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Integration of herbicides with manual weeding for controlling the weeds in rice under saline environment

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Abstract

The pot experiment was conducted to select appropriate integrated weed management method in rice under different salinity levels (0, 4 and 8 dS m^{-1}). All the parameters including rice and weed measured were significantly influenced by weed control treatments at all salinity levels. Treatments including weed-free condition, Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding, Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1} + hand weeding performed better under all salinity levels. Pretilachlor @ 0.375 kg ai ha^{-1} with one round of hand weeding and propanil + thiobencarb 0.9 kg ai ha^{-1} + 1.8 kg ai ha^{-1} with one round of hand weeding were comparable to weed-free yields, and were superior to other treatments under salinity condition. Considering all the parameters, pretilachlor @ 0.375 kg ai ha^{-1} + one round of hand weeding (at 65 DAT), propanil + thiobencarb 0.9 kg ai ha^{-1} +1.8 kg ai ha^{-1} + one round of hand weeding (at 65 DAT) gave the most effective control of weeds in rice under saline environments.

Key words

Hand weeding, Herbicides, Integration, Weed Management, Rice, Saline environment

Introduction

Salinity is a problem in agricultural production and is one of the major abiotic stresses that adversely affects metabolic activities and causes plant damage (Tao *et al.,* 2008). It has been estimated that worldwide more than 2 million acres of agricultural land is affected by salinity per year (Summart *et al*., 2010). Rice production, especially in saline areas is becoming more important because more rice areas are becoming saline due to added anthropogenic contributions to global warming. Continuous intrusion of saline water will result in decreasing areas for rice production and lead to food shortages. In arid and semi-arid regions, low levels of salinity hamper plant growth as well as suppress crop production; however, higher levels can cause plant death (Michael *et al.*, 2004). Rice is affected severely by salinity at all growth stages. Seed germination and young seedlings of commonly used rice varieties are sensitive to salinity (Momayezi *et al*., 2009). It has been reported that salinity due to global warming would result in decline in rice yields as well as farm incomes (Vaghefi *et al.,* 2011). Increasing soil salinity may result in up to 50% yield loss in salt sensitive rice varieties (Selamat and Ismail, 2008). Therefore, researchers and policy makers need to consider economic and efficient use of saline areas.

Weed is one of the serious biotic constraints that reduces yields in rice (Subhas and Jitendra, 2001). Allelopathic effects of weeds on rice as well as weeds compete with rice for water, light, physical space, and nutrient thus reducing yield, while weeds contaminate harvested rice grains and lowers grain quality and cash value of crop (Florkowski and Landry, 2002). Worldwide the annual rice yield loss due to weed infestation is about 15-21% (Karim *et al*., 2004). It is a major problem in all rice-producing countries, including Malaysia. Weed is one of the major constraints of rice production and weed management has been a challenge for the rice farmers (Juraimi *et al*., 2013). Annual loss of 10 million metric ton of rice due to weed competition have been reported in China (Zhang, 2001). Recently, rice grain yield loss of about 42% has been reported in uncontrolled field by infestation of *Fimbristylis miliacea* (Hakim *et al*., 2011). However, weed species composition in saline areas is different as compared to flood plain areas. The distribution and nature of weeds of coastal area are different due to salinity (Hakim *et al*., 2013). Salt tolerant weeds include *Cynodon dactylon, Eleusine coracana, Echinochloa crus-galli, Puccinellia ciliate, Cyperus iria* and *E. colona* (Yamamoto *et al*., 2003).

Effective control of salt tolerant weeds is very important for sustainable rice production in saline areas. Chemical control is the most commonly used and reliable method for controlling weeds in rice fields (Anwar *et al*., 2012). Herbicides are now commonly used in controlling weeds and use of herbicides is gaining popularity in rice culture due to their rapid effect as compared to traditional weed control methods (Kim *et al.* 2006). Although herbicides use alleviates the problem of weed infestation, incorrect use of herbicides may cause other environmental problems such as chemical pollution (Labrada, 2003). Reduced dependence on herbicides may reduce the cost of crop production and retard the development of herbicide resistance in weed (Lemerle *et al*., 1996; De Vida, 2006). Recently, attention has shifted to integrate non-chemical methods of weeds control into the current farming systems to reduce herbicide use (Mcdonald, 2003), such as development of competitive rice cultivars which provide a safe and environmentally benign tool for integrated weed management (Fischer *et al*., 2001).

