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EVALUATION OF HERBICIDE EFFICACY ON WEED CONTROL AND GRAIN YIELD IN RICE FIELD UNDER FLOODED CONDITION

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Abstract

Weeds listed as one of the biotic factors that increase the rice production cost worldwide. The importance of their control has always been highlighted by many researchers in years. Application of herbicides accompanied by appropriate water management can increase efficacy of weed control and consequently increase the grain and yield quality. Therefore, this investigation was carried out to assess the herbicides performance under flooded condition on weed control and grain yield in Kelantan, Malaysia. This experiment was evaluated for two seasons which are main season and off season. This experiment was performed in randomised complete block design (RCBD) with three replications. Herbicide evaluation found twelve weed species grown in the experimental plot, where *Monochoria vaginalis* and *Echinochloa crus-galli* were the most dominant weed species discovered in both seasons, followed by *Leptochloa chinensis*, *Fimbrystylis milliacea*, *Ludwigia hyssopifolia*, *Limnocharis flava*, *Cyperus iria* and *Scirpus grossus*. The herbicide treatments showed significant results in terms of weed control, grain yield and higher net benefits from economic analysis aspect. From this study, the herbicide combinations of pretilachor fb bentazon/MCPA, pretilachor+pyribenzoxim, fb bentazon/MCPA, bispyribac-sodium fb bentazon/MCPA and pyrazosulfuron fb bentazon/MCPA performed best in the flooded condition with high WCE in both seasons and pyrazosulfuron fb bentazon/MCPA resulted as the highest net benefit amongst treatments.

Key words: Herbicides combination; Weed management; rice production

Introduction

Weeds are serious constraint to the productivity of rice if left uncontrolled. A significant grain yield loss between 10 to 100% loss of yield in severe weed interferences (Singh *et al.,* 2014). The mechanical or hand weeding is often done by small-scale rice growers in an irrigated rice system as it is cost-effective compared to the other weed control methods, nonetheless it is not recommended at large scale as it is time-consuming and laborious (Hussain *et al.,* 2008). Studies proved that herbicides can effectively control several weed species (Helgueira *et al.,* 2018; Zakaria *et al.,* 2018) and vital for maximum economic return (Singh *et al.,* 2016; Anwar *et al.,* 2012, Chauhan *et al.,* 2014). The herbicide cost of controlling weed in rice fields is not cheap and estimated US $ 4.10 million was spent per year (Karim *et al.,* 2004). Therefore, the strategic plan for herbicide application is important to result at highest herbicide efficacy towards several weed species and increase grain yield.

Malaysia experiences humid weather throughout the year. The average daily temperature across Malaysia is between 21°C and 32°C. In Malaysia, experiments with varies of herbicide combinations and manual weeding have shown the efficacy of rice fields with weed control in the conditions of aerobic soil. The study conducted by Anwar *et al.,* (2012) explained that under aerobic system, several combinations of herbicides might be another alternative for weed control in the context of effectiveness and economically in controlling weed also can avoid the resistance development in weed.

Rice is commonly grown under flooded condition in

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order to provide a favourable condition for rice to compete better with weeds. The depth and duration of flood play an important role in preventing weeds. Any changes in soil moisture levels in rice fields will affect the density, growth, and species composition of weeds. Chauhan & Johnson (2010) observed that the flooding depth of at least 2 cm provides suppressive condition to the germination and growth of weed species; however, it depends on the nature of weed flora (whether dominated by grassy weeds or aquatic weeds).

Thus, the current study was conducted to identify the weed species composition and appropriate selection of herbicides under flooded condition. This information could give a vision on alternative weed control method that effectively control weed species while increasing the grain yield in the flooded rice growing areas.

Materials and Methods

Experimental location

An experiment was carried out in containers in an open area in the Kota Bharu, Kelantan, Malaysia in the main season 2015/2016 and off season 2016. The planting medium was taken from rice fields at Kampung Tunjong, Kota Bharu, Kelantan, Malaysia.

Rice establishment, experimental design and herbicide treatments

A total of 400 kilograms of air-dried sandy clay loam soil from rice fields were used in this study. Bulked soil samples were partly dried and clods were broken into smaller pieces by hand, mixed thoroughly and put into 0.5m × 0.5m × 0.5m containers. Transplanting method was used in this study; rice seedlings at 14 days old were transplanted from wet bed nurseries to the containers by hand with the rate of eight seedlings per hill in-row and inter-row spacing of 10 cm × 25 cm, respectively.

