5 Weedy check

The weeds were allowed to grow along with the crop throughout the crop season in weedy check plots and no control measures were adopted to check the weeds. The weed flora present in the weedy check plots was noted.

3.14.6 Plant protection measures

The crop was attacked by *Scirpopagain certulas* (yellow rice stem borer) 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 *Leptocorisa oratorius* (rice bug) and *Cicadellidae* (leafhopper). The crop was protected from birds during the grain filling period by using the net and covering the experimental field.

3.14.7 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 HYV and hybrid variety due to rainfall.

3.14.8 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 a 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}.

3.14.8.1 Harvesting Date:

V_1 (Chinigura) = 29 November 2019

V_2 (BR 11) = 22 November 2019

V_3 (BRRI dhan 56) = 8 November 2019

V_4 (BRRI hybrid dhan 6**) =** 15 November 2019

3.15 Data collection

The data were recorded on the following parameters

a) Observation on weeds

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

b) Observation on crop

i). Crop growth characters

viii. Plant height (cm)
ix. Number of tillers $hill^{-1}$
x. Leaf area index (LAI)
xi. Dry matter accumulation (g $plant^{-1}$)

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

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

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

ii) Yield contributing characters

xv. Number of effective tillers $hill^{-1}$

xvi. Number of non-effective tillers $hill^{-1}$

xvii. Length of panicle (cm)

xviii. Number of filled grains $panicle^{-1}$

xix. Number of unfilled grains $panicle^{-1}$

xx. Total spikelets $panicle^{-1}$

xxi. Weight of 1000- grain (g)

3.16 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

iii. Relationship between weed control efficiency (%) and grain yield

3.17 Procedure of recording data

i) Weeds flora

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

ii) 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.

iii) Relative weed density in weedy check plot

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

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

iv) 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.

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

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

vi) Weed control efficiency (WCE)

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

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

vii) Weed control index (WCI)

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

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

viii) 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.

ix) Number of tillers hill^{-1}

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.

x) 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.

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

xi) 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.

xii) 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 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

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

The relative growth rate expresses the increase in dry weight at time intervalsconcerningthe 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 = $\frac{Ln(W2)-\text{Ln}(W1)}{(t2-t1)}$

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

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).

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

Where,

LA_1 = leaf area of first sampling

LA_2 = leaf area of 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

xv) Panicle length

Measurement of panicle length was taken from 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.

xvi) 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.

xvii) Number of non-effective tillers hill^{-1}

The total number of non-effective tillers hill^{-1} was counted as the tillers, which have no panicle on the head. Data on non-effective tiller per hill were counted from 5 pre-selected (used in effective tiller count) hills at harvesting time and the average value was recorded.

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

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

xix) Number of unfilled grains penicle^{-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 average number of unfilled grains per panicle was recorded.

xx) Number of total spikelets panicle^{-1}

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

xxi) Weight of 1000-grain

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.

xxi) Grain yield

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:

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

xxiii) Straw yield

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:

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

xxiv) 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.

xxv) Harvest index (%)

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

3.18 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 are 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 Tk. 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:

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

3.19 Data analysis

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 by the Least Significant Difference (LSD) test 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 weed control efficiency of herbicide mixtures in transplanted *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 flora of T. *aman* rice

Thirteen weed species from nine different families were observed in the experimental field where most dominating were broadleaf and sedge weed species (Table 3). Among the infesting different types of weeds species, three were grasses, three sedges, and seven broadleaves. The weed species were belonging to the families of Alismataceae, Menyanthaceae, Asteraceae, Sphenocleaceae, Pontederiaceae, Onagraceae, Papayeraceae, Cyperaceae, and Poaceae. The grasses were *E. cruss-galli, Eleusine indica*, and *E. colona*, sedges were *Scirpus maritimus, Cyperus diformis* and *C. rotundus*, and broadleaved were, *Sagittaria guayansis, Nymphoides cristatum, Enydra fluctuans, Sphenoclea zeylanica, Monochoria vaginalis, Ludwigia octovalvis, and Marsilea quadrifolia*. Bhuiyan, and Mahbub (2020) found infesting different types of weeds in the rice field, two were grasses, two sedges, and four broadleaves of the families of Poaceae, Cyperaceae, Pontederiaceae, Marsileaceae, Sphenocleaceae, and Asteraceae. The broadleaved were *M.vaginalis, Marsilea minuta*, *S.zeylanica* and *Eclipta alba*, grasses were *E. crus-galli*, *Cynodon dactylon*, and sedges were *C.difformis,*and *Scirpus maritimus.* Yadav *et al.* (2009) also reported that the major associated weeds in rice field were *E. glabrescens*, and *E. colona* (L.) among grasses, *Ammannia baccifera* L. and *Euphorbia* sp. among broad-leaved weeds, and *Fimbristylis miliacea* (L.) Vahl, *Cyperus iria* L., *C. rotundus* L., and *C. difformis* L. among sedges. Bari *et al*. (1995) reported that the three important weeds of transplanted *aman* rice fields were *F.miliacea*, *Paspalum scrobiculatum*, and *Lyperus rotundus.* Mamun *et al.* (1993) also reported that *F. miliacea*, *Lindernia antipola,* and *Eriocaulen cenerseem* were important species of weeds in transplant *aman* rice fields.

Table 3. Weed flora of the experimental field in *aman* season

WEED SPECIES					
Local name	English name	Scientific name	Family	Habitat	Weed type
Chapra	Goose grass	*Eleusine indica*	*Poaceae*	Annual	Grass
Choto shama	Jungle rice	*Echinochloa colona*	*Poaceae*	Perennial	Grass
Boro shama	Barnyard grass	*Echinochloa crus-galli*	*Poaceae*	Annual	Grass
Holde mutha	Yellow nutsedge	*Cyperus diformis*	*Cyperaceae*	Perennial	Sedge
Mutha	Nutsedge	*Cyperus rotundus*	*Cyperaceae*	Perennial	Sedge
Cechra	Dwarf Club-rush	*Scirpus maritimus*	*Cyperaceae*	Perennial	Sedge
Shusni shak	European water clover	*Marsilea quadrifolia*	*Papayeraceae*	Perennial	Broadleaf
Chadmala	Guynese arrowhead	*Sagittaria guyanensis*	*Alistamaceae*	Perennial	Broadleaf
Chondromala	Arrowhead	*Nymphoides cristatum*	*Menyanthaceae*	Perennial	Broadleaf
Helenca	Buffalo spinach	*Enhydra fluctuans*	*Asteraceae*	Annual	Broadleaf
Jheel-morich	Gooseweed	*Sphenoclea zeylanica*	*Sphenocleaceae*	Annual	Broadleaf
Soto Pani kochu	Pickerel weed	*Monochoria vaginalis*	*Pontederiaceae*	Perennial	Broadleaf
Pani Long	Mexican PrimroseWillow	*Ludwigia octovalvis*	*Onagraceae*	Perennial	Broadleaf

4.2 Species wise weed population (No. m^{-2}) and relative weed density (%)

Data on species-wise weed population (No. m^{-2}) and relative density (%) of weeds recorded in weedy check plots at 30 DAT and 60 DAT are presented in Table 4. It is apparent from the data that there was a predominance of broadleaf and sedge weeds in weedy check plots of rice during *aman* season. Among the weeds, *M. vaginalis* was the most dominant weed (36, 18 m^{-2} and 15.93, 16.98 %) at 30 and 60 DAT followed by *S. guayansis and C. rotundus* weed species at 30 and 60 DAT. While the dominancy of *S. maritimus* with least at 30 DAT and *M. quadrifolia* at 60 DAT was least among all the weed species.

Table 4. Species wise weed population (No. m^{-2}) and relative weeds density (%) in weedy check plots at 30 and 60 DAT

Scientific name	Weed population (No. m^{-2})		Relative weeds density (%)	
	30 DAT	60 DAT	30 DAT	60 DAT
Sagittaria guayansis	31	12	13.72	11.32
Nymphoides cristatum	10	5	4.42	4.72
Enydra fluctuans	18	8	7.96	7.55
Sphenoclea zeylanica	22	9	9.73	8.49
Monochoria vaginalis	36	18	15.93	16.98
Ludwigia octovalvis	17	9	7.52	8.49
Marsilea quadrifolia	7	2	3.1	1.89
Scirpus maritimus	5	4	2.21	3.77
Eleusine indica	10	6	4.43	5.66
Echinochloa colona	13	9	5.75	8.49
Cyperus diformis	23	9	10.18	8.49
Cyperus rotundus	27	12	11.95	11.32
Echinochloa cruss-galli	7	3	3.1	2.83
Total weed	226	106	100	100

4.3 Weed density m^{-2}

Effect of herbicides

Application of different herbicides significantly affects weed density m^{-2} on transplanting *aman* rice (Fig.1). Results revealed that maximum weed density m^{-2} (25.50 and 13.67 at 30 and 60 DAT) was recorded in weedy check plot while Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide treated plot was recorded minimum weed density m^{-2} (2.33 and 1.78) at 30 and 60 DAT. This was due to the application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g 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 herbicide 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 fieid.

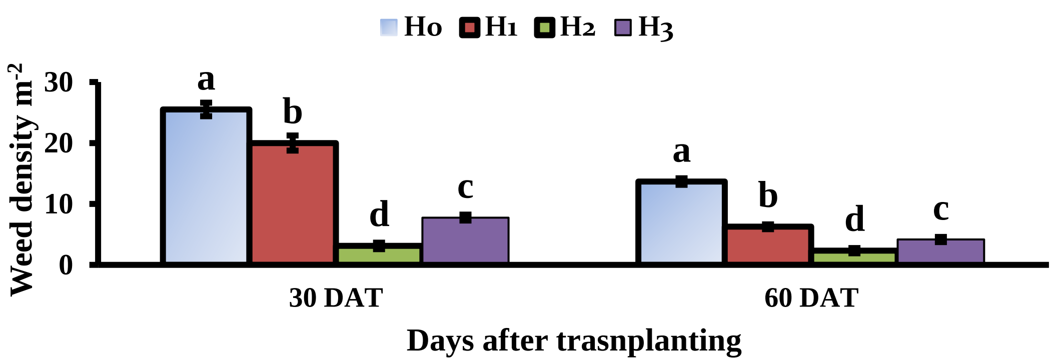


Figure 1. Effect of herbicide on weed density m^{-2} of T. *aman* rice at different days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}

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} (16.92 and 8.08 at 30 and 60 DAT) was observed in the Chinigura rice variety which was statistically similar with BRRI dhan56 (16.08) at 30 DAT while the minimum weed density m^{-2} (10.19 and 4.95 at 30 and 60 DAT) was observed in BR 11 rice variety cultivation. The number of weeds was lower in the high-yielding variety plots and that might be due to vigorous growth of the cultivar 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.

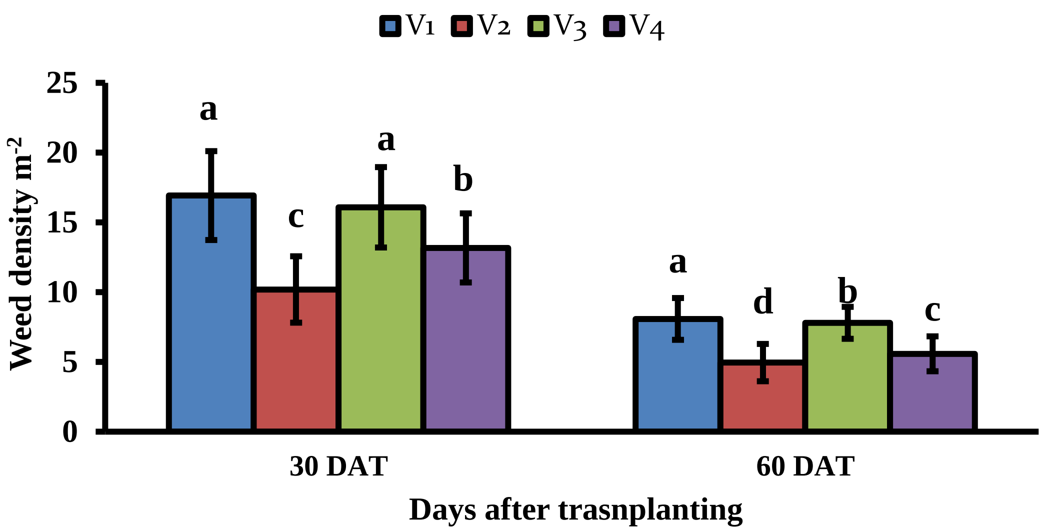


Figure 2. Effect of rice variety on weed density m^{-2} of T. *aman* rice at different days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

The combined effect of herbicide and rice variety showed a significant effect on weeds density m^{-2} at 30 and 60 DAT (Table 5). Experiment results revealed that the weedy check plot along with Chinigura rice cultivor recorded maximum weeds density m^{-2} (29.67 and 16.34) at 30 and 60 DAT. While application of mixed herbicide *i.e.,* Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} along with BR11 rice recorded minimum weeds density m^{-2} (0.11 and 0.33) at 30 and 60 DAT. The variation in weeds density m^{-2} was due to the reason that effective mix herbicide and high yielding rice cultivars reduce the weed density m^{-2} comparable to lower effective single or mix herbicide and low yielding rice varieties treatment.

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

Effect of herbicides

Weed dry weight m^{-2} was significantly influenced due to the application of different herbicides at 30 and 60 DAT (Fig. 3). Results showed that the maximum weed dry weight m^{-2} (8.02 and 5.36 g) at 30 and 60 DAT was recorded in the weedy check (H_0) plot. While Application of mixed herbicide *i.e.,* Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}recorded minimum weed dry weight m^{-2} (1.78 and 1.00 g) at 30 and 60 DAT. The differences of the dry matter accumulation by different weeds m^{-2} were due to the reason that the application of effective mix herbicide 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. Mishra (2019) also found a similar result which supported the present finding and reported that untreated weedy check produced the maximum weed dry weight at all the crop growth stages because of higher weed intensity and its dominance in utilizing the sunlight, nutrients, moisture, *etc*. Suryakala *et al.* (2019) also reported that weed dry matter was highly influenced by the differential application of herbicides.

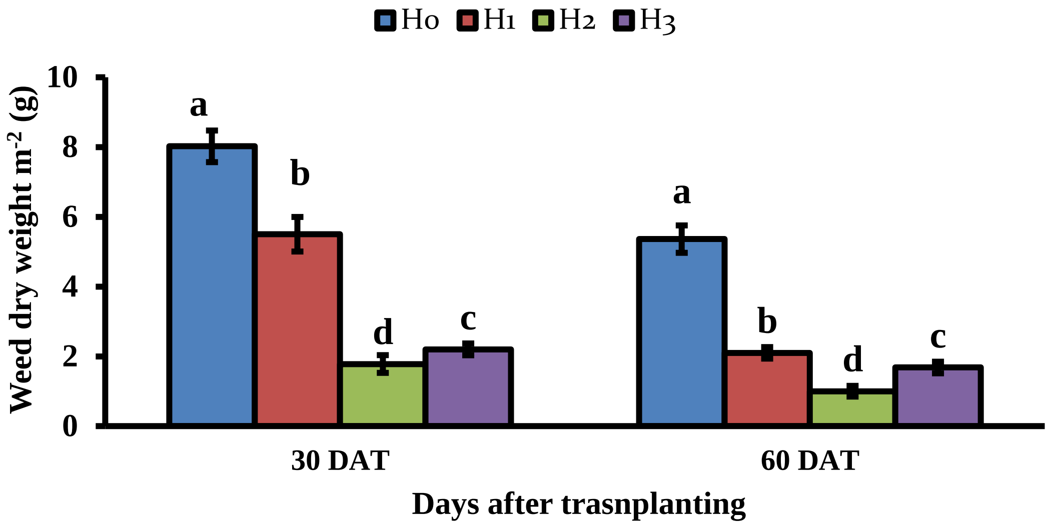


Figure 3. Effect of herbicide on weed dry weight m^{-2} of T. *aman* rice at differ days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}

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} (5.92 and 3.40 at 30 and 60 DAT) was observed in Chinigura rice. While the minimum weed dry weight m^{-2} (3.22 and 1.61 g at 30 and 60 DAT) was observed in BR11 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.

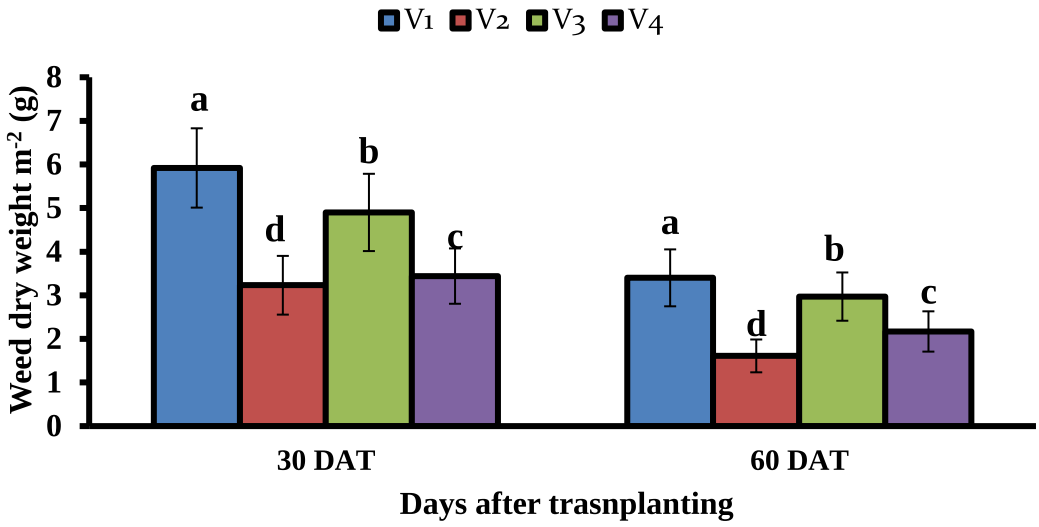


Figure 4. Effect of variety on weed dry weight m^{-2} of T. *aman* rice at different days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR1111, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

The combined effect of herbicide and rice variety 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 Chinigura rice cultivation (H_0V_1) recorded the maximum weeds dry weight m^{-2} (9.70 and 7.08 g) at 30 and 60 DAT. While application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} along with BR 11 rice variety cultivation recorded the minimum weeds dry weight m^{-2} (0.86 and 0.39 g) at 30 and 60 DAT.

Table 5. Combined effect of herbicide and rice variety on weed density and weed dry weight m^{-2} of T. *aman* rice at 30 and 60 DAT

Treatment Combinations	Weed density (m^{-2})		Weed dry weight (g m^{-2})	
	30 DAT	60 DAT	30 DAT	60 DAT
H_0V_1	29.67 ±1.19a	16.34 ±0.82a	9.70 ±0.39a	7.08 ±0.35a
H_0V_2	20.00 ±0.8d	12.13 ± 0.61c	6.51 ± 0.26d	3.68 ±0.18d
H_0V_3	27.33 ±1.09b	13.87 ± 0.69b	9.27 ± 0.37b	5.97 ±0.3b
H_0V_4	25.00 ±1 c	12.34 ± 0.62c	6.580 ± 0.26d	4.71 ± 0.24b
H_1V_1	24.66 ±0.99c	7.33 ± 0.37d	8.03 ± 0.32c	2.73 ±0.14e
H_1V_2	15.33 ± 0.61e	4.67 ± 0.23g	4.01 ± 0.16f	1.35 ± 0.07h
H_1V_3	23.33 ±0.93c	7.67 ± 0.38d	5.83 ± 0.23e	2.48 ± 0.12ef
H_1V_4	16.67 ± 0.67e	5.33 ± 0.27f	4.12 ± 0.16f	1.85 ±0.09g
H_2V_1	4.33 ± 0.17h	3.66 ± 0.18h	3.10 ± 0.12g	1.79 ±0.09g
H_2V_2	0.11 ± 0.01i	0.33 ± 0.02k	0.86 l ±0.03g	0.39 ±0.02j
H_2V_3	4.33 ± 0.17h	3.67 ± 0.18h	1.86 ± 0.07i	1.02 ± 0.051i
H_2V_4	3.67 ± 0.15h	1.66 ± 0.08j	1.31 ± 0.05k	0.81 ± 0.04i
H_3V_1	9.01 ± 0.36fg	4.99 ± 0.25fg	2.85 ± 0.11h	1.98 ± 0.1g
H_3V_2	5.33 ± 0.21h	2.66 ± 0.13i	1.54 ± 0.06jk	1.01 ± 0.05i
H_3V_3	9.34 ± 0.37f	6.00 ± 0.3e	2.64 ± 0.11h	2.40 ± 0.12f
H_3V_4	7.34 ± 0.29g	2.99 ± 0.15i	1.77 ± 0.07ij	1.31 ± 0.07h
SE±	0.88	0.23	0.11	0.13
CV(%)	7.67	4.36	3.18	6.15

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

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1};V_1 = Chinigura, V_2 = BR 11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

4.5 Weed control efficiency (%)

Effect of herbicides

Application of different herbicides significantly affected weed control efficiency of T. *aman* rice at 30 and 60 DAT (Fig.5). Due to herbicide application weed control efficiency was ranged from 22.05 to 88.85 % over the weedy check plot. Experiment results revealed that the higher weed control efficiency was observed in Acitachlor

14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} comparable to others treatments. However, all the herbicides suppressed weeds, but the magnitude of suppression was higher in Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} treated plots and it was (88.85 and 83.74 %) at 30 and 60 DAT. While the minimum weed control efficiency (0.0 and 0.0 %) at 30 and 60 DAT was observed in the weedy check plot. The differences in weed control efficiency were due to variation of weed density in the experiment plot which was attended through different herbicide applications. Herbicides deteriorate the physiological and morphological features of weed and thus reduce weed density and increase weed control efficiency. The results found in this experiment are agreed with Bhuiyan and Mahbub (2020) who reported that weed control efficiency improved with increases of herbicide dose irrespective of weed species. Mishra (2019) also reported that the weed control efficiency was higher with the application of Bensulfuron methyl 60g /ha + Pretilachlor 600 g/ha at 3 DAT than hand weeding which varies from 74% at 30 DAT to 42.9% at 90 DAT. This might be due to the effect of weed during the initial stages of crop growth with herbicide application.

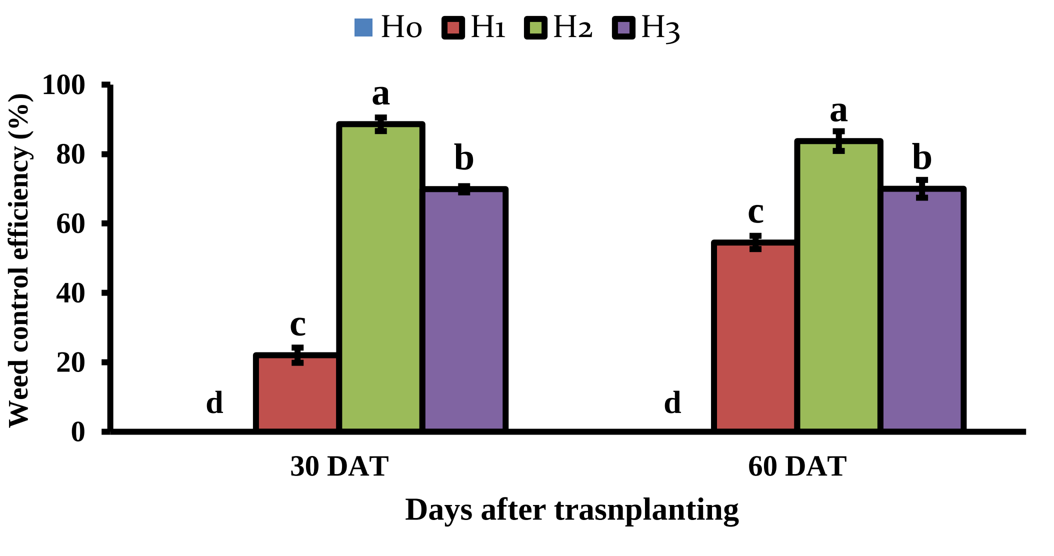


Figure 5. Effect of herbicide on weed control efficiency of T. *aman* rice at different days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

Rice variety significantly effect on weed control efficiency of T. *aman* rice at 30 and 60 DAT (Figure. 7). Due to different rice varieties treatment, the weed control efficiency was ranged from 41.15 to 59.21% over the weedy check plot. Experiment results revealed that cultivation of BR11 rice variety cultivation recorded the maximum weed control efficiency (49.04 and 59.21%) at 30 and 60 DAT while the cultivation of BRRI dhan56 rice variety cultivation recorded minimum weed control efficiency (41.15 and 43.75 %) at 30 and 60 DAT. A similar result was also found by Afrin *et al.* (2015) who reported that weed control efficiency is significantly influenced by different rice varieties.