Numerous reports have been published on salinity stress and weed management in rice (Zeng and Shannon, 2000; Rao *et al*., 2007; Mahajan *et al*., 2009; Chauhan and Johnson, 2011; Juraimi *et al.,* 2012). However, weed integrated management in rice under saline condition is still scanty. In view of environment safety, minimum dose of herbicides for controlling salt tolerant weeds in saline rice fields is very important. So, it is necessary to develop appropriate integrated weed management technology in rice for coastal zones in Malaysia and other Southeast Asian countries. Therefore, the present study was designed to select appropriate integrated method for controlling weeds under saline environment.

Materials and Methods

Experimental site and soil properties : The study was conducted in pots (33 cm diameter × 23 cm depth) at glasshouse of Universiti Putra Malaysia from October 2010 to February 2011. Soil for this experiment was collected from a rice field in Tanjung Karang. The experimental soil was loamy clay in texture (18.3% sand, 43.7% silt, 38% clay) and acidic in reaction (pH 6.1) with 1.02% organic carbon , EC-1.56 dSm^{-1}, soil nutrient status was 0.19% total N, 11.12 ppm available P, 122 ppm available K, 620 ppm Ca, 290 ppm, 7.63 ppm S and 0.96 ppm Zn.

Experimental design : MR232 rice variety (as a salt tolerant) and three weed species *Ehinochloa colona, Cyperus iria* and *Jussiaea linifolia* (as salt tolerant and moderately tolerant) were used as test materials in the present study. The experiment was laid out in randomized complete block design (RCBD) with four replications. The experimental factors consisted under two weeding regimes (weedy and weed free condition).

Treatments included three herbicides namely Pretilachlor (Sofit®), Propanil + Thiobencarb (Satunil®), and Bensulfuron (Tekong®) + MCPA applied at different rates and three salinity levels viz. 0, 4 and 8 dS m^{-1}. Detail of the herbicide treatments is presented in Table 1. Different salinity levels were prepared by dissolving commercial salt (NaCl, Batch# 088K0089, SIGMA-ALDRICH Co., USA) @ 640 mg l^{-1} distilled water for 1 dS m^{-1} salinity level. Distilled water was used as control i.e., 0 salinity. After preparation, salinity levels were checked by electrical conductivity meter (model: Z 865/SCHOTT Instruments, Germany) and necessary adjustment was made.

Pretilachlor (Sofit®) : recommended rate 0.50 kg ai ha^{-1} (2.4 l product ha^{-1}), Propanil + Thiobencarb (Satunil®): recommended rate 1.2 kg ai ha^{-1} + 2.4 kg ai ha^{-1} (6 l product ha^{-1}), Bensulfuron (Tekong®): recommended rate 0.06 kg ai ha^{-1} (2.5 l product ha^{-1}), MCPA: recommended rate 0.1 kg ai ha^{-1} (1.6 l product ha^{-1}).

Soil was pulverized, inert materials, visible insect pests and plant debris were removed. Soil was then crushed, mixed thoroughly, and dried in the sun. The pots were filled with 10 kg prepared soil well mixed with urea, triple supper phosphate, muriate of potash and gypsum as sources of N, P, K and S at the rate of 60 kg N, 80 kg P_2O_5, 150 kg K_2O and 20 kg S ha^{-1}, respectively. Three-week-old rice seedlings were transplanted into the pots with three seedlings per pot. Two weeks after transplanting salt treatments were applied. To avoid osmotic shock, salt solutions were added in three equal portions on alternate days until the expected conductivity (0, 4 and 8 dS m^{-1}) was achieved. Urea was top dressed twice at 30 and 60 days after transplanting at 60 kg N ha^{-1}. Standard agronomic practices were adopted and crop protection measures were carried out as necessary (MARDI, 2006). Leachates of salt solutions were collected daily from each pot, monitored for EC and necessary adjustments were made. Conductivity of soil was determined using conductivity meter (Model: ECTestr, Spectrum Technologies, Inc.). In addition, pre-soaked 25 weed seeds were sown in each pot on the same day of rice transplanting.