The water condition treatment continuously flooded condition (5 cm water level) until maturity. At first, the soil was maintained under saturated condition during sowing and water regime treatments commenced at 7 DAS, following rice transplant. The experiment consisted of ten herbicide treatments table 1 which are unweeded; manual weeding; pretilachor followed by (fb) MCPA/bentazon; pretilachor+pyribenzoxim fb MCPA/bentazon; bispyribac-sodium fb MCPA/bentazon; pyrazosulfuron fb MCPA/bentazon; penoxsulam fb MCPA/bentazon; thiobencarb+propanil fb MCPA/bentazon; fenoxaprop+ethoxysulfuron fb MCPA/bentazon; fenoxaprop fb MCPA/bentazon. The type of the sprayer used is a knapsack sprayer with adjustable flat fan nozzle delivering 450 L ha^{-1} at spray pressure of 220 kPa. Hand weeding was done in weed-free check treatment.

Table 1: Details of the herbicide treatments used in the experiment.

Label	Treatment	Rate of Application	Time of Application
T1	Unweeded		
T2	Manual weeding		At 14 Day After Transplanting (DAT), followed by every 15 DAT until 85 DAT
T3	Pretilachor, fb Bentazon/MCPA	0.5 kg ai ha^{-1}fb. 0.6/0.1 kg ai ha^{-1}	6 DAT, followed by 23 DAT
T4	Pretilachor+Pyribenzoxim, fb Bentazon/MCPA	fb 0.6/0.1 kg ai ha^{-1}	6 DAT, followed by 23 DAT
T5	Bispyribac-sodium, fb Bentazon/MCPA	0.03 kg ai ha^{-1} fb 0.6/0.1 kg ai ha^{-1}	14 DAT, followed by 33 DAT
T6	Pyrazosulfuron, fb Bentazon/MCPA	0.012-0.02 kg ai ha^{-1} fb 0.6/0.1 kg ai ha^{-1}	14 DAT, followed by 33 DAT
T7	Penoxsulam fb Bentazon/MCPA	0.5 liter product/ha fb 0.6/0.1 kg ai ha^{-1}	14 DAT, followed by 33 DAT
T8	Thiobencarb+Propanil, fb Bentazon/MCPA	6 liter product/ha fb 0.6/0.1 kg ai ha^{-1}	14 DAT, followed by 33 DAT
T9	Fenoxaprop+Ethoxysulfuron,fb Bentazon/MCPA	0.5-0.8 liter product/ha fb 0.6/0.1 kg ai ha^{-1}	14 DAT, followed by 33 DAT
T10	Fenoxaprop, fb Bentazon/MCPA	0.7-0.8 liter product/ha fb 0.6/0.1 kg ai ha^{-1}	14 DAT, followed by 33 DAT

Data collection

A 25cm × 25cm quadrat was used for weed sampling to determine weed density and dry weight at different time intervals (30, 60 and 90 days after transplanting (DAT). Weed species present in quadrats were harvested aboveground, identified, separated by species, counted, and listed. Then, each collected weed species was cleaned, dried for 72 h at 70°C and weighed. The summed dominance ratio (SDR) will determine the weed species that dominant in the infesting plots, where the equation of SDR is accordance to Janiya & Moody (1989):

$$\text{SDR (\%)} = \frac{\text{Relative density}(RD) + \text{relative dry weight}\ (RDW)}{2}$$

$$\text{RD} = \frac{\text{Density of a given species}}{\text{Total density}} \times 100$$

$$\text{RDW} = \frac{\text{Dry weight of a given species}}{\text{Total dry density}} \times 100$$

Weed control efficiency (WCE) of each treatment was calculated according to Hasanuzzaman *et al.,* (2008):

WCE (%) = (DWC–DWT) / DWC × 100

Where,

DWC = weeds dry weight in weedy check plots;

DWT = weeds dry weight in treated plots.