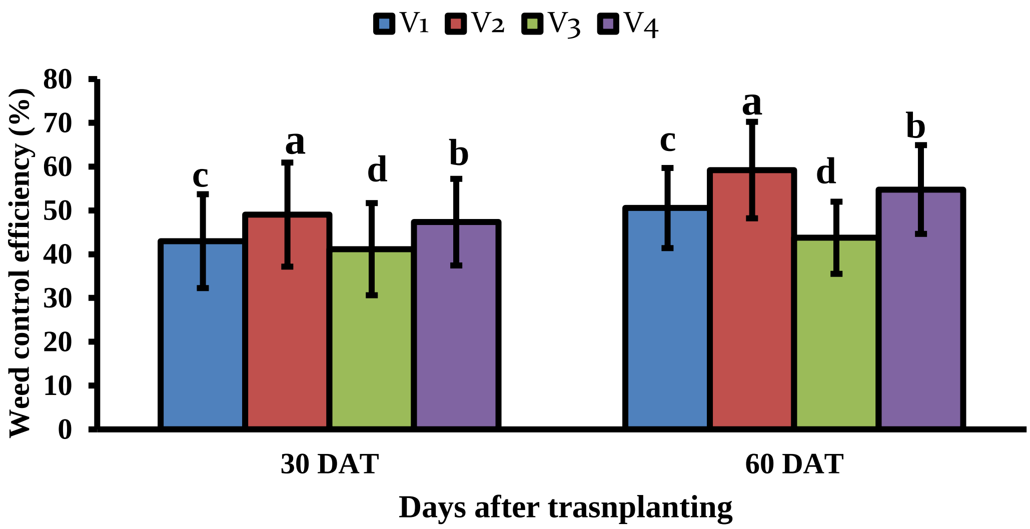


Figure 6. Effect of variety on weed control efficiency of T. *aman* rice at different days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

The combined effect of herbicide and rice variety showed a significant effect on weed control efficiency at 30 and 60 DAT (Table 6). Due to the combined effect of herbicide and rice variety, the weed control efficiency was ranged from 14.64 to 99.45

% over the weedy check plot. Experiment result revealed that the application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide in BR 11 rice variety recorded the maximum weed control efficiency (99.45 and 97.28) % at 30 and 60 DAT due to the reason that application of Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 rice variety reduce weed growth and weed density which influences weed control efficiency comparable to other treatments.While the minimum weed control efficiency (0.0 and 0.0 %) at 30 and 60 DAT was recorded in weedy check plot along with Chinigura rice variety cultivation which was statistically similar with weedy check plot along with BR11 rice variety (0.0,0.0 %); weedy check plot along with BRRI dhan56 rice variety (0.0,0.0 %) and weedy check plot along with BRRI hybrid dhan6 rice variety (0.0,0.0 %) at 30 and 60 DAT.

4.6 Weed control index (%)

Effect of herbicides

Application of different herbicides significantly effect on weed control index of T. *aman* rice at 30 and 60 DAT (Fig. 7). Due to herbicide application, the weed control index was ranged from 32.35 to 82.45 % over the weedy check plot. Experiment result revealed that the higher weed control index was noticed in plots receiving Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide comparable to others treated plots. However, all the herbicidal doses suppressed weeds, but the magnitude of suppression was higher in Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} treated plots and it was(78.73 and 82.45 %) at 30 and 60 DAT while the minimum weed control index (0.0 and 0.0 %) at 30 and 60 DAT was in recorded in weedy check plot. 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. Priya and Kubsad (2013) also reported higher weed control efficiency and lower weed index in herbicide treatments compared to weedy check owing to lower weed dry weight, higher weed control efficiency, and lower weed index due to effective control of complex weed flora.

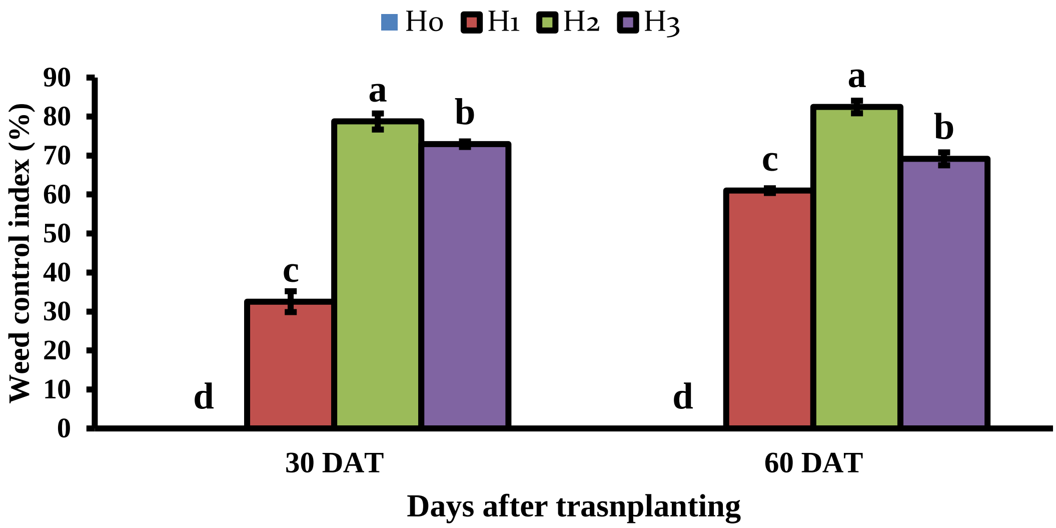


Figure 7. Effect of herbicide on weed control index of T. *aman* rice at different days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}

Effect of variety

Rice variety significantly affected on weed control index at 30 and 60 DAT (Fig. 8). In different rice varieties treatment, the weed control index was ranged from 38.97 to 56.32 % over the weedy check plot. The results revealed that BR11 rice variety recorded the maximum weed control index (50.37 and 56.32 % %) at 30 and 60 DAT while the cultivation of Chinigura rice variety recorded minimum weed control efficiency (38.97 %) at 30 and cultivation of BRRI dhan56 (V_3) recorded minimum weed control efficiency (50.29 %) at 60 DAT. 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.

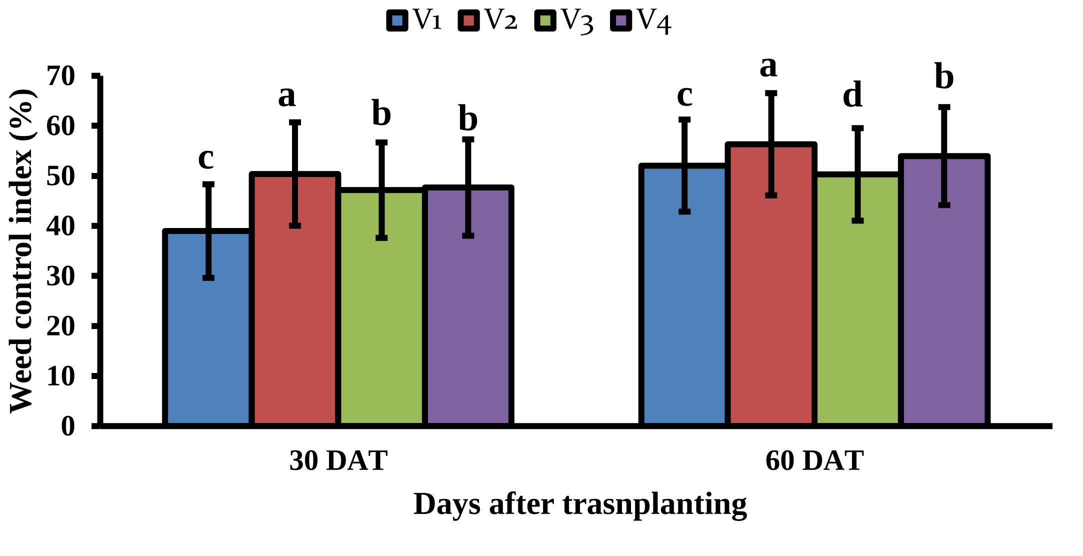


Figure 8. Effect of variety on weed control index of T. *aman* rice at different days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

The combined effect of herbicide and rice variety showed a significant effect on weed control index at 30 and 60 DAT (Table 6). Due to the combined effect of herbicide and rice variety, the weed control index was ranged from 17.22 to 89.31 % over the weedy check plot. Experiment results revealed that application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} along with BR 11 rice variety cultivation recorded the maximum weed control efficiency (86.79 and 89.31 %) at 30 and 60 DAT. 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 Chinigura rice cultivation which was statistically similar with weedy check plot along with BR 11 rice variety cultivation (0.0 and 0.0 %); weedy check plot along with BRRI dhan56 rice variety cultivation (0.0 and 0.0 %) and weedy check plot along with BRRI hybrid dhan6 rice variety cultivation (0.0 and 0.0 %) cultivation at 30 and 60 DAT.

Table 6. Combined effect of herbicide and rice variety on weed control efficiency (%) and weed control index (%) of T. *aman* rice at 30 and 60 DAT

Treatment Combinations	Weed control efficiency (%)		Weed control index (%)	
	30 DAT	60 DAT	30 DAT	60 DAT
H_0V_1	0.00 ±0i	0.00 ±0i	0.00 ±0i	0.00 ±0f
H_0V_2	0.00 ±0i	0.00 ±0i	0.00 ±0i	0.00 ±0f
H_0V_3	0.00 ±0i	0.00 ±0i	0.00 ±0i	0.00 ±0f
H_0V_4	0.00 ±0i	0.00 ±0i	0.00 ±0i	0.00 ±0f
H_1V_1	16.89 ±0.35h	55.12 ±1.84g	17.22 ±0.29h	61.44 ±1.23de
H_1V_2	23.35 ±0.49g	61.50 ±2.05f	38.35 ±0.64g	63.32 ±1.27d
H_1V_3	14.64 ±0.3h	44.73 ±1.49h	37.11 ±0.62g	58.46 ±1.17e
H_1V_4	33.32 ±0.69f	56.81 ±1.89g	37.39 ±0.63g	60.79 ±1.22de
H_2V_1	85.41 ±1.78b	77.60 ±2.59c	68.04 ±1f	74.72 ±1.49c
H_2V_2	99.45 ±2.07a	97.28 ±3.24a	86.79 ±1.28a	89.31 ±1.79a
H_2V_3	84.16 ±1.75b	73.54 ±2.45d	79.94 ±1.18b	82.92 ±1.66b
H_2V_4	85.32 ±1.78b	86.55 ±2.88b	80.14 ±1.18b	82.87 ±1.66b
H_3V_1	69.64 ±1.45d	69.44 ±2.31e	70.62 ±1.04e	72.03 ±1.44c
H_3V_2	73.35 ±1.53c	78.04 ±2.6c	76.34 ±1.13c	72.65 ±1.45c
H_3V_3	65.81 ±1.37e	56.74 ±1.89g	71.52 ±1.05de	59.80 ±1.2e
H_3V_4	70.64 ±1.47cd	75.74 ±2.52cd	73.15 ±1.08d	72.12 ±1.44c
SE ±	1.39	1.72	1.17	1.56
CV(%)	3.78	4.05	3.14	3.61

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

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1};V_1 = Chinigura, V_2 = BR 11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

4.7 Crop growth characters

4.7.1 Plant height (cm)

Effect of herbicides

Plant height is an important morphological character that acts as a potential indicator of the availability of growth resources in its approach. From the experiment, the result exposed that plant height showed significant variation due to the effect of different herbicide treatments (Fig.9). The maximum plant height (40.07 cm) was recorded from Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} (H_2) mixed herbicide treatment at 15 DAT, which was statistically similar with Bispyribac sodium (40.04 cm) and significantly superior over remaining treatments. At 30 DAT the maximum plant height (80.00 cm) was recorded from Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} which was statistically similar with (79.27 cm) Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}. At 45, 60, 90 DAT, and at harvest, respectively the maximum plant height (99.83, 117.25, 136.09, and 138.81 cm) was recorded from Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}which was statistically similar to the Bispyribac sodium (99.40 cm) at 45 DAT, at 60, 90 DAT, and at harvest 118.01, 135.51 and 136.61 cm respectively plant height from Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide,and 115.96, 133.59 and 135.67 cm from Bispyribac-sodium. Whereas the minimum plant height (37.34 cm) was recorded fromAcitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}at 15 DAT which was statistically similar (37.38 cm) with (Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}. At 15, 45, 60, 90 DAT, and at harvest, the minimum (72.79, 92.67, 113.32, 130.68, and 132.90 cm, respectively) plant height was recorded in the weedy check plot. At earlier growth stage spraying mixed herbicide in plants produced a thin layer in the leaf surface area that hampers photosynthesis as a result dry matter accumulation and plant become short for a while comparable to no herbicide treatment or weedy check plot. A similar result was also observed by Das *et al.* (2017) who reported that the application of herbicides did not show any phytotoxic symptoms on rice plants. Teja *et al.* (2017) also reported that the plant height of rice varied significantly among different herbicide treatments.

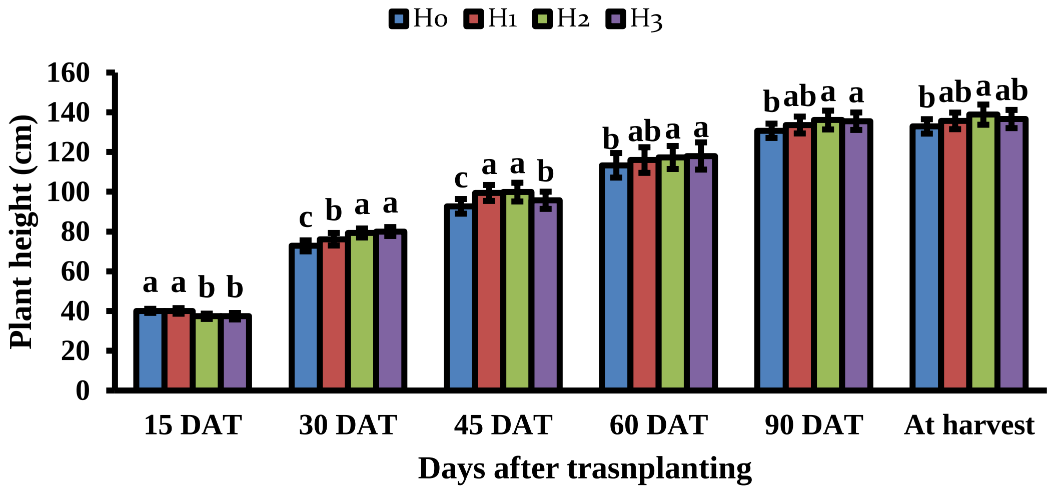


Figure 9. Effect of herbicide on plant height of T. *aman* rice at different days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}

Effect of variety

Different rice varieties significantly differed in plant height at different days after transplanting (Fig. 10). The results showed that Chinigura rice variety had the maximum plant height (45.60, 87.67, 107.99, 130.97, 155.24, and 158.18 cm at 15, 30, 45, 60, 90 DAT and, at harvest, respectively) while BR11 rice variety had the minimum plant height (34.31, 64.58, 74.77, 80.61, 117.76, and 119.86 cm at 15, 30, 45, 60, 90 DAT, and at harvest, respectively). The variation of plant height is probably due to the genetic make-up of the variety. A similar result was also observed by Salam *et al.* (2020) who reported that plant height was significantly influenced by different varieties.

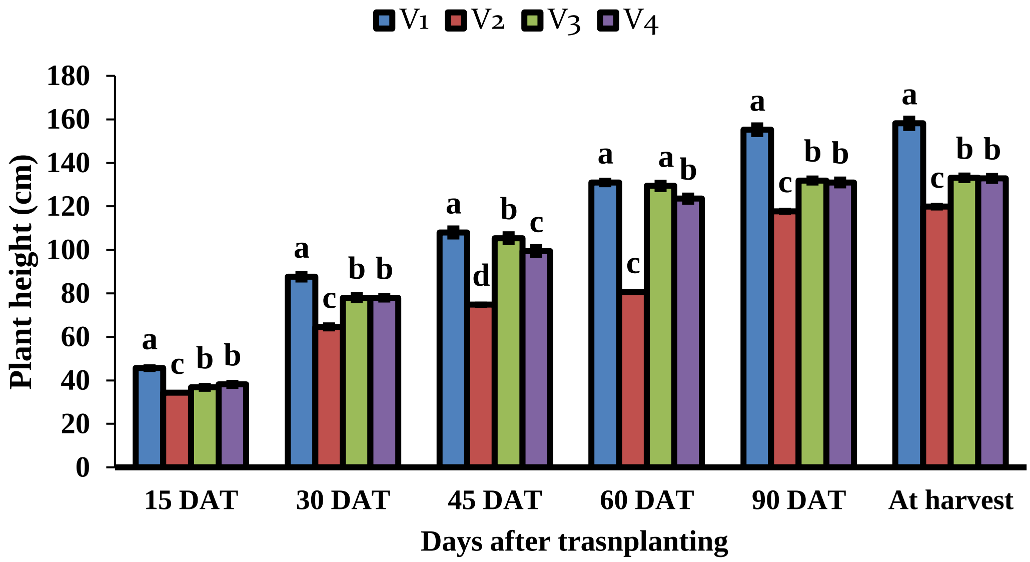


Figure 10. Effect of variety on plant height of T. *aman* rice at different after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

The plant height of T. *aman* rice was significantly different due to the combined effect of herbicide and rice variety (Table 7). Experiment resultsshowedthat at 15 DAT the maximum plant height (46.17 cm) was recorded from the combinaion of Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}with Chinigurawhich was statistically similar tothe combination of Bispyribac sodium with Chinigura(46.16 cm), weedy checkwith Chinigura(45.59 cm),andAcitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} with Chinigura(44.50 cm). At 30 DAT the maximum plant height (89.83 cm) was recorded from the combination of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}with Chinigura which was statistically similar(89.37 cm)with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}and Chinigura and Bispyribac-sodium WP @ 150 g ha^{-1}andChinigura (89.05 cm). At 45 DAT the maximum plant height(111.83 cm) was recorded from Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}with Chinigura which was statistically similar(109.97 cm) with Bispyribac-sodium with Chinigura, Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}withChinigura (109.62 cm), and

Bispyribac-sodium WP @ 150 g ha^{-1} with BRRI dhan56 (109.23 cm). At 60 DAT the maximum plant height (136.07 cm) was recorded from the combination of Pretilachlor 6% + Pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} with BRRI dhan56 which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} and Chinigura (134.00 cm). At 90 DAT and at harvest, the maximum plant height (158.78 and 164.33 cm, respectively) was recorded from the combination of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} with Chinigura which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} and Chinigura (158.37 cm), and Bispyribac-sodium with Chinigura (156.30 cm) at 90 DAT, and with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} and Chinigura (161.81 cm) at harvest, respectively. The minimum plant height (161.81 cm) was recorded from the combination of Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg $ha^{-1}$with BR11 at 15 DAT which was statistically similar with the combination of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} with BR11 (32.89 cm), Bispyribac-sodium WP @ 150 g ha^{-1} with Chinigura (46.16 cm), Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} with BRRI dhan56 and Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} with BRRI hybrid dhan6 (35.65 cm) . At 30, 45, 60, 90 DAT, and at harvest the minimum plant height (58.53, 72.73, 78.67, 116.29 and 117.07 cm, respectively) was observed from weedy check with Chinigura which was statistically similar (60.67 cm) with Bispyribac-sodium and BR11 combination at 30 DAT; Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} and BRRI dhan56 (73.83 cm), and Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and BR11 (74.23 cm) at 45 DAT, Bispyribac-sodium WP @ 150 g ha^{-1} andBR11 (79.27 cm), and Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} and BR11 (80.03 cm) at 60 DAT, Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and BR11 (116.42 and 119.37 cm), Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} and BR11 (117.79 and 121.47 cm), and Bispyribac- sodium WP @ 150 g ha^{-1} and BR11 (120.54 and 121.53 cm) at 90 DAT and at harvest, respectively.

Table 7. Combined effect of herbicides and *aman* rice varieties on plant height at different days after transplanting

Treatments	Plant height (cm)					
	15 DAT	30 DAT	45 DAT	60 DAT	90 DAT	At harvest
H_0V_1	45.59± 1.3a	82.43 ± 4.54b	100.53 ± 3.01d	128.80 ± 2.51c-e	147.53 ± 9.31b	149.33 ± 6.67c
H_0V_2	38.30 ± 1.09b-d	58.53 ± 2.12i	72.73 ± 2.7h	78.67 ± 0.7i	116.29 ± 3.5g	117.07 ± 4.26f
H_0V_3	37.24 ± 1.06c-e	73.90 ± 1.39fg	101.01 ± 6.26d	126.87 ± 2.7c-f	129.58 ± 2.7de	134.2 ± 2.37de
H_0V_4	39.16 ± 1.12bc	76.30 ± 3.64d-f	96.40 ± 5.24ef	118.93 ± 4.24g	129.33 ± 2.9de	130.93 ± 2.8e
H_1V_1	46.16 ± 1.32a	89.05 ± 4.16a	109.97 ± 4.05ab	130.53 ± 1.56bc	156.30 ± 5.19a	157.23 ± 5.76b
H_1V_2	33.33 ± 0.95fg	60.67 ± 2.75i	78.30 ± 2.79g	79.27 ± 0.89i	120.54 ± 3.87fg	121.53 ± 5.4f
H_1V_3	39.59 ± 1.13bc	75.33 ± 2.27e-g	109.23 ± 7.66ab	130.07 ± 0.06bc	131.42 ± 3.03c-e	133.50 ± 4.91de
H_1V_4	41.07 ± 1.17b	79.43 ± 1.22b-d	100.08 ± 1.17de	123.97 ± 3.25e-g	126.10 ± 3.61ef	130.40 ± 3.64e
H_2V_1	44.50 ± 1.27a	89.83 ± 3.33a	111.83 ± 5.93a	130.56 ± 1.91bc	158.78 ± 4.57a	164.33 ± 5a
H_2V_2	32.89 ± 0.94g	69.57 ± 0.86h	74.23 ± 2.32h	84.45 ± 1.77h	116.42 ± 6.47g	119.37 ± 6.62f
H_2V_3	36.32 ± 1.04	80.27 ± 1.14bc	106.27 ± 6.65bc	124.67 ± 4.6d-f	132.72 ± 5.04cd	133.70 ± 5.87de
H_2V_4	35.65 ± 1.02d-g	77.40 ± 2.62c-e	106.97 ± 5.8bc	129.31 ± 1.46b-d	136.43 ± 4.1c	137.83 ± 4.1d
H_3V_1	46.17 ± 1.32a	89.37 ± 2.93a	109.62 ± 6.96ab	134.00 ± 3.03ab	158.37 ± 0.87a	161.81 ± 1.92ab
H_3V_2	32.71 ± 0.93g	69.53 ± 2.73h	73.83 ± 3.54h	80.03 ± 1.57hi	117.79 ± 0.51g	121.47 ± 1.03f
H_3V_3	33.97 ± 0.97e-g	82.50 ± 0.75b	104.36 ± 4.05c	136.07 ± 0.37a	133.80 ± 0.46cd	130.93 ± 0.64e
H_3V_4	36.66 ± 1.05c-e	78.59 ± 2.54c-e	94.46 ± 4.49f	121.93 ± 4.58fg	132.07 ± 0.57cd	132.23 ± 0.64de
SE±	1.59	1.60	1.83	2.45	2.82	3.16
CV(%)	5.04	2.54	2.32	2.59	2.58	2.85

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

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1};V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

4.7.2 Number of tillers hill^{-1}

Effect of herbicides

Different herbicide applications significantly influenced tillers number hill^{-1} at different DAT (Fig. 11). The result showed that the maximum tillers number hill^{-1} (7.70) was observed from Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} which was statistically similar (7.30) with Bispyribac-sodium WP @ 150 g ha^{-1} at 15 DAT. At 30 DAT the maximum tillers number hill^{-1} (11.82) was recorded under Bispyribac-sodium WP @ 150 g ha^{-1}which was statistically similar (11.50) with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}. At 45 DAT the maximum tillers number hill^{-1} (14.22) was found from Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} which was statistically similar (13.92) with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}and weedy check (13.82). At 60, 90 DAT, and at harvest, the maximum tillers number hill^{-1} (17.93, 17.44, and 15.52, respectively) was found Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide treated plants. While the minimum tillers number hill^{-1} (6.08 and 10.78) was recorded in the weedy check which was statistically similar(6.35 and 11.07) at 15 and 30 DAT with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}. At 45 DAT the minimum tillers number hill^{-1} (15.80) was recorded from Bispyribac-sodium treatment. At 60. 90, and at harvest the minimum tillers number hill^{-1} (14.53, 14.46, and 12.56, respectively) was found from the weedy check plot which was statistically similar with Bispyribac-sodium (15.02 and 13.20) at 90 DAT and harvest, respectively. Mixed herbicide reduces weed density and weed crop competition thus helping plant to utilize resources properly which improve crop growth characteristics and increases tillers number hill^{-1} than weed-infested rice. In this experiment among different herbicide applications Acitachlor 14%+ Bensulfuron methyl 4% performs best while the Bispyribac-sodium herbicide application is less effective to control weeds comparable to other treatments. Similar results were also observed by Paulraj *et al.* (2019) who reported that weed control through herbicide application positively affects tiller production in transplanting rice. Lodhi (2016) also reported that different weed control treatments caused remarkable variations in the 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 when the plants received herbicidal treatments.