Crop and weed data measurements : Plant height (cm) was measured from the ground level to the tip of the longest leaf and the total numbers of tillers $hill^{-1}$ were counted at maturity. Leaf chlorophyll content was measured by using a chlorophyll meter (SPAD-502, Minolta Camera Co, Osaka, Japan) using intact leaves at 60 DAT. Crop was harvested at full maturity (when 90% grains became golden yellow), and grain and straw biomass were recorded. The yield was adjusted at 12% moisture basis. Yield components including number of effective tillers $hill^{-1}$, filled grains $panicle^{-1}$, 1000-grain weight and grain yield $hill^{-1}$ were also recorded from three hills pot^{-1}. Number of weed per pot was counted at 60 DAT and it was recorded as number m^{-2}. Dry weight of weeds were recorded after drying at 60 ºC for 72 hrs and it was converted from g pot^{-1} to gm^{-2}. Weed control efficiency (WCE) was calculated on the basis of dry matter using the formula of Hasanuzzaman *et al.* (2009).

Results and Discussion

Plant height of rice was significantly affected by herbicide treatments under different salinity levels (Fig. 1). The tallest plants (109.2 cm) were found in T3 (Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding), and this was comparable to T1 (weed-free) under non-saline conditions while the shortest plants (84.5 cm) were observed in T8 (weedy control). Other treatments produced intermediate plant heights. Similar trend was observed in 4 dS m^{-1}. At 8 dS m^{-1}, highest plant height was produced in T5 (95.3 cm) followed by T3 and T7, while lowest in T8 (69.8 cm). The results indicated that some treatments showed significantly lower plant height due to competition of weeds with rice plants for light, space and nutrients resulting stunted plant growth. Hasanuzzaman *et al.* (2009) reported that Ronstar 25EC at 1.25 l ha^{-1} + IR5878 50 WP at 120 g ha^{-1} produced tallest plants, while shortest plants were found in weedy checks which showed similarity with the present results. Begum *et al.* (2003) also noted that very low doses of Ronstar 25 EC and higher doses of Golteer 5G adversely affected rice plant height, and lowest dose of Ronstar 25 EC reduced plant heights.

Leaf chlorophyll content of rice under different levels of salinity was significantly influenced by herbicidal treatments (Fig. 2). Higher chlorophyll content was observed in T3 (T3= Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding) followed by weed-free treatment and T5 (Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1} + hand weeding (>40) under non saline conditions, while lowest chlorophyll content was recorded in the weedy treatment (33.3) which was similar to T2 (Pretilachlor @ 0.375 kg ai ha^{-1}) at 8 dS m^{-1} salinity level. Weeds generally compete with rice for water, light, physical space and nutrients. Rice plants under weedy conditions resulted in reduced growth and photosynthesis capacity. Reduction in chlorophyll content also results in lower photosynthesis capacity. The results are in accordance with the findings Floskowski and Landry (2002).

