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EVALUATION OF PYRIFTALID + BENSULFURAN METHYL ON WEED SUPPRESSION AND YIELD OF TRANSPLANTED RICE IN BANGLADESH

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ABSTRACT

Weed affect rice production and grain, which not only contest with crop yield but also ruin quality. Pyriftalid + Bensulfuran methyl is a new early post-emergence herbicide in Bangladesh. Field trials were conducted at Bangladesh Rice Research Institute (BRRI), Gazipur during Boro season of 2016-17 and Aman season of 2017 to evaluate the efficacy of the weedicide on weed suppression and performance of transplanted rice. Pyriftalid + Bensulfuran methyl @ 165, 207 and 248 ml a.i. ha^{-1} were applied along with Pyrazosulfuran Ethyl WP @ 12.5 g a.i. ha^{-1}, while weed free and unweeded control was used for the efficacy assessment. Visual inspection indicated that this herbicide possesses high selectivity and not toxic to rice plants. The results revealed that the major weed flora associated with the transplanted rice was mainly comprised of two grasses, two sedges and four broadleaves in Aman, 2017, while two grasses, two sedge and two broad leaves in Boro, 2016-17. The most dominant weeds were *Cyperus difformis, Echinochloa crus-galli, Scirpus maritimus* and *Monochoria vaginalis* in both the growing seasons. Application of Pyriftalid + Bensulfuran methyl @ 207 ml a.i. ha^{-1} was most effective to suppress weed density and dry masses in both the seasons resulting increased grain yield more than 30% as compared to unweeded control. Therefore, Pyriftalid + Bensulfuran methyl @ 207 ml a.i. ha^{-1} should apply at one to two-leaf stage of weed may be recommended for effectively control weeds in transplanted rice.

Keywords: Pyriftalid + Bensulfuran methyl, transplanted rice, weed density, weed control efficiency

INTRODUCTION

Among the cereals, rice (*Oryza sativa* L.) is the most important and extensively grown in tropical and subtropical regions, and is staple food for more than 60 per cent of the world population. The average yield of rice in Bangladesh is 4.5 t ha^{-1} (BRRI, 2019). Rice production needs to be increased by 50% or more above the current production level to meet the rising food demand (Sunyub, 2015). Weed infestation and interference is a serious problem in rice fields that significantly decreases yield. In Bangladesh weed infestation reduces rice grain yield by 70-80% in Aus rice, 30-40% in transplanted aman rice and 22-36% for modern boro rice cultivars and 82% in direct wet seeded rice (BRRI, 2006; Mamun, 1990; Bhuiyan 2016). According to Willocquet (1998) and Mahbub and Bhuiyan (2019) the losses due to infestation of weeds are greater than the combined losses caused by insect, pest and diseases in rice. Weeds not only cause huge reductions in rice yields but also increase cost of cultivation, reduce input efficiency, interfere with agricultural operations, impair quality, act as alternate hosts for several insect pests and diseases, affect aesthetic look of the ecosystem as well as native biodiversity, and affect human and cattle health. Weeds compete with crop for nutrient, space, and sunlight, and consume the available moisture resulting in crop yield reduction (Bhuiyan, 2020). Weed management in rice production is a major constraint and expensive. Since hand weeding and other weed control methods are difficult, chemicals are the obvious and cost efficient weed control practices (Jayadeva, 2010). Chemical weed control has become popular in Bangladesh mainly due to scarcity of labour during peak growing season, and lower weeding cost. In Bangladesh the annual consumption of herbicides grew over 7000 metric tons in 2020 (BCPA, 2021) compared to only 108 tons during 1986-87 (BBS, 1991), and the growth is almost exponential. In Bangladesh the traditional methods of weed control practices include preparatory land tillage, hand weeding by hoe and hand pulling. Mechanical and cultural weed control in transplanted rice is an expensive method. Especially at the time of peak period

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of labor crisis sometimes weeding becomes late causing drastic losses in grain yield (Mahbub *et al.*, 2016). Nowadays use of herbicides is gaining popularity in rice culture due to their rapid effects and less cost involvement compared to traditional methods. Quite a lot of pre and post emergence herbicides such as butachlor, pretilachlor, oxadiazone, pyrazosulfuron ethyl, ethoxysulfuron alone or supplemented with one hand weeding have been found to be useful for weed management in transplanted paddy. Use of single herbicide might be effective for only sedges or only grass or broad leaf weeds. Pyriftalid + Bensulfuran methyl has been recently developed for post emergence control of weeds in rice field. It is a selective herbicide, absorbed mainly by the shoots of germinating plants. It can effectively control most important perennial and annual species of broad leaf weeds, grasses and sedges in transplanted rice. Furthermore, such type of herbicide is quite new in Bangladesh for controlling weeds. So to give farmers a wider choice of effective herbicide there is a need to develop environmental friendly molecules of newer chemistries with different mode of action. The present study was, therefore, planned to evaluate the efficacy of Pyriftalid + Bensulfuran methyl for annual weed suppression and find out an appropriate dose of the herbicide and its impacts on transplanted rice.