Economic Analysis

An economic analysis will determine the cost-efficiency of various treatments (Hussain *et al.,* 2008). The amount of commercial herbicide product needed per hectare was evaluated and the cost for every single herbicide was predictable based on their market price. The laborer cost for manual and herbicide application was estimated at RM 30 per day (half-day) and converted it to per ha in order to represent the actual cost of weed control for one-hectare rice field. The rice market price was compared from various rice cultivation areas and was considered as RM 1200 t^{-1} to calculate the gross return.

Statistical Analysis

All the data obtained were analyzed using SAS statistical software package for analysis of variance (ANOVA) and significant differences were tested using Tukey's studentized range test at the 5% level of probability.

Results and Discussion

Composition and Dominance of Weed Species

Eleven dominant weed species recorded were broadleaved weed, grasses and sedges with the family species of Poaceae, Cyperacea, Pontederiaceae, Euphorbiaceae and Alismataceae table 2. From the Summed Dominance Ratio (SDR) obtained, *Monochoria vaginalis* (Burm.f.) Presl from Pontederiaceae family were able to dominate the plot with SDR 40.8 and 33.1 for main and off seasons, respectively. All broadleaved weed species were observed the highest SDR for the main season which are *Ludwigia hyssopifolia* (G. Don) Exell and *Limnocharis flava* L. Buchenan (main season: 12.3). Consequently, followed by *Leptochloa chinensis* L. Nees (7.3), *Fimbristylis milliacea* L. Vahl (6.7), *Cyperus iria* L. (6.3), *Echinochloa colona* L. Link (4.5) and *Cyperus difformis* L. (4). The SDR in off season recorded that the second predominant weed species was *Limnocharis flava* L. Buchenan (11.5), *Echinochloa crus-galli* L. Beauv (11), *Ludwigia hyssopifolia* (G. Don) Exell (10.5), *Echinochloa colona* L. Link (8.9), *Leptochloa chinensis* L. Nees (7.8), *Scirpus grossus* L. f. (6.7), *Fimbristylis milliacea* L. Vahl (5), *Ischaemum rugosum* Salisb (3.2), *Cyperus iria* L. (2.3).

Table 2: SDR of weed species at 60 DAT in main and off season.

No.	Weed species	Main Season	Off Season	Weed type	Family
1.	*Monochoria vaginalis* (Burm.f.) Presl	40.8	33.1	BL	Pontederiaceae
2.	*Ludwigia hyssopifolia* (G. Don) Exell	12.8	10.5	BL	Euphorbiaceae
3.	*Limnocharis flava* (L.) Buchenan	12.3	11.5	BL	Alismataceae
4.	*Echinochloa crus-galli* (L.) Beauv	4.5	11	G	Poaceae
5.	*Leptochloa chinensis* (L.) Nees	7.3	7.8	G	Poaceae
6.	*Echinochloa colona* (L.) Link	5.3	8.9	G	Poaceae
7.	*Ischaemum rugosum* Salisb	-	3.2	G	Poaceae
8.	*Fimbristylis milliacea* (L.) Vahl	6.7	5	S	Cyperaceae
9.	*Cyperus iria* L.	6.3	2.3	S	Cyperaceae
10.	*Scirpus grossus* L. f.	-	6.7	S	Cyperaceae
11.	*Cyperus difformis* L.	4	-	S	Cyperaceae

This result showed that the broadleaved weed species constitutes the highest in the flooded condition as compared to grasses and sedges weed species. According to Ismail *et al.,* (2012), well adopted weed species to flooded soils and aquatic weeds are major problems in lowland rice fields, and this situation was observed in this study where the highest number of weed species recorded was broadleaved weed species that can survive in the flooded condition. Similarly reported by Antralina *et al.,* 2015, broadleaved weeds were dominant over grassy and sedges in the flooded condition. Moreover, the increasing in flooding depth and flooding condition encouraged the presence of most of the broadleaved weeds (Kent & Johnson, 2001) and the distribution pattern and weed succession in the rice fields were depending on the water management, cultural practices, space and time aspects (Juraimi *et al.,* 2013).

Table 3: Effect of weed control treatments on WD and WCE (%) in the main season.