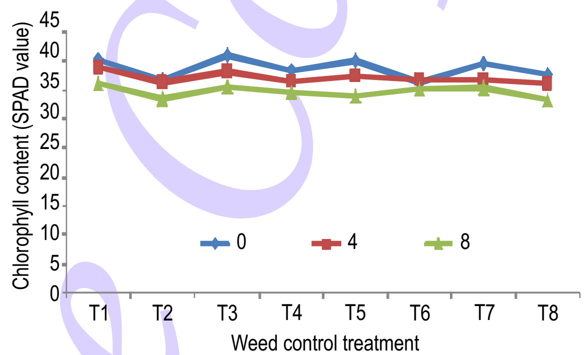

Fig. 2 : Effect of weed control treatments on chlorophyll content (SPAD value) under varying salinity regimes; T1=Weed-free, T2= Pretilachlor @ 0.375 kg ai ha^{-1}, T3= Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding, T4= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1}, T5= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1} + hand weeding, T6= Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1}, T7= (Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1} + hand weeding, T8=Weedy

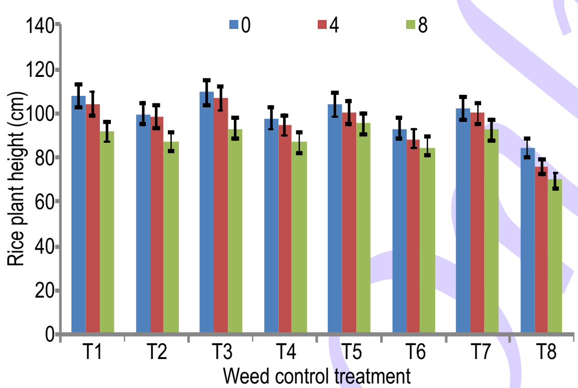

Fig. 1 : Effect of weed control treatments on rice plant height under varying salinity regimes; T1=Weed-free, T2= Pretilachlor @ 0.375 kg ai ha^{-1}, T3= Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding, T4 = Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1}, T5=Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1} + hand weeding, T6= Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1}, T7= (Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1} + hand weeding, T8=Weedy

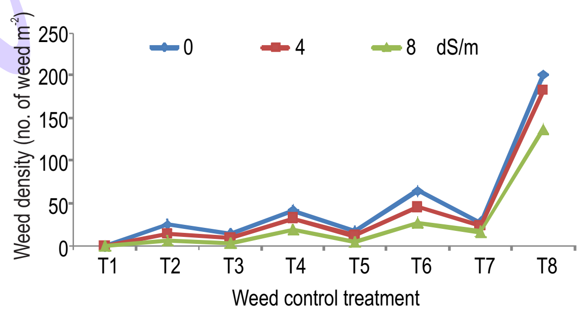

Fig. 3 : Effect of weed control treatments on weed density under varying salinity regimes; T1=Weed-free, T2= Pretilachlor @ 0.375 kg ai ha^{-1}, T3= Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding, T4= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1}, T5= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1} + hand weeding, T6= Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1}, T7= (Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1} + hand weeding, T8=Weedy

Table 1 : Herbicide treatments used in the study

Code	Treatments	Rate (kg ai ha^{-1})	Application time
T1	Weed free	-	Season-long
T2	Pretilachlor (Sofit®)	0.375 kg ai ha^{-1}	4 DAT
T3	Pretilachlor (Sofit®) + hand weeding	0.375 kg ai ha^{-1}	4 DAT+ 65 DAT
T4	Propanil + Thiobencarb (Satunil®)	0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1}	10 DAT
T5	Propanil + Thiobencarb (Satunil®) + hand weeding	0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1}	10 DAT+65 DAT
T6	Bensulfuron (Tekong®) + MCPA	0.045 kg ai ha^{-1} +0.075 kg ai ha^{-1}	7 DAT+40 DAT
T7	Bensulfuron (Tekong®) + MCPA +hand weeding)	0.045 kg ai ha^{-1} +0.075 kg ai ha^{-1}	(7 DAT+40 DAT) + 65 DAT
T8	Weedy	-	Season-long

DAT= Days after transplanting; Pretilachlor (Sofit®): recommended rate 0.50 kg ai ha^{-1} (2.4 l product ha^{-1}), Propanil + Thiobencarb (Satunil®): recommended rate 1.2 kg ai ha^{-1} + 2.4 kg ai ha^{-1} (6 L product ha^{-1}), Bensulfuron (Tekong®): recommended rate 0.06 kg ai ha^{-1} (2.5 l product ha^{-1}), MCPA: recommended rate 0.1 kg ai ha^{-1} (1.6 l product ha^{-1})