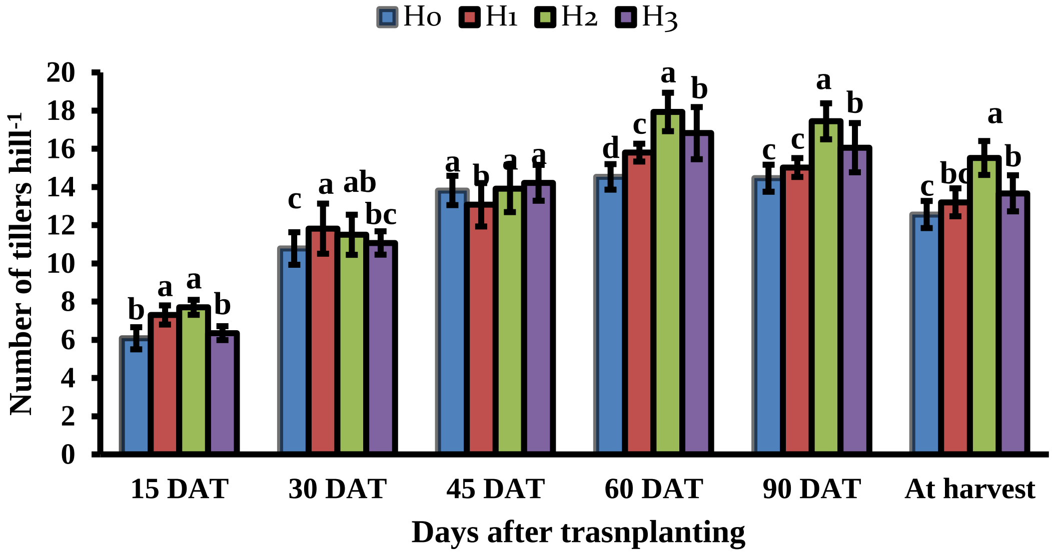


Figure 11. Effect of herbicide on number of tillers hill^{-1} of T. *aman* rice at different days after transplanting(Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

Rice variety significantly differed in tiller number hill^{-1} at different days after transplanting (Fig. 12). Experimental results revealed that the Chinigura rice variety recorded the maximum tiller number hill^{-1} (8.33, 15.30, 17.83, 21.04, 19.71, and 17.92) at 15, 30, 45, 60, 90 DAT and at harvest respectively. While BRRI hybrid dhan6 showed minimum tiller number hill^{-1} (5.49) at 30 DAT. BRRI dhan56 recorded minimum tiller number hill^{-1} (8.18, 9.62, 13.68, 12.83, and 10.60) at 30, 45, 60, 90 DAT, and at harvest, respectively. The variation in tiller number hill^{-1} is due to the effect of varietal differences. The variation of tiller number hill^{-1} is probably due to the genetic make-up of the cultivars. Similar results were also observed by Paul *et al.* (2019) who reported that local or low-yielding rice varieties have comparatively more tillers than hybrid or high-yielding rice varieties.

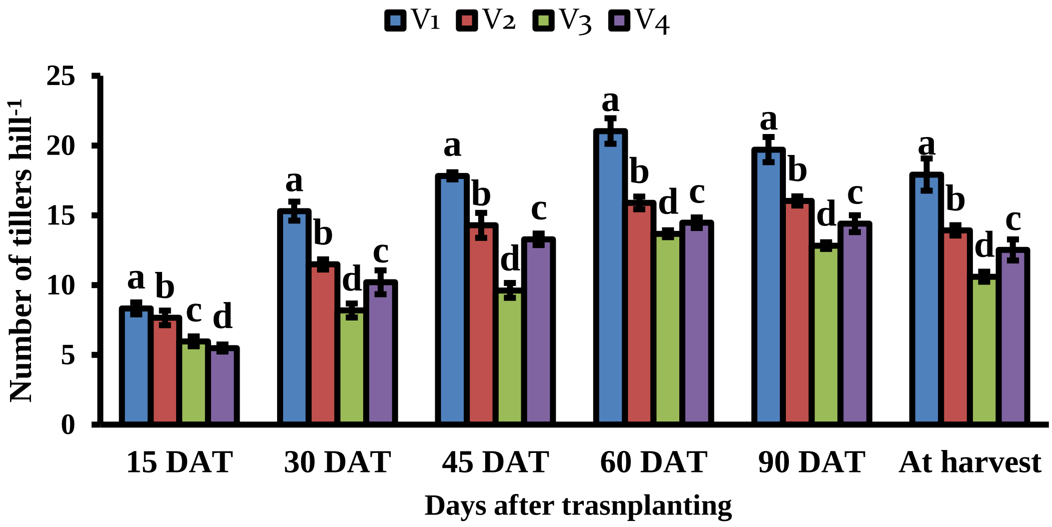


Figure 12. Effect of variety on number of tillers hill^{-1} of T. *aman* rice at different days after transplanting(Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Tiller number hill^{-1} of T. *aman* rice was significantly differed due to the combined effect of herbicide and rice variety (Table 8). Experimental results revealed that at 15, 30, and 45 DAT the maximum tiller number hill^{-1} (9.20, 18.07, and 18.13) was recorded under Bispyribac-sodium WP @ 150 g ha^{-1} along with Chinigura rice variety cultivation which was statistically similar with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 rice variety (9.00) at 15 DAT and with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BR11 rice variety cultivation (17.93), Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with Chinigura (17.80) and weedy check along with Chinigura (17.46) at 45 DAT. At 60 and 90 DAT the maximum tiller number hill^{-1} (24.34 and 22.63) was recorded under Pretilachlor 6% + Pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with Chinigura which was statistically similar with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide with BR11 rice (23.04 and 21.53) at 60 and 90 DAT. At harvest, the maximum tiller number hill^{-1} (20.33) was recorded from the application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with Chinigura rice variety which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with Chinigura rice variety (19.37). Whereas the minimum tiller number hill^{-1} (4.67) was recorded under weedy check along with BRRI hybrid dhan6 cultivation which was statistically similar with Pretilachlor 6% + Pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BRRI dhan56 cultivation (4.73) at 15 DAT. At 30 DAT the minimum tiller number hill^{-1} (6.27) was recorded under Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with BRRI dhan56 which was statistically similar with weedy check plot along with BRRI hybrid dhan6 (6.47). At 45 DAT the minimum tiller number hill^{-1} (7.93) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BRRI dhan56. At 60, 90 DAT, and at harvest, the minimum tiller number hill^{-1} (12.14, 11.40, and 9.07, respectively) was found from weedy check plot along with BRRI hybrid dhan6 which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BRRI dhan56 (12.85), and weedy check with BRRI dhan56 (13.12). Bispyribac-sodium WP @ 150 g ha^{-1} herbicide with BRRI dhan56(12.00 and 9.53, respectively) treatment combination at 90 DAT and at harvest respectively and Pretilachlor 6% + Pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide with BRRI dhan56 (10.00) treatment combination at harvest, respectively.

Table 8. Combined effect of herbicide and rice variety on number of tillers hill^{-1} at different DAT of T. *aman* rice

Treatments	No. Tillers hill^{-1}					
	15 DAT	30 DAT	45 DAT	60 DAT	90 DAT	At harvest
H_0V_1	8.27 ±0.44bc	13.80 ± 0.12c	17.46 ± 0.92a	18.33 ± 0.5b	16.87 ±0.24bc	15.33 ± 1.56c
H_0V_2	5.67 ± 1.44f	12.07 ± 1.01e	14.53 ± 0.87c	14.52 ±0.2d-f	15.77 ±1.03cd	13.57 ± 1.67d
H_0V_3	5.73 ± 1.51f	10.80 ± 0.24f	11.53 ± 0.38e	13.12 ±0.24f-h	13.80 ± 0.37e	12.27 ± 0.83ef
H_0V_4	4.67 ± 0.84g	6.47 ± 0.48i	11.73 ± 1.38e	12.14 ± 0.13h	11.40 ± 0.93g	9.07 ± 1.13i
H_1V_1	9.20 ± 0.53a	18.07 ± 0.37a	18.13 ± 0.5a	18.45 ± 1.03b	17.80 ± 1.92b	16.67 ± 1.83b
H_1V_2	8.13 ± 1.8c	9.53 ± 0.48g	10.47 ± 1.75f	14.75 ±0.37c-e	15.00 ± 0.77d	13.27 ± 0.81de
H_1V_3	6.20 ± 0.72f	6.27 ± 0.24i	9.47 ± 0.38g	13.97 ±0.52e-g	12.00 ±0.12fg	9.53 ± 0.97hi
H_1V_4	5.67 ± 0.64f	13.40 ±1.03cd	14.20 ±1.84cd	16.04 ±0.74cd	15.27 ± 1.13d	13.33 ± 0.47de
H_2V_1	8.87 ±1.33ab	17.00 ± 0.44b	17.93 ± 0.81a	23.04 ± 0.27a	21.53 ± 0.38a	20.33 ± 2.42a
H_2V_2	9.00 ± 1.36a	12.60 ±1.05de	15.93 ± 0.67b	18.14 ± 0.18b	17.37 ± 0.85b	15.10 ± 1.19c
H_2V_3	7.20 ±0.82de	7.93 ± 0.13h	7.93 ± 1.29h	14.77 ±0.24c-e	12.87 ±0.32ef	10.60 ±0.48gh
H_2V_4	5.73 ± 0.57f	8.47 ± 0.07h	13.87 ±1.33cd	15.77 ±0.83cd	18.00 ± 1.37b	16.07 ±1.06bc
H_3V_1	7.00 ± 1.35e	12.33 ± 0.29e	17.80 ± 1.13a	24.34 ± 0.24a	22.63 ± 0.24a	19.37 ± 6.87a
H_3V_2	7.80 ±1.25cd	11.73 ± 0.13e	16.20 ± 0.55b	16.15 ± 0.24c	16.00 ±0.47cd	13.73 ± 0.71d
H_3V_3	4.73 ± 0.29g	7.73 ± 0.35h	9.53 ± 0.62fg	12.85 ±0.33gh	12.67 ±0.89ef	10.00 ± 0.44hi
H_3V_4	5.87 ± 1.2f	12.47 ± 0.18e	13.33 ± 1d	13.93 ±0.18e-g	12.93 ±0.52ef	11.60 ± 1.06fg
SE±	0.32	0.43	0.45	0.73	0.58	0.57
CV(%)	5.87	4.73	4.06	5.54	4.49	5.55

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

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1};V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

4.7.3 Leaf area index

Effect of herbicides

The levels of LAI vary with the canopy architecture, which depends on the cultivars, geography, and different field management practices such as weed management through different herbicide applications. Different herbicide applications significantly affected on leaf area index at different DAT (Fig. 13). Result revealed that Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide treated plot markedly increasing leaf area index (0.77, 3.50, 4.25 and 3.53) at 30, 45, 60 and 90 DAT which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide treated plot (4.24) at 60 DAT and Bispyribac sodium WP @ 150 g ha^{-1} herbicide treated plot (4.19 and 3.44) at 60 DAT and 90 DAT. While the minimum leaf area index (0.71) was recorded in Bispyribac sodium WP @ 150 g ha^{-1} herbicide treated plot at 30 DAT which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide treated plot (0.73) and weedy check plot (0.73). At 45 and 60 DAT the minimum leaf area index (3.37 and 3.79) was recorded in weedy check plot which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide treated plot (3.38) and Bispyribac-sodium WP @ 150 g ha^{-1} herbicide treated plot (3.40) at 45 DAT. At 90 DAT the minimum leaf area index (3.11) was recorded in Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide. The weed suppression enhanced increased LAI. Application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide (H_2 treatment) produced the higheest leaf area index comparable to other herbicide treatment due to the fact that application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide gave good weed control in the early growth stage which helped the plant to easily establishment and resources utilization thus suppressed weed population comparable to others treatment.

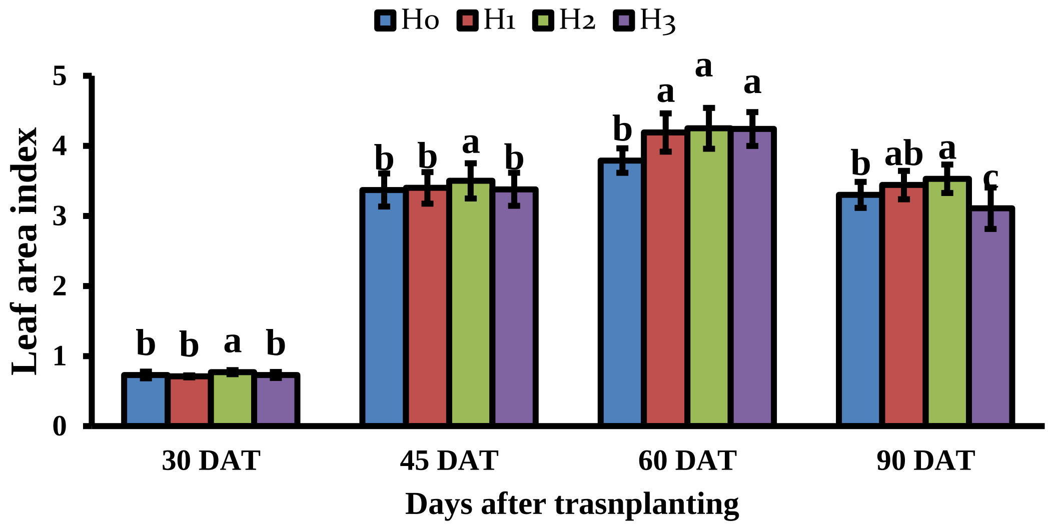


Figure 13. Effect of herbicide on leaf area index of T. *aman* rice at different days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}

Effect of variety

The leaf area index (LAI) of the crop is crucial in the quantitative description of the canopy structure and photosynthetic processes. Since leaves are essential for photosynthesis and produce the bulk of biomass, the number of leaves and leaf area index will also influence yield. Leaf area index is significantly affected by different rice varieties at different DAT (Fig. 14). The experiment result showed that BR 11 rice variety recorded the maximum leaf area index (0.83, 3.90, 5.02, and 4.25) at 30, 45, 60, and 90 DAT which was due to the varietal potentiality comparable to other rice varieties and it was statistically similar with BRRI hybrid dhan6 (0.82) at 30 DAT. While the Chinigura rice variety recorded minimum leaf area index (0.57, 2.35, 3.06, and 2.42, respectively) at 30, 45, 60, and 90 DAT respectively. The variation in leaf area index is due to the effect of varietal differences.

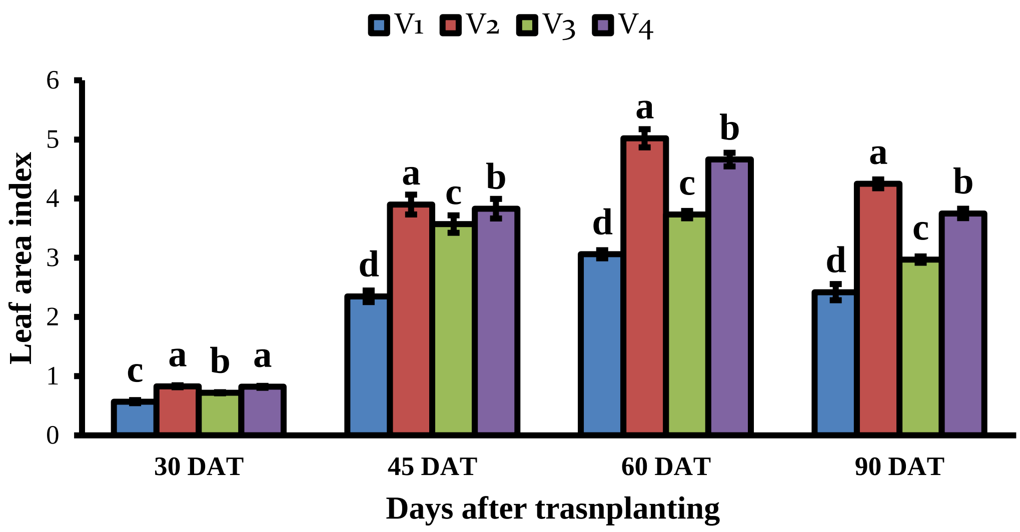


Figure 14. Effect of variety on leaf area index of T. *aman* rice at different days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR 11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Monitoring of the distribution and changes of leaf area index (LAI) is important for assessing the growth and vigor of vegetation on the plant. Application of different herbicides and varieties significantly affected on leaf area index at different DAT (Table 9). Results shown that Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide with BR11 rice cultivation recorded the maximum leaf area index (0.87, 4.18, 5.31, and 4.33, respectively at 30, 45, 60, and 90 DAT, respectively) which was statistically similar with weedy check plot along with BR11 rice cultivation (0.86), Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide with BRRI hybrid dhan6 (0.85), Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide with BRRI hybrid dhan6 cultivation (0.84), 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide treated plot along with BR11 rice (0.84), and weedy check plot along with BRRI hybrid dhan6 cultivation (0.84) treatment combination at 30 DAT, with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide with BR11 rice cultivation (5.26) and Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with BR11 rice (5.23) treatment combination at 60 DAT, and Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BR11 rice cultivation (4.28) and Bispyribac-sodium WP @ 150 g ha^{-1} herbicide with BR 11 rice cultivation (4.27) treatment combination at 90 DAT. While weedy check plot with Chinigura rice variety cultivation recorded minimum leaf area index (0.47, 2.30, and 2.93, respectively) at 30, 45 and 60 DAT which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide with Chinigura rice variety cultivation (0.50 and 2.32) at 30 DAT and 60 DAT, Bispyribac sodium WP @ 150 g ha^{-1} herbicide with Chinigura rice variety cultivation (2.40 and 2.98) and Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with Chinigura rice variety cultivation (2.40 and 3.00) at 45 and 60DAT and at 90 DAT. Pretilachlor 6% + Pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide with Chinigura rice recorded minimum leaf area index (0.47).

Table 9. Combined effect of herbicide and rice variety on leaf area index at different DAT of T. *aman* rice

Treatment Combinations	Leaf area index			
	30 DAT	45 DAT	60 DAT	90 DAT
H_0V_1	0.47±0.02e	2.30 ±0.38g	2.93±0.2g	2.60±0.17g
H_0V_2	0.86 ±0.03a	3.80 ±0.63b-d	4.28±0.29d	4.10±0.27ab
H_0V_3	0.74 ±0.03bc	3.56 ±0.59ef	3.73 ±0.25e	2.90 ±0.19ef
H_0V_4	0.84 ±0.03a	3.82±0.64bc	4.22±0.28d	3.60±0.24d
H_1V_1	0.65 ±0.03d	2.40±0.4g	2.98±0.2g	2.64±0.18g
H_1V_2	0.75 ±0.03b	3.80 b±0.63b-d	5.23 ±0.35a	4.27 ±0.28a
H_1V_3	0.69 ±0.03cd	3.67±0.61de	3.78 ±0.25e	3.02 ±0.2e
H_1V_4	0.74 ±0.03bc	3.7±0.62cd	4.78±0.32bc	3.83±0.26cd
H_2V_1	0.65±0.03d	2.40±0.4g	3.00±0.2g	2.75±0.18fg
H_2V_2	0.87 ±0.04a	4.18±0.7a	5.31±0.35a	4.33±0.29a
H_2V_3	0.71 ±0.03bc	3.50±0.58f	3.70 ±0.25e	3.07±0.2e
H_2V_4	0.85±0.03a	3.90±0.65b	4.97±0.33b	3.97±0.26bc
H_3V_1	0.50 ±0.02e	2.32 ±0.39g	3.32±0.22f	1.67±0.11h
H_3V_2	0.84 ±0.03a	3.83 ±0.64bc	5.26 ±0.35a	4.28±0.29a
H_3V_3	0.73 ±0.03bc	3.53±0.58f	3.72 ±0.25e	2.90±0.19ef
H_3V_4	0.83±0.03a	3.84 ±0.64	4.66±0.31c	3.59±0.24d
SE ±	0.02	0.06	0.10	0.11
CV(%)	3.89	2.30	3.27	4.34E

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

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1};V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

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

Effect of herbicides

The dry matter accumulation (g plant^{-1}) consists of all its constituents excluding water. Application of different herbicide significantly affected on dry matter accumulation (g plant^{-1}) of T. *aman* rice at different days after transplanting (Fig.15). Experiment result showed that under Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1}recorded the maximum dry matter accumulation (9.23, 27.47, 63.81 and 108.13 g respectively plant^{-1}) at 30, 45, 60 and 90 DAT which was statistically similar with Bispyribac-sodium WP @ 150 g ha^{-1} herbicide (27.18, 63.97 and 105.81 g respectively plant^{-1}) at 45, 60 and 90 DAT. Whereas weedy check plot recorded the minimum dry matter accumulation (5.66, 20.95, 49.53 and 90.28 g plant^{-1})at 30, 45, 60 and 90 DAT respectively. The dry matter accumulation (g plant^{-1}) differences over weedy check (H_0) treatment was due to reason that application of herbicide reduced weed density which ultimate help undisturbed plant growth by utilizing its surrounded resources. Similar result 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. Weedy check plots had the minimum quantity of dry matter production, which increased appreciably at all the growth intervals as the plots received weed control treatments.

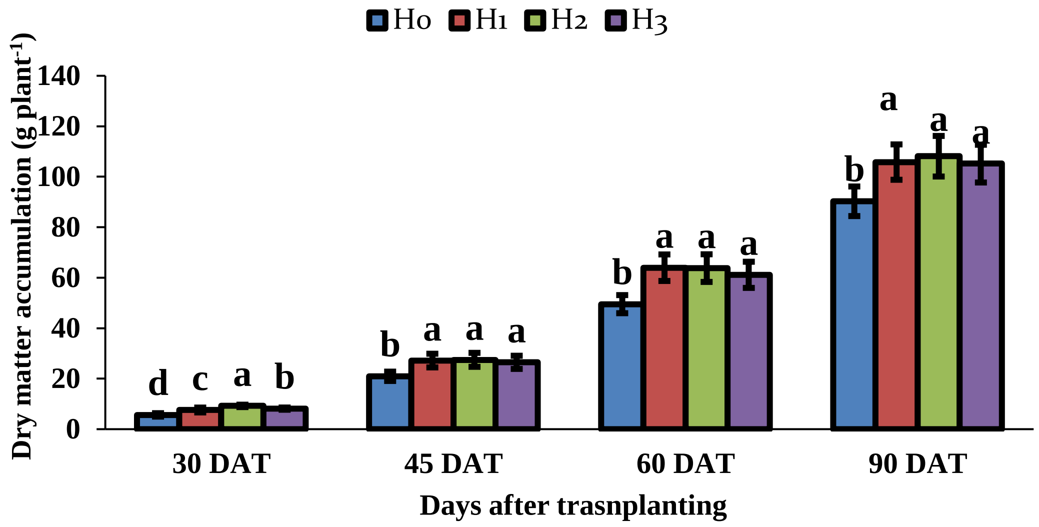


Figure 15. Effect of herbicide on dry matter accumulation plant^{-1} of T. *aman* rice at different days after transplanting(Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

The dry matter accumulation (g plant^{-1}) differ among different varieties due to reason that individual variety have individual leaf area, growth stage, and resources utilization its surrounded which influences the dry matter accumulation (g plant^{-1}). In this experiment showed that different rice varieties significantly effect on dry matter accumulation (g plant^{-1}) of T. *aman* rice at different DAT (Fig.16). Among different rice varieties BR11 rice variety recorded the maximum dry matter accumulation (8.32, 32.61, 74.26 and 125.85 g plant^{-1}) at 30, 40, 60 and 90 DAT respectively which was statistically similar with BRRI hybrid dhan6 (8.30, 32.46 and 73.42 g plant^{-1}) at 30, 40 and 60 DAT. While Chinigura rice variety recorded the minimum dry matter accumulation (7.18, 15.42, 39.27 and 72.95g plant^{-1})at 30, 40, 60 and 90 DAT which was statistically similar with BRRI dhan56 (6.83 g plant^{-1}) at 30 DAT. Competition, weed suppression and resources utilization ability had greater in high yielding or hybrid varieties comparable to local one which influences the dry matter accumulation. The result found in this experiment is agreed with Nahida *et al.* (2013) who reported that dry matter (DM) accumulation over time varied considerably due to variety and it is more in high yielding variety comparable to local one.

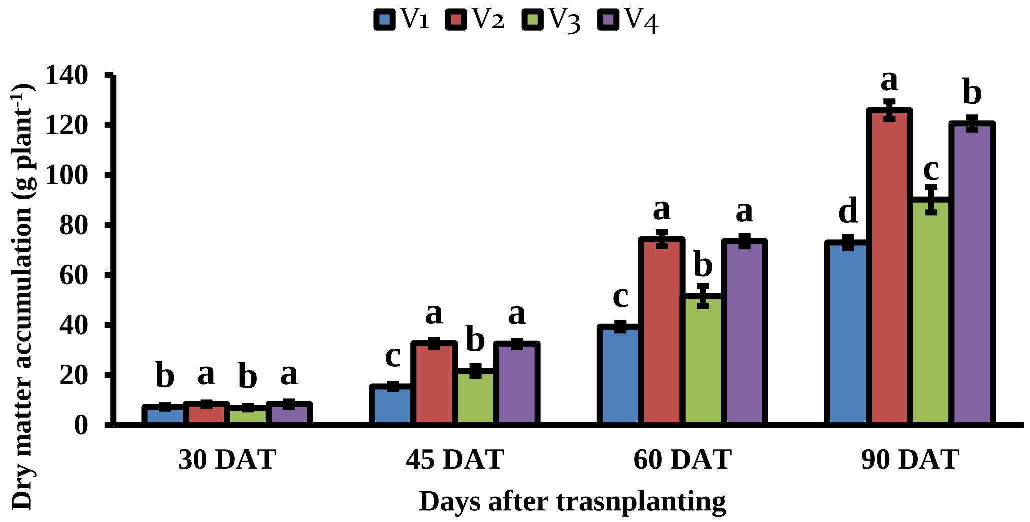


Figure 16. Effect of variety on dry matter accumulation plant^{-1} of T. *aman* rice at different days after transplanting (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR 11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Dry matter accumulation (g plant^{-1}) significantly varied due to combined effect of herbicide and rice variety at different DAT (Table 10). Experiment showed that Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 rice recorded the maximum dry matter accumulation (10.26, 37.45, 84.40 and 138.76 g plant^{-1}) at 30, 45, 60 and 90 DAT respectively which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BRRI hybrid dhan6(9.84 g plant^{-1}) at 30 DAT; with Pretilachlor 6% + Pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BR11 rice (35.58, 79.97 and 133.15 g plant^{-1}) and Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along BRRI hybrid dhan6 (35.56, 79.28 and 130.42 g plant^{-1}) treatment at 45, 60 and 90 DAT respectively. While weedy check plot along with Chinigura recorded the minimum dry matter accumulation (5.32 g plant^{-1}) at 30 DAT which was statistically similar with BRRI dhan 56 (5.58 g plant^{-1}) and weedy check plot along BRRI hybrid dhan6 (5.58 g plant^{-1}). At 45 and 60 DAT Bispyribac-sodium WP @ 150g ha^{-1} herbicide along with Chinigura recorded the minimumdry matter accumulation (12.20 and 33.89 g plant^{-1}) which was statistically similar with weedy check plot along with Chinigura (13.80 and 34.99 g plant^{-1}) at 45 and 60 DAT. At 90 DAT weedy check plot along with Chinigura rice recorded the minimum dry matter accumulation (66.00 g plant^{-1}) which was statistically similar with Bispyribac-sodium WP @ 150 g ha^{-1} herbicide with same cultivar (66.00 g plant^{-1}).