Herbicide treatments	Weed density (number m^{-2})			Weed control efficiency (%)		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T1	54.67a	34.67a	18.67a	0.00a	0.00c	0.00b
T2	0.00c	0.00b	0.00b	100.00a	100.00a	100.00a
T3	0.00c	0.00b	0.00b	100.00a	100.00a	100.00a
T4	0.00c	2.67b	0.00b	100.00a	96.33ab	97.67a
T5	8.00bc	2.67b	0.00b	93.33ab	95.67ab	98.00a
T6	8.00bc	0.00b	0.00b	85.33ab	100.00a	100.00a
T7	9.33bc	0.00b	0.00b	88.67ab	100.00a	100.00a
T8	21.33bc	10.67b	6.67b	78.67ab	78.33ab	83.67a
T9	21.33bc	8.00b	2.67b	71.33bcd	81.67ab	87.67a
T10	25.33bc	8.00b	4.00b	54.33c	70.00b	79.67a

At a single sampling date, in a column, means followed by the same letter are not significantly different at 5% level by LSD test.

W1 = Flooding at 5cm; W2 = Flooding at 2cm; W3 = Saturated condition; W4 = Field capacity condition; T1 = Unweeded; T2= Manual weeding; T3 = Pretilachor, followed by Bentazon/MCPA; T4 = Pretilachor+Pyribenzoxim, followed by Bentazon/MCPA; T5 = Bispyribac-sodium, followed Bentazon/MCPA; T6 = Pyrazosulfuron, followed by Bentazon/MCPA; T7 = Penoxsulam, followed by Bentazon/MCPA; T8 = Thiobencarb+Propanil, followed by Bentazon/MCPA;T9 = Fenoxaprop + Ethoxysulfuron, followed by Bentazon/MCPA; T10 = Fenoxaprop, followed by Bentazon/MCPA.

Table 4: Effect of weed control treatments on WD and WCE (%) in the off season.

Herbicide treatments	Weed density (number m^{-2})			Weed control efficiency (%)		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T1	41.33a	26.67a	10.67a	0.00c	0.00e	0.00d
T2	0.00d	0.00d	0.00c	100.00a	100.00a	100.00a
T3	0.00d	0.00d	0.00c	100.00a	100.00a	100.00a
T4	2.67cd	0.00d	2.67bc	96.00ab	100.00a	100.00a
T5	13.33bcd	6.67cd	0.00c	78.00ab	85.67ab	100.00a
T6	0.00d	0.00d	0.00c	100.00a	100.00a	100.00a
T7	16.00b	2.67cd	1.33bc	64.33b	97.00ab	96.00a
T8	13.33bc	9.33bc	8.00ab	82.67ab	70.33bc	51.67bc
T9	21.33b	8.00cd	2.67bc	63.33b	33.00d	83.33ab
T10	17.33b	17.33b	6.67abc	54.33b	49.67cd	21.00cd

At a single sampling date, in a column, means followed by the same letter are not significantly different at 5% level by LSD test.

T1 = Unweeded; T2= Manual weeding; T3 = Pretilachor, followed by Bentazon/MCPA; T4 = Pretilachor+Pyribenzoxim, followed by Bentazon/MCPA; T5 = Bispyribac-sodium, followed Bentazon/MCPA; T6 = Pyrazosulfuron, followed by Bentazon/MCPA; T7 = Penoxsulam, followed by Bentazon/MCPA; T8 = Thiobencarb+Propanil, followed by Bentazon/MCPA;T9 = Fenoxaprop+Ethoxysulfuron, followed by Bentazon/MCPA; T10 = Fenoxaprop, followed by Bentazon/MCPA.

Weed Density (WD) and Weed Control Efficiency (WCE)

The highest weed density (WD) was observed in all T1 plot (unweeded) for both main and off seasons. Table 3 and 4. The low number of WD means the successful of WCE. In the main season of 30 DAT, treatments T2 (manual weeding), T3 (pretilachor, fb bentazon/MCPA), T4 (pretilachor+pyribenzoxim, fb bentazon/MCPA), T5 (bispyribac-sodium, fb bentazon/MCPA), T6 (pyrazosulfuron, fb bentazon/MCPA), T7 (penoxsulam fb bentazon/MCPA) and T8 (thiobencarb+propanil, fb bentazon/MCPA), exhibited significantly excellent weed control that ranges from 78% to 100% control efficacy as compared to T1 (unweeded), T9 (fenoxaprop+ethoxysulfuron, fb bentazon/MCPA) and T10 (fenoxaprop, fb bentazon/MCPA). At 60 DAT, all weed control treatments showed almost 80% weed control efficacy except and T1 (unweeded; 0%) and T10 (fenoxaprop, fb bentazon/MCPA; 70%). Meanwhile, at 90 DAT, all herbicide treatments except T1 (unweeded) resulted in maximum weed control.