MATERIALS AND METHODS

Experiments were conducted during Boro, 2016-17 and Aman, 2017 seasons at the Bangladesh Rice Research Institute, Gazipur, situated at $23^0 59´33´´$ N and $90^0 24´19´´$ E at an elevation of 8.4 m from the mean sea level, and is characterized by sub-tropical climate The soil of the experimental site was non-calcareous dark grey flood plain (FAO, 2004) with pH around 6.2 and low in organic matter (1.2%). The experiment was carried out with six (6) treatments viz., i) T_1= Pyriftalid + Bensulfuran methyl @ 300 ml ha^{-1} (165 ml a.i. ha^{-1}), ii) T_2= Pyriftalid + Bensulfuran methyl @ 375 ml ha^{-1} (207 ml a.i. ha^{-1}), iii) T_3= Pyriftalid + Bensulfuran methyl @ 450 ml ha^{-1} (248 ml a.i. ha^{-1}), iv) T_4= Pyrazosulfuran Ethyl @ 125 ha^{-1} (12.5 g a.i. ha^{-1}), v) T_5= Weed free by hand weeding and vi) T_6=Control (Unwedded). All the treatments were laid out in a randomized complete block design with three replications. Twenty-five days of BRRI dhan56 for Aman, 2017 and thirty-five days old seedlings of BRRI dhan28 for Boro, 2016-17 were transplanted at 20 cm × 20 cm spacing with 2 seedlings $hill^{-1}$. Fertilizer was applied following BRRI recommended dose Aman: N:P:K:S= 69:10:41:11 kg/ha and Boro; N:P:K:S= 120:19:60:24 kg/ha [BRRI, 2013]. Herbicides were sprayed 7 days after transplanting with the help of a knapsack sprayer. In weed free treatment, the plots were kept weed free up to 50 DAT by three hand weeding and check herbicide was Pyrazosulfuran Ethyl which commercial name is Sathi 10 WP. Pyriftalid + Bensulfuran methyl herbicide is innovative in Bangladesh and its phytotoxicity needs to be evaluated on rice crop. The commercial name of the herbicide is Apiro Forte 55.08 SC. The phytotoxicity of the herbicide to rice plants was determined by visual observations (yellowing leaves, burring leaf tips, stunting growth etc). The degree of toxicity on rice plant was measured by the following scale used by (IRRI, 1965).

1. No toxicity
2. Slightly toxicity
3. Moderate toxicity
4. Severe toxicity
5. Toxic (plant kill)

The rating of toxicity was done within 7 days after application of herbicides. It was observed three times at 3, 5 and 7 days after application of herbicide and the mean rate was calculated from 10 sample plants of a unit plot.

Data on weed density and dry weight were taken from each plot on 40 DAT. The weeds were identified species-wise. Dry weights of weeds were taken by drying them in electric oven at 60 ^{0}C for 72 hours followed by weighing by digital balance. Relative weed density (RWD), relative weed biomass (RWB) and weed control efficiency (WCE) of different weed control treatments were calculated with the following formulas (Bhuiyan *et al.*, 2017a)-

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

$$\text{RWB (\%)} = \frac{\text{Dry weight of a given oven dried weed species}}{\text{Dry weight of all oven dried weed species}} \times 100$$

$$\text{SDR (\%)} = \frac{\text{RWD (\%)} + \text{RWB (\%)}}{2}$$

$$\text{WCE (\%)} = \frac{\text{(Dry weight of weeds in weedy check plots - Dry weight of weeds in treated plots)}}{\text{Dry weight of weeds in weedy check plots}} \times 100$$

$$\text{Weed Index} = \frac{\text{Yield in weed free plot - Yield in treated plot}}{\text{Yield in weed free plot}} \times 100$$

Data on panicle m^{-2}, grains $panicle^{-1}$, sterility and grain yield were collected. Yield attributes data were analyzed with analysis of variance and also graphical presentation by using STAR 2.0.1 software.