Table 10. Combined effect of herbicide and rice variety on dry matter accumulation at different DAT of T. *aman* rice

Treatment Combinations	Dry matter accumulation (g plant^{-1})			
	30 DAT	**45 DAT**	**60 DAT**	**90 DAT**
H_0V_1	5.32 ±2.15i	13.80 ±1.2g	34.99 ±0.58g	66.00 ±0.75h
H_0V_2	6.14 ±1.3gh	26.11 ±0.43e	60.05 ±1d	108.07 ±1.16f
H_0V_3	5.58 ±0.51hi	16.70 ±2.14f	40.74 ±0.68f	76.51 ±0.85gh
H_0V_4	5.58 ±4.84hi	27.16 ±4.13e	62.34 ±1.17d	110.55 ±1.33e
H_1V_1	7.24 ±3.12f	12.20 ±3.72g	33.89 ±0.59g	66.00 ±0.76h
H_1V_2	8.14 ±2.93e	31.28 ±3.31d	72.61 ±1.23c	123.43±1.24bd
H_1V_3	6.71 ±3.88fg	32.37 ±4.3cd	73.82 ±1.25c	119.1 ±1.35ce
H_1V_4	8.29 ±5.08d	32.88 ±1.87cd	75.57 ±1.28bc	114.69±1.45de
H_2V_1	8.91 ±1.25cd	18.13 ±2.14f	45.33 ±0.76ef	80.78 ±0.9g
H_2V_2	10.26 ±1.94a	37.45 ±1.42a	84.40 ±1.41a	138.76 ±1.54a
H_2V_3	8.27 ±2.16d	18.72 ±1.68f	46.23 ±0.77e	82.57 ±0.92g
H_2V_4	9.48 ±1.44bc	35.56 ±1.45ab	79.28 ±1.32ab	130.4 ±1.48ab
H_3V_1	7.24 ±1.75f	17.55 ±2.44f	42.93 ±0.72ef	79.04 ±0.88g
H_3V_2	8.74 ±0.44cd	35.58 ±0.81ab	79.97 ±1.33ab	133.1 ±1.48ab
H_3V_3	6.78 ±0.55fg	18.58 ±2.51f	45.19 ±0.75ef	82.15 ±0.92g
H_3V_4	9.84 ±0.67abg	34.24 ±2.63bc	76.50 ±1.28bc	126.44±1.43bc
SE ±	0.35	1.21	2.54	5.09
CV(%)	5.73	5.84	5.21	6.10

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

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1};V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

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

Effect of herbicides

Crop growth is less than potential when the uptake of water, oxygen, or nutrients is less than the demand of the crop**.** Less nutrients uptake occurred due to weeds infestation in the crop field. Effective herbicide reduced weed crop competition and increasing crop growth. Different application of herbicide significantly affected on crop growth rate by reducing weed density in crop field (Fig.17) showed that the maximum crop growth rate (3.94 mg cm^{-2} day^{-1}) was recorded with the Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide (3.92 mg cm^{-2} day^{-1}) while the minimum crop growth rate (3.63 mg cm^{-2} day^{-1}) was recorded under weedy check plot. Similar result also observed by Lodhi (2016) who reported that different weed control treatment increasing crop growth rate comparable to weedy check.

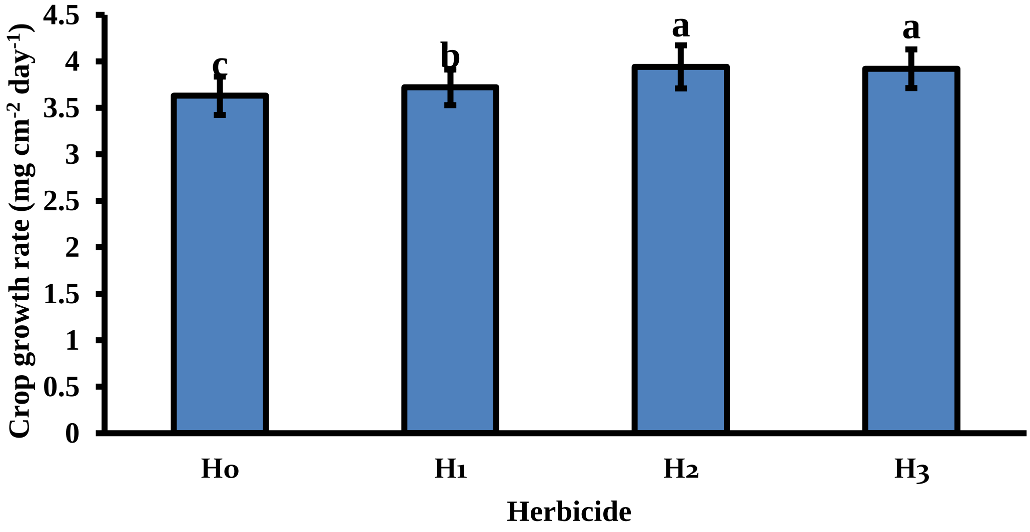


Figure 17. Effect of herbicide on crop growth rate of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

Different rice varieties significantly effect on crop growth rate (Fig.18). It was clear from the experiment result that the maximum crop growth rate (4.59 mg cm^{-2} day^{-1}) was recorded under BR11 rice variety while the minimum crop growth rate (2.99 mg cm^{-2} day^{-1}) was recorded under Chinigura rice variety. In this experiment it was observed that high yieldingvarieties give better response to nutrients utilization and thus, their production rate increases substantially comparatively to local variety. Mia and Shamsuddin (2011) also found similar result with the present study and reported that the CGR is the product of LAI and NAR values and higher CGR achieved in of the modern varieties than the aromatic varieties may be due to the higher LAI.

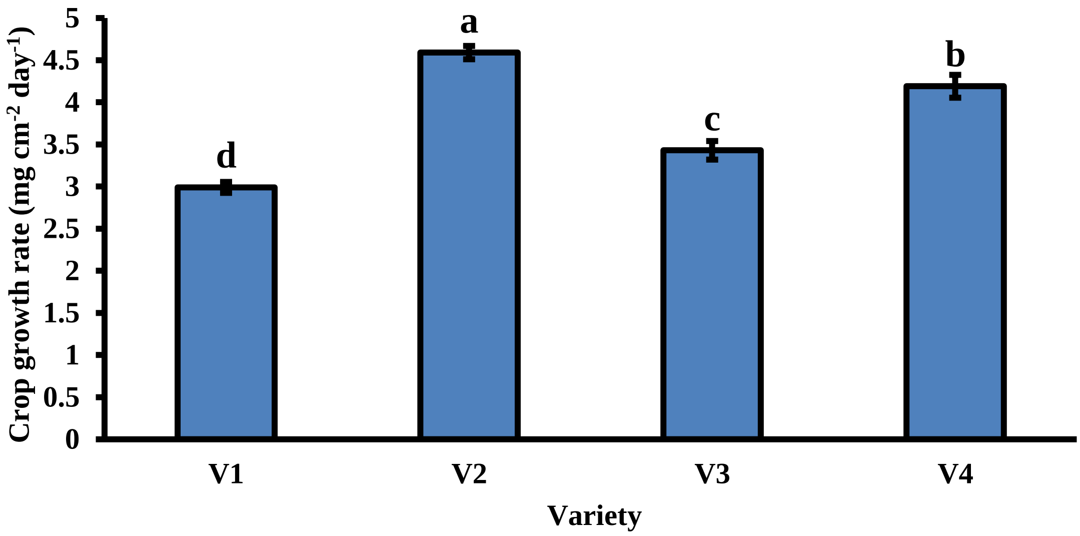


Figure 18. Effect of variety on crop growth rate of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

It is clear from combined effect of herbicide and rice variety showed significant differences in crop growth rate (Table 11). Among different treatment combinations Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 rice recorded the maximum crop growth rate (4.83 mg cm^{-2} day^{-1}) which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BR11 rice (44.73 mg cm^{-2} day^{-1}) H_3V_2 treatment. While the minimum crop growth rate(2.76mg cm^{-2} day^{-1}) was recorded under weedy check plot along with Chinigura rice which was statistically similar with Bispyribac - sodium WP @ 150 g ha^{-1} herbicidealong with Chinigura rice (2.85mg cm^{-2} day^{-1}).

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

Effect of herbicides

Different herbicide application significantly affected on relative growth rate (mg g^{-1} day^{-1}) of T. *aman* rice (Fig.19). Result revealed that weedy check plot recorded the maximum relative growth rate (20 mg g^{-1} day^{-1}) while Bispyribac-sodium WP @ 150 g ha^{-1} herbicide recorded the minimum relative growth rate (17.40 mg g^{-1} day^{-1}). The differences of relative growth rate among different treatments may attributed to the dry matter accumulation (g $plant^{-1}$). As relative growth rate is determine by dry matter accumulation (g $plant^{-1}$) thus higher the dry matter accumulation (g $plant^{-1}$) lower the relative growth rate and in this experiment it is clear that dry matter accumulation (g $plant^{-1}$) was significantly effect on different herbicide application due to effective control of weeds comparable to weedy check plot. Olayinka and Etejere (2015) also found similar result which supported the present finding and reported that all the weed control treatments had higher RGR as compared to the weedy check.

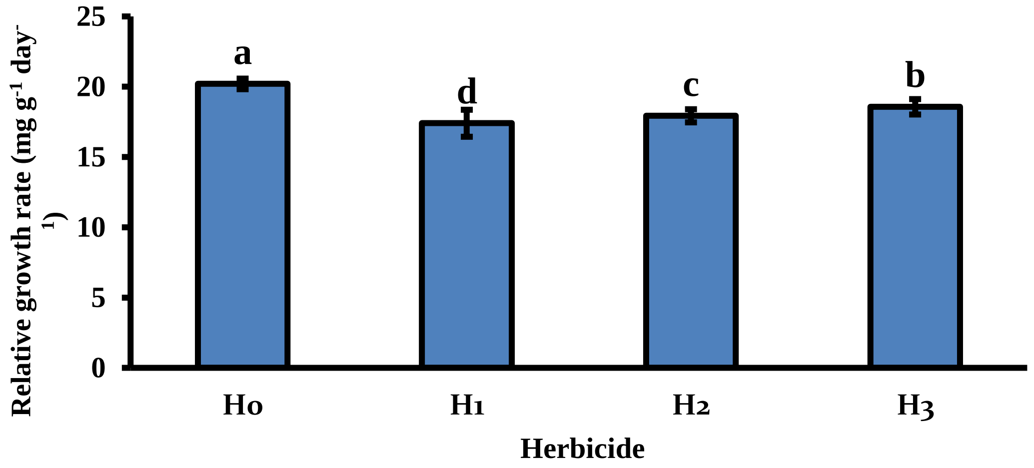


Figure 19. Effect of herbicide on relative growth rate of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

Variety in an important factor because it's impact on crop growth, development and grain production. High yielding or hybrid rice varieties produce more grain yield and dry matter accumulation (g plant^{-1}) comparable to local variety (Figure. 21). As relative growth rate is related to dry matter accumulation (g plant^{-1}) and in this experiment maximum relative growth rate (20.76 mg g^{-1} day^{-1}) was recorded under Chinigura rice which was due to reason that local rice variety accumulate low dry matter comparable to hybrid or high yielding rice variety and minimum relative growth rate (16.57 mg g^{-1} day^{-1}) was recorded under BRRI hybrid dhan6 rice variety followed by BR11 rice variety (17.71 mg g^{-1} day^{-1}). Amin *et al.* (2002) reported that RGRs of local varieties were generally higher than those of improved varieties under low N supply.

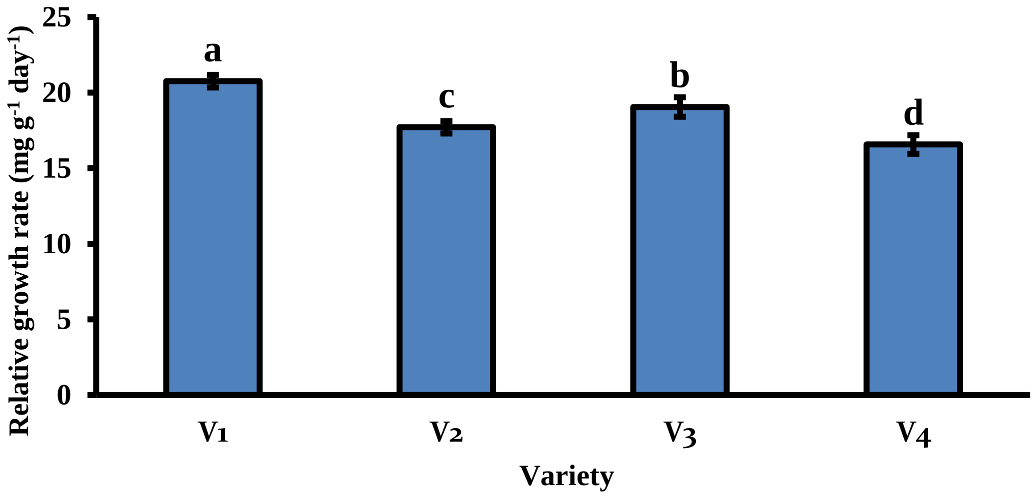


Figure 20. Effect of variety on relative growth rate of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Relative growth rate significantly influenced by the combined effect of different herbicide and rice variety (Table 11). Result showed that the maximum relative growth rate (22.24 mg g^{-1} day^{-1}) was recorded under Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with Chinigura rice variety while the minimum relative growth rate (13.89 mg g^{-1} day^{-1}) was recorded with Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with BRRI hybrid dhan6.

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

Effect of herbicides

The net assimilation rate is an important factor as its related to crop growth and development. Net assimilation rate was influenced significantly differed due to different herbicide treatments (Fig.21). It is clear from experiment that Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide recorded the maximum net assimilation rate (7.46 mg cm^{-2} day $^{-1}$) while the minimum net assimilation rate (6.20 mg cm^{-2} day $^{-1}$) was recorded with Bispyribac-sodium WP @ 150 g ha^{-1} herbicide due to reason that effective mixed herbicide reduced competition period between crop and weed and increasing the NAR probably due to higher leaf area and undisturbed availability of other growth factors (nutrient, space, water etc). In this experiment application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide showed positive effect while application of Bispyribac-sodium WP @ 150 g ha^{-1} showed negative effect by causing injury to the leaf of crop plant which ultimately reduced leaf area and impact on photosynthesis, dry matter accumulation, crop growth rate. Shultana *et al.* (2013) reported that increase in competition period between weeds and crop decreased the NAR probably due to less leaf area and shortage of other growth factors (nutrient, space, water etc).Maqsood (1998) also reported that mostly cereals such as rice had NAR up to 6 g m-2 day-1 and that LAI was positively associated with NAR.

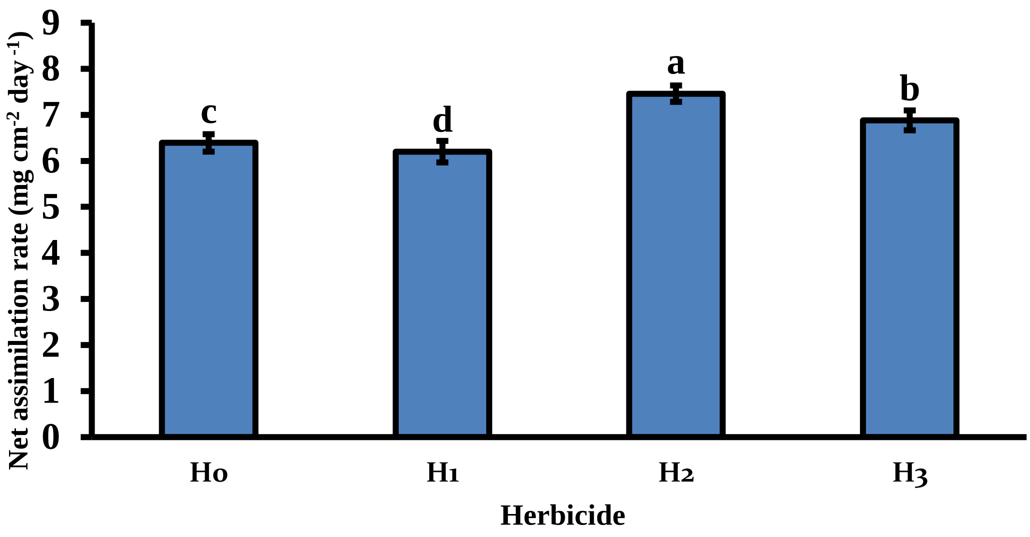


Figure 21. Effect of herbicide on net assimilation rate of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

Different rice variety significantly influenced on net assimilation rate due to reason that individual variety had individual leaf area, growth rate and resources utilization ability and genetic make-up (Fig.22). Experimental results revealed that the maximum net assimilation rate (6.85 mg cm^{-2} day $^{-1}$) was recorded with BR11 rice variety which was statistically similar with Chinigura rice (6.79 mg cm^{-2} day $^{-1}$) and BRRI hybrid dhan6 rice variety (6.78 mg cm^{-2} day $^{-1}$). While the minimum net assimilation rate (6.50mg cm^{-2} day $^{-1}$) was recorded with BRRI dhan56 rice variety cultivation.The result obtained from the present study was similar with the findings of Lu *et al.* (2000) who observed that decrease in the rate of photosynthesis in leaves cause parallel decrease in NAR and eventually low grain yield.

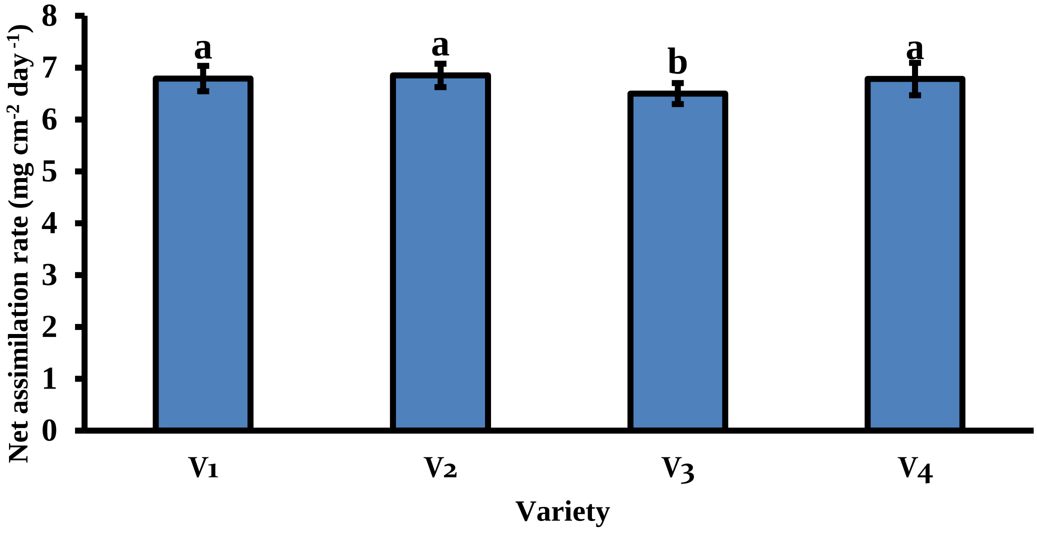


Figure 22. Effect of variety on net assimilation rate of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR 11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Combined effect of herbicide and rice variety showed significant variation on net assimilation rate(Table 11). From the experiment it was revealed that the maximum net assimilation rate (7.93 mg cm^{-2} day $^{-1}$) was recorded with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide treated plot along with BR11 rice which was statistically similar with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along BRRI hybrid dhan6 (7.82 mg cm^{-2} day $^{-1}$) and Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along Chinigura (7.76 mg cm^{-2} day $^{-1}$) treatment combination while the minimum net assimilation rate (5.22 mg cm^{-2} day $^{-1}$) was recorded with Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with BRRI hybrid dhan6.

Table 11. Combined effect of herbicide and rice variety on 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
H_0V_1	2.76 ±0.11g	21.21 ±1.06b	6.04 ±0.4fg
H_0V_2	4.27 ±0.17c	19.59 ±0.98d-f	6.44±0.43de
H_0V_3	3.18 ±0.13f	21.00 ±1.05bc	5.83 ±0.39g
H_0V_4	4.29 ±0.17c	18.98 ±0.95f	7.19±0.48b
H_1V_1	2.85 ±0.11g	22.24 ±1.11a	6.15±0.41e-g
H_1V_2	4.52 ±0.18b	17.69 ±0.88g	6.25 ±0.42ef
H_1V_3	4.03 ±0.16d	15.78 ±0.79i	7.19 ±0.48b
H_1V_4	3.48 ±0.14e	13.89 ±0.69j	5.22 ±0.39h
H_2V_1	3.15 ±0.13f	19.25±0.96ef	7.19 ±0.48b
H_2V_2	4.83 ±0.19a	16.57±0.83hi	7.93 ±0.53a
H_2V_3	3.23 ±0.13f	19.34 ±0.97ef	6.91±0.46bc
H_2V_4	4.55 ±0.18b	16.57±0.83hi	7.82±0.52a
H_3V_1	3.21 ±0.13f	20.35±1.02b-d	7.76±0.52a
H_3V_2	4.73 ±0.19a	16.9±0.85gh	6.74±0.45cd
H_3V_3	3.29 ±0.13f	20.09 ±1c-e	6.05±0.4fg
H_3V_4	4.44 ±0.18b	16.85±0.84gh	6.96±0.46bc
SE ±	0.06	0.45	0.17
CV(%)	2.17	3.03	3.26

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

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1};V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

4.8 Yield contributing characters

4.8.1 Number of effective tillers hill^{-1}

Effect of herbicide

It is obvious from the data that number of effective tillers hill^{-1} varied significantly under different herbicide treatments (Fig. 23). Among all the treatments, the minimum number of effective tillers hill^{-1} (10.66) was recorded under weedy check plot which enhanced significantly with different herbicide application. The maximum number of effective tillers hill^{-1} (14.41) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide which was appreciably superior over all the other herbicide weed control treatments. Similar result also observed by Yadav *et al.* (2018) who reported that herbicide application improved number of effective tillers in treated plot comparable to weedy check plot. Jabran *et al.* (2012) also reported that the herbicides' application effectively improved the yield and yield-related traits of DPR (Direct planted rice) over the control (weedy check).

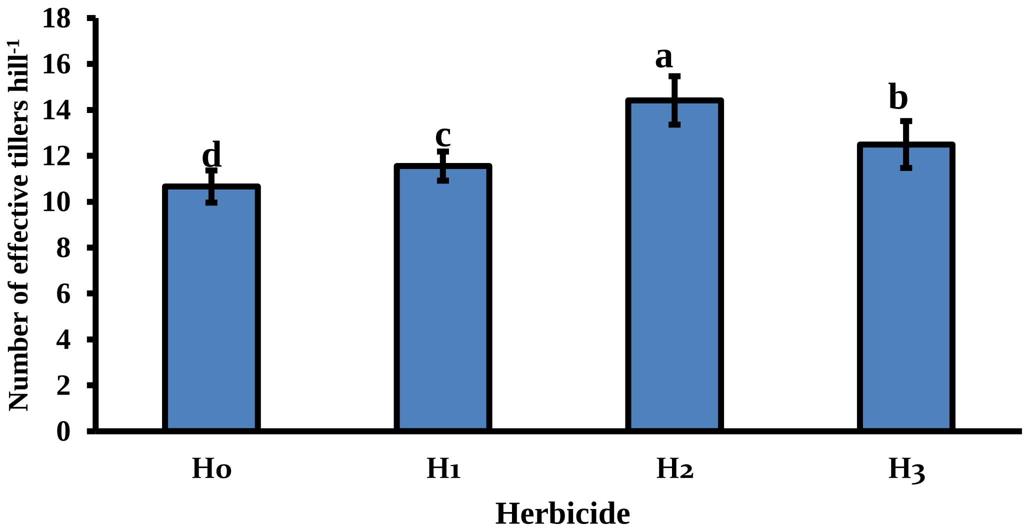


Figure 23. Effect of herbicide on number of effective tillers hill^{-1} of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}

Effect of variety

Rice variety significantly affect on number of effective tillers hill^{-1} of T. *aman* rice (Fig24). The maximum number of effective tillers hill^{-1} (14.84) was recorded in Chinigura while the minimum number of effective tillers hill^{-1} (9.83) was under BRRI dhan56. The variation of effective tillers hill^{-1} is probably due to the genetic make-up of the variety. The results obtained from the present study was similar with the findings of Nahida *et al.* (2013) who reported that the reason of difference in effective tillers hill^{-1} is the genetic makeup of the variety, which is primarily influenced by heredity.