For the off season, result at 30 DAT showed that the effective weed control (100%) was T2 (manual weeding), T3 (pretilachor fb bentazon/MCPA) and T6 (pyrazosulfuron fb bentazon/MCPA) followed by T4 (pretilachor+pyribenzoxim fb bentazon/MCPA; 96%), T8 (thiobencarb+propanil, followed by bentazon/MCP; 82%) and T5 (bispyribac-sodium fb bentazon/MCPA; 78%) while T10 (fenoxaprop fb bentazon/MCPA; 54%) recorded the lowest efficacy of weed control amongst treatments. The best weed control effectiveness for 60 DAT at the ranged of 85% to 100% except for T1 (unweeded), T8 (thiobencarb+propanil, followed by bentazon/MCP), T9 (fenoxaprop+ethoxysulfuron, followed by bentazon/ MCPA) and T10 (fenoxaprop fb bentazon/MCPA), ranging between 0% to 70% control efficacy. For 90 DAT, the best weed control was recoded in T2 (manual weeding), T3 (pretilachor fb bentazon/MCPA), T4 (pretilachor+pyribenzoxim fb bentazon/MCPA), T5 (bispyribac-sodium fb bentazon/MCPA) and T6 (pyrazosulfuron fb bentazon/MCPA) with fully weed control (100%) table 4.

The current study presents all herbicide combinations have shown a significant result for weed control and successfully contribute to the high grain yield. Similarly reported by Zia-Ul- Haq *et al.,* (2019) that the weed density was significantly reduced by the sequential application of pre- or post-emergence herbicides were followed by broad spectrum herbicide tank mixture. Among the herbicide treatments, T3, T4, T5 and T6 recorded the highest WCE for all DAT for both seasons. Pretilachor is a pre-emergence and control broad-spectrum of weed in rice. This herbicide effectively controls the weeds in the water level of 2-3cm, immediately sprayed after transplanting to within 4 days after transplanting. The herbicide combination with post-emergence (Bentazon/MCPA) showed the effective weed control throughout the study. This herbicide selection (pretilachor fb bentazon/MCPA) is a good combination that can effectively control broadleaved and sedges weed species in the flooded condition. There was insignificant difference between pretilachor fb bentazon/ MCPA (T3) and pretilachor+pyribenzoxim fb bentazon/ MCPA (T4) in terms of WCE. The pyribenzoxim is a post emergence herbicide that able to control grasses weed type added in this herbicide combination (T4) was not contributed to the increasing of WCE. Thus, this study showed that pretilachor fb bentazon/MCPA was effective to control broad spectrum in flooded condition even though there is unadded pyribenzoxim herbicide. The sequential herbicide treatments efficiently control weeds at utmost level observed in this study and in line with Zia-Ul- Haq *et al.,* (2019) reported that the weed survived pre- and postemergence application of pendimethalin and