RESULTS AND DISCUSSION

Phytotoxicity of herbicides on rice plant

The degree of toxicity of the herbicide to rice plants and the symptoms produced on plant are presented in Table 1. It is observed that Pyriftalid + Bensulfuran methyl @ 300 and 375 ml ha^{-1} showed no toxicity while 450 ml ha^{-1} showed temporary yellowing of leaves. It is also observed that phytotoxicity symptoms were not more prominent for using this herbicide. Phytotoxicity of rice plant by combined herbicide is less which is similar to the findings of (Bhuiyan et al., 2017b).

Table 1. Rating of herbicide toxicity on rice plant under different treatments

Treatments	Rating		Symptom observed in rice field
	Boro, 2016-17	Aman, 2017	
Pyriftalid + Bensulfuran methyl @ 300 ml ha^{-1} (165 ml a.i. ha^{-1})	1.20	1.10	No toxicity
Pyriftalid + Bensulfuran methyl @ 375 ml ha^{-1} (207 ml a.i. ha^{-1})	1.30	1.30	Sometimes slight yellowing of leaves
Pyriftalid + Bensulfuran methyl @ 450 ml ha^{-1} (248 ml a.i. ha^{-1})	2.90	2.70	Slight yellowing of leaves which required 5-7 days to recover
Pyrazosulfuran Ethyl @ 125 ha^{-1} (12.5 g a.i. ha^{-1})	1.10	1.10	No toxicity

Weed infestation

Boro season, 2016-17

The number of infesting weed species was slightly different in Boro season than that of Aman. These weed flora were ecologically categorized into two broad leaved species, two sedge and two grasses (Table 2). The major weed was *Cyperus difformis* of which the relative weed density (RWD) and relative weed biomass (RWB) were 33.50% and 34.90%, respectively. The second top weed was *Echinochloa crus-galli* of which the RWD was 31.40% and relative weed biomass (RWB) was 32.70%. So in Boro season broad leaf weeds were less dominating than that of Aman season. Combination of different herbicides effectively control *Echinochola* and *Cyperus* sp. which found by Mahbub *et al.* (2017).

Aman season, 2017

Eight different weed species were observed in unweeded (control) plot where most dominating weeds were sedges and broad leaf (Table 3). 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.* Among the weed species maximum relative weed density (RWD) was observed for *Cyperus difformis* (32.40%) followed by *Echinochloa crus-galli* (30.50%) but the highest relative weed biomass (RWB) observed for *Echinochloa crus-galli* (33.80%) followed by *Cyperus difformis* (32.10%). Among the weeds *Eclipta alba* was the minor weed with 1.60% RWD and 1.20% RWB. In this study it was also observed that broad leaf weeds were less dominating species. Bhuiyan *et al*. (2018) revealed that efficacy of combined herbicide reduced the weed infestation.

Table 2. Weed composition, Relative weed density (RWD) and Relative weed biomass (RWB) in the untreated control plots in Boro, 2016-17 at BRRI, Gazipur

Name of Weed Species	Family	Class	RWD (%)	RWB (%)
Cynodon dactylon	Poaceae	Grass	3.40	3.10
Echinochloa crus-galli	Poaceae	Grass	31.70	32.40
Cyperus difformis	Cyperaceae	Sedge	33.90	34.50
Scirpus maritimus	Cyperaceae	Sedge	25.30	27.60
Monochoria vaginalis	Pontederiaceae	Broad leaf	11.20	10.70
Marsilea minuta	Marsileaceae	Broad leaf	3.10	4.30

Table 3. Weed composition, Relative weed density (RWD) and Relative weed biomass (RWB) in the untreated control plots in Aman, 2017 at BRRI, Gazipur

Name of Weed Species	Family	Class	RWD (%)	RWB (%)
Cynodon dactylon	Poaceae	Grass	3.60	2.80
Echinochloa crus-galli	Poaceae	Grass	30.50	33.70
Cyperus difformis	Cyperaceae	Sedge	32.10	32.90
Scirpus maritimus	Cyperaceae	Sedge	22.60	20.80
Monochoria vaginalis	Pontederiaceae	Broad leaf	10.50	11.20
Marsilea minuta	Marsileaceae	Broad leaf	5.50	6.10
Sphenoclea zeylanica	Sphenocleaceae	Broad leaf	2.70	3.40
Eclipta alba	Asteraceae	Broad leaf	1.70	1.30

Weed ranking

The summed dominance ratio (SDR) is an important pointer of showing ranking of weeds. The most dominant weeds in Aman season, 2017 were *Cyperus difformis, Echinochloa crus-galli, Scirpus maritimus and Monochoria vaginalis* (Figure 1). *Cyperus difformis, Echinochloa crus-galli, Scirpus maritimus and Monochoria vaginalis* were also the most dominant weeds in Boro saeson, 2016-17. Mahbub and Bhuiyan (2018) showed that SDR of a weed against same herbicide is more or less similar in different seasons.