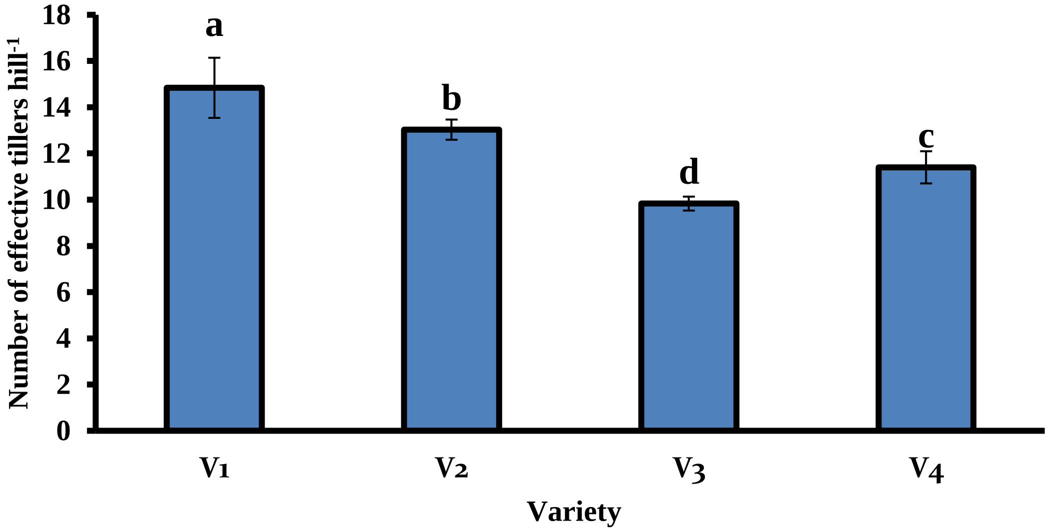


Figure 24. Effect of variety on number of effective tillers hill^{-1} of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety.

Number of effective tillers hill^{-1} was significantly influenced due to the combined effect of herbicide and rice variety (Table 12). The maximum number of effective tillers hill^{-1} (18.60) was recorded with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with Chinigura which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with Chinigura (17.50). While the minimum number of effective tillers hill^{-1} (8.40) was recorded with weedy check plot along with BRRI hybrid dhan6 which was statistically similar with Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with BRRI dhan56 rice variety (8.80) and retilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide treated plot along with BRRI dhan56 (9.47).

4.8.2 Number of non effective tillers $hill^{-1}$

Effect of herbicide

Weeds compete with crops for water, nutrients and light. Being hardy and vigorous in growth habit, they grow faster than crops and consume large amount of water and nutrients, thus causing heavy losses in yields. Different herbicide treatment significantly affected the number of non effective tillers $hill^{-1}$ of T. *aman* rice (Fig. 25). Rice field infested with various weeds in weedy check plot cause higher number of non effective tillers $hill^{-1}$ (1.90) due to reason that high density of weed consume maximum nutrient as a result crop cannot utilize its surrounded resources properly causing slow growth and increasing higher number of non effective tillers $hill^{-1}$, while the minimum number of non effective tillers $hill^{-1}$ (1.12) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}mixed herbicide(1.18). The reduction of non effective tillers $hill^{-1}$ was due to effective mixed herbicide application that reduce wider weed density and influences plant growth by reducing weed crop competition. Similar result also found by Raju *et al.* (2003) and reported that the use of weedicide gave the highest tiller $hill^{-1}$ and control plot produced maximum non effective tiller.

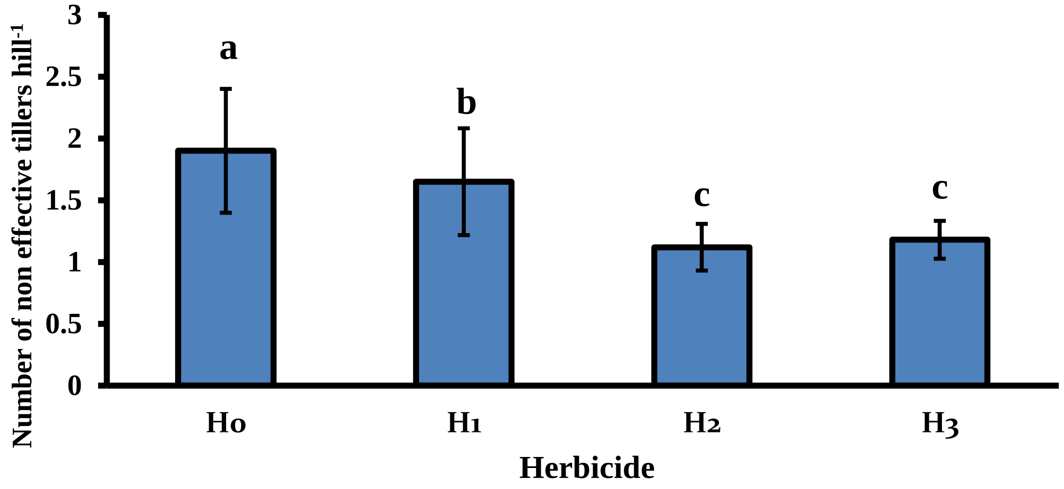


Figure 25. Effect of herbicide on number of non effective tillers hill^{-1} of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

Rice variety significantly effect on number of non effective tillers hill-1 of T. aman rice (Fig 27). Result revealed that Chinigura rice recorded the maximum number of non effective tillers hill-1 (3.08) while BRRI dhan56 rice recorded the minimum number of non effective tillers hill-1 (0.77). The differences of non effective tillers hill-1 is the genetic makeup of the variety. The result obtained from the present study was similar with the findings ofAkter et al. (2020) who reported that non effective tillers hill-1 varied with different varieties and it is higher in local variety comparable to high yielding varieties.

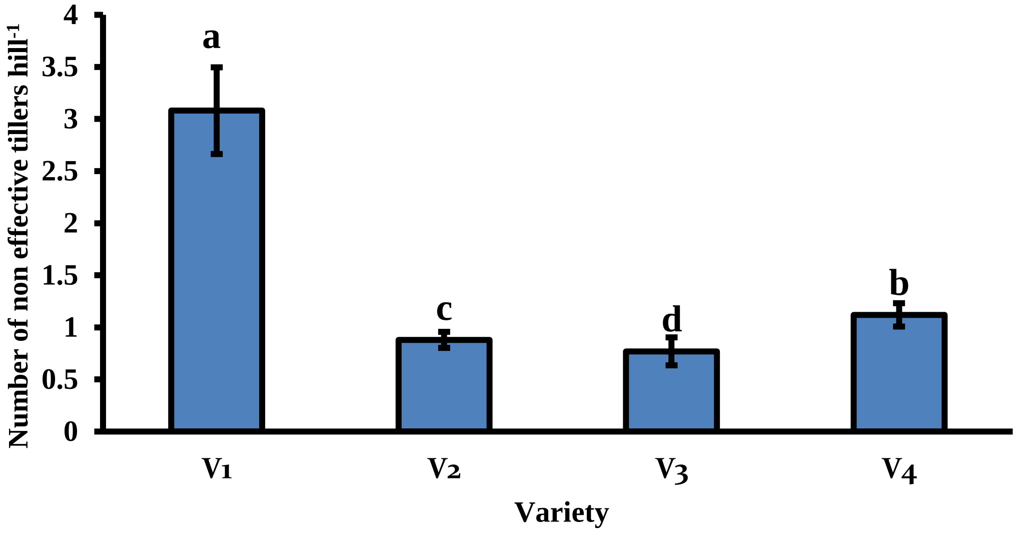


Figure 26. Effect of variety on number of non effective tillers hill^{-1} of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Number of non effective tillers hill^{-1} was significantly influenced due to the combined effect of herbicide and rice variety. Experimental result showed that weedy check plot along with Chinigura recorded the maximum number of non-effective tillers hill^{-1} (4.67) while the minimum number of non effective tillers hill^{-1} (0.33) was recorded with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BRRI dhan56.

4.8.3 Length of panicle (cm)

Effect of herbicide

Panicle is an important yield contributing character as its bear grains and significantly influenced due to different herbicide treatment (Fig 27). Result revealed that among all the treatments the maximum panicle length (25.46 cm) was recorded with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}mixed herbicide (25.40 cm) and Bispyribac-sodium WP @ 150 g ha^{-1}herbicide(25.31 cm). While weedy check plot recorded the minimum panicle length (24.51 cm). The variation of result due to the effectiveness of herbicide on weed diversity in crop field. Jabran *et al.* (2012) and Mahajan *et al.* (2003) from their study concluded that weed management through herbicide application resulted the highest panicle length comparable to weedy check (control).

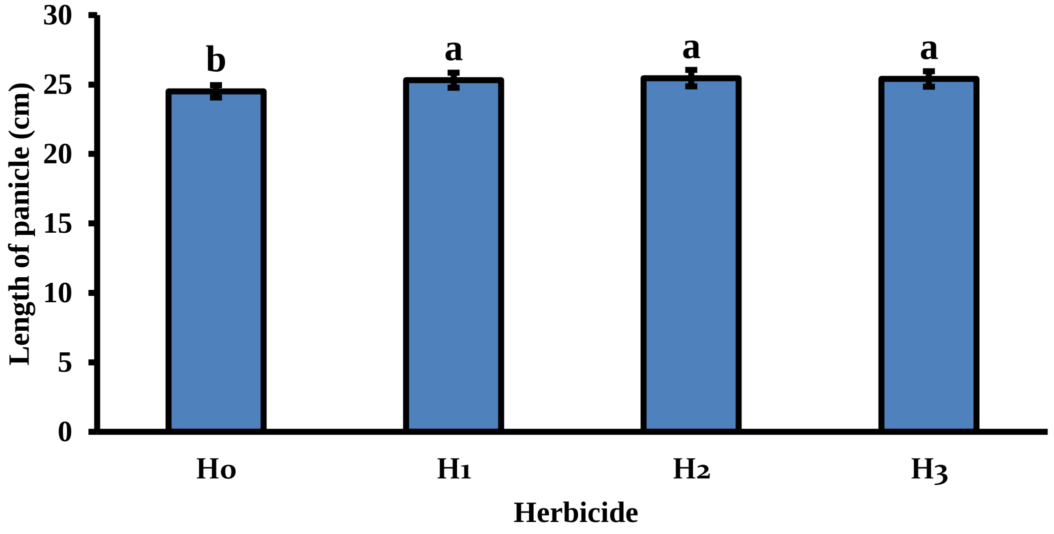


Figure 27. Effect of herbicide on panicle lengthof T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H1= Bispyribac sodium WP @ 150 g ha-1, H2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha-1 and H3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}

Effect of variety

Panicle length is one aspect of panicle architecture and is usually measured as a yield-related trait. Panicle length, together with spikelet number and density, seed setting rate and grain plumpness, determines the grain number per panicle; hence, yield increases in rice. The results revealed that different rice variety significantly varied in panicle length of T. aman rice (Fig.28). From the experiment result it was clear that cultivation of BR11 rice variety recorded the maximum panicle length (27.30 cm) while the Chinigura recorded minimum panicle length (23.98 cm) which was statistically similar with the cultivation BRRI dhan56 rice (24.22 cm). Different rice varieties have different panicle length 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 result which supported the present study and reported that panicle length varied among varieties.

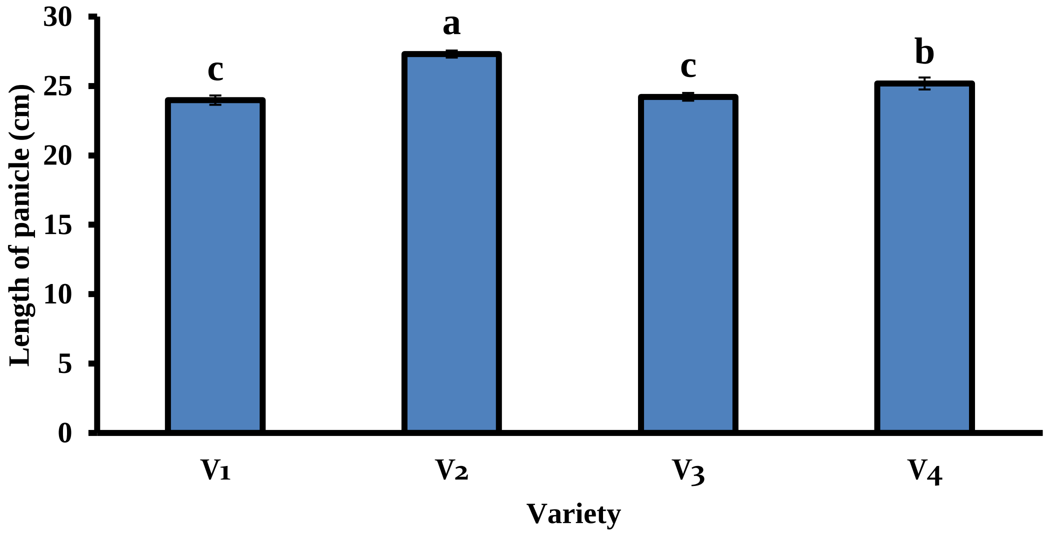


Figure 28. Effect of variety on panicle length of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Panicle length was significantly affected due to combined effect of herbicide and rice variety (Table 12). Experimental results revealed that application of mixed herbicide and high yielding rice variety increasing panicle length *i.e.,*Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 rice recorded the maximum panicle length (27.89 cm) which was statistically similar with Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with BR11 rice variety cultivation (27.38 cm) and Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} with BR11 rice variety(27.32 cm). While weedy check plot along with Chinigura rice recorded the minimum panicle length (22.86 cm).

Table 12. Combined effect of herbicide and rice variety on number of effect, non effective tillers hill^{-1} and panicle length of T. *aman* rice

Treatment Combinations	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)
H_0V_1	10.66 ±3.2de	4.67 ±0.78a	22.86 ±1.4i
H_0V_2	12.77 ±2.12c	0.80 ±0.13h	26.62 ±0.66b
H_0V_3	10.80 ±1.14d	1.47 ±0.24e	23.66 ±1.44h
H_0V_4	8.40 ±1.45f	0.67 ±0.11h	24.91 ±1.4c-e
H_1V_1	12.60 ±3.06c	4.07 ±0.68b	23.90±1.64gh
H_1V_2	12.53 ±0.99c	0.73 ±0.12h	27.38 ±1.4a
H_1V_3	8.80 ±0.92f	0.73 ±0.12h	24.73±0.85d-f
H_1V_4	12.27 ±0.31c	1.07 ±0.18g	25.22 ±0.6cd
H_2V_1	18.60 ±4.01a	1.73 ±0.29d	24.65±1.5d-f
H_2V_2	14.37±1.67b	0.73 ±0.12h	27.89 ±0.32a
H_2V_3	10.27 ±0.6de	0.33 ±0.06j	24.11±0.37f-h
H_2V_4	14.40 ±1.22b	1.67 ±0.28d	25.18 ±0.66cd
H_3V_1	17.50 ±3.12a	1.87 ±0.31c	24.51±0.67e-g
H_3V_2	12.46 ±0.83c	1.27 ±0.21f	27.32 ±0.92a
H_3V_3	10.66 ±3.2de	4.67 ±0.78a	22.85±1.4i
H_3V_4	12.77 ±2.12c	0.88±0.13h	26.62±0.66b
SE ±	0.73	0.06	0.30
CV(%)	5.73	5.14	1.49

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

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1};V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

4.8.4 Number of filled grains panicle^{-1}

Effect of herbicide

Herbicide application significantly influenced number of filled grains panicle^{-1} of T. aman rice (Fig.29). Experiment result showed that experiment plot treated with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide was recorded the maximum number of filled grains panicle^{-1} (165.24) while weedy check plot recorded the minimum number of filled grains panicle^{-1} (142.24) which was statistically similar with plot treated with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide (148.20) and with Bispyribac-sodium WP @ 150 g ha^{-1} herbicide (148.04). The differences of filled grains panicle^{-1}among different treatment might be that the weed free situation at early stage favored the vigorous growth of seedling, without any crop weed competition and sustained nutrient availability leads to better uptake of NPK by the crop might have contributed to synchronous tillering and spikelet formation leading to higher number of panicles m^{-2} and higher post flowering photosynthesis and higher number of filled grains panicle^{-1}. The result obtained from the present study was similar with the findings of Teja *et al.* (2017) who reported thateffective and timely management of weeds through effective herbicides application facilitated the crop plants to have sufficient space, light, nutrient and moisture and thus the yield components like number of filled grains per panicle increased.

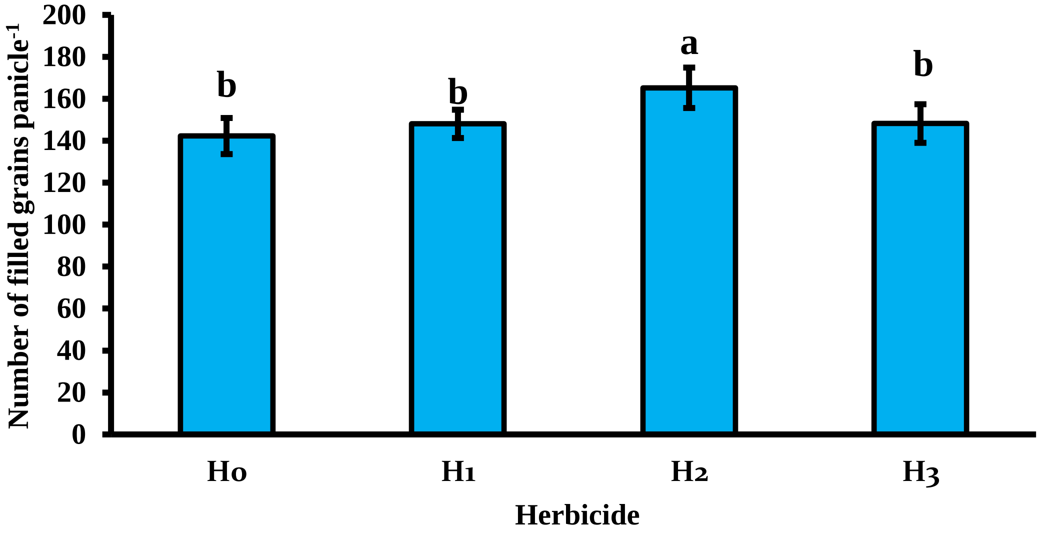


Figure 29. Effect of herbicide on number of filled grains panicle^{-1}of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

It is clear from the experiment data that different rice variety significantly influenced number of filled grains panicle^{-1} of T. *aman* rice (Fig.30). Results showed that among different rice varieties, BR11 rice variety recorded the maximum number of filled grains panicle^{-1} (189.55) while cultivation of Chinigura rice variety recorded the minimum number of filled grains panicle^{-1} (116.12). The result obtained from the present study was similar with 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.

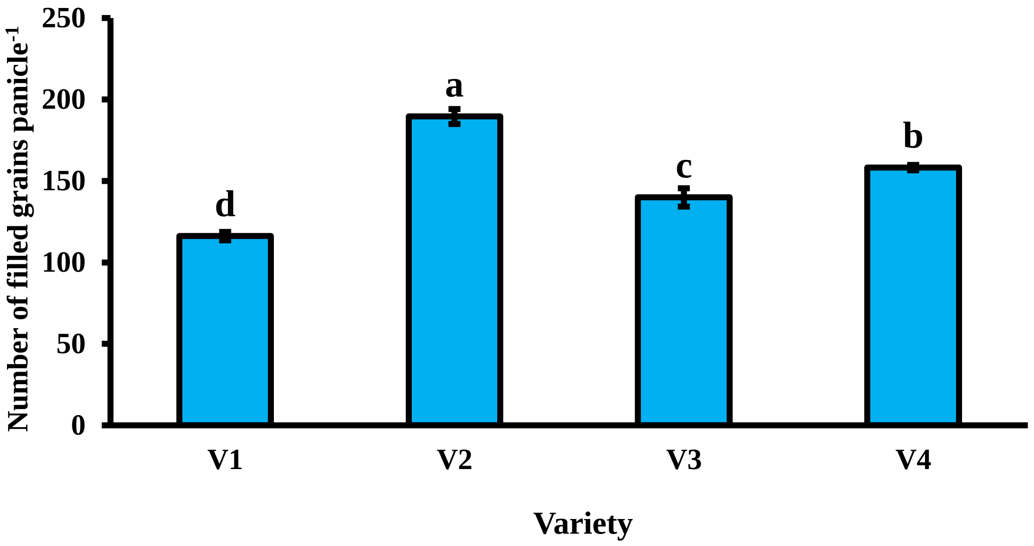


Figure 30. Effect of variety on number of filled grains panicle^{-1}of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Filled grains panicle^{-1} significantly influenced by the combined effect of herbicide and rice variety (Table 13). Form the experiment data showed that the maximum number of filled grains panicle^{-1} (212.20) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide treated plot along with BR11 rice variety while the minimum number of filled grains panicle^{-1} (102.14) was recorded under weedy check plot along with Chinigura.

4.8.5 Number of unfilled grains panicle^{-1}

Effect of herbicide

Among the undesirable traits, number of unfilled grains panicle^{-1} was important one and played a vital role in yield reduction. Different herbicide application significantly influenced number of filled grains panicle^{-1} of T. aman rice (Figure. 32). Experiment result revealed that among all the treatments, the maximum number of unfilled grains panicle^{-1} was recorded under weedy check (34.66) which was statistically similar with Bispyribac sodium WP @ 150 g ha^{-1} herbicide treated plot (33.23) and it reduced significantly with effective mixed herbicide treatment to weeds control population. The minimum number of unfilled grains panicle^{-1}(27.79) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide treated plot. Weeds management through effective mix herbicides application reduced weed density and increasing better resources utilization of the plant growth and development which increasing filled grains and reduced unfilled grains panicle^{-1} comparable to weedy check treatment.

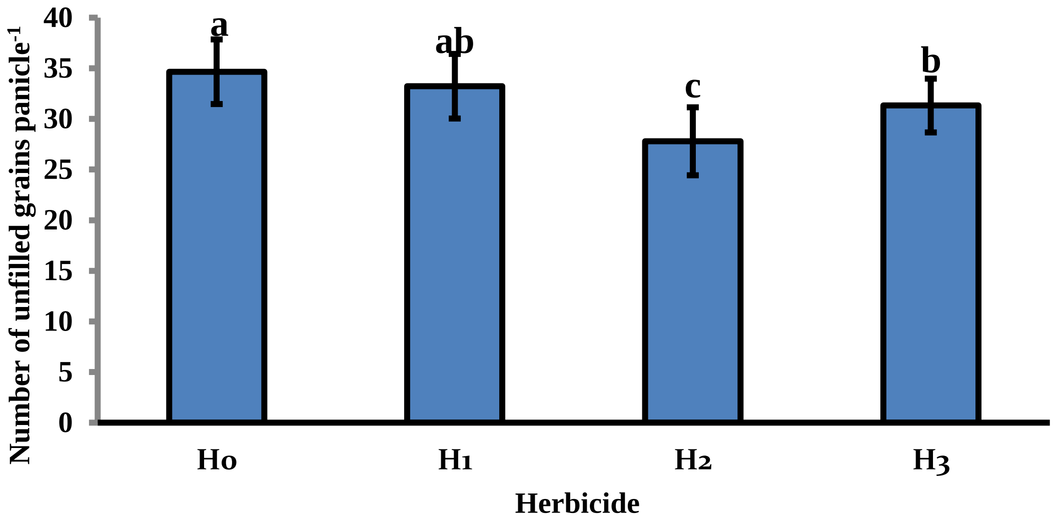


Figure 31. Effect of herbicide on number of unfilled grains panicle^{-1} of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

Different rice variety showed significant effect on number of unfilled grains panicle^{-1} (Figure. 33). Experiment result revealed that the maximum number of unfilled grains panicle^{-1} (42.52) was recorded under Chinigura while the minimum number of unfilled grains panicle^{-1} (21.44) was recorded in BR11 rice which was statistically similar with BRRI dhan56 (22.64). Similar result also found by Nahida *et al.* (2013) and reported that variation in number of unfilled grains panicle^{-1} might be due to genetic characteristics of the varieties. Sohel *et al. (*2009) also reported that difference in spikelets sterility varied significantly by variety and plant spacing.

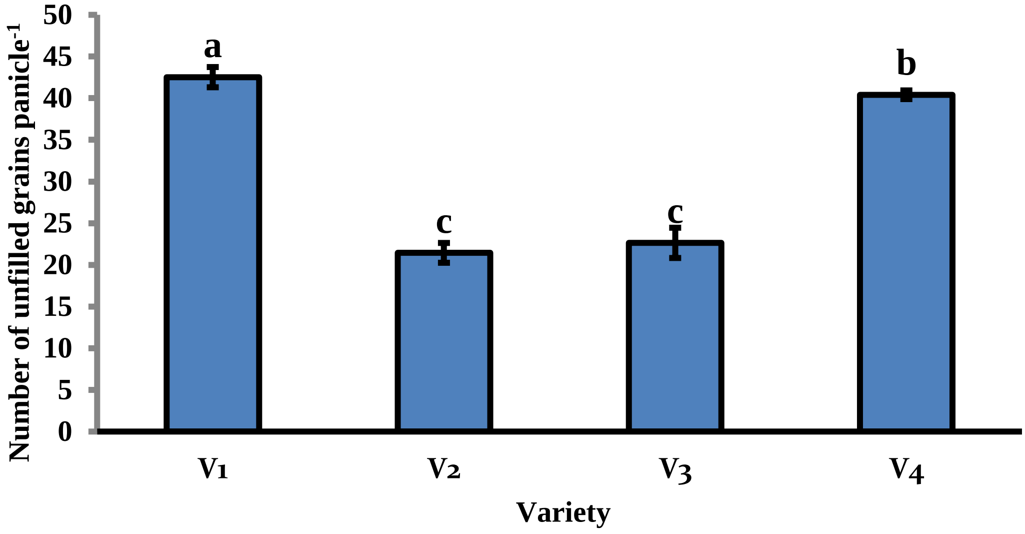


Figure 32. Effect of variety on number of unfilled grains panicle^{-1} of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Unfilled grains panicle^{-1} significantly influenced by the combined effect of herbicide and rice variety (Table 13). Form the experiment result data showed that the maximum number of unfilled grains panicle^{-1} (47.52) was recorded under weedy check plot along with Chinigura while the minimum number of unfilled grains panicle^{-1} (16.59) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 which was statistically similar with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BRRI dhan56 (16.90), weedy check plot along with BR11 and (19.01) and Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with BRRI dhan56.