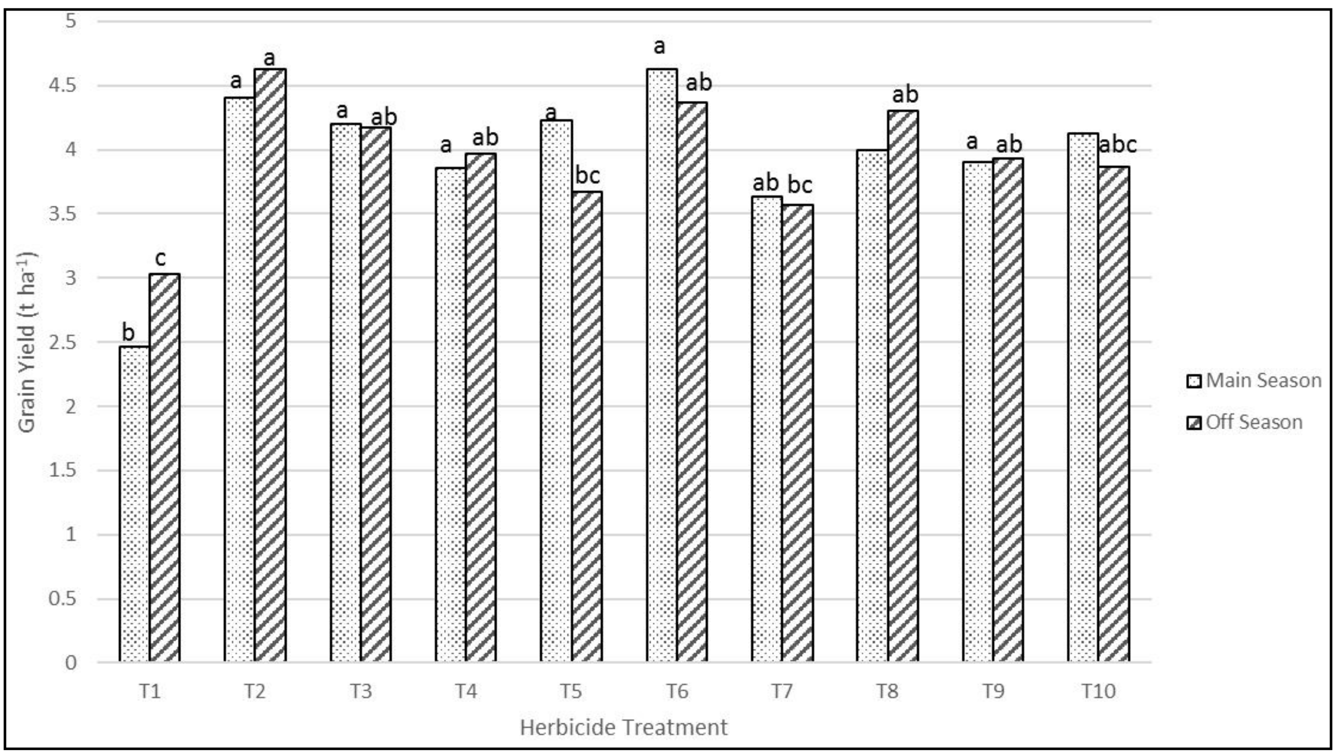

Fig. 1: Influence of herbicide treatments on grain yield (t ha^{-1}).

T1 = Unweeded; T2= Manual weeding; T3 = Pretilachor, followed by Bentazon/MCPA; T4 = Pretilachor+Pyribenzoxim, followed by Bentazon/MCPA; T5 = Bispyribac-sodium, followed Bentazon/MCPA; T6 = Pyrazosulfuron, followed by Bentazon/ MCPA; T7 = Penoxsulam, followed by Bentazon/MCPA; T8 = Thiobencarb+Propanil, followed by Bentazon/MCPA; T9 = Fenoxaprop+Ethoxysulfuron, followed by Bentazon/MCPA; T10 = Fenoxaprop, followed by Bentazon/MCPA.

bispyribac sodium or those emerging later in the season, were efficiently controlled by late season application of herbicide tank mixture. According to Singh *et al.,* (2016) also reported that herbicide mixture can results a good weed control as compared to a single herbicide in direct seeded rice.

Grain Yield and Economic Analysis

The data on rice grain yield shown that different treatments exhibited significantly different responses to various weed species and affected grain yield Fig. 1. In the main season, the treatment Pyrazosulfuron, fb bentazon/MCPA (T6) recorded the maximum rice production of 4.63 t ha^{-1} insignificantly different with all treatments except unweeded plot (2.46 t ha^{-1}), whilst in the off season, the highest rice production was recorded in manual weeding (4.63 t ha^{-1}) insignificant difference with Pretilachor, fb bentazon/MCPA (4.17 t ha^{-1}), Pretilachor + pyribenzoxim, fb bentazon/MCPA (3.97 t ha^{-1}), Pyrazosulfuron, fb bentazon/MCPA (4.37 t ha^{-1}), Thiobencarb + propanil, fb bentazon/MCPA (4.3 t ha^{-1}), Fenoxaprop + ethoxysulfuron, fb bentazon/MCPA (3.87 t ha^{-1}). The minimum production of rice was recorded in T1 (unweeded) with 3.03 t ha^{-1}, insignificantly different with herbicide treatments namely Bispyribac-sodium, fb bentazon/MCPA (3.67 t ha^{-1}), Penoxsulam fb bentazon/MCPA (3.57 t ha^{-1}), Fenoxaprop + ethoxysulfuron, fb bentazon/MCPA (3.87 t ha^{-1}). From this result, the unweeded treatment reduced grain yield in the range of 32% to 47% for main season, whereas 15% to 34% in the off season. Mostly, number of weed species population is getting decrease with the increasing of water depth. Flooding irrigation will reduce weed growth but will leave the rice plant undisturbed (Antralina *et al.,* 2015), however from this study, the flooded area solely without herbicide treatments (unweeded) was not really effective as the other treatments. Nevertheless, the combination of herbicide treatments with continuous flooding at 5 cm throughout this study has proved that several herbicide treatments effectively control the weed and significantly increase grain yield.