Table 2 : Effect of weed control treatments on productive tillers and percent filled grains under varying salinity regimes

Treatments	Salinity levels (dS m^{-1})					
	Effective tillers per hill			Percent filled grain per hill		
	0	4	8	0	4	8
T1	8.51 a	7.12 a	5.98 a	88.00 a	81.84 a	72.58 a
T2	8.04 ab	6.72 a	5.45 a	80.27 cd	72.05 d	66.01 b
T3	8.48 a	7.09 a	5.80 a	84.80 abc	79.29 ab	71.58 a
T4	7.23 ab	5.81 ab	4.43 ab	80.63 cd	76.75 bc	70.38 ab
T5	7.89 ab	6.89 a	5.47 a	85.99 ab	78.57 ab	71.11 ab
T6	7.51ab	6.64 a	4.58 ab	78.02 d	72.61 cd	64.89 b
T7	7.62 ab	6.97 a	5.69 a	81.31 bcd	76.72 bcd	68.48 ab
T8	4.64 b	2.76 b	1.74 b	62.38 e	52.65 e	42.53 c

Means within columns with the same letters are not significantly different (LSD, pd”0.05); T1=Weed-free, T2= Pretilachlor @ 0.375 kg ai ha^{-1}, T3= Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding, T4= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1}, T5= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1} + hand weeding, T6= Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1}, T7= (Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1} + hand weeding, T8=Weedy

Herbicide treatments had a significant influence on effective tillers hill^{-1} (Table 2). Season-long weed free conditions produced highest number of effective tillers (8.51) under non saline conditions, while lowest number (1.74) was noted in weedy treatments under 8 dS m^{-1} (Table 2). Under saline condition, T1 produced highest number of tillers followed by T3 and T7. A similar trend was observed at 4 and 8 dS m^{-1} saline conditions.

The herbicide treatments produced significantly more percent filled grain than weedy treatments. Highest percent filled grain (88.00 %) was obtained in T1 under non-saline condition, while lowest value (42.53%) was in T8 at higher (8 dS m^{-1}) saline condition (Table 2). T1 produced longest panicle (23.15 cm) at non-saline condition, while shortest was recorded in T6 (18.78 cm) at higher salinity (8 dS m^{-1}) (Table 3). The results showed that the weedy treatments produced significantly shorter panicles at all salinity levels (Table 3). Thousand grain weight was also influenced by the effect of different herbicidal treatments. Highest 1000 grain weight was found in T1 and T3 at all saline conditions, while lowest was recorded in the weedy treatment (Table 3). Herbicide treatments also produced significantly higher grain and straw yields than in weedy treatment at all salinity levels (Table 4). Highest grain yield was found in weed- free treatments at 0 and 4 dS m^{-1}, but T3 attained highest grain yield at higher (8 dS m^{-1}) salinity levels. Highest straw yield was found in weed free treatments under non-saline conditions, while lowest was observed in T8 at 8 dS m^{-1} (Table 4). At 4 dS m^{-1}, weed free treatments again produced highest amount of straw followed by T3 and T5 with >12 g hill^{-1}. A similar trend was observed at higher salinity levels. The results revealed that herbicide treatments followed by one round of hand weeding performed better under saline conditions, especially at higher salinity levels. This may be attributed to longer critical period of weed competition in higher saline conditions. The results showed that yield and values of yield contributing components decreased in weedy treatments as compared to weed control treatments due to weed infestation. The results are in accordance with the findings of Ashraf *et al.* (2006).