4.8.6 Total spikelets panicle^{-1}

Effect of herbicide

Different herbicide application significantly influenced total grains panicle^{-1} of T. aman rice (Fig.33). the results showed that among different herbicide application treatment the highest number of total spikelets panicle^{-1} (181.27) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide while the weedy check recorded the lowest number of total spikelets panicle^{-1} (176.90) which was statistically similar with all others treatment except Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide. Similar result also observed by Hossain (2015) who reported that herbicide treated plot increasing total grains panicle^{-1} over weedy check or control plot.

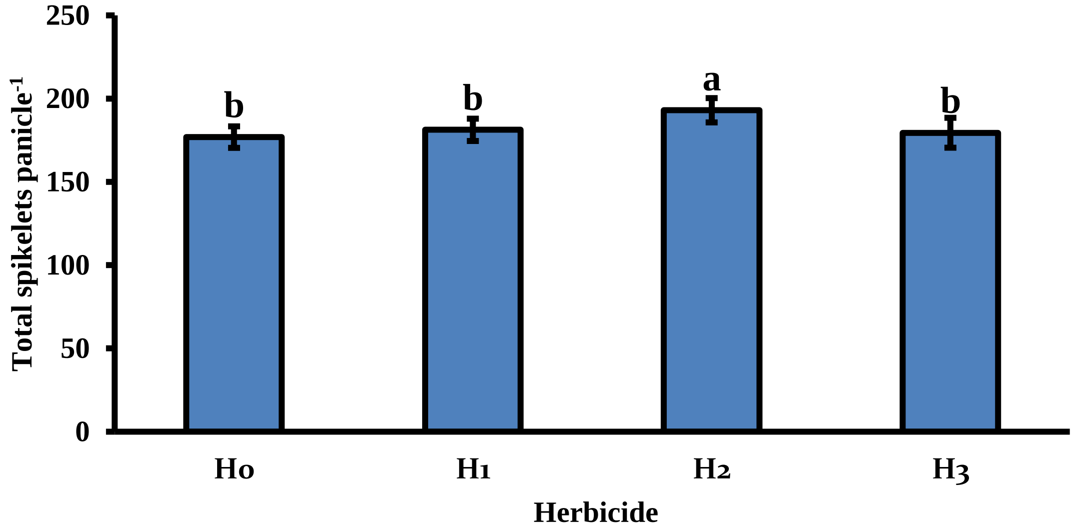


Figure 33. Effect of herbicide on number of total spikelets panicle^{-1} of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}

Effect of variety

Total spikelets panicle^{-1} significantly influenced by different rice varieties (Fig.34). Among different rice varieties, BR11 recorded the highest number of total spikelets panicle^{-1} (210) while the lowest number of total spikelets panicle^{-1}(158.64) was recorded in Chinigura which was statistically similar with BRRI dhan56 rice (162.51).

Similar result also observed by Jisan *et al.* (2014) who reported that total grains panicle^{-1}significantly differ among different rice varieties. Roy *et al.* (2014) also reported that the number of spikelets per panicle in indigenous rice is generally lower compared to high yielding varieties.

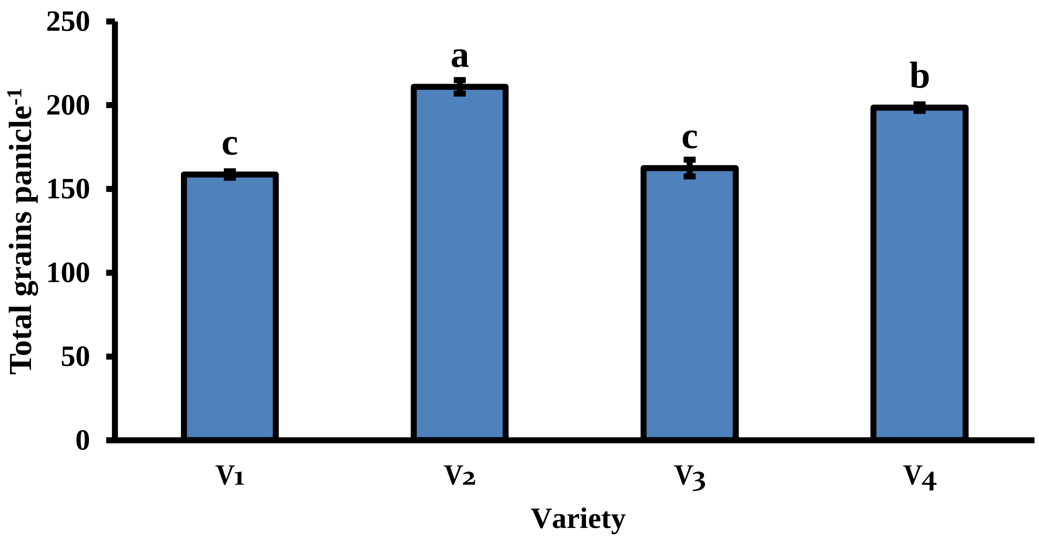


Figure 34. Effect of variety on number of total grains panicle^{-1} of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

It is clear from the experiment result that the total spikelets panicle^{-1} significantly influenced by the combined effect of herbicide and rice variety (Table 13). Experiment result showed that the highest number of total spikelets panicle^{-1} (228.79) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} along with BR11 (217.72) while the lowest number of total spikelets panicle^{-1} (142.40) was recorded under Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} along with BRRI dhan56 which was statistically similar with weedy check plot along with Chinigura (149.65).

4.8.7 1000- grain weight (g)

Effect of herbicide

It is obvious from the experiment result that the 1000 grains weight significantly varied due to different herbicide treatment (Fig.35). Among all the treatments, weedy check plot recorded the minimum 1000 grains weight (19.28 g) which enhanced significantly with different herbicide application. The maximum 1000 grains weight (21.97 g) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide treated plot which was statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide treated plot (21.57 g) and Bispyribac-sodium WP @ 150 g ha^{-1} herbicide (21.08 g) H_1 (Bispyribac-sodium) treatment. Jabran *et al.* (2012) also found similar results with the present study and reported that the highest 1000 grains weight (22.5 g) of rice was observed in weed free condition and the lowest 1000 grains weight was observed in weedy check.

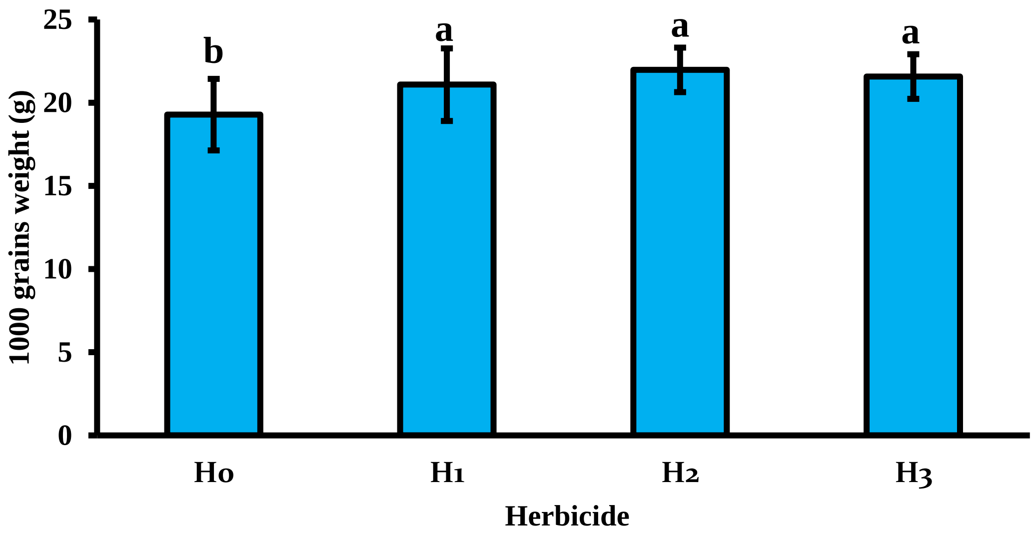


Figure 35. Effect of herbicide on 1000- grain weight of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

Different rice variety significantly affected on 1000 grains weight of rice (Fig.36). Experiment result revealed that the maximum 1000 grains weight (25.08 g) was recorded in BR11 which was statistically similar with BRRI hybrid dhan6 (24.52 g) while the minimum 1000 grains weight (11.52 g) was recorded in Chinigura. The differences of the 1000 grains weight among different rice varieties may be attributes to the varietal performance and genetic makeup of the varieties. Khatun *et al.* (2020); Roy *et al.* (2014) and Aminpanah *et al.* (2013) found similar result which supported the present study and reported that different rice varieties showed different 1000 grains weight which is due to morphological and varietal variation.

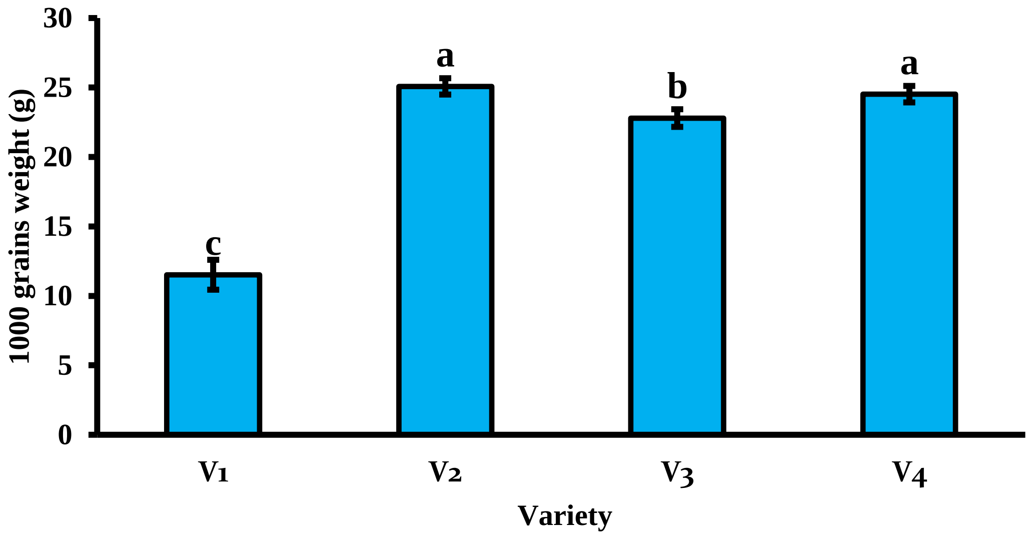


Figure 36. Effect of variety on 1000 grains weight of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Combined effect of herbicide and rice variety showed significant effect on 1000 grains (Table 13). Experiment result revealed that the maximum 1000 grains weight (25.67 g) was recorded under Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 which was statistically similar with Bispyribac-sodium WP @ 150 g ha^{-1} herbicide treated plot along with BR11 (25.47 g), Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with BRRI hybrid dhan6 (25.03 g), Pretilachlor 6% + Pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BR 11(25.00 g), Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with BRRI dhan56 (24.93 g), Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BRRI hybrid dhan6(24.70 g), Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BRRI hybrid dhan6 (24.50 g) and weedy check plot along with BR11 (24.17 g)while the minimum 1000 grains weight (7.33 g) was recorded under weedy check plot along with Chinigura which was statistically similar with Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with chinigura.

Table 13. Combined effect of herbicide and rice variety on filled, unfilled, total grains panicle^{-1} and 1000 grains weight of T. *aman* rice

Treatment Combinations	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Total grains panicle^{-1} (no.)	1000 grains Weight (g)
H_0V_1	102.14 ±2.13i	47.52 ±1.05a	149.65±3.19ef	7.33 ±0.67f
H_0V_2	176.77 ±1.47c	19.01±1.29hi	195.78±2.76d	24.17 ±2.2ab
H_0V_3	130.59±1.73g	32.24±1.5e	162.83±3.22e	21.80 ±1.98d
H_0V_4	159.44±4.69e	39.88±0.43cd	199.32±5.12d	23.83±2.17bc
H_1V_1	117.51 ±2.61h	43.62 ±2.98b	161.13±5.59e	8.90 ±0.81f
H_1V_2	175.13±2.04c	26.54 ±0.63f	201.67±2.66c	25.47±2.32a
H_1V_3	139.04±6.7f	19.56±1.57hi	158.60±8.27e	24.93 ±2.27ab
H_1V_4	160.44±9.35e	43.20±0.47bc	203.68±9.81c	25.03±2.28ab
H_2V_1	123.83±0.24h	38.63±2.9d	162.47±3.15e	15.17±1.38e
H_2V_2	212.20±4.89a	16.59 ±0.86i	228.79±5.75a	25.67±2.33a
H_2V_3	169.29±5.42cd	16.90±0.47i	186.19±5.9d	22.36 ±2.03cd
H_2V_4	155.63±5.11e	39.05±0.44d	194.67±5.6cd	24.70±2.26ab
H_3V_1	121.01±2.55gh	40.29±3.06b-d	161.31±5.6e	14.67 ±1.33e
H_3V_2	194.12±1.35b	23.61±0.08fg	217.72±1.43b	25.00±2.28ab
H_3V_3	120.54±4.67gh	21.86 ±3.05gh	142.40±7.72f	22.10±2.01d
H_3V_4	157.12±3.31de	39.51 ±0.79d	196.63±4.11cd	24.50 ±2.23ab
SE ±	4.35	1.55	3.70	0.88
CV(%)	4.98	6.77	4.89	4.46

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, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}. V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

4.9 Yields characters

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

Effect of herbicide

Grain yield of rice was significantly influenced due to different herbicide application. It is clear from the result that different herbicide treatments caused marked variations in grain yield of rice (Fig. 37). The grain yield was lowest in weedy check plots (3.25 t ha^{-1}) where weeds were allowed to grow throughout the crop season but it was increased when effective herbicides were applied. Among different herbicide treatments Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide recorded maximum grain yield (4.49 t ha^{-1}) and it is superior over all other herbicide treatment for weed control. Effective mix herbicide affected on wide range of weed species causing reduction of weed density comparable to single or others low effective mix herbicide application. Similar result observed by Suryakala *et al.* (2019) who reported that grain yield production was lower in un weeded control, respectively indicating the importance of weed management in the critical growth period of crop by herbicide application, which facilitated the efficient use of resources. Hossain and Mondal (2014) also reported that tank-mix application of bispyribac + ethoxysulfuron, pretilachlor fb metsulfuron-methyl + chlorimuron-ethyl and pretilachlor + bensulfuron resulted in more rice grain yield than their sole application. Mastana *et al.* (2012) reported better performance of herbicide combination in controlling weeds and increasing yield in transplanted rice.

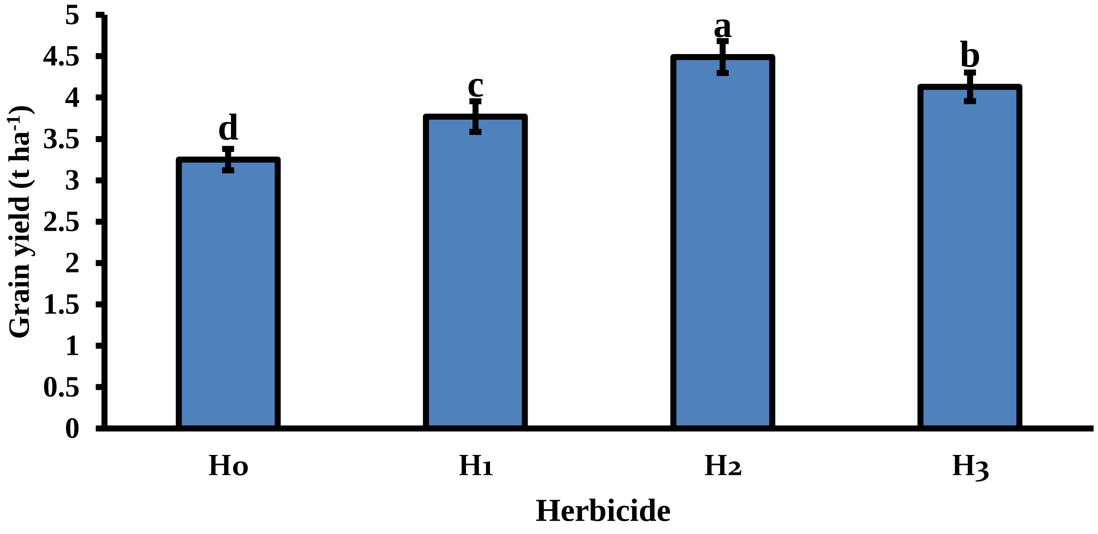


Figure 37. Effect of herbicide on grain yield of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

Different rice varieties significantly influenced grain yield (Fig. 38). Experiment result showed that among different rice varieties BR11 rice variety recorded the maximum grain yield (4.71 t ha^{-1}) due to reason that filled grains per panicle along with maximum 1000-seed weight collectively contributed to higher grain yield while Chinigura recorded the minimum grain yield (2.63) compared to others varieties. Different rice variety have individual genetic makeup which influenced the growth and yield among different varieties. The result obtained from the present study was similar with the findings of Islam *et al.* (2013) who reported that the varieties which produced higher 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 higher number of effective tillers per hill and higher number of grains per panicle also showed higher grain yield in rice.

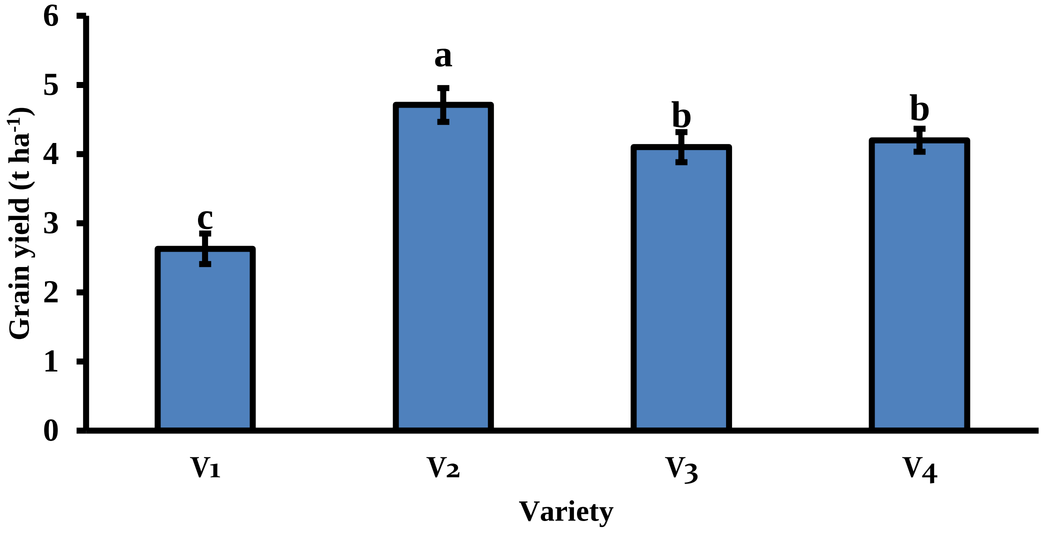


Figure 38. Effect of variety on grain yield of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = B 11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Grain yield significantly influenced due to the combined effect of herbicide and rice variety (Table 12). It is clear from the experiment data that Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 rice variety cultivation recorded the maximum grain yield (5.57) while weedy check plot along with Chinigura recorded the minimum grain yield (2.26 t ha^{-1}) which was statistically similar with Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with Chinigura (2.32 t ha^{-1}).

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

Effect of herbicide

After removing grains from the panicle the rest part were considered as straw. It is evident from the data that the weed control through different herbicide treatments caused significantly varied on straw yield of rice (Fig.39). The straw yield was minimum in weedy check plots (5.69 2.26 t ha^{-1}) where weed control measures were not adopted throughout crop season, and it is statistically similar with Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide (5.64 t ha^{-1}) and Bispyribac sodium WP @ 150 g ha^{-1} herbicide (5.74 t ha^{-1}) but worthy increment in plot receiving Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide and recorded maximum straw yield (6.38 t ha^{-1}). Hossain (2015) also found similar result which supported the present finding and reported that the straw yield of rice differ, due to application of different mix herbicide comparable to weedy check.

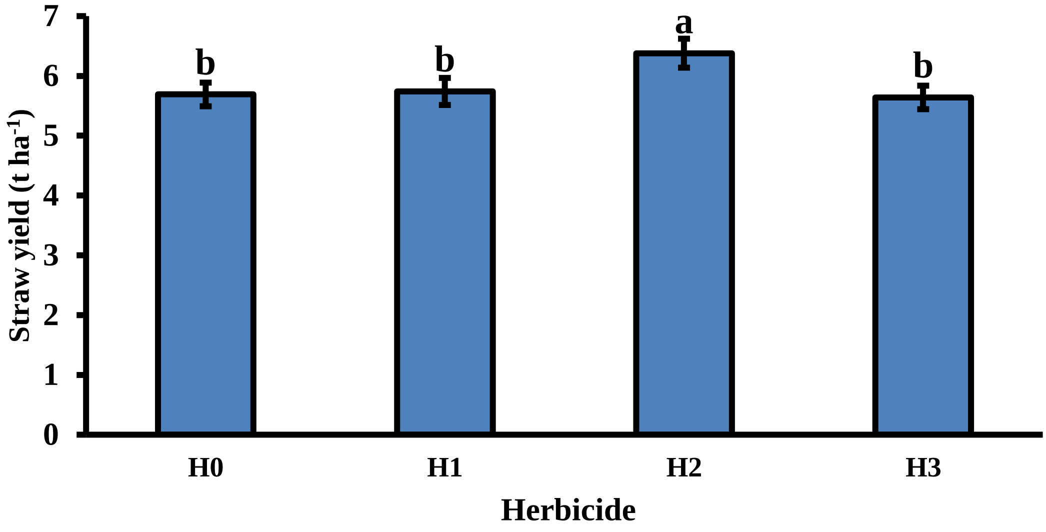


Figure 39. Effect of herbicide on straw yield of T. *aman* rice.

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of variety

It is evident from the data that different rice variety caused significantly varied on straw yield of rice (Fig.40). Among different rice variety BR11 rice recorded the maximum straw yield (6.40 t ha^{-1}) while Chinigura recorded the minimum straw yield (5.13 t ha^{-1}). The differences of straw yield may be attributed to the genetic makeup and variation of the different rice varieties. Mahmud *et al.* (2017) and Tyeb *et al.* (2013) also found similar result and they reported that the variation in straw yield due to the effect of varietal differences.

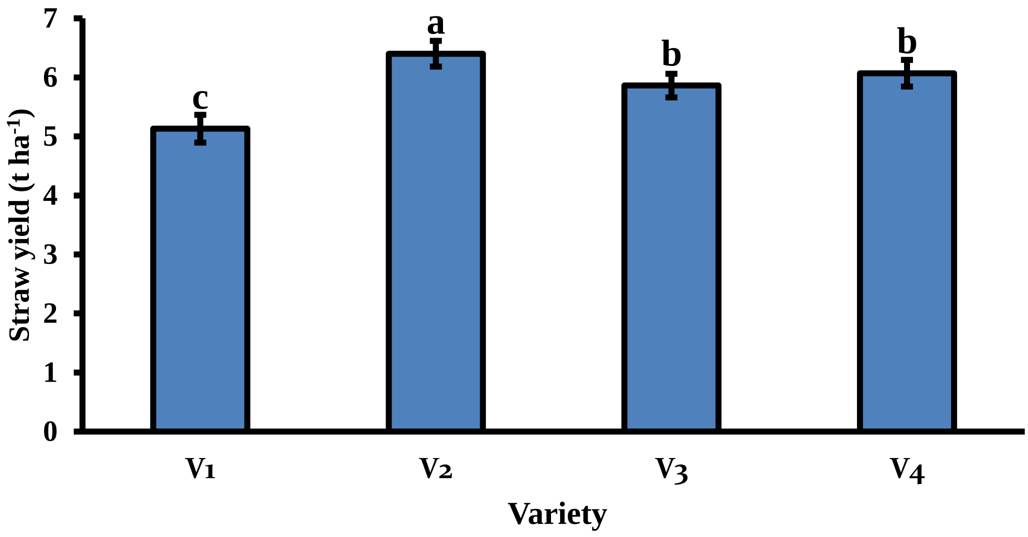


Figure 40. Effect of variety on straw yield of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Straw yield significantly influenced due to the combined effect of herbicide and rice variety (Table 12). Experiment result revealed that the maximum straw yield (6.76 t ha^{-1}) was recorded under Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide treated plot along with BR11 rice variety which was statistically similar with Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide treated plot along with Chinigura rice (6.71 t ha^{-1}), Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with BR11 (6.58 t ha^{-1}) and Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with BRRI hybrid dhan6. While the minimum straw (4.21 t ha^{-1}) was recorded under Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with Chinigura which was statistically similar with weedy check plot along with Chinigura (4.79 t ha^{-1}) and Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with Chinigura.

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

Effect of herbicide

It is evident from the data that the weed control through different herbicide treatment caused significantly varied on biological yield of rice (Fig.41). The biological yield was minimum in weedy check plots (8.94 t ha^{-1}) where weed control measures were no adopted throughout crop season, but worthy increment was noticed when Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide applied to the plots. It was significantly superior over other herbicide treatments and recorded the maximum biological yield (10.87 t ha^{-1}). The result obtained from the present study was similar with the findings of Hasanuzzaman *et al.* (2008) who observed that the yield (grain, straw and biological yield) and the yield contributing characters were influenced by the effectiveness of the herbicidal treatments.