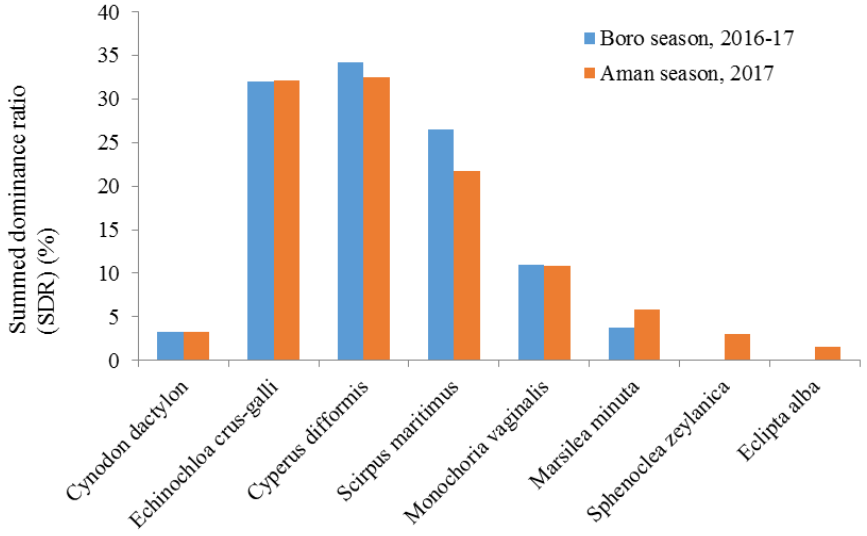


Fig. 1. Summed dominance ratio (SDR) of infesting weeds in transplanted rice

Weed control efficiency (WCE)

Lower weed biomass as well as higher weed control efficiency in all the growing seasons exhibited by Pyriftalid + Bensulfuran methyl. Weed control efficiency improved with increases of herbicide dose irrespective of weed species. Treatment, T_1 controls all the weeds less than 80% due to lower dose of application, whereas T_2, T_3 and T_4 (check) control *Echinochloa crus-galli, Cyperus difformis, Scripus maritimus* and *Marsilea minuta* more than 80% in Boro season (Table 4).

Table 4. Effect of Pyriftalid + Bensulfuran methyl on weed control efficiency in transplanted rice in Boro, 2016-17 at BRRI, Gazipur

Name of weeds	Weed control efficiency (%)			
	T_1	T_2	T_3	T_4
Cynodon dactylon	31.50	40.70	45.80	48.40
Echinochloa crus-galli	63.90	80.70	83.60	84.50
Cyperus difformis	70.80	83.30	85.60	85.90
Scripus maritimus	64.60	81.60	84.20	88.60
Monochoria vaginalis	62.40	71.30	76.40	78.90
Marsilea minuta	51.70	80.50	82.20	83.50

T_1= Pyriftalid + Bensulfuran methyl @ 165 ml a.i. ha^{-1}, T_2= Pyriftalid + Bensulfuran methyl @ 207 ml a.i. ha^{-1}, T_3= Pyriftalid + Bensulfuran methyl @ 248 ml a.i. ha^{-1} and T_4= Pyrazosulfuran Ethyl WP @ 12.5 g a.i. ha^{-1}

The trend of weed control efficiency in Aman 2017 was almost similar as Boro 2016-17. All the treatments controlled most of the weeds more than 80% except T_1. Treatment, T_2, T_3 and T_4 controls *Echinochloa crus-galli*, *Cyperus difformis*, *Scripus maritimus* and *Marsilea minuta* more than 80% (Table 5). It was evident from the study that the post emergence herbicide Pyriftalid + Bensulfuran methyl @ 207 and 248 ml a.i. ha^{-1} was effective for controlling weed than other doses of that herbicide. Bhuiyan, (2017b and 2018) reported that the mixture of herbicides gave 80% control of annual and perennial weeds.

Table 5. Effect of Pyriftalid + Bensulfuran methyl on weed control efficiency in transplanted rice in Aman, 2017 at BRRI, Gazipur

Name of weeds	Weed control efficiency (%)			
	T_1	T_2	T_3	T_4
Cynodon dactylon	29.50	41.70	45.30	40.20
Echinochloa crus-galli	60.40	81.20	83.30	83.90
Cyperus difformis	64.20	80.90	84.50	86.30
Scripus maritimus	68.30	82.50	85.10	87.40
Monochoria vaginalis	61.50	72.30	75.40	82.70
Marsilea minuta	52.70	80.90	81.80	84.60
Sphenoclea zeylanica	52.60	71.50	75.90	80.60
Eclipta alba	50.80	62.70	69.40	68.50