Similar responses in tiller production and grain yield as a result of using effective herbicides have been previously reported

Table 3 : Effect of weed control treatments on panicle length and thousand grain weight under varied salinity regimes

Treatments	Salinity levels (dS m^{-1})					
	Panicle length (cm)			1000 grain weight (g)		
	0	4	8	0	4	8
T1	23.15 a	21.89 a	20.86 a	23.28 a	22.83 a	20.48 a
T2	21.81 ab	20.65 abc	18.50 cd	23.12 a	22.37 ab	20.65 ab
T3	23.10 a	21.59 a	20.34 a	23.24 a	22.86 a	21.42 a
T4	21.04 b	19.65 c	18.34 d	22.17 a	21.12 ab	19.74 ab
T5	22.50 ab	21.05 ab	20.09 ab	22.91 a	22.11ab	21.33 a
T6	21.16 b	20.06 bc	18.78 bcd	22.44 a	21.39 ab	20.01 ab
T7	21.95 ab	20.96 ab	19.73 abc	23.04 a	22.29 ab	20.91 ab
T8	18.01 c	16.45 d	15.43 e	19.62 a	18.57 b	17.19 b

Means within columns with the same letters are not significantly different (LSD, pd”0.05); T1=Weed-free, T2= Pretilachlor @ 0.375 kg ai ha^{-1}, T3= Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding, T4= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1}, T5= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1} + hand weeding, T6= Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1}, T7= (Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1} + hand weeding, T8=Weedy

Table 4 : Effect of weed control treatments on straw and grain yield of rice under varying salinity regimes

Treatments	Salinity levels (dS m^{-1})					
	Straw yield (g hill^{-1})			Grain yield (g hill^{-1})		
	0	4	8	0	4	8
T1	15.31 a	12.58 a	9.83 a	14.55 a	11.46 a	8.23 a
T2	14.58 abc	11.21 bc	8.52 bc	11.88 bc	9.36 bc	6.82 bc
T3	14.98 ab	12.05 ab	9.25 ab	12.86 abc	10.95 ab	8.35 a
T4	13.90 c	11.04 c	8.54 bc	11.55 c	9.09 c	6.11c
T5	14.80 abc	12.52 a	9.14 ab	13.60 ab	11.10 a	8.03 a
T6	14.06 bc	11.88 abc	8.11 c	11.72 bc	9.22 bc	6.75 bc
T7	14.75 abc	12.02 ab	8.85 abc	13.33 abc	10.22 ab	7.74 ab
T8	7.67 d	5.14 d	3.39 d	4.02 d	2.71 d	1.20 d

Means within columns with the same letters are not significantly different (LSD, pd”0.05); T1=Weed-free, T2= Pretilachlor @ 0.375 kg ai ha^{-1}, T3= Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding, T4= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1}, T5= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1} + hand weeding, T6= Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1}, T7= (Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1} + hand weeding, T8=Weedy

Table 5 : Effect of weed control treatments on weed biomass and weed control efficiency in rice under varying salinity regimes

Treatments	Salinity levels (dS m^{-1})					
	Weed biomass (g m^{-2})			Weed control efficiency (%)		
	0	4	8	0	4	8
T1	0.0 d	0.0 e	0.0 f	100 a	100 a	100 a
T2	4.08 bc	3.15 bc	2.03 c	81.77 bc	82.16 cd	88.50 c
T3	3.06 c	1.97 d	0.93 e	84.87 b	90.76 b	94.60 ab
T4	5.49 b	4.19 b	2.24 b	74.63 c	73.20 e	80.60 d
T5	3.57 c	2.19 cd	1.43 d	82.60 bc	88.36 b	91.13 bc
T6	4.48 bc	3.43 b	2.33 b	81.4 bc	76.26 de	80.43 d
T7	2.70 c	2.25 cd	1.34 d	85.40 b	87.06 bc	91.96 bc
T8	24.95 a	17.86 a	12.06 a	0.0 d	0.0 f	0.0 e

Means within columns with the same letters are not significantly different (LSD, pd”0.05); T1=Weed-free, T2= Pretilachlor @ 0.375 kg ai ha^{-1}, T3= Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding, T4= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1}, T5= Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1} + hand weeding, T6= Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1}, T7= (Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1} + hand weeding, T8=Weedy

(Sandeep *et al*., 2002; Ishaya *et al*., 2007; Begum *et al*., 2008; Hasanuzzaman *et al.,* 2009).