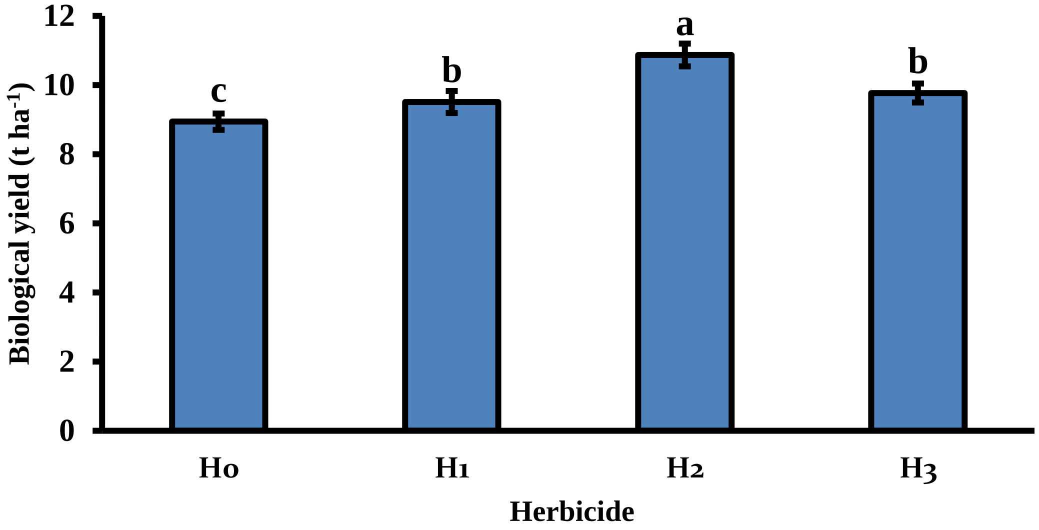


Figure 41. Effect of herbicide on biological yield of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of rice variety

Different rice variety caused significantly varied on biological yield of rice (Fig.42). Among different rice variety BR11 recorded the maximum biological yield (11.11 t ha^{-1}) while Chinigura recorded the minimum biological yield (7.75 t ha^{-1}). The differences of straw yield may be attributed to the genetic makeup and variation of the different rice varieties. Hossain *et al.* (2014b) found similar results with the present study and reported that, the variation in biological yield was also found due to the variation in grain and straw yield.

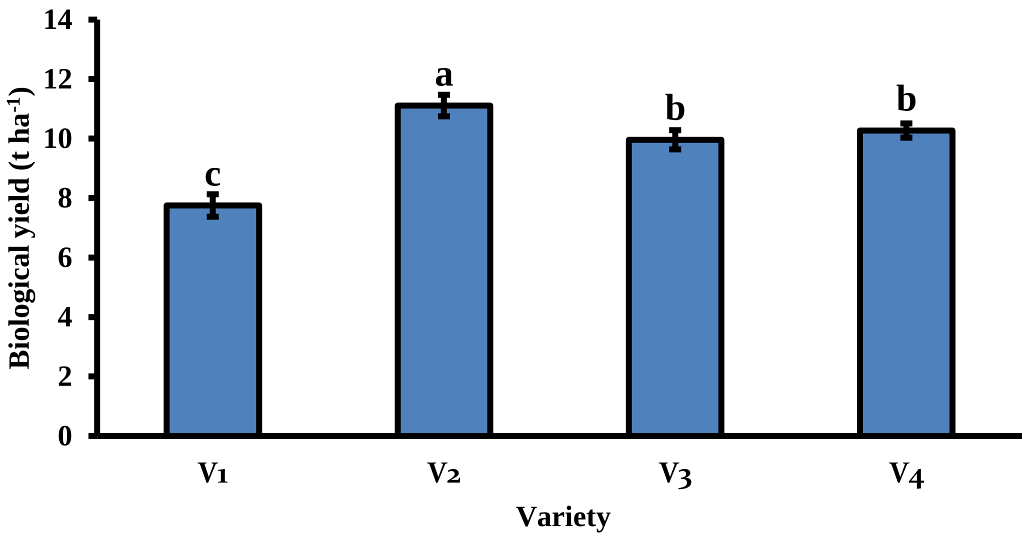


Figure 42. Effect of herbicide on biological yield of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Biological yield was significantly influenced due to the combined effect of herbicide and rice variety (Table 14). Experiment result revealed that the maximum biological yield (12.33 t ha^{-1}) was recorded under Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 while the minimum biological yield (6.53 t ha^{-1}) was recorded under Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with Chinigura which was statistically similar with weedy check plot along with Chinigura (7.05 t ha^{-1}).

4.9.4 Harvest index (%)

Effect of herbicide

Different herbicide treatment had significantly affected on harvest index of rice (Figure. 43). The harvest index was minimum in weedy check plots (36.00 t ha^{-1}) where weed control measures were no adopted throughout crop season, but worthy increment was noticed when mixed herbicides were applied to the plots. Experiment data showed that Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide recorded the maximum harvest index (42.02 %) which was statistically similar with Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide(40.87 %).The variation of harvest index which was due to reason that the effective weed control in mixed herbicide treatment 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 weedy check. Hossain (2015) also found similar result which supported the present finding.

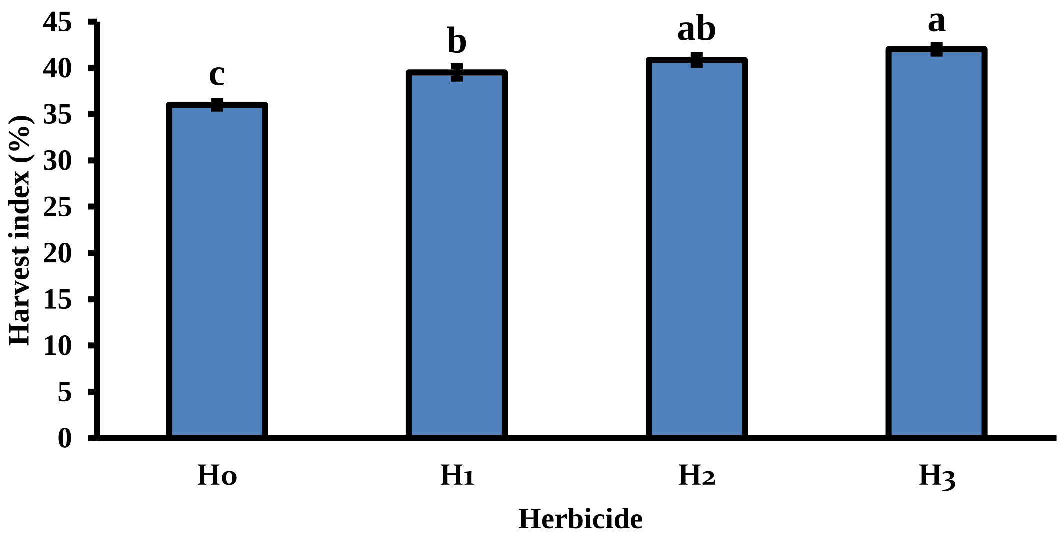


Figure 43. Effect of herbicide on harvest index of T. *aman* rice (Bars representative ±SD values obtained from three biological replicates).

Here, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}.

Effect of rice variety

It is evident from the data that different rice variety caused significantly variation on harvest index of rice (Fig.44). Among different rice variety BR11 rice variety cultivation recorded the maximum harvest index (42.17 %) which was statistically similar with BRRI dhan56 (40.98 %) and BRRI hybrid dhan6 (40.98 %) while Chinigura recorded the minimum harvest index (34.27 %). Chowhan *et al.* (2019) also found similar result which supported the present finding and reported that hybrid rice maintained higher harvest index. Uddin *et al.* (2011) reported that the harvest index differed significantly among the varieties due to its genetic variability. Shah *et al.* (1991) reported that variety had a great influence on harvest index.

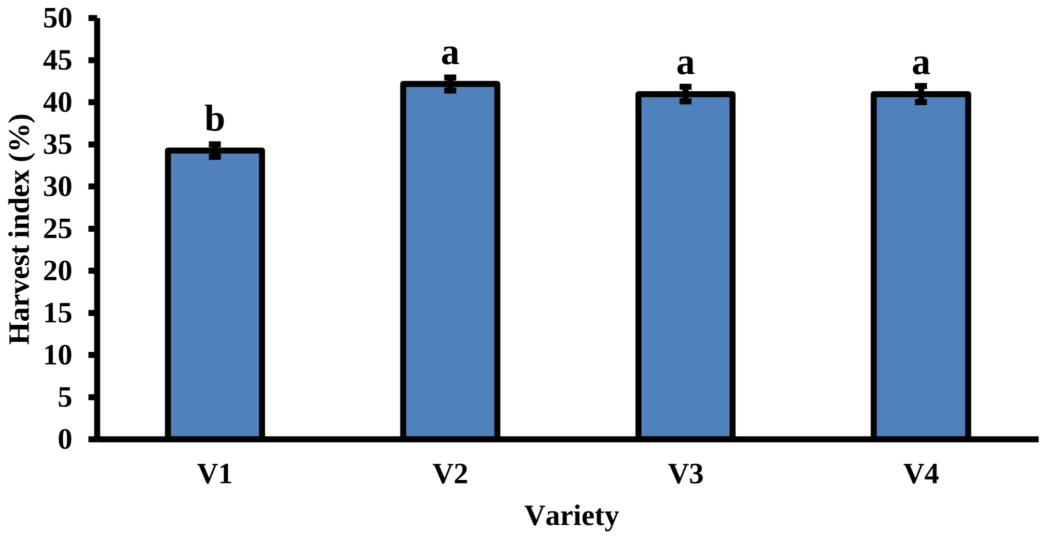


Figure 44. Effect of variety on biological yield of T. *aman* rice (LSD$_{(0.05)}$ = 1.77) (Bars representative ±SD values obtained from three biological replicates).

Here, V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

Combined effect of herbicide and rice variety

Harvest index was significantly influenced due to the combined effect of herbicide and rice variety. Experiment result revealed that the maximum harvest index (45.09 %) was recorded under Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 which was statistically similar with Acitachlor 14%

+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BRRI hybrid dhan6 rice variety cultivation (44.14%), Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BR11 (43.82 %), Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BRRI hybrid dhan6 (43.63 %), Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BRRI dhan56 (43.49 %) and Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide along with BRRI dhan56 rice variety cultivation (42.63) while the minimum harvest index (30.75 %) was recorded under under Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along Chinigura rice variety which was statistically similar with weedy check plot along with Chinigura (32.00 %).

Table 14. Combined effect of herbicide and rice variety 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 (%)
H_0V_1	2.26±0.41g	4.79±0.72e	7.05 ±0.75fg	32.00 ±0.86f
H_0V_2	3.78 ±0.47e	5.94± 0.74b-d	9.72 ±0.81de	38.89 ±0.93de
H_0V_3	3.26±0.41f	5.70 ±0.71cd	8.96 ±0.75e	36.38 ±0.87e
H_0V_4	3.68±0.46e	6.34±0.79a-c	10.02 ±0.84cd	36.73 e±0.87e
H_1V_1	2.32±0.42g	4.21 ±0.74e	6.53±0.77g	36.35 ±0.86e
H_1V_2	4.55±0.57c	6.58±0.82ab	11.13±0.93b	40.88 ±0.97b-d
H_1V_3	3.98 ±0.5de	5.63 ±0.7d	9.61 ±0.8de	41.42 ±0.97b-d
H_1V_4	4.24±0.53cd	6.52±0.82ab	10.76 ±0.9bc	39.41± 0.94c-e
H_2V_1	2.98 ±0.6f	6.71 ±0.86a	9.69 ±0.97de	30.75±0.98f
H_2V_2	5.57±0.7a	6.76±0.85a	12.33±1.03a	45.09±1.07a
H_2V_3	4.88±0.61b	6.34±0.79a-c	11.22±0.94b	43.49±1.04ab
H_2V_4	4.52±0.57c	5.72 ±0.72cd	10.24±0.85cd	44.14 ±1.05ab
H_3V_1	2.94 ±0.49f	4.80±0.73e	7.74 ±0.81f	37.98±0.96de
H_3V_2	4.93 ±0.62b	6.32±0.79a-c	11.25 ±0.94b	43.82±1.04ab
H_3V_3	4.28±0.53cd	5.76 ±0.72cd	10.04±0.84cd	42.63±1.01 a-c
H_3V_4	4.36±0.54c	5.69 ±0.72cd	10.05±0.84cd	43.63±1.04ab
SE ±	0.11	0.31	0.38	0.45
CV(%)	4.84	6.61	4.87	5.31

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, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}. V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

4.10 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. It was evident from the Fig. 45 and 46 that the regression equation y = 0.912x +0.855 and y = 27.81x + 9.304 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.542 and 0.700) 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 T. *aman* rice. Grain yield and total try matter production depends on leaf area index as leaf area index measure of the photosynthetic active area, and at the same time of the area subjected to transpiration. It is also the area which becomes in contact with air pollutants. The LAI is further an indication of how much light is coming through the canopy. The energy light that plants absorb from the Sun through leaf area is the energy supply for the building of simple sugars that are then converted into starch for storage. The plant can then use this energy store to grow and grain production. In the present experiment the yield and yield contributing character were significantly varied due to application of different herbicide and rice variety and among different treatment combination maximum leaf area index was recorded under Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 rice variety cultivation. Due to leaf area increased grain yield and total dry matter production increased 54.2 % and 70 %, respectively.

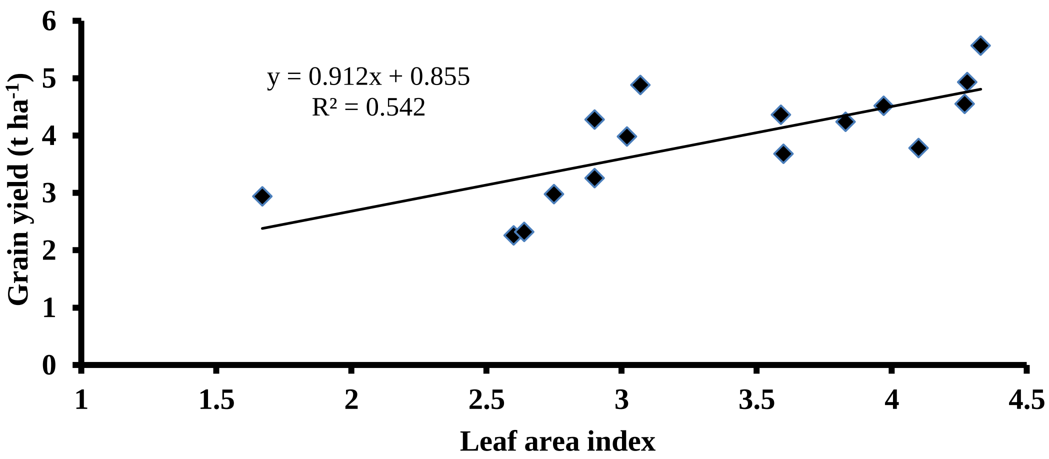


Figure. 45. Relationship between leaf area index (LAI) and grain yield.

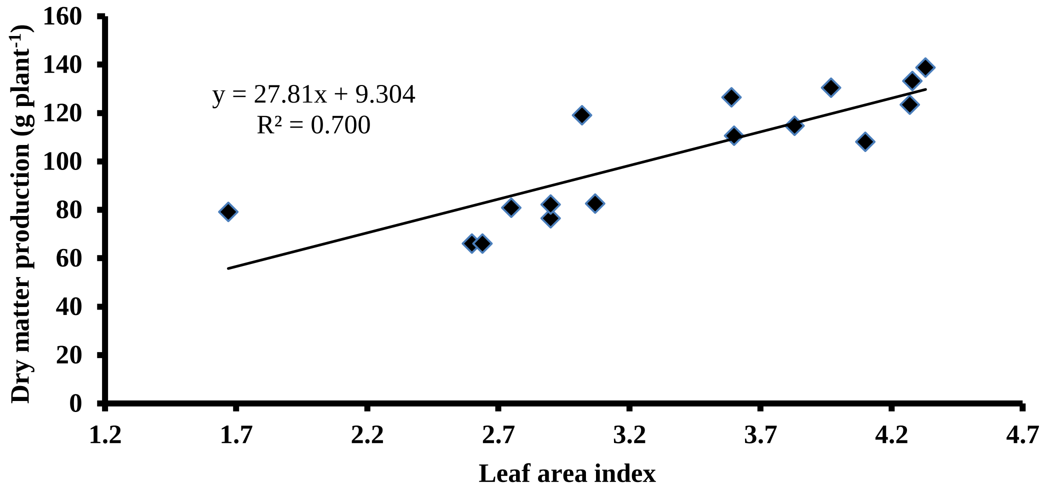


Figure 46. Relationship between leaf area index (LAI) and total dry matter production.

4.11 Correlation of grain yield with panicle length, grains panicle^{-1} and 1000-grain weight and weed control efficiency

From the (Figure.48, 49 and 50) it was noticed that grain yield was positively correlated with panicle length (R^2=0.515) grains panicle^{-1} (R^2=0.530), 1000-grains weight (R^2=0.736) andweed control efficiency (R^2=0.265). From the correlation study, it appears that grain yield increase with increasing panicle length, grains panicle^{-1} and 1000 grains weight. And in this experiment maximum grain yield was recorded under Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide treated plot along with BR 11 rice variety cultivation.

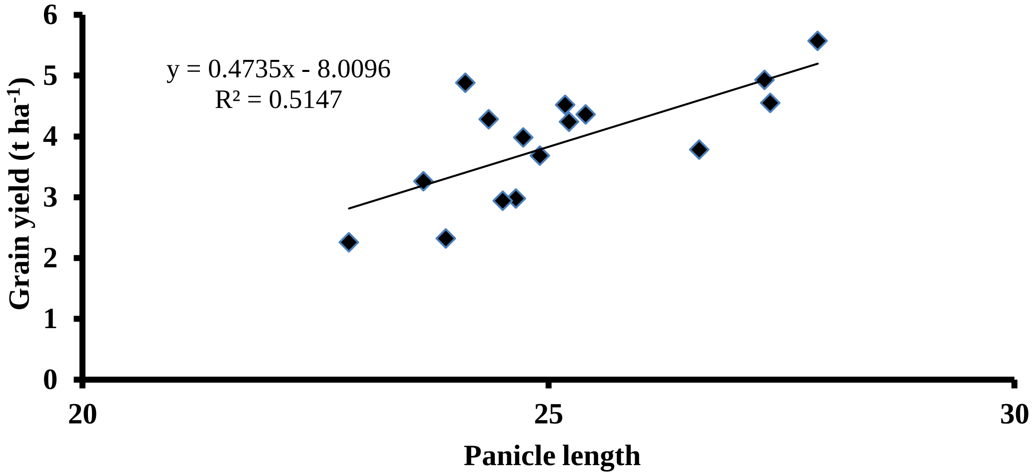


Figure 47. Relationship between panicle length and grain yield

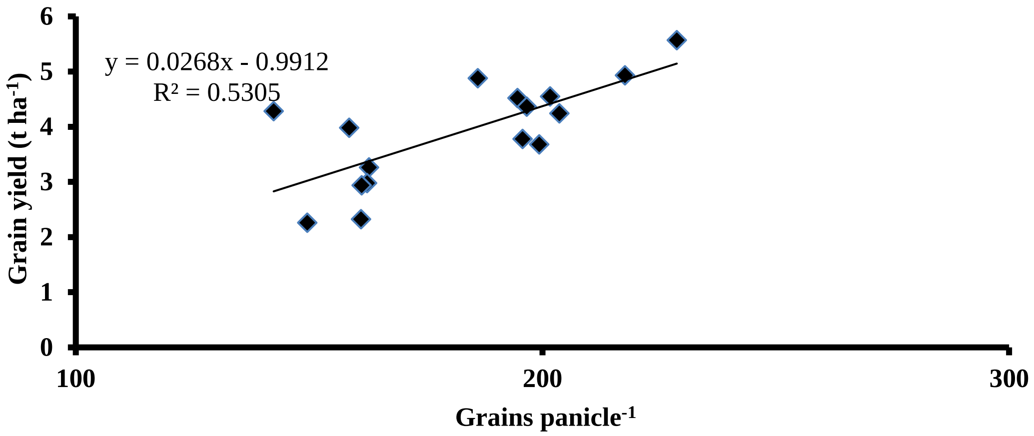


Figure. 48. Relationship between grains panicle^{-1}and grain yield

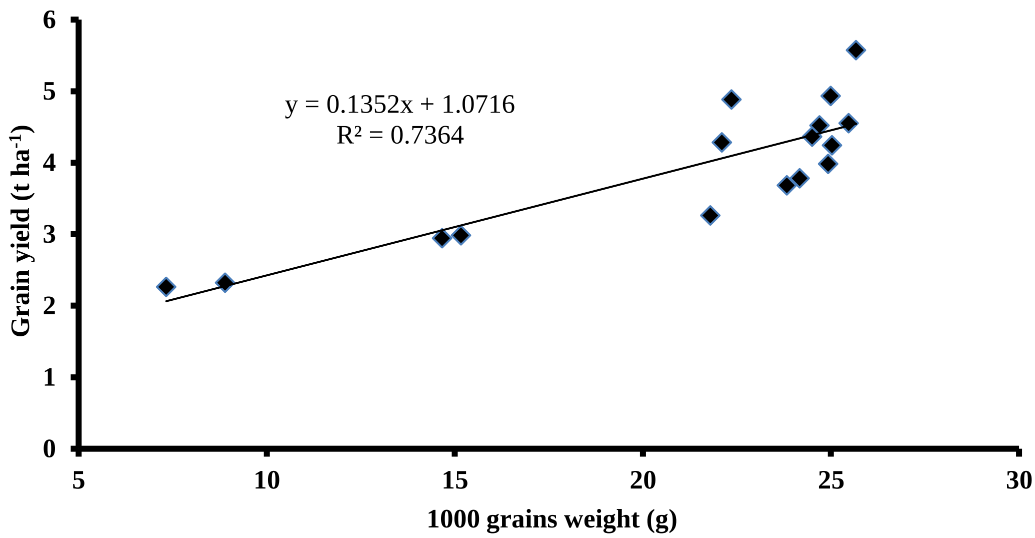


Figure 49. Relationship between 1000 grains weight and grain yield

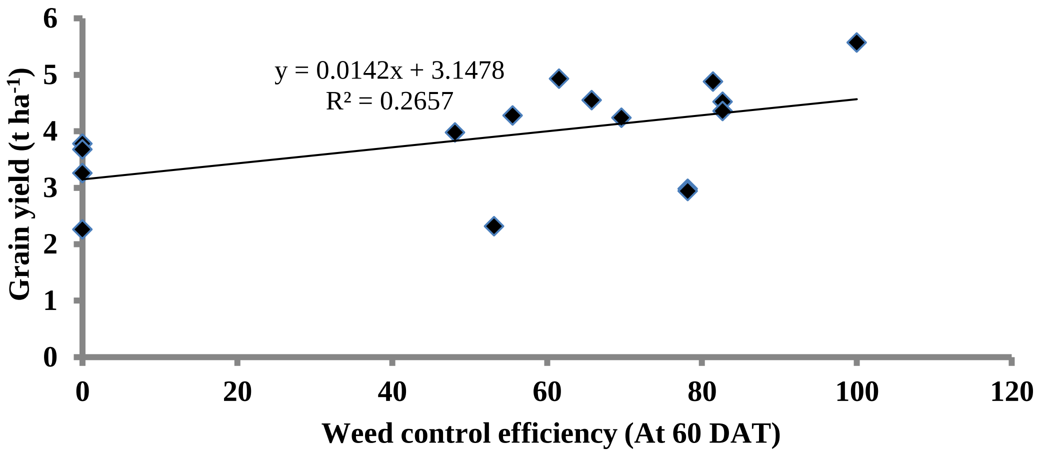


Figure 50. Relationship between weed control efficiency and grain yield

4.12 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 15).

4.12.1 Total cost of production

Cost of production varied due to different herbicide application and rice variety cultivation. The cost of production was varied mainly for the herbicide application. In case of weedy check, there was no involvement of cost for herbicide application. In this experiment highest total cost of production was occurred in Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} mixed herbicide application along different rice variety cultivation and lowest in weed check field along with different rice variety cultivation.

4.12.2 Gross return (Tk)

Gross return was influenced by different herbicide treatments along with different rice variety. The highest gross return (146010 taka) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 while the minimum (61290 taka) in weedy check plot along with Chinigura.

4.12.3 Net return (Tk)

Net return was varied by different herbicide treatments along with different rice variety. The highest net return (88699 taka) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 while the minimum (4849 taka) in Bispyribac sodium WP @ 150 g ha^{-1} herbicide along with Chinigura.

4.12.4 Benefit cost ratio (BCR)

Benefit cost ratio varied in different herbicide treatment along with different rice variety. The highest benefit cost ratio (2.55) was recorded under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 due to reason that higher grain yield (5.57 t ha^{-1}), straw yield (6.76 t ha^{-1}) and lower weed density (0.11) and weed biomass (0.33) per meter square were recorded under this treatment combination while the minimum (1.08) in Bispyribac-sodium WP @ 150 g ha^{-1} herbicide along with Chinigura. Due to reason that effective mix herbicide reduced wide density weed population while helps plant to higher production due to less weeds competition on the other hand single herbicide reduce weed density of one or two species which helps to grow others weeds and they grow vigorously and consume more resources result in poor growth of the crop plant. This result supports the findings of Salam *et al.* (2020) who reported that benefit cost ratio varied among different rice varieties. Sunil *et al.* (2010) also reported that pre-emergence application of application of bensulfuron methyl + pretilachlor (6.6 GR) @ 0.06 + 0.6 kg ha^{-1} + one inter cultivation at 40 DAS recorded significantly higher grain and straw yields (4425 and 5020 kg ha^{-1}), lower weed population and dry weight (17 and 2.32 g m^{-2}). This treatment also resulted in higher net returns and B:C ratio.