T_1= Pyriftalid + Bensulfuran methyl @ 165 ml a.i. ha^{-1}, T_2= Pyriftalid + Bensulfuran methyl @ 207 ml a.i. ha^{-1}, T_3= Pyriftalid + Bensulfuran methyl @ 248 ml a.i. ha^{-1} and T_4= Pyrazosulfuran Ethyl WP @ 12.5 g a.i. ha^{-1}

Weed Index

The efficiency of various treatments with respect to weed control efficiency fluctuated to a greater extent under the influence of various weed control treatments (Table 4 &5). Lower weed index was noted with Pyrazosulfuran Ethyl WP @ 12.5 g a.i. ha^{-1} and was followed by Pyriftalid + Bensulfuran methyl @ 207 ml a.i. ha^{-1} at both Boro and Aman season (Figure 2). Weedy check recorded the highest weed index in both seasons which indicated the losses caused due to weeds.

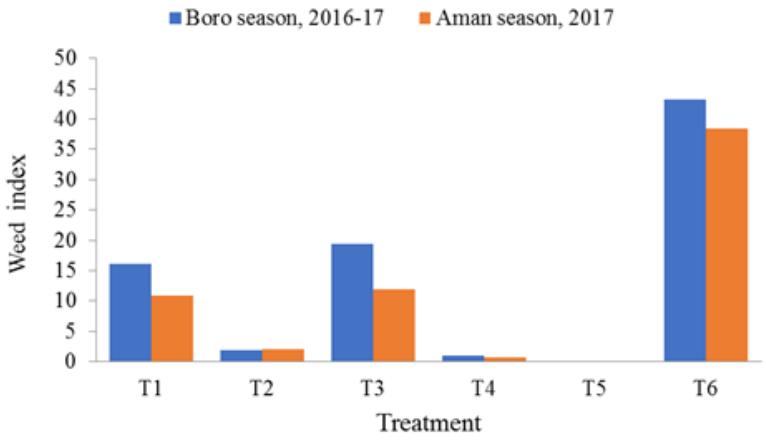


Fig. 2. Weed index of transplanted rice at BRRI, Gazipur. Here, T1= Pyriftalid + Bensulfuran methyl @ 165 ml a.i. ha^{-1}, T2= Pyriftalid + Bensulfuran methyl @ 207 ml a.i. ha^{-1}, T3= Pyriftalid + Bensulfuran methyl @ 248 ml a.i. ha^{-1}, T4= Pyrazosulfuran Ethyl WP @ 12.5 g a.i. ha^{-1}, T5= Weed free and T6= control (unweeded)

Yield and yield attributes

Grain yield is the function of an interaction among various yield components, which are affected differentially by the growing conditions and crop management practices. From Table 6 it was found that all the treatments significantly increased rice grain yield over unweeded control plot. In Boro season, 2016-17 the highest grain yield (5.58 t ha^{-1}) was recorded in the T_5 treatment which was statistically similar to treatments T_2 and T_4 producing grain yields of 5.47 and 5.52 t ha^{-1}, respectively. Minimum grain yield (3.17 t ha^{-1}) was found in weedy check plots as compared to weed free treatment due to high weed density which resulted less number of panicle m^{-2}, grains $panicle^{-1}$ and high sterility. Treatment wise boxplot of yield attributes in Boro season, 2016-17 confirm that most of the yield contributing characters are showed similar range in T_2, T_4 (check) and T_5 (weed free) treatments; whereas T_6 was outside of the normal range and its data was also in disperse condition than other treatments due to severe weed infestation (Figure 3).