Table 5: Cost effectiveness of various herbicide treatments.

Herbicide treatments	Herbicides cost (RM/ha)	Labour cost for spraying/ weeding (RM/ha)	Total cost (RM/ha)	Gross income (RM/ha)	Net benefit (RM/ha)
T1	0.00	0.00	0.00	3,756.00	3,756.00
T2	0.00	3,150.00	3,150.00	5,280.00	2,130.00
T3	180.00	120.00	300.00	5,040.00	4,740.00
T4	178.00	120.00	298.00	4,632.00	4,334.00
T5	200.00	120.00	320.00	4,920.00	4,600.00
T6	233.00	120.00	353.00	5,232.00	4,879.00
T7	153.00	120.00	273.00	4,356.00	4,083.00
T8	136.00	120.00	256.00	4,800.00	4,544.00
T9	304.00	120.00	424.00	4,680.00	4,256.00
T10	174.00	120.00	294.00	4,956.00	4,662.00

T1 = Unweeded; T2= Manual weeding; T3 = Pretilachor, followed by Bentazon/MCPA; T4 = Pretilachor+Pyribenzoxim, followed by Bentazon/MCPA; T5 = Bispyribac-sodium, followed Bentazon/MCPA; T6 = Pyrazosulfuron, followed by Bentazon/MCPA; T7 = Penoxsulam, followed by Bentazon/2,4-D; T8 = Thiobencarb+Propanil, followed by Bentazon/2,4-D;T9 = Fenoxaprop+Ethoxysulfuron, followed by Bentazon/MCPA; T10 = Fenoxaprop, followed by Bentazon/MCPA; RM: Ringgit Malaysia. Market price of herbicide commercial products: Pretilachor (Sofit) = RM135/ha, Pretilachor+Pyribenzoxim (Solito) = RM 98/ha, Bispyribac-sodium (Nominee) = RM 120/ha, Pyrazosulfuron (Basmin) = RM153/ha, Penoxsulam (Rainbow) = RM 73/ha, Thiobencarb+Propanil (Satunil) = RM 55/ha, Fenoxaprop+Ethoxysulfuron (Tiller-G)= RM 130/ha, Fenoxaprop (Rumpas M)= RM94/ha, Bentazon/MCPA (Basagran) = RM 83 /ha. Manual weeding cost: 15 laborers/ha for 7 weeding at RM30/laborer/day, herbicide application cost: 1 laborer/ha/round at RM30/laborer/day; market price of paddy: RM 1,200.00 t/ha, gross income= paddy yield (t/ha) x market price (RM t/ha) and net benefit = gross income – total cost.

The high net benefits were observed in all herbicide treatments as compared to unweeded and manual weeding plots table 5. The highest net benefit of different herbicide treatments was obtained in T6 (pyrazosulfuron, followed by bentazon/MCPA; RM 4,879 ha^{-1}). This was then followed by T3 (pretilachor, followed by bentazon/MCPA; RM 4,740 ha^{-1}), and T10 (fenoxaprop, followed by bentazon/MCPA; RM 4,662 ha^{-1}) versus the manual weeding net benefit of RM 2,130 ha^{-1}. The economic analysis of various herbicide treatments was carried out as shown in Table 5 to evaluate the most beneficial and economical treatment for rice cultivation under water regime practices. Result from this study confirmed that all herbicide treated plots that succeeded by bentazon/MCPA contributed a notable higher net benefit and more economical value as compared to manual weeding. It is not suggested to use manual weeding for controlling weed in the rice fields because it is very costly. According to Hussain *et al.,* 2008; Islam *et al.,* 2000, herbicide applications potentially give the high net benefit than manual weeding. Therefore, herbicides application at an appropriate time and condition is important to deliver maximum control of weeds in rice fields. These results show that different herbicides combinations were effective under flooded condition in controlling weeds and contribute to high production of rice.