Herbicidal treatments significantly affected weed density at flowering stage (Fig. 3). Highest weed density (200.6 m^{-2}) was found in weedy check under non-saline conditions, while lowest density (2.69 m^{-2}) was observed in T3 (Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding) at 8 dS m^{-1} (Fig. 3). Among the herbicidal treatments, maximum weed density (51.2/m^2) was found in T6 (Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1}) which was statistically similar to T4, while least density (14.3 m^{-2}) was obtained in Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding followed by T5 with values of <20 under non-saline environment. Similar trend was found in At 4 dS m^{-1}, but at 8 dS m^{-1} highest weed density (25.3 m^{-2}) was seen in T4 followed by T6 (19.8 m^{-2}) and lowest (2.62 m^{-2}) in T2 followed by T5 with ≤ 4 m^{-2}, respectively.

Weed biomass and weed control efficiency were significantly affected by different weed control treatments (Table 5). Highest weed biomass (24. 95 g m^{-2}) was found in T8 (weedy check) under non saline condition, while lowest (0.93 g m^{-2}) in T3 (Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding), followed by T5 and T7 having <1.5 g m^{-2} (Table 5). Similar trend was seen at 4 and 8 dS m^{-1} treatment.

There were significant differences in weed control efficiency (WCE) under varied salinity regimes (Table 5). Highest WCE (85.40%) was observed in T7 (Bensulfuron + MCPA @ 0.045 kg ai/ha + 0.075 kg ai ha^{-1} + hand weeding), while lowest (74.63%) in T4 (Propanil + Thiobencarb @ 0.9 kg ai ha^{-1}) under non-saline condition. At 4 dS m^{-1}, highest value was found in T3 (Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding) with 90.76% WCE, while lowest in T4 (Propanil + Thiobencarb @ 0.9 kg ai ha^{-1}) with 73.20% WCE. At 8 dS m^{-1}, better weed control was observed in T3 (Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding) with 94.60% WCE, while all other treatments showed more than 80% WCE due to negligible weeds in each experimental pot.

The present results showed that lowest weed density, weed biomass and highest weed control efficiency in the treatment of T3 (Pretilachlor @ 0.375 kg ai ha^{-1} + hand weeding) followed by T5 (Propanil + Thiobencarb @ 0.9 kg ai ha^{-1} and 1.8 kg ai ha^{-1} + hand weeding) and T7(Bensulfuron + MCPA @ 0.045 kg ai ha^{-1} + 0.075 kg ai ha^{-1} + hand weeding).

The results revealed that herbicidal treatments followed by hand weeding produced less weed density, weed biomass and higher weed control efficiency (%) as compared to other treatments under saline condition, especially at 8 dS m^{-1}. The results clearly showed that all the treatments reduced weed density and weed biomass significantly as compared to weedy check at all salinity levels. Hasanuzzaman *et al.* (2009) observed that weed density and weed dry matter significantly differed in different weed control treatments and weed control efficiency was also significantly influenced by weed control methods. Similar result was found by Pal *et al*., (2009) where weed density and biomass were significantly higher in weedy treatment as compared to all herbicidal treatments in transplanting rice and lowest biomass of weeds resulted in highest weed control efficiency. Herbicidal treatment had significant effect on dry matter of barnyard-grass (*Echinochloa crus-galli*) (Mussavi *et al.,* 2009). These findings, indicated that weed density and weed biomass was inversely correlated to weed control efficiency which is in agreement with the present study. The results suggested that in addition of herbicide spraying one hand weed must be needed for proper weed management in the rice field under saline condition.

All the tested herbicidal treatments were effective in controlling *C. iria, E. colona* and *J. linifolia*, except at the lower doses. All the parameters measured were significantly influenced by weed control treatments at all salinity levels.

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