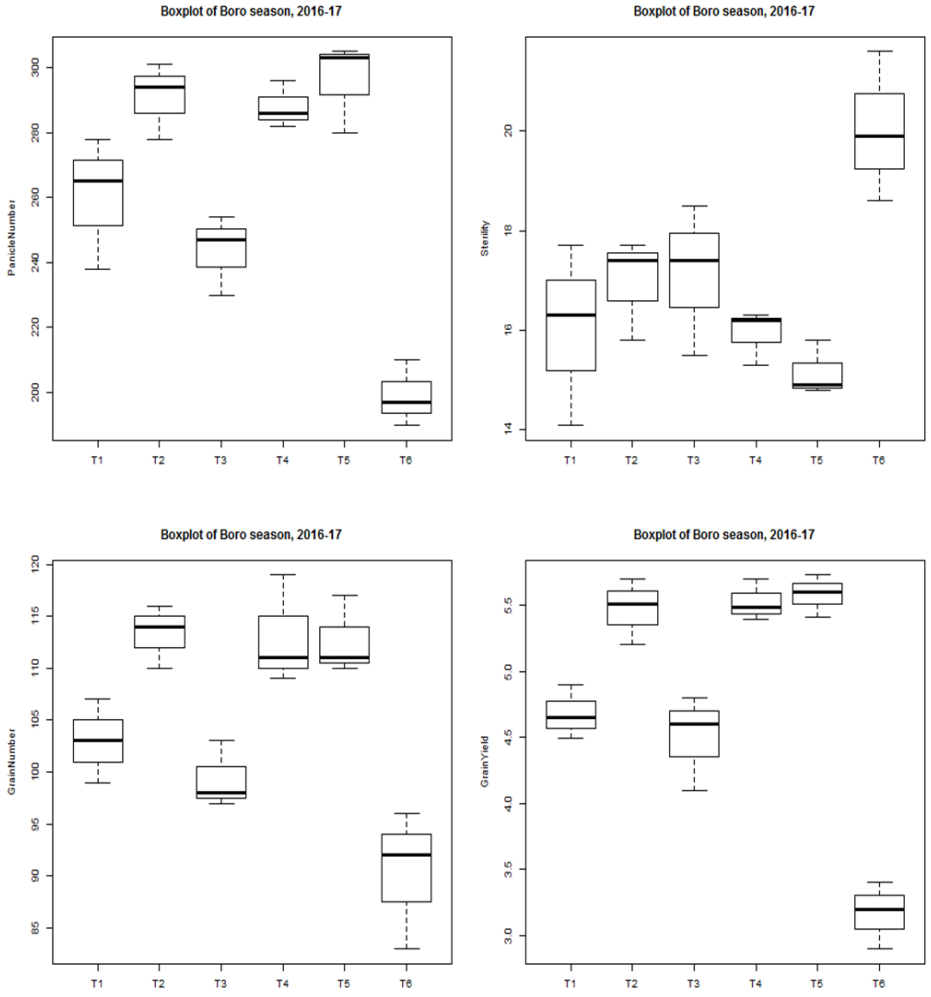


Fig. 3. Boxplot of yield attributes in Boro season, 2016-17 at BRRI, Gazipur [T_1= Pyriftalid + Bensulfuran methyl @ 165 ml a.i. ha^{-1}, T_2= Pyriftalid + Bensulfuran methyl @ 207 ml a.i. ha^{-1}, T_3= Pyriftalid + Bensulfuran methyl @ 248 ml a.i. ha^{-1}, T_4= Pyrazosulfuran Ethyl WP @ 12.5 gm a.i. ha^{-1}, T_5= Weed free and T_6= control (unweeded)]

Similar trend of results was observed during the Aman, 2017 where unweeded control (T_6) produced minimum number of panicles m^{-2}, grains $panicle^{-1}$ and high sterility which resulting lowest grain yield (2.67 t ha^{-1}). The minimum number of panicles m^{-2} in the control plot was the result of higher competition for nutrient, air space, light and water between crop plants and weeds. Hasanuzzaman (2009) reported similar results. Maximum grain yield of 4.34 t ha^{-1} that was recorded with T_5 treatment could be due to lower weed-crop competition at crop growth stages. In Aman season, 2017; T_2, T_4 (check) and T_5 (weed free) treatments are in similar range in boxplot of yield attributes (Figure 4). Pyriftalid + Bensulfuran methyl @ 207, 248 ml a.i. ha^{-1} gave effective control of grass, sedge and broad leaf weeds lead to increased grain yield. Herbicide treatments contributed to higher yield performance compared to control in all the growing seasons.