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References

Antralina, M., I.N. Istina, Y. Yuwariahc and T. Simarmata (2015). Effect of difference weed control methods to yield of lowland rice in the SOBARI. *Procedia Food Sci.* **3:** 323 – 329.

Anwar, M.P., A.S. Juraimi, A. Puteh, A. Man and M.M. Rahman (2012). Efficacy, phytotoxicity and economics of different herbicides in aerobic rice. *Act.a Agr. Scand. B-S. P.,* **62:** 604–615.

Chauhan, B.S. and D.E. Johnson (2010). The role of seed ecology in improving weed management strategies in the tropics. *Adv. Agron.*, **105:** 221-262.

Chauhan, B.S., T.T.N. Son, D. Duong and L.N. Phuong (2014). Effect of Pretilachlor on weedy rice and other weeds in wet-seeded rice cultivation in South Vietnam. *Plant Prod. Sci.*, **17:** 315-320.

Hasanuzzaman, M., O. Islam and S. Bapari (2008). Efficacy of different herbicides over manual weeding in controlling weeds in transplanted. *Aust. J. of Crop Sci.,* **2:** 18–24.

Hussain, S., M. Ramzan, M. Akhter and M. Aslam (2008). Weed management in direct seeded rice. *J. Anim. Plant Sci.,* **18:** 86–88.

Helgueira, D.B., T. D'avila Rosa, L. Galon, D.S. Moura, A.T. Martini and J.J.O. Pinto (2018). Weed management in rice under sprinkler and flood irrigation systems. *Planta Daninha*, **36:** e018177637.

Islam, T., M.K. Bhowmic, R.K. Ghosh and G. Sounda (2000). Effect of pretilachlor on weed control and yield of transplanted rice. *Environ. Ecol.*, **19:** 265-268.

Ismail, A.M., D.E. Johnson, E.S. Ella, G.V. Vergara and A.M. Baltazar (2012). Adaptation to flooding during emergence and seedling growth in rice and weeds and implications for crop establishment. *AoB PLANTS*., pls019.

Janiya, J.D. and K. Moody (1989). Weed populations in transplanted ana wet-seeded rice as affected by weed control method. *Trop. Pest Manag.*, **35:** 8-11.

Juraimi, A.S., M.K. Uddin, M.P. Anwar, M.T.M. Mohamed, M.R. Ismail and A. Man (2013). Sustainable weed management in direct seeded rice culture: a review. *Aust. J. of Crop Sci.,* **7:** 989–1002.

Karim, R.S.M., A.B. Man and I.B. Sahid (2004). Review paper**:** Weed problems and their management in rice fields of Malaysia: An overview. *Weed Biol Manag.,* **4:** 177–186.

Kent, R.J. and D.E. Johnson (2001). Influence of flood depth and duration on growth of lowland rice weeds, Coˆte d'Ivoire. *Crop Prot.*, **20:** 691-694.

Singh, M., M.S. Bhullar and B.S. Chauhan (2014). The critical period for weed control in dry-seeded rice. *Crop Prot.*, **66:** 80-85.

Singh, V., M.L. Jat, Z.A. Ganie, B.S. Chauhan and R.K. Gupta (2016). Herbicide options for effective weed management in dry direct-seeded rice under scented rice-wheat rotation of western Indo-Gangetic Plains. *Crop Prot.*, **81:** 168–176.

Zakaria, N., M.S. Ahmad-Hamdani and A.S. Juraimi (2018). Patterns of Resistance to AHAS Inhibitors in *Limnocharis flava* from Malaysia. *Plant Protec Sci*., **58:** 48-59.

Zia-Ul-Haq, M., A. Khaliq, Q. Sheng, A. Matloob, S. Hussain, S. Fatima and Z. Aslam (2019). Weed growth, herbicide efficacy, and rice productivity in dry seeded paddy field under different wheat stubble management methods. *J. Integr. Agric.*, **18:** 907–926.