Table 15. Cost of production, return and Benefit cost ratio (BCR) of transplanted aman rice varieties *i.e*, Chinigura, BR11, BRRI dhan56 and BRRI hybrid dhan6 under different treatments

Treatment Combinations	Fixed variable cost	Herbicide application cost	Total cost of production	Gross return (Tk)	Net return (Tk)	BCR
H_0V_1	55865	0	55865	61290	5425	1.10
H_0V_2	55865	0	55865	100440	44575	1.80
H_0V_3	55865	0	55865	87200	31335	1.56
H_0V_4	55865	0	55865	98340	42475	1.76
H_1V_1	56016	1345	57361	62210	4849	1.08
H_1V_2	56016	1345	57361	120330	62969	2.10
H_1V_3	56016	1345	57361	105130	47769	1.83
H_1V_4	56016	1345	57361	112520	55159	1.96
H_2V_1	56011	1300	57311	81210	23899	1.42
H_2V_2	56011	1300	57311	146010	88699	2.55
H_2V_3	56011	1300	57311	128340	71029	2.24
H_2V_4	56011	1300	57311	118720	61409	2.07
H_3V_1	56243	3364	59607	78300	18693	1.31
H_3V_2	56243	3364	59607	129570	69963	2.17
H_3V_3	56243	3364	59607	112760	53153	1.89
H_3V_4	56243	3364	59607	114690	55083	1.92

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, H_0 = Weedy check , H_1= Bispyribac sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}. V_1 = Chinigura, V_2 = BR 11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6

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 during July to December-2019, to investigate the efficiency of herbicide mixtures against weeds in transplanted *aman* rice varieties of Bangladesh. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment was consisted of two factors *viz,* Factor A: herbicide treatment (4) *viz:*H_0 = Weedy check , H_1= Bispyribac-sodium WP @ 150 g ha^{-1}, H_2 = Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and H_3 = Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1} and and Factor B: T. *aman* rice varieties4) *viz:*V_1 = Chinigura, V_2 = BR11, V_3 = BRRI dhan56 and V_4 = BRRI hybrid dhan6. The total numbers of unit plots were 48. The size of unit plot was 5.04 m^2 (2.8 m × 1.8 m). The experiment was laid out in a split-plot design having three replications. In the main plot, there was herbicide treatment and in the subplot was varieties. There were 16 treatment combinations and 48 unit plots. The unit plot size was 5.04 m^2 (2.8 m × 1.8 m). Twenty five days old seedlings of Chinigura, BR11, BRRI dhan56 and BRRI hybrid dhan6 rice varieties were transplanted on the well puddled experimental plots on August 3,2019 by using two seedlings hill^{-1}. Bispyribac-sodium WP @ 150 g ha^{-1} post-emergence herbicide was applied at 20 DAT when weeds were 3-4 leaf stage, Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1}systemic mixed herbicide was applied at 12 DAT when weeds were 1-2 leaf stage and 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.

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}) relative weed density (RWD %), weed density (no. m^{-2}), weed biomass (g m^{-2}) weed control efficiency (%) and weed control index were examined 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 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 panile^{-1}, total grains panile^{-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 herbicide treatment to control weeds on T. *aman* rice, the total cost of production, gross return and net return were calculated to determine the benefit cost ratio.

Thirteen different weed species infested the experimental plots belonging to nine families, where the most dominating was broad leaf and sedge weed species among different weeds, *Monochoria vaginalis* was the most dominant weed and recorded maximum (36 and 18 m^{-2} respectively) and relative density (15.93 and 16.98 %, respectively) in weedy check plot followed by *Sagittaria guayansis and Cyperus rotundus* weed species at 30 and 60 DAT. While the dominancy of *Scirpus maritimus* with least at 30 DAT and *Marsilea quadrifolia* at 60 DAT among all the weed species.

Different herbicide treatment significantly effect on weeds and influence crop growth, yield and yield contributing characters. Among different herbicide treatment at 30 and 60 DAT mixed herbicide *i.e*., Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1}was recorded the minimum weed density m^{-2} (2.33 and 1.78, respectively), weed dry weight m^{-2} (1.78 and 1.00 g, respectively), the maximum weed control efficiency (88.85 and 83.74 %, respectively) and weed control index (78.73 and 82.45 %,respectively). The highest growth characters of rice viz. plant height, number of tillers hill^{-1}, LAI, dry matter accumulation plant^{-1}, CGR (3.94 mg cm^{-2} day^{-1}), net assimilation rate (7.46 mg cm^{-2} day $^{-1}$) were highest from Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} among all others herbicide treatment for weed control.

Yield contributing characters *viz.* effective tillers hill^{-1} (14.41), panicle length (25.46 cm), filled grains panicle^{-1} (165.24), total grains panicle^{-1} (181.27) and 1000 grains weight (21.97) were significantly highest under Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide.

Application of Acitachlor 14% + Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide gave the maximum grain yield (4.49 t ha^{-1}), straw yield (6.38 t ha^{-1}), biological yield (10.87t ha^{-1}) and harvest index (40.87) and minimum yield were recorded from weedy check plot.

Rice varieties significantly effect on weeds and influence crop growth, yield and yield contributing parameters. AT 30 and 60 DAT among different rice varieties, cultivation of BR11 rice variety was recorded the minimum weed density m^{-2} (10.19 and 4.95, respectively), weed dry weight m^{-2} (3.22 and 1.61 g, respectively), the maximum weed control efficiency (49.04 and 59.21 %,respectively) and weed control index (50.37 and 56.32 % respectively). Growth parameters of rice (*viz.* plant height, number of tillers $hill^{-1}$,LAI, dry matter accumulation $plant^{-1}$, CGR (4.83 mg cm^{-2} day^{-1}), Net assimilation rate (6.85 mg cm^{-2} day $^{-1}$) were highest in BR11 rice variety comparable to others rice varieties.

The highest effective tillers $hill^{-1}$ (14.84) was recorded under chinigura rice variety, panicle length (27.30 cm), filled grains $panicle^{-1}$ (189.55), total grains $panicle^{-1}$ (210) and 1000 grains weight (25.08) were significantly highest under BR 11 rice variety, while non effective tiller $hill^{-1}$ (0.77) was minimum in BRRI dhan56 and unfiled grains panicle $^{-1}$ (21.44) was markedly less under BR11 rice variety.

BR11 rice variety recorded the maximum grain yield (4.71 t ha^{-1}), straw yield ((6.40 t ha^{-1}), Biological yield (11.11 t ha^{-1}) and harvest index (42.17) while minimum chinigura local rice variety.

Weed control treatment along with rice varieties significantly effect on weeds and influence crop growth, yield and yield contributing parameters. Among different treatment combinations at 30 and 60 DAT Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} along with BR11 gave the minimum weed density m^{-2} (0.11 and 0.33), weed dry weight m^{-2} (0.86 and 0.39 g), the maximum weed control efficiency (99.45 and 97.28 %, respectively) and weed control index (78.73 and 82.45 %, respectively).Growth characters of rice (*viz.* plant height, number of tillers $hill^{-1}$, LAI, dry matter accumulation $plant^{-1}$, CGR (4.83 mg cm^{-2} day^{-1}), net assimilation rate (7.93 mg cm^{-2} day $^{-1}$) were recorded higher under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 combination.

Yield contributing characters *viz.* the highest effective tillers hill^{-1} (18.60) was found from with Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} combination with Chinigura rice variety. The maximum panicle length (27.89 cm), filled grains panicle^{-1} (212.20), total grains panicle^{-1} (228.79) and 1000 grain weight (25.67) were significantly highest under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750g ha^{-1} along with BR11 while non effective tiller hill^{-1} (0.33) was minimum in Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BRRI dhan56 cultivation and unfiled grains panicle $^{-1}$ (16.59) was less under Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide along with BR11 rice varieties cultivation.

Yield characters *viz.* Grain yield, straw yield, biological yield and harvest index were significantly differ among treatment combinations. Combination of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} with BR11 rice varieties gave the maximum grain yield ((5.57 t ha^{-1}), straw yield ((6.76 t ha^{-1}), Biological yield (12.33 t ha^{-1}) and harvest index (45.09) and minimum yield characters were recorded from weedy check plot along with Chinigura rice varieties.

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 herbicide treatment along with rice varieties cultivation for weed control. Due to leaf area increased grain yield and total dry matter production increased 54.2 % and 70 % respectively. 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.

Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} combination with BR11 was the most economically viable treatment and the highest gross return (146010 taka), net return (88699 taka), and benefit cost ratio (2.55) comparable to others treatments combination.

Based on the above results of the present experiment, it was observed that there was dominance of *Monochoria vaginalis, Sagittaria guayansis and Cyperus rotundus* weed species in transplanted *aman* rice. However, weeds like *Scirpus maritimus* and *Marsilea quadrifolia* also marked their presence in less numbers. Application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide was found most effective for weed control in transplanted *aman* rice. Growth parameters (*viz*. plant height, number of tillers $hill^{-1}$, LAI, CGR and NAR), yield contributing parameter (viz. effective tillers $hill^{-1}$, panicle length, filled grains per $panicle^{-1}$, unfilled grains $panicle^{-1}$,total grains per $panicle^{-1}$ 1000 grain weight) and yields parameter (grains, straw, bilogical and harvest index) were significantly the highest with the application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} than the rest of treatment. Application of Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} mixed herbicide combination with BR11 rice variety gave the maximum grain yield (5.57 t ha^{-1}), straw yield ((6.76 t ha^{-1}), biological yield (12.33 t ha^{-1}) and harvest index (45.09) which showed positive relationship among grain yield and yield contributing characters and found the highest gross return (146010 Tk.), net return (88699 Tk.), and benefit cost ratio (2.55) comparable to others treatment combinations. However, further investigation is necessary for the other soil types under different AEZ in Bangladesh.

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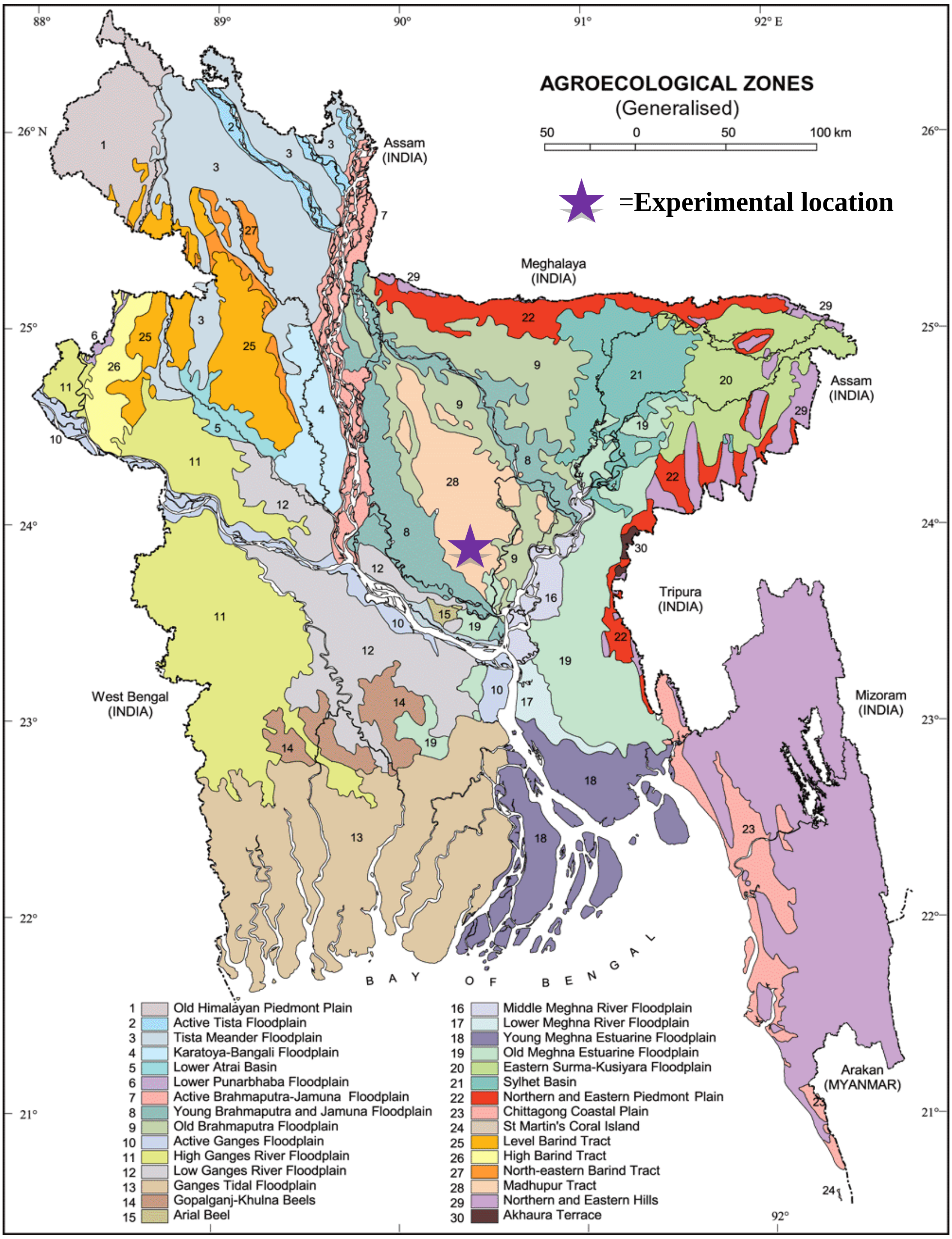
APPENDICES

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)

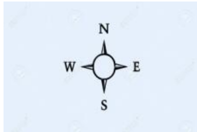
Physical characteristics	
Constituents	**Percent**
Sand	26 %
Silt	45 %
Clay	29 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10

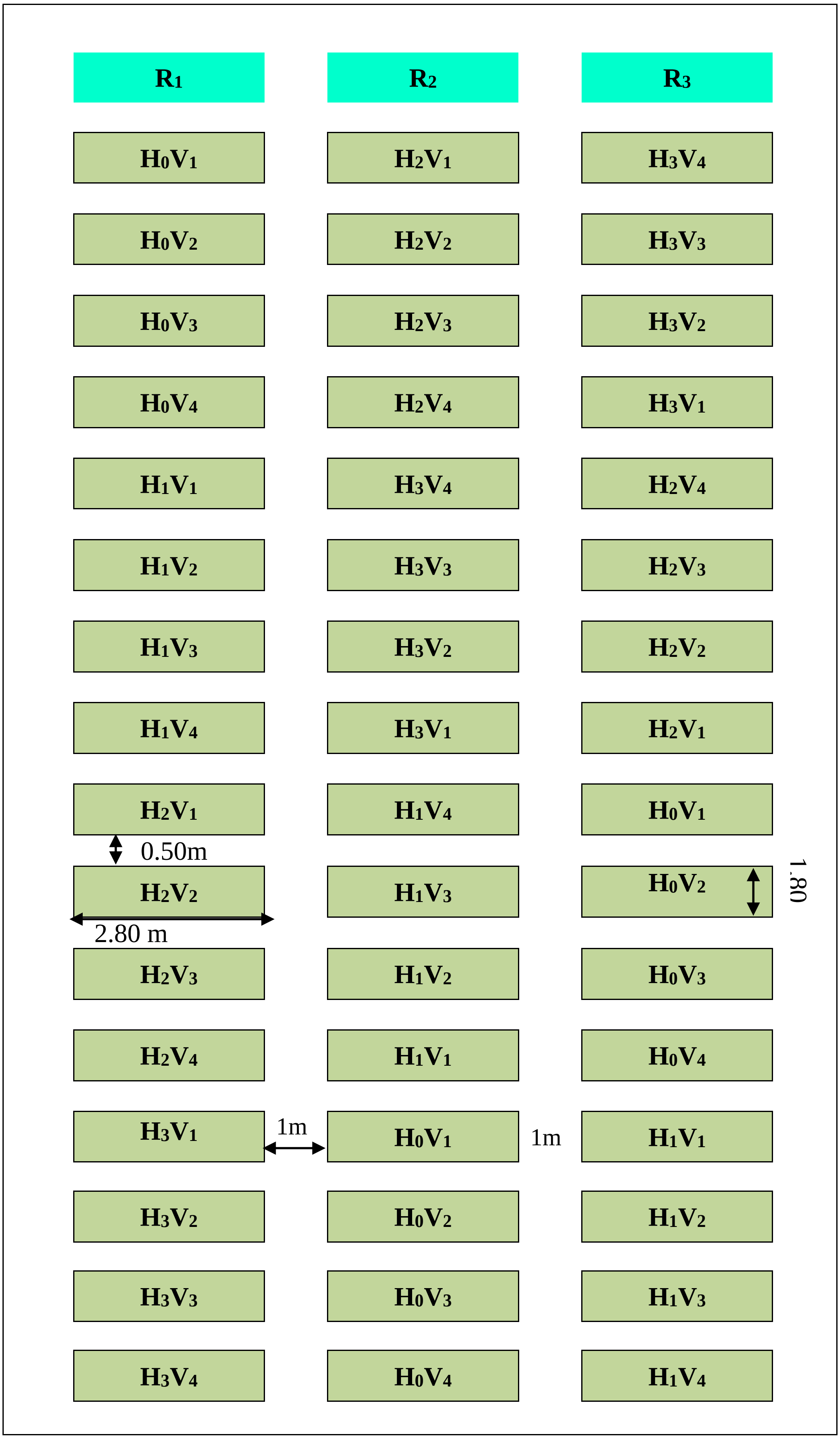
Appendix III. Monthly meteorological information during the period from July 2019 to December, 2019

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

Herbicide treatment (4) viz;

H_0= Weedy check,

H_1= Bispyribac sodium WP @ 150 g ha^{-1},

H_2= Acitachlor 14%+ Bensulfuron methyl 4% WP @ 750 g ha^{-1} and

H_3= Pretilachlor 6% + pyrazosulfuron 0.15% WP @ 9.88 kg ha^{-1}

Rice varieties (4) viz;

V_1= Chinigura,

V_2= BR 11,

V_3= BRRI dhan56 and

V_4 = BRRI hybrid dhan6

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	0.62	0.021	0.019	0.022
Herbicide (H)	3	1303.12**	297.13**	103.88**	45.03**
Error (A×H)	6	0.83	0.104	0.020	0.022
Rice varieties (V)	3	112.00**	29.61**	19.36**	7.68**
H×L	9	9.12**	1.30**	1.35**	0.76**
Error (A×H×V)	24	1.17	0.083	0.02	0.024
Total	47				

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

Appendix VI. Analysis of variance of the data of weedcontrol 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	0.4	9.4	4.5	0.6
Herbicide (H)	3	20277.3**	16166.8**	16371.8**	16005.1**
Error (A×H)	6	0.7	9.4	5.3	0.7
Rice varieties (V)	3	162.0**	519.1**	290.5**	80.2**
H×L	9	78.7**	79.3**	74.7**	52.0**
Error (A×H×V)	24	2.9	4.4	2.1	3.7
Total	47				

**: 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	15 DAT	30 DAT	45 DAT	60 DAT	90 DAT	At harvest
Replication (A)	2	1.94	5.25	14.65	4.56	6.52	9.77
Herbicide (H)	3	29.09 *	130.37* *	136.45* *	50.88*	71.15*	71.95*
Error (A×H)	6	4.44	6.92	4.98	10.56	14.52	32.27
Rice varieties (V)	3	283.7 8 **	1080.49 **	2762.56 **	6854.98 **	2914.73 **	3082.61 **
H×L	9	9.48*	20.92**	28.13**	38.34**	30.27*	37.75*
Error (A×H×V)	24	3.81	3.83	5.06	9.06	11.94	14.98
Total	47						

**: 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	15 DAT	30 DAT	45 DAT	60 DAT	90 DAT	At harvest
Replication (A)	2	0.12	0.44	0.19	1.18	0.25	0.29
Herbicide (H)	3	7.04**	2.52*	2.87*	25.22**	20.65**	19.51**
Error (A×H)	6	0.22	0.27	0.35	0.69	0.58	0.68
Rice varieties (V)	3	21.93**	107.80**	136.99**	131.41**	104.31**	115.55**
H×L	9	1.95**	22.55**	9.51**	8.07**	10.80**	9.65**
Error (A×H×V)	24	0.16	0.29	0.31	0.813	0.50	0.58
Total	47						

**: 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	30 DAT	45 DAT	60 DAT	90 DAT
Replication (A)	2	0.00042	0.00713	0.01633	0.01486
Herbicide (H)	3	0.00832*	0.03914*	0.57534**	0.40200**
Error (A×H)	6	0.00094	0.00581	0.01866	0.02311
Rice varieties (V)	3	0.17672**	6.21707**	9.51557**	7.90265**
H×L	9	0.01264**	0.03417**	0.18674**	0.16845**
Error (A×H×V)	24	0.00081	0.00614	0.01807	0.02104
Total	47				

**: 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	30 DAT	45 DAT	60 DAT	90 DAT
Replication (A)	2	0.1075	16.701	35.85	131.03
Herbicide (H)	3	26.8992**	113.648**	562.54**	796.23**
Error (A×H)	6	0.2208	7.528	17.18	43.40
Rice varieties (V)	3	6.9997**	863.298**	3536.90**	7589.41**
H×L	9	1.0287**	61.932**	242.59**	450.94**
Error (A×H×V)	24	0.1925	2.221	9.66	39.01
Total	47				

**: 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	0.00107	0.0775	0.00766
Herbicide (H)	3	0.28172**	17.6257**	3.81540**
Error (A×H)	6	0.00874	0.0608	0.00766
Rice varieties (V)	3	6.23747**	39.0488**	0.31115**
H×L	9	0.41250**	7.1002**	1.64518**
Error (A×H×V)	24	0.00682	0.3150	0.04828
Total	47			

**: 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	0.2475	0.0053	0.0040
Herbicide (H)	3	30.9585**	1.6987**	2.3363**
Error (A×H)	6	0.5775	0.0058	0.1873
Rice varieties (V)	3	55.5266**	14.2691**	27.5122**
H×L	9	12.3171**	2.1737**	0.3966*
Error (A×H×V)	24	0.4950	0.0057	0.1415
Total	47			

**: 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	87.7	2.44	104.81	0.438
Herbicide (H)	3	1184.7**	106.10**	610.40*	16.874**
Error (A×H)	6	79.4	5.35	110.23	1.021
Rice varieties (V)	3	11513.0**	1521.11**	8156.34**	488.540**
H×L	9	447.3**	48.77**	401.66**	13.019**
Error (A×H×V)	24	56.5	4.63	79.71	0.875
Total	47				

**: 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	0.05396	0.25870	0.4409	6.883
Herbicide (H)	3	3.37158**	1.45236**	7.8878**	81.648**
Error (A×H)	6	0.02979	0.11403	0.1551	3.591
Rice varieties (V)	3	9.63500**	3.47628**	24.5528**	155.099**
H×L	9	0.17498**	1.11507**	1.4523**	15.195**
Error (A×H×V)	24	0.03583		0.2265	4.414
Total	47				

**: 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

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

Harbicide application cost

Items	Items Cost (Amount/Taka)	Quantity/ha	Cost (Tk/ha)	Application cost (Tk) (Equipments and others)	Total cost (Taka)
H_0	0	0	0	0	0
H_1	20g/126 taka	150 g/ha	945	400	1345
H_2	100g/120 taka	750 g/ha	900	400	1300
H_3	1kg/300 taka	9.88 kg/ha	2964	400	3364

Note *viz. Here,*H_0= No herbicide, H_1= Bispyribac sodium, H_2= Acitachlor 14%+ Bensulfuron methyl 4% and H_3= Pretilachlor 6% + pyrazosulfuron 0.15%

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)	Herbicide cost (ii. b)	Total input cost (A = i+ ii) Here, ii= a+b	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	1345	40325	2520	2016	12500	57361
19600	19380	1300	40280	2517	2014	12500	57311
19600	19380	3364	42344	2646	2117	12500	59607

(Note: Fixed cost is total cost of production - Herbicide application cost)

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)
H_0V_1	2.26	56500	4.79	4790	61290
H_0V_2	3.78	94500	5.94	5940	100440
H_0V_3	3.26	81500	5.7	5700	87200
H_0V_4	3.68	92000	6.34	6340	98340
H_1V_1	2.32	58000	4.21	4210	62210
H_1V_2	4.55	113750	6.58	6580	120330
H_1V_3	3.98	99500	5.63	5630	105130
H_1V_4	4.24	106000	6.52	6520	112520
H_2V_1	2.98	74500	6.71	6710	81210
H_2V_2	5.57	139250	6.76	6760	146010
H_2V_3	4.88	122000	6.34	6340	128340
H_2V_4	4.52	113000	5.72	5720	118720
H_3V_1	2.94	73500	4.8	4800	78300
H_3V_2	4.93	123250	6.32	6320	129570
H_3V_3	4.28	107000	5.76	5760	112760
H_3V_4	4.36	109000	5.69	5690	114690

PLATE

Plate 1. Field view of various weed infestation in weedy check plot

Plate 2. Plot view showing Shusni shak (*Marsilea quadrifolia)*

Plate 3. Plot view showing Soto Pani Chochu (monochoria vaginalis)

Plate 4. Plot view showing Helencha (*Enydra fluctuans*)

Plate 5. Plot view showing Boro Shama (*Echinochloa cruss-gali)*