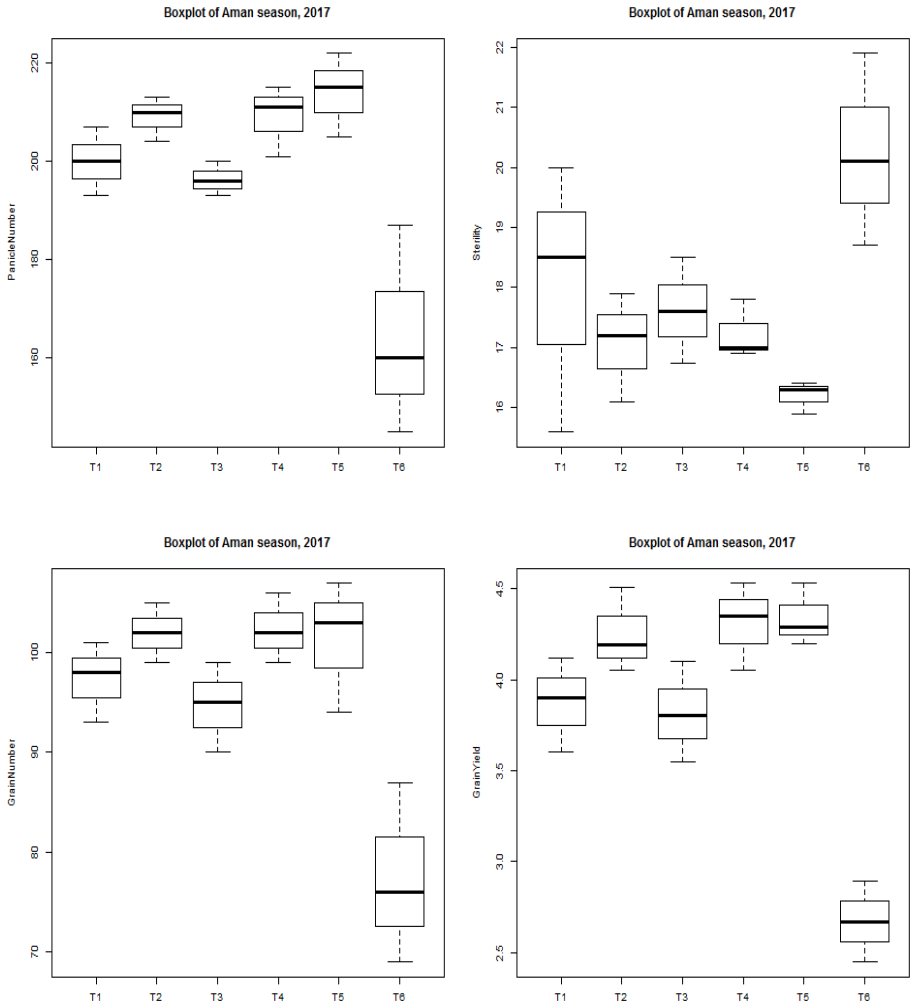


Fig. 4. Boxplot of yield attributes in Aman season, 2017 at BRRI, Gazipur. [Here, T_1= Pyriftalid + Bensulfuran methyl @ 165 ml a.i. ha^{-1}, T_2= Pyriftalid + Bensulfuran methyl @ 207 ml a.i. ha^{-1}, T_3= Pyriftalid + Bensulfuran methyl @ 248 ml a.i. ha^{-1}, T_4= Pyrazosulfuran Ethyl WP @ 12.5 g a.i. ha^{-1}, T_5= Weed free and T_6= control (unweeded)]

Table 6. Effect of Pyriftalid + Bensulfuran methyl on yield attributes of transplanted rice at BRRI, Gazipur

Treatments	Panicles m^{-2}		Grains $panicle^{-1}$		Sterility (%)		Grain yield (t ha^{-1})	
	Boro, 2016-17	Aman, 2017	Boro, 2016-17	Aman, 2017	Boro, 2016-17	Aman, 2017	Boro, 2016-17	Aman, 2017
T_1	260	200	103	97	16.03	18.03	4.68	3.87
T_2	291	209	113	102	16.97	17.07	5.47	4.25
T_3	243	196	99	94	17.13	17.61	4.50	3.82
T_4	288	209	113	102	15.93	17.23	5.52	4.31
T_5	296	212	112	101	15.17	16.20	5.58	4.34
T_6	199	164	90	77	20.03	20.23	3.17	2.67
CV (%)	5.49	5.54	4.58	5.89	6.76	6.22	5.19	6.37
LSD	26.27	20.01	8.76	10.27	2.07	2.01	0.45	0.44

T_1= Pyriftalid + Bensulfuran methyl @ 165 ml a.i. ha^{-1}, T_2= Pyriftalid + Bensulfuran methyl @ 207 ml a.i. ha^{-1}, T_3= Pyriftalid + Bensulfuran methyl @ 248 ml a.i. ha^{-1}, T_4= Pyrazosulfuran Ethyl WP @ 12.5 g a.i. ha^{-1}, T_5= Weed free and T_6= control (unweeded)

CONCLUSION

Based on the results, yield and yield attributing parameters and weed dynamics were greatly influenced by different weed management practices. Pyriftalid + Bensulfuran methyl @ 248 ml a.i. ha^{-1} showed a good weed control efficiency though phytotoxity was found with this dose. So it may be suggested that Pyriftalid + Bensulfuran methyl @ 207 ml a.i. ha^{-1} applied during one to two leaf stage of weed may be effective for annual weed control option and also have not hamper the rice yield.

EFERENCES

BRRI (Bangladesh Rice Research Institute), 2019. Adhunik Dhaner Chas. Bangladesh Rice Research Institute, Joydebpur, Gazipur, Bangladesh.

Sunyob, N. B., Juraimi, A. S., Hakim, M. A., Man, A., Selamat A. and Alam, M. A. 2015. Competitive ability of some selected rice varieties against weed under aerobic condition. *Intl. J. Agric. Biol.* 17: 61–70.

Bhuiyan, M. K. A. 2016. Effect of resource conservation technologies and weed management on nitrogen use efficiency, growth and yield of rice. Phd thesis

BRRI (Bangladesh Rice Research Institute), 2006. Weed identification and management in rice. Bangladesh Rice Research Institute, Joydebpur, Gazipur, Bangladesh.

Mamun, A. A., 1990. Weeds and their control: A review of weed research in Bangladesh. Agricultural and Rural Development in Bangladesh. Japan Intl. Co-operation Agency, Dhaka, Bangladesh. JSARD., 19: 45-72.

Willocquet, L., Savary, S., Fernandez, L., Elazegui F. and Teng, P. 1998. Simulation of yield losses caused by rice diseases, insects, and weeds in tropical Asia. *IRRI Discussion Paper Series*. 34:18-20.

Mahbub, M. M. and Bhuiyan, M. K. A. 2019. Performance of Quinclorac + Fenoxaprop-P-Ethyl + Pyrazosulfuran-Ethyl 70% WP against annual weeds of transplanted rice. *American-Eurasian J. Agric. Environ. Sci.* 19(6): 439-447.

Bhuiyan, M. K. A. and Mahbub, M. M. 2020. Performance of Bensulfuron Methyl 1.1% + Metsulfuron Mthyl 0.2% + Acetochlor 14% WP against wide range of weed control in transplanted rice of Bangladesh. *American-Eurasian J. Agric. Environ. Sci.* 20 (5): 358-366.

Jayadeva, H. M. 2010. Bioefficacy of post emergent herbicides in weed management of transplanted rice (*Oryza sativa* L.). *J. Crop Weed.* 6(2): 63-66.

BCPA. 2021. Office Records of the Bangladesh Crop Protection Association. Dhaka, Bangladesh.

BBS. 1991. Bangladesh Bureau of Statistics, Ministry of Planning, Dhaka.

Mahbub, M. M., Rahman, M. M., Hossain, M. S., Nahar, L. and Shirazy, B. J. 2016. Morphophysiological variation in soybean (*Glycine max* (L.) Merrill). *American-Eurasian J. Agric. Environ. Sci.* 16(2): 234-238.

FAO, 2004. Production Year Book. Food and Agriculture Production Function, Iowa State University press, Ames, Iowa, USA. pp. 63, 105-229.

BRRI (Bangladesh Rice Research Institute). 2013. Adhunik Dhaner Chas. Bangladesh Rice Research Institute, Joydebpur, Gazipur, Bangladesh.

IRRI, (International rice Research Institute). 1965. Annual Report for 1963. IRRI, Los Banos, Philippines. pp. 224-231.

Bhuiyan, M. K. A. and Mahbub, M. M. 2017a. Efficacy of Pretilachlor 50% + trisulfuran 2% WP for control of annual weeds. *Bangladesh J. Weed Sci*. 6(1&2): 7-15.

Bhuiyan, M. K. A., Mahbub, M. M., Baki, Z. I. and Nahar, L. 2017b. Sensitivity of Annual Weeds against Sulfentrazone 48 SC herbicide in Rice Cultivation. *Bangladesh Rice J*. 21 (1): 67-76.

Mahbub, M. M., Bhuiyan, M. K. A. and Kabir, M. M. M. 2017. Performance of Metsulfuron Methyl 10% + Chlorimuron Ethyl 2% WP against annual weed inhibition in transplanted rice. Haya: *Saudi J. Life Sci*. 2(8):298-305.

Bhuiyan, M. K. A., Mahbub, M. M. and Baki, M. Z. I. 2018. Sensitivity of annual weeds against Metolachlor + Bensulfuron-Methyl herbicide in transplanted rice. *Bangladesh Agron. J.* 21 (1): 61-70.

Mahbub, M. M. and Bhuiyan, M. K. A. 2018. Performance of Bensulfuran Methyl 12% + Bispyribac Sodium 18% WP against annual weeds in transplanted rice (*Oryza sativa*) cultivation in Bangladesh. *Sci. Agri*. 21 (3): 85-92.

Hasanuzzaman, M., Islam, M. O. and Bapari, M. S. 2009. Efficacy of different herbicides over manual weeding in weed control in transplanted rice. *Aust. J. Crop Sci*. 2(1): 18-24.